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THE VOLCANO LETTER

A Weekly news leaflet ot the Hawaiian Volcano Research Association

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NO. 1 January 1, 1925

KILAUEA REPORT

DECEMBER 31, 1924
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in Charge

Other notices in the press than those mentioned last week indicate that the seismographs of the world are recording large earthquakes and Tokyo mentions a strong felt shock that did damage in Japan. Two slight records of distant earthquakes were made on the Kilauea seismograph December 27 at 1:01 a. m. and December 28 at 12:34 p. m. Thirty local shocks were registered, two of which were felt, respectively on the 25th and the 30th, both in the evening. Tilting was to the northeast, a direction favorable for rising lava, but no new sign of lava has appeared in the pit.

About half of the local earthquakes were of the prolonged type characteristic of Halemaumau avalanches, and such slides were observed or heard repeatedly during the week. They made no large dust clouds.

A notable change now seen at Halemaumau, and occasioned by the big avalanche of December 12, is the cessation of smoking of the north wall. This blue fume was in evidence all summer and autumn, coming from a solfataric patch in the upper wall. The avalanche in question stripped that wall, and left a surface whitened with sulphates, but if any fume remains it is now mixed with the steam at the base of the wall.

The avalanches of the past week have continued to strip the north wall and to pile up the debris below so as to cover with talus the bottom part of the big intrusive sill. A faint sulphur odor was detected at some of the cracks back of the NNW rim of Halemaumau. With the undermining of the rock slides these cracks have increased at the north, outlining freshly broken segments of the rim scores of feet back from the edge, and breaking the earth along new steamy cracks parallel to the rim in many places. At one of these big chasms the surface rock has all caved in revealing an inclined cavern below The hole is ten to fifteen feet across and plunges downward at an angle of thirty degrees, with a slope of caved debris on one side. The roof and sides are broken and so close to the pit rim, where avalanching is always going on, that the whole mass appears to be settling.

Some of the steam cracks near the rim at the west are continuous for long distances, with hot vapor rising in puffs.

During the gentle swaying earthquake of the evening of December 30 at 8:51 p. m. a pheasant was heard to squawk at the moment of the shock. In Japan slight forewarning of quakes has sometimes been given by pheasants.

CHILEAN VOLCANOES

There are some parts of the world of volcanology that yield very little published information and one of them is Chile. Dr. Karl Sapper of Strasbourg mentions 14 eruptions in 13 years between 1901 and 1913 (Summary of volcanic data, Beitraege zur Geophysik, 1915). The very names of these volcanoes are unknown to most of us. Huallatri and Isluga at the north vented light smoke and black smoke and fire in 1913, and these about 19 degrees S. lat. are as far south of the equator as Hawaii is north. Next come San Pedro and Antofalla which vomited smoke in 1901 and 1911. Moving south to 35° we find Cerro Azul and Descabezado making explosive eruptions in 1907 and 1913, the former a peak 10,500 feet high. Chillan in lat. 36° opened a new crater in 1906, and Llaima appears to be a formidable volcano that kept up action for five years from 1903 to 1908 with both explosions and lava. Maipo was active in 1905.

The Chilean district of about 40° S. near the port of Valdivia appears to be a lively volcanic neighborhood where Villarica was erupting and throwing stones from 1906 to 1908. In the same region Rininahue in April of 1907 built up a cone of lapilli and ash, and the dust fell at Valdivia. Calbuco and Huequi are a little farther south and were making explosive steam clouds and smoke clouds in 1906-07.

All this shows that while there was no activity reported between 1895 and 1900, there were two eruptions in 1901, one in 1903, one in 1905, five in 1906 when Valparaiso and San Francisco had their earthquakes, four in 1907 when Jamaica had its earthquake, two in 1908 when Messina had its earthquake, one in 1911 and two in 1913.

Sapper shows that this 1906-07 time produced the most volcanic eruptions in nineteen years both for the whole world and for the Pacific half of the earth. Out of 414 eruptions between 1895 and 1913 there were 25 in 1906 and 31 in 1907. There were eruptions on Mauna Loa, at Bogoslof in the Aleutian Islands, at James in the Galapagos, at Vesuvius, on Savaii in Samoa, Kartala of the Comoro Islands east of Africa (1904), Namlagira, a lava maker in east Africa, Cotopaxi, Sangay, and numerous volcanoes of the Molucca-Philippine-Japan series. It is remarkable that this was also a period of some of the world's greatest earthquakes, including a big one in India.

It thus appears that certain years in the world's history are seismo-volcanic centers in time, just as districts are similar centers in place. About 1883-86 was another such time center with Java, Japan and New Zealand producing titanic eruptions, and in America came the Charleston earthquake.

T. A. J.

PERRET'S GREAT MONOGRAPH ON VESUVIUS

Those in Hawaii who remember Mr. F. A. Perret's fine work here dwelling on the rim of Halemaumau pit in 1911, and his wonderful faculty for making good photographs under adverse conditions, will wish to see and study the splendid volume by him just published, with noble pictures of craters, cones, cauliflower clouds, lava flows and avalanches of dust and debris. (The Vesuvius Eruption of 1906, Carnegie Institution, Washington, D. C. quarto, 151 pp. $4).

Mr. Perret discusses the preliminaries of that great eruption, presents a narrative and an analysis of every detail of its progress illustrated photographically, then recites the after effects as observed on the ground through the repose period of seven years, and finally gives most interesting account of the revival after 1913. For comparison with Hawaii this memoir is invaluable. In his last part he describes his instruments, comparative data of the 1872 eruption, and Dr. Washington discusses the petrology of the lavas. Dr. Washington has done admirable work in editing the volume, so as to introduce the vast experience of the Geophysical Laboratory of Washington in technical and bibliographic matters.

It is interesting to note that Perret says the "average interval between eruptions for Vesuvius during the 19th century was less than ten years." For Kilauea-Mauna Loa the cycle also is about nine years long.

T. A. J.

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JAN 9

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NO. 2 RELEASED WITHOUT COPYRIGHT RESTRICTION January 8, 1925

KILAUEA REPORT NO. 678

WEEK ENDING JANUARY 7, 1925
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in Charge

Halemaumau, the active pit of Kilauea volcano, was left by the explosive eruptions of May, 1924 an enormous blank cauldron lined with broken rock. It is 1280 feet deep, oval in plan, and 3400 feet long. The lava returned to the bottom for a fortnight in July so as to make a rock floor. Avalanching from the walls has been the principal process of change in evidence since the first of August, when all flow of lava stopped. These slides have made the debris slopes grow. The walls are precipitous and unstable. The bottom yields much steam mixed with sulphur gas and hydrogen sulphide, but in fair weather all the walls are in plain view and no vapor rises above the pit rim. There are vaporing cracks moderately hot parallel to and near the rim.

During the past week avalanching decreased, but a pinnacle of poised rock at the south has fallen in . This was a conspicuous landmark, and all that is left is a slender spire surmounting a sheet of rock partially split from the face of the wall. Some of the steam-holes in the talus are dry, hence probably very hot, others are wet. The Observatory registered 22 local earthquakes and northeasterly tilt. Two noisy avalanches were heard the forenoon of January 3, and half the earthquakes recorded were of the avalanche type. At night no glow is discernible in the pit.

LOCATING EARTHQUAKES

An earthquake is a sudden bump or break or slip in a definite place within the crust of the earth. The jarring moves out from that place as waves in the rock. Some of the waves are like sound waves, some are like water waves and travel with different speeds. If a blast were fired in a lake, the sound under water would reach you before the surface waves from the explosion. So it is with an earthquake in solid sandstone or granite. And the delicate pendulum called a seismograph, scratching a straight line on paper all the time, with tick marks at the side from the minute hand of a clock, makes a wobbly mark the instant the quicker waves get to it, and a big zigzag mark some moments later when the surface waves arrive. In the case of big earthquakes the marks are registered even 7,000 miles away.

As the quick waves race in a straight line through the earth at a speed that is independent of the severity of the earthquake, and that speed is known by experiment; and the surface waves go more slowly, also at a known speed: it follows that the difference in time of arrival of the two, measured in minute tick marks on the paper will be the greater as the distance away is greater. This time-distance relation, or "duration of the preliminary tremor," has been worked out for all distances and published in tables. It is not quite so simple as told here, for there are two kinds of preliminary wave, but that all appears in the tables. The velocity of the most rapid earthquake waves averages over 300 miles a minute and the slowest waves can travel entirely around the world in about three hours.

The distance unit in the Zeissig tables, commonly used at most seismographic observatories, is 10 kilometers (6¼ miles), but these tables are mainly designed for big earthquakes many hundreds of miles away. At this Observatory Omori's tables, published in the Bulletin of the Imperial Earthquake Investigation Committee of Japan, Vol. 9, No. 1, p. 39 have been found much more satisfactory than any other. Omori's values are given to fractions of a mile. His fractions seem justified as it is easily possible to distinguish differences in shakes whose origins are only two and three miles away. The distances of quakes up to 40 miles determined from Omori's tables are from one to six miles less than those given in the Zeissig table. That Omori's tables are better than the Zeissig table for very local earthquakes, near a volcano at least has, repeatedly been shown here by the nice agreement between computed and actual distances of many quakes whose origins are known, as for instance by newly formed cracks at the center of disturbance. R.H.F.

HAWAIIAN SEISMOGRAPHIC STATIONS

The Volcano Research Association maintains three outlying stations on the island of Hawaii for registration of earthquakes, besides the main laboratory of the Observatory at Kilauea. The latter is now operated by the United States Geological Survey; it passed from the Weather Bureau to the Survey July 1, 1924. The outer stations are equipped with instruments built here by Dr. A. Romberg. They are at Kealakekua in Kona, Observer R. V. Woods: Hilea in Kau, Observer Ella W. Stephens; and Hilo, Observer J. B. Albert. The magnifications of the instruments are 25X and 50X (Kona). The Kona instrument also records tilt. Hilea gets the most small shocks (next to Kilauea), Kona next and Hilo fewest. Kona and Kilauea have horizontal pendulums, the others normal pendulums of short period.

The Volcano Research Association is working cooperatively with the Survey through the Observatory. Since 1920 it has built up the seismograph stations, conducted boring experiments at Kilauea, equipped a chemical laboratory at the Observatory, maintained a research fellowship at the station for a year, sent an expedition to investigate the Tokyo earthquake, assisted printing and publications, built an iron archives andoffice building for the Observatory and apparatus and books: and finally, the present campaign of the Association, which has been in progress for over a year, has in view supporting and promoting publication of th scientific results of the fifteen years of work at Kilauea done by its employees and by the government.

T.A.J.

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NO. 3 RELEASED WITHOUT COPYRIGHT RESTRICTION January 15, 1925

KILAUEA REPORT NO. 679

WEEK ENDING JANUARY 14, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in Charge

The past week has been a rainy one at Kilauea with 5:88 inches of rainfall January 6-9 inclusive along with strong northeasterly wind. This however occasioned no increase of avalanching at Halemaumau pit. Both the seismographs, which appear to record ordinary avalanches, and the daily observation visits have indicated that the motion of the rock slopes was much less than hitherto.

The number of local earthquakes registered during the week was thirteen. On successive weeks beginning with that ending December 3, the numbers per week were 19, 41, 50, 33, 30, 22, 13. The maximum of 50 was just at the solstice, when there was notable avalanching that stripped the northeast wall of the pit, and also one strongly felt earthquake.

During the rainy spell there were electrical storms and snow fell on Mauna Loa and Mauna Kea, covering the cones at the 10,000 foot level and above.

Visited after the rains on January 10, the bottom of Halemaumau was steaming vigorously and vapor rose even from cracks in the rocky wall all the way up to where they join the tangential steaming fissures on the rim. The increased volume of bottom steam made more visible the sulphurous fume that is mixed with it, giving the vapor bluish edges and leaving blue gas where the vapor dissipates above. From a northwest pocket of the bottom and from the south talus the densest volutes of steam go puffing upward. At the bottom pocket January 12 there appeared to be puffing.

A second visit at 6 p. m. the same day discovered no more such noises, nor were they heard on the following days. At dark no glow could be seen. The whitening of the walls on drying after rain was especially noticed above the hot intrusive bodies, as though these were still emitting acid gases.

THE INSIDE OF THE EARTH

The distance to the center is 3960 miles. The outer crust, it is commonly agreed, within a depth of 35 miles changes from granite to a heavier dark olivine rock. Below the crust lies a zone of these rocks 960 miles thick growing heavier. Then comes a shell of mixed rock and metal about 870 miles thick, the outer part silicates pocketed with nickel-iron alloy, the inner a metallic matrix containing scattered clusters of olivine crystals. The specific gravity of this shell (its weight compared with water) varies from 4 to 9 going inward. Ordinary lava averages about 3.

We have now gone down 1865 miles and arrived at a red hot stiff sea of metal. This is the central core, its substance like the nickel-iron meteorites, its diameter 4200 miles, its specific gravity 10. This it is that brings up the average density of the globe to 5.5.

All of this doctrine comes from up-to-date experiment, analysis, and computation by Williamson, Washington and Adams of the Geophysical Laboratory of the Carnegie Institution of Washington, Dr. A. L. Day, Director. (Journ. Wash. Acad. Sci. 1923, 413; 1924, 333, 435, and 459).

The arrangement in shells agrees with the analogy drawn from the metal and stone meteorites, with the weight, rigidity, and compressibility of materials required for the waves from big earthquakes to pass through the earth as they do; with the inertia of the earth in its rotation and tides, and with compression calculated as varying with depth. At the center of the earth the pressure is amout 22000 tons per square inch.

The earth is not conceived to be a big meteorite, but a planet of graded substance metallic to rocky from within outward. If torn to pieces the fragments would be meteorites of the iron, part-iron and stony sorts. A Greenland lava contains 31 per cent of metallic iron, showing that some pockets of the rock-iron mixture come within reach of volcanoes.

Chemically the nickel-iron at the center, by analogy with known meteorites, is free from oxygen and silicon, but contains sulphides, carbides and phosphides. In the next rock-iron zone, crystalline compounds of silicon, oxygen, iron and magnesium are formed in a mother liquor of metal. In the next zone outward this changes to basic silicate magma with only pockets of iron. Oxides like magnetite now appear also feldspars introducing aluminum and calcium, along with borides and nitrides. Lastly the thin outer crust brings in sodium in its lower part and potassium above, and finally free silica as quartz and free oxygen in the air.

The metals from inside outward are in the order of increasing affinity for silica and for oxygen and grade from electro-negative to electro-positive. Of the whole earth 99.60 percent consists, in order, of iron, oxygen, silicon magnesium, nickel, calcium and aluminum, with subordinate amounts of sulphur, sodium chromium and potassium. These with hydrogen and cobalt are also the principal elements we know spectroscopically in the sun.

The amount of oxygen in the iron core is zero, in the crust it is 47 per cent. The iron in the core makes up 91 per cent, in the crust only 5 per cent. Has there been a progressive oxidation of an elemental sphere, and is volcanism the relic of that process?

The last paper by L. H. Adams calculates the temperatures in the upper 180 miles. Radio-activity, melting-points, viscosity and circulation from the days of an original molten surface play their parts. The magma crystalized from below upward, concentrating a residue of basalt 60 miles thick which crusted over. The crusts foundered and left a honeycomb with liquid layers of great size. The age of the earth since cooling began is placed at 1600 million years. Final concentration produced granite.

The increase of temperature downward in the upper crust is much more rapid than it is below. It comes out

at	12	miles	depth	500	degrees Cent.
"	32	"	"	1000	" "
"	79	"	"	1500	" "
"	135	"	"	2000	" "
"	183	"	"	2450	" "

which is less by 1000 degrees than the temperature of the carbon electric arc. T. A. J.

ERRATUM

A misprint in the sixth line from the end, last number of Volcano Letter, should read: The Volcano Research Association "built an iron archives and office building for the Observatory records, also an iron steam laboratory over the bore holes at Sulphur Bank, furnished the station with machinery and apparatus and books, and finally" entered on a campaign of publication.

SAMPLE COPY

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NO. 4 RELEASED WITHOUT COPYRIGHT RESTRICTION January 22, 1925

KILAUEA REPORT NO. 680

WEEK ENDING JANUARY 21, 1925
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

During the week at the Hawaiian Volcano Observatory on the rim of Kilauea crater the weather has been mostly without rain after the heavy downpour of the afternoon of the 15th when there was thunder and lightning. The wind has been fresh from the northeast, the barometer normal, and thermometer minimum 48° F.

The number of local earthquakes registered per week jumped from 13 to 27. Of the 27 for the past week three were perceptible. Fourteen of the shocks occurred in one day, January 17, about a half of them being of the avalanche type. Some noisy avalanches occurred at Halemaumau during the week but no very big ones. One distant earthquake was recorded at 2:45 a. m. on both the Kona and Kilauea seismographs January 18th, the indicated distance of origin being 3600 miles. From the 16th the tilting of the ground at Kilauea was northerly.

The pit Halemaumau, though devoid of active lava, performed peculiarly on the eve of Saturday the 17th, the day of the many earthquakes. On Thursday there had been a few avalanches. On Friday they were more numerous, and at 7 p. m. a strong roar from the pit was heard at the Observatory. The pit had been visited between 5 and 6 p. m. and about every ten minutes more or less, there was noticed an echoing hiss ending with the rattle of sliding rocks, like the steady puffing that had been observed the week before.

Steam obscured the west debris slope whence the noises proceeded, but some angular scarps in the gravel heap of the bottom were noted. There were small rock falls from the wall that made a different sound. The seeming hiss would prolong itself into the clatter of a sliding ribbon of talus, and while the moving fragments were not seen, the loud grating noise was believed due to the caving in of the northwestern and northern talus, the fragments sliding into a crack that was opening beneath. Possibly the lava column was disturbed below and made some kind of an opening.

Some hissing was heard again January 18th, but believed due to wind. Nothing more was heard of it. The northern walls have developed more white stain and the eastern wall has caved in so as to destroy the flag station. New cracks have appeared in the dirt back of the east rim.

A MODERN SUMMARY OF EXISTING VOLCANOES

It is no small task (see Sapper, Volcanological Review, III, 65, 1917) to compile from existing documents the number, kinds, activities, distribution, output and periodicities of the known active volcanoes. And there are some in remote lands, or under ice, or under the sea, which are unknown. Moreover many volcanoes exist which appear fresh, but no one knows their records. Of 202 volcanoes and lava fields mapped in Chile and Argentina, only 30 have active records. Of 165 volcanoes in Japan, 58 are ranked as active. Sapper makes the total number of active volcanoes on earth 430, of which 80 are submarine, as reported from time to time by mariners. Sixty-four per cent are in the northern hemisphere and thirty-six per cent in the southern. More than half of the total number lie within 30 degrees of the equator.

The Indo-Atlantic half of the world has only 94 active volcanoes as against 336 for the Pacific half. And most of these Pacific vents for the earth's internal fire are around the margin of the ocean, for only fifteen are in the middle. About 2500 eruptions are known to all history as hitherto compiled, and more than 2000 of these were about the Pacific.

As to the kinds of activity exhibited, to get reliable data on lava flows as contrasted with explosions or mixed eruptions, it is necessary to take a group of modern dates. From 1895 to 1913, of 396 eruptions in the world, 284 were explosive, 83 were mixed lava and ash producers, and only 29 were purely lava flows. Of the explosive, 255 or 90 per cent were from the Pacific border region. The Indo-Atlantic half of the globe has explosive, mixed and lava types all three, while the central Pacific rarely has explosive eruptions pure and simple. Since the year 1500 the total output of lava is estimated by Sapper at 12 cubic miles, and of fragmental material such as rocks, sand and ash 72 cubic miles. Of these last, 86% came from the Pacific Hemisphere.

The greatest lava-producers in single eruptions were the volcanoes Leirhnukur, Laki and Eldgja in Iceland, Lanzarote in the Canary Isles Kliutschew in Kamtchatka, Savaii in Samoa, and Sakurajima in Japan. Mauna Loa is possibly in this first class. In the second class of lava-makers are Etna, Vesuvius, Hecla, Kilauea, Asama, Mont Pele', and two Philippine volcanoes, Camiguin del Sur and Mayon. Other lava producers little known but important are Namlagira in central Africa, Kartala off the east African coast and Piton de la Fournaise in the island of Reunion.

A striking fact about lava outflow since 1701 is that high latitudes have produced twelve times as much lava per unit of area as the equatorial belt, whereas the equatorial region has produced eleven times as much explosive material as the latitude of Iceland. And the Iceland-Kamtchatka latitudes have produced twice as much lava as ash. Iceland alone in the eighteenth century was responsible for more than a third of the world's lava flows of the last 225 years. T.A.J.

FREQUENCY OF HAWAIIAN EARTHQUAKES

During the year 1924, 5877 local earthquakes were registered on the seismographs of this Observatory. Of this number, 772 were perceptible shakes, the remainder being detectible only by delicate seismographs. This is the largest number recorded here in any one year since the establishment of the Observatory in 1912 and is much above the yearly average.

The greatest number recorded in any one month was 3961 in May. The least was 21 in January. 1924, when the pit was full of lava. The large number in May accompanied the explosions and the collapse of the floor of the fire pit. This year confirms previous observations that seismic frequency and intensity are higher when the pit is quiet than when molten lava is visible. R.H.F.

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NO. 5 RELEASED WITHOUT COPYRIGHT RESTRICTION January 29, 1925

KILAUEA REPORT NO. 681

WEEK ENDING JANUARY 28, 1925
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

The weather of the week has been fair with variable winds and calms, and one rainy day on the 26th. There are two conspicuous features in Halemaumau pit during the present quiet solfataric spell following the eruption of May, 1924, which change with the weather. One is the efflorescence of white sulphates on the walls after dry sunny weather, increasing the more such weather is prolonged. The other feature is the visibility and apparent density of the vapor jets about the bottom, and of the larger vapor cloud which condenses above the whole pit. In rainy weather the dense vapor of the small jets at the bottom may fill the whole pit and merge with the cloud above that rolls away to leeward. In sunny or cloudy weather this big cloud may be wholly invisible or merely shreds of rapid-rising cumulus high above the pit, and the steam jets on the bottom appear thinner, less flocculent and more idle in their rising activity.

At the beginning of the week after a dry spell the walls were notably white and chalky with magnesium sulphate, especially above the two ends of the hot north sill. On the 26th after a rainy day it was remarkable how these big areas of white stain disappeared.

This whitening is different from the true solfataric action of the live vents about the bottom depositing sulphur and sulphates yellow, cream colored or greenish or even pink, with hot steam making dry patches in the midst of stones dark with moisture roundabout. There are three such deposits at the base of the southeastern wall, eight patches in the talus west, south and east, and two stained areas fuming in the floor. These places are very hot, but they also become inconspicuous in coloring after excessive rains.

The vast pit of Halemaumau shows only gradual changes. Small rock slides have occurred mostly at the north intrusive sill. The peculiar sliding noise reported last week has not recurred, but in morning sunlight on the 25th a depression was detected about 20 feet wide extending N-S across the W side of the floor. The mud drainage was toward this place indicating extreme lowness, and here is the west pocket with salts and hottest and densest steam jets. The peculiar slides may have been into this depression.

The seismographs have recorded 11 local earthquakes, one of these January 26 at 6:42 a. m. showing indicated origin 11 miles from the Observatory, probably to the southeast. Tilting of the ground has been to the south-southwest.

Temperature measurements at vapor cracks from rim of pit outward from Halemaumau gave 162° Fahr. at south rim, 167° west rim, 169° southeast rim, 187° at a purring vent 100 feet back of southwest rim, 189° at road terminus 2000 feet back southeast and 194° at old sulphurous cracks south of Kilauea crater at the contact of lava and gravel. This last place was also blowing. If we go still farther outward to the Sulphur Bank at Volcano House we get 204°. Thus cracks are deeper and hotter the farther we go from the volcanic center.

A VOLCANIC OUTBREAK THAT SHOOK THE GLOBE

World-shaking earthquakes are well known. Sudden release of stress occurs somewhere in the earth, and a big earthquake is registered on seismographs thousands of miles away. It is commonly thought volcanoes have little to do with it. Many big earthquakes happen under deep oceans for the centers can be located by the seismographs. Of lava outpourings under the deep sea we know nothing; they may very possibly occur.

Dr. Tams of the Hamburg earthquake station (Volcanological Review, 1924, 137) shows that Katmai volcano in Alaska, in June 1912 produced eleven earthquakes which were well registered at St. Petersburg. The actual swing of the ground at the Russian station was from a thousandth to six-tenths of a millimeter. The instrument magnifies the movement and makes it visible as a written zigzag line. The Katmai earthquakes were registered at other stations in Europe, America, Asia and Africa. During the first three days of the tremendous explosions that gave birth to the Valley of Ten Thousand Smokes, two of the shocks were registered at Cape Town 11,000 miles away. Their centers were not right at the volcano, but at places 60 or 90 miles to the west.

All the centers located were notably along belts parallel with the line of volcanoes and 50 to 100 miles away. There were also big shocks in the Mt. McKinley range at the end of the line, and in the deep Aleutian trough of the Pacific.

Many earthquakes were strongly felt in towns near the volcano about the time of the disaster June 6th, 1912. The eruptions continued all summer with loud noises and numerous earthquakes. Dr. Griggs (Nat. Geog. Soc. 1922) and his colleagues estimated that six cubic miles of ash were ejected.

Mt. Katmai lost two cubic miles of rock unaccounted for in the ejecta. A big crater and many cracks remained, two new adjacent craters appeared, and in one of them stood an obsidian dome of new lava 200 feet high and 800 feet across. A fill of hot sand with hundreds of fumaroles occupied a valley representing a zone of fractures crossing the Alaskan peninsula. It was thought that a large body of siliceous lava underlay the peninsula and the earthquakes and eruptions accompanied movements of the earth's crust wherein tension cracks opened. It is a matter of theory as to which was cause and which was effect.

The seismographs of Europe were calibrated by the Sakurajima earthquake of 1914. This in Japan destroyed houses and lives. Registered in St. Petersburg it swung the pendulum four-hundredths of a millimeter. From St. Petersburg Alaska is the same distance away as Japan. Therefore Katmai earthquakes swinging the St. Petersburg pendulum twice as far and fifteen times as far as did the Sakurajima shock, were twice as big and fifteen times as big. In this way the size as well as the location of earthquakes in the Alaskan wilderness, were better determined in a quiet cellar in Russia than they could be by any evidence available in the region where they occurred.

Big earthquakes near volcanoes are not unusual. The Sakurajima eruption was itself a trigger that turned loose the big shock in South Japan. Large earthquakes near Etna in Sicily at times of eruption have been recorded on the seismographs of Europe. And lastly, the big lava flows of Hawaii in 1868 were preceded by an earthquake of the globe-shaking variety which was felt 300 miles from the volcanoes.

T.A.J.

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NO. 6 RELEASED WITHOUT COPYRIGHT RESTRICTION FEBRUARY 5, 1925.

KILAUEA REPORT NO. 682

WEEK ENDING FEBRUARY 4, 1925
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

The crater pit Halemaumau of Kilauea volcano remains quiet so far as lava activity is concerned. After January 29th, however, there was some revival of avalanching from the walls of the big cauldron, which is 1280 feet deep. Along with this came tremors recorded on the seismograms at the Observatory 2.1 miles from the pit. The number of local tremblings was 34, but of these only eight had amplitude enough to be conspicuous on the record sheets, and but few of these seismic movements had the sudden beginnings of local earthquakes. They begin as small quick tremors sometimes a half-minute before they develop gradually an amplitude sufficient to be read without a magnifier. Their correlation with avalanching may be caused by settlement or uplift under the pit, or the avalanches may directly cause the tremors. On the evening January 30th a small earthquake was followed by the squawking of a pheasant and then by a roar from the pit.

Two very slight distant earthquakes were registered respectively at 7:19 a m. January 30th and 10:48 a. m. February 2nd. Tilting of the ground has been away from the pit toward the east and north.

On January 29th fresh cracks in the ash southeast of Halemaumau showed that wall of the pit to be working. On the 31st fresh sulphur deposit was noticed at the bottom on the south side. There were dusty avalanches February 1st and three pronounced quakes on the following night were coincident with strong avalanche signs discovered the next morning at the southwest wall. Adjacent to the tunnel of the Kau Desert rift, in the wall of the pit, the whole upper part of the precipice was freshly broken away, and one of the signal flags was gone. On the bottom were fresh fragments, and clouds of dust had powdered all the solfataric deposits, obscuring them. The ash was newly cracked for 100 feet back all along the southwest side. All that region is heavily crevassed back from the rim.

February 3rd and 4th the slides decreased and the pit was quiet. With sunny weather the gravel fields of 1924 debris northeast and the southwest of Halemaumau appear white with efflorescence of salts.

VOLCANOLOGY IN JAVA

The most colossal explosive eruption in all histroy is believed to be the Tambora outbreak of 1815. This volcano is on the island of Sumbawa east of Java. As is so often the case, it was supposed to be extinct. It began to throw out ash in 1814, became violent April 5, 1815, reached its maximum April 10, and became quiet by July 15. The top of the cone was destroyed and lowered from a height of 13,000 to 9,000 feet. The crater pit left was four miles across and 425 feet deep. The current estimate for rocks and ash ejected is 36 cubic miles. Ten thousand people were killed by burial under ash, and drowning by engulfment in the sea-waves, and 37,000 by famine and disease. The crops of the neighboring islands were buried under two feet of ash, and the houses necessarily crushed. At the height of the eruption the whole mountain was covered with showers and blasts of glowing gravel and sand, but not lava flows. The coast was reported lowered 18 feet, and elsewhere harbors had shoaled.

The volcanoes of the Dutch East Indies have produced vastly more explosive matter than all the rest of the world. There are at least four hundred of them, of which 80 show activity, and about 36 have had explosive eruptions, which ravage fearfully the fertile lands of Java and Sumatra.

Excellent topographic maps and investigations by the Office of Mines of the Dutch government at Batavia have been made for many years, but a new Volcano Committee was organized in 1919 under the direction of Dr. Kemmerling, and now under Mr. Taverne. Six memoirs on volcanoes have been issued since 1918, with colored maps and photogravure illustrations. A new one in press exhibits volcano studies made from airplane by Mr. Taverne. (G. Kolff & Co., Weltevreden, Java. Vulkanologische Mededeelingen Nos. 1-7). The photography, press work and engraving (done in Amsterdam) are admirable. Some of the large-scale maps would be improved if ruled scale, and contour interval, were given, and all these books need index maps to locate the small maps.

The first memoir deals with Sumatran volcanoes, caldera lakes and hot springs. The second is on Kelut volcano, which took 5500 lives in 1919 by throwing out its crater lake. A tunnel is beiog driven to drain it. Merapi in Java forms the subject of the third; this volcano ejected incandescent blasts in 1920-21. In the fourth the Bromo-Smeru country is described, with its saud-sea in the Tengger. The fifth deals with the northeastern archipelago, Minahassa and the Sangi islands, where the crater lake and mud eruptions of Awuh are like Kelut. And the sixth, with airplane illustrations, describes the outbreak of Galunggung 1918, with lava in the form of an andesite dome. T. A. J.

ENGINE-MADE EARTH SHAKINGS

A measure of the sensitivity of a delicate seismograph is shown by the fact that as soon as the Fairbanks-Morse oil engine of the Kilauea Volcano House electric-lighting plant was started in December 1921, the operation of the engine was recorded on the seismographs of the Observatory about 800 feet away. Variations in the engine-speed or changes in load as well as exact times of starting and stopping were duly recorded. The engine record on the seismograms was shown as about six very minute vibrations per second. This corresponds with the number of explosions of the engine per second. Originally the engine exhausted into a steam crack adjacent to the power house, and when the exhaust was directed into the air in November 1924 the engine ceased to be recorded on the seismograph. R. H. F.

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NO. 7 RELEASED WITHOUT COPYRIGHT RESTRICTION February 12, 1925

KILAUEA REPORT NO. 683

WEEK ENDING FEBRUARY 11, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

Conditions remain tranquil at Halemaumau pit. In the seismological laboratory of the Observatory twenty-six local seismic movements have been registered, of which more than half were prolonged tremors such as usually accompany avalanches in Halemaumau. Ten of the earth movements occurred on February 9th. At 1:34 p. m. of the 8th a felt earthquake occurred, with so short a preliminary tremor that the center must have been within a mile of the Observatory. The tilting of the ground at Observatory has been very slight to the west.

The journal of events recorded shows nothing remarkable for the 9th except a brisk northeast wind that made dust clouds on the desert, kept the debris more or less in motion in the pit, and thereby perhaps occasioned some avalanches, as the wall material in places is nicely poised. About that time also the smell of spicy sulphur from the bright yellow patch at the foot of the east talus had become strong, and that solfatara had become particularly bright in coloring. There was more of the sulphur odor than of hydrogen sulphide.

February 6th was dry and avalanches had notched the wall NNE. On February 7th there were three noisy slides in the early afternoon. There was fresh debris left on the northeast talus, and sulphur crystals were bright colored at the steam patch at the base of that slope. On both the 8th and 9th strong odor of sulphur rose. Fresh movement of the cracks back of rim southeast was observed. There was continuous rattle of falling stones southwest on the 9th, and the wall at the SW rift showed signs of more stripping.

On the 11th there was breakage in the talus, like an incipient landslip under the big north sill. In the wall made by the sill itself two vertical cracks were seen. These gaped open a foot or more and extended up and down for from 50 to 100 feet. There were possibly some corresponding cracks in the lava floor. This region at the northeast end of the pit corresponds to the place newly notched by avalanching southwest, as though the rift belt were in motion.

ROOTS OF A SCOTTISH KILAUEA

An area eighteen miles square, seventeen authors and twenty-three years of work are the elements of a new publication of the British Geological Survey, J. S. Flett, Director (Mull, Sheet and Text 44, 1924, Stanford, London, 18s.). This is a model of condensed statement, and the colored geological map needs only intercalated profile structure-sections to make it perfect.

Central Mull, surrounded by fjords, with mountains 2000 feet high, is the relic of an ancient Kilauea lowered by ring faults and profoundly worn away. The original lava dome was several thousand feet above. The root of the volcano shows siliceous and basic intrusions in a young inner series of lavas, surrounded by older plateau basalts.

Three cycles of change are shown from a basaltic mother lava to later granitic intrusives, with gradations. Silica ranges from 45% to 70%. Olivine decreases from earlier to later lavas. Inside of an encircling zone of 15 miles diameter the olivine crystals show alteration by vapors. Enough gneisses and sedimentary rocks occur both as ledges and inclusions to suggest assimilation of these rocks in the magma. The Mull complex differs from Hawaii in its siliceous sediments and granitic intrusives.

The analogies with Hawaii are many. "Pillow" lavas, bulbous, with glassy shells, are mapped in thirty places in the Mull crater area, and are supposed to have flowed into a crater lake. They are like the glassy pahoehoe formed during torrential rainstorms in Hawaii. Very Hawaiian are the ring-fractures and dykes, suggesting the "wall-crack fills" of Halemaumau. The double crater, plateau lavas, explosion dykes, vent agglomerates and gabbro intrusions all have parallels in Hawaii. The dyke swarms trending in one direction suggest the rift trends that are so definite on Mauna Loa and Kilauea, often productive of fissure eruption in Hawaii just as in Iceland.

The cone sheets of Mull are hundreds of concentric dyke-like intrusions dipping funnel-wise toward the volcanic center. Upward pressure of magma at one point is believed to have produced the funnel fractures, but the Hawaiian sinks make such inward dipping fractures by inbreak when the lava column withdraws. The ring-dykes are vertical or outward dipping crescent bodies about the central vent. One of them is an almost complete fault ring of size and shape like Kilauea, filled as a dyke with augite rhyolite. Ring tendency appears also in border folds eight miles from the center. T.A.J.

MAGNETISM IN HAWAIIAN BASALT

The magnetic compass points due north at only a few places on the earth's surface. At other places it points either to the east or west of north by know amounts. This compass error, declination or variation as it is called, is not constant for any one place but is always slowly changing.

At the rim of Halemaumau, the pit in the crater of Kilauea volcano, the behavior of the compass needle is very erratic. At some places it may show 10° easterly declination, the approximate correction for the Hawaiian Islands, a short distance away a much greater declination, no declination at all, or even a westerly declination.

Some such variation in the compass needle is to be expected in a region whose rock contains as much iron as that of Hawaii. In certain localities the percentage of iron is higher than the average or an appreciable part of the iron is in the form of the magnetic oxide and there the compass needle is very unreliable as a direction finder. One such place was found in a kipuka (a small area of older lava or soil surrounded by new lava—an oasis in a lava flow) in the 1859 lava flow from Mauna Loa by E. G. Wingate while making topographic maps for the U. S. Geological Survey in 1923. In the kipuka the compass pointed 50° to the east of north. R.H.F.

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NO. 8 RELEASED WITHOUT COPYRIGHT RESTRICTION FEBRUARY 19, 1925

KILAUEA REPORT NO. 684

WEEK ENDING FEBRUARY 18, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

The conditions at Halemaumau pit remain as they have been, and the greater part of the local seismic movements registered at the observatory were of the tremor type associated with avalanches at the pit. Thirty seismic movements were registered, of local origin, of which twenty-three were of the tremor type without the marked phases characteristic of sudden local earthquakes. Of the sudden ones two were felt at Kilauea, one at 6:43 a. m. February 12, and another 11:52 p. m. February 17. The tilting of the ground was moderate to the SSW.

Events at Halemaumau have shown continued peeling of the pit walls. No further developments have been observed in the crack athwart the big sill in the northeast wall reported February 11. In the different lighting of a cloudy day, February 12, the upper part of this crack appeared to have a red filling but underneath it appeared as a dark crevice extending all the way down to the talus.

On February 14 in the forenoon it was discovered that the inner ledge with its loose blocks a few feet below the rim at the tourist station southeast had fallen in. There was no fresh cracking back of the rim but there had been such cracking the previous week, showing that that edge of the pit was in motion. The portion that had fallen was the thin edge of an upright slab which has been partially detached from the wall and hanging out into the pit ever since the May eruptions of 1924.

On the 15th a new upright crack appeared in the lower northwestern wall in one of the promontories or buttresses which are characteristic of the lower walls in several places. This crack bounded a semi-detached crag about 150 feet long up and down next to a depression occupied by the northwest talus slide. On the 17th this wall was working steadily and three avalanches were seen in the wall adjoining this crack. By the next day the promontory was stripped and the crack gone.

During the last three days with light southerly wind and in spite of dry weather the steam on the bottom of the pit has been voluminous and a new sulphur patch has appeared in the east talus.

COMPARATIVE VOLCANIC ACTIVITY

One method of measuring comparative volcanic activity of different Pacific regions is by the proportion of extinct volcanoes to the total number for each district. This is based on the theory that all volcanic districts are remnants of greater activity in the Tertiary age. The percentage of dead cones in a district is called the "index of decadence." The lower the index number, the higher the percentage of live vents, hence the higher the activity as compared with other places.

In Hawaii, counting only the five complete volcanoes uninjured by faulting or erosion, only one, Mauna Kea, is extinct. Index of decadence then is one-fifth or 20%.

Von Wolff (Vulkanismus, Vol. II, Enke, Stuttgart 1923) arrives at the following index numbers (the Hawaii number is ours):—

		Volcanoes	Extinct	Index Number
1.	Sumatra	117	106	90
2.	S. Japan	22	16	73
3.	Fuji cross-zone	40	25	62
4.	Kurile Is.	51	27	52
5.	Tonga Is.	15	5	33
6.	Hawaii Is.	5	1	20

The extinction becomes less and the activity greater as we get more and more into the ocean.

Comparing with this the number of historical "outbreaks," we get a different order (Schneider, Volcanic Phenomena, Borntraeger, Berlin 1911).

1.	S. Japan	160 eruptions
2.	Fuji Zone	101 "
3.	Hawaii Is.	31 "
4.	Sumatra	23 "
5.	Kurile Is.	18 "
6.	Tonga Is.	10 "

This list means in general that the oceanic volcanoes have fewer explosive collapses than the Pacific margin, and also that Japan has the most complete records. The 160 eruptions for south Japan concern only five active cones.

Both of these lists are unsatisfactory, as the perfection of records and comparative numbers are too various, and the definitions of "extinct" and "outbreak" are elastic. But they mark progress. T. A. J.

EROSION REVIVED BY ASH-FALL

An interesting effect of the dust from the explosions of Kilauea last May is still to be seen at the sand spit on the crater floor southeast of Halemaumau and at other places along the south rim of the crater. Formerly most of the rain that fell on this sand spit quickly sank into old ash beds. Now, owing to the somewhat impervious fine ash covering, a heavy shower develops rapidly flowing streams that cut into the old ash beds and in one place the road to the pit is eroded to a considerable extent. The increased run-off is still striking even nine months after the laying down of the dust. The first downpour, after considerable dust had been deposited and before much had been either washed or blown away, produced the most remarkable erosion effects.

R. H. F.

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NO. 9 RELEASED WITHOUT COPYRIGHT RESTRICTION February 26, 1925

KILAUEA REPORT NO. 685

WEEK ENDING FEBRUARY 25, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

There was less apparent avalanching in Halemaumau pit during this week than in the previous one, and much of the time during visits to the pit the big cauldron was quiet without any noise of sliding rocks. On a very dry day February 19 the steam jets at the base of the east talus were so thin that the vents amid the broken rocks could be plainly seen and it there appeared in three places that bright yellow sulphur crystals were being deposited. These solfataras had developed rapidly, for they were amid fallen bowlders of the December avalanches. The contrast between these deposits of pure sulphur and others pale greenish-yellow at the foot of the north and south taluses is striking. Probably the sulphur at the latter is mixed with sulphates, such as are very conspicuous in vertical streaks of yellow and white at the base of the southeast wall, and in sheets of waxy white salts at the steaming vents in the lava floor near the center of the pit.

After the recent avalanches the northwest wall was seen to be notched so as to make three jagged abutments. Frequent small slides at the north wall, the odor of hydrogen sulphide, and faint hissing from the bottom of the pit were reported on the morning of February 20. Another small slide at the pit was heard that afternoon, and about 8:45 p. m. three deep detonations were heard at the Observatory.

With the dry weather chalky salts have again appeared on the high walls. In three places on the bottom of the pit there are mud flats, two of them showing much white stain when dry. During this week vapor appeared more conspicuously toward the top of the several taluses and in the wall just above the talus than heretofore. The stripping of the southwest wall has so freshened the rift dyke above the 1920 tunnels as to show that it is double, with country-rock between the two members, and a dark red fill. This is quite different from what the same dyke becomes below the big tunnel. Here it is thick and whitish. On the 23rd distinct upright steaming cracks in the body of the north talus were observed, showing that the talus matter breaks as a cake. It is remarkable how the very hot steaming slopes south and west make no deposits, although close at hand others deposit sulphur and salts. The sulphur is confined to the edges of the lava that came into the bottom in July, 1924.

Seventeen local seismic movements were registered during the week, of which seven were without evidence of preliminary tremors. One about 10:18 a. m. February 18 was felt in Kohala, and a pronounced shock partially dismantlling the seismograph at 10:20 a. m. February 23 came from an origin indicated by the seismogram as 13 miles from the Observatory. A distant strong earthquake at 1:31 p. m. February 23 appeared to originate about 4250 miles from the station, but neither the time nor the distance accorded with the destructive shock reported from Seward, Alaska. Tilting was moderate to the NNW.

INTERNATIONAL VOLCANOLOGY

The first publication of the volcano research section of the International Geodetic and Geophysical Union has made its bow to the public. This quarterly bulletin was published in Naples, September, 1924, by the secretary-general, Professor A. Malladra, Director of the observatory on Vesuvius. (Bulletin volcanologique, Royal Vesuvian Observatory, Resina, Italy, 30 fr. per annum).

It is in French and Italian and deals with the meetings in Rome and Naples 1922, and the program of the Madrid conference 1924. The American committee was evidently active, and its personnel and recommendations reflect the recent Pan-Pacific Science conferences.

Plans are outlined for a Central Bureau of Volcanology, which has now been established at Naples; for subordinate branches, with international libraries, at the Hawaiian Volcano Observatory and at the Italian institute of Catania, Sicily; for international cooperation that will furnish information instantly by wire or post, through the Bureau or its branches, of new volcanic activity anywhere; for urging naval establishments and mariners to give information about marine or submarine volcanic happenings; and for the preparation by each nation of a topographic, historical and statistical catalogue and bibliography of its volcanoes.

On May 8, 1922, on motion of Professor A. Lacroix, President of Section, it was

Resolved:—"(1) That, by reason of the services rendered to date by the volcanologic observatories of Vesuvius and of Kilauea, facilities should be accorded them for continuation of their work, and an institute of the same kind should be established for the study of Etna and the Eolian Islands;"

"(2) That continuous observations of volcanic phenomena should be made at the island Re'union."

Other matters given attention were underground thermal gradients, volcano borings, utilization of volcanic energy; papers published are on the activity of Vesuvius and Etna, on a new cinder island off the coast of Cochin China, on the power plant of Prince Ginori Conti using natural steam in Tuscany, and on volcanic potash, alumina and silica obtainable in the United States and Italy; and a notice on the work of the late honored Professor A. Ricco of Catania, student of Etna, the first president of the volcano research section. T. A. J.

THE VOLCANIC DEATH-TOLL

Since the year A. D. 1500, 98 eruptions of 57 volcanoes have destroyed 190,000 people. Of these 176,509 died on the Pacific half of the earth. Tambora near Java in 1815 accounted for more than 56,000 victims; next came Krakatoa in the Sunda Strait in 1883, killing 36,400 mostly by a flood. This was set up by the collapse of the island, and engulfment of the sea; outgoing tidal waves swamped the fishing villages on the neighboring coasts of Java and Sumatra. Mont Pe'le' in Martinique and Soufriere in St. Vincent in 1902 together accounted for some 30,000 lives by ejecting fiery blasts and showers of stones. Ten thousand deaths each are credited to the volcanoes Laki in Iceland in 1783, Kelut in Java 1586 and Unzen near Nagasaki in Japan 1792. To these seven eruptions four-fifths of the death toll have been paid. These figures have nothing to do with the terrible earthquakes and consequent fires of volcanic regions, such as Tokyo in 1923 and Messina in 1908. These two modern earthquakes destroyed more than twice as many lives as all the volcano outbreaks of history. (See Sapper's catalogue of eruptions, Strassburg Scientific Society, 1917). T. A. J.

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NO. 10 RELEASED WITHOUT COPYRIGHT RESTRICTION MARCH 5, 1925

KILAUEA REPORT NO. 686

WEEK ENDING MARCH 4, 1925

Issued by the Observatory, U. S. Geological Survey:

T. A. Jaggar, Official in charge

The week has been rather quiet with reference to avalanching in Halemaumau pit, and on some days a visitor to the pit heard no rocks sliding at all. At noon of March 2nd however during fresh squally northeast wind and very dry weather, the northeast corner of the pit started caving away.

The air in the pit became charged with dust so that the whole orifice was outlined by the swirling veils. Occasional small individual clouds of dust rose, but nothing that suggested a big avalanche. The whole northeast talus next day was covered with fresh red rock fragments. In the middle of the wall above, about the eastern horn of the large sill, a notch several hundred feet high had been left, revealing red ochreous rock and white or greenish brown vein matter. The notched place was fissured up and down for hundreds of feet, the fractures appearing to trend in the direction of Keanakakoi.

Nothing but small slides have occurred during visits to the pit. There are six sulphur-lined holes venting steam in the east talus where the latter overrides the lava floor, and there is also sulphur at the top of that talus. The hotter looking vents, giving up dense flocculent steam south and west, deposit no sulphur. Irregular red bodies of large size, above and surrounded by the big sill north and the large intrusive mass west appear as though they might have been crags in an ancient pit of which the sills formed the bottom. The middle of the north sill has an upward extension in section shaped like a mushroom, with fossil talus slopes on each side. Right and left the sill rises into horns behind these taluses, suggesting the vents that we have seen so often breaking out from the top of a debris slope.

It is difficult to say what starts the avalanche notches to working as on March 2 mentioned above. The steep northeast and southwest walls have breakage lines up and down that the other walls do not have, possibly traces of the Kau Desert shear zone. The northeast wall has avalanched more than any other. It may be that this zone moves seismically. There have been 17 local shocks during the past week, 12 of them without earthquake phases, and one at 7 a. m. February 28 felt here with indicated origin 2 miles away. Tilt was moderate to the northeast.

MORE COMPARISONS OF VOLCANO DISTRICTS

Taking Sapper's data and combining his small zones into districts with a view to getting 18 to 32 volcanoes in each district, we have the following:

Activity by number of volcanoes active for aggregate length of volcanic zone.

	Total number active	District	One volcano active per length of	
1.	25	Iceland	25	kilometers
2.	26	Central America	45	"
3.	25	Aleutian Is.	50	"
4.	19	Java	55	"
5.	18	New Zealand—Tonga	77	"
6.	24	Kamtchatka—Kurile	85	"
7.	25	Japan	100	"
8	41	South America	104	"
9.	18	Mediterranean	120	"
10.	26	Sumatra—Sunda Is.	127	"
11.	32	Philippines—Molucca	138	"
12.	18	Atlantic Ocean	192	"
13.	25	Melanesia	224	"
14.	30	North America	275	"

The central Pacific islands (Juan-Fernandez, Galapagos, Hawaii, Samoa and submarine eruptions) number 15 or 16 known vents and in indefinite number of unknown ones. They cannot be treated by length of belts.

To one knowing the places, the order of this table as showing decreasing volcanic activity is no more satisfactory than Von Wolff's table by "index of decadence." Both are based on unproved theoretical assumptions. This one assumes that the number still smoking in a given distance is an index of the activity of that area. But it overlooks the fact that two regions may have the same number of active volcanoes for the same distance or area, yet the activity of the whole district may be much greater in the one than in the other. (See Sapper, Volcanological Review, 1917). T. A. J.

EARTHQUAKE IN ST. LAWRENCE VALLEY

Press reports of this week tell of a disastrous earthquake February 28 in eastern Canada, centering about the St. Lawrence, with the loss of at least three lives, and "scores of homes damaged by earthquakes and fire, and one church collapsed." The Saguenay river was near the center. This is a deep canyon forming a northern tributary of the St. Lawrence, below the Thousand Islands, with Tadousac at its mouth. It is well known earthquake district, and so is the Labrador, farther to the east.

This recalls the earthquake of 1663 in the same district, of which Clarke, state geologist of New York, writes that "no like catastrophic upheaval of the earth has ever occurred here within the memory of man." "With a roar as of artillery the earth leapt up, houses tottered, walls were split, river banks were levelled, new lakes were seen, two mountains were overturned into the river and dammed it; forests were swallowed up leaving what looked like ploughed fields; chasms of wonderful depth exhaled a foul stench, and rivers resembled in color streams of milk or blood." So run the old Jesuit chronicles. T. A. J.

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NO. 11 RELEASED WITHOUT COPYRIGHT RESTRICTION March 12, 1925

KILAUEA REPORT NO. 687

WEEK ENDING MARCH 11, 1925

Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, Temporarily in Charge

The past weeks was rather quiet up to March 10th. On this day some of the most spectacular avalanches in several weeks occurred. One at 12:52 p. m. sent up cauliflower clouds that maintained a hard outline for some little distance above the rim of Halemaumau pit. There was another large avalanche at 5:09 p. m. that crashed to the bottom with a roar that was almost deafening to observers standing on the rim. The pit was more or less dusty all day from the many small avalanches.

At the same time as the increase of avalanching there was an increase in the number of earthquakes. During the past week 32 earthquakes were registered at the Observatory, 23 of which occurred between 10 p. m. of March 9 and 6 a. m. of March 11. Four of the earthquakes were of sufficient intensity to be perceptible. The one at 8:14 a. m., March 10, felt as a distinct vertical jolt, had an indicated distance of about 1 mile. Another at 1:06 a. m. March 11 with about the same indicated distance, dismantled the seismographs and awakened many people.

The tilt for the week as a whole was moderate to the east-northeast. Just preceding the increased earthquaking the tilt changed from moderate southeasterly to moderate northeasterly.

A heavy fall of snow on Mauna Kea and Mauna Loa that accompanied the general rainstorm of March 7 and 8, will help to increase the available water supply on the two mountains next summer.

Immediately following the rain storm a large portion of the walls of Halemaumau showed a deep red color, giving the walls almost a velvety appearance. The red color is probably due to rain water percolating through the rock and bringing some of the iron salts to the surface where they are oxidized to iron rust. The bright red color persisted for but a short time probably becoming obscured mainly by dust from avalanches.

EARTHQUAKES IN HAYTI

A welcome volume has just appeared on the geology of Hayti by geologists Woodring, Brown, and Burbank, who were loaned to the West Indian republic by the U. S. Geological Survey. Volcanic lavas poured out in basaltic floods from central vents when the land mass was greater than at present. This was in Jurasic time or earlier. Andesites and more silicious lavas came later. There is still younger basaltic series, with intrusive rocks, of age between Mesozoic and Tertiary. Then came later acid andesites and quartz diorites. All of this was amid marine and non-marine sediments with folding, metamorphism and faulting from Mesozoic times on, and present day features are many of them the products of late Tertiary crumpling.

This movement is still going on, earthquakes are frequent, and those that are felt generally in Hayti originate in the ocean troughs, more localized shocks are related to particular peninsulas, and the central mountains are mostly immune. This is like the situation in the Philippines and the continental island masses. The recent volcanic and sesismic geology are typically cordilleran and like Alaska and the Coast Ranges.

At the meteorological observatory in charge of Rev. J. Scherer, Port-au-Prince, is installed a pair of Bosch-Omori horizontal pendulum seismographs, magnification 40X, which is stated to be "useless for determining the direction and amplitude of local shocks." This machine ought to be ideal for local shocks, with suitable modification of speed of drum and damping such as a physicist-experimenter could easily devise. We suspect that the Bosch air damper is making trouble, and it should be replaced by two or three metal vanes in oil.

The attitude toward this instrument as quoted is typical of much amateur handling of seismographs, owing to unwillingness to experiment, and an unnecessary awe of the supposed constants of the pendulums.

There were seven disastrous earthquakes in Hayti between 1551 and 1908, none of them occurring in the central region. They usually were accompanied by flood waves. The chart shows from six to forty earthquakes recorded in different places between 1909 and 1922, of which from two to twelve at each locality represented general shocks of widespread importance. The northwest peninsula and the north side of the southern peninsula are the regions of highest seismicity. None of the recent shocks was accompanied by a sea wave.

Most of them have intensity II to IV (Rossi-Forel), but a few reach grade VI. A shock on January 15, 1922 cracked ferro-concrete houses. (Geology of Hayti, 1924, English and French editions, Department of Public Works, Port-au-Prince). T. A. J.

VISITORS AT THE OBSERVATORY

On March 10 and 11 the Observatory was fortunate in having as visitors the distinguished geologists of the Third Asiatic Expedition of the American Museum of Natural History, Dr. C. P. Berkey and Frederick K. Morris and the topographer, Major L. B. Roberts.

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NO. 12 | RELEASED WITHOUT COPYRIGHT RESTRICTION | MARCH 19, 1925

KILAUEA REPORT NO. 688

WEEK ENDING, MARCH 18, 1925

Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, Temporarily in Charge

After the avalanching and earthquakes reported last week Halemaumau became more quiet and during the past week only thirteen earthquakes were registered at the Observatory. None of the earthquakes were perceptible at Volcano House and seven of them were without phases.

Some of the cracks concentric to rim of pit where there has been movement recently are quite hot. One of them that crosses the trail to the pit shows but little steam ordinarily but if a lighted match is held near it great volumes of steam become apparent. Smoke from a burning object affords an opportunity for the moisture to condense and if held near a hot crack that is already steaming vigorously there will be a great increase in visible moisture.

On March 13 the steam from the bottom, which is always present, rose in hard outlines as though with a greater velocity or hotter than common. During rainstorms and on rainy days the pit is often so full of steam that the bottom can only be seen occasionally.

The sulphur stained area near the southeast border of Halemaumau floor that was obscured by recent avalanches is again visible.

Tilting during the week was moderate to the south-southwest.

PHILIPPINE EARTHQUAKES

Recent papers in the Bulletin of the Weather Bureau, Manila, by Father Maso, show that 52 destructive earthquakes, or about two per year, occurred in the Philippines during the first 22 years of this century. The strongest originated in the Pacific and in the Celebes Sea. Shocks from the land or the shallow seas were of small extent. The damage was mostly to old or badly preserved buildings. Old tile roofs were particularly dangerous. Places in recent alluvial soils suffered most.

Shocks became more numerous from west to east, or in the Pacific direction, where the relief due to profound deeps is most pronounced. Shocks occur in clusters, calm years alternating with disturbed periods, and infested places likewise shifting. Manila had bad earthquakes in 1863 and 1880. 320 people were killed in 1863, and only about 20 in 1880. Houses of mixed construction, masonary below and wood above, resisted the earthquakes well.

The Agusan Valley in eastern Mindano is the most active region seismically. The earthquakes are most felt in the level marshy central part of the valley where there are lakes and where subsidence occurred during earthquakes of 1893 and 1894. Just to the east lies the great Pacific trough. A big earthquake occurred in this valley, July 12, 1911. T. A. J.

VOLCANIC ACTIVITY BY OUTPUT

		Cubic Kilometers Lava	Cubic Kilometers Explosive
1.	Iceland	15.5	10.0
2.	Central Pacific	10 plus	1.0
3.	Kamtchatka-Kurile	6.0	1.2
4.	Mediterranean	5.1	4.0
5.	Atlantic	4.5	2.2
6.	Japan	3.00	6.2
7.	South America	1.2	9.0
8.	North America	1.0	1.2
9.	Central America	0.6	44.0
10.	Aleutian Is.	0.5	2.5
11.	Philippines-Molucca	0.4	5.8
12.	Melanesia	0.1	3.1
13.	Java	0.1	10.0
14.	Sumatra-Sunda Is.	0.1	172.0
15.	New Zealand-Tonga	0.01	3.1

This table, arranged by decreasing lava production as estimated from eruptions since the year 1500 A. D., and exhibiting for comparison the production of explosive material, shows that lava and explosive material are at opposite ends of the series. Iceland, the Mediterranean and Japan indicate that both may be ejected in large quantities from the same region. Volcanologically this table is satisfactory. The oceans and sub-arctic regions are the great lava producers, the continental borders and the tropics produce much explosion. It is remarkable that the Americas fall together the Atlantic with the Mediterranean, and the Pacific island chains at the explosive end of the series.

Yachtsmen fond of exploring may with the new hydrophones make great discoveries of immense volcanic domes, as large as Mauna Loa perhaps, on the bottom of the oceans. A mountain 8000 feet high stands on the sea-bottom between San Francisco and Honolulu. (Data above arranged from Sapper). T. A. J.

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NO. 13 RELEASED WITHOUT COPYRIGHT RESTRICTION MARCH 26, 1925

KILAUEA REPORT NO. 689

Week ending March 25, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in Charge

The equinox produced no crisis at the volcano. Seismically the past week was the quietest since last November, only eight earthquakes being recorded. An earthquake with an indicated distance of four miles at 5:34 p. m. on March 20 was strong enough to be perceptible. The other seven shakes were very small, three of them being without phases. A distant earthquake with poorly indicated distance of 3600 miles from Observatory occurred at 10:28 p. m. March 21. A report from another station points to a possible location near Kamtchatka.

Some avalanching took place at Halemaumau, the active pit of Kilauea volcano, on March 20 and 21. The majority of the earthquakes for the week occurred on those days. Since the last named date the pit has been rather quiet. A large piece of the eastern end of the northern intrusive body broke off on March 20 making a gray talus slope below. On March 25 the northeast and north wall were avalanching slightly.

Tilting during the week was slight to the east-southeast.

A SHARP TRANSITION FROM FOREST TO DESERT

An interesting but often unnoticed sight on the road to Halemaumau in Hawaii National Park is the sudden change from forest to desert. The northeastern slope of Kilauea is forested and most of the southwestern slope is a desert. The zone of transition is near the summit of the mountain. Instead of being a broad zone that commonly separates forested from desert lands here the zone is narrowed almost to a line. In traversing a distance of 1000 feet one leaves a forested area and enters an open desert.

The change is due almost entirely to difference in rainfall nad not to volcanic fume as is sometimes supposed. The soil in the desert, volcanic ash, is the same as that of the forest. In order for fume to cause the sharpness of the desert edge there should be considerable westerly wind, but west winds are very uncommon at Kilauea. Southwest winds are not uncommon during winter months and occasionally trees are partially defoliated by volcanic fume near Volcano House but rapid growth soon covers up such effects. Stunted growths of ferns, shrubs, and trees are to be found on the lee, or fumy, side of the fire pit, occasionally less than half a mile away. The transition from forest to desert continues as a line extending for several miles down the mountain side.

The rainfall is controlled by topography and constancy of wind direction. In the forested area the air of the northeast trade winds is forced up the mountain slope and cooled off to produce rain. On account of thus losing moisture, air on the lee slope of the mountain is drier that it is on the windward slope. As soon as the air starts down the mountain slope its temperature rises and not only does the rainfall diminish but even the clouds tend to evaporate. R. H. F.

ANNUAL MEETING OF THE ASSOCIATION

The Hawaiian Volcano Research Association at its meeting in Honolulu March 12 reelected its Board of Directors. The officers are L. A. Thurston, president; C. H. Atherton and W. F. Dillingham, vice-presidents; L. Tenney Peck, treasurer; directors are W. R. Castle, Arthur L. Dean, W. W. Thayer. L. W. de Vis-Norton, Young Building, Honolulu is secretary of the Association.

Reports were read by the treasurer and the secretary, and addresses made by the president and by the volcanologist of the Hawaiian Volcano Observatory, who acts as scientific director for the Association.

At present the division of effort between the Government, through the United States Geological Survey, and the Association is as follows. The Government pays salaries, keeps daily journal and seismograms, prepares and issues the routine reports, maintains the plant, the routine, and expeditions when needed, and provides for the larger publications in Washington. The Association is improving the outlying seismological stations and operating them, building up the library of the station, providing for publication of a popular book on volcanism, printing the local publications including the VOLCANO LETTER, and is ready to assist in securing the services of cooperative workers in the chemical laboratory and in the laboratory for steam experiments built over the bore holes at Sulphur Bank.

The address of the Volcanologist was entitled "'National standards of volcano and earthquake research" and will be printed in the March Bulletin of the Observatory. The staff of the Observatory has succeeded in bringing the printing of the monthly bulletins nearly up to date, they are published and distributed to November 1924 inclusive, and ready for the press to February 1925. The December number will contain a discussion of "Volume relations of the explosive eruption." T. A. J.

TIDAL OSCILLATIONS IN HALEMAUMAU

Dr. Ernest W. Brown, in charge of the Department of Mathematics at Yale University and well known for his astronomical work as computer of the complicated motions of the moon, has published an analysis of the lava tide measurements of Halemaumau made by the staff of the observatory in 1919. He concludes that there is enough evidence of tidal effect to warrant repeating the work by a different method for a longer period. (American Journ. Sci. February, 1925). T. A. J.

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NO. 14 RELEASED WITHOUT COPYRIGHT RESTRICTION APRIL 2, 1925

KILAUEA REPORT NO. 690

WEEK ENDING APRIL 1, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in Charge

Halemaumau pit remains tranquil, after a week of extremely rainy weather, and by the wetting of the walls the red color of lava layers is brought into prominence. The reddening is due to oxidation of the iron in the rock, and above the several intrusive bodies is far more conspicuous than elsewhere. The bank of yellow and white sulphates at the base of the southeast wall lost all its color after the rains. The alums and other soluble salts at the edge of Kilauea crater were also washed down. There must be a concentration of these soluble products underground.

In the pit there has been very little sliding of debris. Some new fallen fragments were observed on the northeast talus. A dry patch with sulphur stain on the high north wall, where the rock all around was wet with rain, appears to mark the site of the blue fume vent which disappeared during a November avalanche. The steep cavern in cracked ground north of Halemaumau has recently collapsed, and is now close to rim of pit, so much has the edge caved away.

An examination of Keanakakoi gulch March 28th revealed new erosion and a new debris fan on the Kilauea floor. The 1924 ash both increased the run-off by its impervious surface and furnished cutting material to the water. New white spots on the Kilauea Iki floor are rain-wash hollows filled with ash-mud.

Fourteen seisms were recorded during the week, seven of which were without phases, and five very small were on March 31. A local shock at 12:30 a. m. March 29 was perceptible and had indicated origin distance of about one mile. Tilt was slight to the ENE.

ERUPTION OF BOQUERON, 1917

The republic of Salvador on the southwest coast of Central America contains ten active volcanoes along a zone of volcanic upbuilding over fault fractures between the Pacific coastal plain and the Guatemalan plateau. The zone trends curving into Mexico and Nicaragua with convexity toward the ocean as in so many of the Pacific chains of volcanoes. At the south end of the line is Coseguina and near the north end Santa Maria, both volcanoes that have made gigantic explosive eruptions in the last century. Salvador in the middle of the curve has a group of lava-making volcanoes rising to heights of 6000 feet from a plateau 2000 feet above the sea.

West of the capital San Salvador rises the volcanic peak of the same name 6400 feet above sea level, and a little lower on the west is an active volcano whose crater "Boqueron" contains a lake of water 1300 feet in diameter and 1200 feet below edge of its pit. In the district are other crater lakes and volcanoes such as El Playon and Izalco. El Playon produced a lava flow 3 miles long in 1659. Fiercely destructive earthquakes have wrecked San Salvador city twelve times, usually with volcanic accompaniments.

Beginning June 6, 1917 the volcano Boqueron achieved the thirteenth catastrophe, splitting open its northwestern flank, throwing forth a stream of rough aa lava, flinging up ash and cinder with thunderous noise, and wrecking towns and coffee plantations with a succession of earthquakes that lasted a week.

At 6:55 p. m. June 6 came a terrific shock of 15 seconds duration, fifteen towns were wrecked including the capital, 100,000 people were left roofless, several hundred were killed and many were wounded. Streams were dammed and deflected, water supplies were cut off, bridges fell, refugees in the country found the public ways broken and blocked, and mountain sides slid down. The district of wreckage was twenty miles across. In its midst stood Boqueron.

At the first shock buildings went to pieces, at the second landslips broke loose, and at the third the flank of the volcano exploded. The new crater fissure opened just above the plantation Las Granadillas. Nine craterlets formed in a row five miles long, the lowest "El Tronador" or the "thunderer" giving vent to a lava flow. The lava was at first so liquid that some people were caught and killed by it. There were houses only fifty feet from the place of outbreak, and these along with several plantations in the track of the flow were destroyed. The flow reached a length of four miles.

Cinder and ash explosions accompanied the outbreak, and mud rains fell at the city to add to the sufferings of the homeless population. The volcanic gases were strong, and the acid ash rain on bare-headed wanderers was said to cause the hair to fall out. The coffee plants were defoliated for miles around. Nine plantations were partly or wholly demolished. In them the explosive material averaged six inches in depth, but in Las Salinas the ash was four feet deep. In its deeper fillings the lava was 160 feet deep.

The crater lake at Boqueron showed boiling and wave motion, there were steam jets, incaving sides to the big crater, and cracks back from the rim. In June there was an apparent rise of lake level. In July the lake had sunk away and evaporated, white cauliflower clouds came through a bottom fissure, and then a circular cinder cone was built up. (Friedlaender, Volcanological Review, 1918).

T. A. J.

VOLCANOLOGY IN SALVADOR

We have received from Senor Jorge Larde' an account of the volcano Izalco (Government publication, San Salvador 1922). An observatory with seismograph has been established. Izalco is almost continuously active, the Republic is a stable well-governed little country, and with seismic and volcanic events numerous throughout the land, Salvador is an ideal laboratory of volcanologic science for any benefactor or institution wishing a place wherein to establish continuous work. The writer visited Salvador in 1910 and found it most hospitable and attractive. T. A. J.

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NO. 15 RELEASED WITHOUT COPYRIGHT RESTRICTION APRIL 9, 1925

KILAUEA REPORT NO. 691

WEEK ENDING APRIL 8, 1925
Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, Temporarily in Charge

The volcano continues to be rather quiet. Avalanches have been rather infrequent since the middle of March. During the past week the few avalanches noted occurred mainly on March 6, 7, and 8. Considerable steam arises from cracks concentric to the rim of the great pit in Kilauea crater as well as from the floor of the pit itself. The odor of hydrogen sulphide has been very slight during the last few days.

Not only is the pit quiet as observed by the eye but also the seismographs at the Observatory two miles away show less activity than at any time since the middle of November 1924. Only eleven earthquakes were recorded during the week, none of them being perceptible at the Volcano House. The tilt was very slight to the south-southwest. This is the usual direction of tilt for this time of year but the amount is smaller than usual.

During the recent rain spell one could frequently be in the midst of light rain at the hotel and observe dust clouds about three miles away in the desert.

THE VOLCANOLOGICAL REVIEW

Articles from the "Volcanological Review" have been quoted in the LETTER. The Zeitschrift fur Vulcanologie is issued from Naples, with the title in German, Italian, English, and French and printed in Berlin (Dietrich Reimer Co., Berlin, SW. 48. Wilhelmstrasse 29, 20 marks per volume). Dr. I. Friedlander is the founder and financier of the magazine at his Volcanologic Institute in Naples. The type is large, the paper heavy, the plates in heliotype and color, the substance sound, cosmopolitan and scientific. Four to six numbers are issued per year and the authors are of all nations, writing texts in any of the four languages. Six extra monographs, in part subsidized by the Institute, have dealt with volcanic bombs, the north Moluccas, Vulcano in the Lipari Isles, the Nyassa volcano district of Africa, the Cape Verde islands and some volcanoes of Iceland.

The seven volumes from 1914 to 1924 contain, by American authors; a description of the Teneriffe eruption in 1909 by Perret; another by the same author on Sakurajima; a discussion of lava tunnels in Hawaii by Hobbs; recent eruptions of Poas in Costa Rica by Tristan; new islands at Sakurajima by Powers, and articles by him on intrusions at Kilauea, and on Yakedake in Japan; and the activity of Irazu in Costa Rica by Tristan.

Hawaii is abundantly noticed with many reviews of work done here, descriptions of its peculiar stalacities, bombs, and small products, its fault valleys, the spacing of its volcanoes, its gases, its blowing cones, and by a special article by Friedlander on the island Kaula.

There are articles on the volcanoes in Java, the Moluccas, New Guinea, Central and East Africa, Iceland, Mexico, Nicaragua, Japan, Guatamala with its pairs of twin volcanoes, Lower California, and Italy, as well as reviews and descriptions of old volcanic districts in many parts of the world.

Of philosophical interest are the studies of hydrostatic equilibrium at volcanoes by Friedlander; of temperature and pressure inside the globe by Klussman; of the rift valleys and seismicity of Africa and the Red Sea by J. W. Gregory and E. Kreubel; of the spacing of volcanoes by Friedlander; of the geography of volcano distribution by Sapper, Arldt. and Schneider, of the crustal mechanism of granite intrusion by Cloos; of volcanic activity by Hempel; of earthquake depth by Quervain; of volcanic fault valleys, like the Haleakala gaps, by Friedlander; of magmatic distillation processes by Niggli; of volcanism and mountain building by Schwinner; of volcanic fault-block mountains by Reck; of volcanic gases by Salvatore, Friedlander, and Allen (review by Sonder).

No single publication in the history of science has done so much to establish volcanology on a sound and common sense basis as Dr. Friedlander's splendid publications, and as he is well known in Hawaii for his travels here, his interest in Kona, and the explorations of himself and his brother on Mauna Loa and Kilauea, these volumes should have a place on many Hawaiian shelves. T. A. J.

VOLCANIC ASH CEMENT

If one takes a walk into the desert to the southwest of Halemaumau he can not fail to notice the hard cemented crust that covers the ash from Kilauea in many places. The natural cementing action of the 1790 ash has preserved footprints of that time so that not only do the outlines of the feet show but also the individual toes.

The use of volcanic ash in cements was well known by the ancient Greeks and Romans and many structures made with this material and slaked lime as cement are in good state of preservation today.

Experiments on the nature of the cementing action of the 1790 ash from Kilauea made by J. C. Riperton of the Federal Experiment Station in Honolulu indicated that it is due to the formation of collodial or gelatinous compounds of silicon and subsequent dehydration. It should be noted that such an action is one of the explanations for the setting of Portland cement. R. H. F.

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NO. 16 RELEASED WITHOUT COPYRIGHT RESTRICTION APRIL 16, 1925

KILAUEA REPORT NO. 692

WEEK ENDING APRIL 15, 1925
Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, Temporarily in Charge.

Seismically the past week was the most active in a month. Of the 15 earthquakes that were registered at the Observatory, five gave records distinct enough for the distance away of the shaking to be calculated. The one at 1:37 a. m. April 9 awakened many people at the Volcano House and vicinity and dismantled one of the seismographs. The three local earthquakes on April 11 were at indicated distances from Observatory of 13, 6, and 2 miles respectively. The recording of earthquakes of such distances so close together may be taken as an indication of movement along either the northeastern or southwestern rift from Kilauea. A slight earthquake that awakened a few people near the Volcano House at 5:38 a. m. April 15 had an indicated distance to origin of 19 miles. The distance away of a slight distant shake at 2:31 a. m. April 11 could not be determined.

The resultant tilting for the week was very slight to the north-northwest, though there was a moderate southeast tilting on the 10th following by a rapid recovery or northwesterly tilting on the 11th.

The volcano as a whole has been rather quiet, though avalanches from the walls of Halemaumau can be seen and heard nearly every day. Most movements appear to be at the north wall above the large gray intrusive body there. In some places the accumulation of avalanche material is sufficient to bury a large part of the intrusive body. A sulphur stained area near southeastern border of the pit floor has been extending itself toward the center of the pit on the black lava fill of July 1924.

The brisk winds on April 15 stirred up heavy dust clouds in the Kau Desert and small ones on the Kilauea crater floor.

SUBMARINE LAVA FLOWS

Several submarine eruptions have been reported from different places off the coast of the island of Hawaii and other ones, not observed, have been surmised.

The northeast and southwest rifts from Kilauea and the southwest rift from Mauna Loa are known to terminate under the ocean and as lava flows are known to issue as fissure eruptions all along these rifts from the summit of the mountains to the shore it is easily possible that some of them still take place under the water.

The frequent withdrawal of lava from Halemaumau, the active pit of Kilauea, has sometimes been explained by assuming a submarine drainage. This may or may not be true as a subterranean flow within the northeastern or southwestern rifts might easily account for all the liquid lava that disappears from view.

In 1868 there was a withdrawal of liquid lava from Halemaumau followed by a profound collapse. A small amount of lava appeared along the southwestern rift about 10 miles from the volcano, and the ground was fissured at least as far as the ocean near Pahala. There are nothing but very meagre reports of the possibility of the lava appearing on the ocean floor along the extension of southwestern rift in this year.

In 1877 good observations were obtained of a submarine eruption from Mauna Loa but not along the well known southwestern rift. This eruption was in Kealakekua Bay almost due west from the summit of Mauna Loa. On February 24, 1877, following activity at the summit by a few days, there were earthquakes near Kealakekua Bay that left a visible fissure on land. Red, green, and blue lights, amidst steam, appeared about one mile off shore. The boats that were rowed through the scene of action were frequently hit by rising pieces of lava. These lava fragments, very light and frothy, were generally red hot when they reached the surface of the water but quickly cooled and sank.

One of the strangest accounts of a submarine eruption here is given on pages 245-246 in Vol. 2, Fire Fountain of Hawaii, by C. F. Gordon Cumming This eruption is strange because reported from a place where such an eruption might not be expected, off the northeast coast of the Island of Hawaii. The 1880-81 lava flow from Mauna Loa that started on November 5, 1880 was in progress and the entire Island was shrouded in smoke. About November 19 while the schooner Pauahi lay to, apparently near Honokaa, "The sea seethed and boiled, clouds of steam and masses of pumice were thrown up as in a fountain and the display lasted about three minutes." A similar display astern of the schooner immediately followed.

Hitchcock in Hawaii and its Volcanoes mentions a submarine flow off Puna in 1884 and another off Hilo in 1906 but gives no detailed information nor authority.

Submarine contours indicate numerous flows off the east and south points of the Island of Hawaii. The northeastern rift from Kilauea and the southwestern rift from Mauna Loa enters the ocean near these points respectively.

In 1922 and 1923 there were subterranean drainage and collapses of Halemaumau with very small lava flows appearing in or near Makaopuhi crater about eight miles away. In 1924 there was a profound collapse of Halemaumau and indications of a subterranean, possibly submarine, drainage in the northeastern rift. R. H. F.

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NO. 17 RELEASED WITHOUT COPYRIGHT RESTRICTION APRIL 23, 1925

KILAUEA REPORT NO. 693

WEEK ENDING APRIL 22, 1925
Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, Temporarily in Charge.

There is but little change in visible conditions at the volcano. While avalanches occur nearly every day they are for the most part rather small and merely represent progress of the material in a steep wall toward a more stable angle of repose. None of the earthquakes during the past two weeks seem to have affected the walls of Halemaumau to any extent as there is no evidence of any appreciable movement along the cracks concentric to the rim.

The odor of hydrogen sulphide has been rather noticeable of late and occasionally one can detect the odor of free sulphur. When gases are emanating from a volcano during quiet spells hydrogen sulphide is usually conspicuous while with molten lava present sulphur dioxide is the most characteristic gas. Hydrogen sulphide is a combustible and explosive gas and sulphur dioxide is a burned gas.

Considerable sulphates in the form of white incrustations are to be seen on the walls of the pit as well as on the floor. The deposits on the floor area are for the most part, along three parallel steaming lines that trend northeast-southwest.

During rainy spells the pit is often so full of steam that one can scarcely see into the pit. The noise from a large avalanche at such a time is exceedingly wierd.

Seventeen earthquakes were recorded during the past week. The one at 8:52 p. m. April 20 which was felt locally had the appearance of a Mauna Loa shake. An earthquake that was generally felt at Volcano House at 12:29 p. m., April 16, had an indcated distance to origin of two miles from Observatory. Most of the other local earthquakes appeared to have their origins one to two miles away. A slight record of a distant earthquake was written on the Observatory seismographs about 5:30 a. m., April 19. Newspapers report a disturbance in Japan about this time.

Tilting during the week was moderate to the west-southwest.

THE ASH DEPOSITS AT KILAUEA VOLCANO

While excavating for a cesspool in the Observatory grounds on July 12, 1924, good evidence was obtained to prove that the ash surrounding Kilauea Volcano represents the deposits of several different explosive periods. While the deposit is frequently spoken of as "the 1790 ash," the majority of geologists who have worked around Kilauea assumed that it represents at least two or more distinctly separated explosive periods.

Hitchcock in "Hawaii and its Volcanoes," speaks of soil interbedded in the ash and calls the 1790 discharge comparatively mild. Dr. Sydney Powers (American Journal of Science, March, 1916) who was one of the first to make any extended study of the ash, found not only evidence of an appreciable time interval between the laying down of different layers (uncomformity) but also that the Keomoku lava flow from Mauna Loa, which occurred prior to 1790, overlies ash deposits. Prof. Sherzer (Science, April 20, 1923) thought that the ash deposits are the product of three explosive eruptions though it may well be that there were many more than this number.

At the base of Uwekahuna Bluff there is an ash bed (now nearly obscured by the lava flows of 1919) under nearly 500 feet of lava flows that must have been laid down long before the deposition of the oldest of the deposits that now compose the present surface.

An unconformity between a thin superficial layer and older deposits that can be traced up hill and down dale at the south side of Kilauea indicates that only a small fraction of the total ash beds represents the 1790 ash. When the 1924 explosion material on the crater floor shall have become buried by lava flows the only evidence left of the 1924 explosion will be a thin layer of ash outside the crater on the desert side and it will be difficult to find any separation between the 1790 and 1924 deposits.

The molds of several small trees or other vegetal growth were found in the excavation in a slightly eroded layer about two and a half feet below the present surface. Two feet or so below this layer other and larger holes were found that may well have had their origin in the decay of buried trees. In all about 15 well defined were strata noted. In several cases there were indications of deposits on old and weathered surfaces of previous ash layers. It should be noted that any explosive period may lay down several well defined strata.

As the tree molds were excavated in the rain belt and considering the natural cementing qualities of the ash as well as the fact that the thickness of each layer was quite constant it does not seem probable that much of the material was ever moved by wind after it was laid down. Owing to the flatness of the location and to the porosity of the ash the possibility of erosion and transportation by water to effect the burial of small trees or sticks may be dismissed. The only other explanation is that the vegetal growth was buried by ash during some explosion of an appreciably later date than the one represented by the layer in which the vegetation was growing. What the time interval between the deposition of these layers was is not known that it may well have been 65 or 130 years or more.

R.H.F.

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NO 18 | **RELEASED WITHOUT COPYRIGHT RESTRICTION** | APRIL 30, 1925

KILAUEA REPORT NO. 694

WEEK ENDING APRIL 29, 1925

Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, Temporarily in Charge.

Landslides were rather infrequent during the past week though very small rock falls could be heard every day. The place on the floor where the densest steam escapes at present is a little way up the south talus slope, to the left of the place where visitors usually stand. On dry days like April 24 and 25 great quantities of white salts that resemble a light fall of snow can be seen on the ash around pit rim. The spicy odor of free sulphur is now very noticeable.

Twenty-three earthquakes were registered on the seismographs during the week though none of them were felt locally. Of this number 19 occurred on April 24 and 25. Several of the shakes had the appearance of having had their origins along the northeastern rift of Mauna Loa.

Tilting during the week was moderate to the southwest.

FOUNDING A VOLCANO OBSERVATORY

The essential features of a volcano observatory are a volcano, an observer and the record made by the observer. For success there are needed two things more -enthusiasm in the observer and publication of his record. It is an error to suppose that the purchase and maintenance of expensive buildings and instruments are among first requirements. A physicist living continuously at Galapagos, or on Kamtchatka, or in the New Hebrides, and keeping a diary, is a potentioal observatory. Students of volcanism the world over want to see that diary. Essentials of the record are exact places, maps and photographs, correct times, and descriptions and measurements of all volcanic and seismic events describable or measureable.

It is this matter of measurement that leads the observer to equip himself with instruments. But the object is not the instrument, it is the measurement. Many measurements may be made with a foot-rule, a thermometer, and a watch. The good observer uses these tools all the time. A transit or plane-table is only an extention of the foot-rule, a seismograph an extention of observation with the watch. When an observer has to remain awake all night in order to record all the earthquakes, he bethinks him of automatic recorders.

There are over four hundred more or less active volcanoes in the world not being continuously observed. Twenty or more of these are splendid natural laboratories. Such volcanoes are Stromboli in the Lipari Isles, Izalco in Salvador, Villarica in Chile, Tanna in the New Hebrides, Akutan in the Alentian islands, Waimangu in New Zealand, Bromo in Java, Oshima in Japan, Lassen in the United States, Colima in Mexico. Continuity of action, hot gases, frequency of ground movements, representatives character and position—such are some of the qualities that make a given volcanic center attractive. It is not the highest or most famous volcanoes in a given belt that should be selected for steady work, but those that are practicable and reasonably free from danger. In many places there are hardships aplenty without seeking them in the scientific work.

One feature that is desirable is a settlement near at hand where reports may be published and mailed, where supplies may be obtained and where headquarters may be made in case the volcano district itself is wild.

Generally exploration is necessary in addition to routine cataloguing of events. A place like Salvador, for example, has a dozen volcanic centers, some of which occasionally break into activity, although Izalco is the most faithful of the outlets. A volcano observatory is always striving to see underground. Hence the observing of slight tilts, or changes of temperature, or tremors, and the employment of volunteer observers among planters, school teachers, ministers and government officials.

Any university or museum that can find a man willing to go to one of these countries and to live there and use his influence while there to promote volcanology and local seismology, will have taken the initial step in founding an observatory. Such a man is a missionary of science.

T. A. J.

THE 1823 LAVA FLOW FROM KILAUEA

A curious and rather unaccountable error has crept into the literature of Kilauea and onto the maps of the Islands of Hawaii. The westermost of the most recent lava flows from Kilauea that entered the sea or nearly reached it near Pahala is commonly spoken of as having occurred in 1868 though it really occurred in 1823. W. O. Clark, geologist at Pahala, called the attention of F. A. Danforth, topographer who was mapping in that region in 1920. to the fact that nowhere in existing literature could he find authority for dating the Keaiwa flow 1868. (See map of the U. S. Geological Survey, Pahala quadrangel). He also pointed out that the Rev. Wm. Ellis in his "Journal of the Tour Around Hawaii" definitely placed it in 1823. and that the Rev. Titus Coan's account did not make it 1868. Coan mentions small outbreaks of lava in 1868 about 11 miles southwest from Kilauea but says nothing about a large lava flow near the sea though he was specifically looking for lava outbreaks. In 1868 the inhabitants of Pahala saw glow from a lava flow to the northeast but no record is found of their observing a brilliant glow to the east, which they no doubt would have seen had the flow in question occurred in that year. The so-called 1823 lava flow does not reach the sea while Ellis describes the real 1823 flow as reaching the sea and destroying a canoe at Mahuka. Mr. Danforth pursued the subject farther and found an old cowboy who stated that the trial across the so-called 1868 flow was indentical with the present trail prior to 1868.

On the new topographic maps the real 1823 flow is called the "Keaiwa Lava Flow" and what was formerly called the 1823 flow, which is really prehistoric, is designated the "Kamooalii Lava Flow."

R. H. F.

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NO 19 RELEASED WITHOUT COPYRIGHT RESTRICTION MAY 7, 1925

KILAUEA REPORT NO. 695

WEEK ENDING MAY 6, 1925

Issued by the Observatory, U. S. Geological Survey:

R. H. Finch, Temporarily in Charge.

On May 6 there were some slight indications that Halemaumau, the great pit in Kilauea Crater, was a little hotter than during the past several weeks.

The heavy steam cloud rising from south talus noted in last weeks report has become less conspicuous. The lower part of a steam line in the southwest talus that extends all the way from the July 1924 lava fill to the top of the talus is steaming less than before as though the deposition of salts and action of steam on the rock had plugged up the steam vents in that vicinity. The walls and even the floors have been quite red. On May 5 the odor of hydrogen sulphide was quite noticeable after having been scarcely detectable for a few days. An avalanche of considerable size fell from the north wall during the night of May 4-5. The wall rock from where it fell appears to be very rotten.

Nine local earthquakes were recorded at the Observatory during the week. The one at 8:12 a. m. April 29 had an indicated distance to origin of three miles. Slight records of three distant earthquakes were recorded at the following times: May 3, 7:03 a. m. and 12:48 p. m.; May 4, 11:47 p. m..

Tilting was slight to the northeast. This indicates a slight tumescing in the top of the mountain. As rule during this time of year the top of the mountain is subsiding.

IZALCO VOLCANO

Attention has been called to Izalco as a place worthy of an observatory. It is representative of ten active volcanoes in Salvador and of a region producing destructive earthquakes. It is a cordilliran region of the same Pacific coastal zone with Seattle, San Francisco and Los Angeles, but with its volcanic gases more in evidence.

Izalco is much misconstrued in the stories about it. In an article published in 1923 appears the statement that in 150 years Mt. Izalco "has risen from the surface of a level plain that was devoted to stock farming, to a majestic height of more than 6,000 feet above sea level." In the same article appear two photographs of Boqueron activity in 1917, purporting to be Izalco. In 1917 Izalco was quiet. As to the stock farm story, Izalco as it is today was built up by lava flows and cinder on the southern slope of Santa Ana volcano, making a total accumulation of about a thousand feet. The writer quoted above failed to state that the growth started on a lava spur of the older mountain already 5,000 feet above the sea.

The year of first outbreak of the flank cone destined to become Izalco is commonly quoted as 1770, but Larde' corrects this. In 1524 there was a solftara there giving vent to a rill of boiling water. In 1576 this had disappeared. In 1636 there was a craterlet in action at the same place throwing up smoke and incandescent substances, but not yet an independent cone. Therefore as a matter of fact Izalco was born about the beginning of the 17th century.

The eruptions from 1636 on produced a confused mass of lavas and there was a culminating eruption in 1722. There was no very definite hill in 1753. Big eruptions in 1770 inaugurated more continuous activity and still more so in 1798, so that a true cone grew up that was worthy of a name distinct from Santa Ana, the mother volcano. By the end of the 18th century Izalco was in full blast as an independent lava factory.

We learn that the major activity of the 18th century began with eruptions in 1802, 1805, 1806, 1807, and 1825. In the last a river course was changed. There were bad earthquakes in 1830, 1831, 1860, 1861 and 1863. In 1840 there were three crater orifices, one of them quiet, one making dark blue fume, and an active one throwing up stones and black clouds. In 1854 there were explosions every five minutes and lava flows in motion. From 1856 to 1859 there was much extrusion and in 1859 there were earthquakes and an ash eruption. Churches and towns were damaged. From 1860 to 1865 there was repeated activity. Other eruptive times were 1867, 1868, 1869, 1870, 1873, 1874, 1875, 1879, 1880, 1882, 1883, 1885, 1887, 1889, 1890 (lava), 1891, 1894 (continual eruptions), 1895-97; at this time it was compared to Stromboli as the "Central American lighthouse." May, June and July of 1898 Izalco continued its extrusions, and an important eruption occurred in 1899-1900.

Inactivity lasted from March, 1900 to May 1902. Then came an outbreak, followed by lava flow in September. A crack opened from top to bottom of the cone. In 1904-05 there was activity. In 1907 this abated. New activity started 1912 and continued, there was a disastrous earthquake in 1915, and Izalco quieted again January 26, 1916. From October, 1920 to April 1921 there were new explosions, lava flows and hydrochloric acid gas. In 1922 there was only fume. (J. Larde, El Volcan de Izalco, 1923). T. A. J.

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NO. 20 RELEASED WITHOUT COPYRIGHT RESTRICTION MAY 14, 1925

KILAUEA REPORRT NO. 696

WEEK ENDING MAY 13, 1925

Issued by the Observatory, U. S. Geological Survey:

R. H. Finch, Temporarily in Charge.

The Volcano continues to be quiet. During the last few days, however, there was a slight increase in the number of avalanches. These avalanches, for the most part, were from the north wall. Portions of the gray intrusive body broke off though most of the avalanche material was from the rather rotten rock just above the intrusive body. Neither the odor of free sulphur nor hydrogen sulphide has been noticed for several days.

Fourteen earthquakes were registered by the Observatory seismographs, though none were perceptible at Volcano House. At the beginning of the week there was a slight northeast tilt. During the latter part of the week the direction of tilting changed to southwest with the result that the net tilt for the week was very slight to the south.

EXPERIMENTAL SEISMOGRAPH

Mr. H. O. Wood reports tests of five horizontal torsion pendulum seismographs and one vertical torsion instrument of the new type designed by Dr. Anderson at the Mount Wilson Observatory laboratory in Pasadena, California. (Report of Seismology Committee, Carnegie Institution, Bulletin Seismological Society, America, Sept, 1924.)

The seismometer consists of nothing more than a vertical "bow-string" bearing a tiny mirror. This is the pendulum, oscillating about the torsion axis of the string, and writing photographically with high magnification. Magnets damp the horizontal swing and a drop of oil in a sleeve damps against vibration.

Two initial instruments had free periods of 0.8 second and static magnification of 1200 times the displacement of the earth. Another was given a magnification of 2500. Damping used in these short period instruments was about one fifth of the amount required for the critical, or aperiodic, condition. The short period pendulums registered local earthquakes well also the first phases of distant quakes. The first phases were registered of aftershocks of the Tokyo earthquakes. Many regional California shocks show pre-phases even earlier than the normal first phase, owing to the extremely high magnifications employed and the adaptability by resonance of a critically damped pendulum of period as short as the earthquake vibration itself.

An improved short period torsion seismograph was made with convenient adjustments for levelling, damping and measuring periods, using a meter-focus concave mirror, a static magnification of over 4000, and a bright light source prevented from fogging in quiet times by a slotted disc. This brighter recording point of light prevented underexposure during earthquakes.

Also a long period torsion seismometer was operated and found satisfactory for distant earthquakes. The period was from 5 to 15 seconds, damping ranged from underdamping to overdamping, and magnification was 300. The instrument showed little disturbance from tilting or temperature. A major teleseism recorded in June 1924 showed clearly the long-period surface waves which had travelled a major arc of the earth's circumferance, and others that had traversed both the minor arc from the source to the station, and the complete circumference of the earth in addition.

Most of the local California earthquakes registered originated at distances 25 to 200 miles from the station. They were numerous. Microseisms were best registered on the long period machines and were small. Engine vibrations and blasts were recorded. A good test of the rate of transmission of earth waves was furnished by the detonation of 182 tons of dynamite 67 miles from the station in hard rock. The timing was checked, good records were written by the machines, and these records are easy to interpret on both the long and short period instruments.

A torsion-suspension vertical component seismograph with period of one-half second was operated successfully with critical magnetic damping. A long period instrument of this type is unstable. It is interesting to observe in all this work of Anderson and Wood that synchronizing of pendulum with earth period, through different instruments for different types and parts of earthquake motion is the key to success. T. A. J.

A NEW TYPE OF SEISMOGRAPH

Dr. Paul Kirkpatrick of the University of Hawaii has devised a novel type of seismograph. Instead of employing a pendulum bob as a steady mass from which to record the movements of earthquakes, the common practice, Dr. Kirkpatrick proposes to use a falling body as a steady point. The course of a falling body is not affected by any change in earth motion during the period of its fall. A continuous liquid jet is used instead of a series of individual falling bodies. The record is made by projecting the shadow of the falling jet onto photographic paper. With such a seismometer it should be quite easy to determine the absolute motion of the ground. With the ordinary pendulum seismograph such a determination, with precision, is difficult. Some of the practical applications of the seismograph, such as determination of the seismicity of a place and aproximation location of the seat of earthquakes, and recording the tilting of the ground from which the probable time and location of earthquakes may be foretold, can be made as well, however, with a pendulum instrument. (Nature, April 11, 1925, p. 530). R. H. F.

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NO. 21 | RELEASED WITHOUT COPYRIGHT RESTRICTION | MAY 21, 1925

KILAUUEA REPORT NO. 697

WEED ENDING MAY 20, 1925

Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, Temporarily in Charge.

Seismically the past week was the most active one in over a month. Forty earthquakes were registered at the Observatory. Of this number, however, half were of the type that accompanies avalanches.. A shake at 2:02 a. m. May 17 was slightly felt at Volcano House and plainly felt at Hilea. Its indicated distance from the Observatory was 18 miles. At 10:26 p. m., may 19 there was another shake with the same indicated distance. A distant earthquake was recorded at 7:13 p. m. of the 18th.

Along with the increase in number of avalanche type of earthquake there was an observed increase in the number of avalanches. For the most part the avalanches were from the north wall though small ones fell from all sides of the pit.

There was a slight northerly tilt during the first five days of the week and a moderate southerly tilt during the last two days. The net result for the week was a very slight north-northwesterly tilt.

LASSEN PEAK

The Carnegie institution of Washington has recently published a great work on the volcano activity and hot springs of Lassen Peak. The first part deals with the explosive eruption of Lassen Peak from May 1914 to August 1917. Part two deals with the Hot Springs of Lassen National Park. It is published under the joint authorship of Dr. A. L. Day and Dr. E. T. Allen.

Lassen has been active in recent historical time, probably less than 200 years ago, as have some other peaks in the same volcanic region, viz., Mount St. Helens and Mount Hood.

The eruptions were more or less continuous from the start on May 30, 1914 until May 22, 1915 when the largest explosions of the series occurred. Thereafter there was a decline in activity that practically ceased by August 1917. The exlosion cloud on May 22 reached a height of 25,000 feet above the mountain top. In 1917 as 1914 and 1915 may seemed to be a critical month.

On May 19 and May 22, 1915 there were horizontal blasts, similar to the one from Mount Pelee that destroyed St. Pierre in 1902. Nearly every tree in the valley through which the blasts went were either destroyed by the blasts or by a mud flow started by water from snow melted by the first blast.

In May 1915 there was an upheaval of the crater floor to a height of some 300 feet above the original floor-level. This to a great many people will recall the spine in the crater of Mount Pelee though the authors state on page 72 that Lassen had no happenings like the Pelee spine.

The authors assume an earthquake preceding the first explosion which by openeing a crack admitted water to magma below. A magma at a proper temperature and containing water and other volatile ingredients in cooling and crystallizing may produce a tremendous pressure of water vapor. That such a mechanism may produce a high pressure, is easy to follow, but, in the opinion of the reviewer, whether the earthquakes introduced water into the system with a consequent increase of pressure and resulting explosions or whether the earthquakes were the result of a growing strain within the mountain that ruptured the mountain top and finally produced the explosions, is a mooted question.

Part two is a valuable contribution to our knowledge of the temperature and chemical composition of waters in hot springs. It throws considerable light on the formation of ore deposits. Both parts are profusely illustrated and defintelv related They constitute one of the most complete accounts, descriptive and causative, of volcanic on record. R. H. F.

TROUGHS OFF CENTRAL AMERICA

Commander Heck reports (Bull. Seismological Society of America, Sept. 1924) two newly discovered deep troughs detected by sonic soundings. One from 18,000 to 21,000 feet deep lies roughly parallel to the Pacific coast of Guatemala about 90 miles off shore. It is more than 300 miles long with steep slopes on both the shoreward and oceanward sides. the latter over 6,000 feet high to an ocean bottom lying about 13,000 feet below sea level.

The second trough is a narrow one 40 miles from shore between Tehauntepec and Cape Corrientes along the Pacific coast of Mexico. It is 650 miles long and from 13,000 to 17 000 feet deep. with shallower depths on both sides. These deeps are of interest as lying opposite two volcanic districts on shore, the Guatemala-Salvador belt and the Mexican plateau. T. A. J.

UNCONFORMITY IN THE ASH DEPOSITS NEAR GLENWOOD

In a cut through yellow ash in the road near Glenwood, Hawaii a dark streak representing old soil may be seen a foot or two below the surface. In this old soil layer old tree ferns may be found. This shows an appreciable time interval between the laying down of the layer containing the soil and the one on top. R. H. F.

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NO. 22 RELEASED WITHOUT COPYRIGHT RESTRICTION MAY 28, 1925

KILAUEA REPORT NO. 698

WEEK ENDING, MAY 27, 1925
Issued by the Observatory, U. S. Geological Survey;
R. H. Finch, Temporarily in charge

The strongest earthquake that has been felt at Volcano House since the fore part of April occurred at 9:01 A. M. May 26. It was accompanied by a roar and dismantled one of the seismographs at the Observatory. At 8:47 p. m. of the same day there was a very small shake with the same apparent distance to origin, about 2 miles. Altogether 23 earthquakes were registered during the week. Of this number six were of the avalanche type of earthquakes.

Tilting was a little stronger than for several weeks and was moderate to the southwest.

The increase in the avalanching noted last week continued into the present week. For the most part the avalanches were small though several sent up dust clouds well above the rim of pit.

CALIFORNIA EARTH MOVEMENT

Dr. Arthur L. Day of the Geophysical Laboratory reports for the several organizations working on California earth movements in "Science," March 27, 1925. The object is to focus scientific measurements on the inside of mountain ranges and sea-bottom so as to localize, not only the sources of earthquakes, but the centers of mountain building and creep of surface ground. To this end the Carnegie institution, the California universities, the U. S. Geological Survey, the Navy, and the U. S. Coast and Geodetic Survey are cooperating. The Advisory Committee on Seismology is aided by both the Geophysical Laboratory of Washington and the shops and laboratories of the Mount Wilson Observatory at Pasadena.

The Committee was appointed in 1921. Lawson had concluded from variation-of-latitude observations that the earth's crust near San Francisco had been drifting north a foot a year for 20 years. Lambert showed that probable errors were of the same order of magnitude as the assumptions indicating creep, so that Lawson's conclusion was not final. There are lateral displacements of 20 feet in places along the great fault that moved during the earthquake of 1906. A new base line for triangulation of the whole region was adopted recently in the Sierra Nevadas, and work for several years including 1925, supplemented by levelling, shows that a prior base line nearer San Francisco has itself moved southward some five feet. Another region to the south and some distance from the fault slip has moved north 24 feet.

Messrs. Noble and Kew have located new active faults in southern California. The Hydrographic Office of the Navy with sonic sounding apparatus, assisted by the Coast Survey, is developing new maps of the sea bottom off California. For determining local earthquakes, tremors, and tiltings J. A. Anderson and H. O. Wood have made new instruments in Pasadena, these are being tested, improved and manufactured, and seismographs on a new principle are actually working at magnifications of from 1200 to 4000. Other devices are being experimented with to solve the problem of uniform time service at separated stations. A number of California and Arizona stations have been selected for work on local motion. Eventually the Coast Survey hopes to standardize and improve registration of distant large earthquakes, at such stations as Hawaii, Alaska, Arizona, Washington, and Porto Rico. Dr. Day mentions in his report the interesting possibility of instrumental measurement continuously of deep-seated rock pressures underground, through some such instrument as a metal bulb containing a fluid connected by a tube with the surface, the bulb being cemented in a deep subterranean chamber.

If tilt and creep and changes of level can be precisely measured, Dr. Day thinks that in any given place known to be moving, the site of the next sudden release may be reasonably determined in advance. Prediction of the time of rupture is much more difficult. This whole California enterprise is of the utmost interest to seismologic science, and it is to be hoped that Hawaii may with her volcano facilities be able to add an item of cooperation. T. A. J.

THE SEISMOGRAPH IN OIL FIELDS

The difference in the records of the same or a similar seismograph in different locations in response to a constant disturbance is often very striking. With the magnification, period, and sensitivity of the instruments the same such differences must be due to differences in the soil or rocky layers underground.

Differences in underground characteristics at St. Mary's School in Hilo and at Hilea, Kau, both on the Island of Hawaii, were recently shown during the installation of very similar instruments with about the same magnification at the two places. The record from the Hilo instrument leads one to surmise that it is installed over a lava tube or over loose and broken pahoehoe slabs.

A recent application of the seismograph's ability to through light on underground structure is in locating places that are geologically favorable for the retention of oil. R. H. F.

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NO. 23 RELEASED WITHOUT COPYRIGHT RESTRICTION JUNE 4, 1925

KILAUEA REPORT NO. 699

WEEK ENDING JUNE 3, 1925

Issued by the Observatory, U. S. Geological Survey;
R. H. Finch, Temporarily in Charge

Kilauea volcano continues to be in a quiet state, save for avalanches from the walls of Halemaumau, the great pit in the floor of Kilauea.

The depth of the pit has remained unchanged since the slight filling by lava last July. The area of the hole, however, has been slowly increasing by avalanches from the rim. There have been avalanches from all the walls. The maximum recession of the rim amounts to 10-15 feet or more. The greatest movement in the cracks back of the rim has been at the south where the recession of the rim is the least.

The steam that escapes from the floor of the pit seems to be nearly pure now as only rarely can the odor of hydrogen sulphide or other gases be detected.

May 1925 has come and gone without any very unusual signs from the volcano and it will soon be a year since the last small explosion.

Only six earthquakes were recorded during the week. This is the smallest number recorded here in a like period since the latter part of November 1924. None of the earthquakes were strong enough to be felt at Volcano House and two of them were of the avalanche type. Small avalanches occur daily at the pit. Tilting was very slight to the northwest.

EARTHQUAKES AT KATMAI

A review of an article by Dr. Tams on the earthquakes that accompanied the Katmai eruption in Alaska in June 1912 appeared in No. 5 of the VOLCANO LETTER. A rather complete discussion of "Earth Movements Accompanying the Katmai Eruption" is given by Dr. C. N. Fenner in the February-March and April-May numbers of the Journal of Geology. Much has been published about the eruption and the resulting "Valley of Ten Thousand Smokes." Some of the facts about the eruption used by Dr. Fenner were obtained by G. C. Martin on a trip for the National Geographic Society, to the Katmai region in 1913, just after the eruption. The rest of the information was obtained on trips by Dr. Fenner in 1919 and 1923, several years after the outbreak.

Field observations near Katmai indicated a lack of violent earthquakes. A deep seated tectonic earthquake (earthquakes resulting from growth of the earth's crust, according to one definition) that was recorded on seismographs all over the world accompanied one of the larger explosions. Many of the earthquakes were felt over 500 miles away. The noise of one explosion was heard at Juneau, 745 miles from Katmai.

Most of the earth movements noted are in a valley between Mount Katmai and Mount Trident with some movement on the mountains themselves. Dr. Fenner is of the opinion that the fracturing of the valley followed by numerous fumaroles, making it a valley of "Ten Thousand Smokes," was due to the intrusion of a sill of hot lava.

Dr. Fenner has handled the information at his disposal in a masterly manner but the exact sequence of earthquakes and explosions must remain unknown. All the discussions of the Katmai eruption point to the need of continuous observations of such events.

Some stress is laid on the distinction between tectonic and volcanic earthquakes. Any definition of tectonic earthquakes will likely include many volcanic shakes as there is no sharp division between the two. "Tectonic" earthquakes in a volcanic region or its immediate vicinity frequently appear to have a much shallower origin than others in a region more remote from a volcano. In volcanic regions hot and somewhat plastic rock must be nearer the surface than in non-volcanic regions. R. H. F.

PUBLICATIONS OF THE NATIONAL RESEARCH COUNCIL OF JAPAN

No student of any science can afford to be without the publications of the National Research Council of Japan. Of these publications those that are of especial interest to students of volcanology and seismology are, Japanese Journal of Astronomy and Geophysics and Japanese Journal of Geology and Geography. These publications made their appearance in 1922. In addition to original articles such as Relations Between Frequency of Earthquakes and Atmospheric Pressure, and the Japanese Earthquake of Sept. 1, 1923, several of the numbers contain abstracts of articles published in other journals such as Seismological Notes of the Imperial Earthquakes Investigation Committee and in journals written in Japanese. R. H. F.

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NO. 24 RELEASED WITHOUT COPYRIGHT RESTRICTION June 11, 1925

KILAUEA REPORT No. 700

WEEK ENDING JUNE 10, 1925

Issued by the Observatory, U. S. Geological Survey;
R. H. Finch, Temporarily in Charge

Seismically, and otherwise, the volcano continues to be quiet. Only eight local earthquakes were recorded during the past week. None of the earthquakes were perceptible at Volcano House. The number of local earthquakes is getting to be nearly comparable to the number commonly recorded when molten lava is visible.

Two distant earthquakes were recorded as follows: June 4, 1:47 AM., slight; June 9, 3:21 AM, slight. The latter had an indicated distance to origin of 4750 miles, equal to the distance to the Philippines or Formosa.

Avalanches have been slightly more numerous and dust clouds that rose well above the rim of pit were common. But very few disturbances have been recorded on the seismographs to correlate with the avalanches. Most of the avalanches fell from the north wall.

THE DISTRIBUTION OF VOLCANOES

The some 430 active volcanoes in the world are widely scattered. The form of activity that a volcano may take varies greatly, from the quiet extrusion of fumes to an explosion like that of Krakatoa in 1883 that sent up dust clouds to a height of 17 miles.

In general, active volcanic regions are also regions of high seismicity. Not all regions subject to frequent earthquakes, however, have active volcanoes as for instance the middle Mississippi Valley, eastern South Carolina and the southern Appalachians in the United States. Volcanic regions cover a limited portion of the earth's surface, but no place is entirely immune from earthquakes.

In volcanic regions one can not say definitely that a volcano is the cause of all the earthquakes nor that the activity of the volcano is due to earthquakes. It would appear that both can frequently be referred to a common origin. If this is true then the terms "tectonic" and "volcanic" as applied to earthquakes refer more to different grades than to different causes.

Volcanoes usually are located in well defined zones. Sometimes the zone is comparatively short as in the Hawaiian Archipelago; and sometimes very long as the border of the Pacific Ocean.

The Pacific border chain of active or recently active volcanoes is in recent geological formation and crustal movements are still taking place. This is more or less common to all volcanic regions. For the most part ocean deeps are close to the shore so that the difference in elevation between volcano peaks and adjacent deeps is startling. Hawaii furnishes an example of proximity of elevation and deep more striking even than that of the west coast of South America. From the summit of Mauna Kea to a deep about 50 miles to the northeast there is a continuous land slope of about 37,000 feet.

In South America, Central America and Mexico the volcano chain is quite complete. In the United States the Pacific belt finds but few active volcanoes though several, in addition to Lassen's Peak, have been active in recent historic time and others in recent geologic time. Canada furnishes a near approach to a gap in the chain before Alaska with its several volcanoes is reached. The chain is continued by the Aleutian Islands to Kamchatka and Japan. In going south from the Philippines the chain fans out to include a large part of the southwestern Pacific Ocean.

Undoubtedly several of the island volcanoes started in as submarine eruptions on the ocean floor and built up the island and mountain. Scattered reports indicate that submarine volcanoes are still at work endeavoring to form new islands.

The Atlantic Ocean, while not so well supplied with volcanoes as the Pacific, has several in Iceland, the Azores, Canaries, and Cape Verde islands. In the Lesser Antilles group of the West Indies and in the Mediterranean Sea there are several volcanoes. The Mediterranean belt is almost continuous eastward for some distance into Asia.

Volcanoes are found in all oceans. The Artic ocean has its Jan Mayen volcanic island while in the Antartic are the volcanoes Erebus and Terror on Ross Island. One of the most active of volcanoes is on the Island of Reunion in the Indian Ocean about 400 miles southeast of Madagascar. It has been in eruption about every five years for a great many years and has been reported to show a continuous lake of molten lava similar to the one for which Kilauea is famous.

At times one of the most continuous volcanic spectacles is to be found at Matavanu volcano on the island of Savaii, one of the Samoan group. Starting in August 1905 Matavanu sent forth a lava flow that poured into the ocean continuously for about five years. R. H. F.

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NO. 25 RELEASED WITHOUT COPYRIGHT RESTRICTION JUNE 18, 1925

KILAUEA REPORT NO. 701

WEEK ENDING JULY 17, 1925

Issued by the Observatory of the U. S. Geological Survey:
R. H. Finch, Temporarily in charge

The seismic lull that started during the latter part of May still continues. During the week ending during the forenoon of June 17 nine local earthquakes were recorded at the Observatory. None was perceptible at Volcano House and only one was large enough to enable one to determine the approximate distance away. This one occurred at 10:09 P. M., June 10 with an indicated distance of 20 miles. Four of the others probably occurred at about the same distance from the Observatory. Seven of the nine shakes occurred on June 10 and 11.

The direction of the tilt was to the northeast. As during the preceding week the amount of tilt was very slight.

There were numerous avalanches during the week though for the most part they were less spectacular than during the preceding week.

Tremendous dust clouds were raised in the Kau Desert by the brisk wind on June 15. The desert showed a marked wall of dust that was fully 500-600 feet above the ground.

AN OFT-REPEATED MISSTATEMENT

How often we hear the assertion that the crater of Haleakala is "the largest crater in the world!" There are, however, two mistakes in this proposition. In the first place, the depression at the summit of Haleakala is smaller than are various craters in other parts of the world. And in the second place, this depression is not a crater at all.

Publications of the tourist agencies give the area of Haleakala "crater" as 19 square miles, its extreme length as nearly 7½, its extreme width as less than 2½ miles, and its perimeter as 20 miles. Anakchiak Crater, discovered in 1922, on the Alaska Peninsula is six miles in diameter but little more is known about it. If it is of circular outline, its area would be 28 squire miles and its perimeter 18 miles. This crater exceeds Haleakala in area though it does not equal in perimeter the long, irregular rim of the Haleakala rift.

In Tanganyika Territory (formerly German East Africa) there is a plateau called the "Highland of the Great Craters." This region has not been thoroughly explored but enough is known to justify the name. The best known crater is "Ngorongoro," which is about 12 miles across and has an area of 110 square miles. The surrounding walls are in general 2,000 feet high but two parasitic volcanic cones rise about 2,000 feet above the rim. There are only three or four possible routes of descent into the crater and the floor forms a natural game preserve with some 50,000 head of wildebeest and 25,000 head of other game. A single small volcanic cone rises from the crater floor.

A crater, according to Webster's New International Dictionary, is "the basinlike or funnel-shaped opening which marks the vent of a volcano." Undoubtedly the main, central vent of Haleakala was formerly in the region occupied by the present magnificent depression, the sight of which well repays those who climb to its rim. But the present form of this depression seems to have been caused not by volcanic action but by collapse within the mountain. The fracture at the surface took the form of a stretched letter "Z," the middle bar of which runs east-west while the others run south from the east end of the middle bar and north from the west end. The gash or rift made in this way has widened out a great deal by avalanching of the walls, much as Halemaumau has widened out in the last year. The subterranean continuation of the fracture has served as a channel for the ascent of small amounts of volcanic matter which have built cinder cones within the rift basin. True craters are of circular or oval groundplan and not of the irregular shape found on Haleakala. True craters are due to the processes that go on in and around volcanic vents ,whereas the Haleakala depression is due to processes independent of volcanism.

H. S. PALMER.

EARTHQUAKES AT KILAUEA DURING TIMES OF EXPLOSION AND TIMES OF QUIET

To show the difference in the number of earthquakes by months when the volcano is explosive and when it is quiet, the quiet lava activity of the year 1920 is compared with 1924 in the following table. In 1924 up to the 20th of February there was a large lake of molten lava. The extraordinary large number of earthquakes during April, May and June 1924 accompanied the subsidence of Halemaumau and the explosive eruption. The number of earthquakes to date in 1925 is comparable to the last six months in 1924.

	Number of Earthquakes 1920	1924
January	7	21
February	10	36
March	20	78
April	5	358
May	11	3961
June	13	801
July	9	110
August	15	90
September	8	116
October	35	106
November	36	51
December	40	169

R. H. F.

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NO. 26 | RELEASED WITHOUT COPYRIGHT RESTRICTION | JUNE 25, 1925

KILAUEA REPORT NO. 702

WEEK ENDING JUNE 24, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

The general situation volcanically of Halemaumau pit at the end of the year following the great collapse of May-June 1924 is extremely peaceful. During the spring earthquakes and avalanches have declined in numbers except for a minor revival in the latter part of May. In June earthquakes and avalanches showed another revival at the solstice, which was remarkable in that the greatest slide seen here for many months came at noon on June 20th.

On June 18th there had been two slides, on the evening of the 19th another, one about 4 a. m. of the 20th and then began an undermining of the northwest wall with increasing slides from 9:30 to 11:30. At 11:40 a beautiful avalanche there sent a crescent of cauliflower cloud across the bottom with a roar. Then came the climax at 11:48 a. m. when the whole wall up to the top stripped off with a thunderous crash that could be heard miles away and the whole pit was filled with clouds of red dust for a half hour. Yellow sulphur stain that had been visible at the east side of the botttom became obscured by the dust-fall, and the seismograph at the Observatory registered vibration for two minutes.

The week has recorded 18 earthquake movements of local origin, of which 6 were of the avalanche type, and 5 indicated distance of source greater than the 2 miles between Halemaumau and the Observatory. None was felt. Tilt was slight SSW.

THE ENGULFMENT-COMBUSTION THEORY

The nearly complete oxidation of the hydrogen, sulphur and carbon gases of Hawaiian lava lakes, and the availability of abundant oxygen in earth and air as a heat-producing agent of combustion, have led us for many years to seek a logical combustion hypothesis of volcanism (Jaggar, Amer. Jour. Sci. Sept. 1917). Day, Shepherd and Allen have analyzed the gases and proved their extraordinary irregularity in composition and their oxidized condition when they reach the surface (Bull. Geol. Soc. Amer. 1913, 573: Bull. Hawaii. Volc. Obsy. July 1919, May 1920, May 1921, Aug. 1922). Jaggar and Finch have demonstrated that the explosive eruption of Kilauea was an incident of a low temperature engulfment process. The volume of rusty rocks engulfed was 253 times the volume of ejected matter; this should be known as the ejection-engulfment ratio 1/253. Every short cycle of slow lava rising ends with rapid collapse and engulfment. (Amer. Jour. Sci. Nov. 1924, Bull. Haw. Volc. Obsy. May Dec. 1924).

At the meeting in Washington, April 30, 1925, of the American Geophysical Union, Shepherd and Jaggar presented an engulfment-combustion hypothesis based on a conception of subterranean normal magma containing combustible gases in solution and iron mostly ferrous; while engulfment down vertical chasms was conceived as a normal process for introducing to the magma oxidized rock matter containing ferric oxide. This holds an excess of oxygen from the rusting of old lava exposed to the air and acids.

In the presence of hydrogen, for example, the ferric oxide would be reduced to ferrous and the hydrogen would be oxidized to water vapor with evoluttion of heat. Given a moderate amount of hydrogen in the new magma rising, and oft-repeated engulfment of rusty crater rock, enough heat would be supplied to keep lava volcanoes in activity without much fresh lava from great depths. By this hypothesis explosive steam eruptions become nothing more than accidents due to engulfment-plugging of craters over ground-water boilers below.

The two novel features confirmatory of this explanation are the ejection-engulfment ratio 1/253 measured for the first time at Kilauea in 1924, and the excessive amount of red oxide of iron there revealed in the wall-rock fragments. Seven billion cubic feet of this rip-rap were precipitated several thousand feet deep into the heart of the mountain. The new lava that reappeared in the pit July, 1924 had frothed its way up through the crevices of this oxidized breccia. It took up oxygen and was heated as it rose. Doubtless other oxygen was entrapped as air. The agglomerate is both a porous heat insulator and an oxygen supply for the burnable magmatic gases. If three percent of the breccia were ferric oxide reduced back to ferrous iron, enough heat would be suplied to raise seventy million cubic feet of the debris from air temperature 20°C. to the temperature of liquid lava 1200° C.

This theory accounts for the excess of water vapor in lava, for the oxidized condition of the other gases, for the rapid passage of gas up the lava column, for the channels and tunnels of the lava lake bottoms. The half-melted breccia is lifted or lowered as a whole by the gas-charged melt in its honey-comb, and this explains the "bench magma" with its puzzling crags, islands and floors. Convection through the crevices produces the varying currents of the lava lakes. The upper portion of the breccia is renewed by every crateral subsidence; this makes a concentration mechanism for the less volatile gases such as sulphur, and the sulphur acids in turn powerfully oxidize the crater rocks.

The world-wide history of volcanoes agrees with the hypothesis. Enormous engulfments went unmeasured at Krakatoa and Sumbawa. Downfaulting since Tertiary time is the rule around the Pacific. Downfaulting is the age-long process at volcanic craters everywhere. Subsided crater floors are dominant on the moon. Downfaulting is what may be expected above subterranean chasms that open laterally and engulf large masses of their wall rock. Collapsing of crater regions with or without explosion has volumetrically been the biggest volcanic process of post-Tertiary time. Engulfment on a gigantic scale appears to have occurred along the Cordilleran intrusive belts. Agglomerate necks, plugs, domes and dykes are common. Hydrogen throughout the solar system is the dominant volcanic gas and the current theory of the earth's interior shows an evolution that has produced oxides, including water, increasing from within outward, and metallic iron increasing inward.

T. A. J,

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NO. 27 | RELEASED WITHOUT COPYRIGHT RESTRICTION | July 2, 1925

KILAUEA REPORT NO. 703

WEEK ENDING JULY 1, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

Halemaumau the fire pit of Kilauea remains dormant, the conspicuous changes of the week being increases in the amount of vapor directly caused by heavy rainfalls, after a dry spell when the steam jets on the bottom were only slightly visible.

On June 25th in the forenoon there was fresh debris on the northeast talus, a little sliding was heard at the northwest, and the most vapor was at the west pocket of the bottom. The flat wall slope at the bottom of east side of pit had now lost all its staining with salts. On the 27th there was a little sliding west. The west and north taluses were wet with steam, the east and south ones emitted dry vapor, sulphur being most conspicuous ENE. June 29 in dry weather two sulphur patches SW and in the center showed increase of yellow and creamy crystals, without any vapor at the places in question. The next day after a rainy night the bottom was transformed to a field emitting hundreds of tails of vapor. There were some slides N and NE. Today there is less vapor and the sulphur patches are whitish.

Seventeen local earthquakes were registered, 5 of them of the avalanche type, and 2 were felt, namely at 5:56 a. m. June 25 with origin distance 14 miles, and at 10:42 p. m. June 26 with origin distance about 2 miles.

The beginning of the disastrous earthquake in Montana June 27th was registered here at 3:09 p. m. (6:30 p. m. Montana time.) The Santa Barbara disaster recorded its beginning here at 4:20 a. m. June 29th, (6:50 a. m. California time) the initial wave taking about 6 minutes to reach Hawaii.

Tilting of the ground during the week has been slight to the NNE, compounded of NE tilt during the first two days and thereafter very slight SW.

HAWAII FROM THE AIR

Through the courtesy of Major General E. M. Lewis, Commander of the Hawaiian Department, Messrs. J. B. Stone and R. H. Finch of the U. S. Geological Survey were permitted to make airplane trips over Puna District, Island of Hawaii, on June 27. The planes were piloted by First Lieutenants James D. Givens and Glenn C. Salisbury.

The primary object of the flights was to determine whether any lava reached the surface along the northeastern rift of Kilauea where underground movement was strongly suspected in 1924. No 1924 lava was found, though dead trees along some of the steaming cracks in the rift zone indicate an increase in that form of activity. A similar indicated increase of steaming had been previously noted at Aloi crater farther west.

While flying to and from the Parker Ranch landing field at Waimea good observations were obtained of the entire eastern half of Mauna Kea. It was noted that three stream channels extend well above the timber line nearly to the summit of this mountain. These stream channels will eventually control most of the drainage of the upper reaches of Mauna Kea. Observations of several cones point to the need of detailed investigation. One cone is partially surrounded by a black deposit whose nature could not be determined. It was also determined that the several points of interest on Mauna Kea can fairly easily be reached from existing trails.

Good views were obtained of the northeastern slope of Mauna Loa. Most of the lava flows from this slope come from a well defined rift zone. It was noted that this zone, as far as lava flows from it are concerned, stops and forms a definite shoulder on the mountain about 15 miles from the summit.

The views of Kilauea and its lines of cones, craters, and cracks extending to the northeast and southwest were of great interest.

More inspection can be accomplished in a two hour geological reconnaissance from the air, over the territory traversed, than in two weeks on foot. R. H. F.

SEVERE MONTANA AND CALIFORNIA EARTHQUAKES

The copper region of Montana and the volcanic district of the Yellowstone were shaken destructively by earthquakes beginning about 6:40 p. m. June 27 and continuing the next day. Three Forks reported 41 shocks in 30 hours. $500,000 damage was estimated in Gallatin County and the town Manhattan. Two railways were blocked by slides. Three persons were reported injured, none killed. There were ground cracks and canyon landslips at Livingston, the hotel wall was cracked at Great Falls, avalanches occurred near Lombard, and serious shocks were reported from Billings, Butte, Missoula, Helena, White Sulphur and Anaconda, as well as the Yellowstone Park.

Just thirty-six hours later at 6:44 a. m. June 29, Santa Barbara was bumped upward and then wrenched in all directions by a sudden shock accompanied by noise that seemed like a subterranean explosion. The business district was wrecked, Arlington Hotel was a complete loss, State Street was buckled and cracked, two fires started but were extinguished, water mains and reservoir burst and made a flood, 13 people were killed and 30 injured, damage was estimated at $15,000,000, the lighthouse collapsed, and electric light, power and gas were cut off. Shocks continued. Weather was calm and sultry. Four shocks in the early morning and forenoon of the 30th occurred, one severe. T. A. J.

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NO. 28 RELEASED WITHOUT COPYRIGHT RESTRICTION July 9, 1925

KILAUEA REPORT NO. 704

WEEK ENDING JULY 8, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

Changes in Halemaumau are small. There were small rock slides SW July 3, very little W and NW July 4, hardly any July 5 during time of observation, some N and NW July 7 and fresh debris shown NE. and July 8 there had been a strong avalanche leaving a scar, debris and dust from the NE wall, probably coinciding with the earthquake of 6:45 a. m. There are white stains on the pit wall, a vapor column shows at night and during humid weather, and there is always hot steam on the bottom.

The week registered 12 local earth movements. Perceptible earthquakes occurred July 4 at 7:55 p. m.; distance 22 miles, felt in Hilo; July 6 1:47 p. m. distance 11 miles, EW component dismantled instrument: July 8 6:45 a. m. distance about 11 miles. A distant earthquake at 3:51 a. m. July 7 did not appear to coincide with the disaster reported from Nagoya for that morning, for by Japan time the shock registered here would have been late at night (about 11:30 p. m.). Tilt for the week was very slight to SW.

EARTHQUAKE-PROOF BUILDINGS

More than three hundred books on earthquake-proof construction are on file with the Building Committee of the Seismological Society of America (B. Willis, Bull. Seis. Soc. Amer. Dec. 1924, 256). Good workmanship and materials are of first importance, and are rare. Structures should resist a lateral stress equal 30 pounds per square foot. They should have unity and a natural period of vibration different from that of a strong earthquake. Earthquake periods are from 1 to 2 seconds. The best buildings are rigid and low with a half-second period or less. When the earth and structure synchronize the strain is terrific. Houses of brick or reinforced concrete up to eight stories may be stiffened to swing as natural pendulums with a period of a half second or less. Sky-scrapers have a period of two seconds or more; this was the natural swing of the ground in the Tokyo earthquake. If the vibration is shorter than that of the earthquake, the strain is on the basement; if longer the great stress is two-thirds of the height above ground.

Lack of unity causes the frame to knock the partitions and walls down, or the whole house to knock the chimney down, or the faced lower walls to knock the upper unfaced walls down. If the rectangular cells of a steel frame are distorted to become rhomboids, it stands to reason that a hollow tile partition will "stand about as much chance as a Sevres teacup under a steam hammer." If frames are flexible, then the contents of the frame must be made movable. The stress to be met is a horizontal jerk. If frames are rigid on a unit basement slab, and the walls as strong as the unrights and the horizontal beams, and all tied together, then your house floats on the moving ground like a ship. The ideal earthquake-proof house should stand still, while the ground jerks back and forth under it, like a ship cradled on two sets of rollers.. Stiffness may be greatly increased by diagonal sheathing of wood, metal lath, or steel struts in ferro-concrete panelling.

A well built house is a man's best insurance. The "fallen building" clause should be permanently removed from all insurance policies. There is no wisdom in taking earthquake insurance just after an earthquake, but it should be carried all the time on the principle of life insurance. Our towns are mortal. Let us make them immortal.

There were sixteen large steel-frame buildings in Tokyo of which ten were severely damaged. The undamaged ones used ferro-concrete wall construction which stiffened and braced them, and they suffered no damage whatsoever (Hadley, Bull. Seis. Soc. Amer. March, 1924, 6). In the others everything vertical that was supported by the frames was damaged.

Reinforced concrete performed splendidly. In the city 78 percent of 592 ferro-concrete structures were undamaged, and only 1.3 percent entirely collapsed. In the outside district 75 percent were undamaged and 7 percent collapsed. The remainder in both cases were more or less damaged.

Brick buildings with heavy exterior and division walls well tied together escaped without damage in some cases. The damage was much greater on soft soil than hard. Of 49 brick buildings on hard soil 6 percent entirely collapsed, about 50 percent were ruined, 32 percent were slightly damaged and 12 percent were uninjured. Of 436 on soft soil 10 percent entirely collapsed, 44 percent were ruined, 27 percent were slightly damaged and 19 percent escaped.

T. A. J.

NOTE ON VOLCANIC ORIGIN OF EARTHQUAKES

H. H. Turner (Report Brit. A. A. S. 1913, 65) studied correlation of volcanic eruptions and earthquakes for the period 1790-1900 with reference to times of increasing and decreasing volcanicity and seismicity and found 39 percent of correspondence between the two. He wrote "earthquakes and eruptions are affected by the same cause." This was a quantitative numerical calculation made after the method of an astronomer. Milne has published a world map of elliptical areas enclosing the regions of major earthquakes: the ellipses all enclose volcanic districts.

Volcanism includes underground intrusive action as well as surface craters; and this action may extend 100 miles down. In view of this it is extraordinary how persistent is the tradition among geologists to the effect that "volcanic earthquakes" are trivial, superficial, and limited in extent. Volcanologists generally tend to concur in the views of Oldham, Joly, Heilprin, Branca and others to the effect that great earthquakes may be occasioned by magmatic shifts beneath the earth crust, and even the great fault movements may be effects rather than causes.

T. A. J.

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NO. 29 RELEASED WITHOUT COPYRIGHT RESTRICTION JULY 16, 1925

KILAUEA REPORT NO. 705

WEEK ENDING JULY 15, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

There has been a change during the week in the direction of increased numbers of local earthquakes, avalanches on the west wall of the greater crater of Kilauea, some earthquakes felt that appear to center about Mauna Loa, and a little avalanching in Halemaumau pit. This appears to imply augmented seismic motion in the whole volcanic system, and the northerly tilt at the Observatory, if significant, would imply upward pressure in the underground lava.

July 10 avalanches at the pit made dust clouds at 8 and 11 a. m., and at 2:15 p. m. At 2:30 p. m. a small slide fell from the west niche. A yellow patch was observed east of the dyke in the north wall. July 13 at 4 p. m., a small slide occurred on the northeast wall, there was a little working of the northern walls the next day, and July 15 at 8:05 a. m. there was a considerable northeast avalanche which stripped part of the intrusive sill and left fresh debris and red dust on the northern side of the bottom.

At 8 a. m., and in the afternoon of July 14, slides fell from the high part of the Uwekahuna wall west of Kilauea, and July 15, at 7:20 a. m. and 9:00 a. m., fresh scars were made at the south end of that cliff by avalanches, both at the same place, as though the southwestern rift system were working. Nothing seismic was noticed simultaneously.

In Halemaumau a crack across the floor suggested swelling, but it was not certainly new. There was some blue fume and sulphur smell from this place July 15.

Twenty-seven earthquakes of local origin were registered, of which 3 were of the avalanche type. The earthquake of 6:45 a. m. July 8 was felt all over Hawaii. Two recorded quakes of the evening of July 9 were felt at Pahala. At 4:25 p. m. of the 12th an earthquake was felt here vertically moving accompanied by rumble. A shock registered 3:23 a. m. July 14 indicated an origin 27 miles away and was felt at Pahala, strongly suggesting movement under Mauna Loa.

THE WAR AGAINST CATASTROPHE

The publication of a thoughtful quarterly for the study of calamities ("Materiaux pour l'etude des calamite's," Geographical Society of Geneva under the International Red Cross, $1.25 per year, No. 1 Promenade du Pin, Geneva, Switzerland) was begun with the April-June number of 1924, written in French and English mostly, and has now finished its first year.

The topics considered are earthquakes, eruptions, landslides, floods, tornadoes, droughts, faminies, conflagrations, locusts, epidemics and tidal waves. The motive for the journal is the compilation of a world disaster map by the Red Cross, to assist in the mobilization of relief forces, and the publication is designed to draw together world organizations in reports on frequency, alleviation, preparation, education, defense, mapping, legislation and research.

Each number contains original memoirs, correspondence and reviews. Leading articles to date have dealt with landslides in Italy by Amalgia, the locust problem by Vayssiere, earthquakes and volcanoes by de Launay and Brun, tropical cyclones by Visher, earthquake-proof construction by van de Putte, the Kalahari irrigation project for Africa by Schwarz, tidal waves by Vallaux.

On the practical side of the war against volcanic eruptions Brun recommends geophysical studies at observatories of volcanic gases, magnetism, earth movements, sounds, ground temperatures, and full administrative powers in the matter of forewarnings. Precautions should be enforced and the populace trained in what to expect, in routes of retreat by land and sea, in requisitioning of shipping, in avoidance of beaches on account of probable tidal waves, and in organization of picked men as leaders. Houses with high pitched roofs to throw off the ashes are best in regions of explosive eruption even to distances ten miles or more away from the craters.

De Launay believes strongly in a "pyrosphere" or region of intrusive magma inside the crust of the earth intimately akin to both earthquake and volcanic phenomena. He points out that rise of temperature with depth varies enormously in different places in a proportion even as high as 1 to 10 for the same depth. The most ancient and solid lands are cooler than the younger and thinner parts of the crust. Near Lake Superior it is necessary to dig 124 meters to get a rise of temperature of 1° Cent.; in Tuscany the rate is 10 meters to a degree. The rate in Canada and New England is 124 m.: Bohemia, of Carboniferous age, 60 m.; the Paris basin of flat Teritary strata, 30.; Colorado, a region of extinct Teritary volcanism, 16 m.; and active volcanic centers of the present day, 10 meters or less. What is the temperature under the floor of the deep oceans?

It appears to the reviewer that this magazine of the Geneva Society is a most valuable educator and every Red Cross member should subscribe to it. In science there are two approaches to the earth-mapping problem for earthquake research where everybody may help; one is the distribution broadcast of simple seismoscopes for recording very small shocks so that everyone may become interested. The second is the taking of exact temperatures in hundreds of shallow holes in millions of places in the rock, wherever engineers and quarrymen drill, the world over. The Red Cross is an international organization capable of collecting such data. Both of these are parts of a propaganda for educating the public, and getting returns from the public. It is through such public interest that thousands of rain gauges and thermometers assist our Weather Bureau. It is through the compilation of such data that we may map the local shakiness and heat of the earth.

T.A. J.

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NO. 30 RELEASED WITHOUT COPYRIGHT RESTRICTION JULY 23, 1925

KILAUEA REPORT NO. 706

WEEK ENDING JULY 22, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

The increase in numbers of local earthquakes instrumentally registered continues, the numbers for each of the three weeks of July to date being 12, 27 and 34.

Of the 34 shocks of the past week at least ten were of the type characteristic of avalanches at Halemaumau, and the dust of numerous avalanches has been seen. Some of these avalanches, especially two near midnight July 18-19, were big and carried away the northeast rim of the pit where a new trig station flag had been erected the day before. These falls of wall-rock left the bottom covered with much red dust. A remarkable slide observed the afternoon of July 17 started at a brick-red patch in the middle of the northeastern wall and made a rose-colored cauliflower cloud and a purplish red streak on the wall.

Three local earthquakes perceptible here were at 11:57 p. m. July 16; 8:52 a. m. July 18, and this one was accompanied by rumbling noise; and 8:46 p. m. July 19. Tilting of the ground for the week was very slight to the west.

There has not been much of interest at Halemaumau pit. Small dusty slides were seen by anyone remaining a half-hour or more. At 6:15 p. m. July 16 a northeastern slide was heard at the observatory and the dust-cloud seen. One was seen on the 17th from the southeast wall, which is unusual. Sulphur stain on the bottom was increasing the 18th but the avalanches covered the stain with dust. That afternoon a remarkable fumy cloud was seen over Mauna Loa about 5:45 p. m.

A sharp earthquake producing panic about San Francisco bay (R. F. grade 7) is reported for 11:31 a. m. California time July 19. It was not registered on the Kilauea seismograph.

THE SEA-BOTTOM

The earthquake of October, 1873 west of Greece produced a cliff on the sea-floor where the depth was 2000 feet instead of 1400 feet, the former sounding. A violent earthquake near Crete in 1878 broke the submarine cable in two places and made the bottom so irregular as to make necessary the laying of the new cable in another place. The cable from Zante to Crete was broken by an earthquake in 1886 and at the break soundings revealed an increased depth of 1300 feet. There are cliffs on the Mediterranean bottom 3000 to 5000 feet high. (Scott's Geology, p. 47).

With new precipices forming from time to time several hundred feet high in the depths of the sea, it is certain that the bedrock is accessible, and in many places on the floor of the deep oceans the mud may be thin. Fragments of the bedrock have not been collected.

Seventy-two percent of the bedrock of the earth's surface is thus unexplored. If we add some twenty percent of unexplored territory in the Antarctic, the Asiatic mountains and deserts, about the Arctic circle and the South American and African jungles, it is evident that we know little as yet about the globe and its rocks.

The topography and geology of the sea-floor is the biggest item of ignorance. If it is worth spending millions to study the sea-bottom until at least we know what the rock is. The echo-measurement machine for sounding the oceans is now engaging the attention of the nations. With it hundreds of accurate soundings can be made where one was made with the sounding wire. Soundings can be made while the ships are travelling. An electric buzzer or an explosive detonation makes the sound under water, electrical devices determine with great accuracy the time of discharge and the time of the arrival of the echo, and the difference of these times gives the distance of the bottom. The U. S. Naval Research Laboratory through Dr. H. C. Hayes is working out a new instrumental equipment that will both register and record the depth automatically. The U. S. Coast and Geodetic Survey through Commander N. H. Heck has developed a method of accurate loacting of a survey ship by sound ranging to the shore for distances of fifty to a hundred miles. (Jour. Franklin Inst. March 1924).

This type of sounding will quickly produce topographic maps of the hills and deeps on the sea-bottom, but what about the rock specimens? Dredging and tubular sounding irons have secured mud specimens for a few feet of depth into ooze bottoms. Thirty nautical miles east of Hilo, Hawaii, the ocean depth is 18,000 feet. Such depths may be followed for thousands of miles beyond. What is the bedrock? The two possibilities of invention for collecting specimens of the deep sea rock are blasting and boring. They would require long cables and devices operated electrically through them. A mine set off on the bottom followed up by a drag-net might be the simplest solution.

Boring with a rotary diamond drill from an enclosed motor on the sea-bottom set to drive say thirty feet of rods automatically and bite off the core, would be the most elegant device. The frame would have to be heavy and self-adjusting on the bottom. The ship supplying current and holding the cable would have to hold itself fairly stationary or else detach a float. The motor would have to operate at the great pressures of the bottom water. When is the exploration of the unknown seven tenths of the earth to begin? T. A. J.

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NO. 31 RELEASED WITHOUT COPYRIGHT RESTRICTION JULY 30, 1925

KILAUEA REPORT NO. 707

WEEK ENDING JULY 29, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

Halemaumau continues quiet so far as exhibiting live lava is concerned, but seismically it is uneasy, sulphur gases testify to lava below, and exceedingly hot vapor rises in places through the bottom gravel.

Near the road terminus July 24 a new hair line crack crossing the hardened mud of the road and for a short distance on each side along the steam cracks following the southeast margin of Kilauea crater was observed. This showed motion in the floor of the greater crater along cracks parallel to the pit rim but 2000 feet back.

Heavy dust clouds were observed in the Kau desert this day and the next. The northeast trade wind is thereby greatly rearranging the ash and sand of 1924.

There were numerous avalanches July 25, one at the pinnacles east of the south station at 10 a. m. July 27 and at 10:15 a. m. one northeast. During the night preceding July 29 after heavy rain there was a fall of rock from the northeast wall leaving a straight-sided upright band of fresh dry rock in the wall and a new dump of debris at the base. On the opposite side of the pit falling rock was heard at the rift caverns at 9 a. m. July 29.

The seismic frequency diminished from 34 movements the previous week to 27 this week. Fourteen of these were like avalanche jarrings. There were perceptible earthquakes at 8:57 p. m. July 23 and at 2:42 a. m. July 27, the latter indicating origin distance 19 miles. The seismograms showed what appeared to be harmonic tremor the forenoon of July 25 and the morning of July 29: this is a type of motion ordinarily characteristic of active lava at Halemaumau. Tilt for the week was slight SSW, varying from moderate NE to moderate SW.

The summit crater of Mauna Loa was visited July 24 and found to be fuming in two principal places as usual. No remarkable change there was observed.

SURVEY OF THE MOON

The nearest of the heavenly bodies is still incompletely surveyed by modern telescopes. The 100-inch reflector on Mount Wilson reveals thousands of topographic objects on the moon's face hitherto unrecorded (Saunder, Mem. Roy. Astron. Soc. LX, 1-81, 1911-15), and makes possible photographic mapping stereoscopically that will reveal the relief even of the bright lines, hitherto believed to be flat.

A complete survey should contemplate securing two sets of excellent photographs with the big telescope for the two extreme positions of latitude libration, each set covering every hour of the lunar month of approximately 28 days. Once an hour would give a sufficient number of shadow changes on the lunar ridges to measure small items of relief. Roughly this would amount to 672 photographs for extreme north libration, and 672 for south libration, furnishing 672 stereoscopic pairs, or 1344 photographs in all. Comparatively few extra pictures would cover the stereoscopic possibilities of the diurnal and longitude librations.

It would take years to complete this atlas, but in the meantime the photographs taken could be worked up into contour maps as separate atlas sheets, using adjustment or "restitution" cameras, as in aerial topographic mapping, for converting the pictures of the inclined portions of the lunar surface to a suitable uniform projection, and referring the contours to an arbitrary baselevel spheroid. Such an atlas would exhibit everything measurable in the moon on a large scale in terms of measured dimensions. Then and only then could we compare scientifically the craters and other topographic features of the earth with the volcanic relief of the moon, making due allowance for the difference of gravity on the two spheroids, so as to arrive at quantitative conclusions. This result is of first importance for geology. T. A. J.

NEW SAN FRANCISCO EARTHQUAKE

The earthquake shocks of January and February in the eastern United States and Canada gave promise of a seismical year in North America. Numerous subsequent shocks in the eastern states, and in Montana and southern California, partially fulfilled the promise. It continues to be verified. If press report is correct, the latest demonstration is from the northern Coast Range of California. A strong earthquake occurred at 11:31 a. m. by California time, on Sunday forenoon July 19.

The brief telegram announces that what damage there is is not reported (doubtless owing to the usual suppression of earthquake news). The shock was so sharply felt in San Francisco, Oakland and San Jose as to cause church congregations to run into the street. General panic of this type denotes an earthquake of Grade VII of the Rossi-Forel scale, wherein I is very feeble and X very disastrous.

San Jose is 250 miles from the reported center, hence the shock was more widespread than the local but disastrous Santa Barbara quake of June 29. The center of the new shock is said to be 200 miles northwest of San Francisco. This would be either in the ocean floor at the north end of the great rift of 1906, or on land near Cape Mendocino. Along these mountains are boiling springs, steam used for power, quicksilver mines, and very hot ground testifying to subterranean volcanic energy. T.A.J.

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NO. 32 RELEASED WITHOUT COPYRIGHT RESTRICTION August 6, 1925

KILAUEA REPORT NO. 708

WEEK ENDING AUGUST 5, 1925
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

Nothing has occurred of new activity at Halemaumau. Even avalanching is reduced to a minimum. There is some new red debris on the northeast talus. There have been very high winds, dry days and wet days but none of these has produced avalanching.

August 1 and 2 there were destructive sea waves due to high northeast winds, and microseisms became large. For the week there were 24 local earthquake movements, none felt. An earthquake felt on Oahu 9:18 p. m. July 29 was not recorded here. A shock at 8:11 a. m. July 30 indicated origin distance 13 miles and most of the local disturbances appeared to originate farther away than Halemaumau. Tilt was moderate to the NNW. Seasonal northerly tilt is usual in late summer and autumn.

UTILIZING VOLCANIC STEAM

The Larderello electric plant using natural steam (World Power Conference, July 1924, Wembley, address by Prince Ginori Conti; also in "Chimie et Industrie" 1923) is in a region of Liassic, Eocene and Miocene limestones, slates and serpentines. Eight districts of steam blow-holes occur, natural water is scarce, the elevation is 600 to 1600 feet, and the active area covers 100 square miles of hilly country in Tuscany near Volterra and Florence. Borax works have been using the vapors for chemical processes since 1818. The emanations contain besides mineral salts from 94 to 96 percent by weight of steam, and the gases remaining contain percentages by volume of carbon dioxide 92, hydrogen sulphide 2, methane 1.78, hydrogen 2.45, and small amounts of oxygen, nitrogen, argon and helium. Borings yield steam at temperatures varying from 100 to 190 degrees C., and ordinarily pressures of 1 or 2 atmospheres in excess of that of the air.

Ginori Conti applied a jet of this steam to a rotary motor in 1903. He next used a small reciprocating engine connected to a dynamo. Then bore-holes of 12 to 20 inches diameter were drilled and higher temperatures were obtained and a variety of pressures. The temperature was found constant for a given output of steam, but the steam was superheated for an unknown cause and could not be treated as saturated and its pressure measured by its temperature In 1905 a strong well gave 4000 kg. of steam per hour at slightly above atmospheric pressure when fully opened. A 15 h. p. engine was started in 1905 and has been working steadily for 15 years. In 1915 a 250kw. unit with turbo-alternator was started, using aluminum wires and circuit-breakers on account of the corrosion induced by the fumes on copper. This turbine received an effective pressure of 0.5 atm. at 3000 rev. generating a three phase current at 4000 volts and 50 periods frequency. Power was conveyed as far as Volterra In 1916 three units of 2500kw each were installed . The turbines have jet condensers. The natural steam at 120° C. is led through 22 evaporators in which pure water is heated to 110° C. in aluminum tubes, this water being the condensate of natural steam from huge cooling towers. By drilling new wells over 120,000 kg. of steam per hour from wells was supplied. The effective pressure at the turbines is only a quarter atmosphere or about 4 pounds per square inch.

The wells are driven by both percussion and rotary drills. Iron casings are used diminishing the diameter two or three stages to each well. The depths vary from 200 to 600 feet. Steam increases as a well deepens. A headpiece over the well diverts the steam laterally while the working rods pass through an opening at the top. It takes two to six months to complete a well. Sometimes in wet ground little steam comes until a piston is put down and raised suddenly; this starts a geyser of mud and stones followed by steam, which then takes control. The steam output is measured by fitting conical gauge openings on the well, below which a mercury manometer reads the pressure appropriate to the opening: the volume is then calculated by the Saint Vainant formula. By using different openings a diagram is drawn giving the outputs at different pressures.

Since 1923 the evaporators have been abandoned, the natural steam is cleared of its gases by physical condensation and revaporizing, and so is led directly to the turbines. Three such depurators furnished 60,000 kg. of steam per hour with only 0.5 per cent of gas. Some new wells are furnishing 35,000 and 60,000 kg. each per hour. Experiments are successfully progressing with a turbine exhausting into the air, thus doing away with the condenser plant. The net result of the Larderello experiments is that the consumption of natural steam at 2 atm. effective pressure is 40 kg. per kilowatt hour. The plant is now connected with two high tension lines at 38,000 volts for current distribution in Tuscany, running in parallel with several large hydraulic plants.

In view of the great quantities of rocks red with ferric oxide in the Larderello region, and the presence in the dry gases of oxygen along with 6 per cent of hydrogen and its combustible compounds, it appears to the reviewer that the superheat may well be due to slow oxidation of gas with reduction of mineral oxides. T. A. J.

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NO. 33 RELEASED WITHOUT COPYRIGHT RESTRICTION AUGUST 13, 1925

KILAUEA REPORT NO. 709

WEEK ENDING AUGUST 12, 1925

Issued by the Observatory, U. S. Geological Survey:

T. A. Jaggar, Official in charge

Halemaumau, the fire-pit of Kilauea volcano, has reached another extra quiet spell as shown by few avalanches and few earthquakes or tremors for the week. There were 11 local seismic movements of which five appeared to be of the avalanche type. Most of the others were very small and from origins apparently, as determined from their preliminary tremors, more distant than Halemaumau. The pit itself shows sulphur increasing about eastern and southern edges of the bottom, and during an inspection of two hours the forenoon of August 9 small avalanches averaged every fifteen minutes from different parts of the walls.

On that morning there had been a big slide making a dust cloud seen at a distance. This had fallen from the middle of the large gabbroid sill in the northeast wall. Falls at that place had created a new notch in the wall and a new talus conoid below.

Tilting of the ground for the week at the Observatory was moderate to the SSE.

There is nothing to imply "extinction" in present conditions. Extra quiet spells preceded a fortnight by extra quaky ones have come every two months since the beginning of 1925. There have been no big inward tilts to indicate subsidence of the internal lava since it was present in the pit in July 1924.

VOIDS IN LAVA FLOWS

In a typical shelly pahoehoe lava flow quite an appreciable percentage of the total bulk of the flow is represented by voids. A water stream channel developed through such lava has great bottom irregularities as well as numerous voids in its banks.

The large volume of the bottom irregularities and voids in the sides of the channels is often strikingly shown by the behavior of freshets in small streams. The road between Mountain View and Glenwood, Island of Hawaii, crosses the same stream several times within a little over a half mile. Sometimes after a heavy shower in the upper reaches of the stream there is a lapse of nearly an hour between the time of the stream becoming bank full at the upper bridge and the beginning of the flood at a lower bridge about a half mile away. The water is flooding underground before it appears overground. Seepage is probably only a minor factor in controlling such retardations in flood stages. R. H. F.

ENGULFMENT AT CRATER LAKE, OREGON

In view of the remarkable evidence of engulfment as the dominant process at the explosive eruption of Kilauea in May, 1924 (Bull. Hawn. Volc. Obsy. Dec. 1924) wherein the ejected matter was less than one percent of the matter engulfed, Diller's conclusions concerning the origin of the vast crater at Crater Lake National Park, Oregon are interesting. (Jour. Geol. April-May 1923, 226).

The great depression containing the lake is completely encircled by a rim cliff 2000 feet high, the lake is 2000 feet deep, and the outfacing slopes are gentle. The whole constitutes Mount Mazama built up of lavas and ejecta, andesite first, folowed by dacite and dacite pumice. The latest dacite flows outside the crater are not covered by material blown out and flows just inside the rim of the crater as it stands came from a notch produced by the collapse that engulfed the central portion of the volcano.

As the Crater Lake basin with the water removed is five miles in diameter and four thousand feet deep, and this is only one of many volcanoes in the northwestern United States, it would appear that engulfment may be a big process is post-Tertiary volcanism. T. A. J.

ILLINOIS-WISCONSIN EARTHQUAKE OF 1909

The supposition that the central United States is safe against earthquakes was rudely shaken May 26, 1909. Michigan and the great lakes are places seismically quiet according to de Montessus, but at 8:38 a. m. five hundred thousand square miles were shaken from Missouri to Michigan and from Minnesota to Indiana. Buildings were lightly damaged, chimneys fell, furniture was overthrown, dishes were broken, there was much panic. There were three centers and the duration varied from four seconds to a minute. There were rumbling and swishing noises.

Sidewalks were seen to heave and a bridge to sway. People had difficulty in keeping their feet. Glass was shattered. Instruments and machines were put out of commission. Gas pipes were disjointed in Chicago. Fires were started in Aurora and Chicago. Grain bins broke and lost their contents. Italian laborers fell on their knees and prayed. Chicago feared a tidal wave from the lake. Telephone girls left the switch-boards. The top floors of the high office buildings swayed much more than the bottom. (Udden, Pop. Sci. Mon. Aug. 1910). T. A. J.

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NO. 34 RELEASED WITHOUT COPYRIGHT RESTRICTION August 20, 1925

KILAUEA REPORT NO. 710

WEEK ENDING AUGUST 19, 1925

Issued by the Observatory, U. S. Geological Survey:

T. A. Jaggar, Official in charge

Halemaumau remains passive. On August 13 the niche over the northwest talus appeared to be without its former overhang that had made it a kind of a cavern, and the talus below showed fresh debris, showing that the overhang had been falling away. On the 16th and 17th the pit was very quiet, the former being rainy with steam showing in the bottom, the latter dry with hardly any steam. From the northeast side of the pit, the upper rift tunnel in the southwest wall appeared more filled with debris in its bottom part than formerly.

August 18 there were fresh white sulphates at a steaming patch in the middle of the bottom and a sulphur smell was perceptible at the southeast edge of the pit. There has been very little of this odor lately, and the hydrogen sulphide odor, which a year ago was strong even miles away to leeward, is no longer noticed.

August 19 at 2:30 p. m. some light sliding at the northwest wall of the pit was noticed twice during a quarter hour of observation. There had been some recent fresh stripping up and down the west wall. There was fresh white stain on the northeast and southwest walls due to drying after recent rains.

At the Observatory 10 earthquakes of local origin were registered during the week, but for five days from the 10th to the 14th there were not any. One appeared to be an avalanche tremor and all the others were small and unfelt. The net tilt of the ground for the week was zero.

A moderate distant earthquake was recorded at 1:46 a. m. August 19, the seismogram indicating an origin distant about 3000 miles—equal to the distance from Hawaii of Kamtchatka or northern Mexico.

NEW ZEALAND VOLCANO OBSERVATORY

Thanks to the excellent work of Hon. G. M. Thomson and Dr. J. Allan Thomson, it is reported that the Minister for the Interior has approved the proposal of a committee of the New Zealand Institute for establishment in the North Island of a volcano observatory.

As a beginning a suitable man is to be appointed for two years as volcano observer, stationed in the Taupo district, equipped with a motor car, and prepared to make as continuous observations as possible, having in view the selection of a site for a permanent observatory. The publication of regular reports from the New Zealand volcanoes will be welcome to volcanologists. T. A. J.

BATHYSEISMS

Dr. R. D. Oldham, who from 1879 to 1903 studied earthquakes as a member of the Geological Survey of India, in lectures at the Royal Institution January-February, 1923 (Nature, March 31, 1924, 432) reaches the conclusion that great earthquakes may result from rapidly produced strain. They are commonly thought to result from gradual accumulation of strain, which acts from below in opposite directions on some part of the solidified outer shell of rock, so that the shell gives way by faulting or "elastic rebound," and the rupturing motion on the fault-fissure is the earthquake nucleus or center. In such a case the maximum quaking should be at the rupture, the rupture should be parallel to the line of strain, and the strain should be demonstrably slow.

Oldham points out that the maximum quaking is often not at any one rupture or at any visible rupture at all; in the great Indian earthquake of 1897 and the California earthquake of 1906 there were several centers of intense shallow shaking over hundreds of miles, with isoseismal lines close together, and outside of these there are widely separated isoseismal lines for the lesser intensities of shaking. The Charleston earthquake showed no definite faults at all. The fault displacements in the Cutch earthquake of 1819 and in the California earthquake of 1906 reached twenty to thirty-five feet up-and-down or horizontally, but away from the fault plane die out within six miles.

The argument is that the multiple centers are themselves the result of a big movement more profound called a bathyseism; that their close set isoseismals are the results of their own shallow movements; that complicated scattered movements simultaneously over a wide area with outlying centers are incomprehensible results of slow growing strain, but are easily understood if the development of deep strain over a wide area is rapid. L. Pilgrim in 1913 concluded that the origin of the California earthquake lay at a depth of 100 miles, and H. H. Turner concludes on analytical evidence from seismograms that many teleseisms originate from 50 to 300 miles below the surface of the earth. As at these depths the material is weak and plastic, the original motion is not conceived to be fracture, but a volume-density change due to some process of deep-seated volcanism.

The Tokyo and Santa Barbara earthquakes agree with the conception of deep strain. Tokyo showed two distinct displacements; widespread slight shore uplift of one to seven feet due to a deep cause, and a dropped fault-block, locally down six hundred feet in the bay. Santa Barbara lay between measured bench marks that in fifty years have moved respectively 24 feet north and 10 feet south; no north-south fault has been reported on the surface, but the bench-mark creep appears to indicate growing strain, remote from the 1906 movement. Oldham's ideas are in good agreement with many earthquakes where the shock is evenly felt over wide areas. T. A. J.

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NO. 35 RELEASED WITHOUT COPYRIGHT RESTRICTION AUGUST 27, 1925

KILAUEA REPORT NO. 711

WEEK ENDING AUGUST 26, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

Halemaumau has never been quieter. On August 21 the pit was dry and still. On August 22 the only observable change was that a sulphur spot on the bottom appeared brighter yellow. On August 25 after rain the walls were deep red and vapor rose even above the rim.

The seismographs during the week registered 15 earthquakes. One at 11:32 a. m. August 19 was felt in Hilo and Kohala and the seismogram indicated origin 41 miles away. With the same indicated distance came a smaller quake the same day at 3:49 p. m. The other shocks of the week were small and four of them were of the avalanche type accompanying slides in Halemaumau.

Tilting was very slight to the north. At 4:05 a. m. August 21 a meteor was observed at Kilauea, Kohala and Kona.

INCREASED EARTHQUAKE INSURANCE

A New Haven insurance firm states that many firms in the eastern United States are taking out earthquake insurance. This is confirmed by the Spectator, an insurance journal of New York, the Underwriter's Report of San Francisco, and the National Underwriter. The Edison Electric Illuminating Co. of Boston has insured for $45,000,000; the Equitable Building of New York is insured against earthquake for $2,000,000 on a basis of 25 percent coinsurance, and against tornado for $4,000,000 on 50 percent coinsurance. This means that if the total amount of such insurance at time of disaster on the property is less respectively than 25 or 50 percent of cash value by any or all companies insuring, the underwriters of these particular policies shall be liable for those proportions of the actual loss which two million dollars and four million dollars respectively bear to the said 25 percent and 50 percent of total value.

Large buildings in Providence and Philadelphia have been insured up to 90 percent of their value. The New Haven firm above mentioned offers a rate of 40c per $1000 for one year, or $1 per thousand for 3 years on dwellings and fireproof buildings in the East. Revised California and Montana earthquake insurance rates range from 21c to 40c a year on $1000 according to the class of risk and coinsurance percentage, the latter being mandatory with a minimum of 70 percent.

From the Santa Barbara earthquake the estimated total loss given by the insurance journals is under seven million dollars, and the insurance losses under two millions. The amount of insurance written by Los Angeles offices within four days after the Santa Barbara catastrophe was thirty millions, placed all over southern California on all classes of buildings, and all records for earthquake insurance were broken in San Francisco the second week in July when the Assocated Oil Co. purchased thirty-seven million dollars protection for its containers, pipe lines and tanks and their content. The underwriters are described as fairly swamped with earthquake business, which is very complicated in its requirements and necessarily imperfectly understood and badly scheduled. Some companies are declining to write earthquake or raising their rates, maintaining that for such a catastrophe hazard a large reserve should be built up. Usually all companies demand that fire insurance be purchased in at least equal amount with earthquake protection.

The Los Angeles Board of Education has applied for $20,000,000 earthquake insurance on sixty brick school buildings. The San Francisco board of supervisors has passed a resolution calling for a study of Santa Barbara and revision of building regulations. Buildings insured against earthquake are the Woolworth in New York $5,000,000, Kearns in Salt Lake City $360,000, dwellings, offices, warehouses and factories in New Orleans, Boston, Baltimore, Portland, Seattle and cities in New Jersey and in Canada. Many of the smaller buildings have been insured in New York and Brooklyn. The Schuster stores in Milwaukee have been insured for $5,630,000. The companies write a regular earthquake policy covering both seismic danger and the fire that may follow earthquake. They are unhesitatingly accepting more earthquake insurance in Santa Barbara than ever before. T. A. J.

RAPIDITY OF EARTHQUAKE VIBRATIONS

It has long been noted that the period of vibrations of earthquake waves increases somewhat with increase of distance. For some very distant earthquakes the period of the waves in the principal portion of the record on seismographs may be as high as 70 seconds, or less than one vibration per minute. With very local schocks—distance to origin two or three miles—the period is very rapid. Often vibrations at the rate of 200 per minute are recorded. When the distance increases to 10-20 miles the common period of earthquake waves is 0.5 second or 120 vibrations per minute. Periods of 0.6 to 0.8 second or more are commonly observed with earthquakes when the indicated distance to origin is from 30-50 miles. An experienced observer in a suitable building by merely experiencing a perceptible shake can often get some idea of its distance to origin. The long period waves of distant earthquakes do no damage to buildings and are not perceptible to human beings. They can only be detected by seismographs. R.H.F.

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NO. 36 RELEASED WITHOUT COPYRIGHT RESTRICTION September 3, 1925

KILAUEA REPORT NO. 712

WEEK ENDING SEPTEMBER 2, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

The only remarkable change of the week has been a very notable development of spasmodic tremors increasing about September 1, as registered on the seismographs. The pit of Halemaumau has shown no phenomena accordant with the tremors.

August 27 steam was heavy on the taluses after much rain. Blue fume mingled with the steam along the east edge of the floor. August 29 there was fresh debris on the northern slopes. An upward directed cavernous hole was developing above the northwest talus in the wall. Otherwise the pit has been very stable, except for little falls of single stones from the walls.

There were 27 local earthquakes and 36 spasmodic tremors, none of them felt here. A shock at 9:03 p. m. August 28 had an indicated distance to source of 43 miles and was plainly felt in Kealakekua. One at 2:42 p. m. August 29 had distance indicated as 25 miles. Tilting for the week was slight to the northeast and this is the time of year when tilt usually changes radically from southwesterly to northeasterly.

WHAT HOT SPRINGS INDICATE

In a recent symposium on hot springs (Jour. Geol. 1924) physicists and geologists mostly of the Geological Survey and the Geophysical Laboratory described warm springs of Virginia, boiling springs of the west, and scorching fumaroles of Alaska. These are "outpourings of heat energy at the earth's surface," regarded as continuous series. Chemical reaction and radio-activity prove inadequate to explain the high temperatures. Forced flow from a depth of greater pressure may explain part of the slight heating of such warm springs as those in the southern states and Haiti. Heat effects might also be produced by a forced flow of steam from the water excluded from cystallizing lava or magma underground.

From study of rate of increase of temperature downward the Yellowstone boiling waters are calculated to rise from depths of from 3400 to 8000 feet, the water being rain-water that reaches unusual depths. Iceland, Lassen Park, and the Sonoma county boiling waters of California are believed to be more than half rain-water. Geologists differ as to how much magmatic water is mixed with surface water.

Sosman summarizes the discussion by saying that the thirteen authors agree that the source of hot-spring heat is in hot magma under the crust of the earth. These authors represent the southeastern United States, Haiti, Arkansas, California, Greece, Italy, Iceland, Nevada, Utah, Idaho, Katmai in Alaska, and the Yellowstone as places of hot-spring investigation.

The question is left open as to how the volcanic heat is localized and applied. There is no obvious direct connection between volcanic lavas and hot springs, but the heat underground at shallow depths is greater in regions of recent lavas or active intrusives. The increase of temperature downward in flowing wells ranging in depth from 50 to 1600 feet varies from 3 to forty-eight feet per degree Fahrenheit; in mines and non-flowing wells from 20 to 60 feet per degree. The average for flowing wells is about 30 feet, and in mines and still wells about 40 feet per degree. Two hundred and eleven places in the western United States are included.

There is evidently much hot ground in the regions of ore deposits, recent lavas and hot springs, including under "lavas" recent intrusive igneous rocks. Heat of acid formation and of rock oxidation is found by Day and Allen to yield only two percent of the temperature of boiling springs. There seems to the reviewer to be room in the discussion for oxidation of hydrogen and reduction of rock oxides as a prevalent deep intrusive heating process in the outer crust of the earth wherever engulfment and assimilation may be in progress. And oxidized hydrogen is water. T. A. J.

WEST INDIAN EARTHQUAKES

Centers of the many destructive earthquakes recorded in the West Indies are grouped along two east-west lines north and south of very deep ocean troughs south of Cuba and north of Porto Rico. (Taber, Bull. Seis. Soc. Amer. Dec. 1922.) These reach depths of 3500 and 4600 fathoms. The earthquake belts coincide with faults at the edges of the troughs. Haiti suffers most. Sometimes successive earthquakes are on the same fault. There are exceptions to the oft-cited rule that the steepest slopes are the most seismic. High relief does not agree with places of most earthquakes. Permanent changes of shore elevation at time of quakes are rare. Such changes have however occurred gradually within fifty years.

Continued deepening of the troughs accompanies the quaking. Neither tension nor compression agrees particularly with the observed facts. Loading with sediments is not considerable. Big sea-waves have been abundant, usually with withdrawal of water preceding rise, indicating sudden downward displacement of ocean bottom. Disastrous quakes rarely repeat at the same places, hence those places along the belts "near which severe earthquakes have not originated during historic time are to be regarded as most dangerous." As the towns are built on water-logged alluvial soil, and the Antillean masonry is bad construction, the selection of sites and architecture (excepting the modern Kingston) is dangerous both for waves and earthquakes. T. A. J.

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NO. 37 **RELEASED WITHOUT COPYRIGHT RESTRICTION** September 10, 1925

KILAUEA REPORT NO. 713

WEEK ENDING SEPTEMBER 9, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

There has been no change in Halemaumau pit. Very slight falls of rock from the walls have been heard every time the pit has been visited, and on one occasion there appeared to be more sulphurous steam of bluish color at the south talus than usual. A little fresh debris is discernible on the southern taluses.

Forty-four earthquakes and tremors of local origin were registered. Quakes plainly felt in Pahala happened at 8:24 p. m. and 10:40 p. m. September 2. An earthquake felt here at 3:34 p. m. September 5 had origin distance indicated as 39 miles. A slight record of distant earthquake was registered at 6:21 a. m. September 5. Tilt was slight to the west.

RADIOACTIVITY, GEOLOGY AND VOLCANOES

Professor Joly of Dublin accounts for the systematic recurrence of great geologic revolutions accompanied by mountain-building, volcanism and extinction of floras and faunas, by a series of cycles thirty million years long each, occasioned by storage and release of radioactive heat. (Halley Lecture, Oxford University Press, 1925, "The influence of radioactivity on the surface history of the earth," J. Joly. See Nature, May 5, 1923, June 7, 1924 and May 30, 1925). This conception accords well with the volcanologist's experience of short term tides and cycles, and with the evident condition of the earth today volcanically as degenerate compared with Tertiary time.

There is first a lowering of the continents under shallow seas and deep sediments. Then the sediments rise crushed and wrinkled and are worn into mountains. There is outbreak of floods of lava, generally along western coasts. The land attains its former elevation and a long time of comparative quiet ensues with life prospering. Figuring the age of the sedimentary rocks we know from the radioactive degeneration of thorium lead, Joly makes the four or five world revolutions of geology thirty million years apart.

The continents float upon yielding basalt below. The crust is 24 miles deep and the basalt 200 miles. The cooled non-liquid basalt heats itself to liquidity in 25 million years. It becomes lighter on heating, so that the continents sink slightly while the supporting liquid expands and ruptures them. The ubiquitous radioactive elements do the heating. Volumes of lava pour out. The volume increase of the lava substratum is over six percent, enough to increase the surface area of the globe 650,000 square miles.

Tidal effects appear in this sea of lava underground. The continental crust lags behind as the earth rotates and the eastward pressure of the substratum crushes and crumples the deeper portions of the continental blocks filled with sediments, especially on their western sides. These crushed troughs are to become the mountains. The continents drifting relatively west leave the lava on the east under the sea-bottom close to the surface, quicker circulation in the liquid lava causes it to cool and crystallize losing its heat to the oceans, so that the hot eruptive period draws to a close.

With the cooling comes greater density to the basalt and the continents rise by floating higher through a period of some five million years, and volcanic activity wanes. The sea-bottom lava shrinks and lowers. This is the sort of time we are living through now. The early Tertiary age was the last time of revolution. The crushed sediments of the former shallow land-locked seas are heaved higher than the rest of the continents because their roots go lower in the floating, just as a deeper ice-berg lifts a higher peak. The weather and streams erode them into mountain ranges.

It is true that all mountain ranges do not trend north and south like the Cordilleras. But in the cases of the Himalaya and the Pyrenees, for example, the rupturing Eurasian continental blocks had merely to execute slight turning movements to distort the mountain axes. The inter-revolutionary periods are full of small revolutions through graded cycles leading to the big ones. Summarizing, radioactivity furnishes the heat that periodically takes effect by liquefying the outer part of the earth, and the rest of the energy is furnished by the rotation of the earth when the crust becomes mobilized. The globe is enormous and heavy, the crust is trivial and light, and the surface velocity is 1000 miles an hour. T. A. J.

MAXIMUM HEIGHT OF EXPLOSION CLOUDS FROM KILAUEA IN MAY 1924

Owing to the closeness of the Observatory to the seat of the explosions good estimates of the maximum heights of the clouds could not be made. The cloud columns would lean in various directions so that their true distances from the Observatory were not known and one could not measure the angle to their summits and accurately compute their heights. The estimates of the height of one of the tallest clouds noted at the Observatory accordingly varied between 15,000 and 30,000 feet above sea level. The tops of the clouds of the three most violent explosions of the series could not be seen from the Observatory because of general cloudiness.

Good views of several explosion clouds were obtained from Waimea. Waimea is about 50 miles from Kilauea and 2700 feet above sea level. The clouds were observed just to the right of a line to the summit of Mauna Kea from Waimea and appeared to be about 2000 feet higher than the summit. As the summit of Mauna Kea is about 20 miles from Waimea and 13,825 feet above sea level, it would seem that the cloud heights may have been 33,000 feet above sea level. Allowing for possible errors in estimates and some spreading out of the cloud tops, it would appear that the maximum height reached by the explosion clouds was about 30,000 feet. R. H. F.

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NO. 38 RELEASED WITHOUT COPYRIGHT RESTRICTION September 17, 1925

KILAUEA REPORT NO. 714

WEEK ENDING SEPTEMBER 16, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

Nothing new happened at Halemaumau pit until the evening of September 11 when about 11 p. m. the roar of an avalanche of rock was heard in the still night air, the noise proceeding from the pit and quite audible at the Observatory and Volcano House two miles away in an air line. Somewhat later the same night there was another avalanche.

From 10:30 to 11:30 the next forenoon the northeast wall was seen to be working, two slides occurred in a half-hour, and at 1:45 p. m. came a larger slide that sent up a considerable dust cloud from the same place. The weather at this time and for most of the week was hot and sultry, the maximum temperature reaching 82° F. September 14. On that day there were slight slides, but a loose slab that appeared ready to fall at northeast edge of the pit was still in place. A dust cloud rose at 12:50 p. m. September 15. The pit thereafter was tranquil and very dry, the only notable steam patch being at the west pocket. The many avalanches of the year have produced vertical striations on the walls.

Sixteen seismic movements were registered, of which eight were of the avalanche type notably on September 12. Tilting was moderate SSW. None of the earthquakes was perceptible.

EARTHQUAKES IN THE UNITED STATES 1915-23

During the nine full years, 1915-1923, that the U. S. Weather Bureau collected and published in the Monthly Weather Review the earthquake statistics for the mainland of the United States, 955 separate earthquakes distinct enough to be perceptible were reported. This makes the yearly average over 100. Forty-two states and the District of Columbia reported earthquakes. The average number of states reporting one or more earthquakes each year was 19. If the records for 1924 and the first two months of 1925 were included all states excepting Delaware, Florida, and Louisiana would have earthquake reports. An earthquake on October 16, 1916 was undoubtedly perceptible in Florida also, as it was reported from a place in Georgia almost on the Georgia-Florida line.

The number of earthquakes felt in each state is shown in the following table:

State	No. of shakes 1915-23 incl.	State	No. of shakes 1915-23 incl.
Alabama	8	Nebraska	1
Arizona	20	Nevada	36
Arkansas	12	New Hampshire	2
California	594	New Jersey	2
Colorado	19	New Mexico	4
District of Columbia	1	New York	10
Georgia	2	N. Carolina	5
Idaho	15	N. Dakota	1
Illinois	29	Oklahoma	1
Indiana	7	Oregon	17
Iowa	2	Pennsylvania	2
Kansas	3	S. Carolina	17
Kentucky	16	S. Dakota	6
Maine	7	Tennessee	28
Maryland	1	Texas	2
Massachusetts	3	Utah	36
Michigan	4	Vermont	1
Minnesota	2	Virginia	6
Montana	5	Washington	37
Mississippi	4	W. Virginia	1
Missouri	20	Wisconsin	3
		Wyoming	13

As several of the earthquakes were felt in more than one state they were counted more than once so that the sum of the numbers in the above table exceeds the actual number of separate earthquakes. Over half of the earthquakes were reported from California but this is not surprising when one considers the great extent of the state and the fact that it is the most active region, seismically, in the United States.

The most active regions seismically in the eastern United States are along the middle part of the Mississippi River—southern Illinois, western Kentucky and Tennessee, northeastern Arkansas, and southeastern Missouri—and the southern Appalachians. Some of the earthquakes experienced in these regions caused minor damage; though the areas affected were nearly as great as the area affected by the San Francisco earthquake of 1906. This indicates that the actual breaks that cause the earthquakes are, as a rule, at a greater depth below the earth's surface in the eastern part of the United States than in the western part.

During the first part of the nine-year period under discussion several earthquakes were experienced yearly at or near Charleston, South Carolina but during the latter part of the period the frequency of earthquakes at that place seems to have diminished.

The strongest earthquake during the nine-year period occurred in Nevada on October 2, 1915. It was the strongest earthquake that has occurred in the United States since the San Francisco earthquake and was recorded on seismographs all over the world. Cracks 22 miles long were opened in the earth's surface, but little damage was done, however, as the break occurred in a sparsely settled country.

R. H. F.

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NO 39 RELEASED WITHOUT COPYRIGHT RESTRICTION September 24, 1925

KILAUEA REPORT NO. 715

WEEK ENDING SEPTEMBER 23, 1925

Issued by the Observatory, U. S. Geological Survey:

T. A. Jaggar, Official in charge

Nothing has happened as yet to indicate any equinox effect at Halemaumau pit. There has been some stripping of the north wall by avalanches. On the 19th there was a new notch adjacent to and west of the north sill; the debris below was red. On the 23rd there was new dry debris on this same north talus but it was white, and had come from the horn of the sill itself, which consists of a whitish rock.

Not much has been seen of these avalanches. About 1 a. m. of September 22 the roar of an avalanche was heard. That the walls are still unstable was proved on September 22, when some men throwing bowlders over the northwest rim succeeded in starting a slide sufficiently great to make a small dust cloud above the pit. The pit most of the time is quiet. Bluish vapor has been noticed at the base of the wall itself SSW. After rain increased steam returned to the bottom.

Nine earthquakes of local origin were registered on the seismographs. One of these was felt in Hilo at 9.53 a. m. September 17; the seismogram indicated distance to origin from the Observatory at Kilauea of 12 miles. Only one of the registered seisms appeared to be of the avalanche type. Tilt was moderate to the ESE.

COSTA RICAN VOLCANIC DISASTERS

There were many earthquakes, eruptions and floods in the mountainous and volcanic lands of Costa Rica from the seventeenth century on, but reliable records only begin about 1840. From that time some ten to twenty earthquakes per year were sufficiently destructive to be recorded. From 1888, when there was a severe shock in central and western Costa Rica, the Alajuela disaster, a seismologic station was established in the capital San Jose', and from thirty to eighty local earthquakes per year were registered, many very short, only from four to sixteen seconds duration.

Cartago, the second city, and near the continental divide, has suffered terribly from earthquakes in 1822, 1841 and 1910. April 10, 1821, a shock damaged the parochial church, and a year later, May 7, 1822, the whole of central Costa Rica was devastated by a major earthquake, aggravated by the rainy season that deluged the refugees in their straw, plank or skin huts. In 1827 a church at Nicoya on the Pacific coast was ruined. September 27, 1841, Cartago was destroyed anew by a violent quake. The population numbered 17,000, and a third of them were trapped in the ruins and many lost their lives. The center of the city containing 600 large and beautiful buildings including many churches was a total wreck, and 4205 houses were more or less demolished. Shocks continued for twenty-one months, keeping the inhabitants in light shacks exposed to the weather. This was the worst Costa Rican seismic disaster in the 19th century. The year 1851 produced a serious earthquake at San Jose', which is a few miles west of Cartago in the same mountainous central region.

The terrific Cartago earthquake of 1910, on May 4th, demonstrated the obscure but intimate relationships between volcanoes and these shocks. Cartago is at the foot of Irazu volcano and San Jose' near the base of Poas, another active cone with a geyser-like lake of boiling water in its crater. In 1910 Poas became explosive on January 25th and threw much ash over the country and pumice bombs on the borders of its crater. In southern Costa Rica there had occurred a strong shock January 10th. On April 13th there were two midnight shocks of great intensity near San Jose', damaging several towns, and felt from Nicaragua to Panama; the aftershocks were numerous and kept many persons in camp outside of their houses. On May 4th at 6:50 p. m. a tremendous jolt from the east came after an afternoon of many shocks and made of Cartago a heap of rubble, destroying the Carnegie Peace Court, the churches, dwellings, public buildings, and shops. There were killed 272 persons and hundreds were wounded.

Irazu volcano in 1910 showed cracks about its crater, but no activity until 1917 when it broke into explosive eruption damaging the agricultural lands with ash. March 4, 1924, violent earthquakes shook the western half of Costa Rica, again two shocks an hour apart, seriously injuring San Jose', several other towns, the roadways by landslip debris, the western railway and a large country district.

It is worthy of note that in 1891 Cartago was smashed by another type of disaster, a sudden torrential river flood caused by a cloudburst. This started a landslide that dammed a stream, which finally burst the barrier. (Materiaux pour l'e'tude des calamites, April-June 1925, Tristan, p. 62; Viquez, p. 91 See also Jaggar and Spofford, Jour. Assoc. Eng'g Socs., February 1911, Boston).

T. A. J.

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THE VOLCANO LETTER

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NO. 40 | RELEASED WITHOUT COPYRIGHT RESTRICTION | September 30, 1925

KILAUEA REPORT NO. 716

WEEK ENDING SEPTEMBER 30, 1925

Issued by the Observatory, U. S. Geological Survey:

R. H. Finch, temporarily in charge

This week marks the end of 14 months during which the volcano has been quiet. Several avalanches, some of which were loud enough to be heard at Volcano House and sent up dust clouds, occurred during the week.

On September 30 there were several bright red patches on the walls of Halemaumau showing that light rains may produce redness in restricted areas. Heavy rains cause a general reddening of the walls.

Ten earthquakes were registered on the Observatory seismographs. None was perceptible at Volcano House. Excepting three that were of the avalanche type the majority appeared to have had origins at distances considerable in excess of two miles from the Observatory. Tilting was slight to the west.

PRESENT CONSTITUTION OF THE EARTH

Sir Horace Lamb, president of the British Association for the advancement of Science, made a notable address on this subject at the recent Southampton meeting. (Science, Sept. 11, 1925 and Nature, Aug. 29, 1925). "The primary aim of science is to explore the facts of nature, to ascertain their mutual relations, and to arrange them into a consistent and intelligible scheme."

Irregularities in the intensity of gravity have been found to exist over wide areas, proving that in mountainous regions the observed value of gravity, i. e. the weight of the earth crust, is abnormally low, whilst on oceanic islands and about the sea it is abnormally large. The accepted explanation is that the stratum of rock above an imaginary level surface sixty miles down is approximately uniform, in the sense that equal areas of the surface in question bear equal weights. The mountain elevations are held up by the inferior density of the underlying matter, whilst the oceanic hollows are made up for by increased density beneath. The matter in the interior of the earth, below the stratum of "isostatic balance," is in a state of pressure uniform in all directions. The material of the stratum itself is strong enogh to withstand the shearing forces due to the weight of continents and the lack of lateral support at the oceanic depressions.

A rough picture of the material of the inside of the earth makes the central core of about the density of iron, surrounded by an envelope of rock. This satisfies the requirements of gravity distribution, the ascertained velocities of seismic waves from big earthquakes at different depths and the permissible elasticity of the globe.

Lord Kelvin's attempt to limit the age of the earth by loss of heat was upset by the discovery of generation of heat in the processes of radioactive change of elements everywhere present in the rocks. A stratum some ten miles in thickness would provide all the heat wanted for the present known increase of temperature downward. The time elapsed since the consolidation of the earth, estimated by a comparison of the amount of uranium and of the lead associated with it by radioactive degeneration, must be between a thousand million and ten thousand million years.

As to rigidity, the earth itself has a tide occasioned by the deforming action of the sun and moon. The horizontal force of these bodies must slightly deflect the apparent vertical of a pendulum. If the earth were perfectly unyielding, the pendulum would have a calculable displacement. If its observed displacement were less than the calculation, it would mean that the earth itself yielded to that extent. Michelson used two canals E.-W. and N.-S. as pendulums, each 500 feet long, and measured optically their microscopic tides, with a range of movement of the order of a hundredth of a millimeter. The observations magnified exhibit all the features of a tide-gauge record, but the observed tides were only seven tenths as great as those calculated for the canals on an assumed rigid earth. Both E.-W. and N.-S. were alike. The three tenths unaccounted for were taken up by the tides passing through the solid rock. This would amount to a rise and fall of about a rigid, like steel, but not perfectly rigid. The elasticity of foot each half-day. The material of the earth is highly the earth as shown by the wave velocities of compressional and distortional waves from earthquakes, and the ratio of the two, appears to be much like that of ordinary metals and glass. The compressional travel 4½ miles per second and the distortional or transverse waves 2½ miles per second in the outer rocks; thirteen hundred miles down and beyond they travel much faster, 8 and 4 miles per second respectively.

There is an interesting discrepancy between the thermal and tidal arguments about the earth's interior. The thermal argument suggests a plastic condition for the interior. The perfect elasticity shown by the tidal arguments and the earthquake waves indicates great resistance to shearing or flow. Some substances are plastic only to long continued stress. Dr. Lamb suggests that the interior matter of the globe may be plastic under the steady application of centrifugal force, but rigid under such short period forces as the tides or the earthquake waves. T.A.J.

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NO. 41 RELEASED WITHOUT COPYRIGHT RESTRICTION October 8, 1925

KILAUEA REPORT NO. 717

WEEK ENDING OCTOBER 7, 1925

Issued by the Observatory, U. S. Geological Survey:

R. H. Finch, temporarily in charge

After the spell of moderate avalanching noted during the middle and last of September Halemaumau is again rather quiet. Small rock falls, however, can nearly always be heard. On calm days the wierd multiple echoes produced by such falls make it seem as though many landslides were in motion.

Several of the steaming vents on the floor of Halemaumau pit and on the avalanche slopes appear dry as though the visible vapor escaping were live steam. The rapid ascensional rate of some of the steam columns that appear above the rim of pit on damp days also indicates a rather high temperature. The borders of other vents appearing wet leads one to believe that the vapor escaping from them is not excessively hot.

Nineteen local earthquakes, all too small to be perceptible at Volcano House, were registered on the Observatory seismographs. Four of the tremors were of the avalanche type.

Faint records of two distant earthquakes were written at 5:30 p. m. October 3, and 5:58 p. m. October 4.

There was considerable fluctutation in tilt during the week with the net result being slight to the southeast.

Mr. J. B. Stone, geologist of the Bishop Museum, who spent a week on the summit of Mauna Loa with the topographers of the U. S. Geological Survey, now mapping that mountain, reports the usual amount of fume in Mokuaweoweo the summit crater. The odor of sulphur dioxide is quite perceptible at the several fuming vents.

TILTING OF THE GROUND AT HAWAIIAN VOLCANO OBSERVATORY

By tilt is meant a change in the angle of inclination between a portion of the earth's surface and the horizontal. If an entire mountain edifice domes upward symmetrically with a maximum uplift at its central area and decreasing amounts with increase of distance from the center, then at the central area there will be a vertical uplift. Any other surface within the area affected by the swelling will have its angle of inclination with the horizontal changed. There would be a tilt away from the center. Similarly if the mountain subsided there would be a tilt toward the center.

Tilt may be measured by noting the changes in the position of rest of a pendulum. A horizontal pendulum, such as is commonly used for seismographs, may be made more sensitive to tilt than an ordinary pendulum like those in clocks.

Tilt records are affected by temperature changes, probably both by temperature changes in the ground and in the instrument itself. There is a diurnal tilt that closely follows the dirunal temperature change and a seasonal tilt that closely follows the seasonal temperature change. The cylcic seasonal tilt at Kilauea, though large, is small compared with the accumulated tilt for several years.

An attempt was made to find some correlation between tilt and rainfall but no striking results were found. This is surprising as Kilauea is situated at the edge of the rain belt with heavy rains to the northeast and very light rains to the southwest.

Sometimes the area to the northeast of Kilauea will receive in one day a rainfall load of nearly 1,000,000 tons per square mile while the area to the southwest may have but little or no rain.

A very rapid tilt means a rapid bending of the rocky layers that compose the Kilauea mountain edifice. A large and rapid bending of rocky layers is apt to cause breaks with the resultant earthquakes. There seems to be a positive connection between tilt and earthquakes.

At Kilauea there is a connection between tilt and volcanic activity. From 1913 to 1919-1920 there was a gradual rise of the mean lava level of 600 feet. During the same time there was a gradual swelling of the mountain top as shown by the northeast tilt on the Observatory seismographs. This tilt was checked by level lines run in from sea level. They showed that at the Observatory, 2 miles or more from the place of suspected maximum increase of elevation, there had been an increase in elevation of over a foot between 1912 and 1921. At some places nearer Halemaumau the increase in elevation was greater.

From 1919-1920 until the disappearance of lava in 1924 there was a gradual sinking of the lava column. During the same time there was slight accumulation of southwest tilt showing that the mountain was sinking. Coincidental with the rapid sinking of the lava column in the spring of 1924 there was a rapid southwest tilt. The accumulation of southwesterly tilt during the three years ending with 1924 amounted to about one minute and 32 seconds of arc. In September 1925 A. L Burdick, Hilo engineer, kindly ran a level line between the Observatory and two points near Halemaumau. The levelling showed that one point had sunk nine feet and the other five feet with respect to the Observatory. The Observatory itself undoubtedly sank several inches.

This is but an outline of a more complete discussion to be published elsewhere. R.H.F.

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No. 42 RELEASED WITHOUT COPYRIGHT RESTRICTION October 15, 1925

KILEAUEA REPORT NO. 718

WEEK ENDING OCTOBER 14, 1925

Issued by the Observatory, U. S. Geological Survey:

R. H. Finch, Temporarily in charge.

Eleven earthquakes were registered during the week. None was perceptible at the Observatory. A month has elapsed since a perceptible earthquake has occurred at Volcano House.

Avalanches have been rather infrequent during the past week, though small rock falls were occasionally noticed. After the heavy rain of October 13 the walls of Halemaumau were colored a brilliant red excepting for some thick dense layers and instrusive bodies which remained gray.

Tilting was slight to the south-southwest.

Microseismic motion that increased on October 12 indicates the possible presence of a storm at sea near Hawaii. Microseisms became more noticeable on the 13th and continue on the 14th. The only other effects of such a storm noted were southwest winds, thunderstorms, and heavy rainfall.

THIRTY YEARS OF EARTHQUAKES

A summary study of all earthquakes felt in Italy for thirty years following 1891, compiled at the government office, shows that the time of day between 2 and 4 a. m. has the most shocks, while the fewest are from 6 to 8 p. m. There are somewhat more earthquakes in summer than in winter, about 20 per cent more. (Cavasino, Boll. Soc. Sism. Ital. XXV, 49, 1925).

There is great difference between night and day, about twice as many earthquakes being reported at night. This is commonly attributed to fallacy, dependent on more being felt in the quiet hours. To test this, Cavasino listed only strong earthquakes of Grade V of the Mercalli scale or stronger, as these would surely be generally felt either night or day. This special list showed that 1194 shocks of this magnitude came at night as compared with 890 in daytime during the thirty years, making 34 per cent more at night.

He asks, what is the reason? And why is the maximum in the summer and from 2 to 4 in the morning? Cavasino suggests barometric pressure of the atmosphere as a possible control. A millimeter of pressure change on a square kilometer of the earth equals 13.6 million kilograms, sufficient to tilt the adjacent land 0.29 seconds.

Such change gradually applied could have little systematic effect on tectonic earthquakes dependent on accumulating pressure or tension. But for volcanic magma underground the effect might be regular in releasing gas tension. Low barometric pressure would favor such expansion of magma and the pressure of the confined paste on its chamber walls would produce earthquake by repeated rhythmical stresses. The barometer is lowest and the atmosphere presses least at four a. m. for the day and in the summer among the seasons, thus agreeing with the theory. But there is a disagreement; there is a daytime minimum of atmospheric pressure at 4 p. m. without any corresponding earthquake maximum.

An investigation of rainfall by districts in relation to earthquake frequency discovered no correspondences.

The districts of Italy, listed in the order of intensity or violence of their earthquakes, and then in the order of frequency of all earthquakes, showed about the same order of quakiness by both methods. Those places having the most shocks have also the strongest. Sardinia is remarkable in being without earthquakes. In the order of increasing numbers of shocks next came Basilica, Liguria, Lombardy and Piedmont, places of weak seismicity. Next are Lazio, Emilia, Puglia, and Venice, moderate shakiness. Lastly and strongly seismic are in order of increase Campagna, Abruzzo, the March, Tuscany, Calabria, Umbria and Sicily.

In all Italy in thirty years the number of shocks was 13,531 or 451 earthquakes per year felt. Many of these were aftershocks due to the adjustment of local disruptions produced with big earthquakes. Eliminating the aftershocks from the list there are still high frequencies for the years of big earthquakes; such are 1905 (the Calabrian disaster), 1909 (Messina), and 1915 (Avezzano). Apparently some deep-seated process affected all Italy in those years.

Apart from aftershocks, there is an earthquake every two days in Italy, and a disastrous one about every two weeks destroying either property or life. And Italians have done much for practical seismology; may they carry on the work until every dweller in the land feels that his house is safe.

T.A.J.

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NO. 43 **RELEASED WITHOUT COPYRIGHT RESTRICTION** October 22, 1925

KILAUEA REPORT NO. 719

WEEK ENDING OCTOBER 21, 1925
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge.

There are no changes to report in Halemaumau pit. Small slides occur from time to time. The floor vapor continues to rise at several places, increasing after rainfall. On October 15 with southwest wind the vapor condensed about 400 feet below rim and made dense clouds at rim level at 2 p. m. when the weather was foggy. On October 17 small rock falls were heard, and dust from such a fall was seen about 2 p. m. October 21.

For the week seven local seisms were registered, of which four were of the avalanche type and none was perceptible. Tilting of the ground was moderate to the NNE. Microseisms were stronger than common during the forepart of the week.

THE DALY GLACIER ON MAUNA KEA

Evidences of ancient glaciers on the top of Mauna Kea in the form chiefly of stony moraines and ice-scratched ledges and bowlders have been observed since 1909. At that time they were described by R. A. Daly (Am. Jour. Sci. 1910, 279; Science Conspectus, 1911, 120; Proc. Am. Acad. Arts. and Sci. 1915, 158). The writer October 13, 15 and 19 explored the scenes of the Daly glacier and in addition to the other evidences of glacial action discovered large outwash plains from the glacial drainage on the SSW flank of Mauna Kea at elevations about 6600 feet. By the Daly glacier is meant the ice cap that covered the summit flat south of the summit cones. The summit flat ends with a distinct shoulder that edges the plateau, where the slope below increases to thirty degrees or more. The shoulder is at about the 10,500-foot level. Apparently the glacier overhung this shoulder and its drainage swept down 4000 feet to the plain below.

As other moraines are described on the northern parts of the summit area, the ice cap must have been seven or eight miles across. The Daly glacier was over three miles long, now represented by mutton-back ledges elongated to the SSW, scored heavily in grooves and polishings, the rock a smooth trachydolerite whitened by the weather and more or less covered by erratic bowlders. The bowlders are sub-angular, rounded and scratched. The mounds of morainic material make big whitish piles heaped along the mountain shoulder. The ledges are curiously broken up and plucked, as though by the freezing and thawing of snow ice of modern days. There are drainage gorges amid the moraines. The whitish glaciated area is in marked contrast to the red aa lava spurs and red cinder cones which bound it. As to the relation in age between these volcanic eruptions and the glacier, the upper part of the latter appeared to leave debris that was younger than the summit cones of the mountain, but some lower lava cones appeared partially to bury the glacial deposits. This is a matter that requires geologic mapping.

The plain of gravel, rounded bowlders and alluvium below is ten miles long in a WNW direction from Kalaieha, the sheep station, and at a slightly lower level is another series of flood plains about four miles long. The width of the upper plain is four or five miles. It is wonderfully flat, covered with winding stream channels of only a few feet depression, revealing in their banks an upper two or three feet of yellow or buff alluvium, over coarse gravel and stones below. The plain is covered with bunchy grass and scattered mamane trees. The streams appear to converge upward at a big diagonal gorge that led down from the glacier, and west of this are other gorges trenching the pyramid-like face of the mountain below the moraines. Some of the plain areas are bordered by terraces that suggest lake shores, consisting of old aa flows reshaped and partially buried by flood or lake action. The plains are so flat as to remind one of playas. The stones of the flood plain are identical with those of the glacier, and with nothing else.

The big wash plain where it butts against the steep face of the mountain makes a sharper angle in profile than the upper shoulder makes with the summit plateau. This summit plateau is far from flat and is interrupted by immense cones that appear 800 to 1000 feet high or more. These cones threw out bombs of viscous lava in almond shapes and of all sizes, they have cup craters, and aa lava flows emerge from them. The summit lake is at about the head of the Daly glacier. Towards the sheep station there appears to be a zone of cones suggesting the trend of a rift line. T.A.J.

ACTIVITY OF SANTORIN

H. S. Washington of the Geophysical Laboratory of the Carnegie Institution sends word from Greece that the well known volcano Santorin, near the island Thera of the Grecian Archipelago, is again in eruption. The new cone is back of an older one called Mikra Kaimeni, formed in 1573, and within the central group of island cones that recent eruptions have formed, this all being in the middle of a circular oceanic lagoon surrounded by an annular older island. With Professor Ktenas of Athens Dr. Washington is watching the eruption; on September 14 a high Strombolian cloud of steam was rising accompanied by continuous loud roaring and many blocks were ejected without much lava flow being visible.

On September 18 a definite cone had formed which these observers call Fouque' Kaimeni after the distinguished French savant who has monographed Santorin. They approached the cone September 17, but showers of red hot lava blocks prevented them from getting very near. The spectacle was magnificent. T.A.J.

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NO 44. RELEASED WITHOUT COPYRIGHT RESTRICTION October 29, 1925

KILAUEA REPORT NO. 720

WEEK ENDING OCTOBER 28, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge.

The large inner pit of Kilauea crater, Halemaumau, left 3500 by 3000 feet in plan and 1300 feet deep by the activities of 1924, remains inactive with reference to lava activity, but very hot in parts of its bottom and in its convectional emission of gas or vapor. There is little odor. The evidence of heat was striking on the late afternoon of October 26, after a thunder storm with torrential rain, when the vapor jets from all over the Kilauea floor were drawn inward toward a huge cumulus over the pit which billowed up to an immense height. Steam spouts or whirls have been common with the cessation of the trade-wind. With light south wind the gas from the pit nucleates the vapor jets north of it.

Slides have been small. For 15 minutes the morning of October 24 no single pebble fell. There are notable dry hot streaks in otherwise wet talus south and northwest where steam rises. The north and northeast walls have peeled the most showing fresh breaks and cavernous recesses.

The seismographs have registered 10 tremors of which six were pronouncedly of avalanche type and none was perceptible. Tilting was moderate SSE.

A WORLD CAMPAIGN OF EARTHQUAKE SAFETY

"If the seismologic control of the world were put in the hands of some superman with scientific knowledge and authoritative powers it is possible to imagine the way in which he would organize his forces and carry out his task. First of all he would not rest content with the scientific resources in his possession, but would provide for continuous investigation in order to re-examine constantly the knowledge already acquired and to add new information. He woud fit up well-equipped and competently manned centres for investigation. These institutions he would place in strategic positions throughout the world in such a way as to bring the widest variety of earth movements under constant scrutiny. He would further see to it that the staffs of these research centres were in constant communication so that duplication of effort would be avoided and the results secured in one place put quickly at the disposal of workers in all the other institutions. In this way he would organize geonomic research as a world activity, constantly recruiting his groups of investigators and producing steadily new knowledge about the nature and variety of tilts, level changes, tremors, quakings and wave movements, and especially the safe living of mankind with the cataclysms which afflict it."

With only a few words changed (hygienic to seismologic, etc.)' the above is the first paragraph of "International Public Health" by Dr. Vincent, President of the Rockefeller Foundation, in Caldwell and Slosson's "Science remaking the World." What is being done in public health may be done in LOCAL seismology, but this means the creation of just such an organization as the Rockefeller Institute of Medical Research to unite the world in defense against the earthquake "epidemics." All the succeeding measures advocated by Dr. Vincent apply equally to earth study: an administrative world preparedness and construction organization, a centralization of seismic statistics, a positive campaign of house to house education and of training experts. Avoidance of earthquake disaster does not mean stopping the earthquake, but as Mr. John R. Freeman has well said, "seventy-five per cent of the great losses of life and property in the earthquakes of the past could have been prevented by better building, and all within present economic means" (Earthquake Insurance, Manufacturers Mutual Fire Insurance Co., Providence).

It is one of the tasks of the Hawaiian Volcano Research Association to encourage LOCAL study of earth process about the Pacific Ocean. Taking the final paragraph reviewing the success of public health propaganda in Dr. Vincent's article, seismologic science is seen to be backward in comparison; "In the last half-century the scientific resources of modern medicine have been enormously enriched. The causes of a great number of devastating diseases have been discovered; the methods of controlling them have been worked out; medical education has been put upon a higher level; a beginning has been made in the training of expert sanitarians and an entire hygienic personnel. Organization of health administration has been greatly increased in efficiency. The death rates in all the leading countries of the world have fallen in a most gratifying fashion. Beginnings have been made in the education of the public, etc."

To paraphrase this, the scientific resources of modern LOCAL seismology have not been experimentally enriched; the causes of LOCAL earth movements have not been discovered; the methods of LOCAL earthquake-proof placing and construction have not been worked out; seismologic education is not in the school geographies, and except for a few men such as the late honored Professor J. B. Woodworth of Harvard there are few professors of the subject in the universities, and those not reaching the LOCAL, experimental and engineering sides of the subject; no beginning has been made in the training of expert seismic engineers and architects and a seismician personnel. Organization of LOCAL seismologic administration and statistics is still backward. The seismic death and destruction rate in all the earthquake countries of the world is increasing alarmingly without sufficient insurance control of congestion and conflagration, and hardly any beginning has been made in the education of the public.

In view of the colossal destructions of life and capital of the last quarter century this comparison is pregnant with possibilities for reform. The insurance companies are the logical agents to bring about the reform, for the situation affects every department of their business. T.A.J.

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NO. 45 RELEASED WITHOUT COPYRIGHT RESTRICTION November 5, 1925

KILAUEA REPORT NO. 721

WEEK ENDING NOVEMBER 4, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge.

On Saturday, October 31 there were rocks in motion falling from the north and west walls of the Kilauea pit Halemaumau. The north corner showed fresh red debris and dust on the slopes. The recently developed talus cone against the northeast intrusive sill lies below a niche in the wall that has scaled off so as to be bounded on the east by the rift dyke of 1919. On November 3 there were occasional slippings of wall rock SW, NW, and NE. These slides were very small. The steam rising at the west pocket of the bottom is livelier than elsewhere.

Thirteen seisms were registered, mostly little shocks, four were avalanche tremors. A local earthquake at 4:52 p. m. October 28 had indicated origin 8 miles southeast of the Observatory and was of the perceptible class. Tilt was moderate NNE.

TELLING THE AGE OF OLD LAVA FLOWS

It is impossible in Hawaii to guess at the relative ages of lava flows by the vegetation or any such landmark, because the different rainfalls in short distances produce strong differences in apparent weathering and plant growth.

Nature (Oct. 3, 1925, 515) cites M. R. Chevallier who worked on the lava flows of Etna and showed it to be possible "to determine the magnetic declination at the time the lava solidified by observing the direction in which it is now magnetized" (Annales de Physique, July-August 1925). The magnetic declination or compass variation from the true north slowly changes through the centuries at any one place, so that a given year has a characteristic declination.

Chevallier took the average direction of polarity of several pieces of lava from a flow just as they lay, and therefrom obtained a satisfactory agreement with the declination of the year 1911 for the 1911 flow; and with the declination of 1669 for the 1669 flow. This appears to mean that a majority of the crystals of magnetite oriented themselves to the earth's magnetism before the flow congealed. When the declination values so obtained from specimens of earlier lava flows of known dates were plotted, the curve obtained continued the known declination curve of the Etna region symmetrically backward, passing zero declination about 1630, through 18 degrees east about 1440, and through zero again toward westerly variation about 1240. The time intervals from zero to zero are nearly equal and the extremes of declination east and west are the same. These results appear worthy of laboratory experiment on slags containing magnetic minerals. T.A.J.

BUILDING FOR EARTHQUAKE SAFETY

The natural period of vibration of the Claus Spreckels building in San Francisco is 2.3 seconds, about twice that of the ground in a destructive earthquakes. In 1906 the walls were most damaged about the 13th floor, two thirds of the height up. The buildings in Santa Barbara on the other hand had short vibration periods less than that of the ground, and their frames and walls suffered most in the lower stories (Dewell, Building against earthquake shock, The Commonwealth, Sept. 1, 1925, published by the Commonwealth Club of San Francisco).

Block construction is inherently unsatisfactory against earthquake. Dewell lists earthquake-proof construction in order of excellence: first, structural steel frame and reinforced concrete walls; second, ferro-concrete buildings of small height; third, structural steel and brick walls; fourth, reinforced concrete frame and brick walls; fifth and weakest terra cotta buildings without structural frame. All these are fire-proof.

On solid elastic ground the wooden house properly founded and braced suffers only broken chimneys and cracked plaster. But it can be greatly improved. We pile one story on another without continuous members. We could make wooden buildings immune to earthquake if we used the "balloon" framing, with vertical studding continuous, with diagonal bracing continuous cut and nailed into the studs, with floor-joist ends spiked into the studs; and with heavy metal lath instead of chicken-wire in the plaster, this metal reinforcement properly tied at the joints, in plaster thickened using good Portland cement; such construction might increase the cost ten per cent and be opposed by the craftsmen, but it would give the owner of a residence a feeling of real security.

Since 1906 San Francisco has been "letting down the bars." Wind pressure resistance has been reduced from 30 pounds to 15 pounds, and this is earthquake resistance also. Office buildings that resisted the 1906 shock were designed for a floor load of 75 pounds per square foot. Today they are designed for 40 pounds. "Recently the ordinance has again been revised to allow an increase in the permissible unit stresses for structural steel of 12½ per cent, saving one eighth the steel formerly required." Buildings are very much weaker, reinforced concrete is of poor quality, schools are of hodge-podge construction, low cost apartment houses and hotels are being built with light ferro-concrete frame and timber interiors, and another earthquake of the severity of that of 1906 will throw down stores, schools, churches, offices, hotels and apartments. Mr. Dewell concludes that the Californiia public needs to be warned. The warning should be taken to heart away beyond California. T.A.J.

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NO. 46 RELEASED WITHOUT COPYRIGHT RESTRICTION November 12, 1925

KILAUEA REPORT NO. 722

WEEK ENDING NOVEMBER 11, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge.

There is nothing new to report of volcanic or other activity in the Hawaiian volcanoes. They are dormant. Halemaumau pit sent up dust clouds due to avalanches at 9:20 and 10:26 a. m. November 5th from the north side. Fresh red and gray debris was left on the northern slopes.

Twelve local earthquakes were registered, two of them avalanche tremors, and one at 10:44 p. m. November 5 indicated an origin distant 13 miles probably to the NW. This was felt at Volcano House and in Hilo. The long waves of a strong distant earthquake were registered at 3:35 a. m. November 10. Tilt for the week was slight to SE.

A BUSINESS APPRAISAL OF EARTHQUAKE DANGERS

The following paragraphs are from "Earthquake Insurance," a forty-one page pamphlet issued by the Manufacturers Mutual Fire Insurance Co. and five associated companies with headquarters at Providence, Rhode Island, offering "a new service of earthquake coverage for the peace of mind of those already insured in this company who realize that a destructive earthquake can happen in New England or the Mid-west, with as little warning as at Charleston, S. C.,, in 1886."

"Seldom or never has destructive violence extended farther than over spots in a narrow tract, rarely so extensive as 10 miles wide by 50 miles long."

"There is an immunity from tornado and windstorm and lightning loss in the Pacific coast localities, that will go far toward offsetting additional earthquake hazard."

"It is hoped to develop recommendations for obtaining maximum resistance to earthquake shocks, somewhat as heretofore our engineers have developed many aids to fire-resisting construction."

"After a period of activity the internal stress becomes relieved, and there is a long period of quiet."

"The cause of earthquakes is now well established as being a slight slip of a great mass of bedrock, of many cubic miles in quantity."

"Earthquake damage comes nearly always from the elastic oscillation extending out several miles on either side of the deeply buried rift."

"Greatest damage is nearly always found near the border line, between original hard ground and soft marshy ground or 'made land'."

"Earthquakes of greater or lesser intensity somewhere in the world are occurring almost daily." This is an understatement; the average is of the order of 2000 shocks per year on recorded ground, and more than 80 per cent of the world's surface is uninhabited and unknown.

"It was not until about 25 years ago that the modern science of earthquakes, or seismology, was fairly started."

T.A.J.

AMERICAN EARTHQUAKES IN 1924

An earthquake sheet published by the Safe-Cabinet Co. of Marietta, Ohio, makes a serious statement of the congestion-earthquake-tornado-fire menace, which is reliable:

"Two of the greatest fires in history have occurred in the last twenty years as a direct result of earthquakes, those of San Francisco and Tokyo."

"Modern civilization is responsible for the grouping of great numbers of people in one community. It is also responsible for the vast number of fires grouped into these communities for cooking, heating and industrial purposes." It might have added transportation, for every motor-car is burning gasoline.

"The following table, compiled by F. A. Tondorf S. J., chief seismologist of Georgetown University, covers the earthquake record of the U. S. for 1924.

Winchester, Va., Jan.	1	Salinas, Cal., May	26
Greenville, S. C., Jan.	1	Walla Walla, Wash., May	27
Florence, Alabama, Jan	1	Santa Rosa, Cal., July	6
Orderville, Utah, Jan.	1	Brawley, Cal., (2), July	17
Los Angeles, Cal., Jan	2	Eureka, California, July	17
Salinas, California, Jan	4	Brawley, California, July	18
Stanfield, Oregon, Jan.	5	Yellowstone, Wyo., July	20
Walla Walla, Wash., Jan	6	Yorba Linda, Cal., Aug.	26
Milton, Oregon, Jan.	6	Santa Rosa, Cal., Sept.	1
Eureka, California, Jan.	9	Eureka, California, Sept.	7
Yellowstone, Wy., Jan.	11	Summerville, S. C., Sept.	26
Santa Clara, Cal., Feb.	9	St. Johnsbury, Vt., Sept.	30
Seattle, Washington, Feb.	10	Calexico, California, Oct.	2
Calexico, Cal., Feb.	13	Calexico, California, Oct.	3
Summerville, S. C., Feb.	14	Julian, California, Oct.	7
Cairo, Illinois, March	2	Columbia, S. C., Oct.	20
San Francisco, Cal., Mar.	3	Landover, S. C., Oct.	30
Spreckels, Cal., March	9	Los Gatos, Cal., Nov.	12
Spreckels, Cal., April	2	Salinas, Caliornia, Nov.	13
Paducah, Kentucky, April	2	Geneva, Idaho, Nov.	24
Clarksville, Tenn., April	3	Montpelier, Idaho, No.	25
Monterey, Cal., April	3	So. Pass City, Wy., Nov.	25
Yosemite, Cal., April	4	Roanoke, Va., Dec.	25
Kalispell, Montana, April	9	Salinas, Caliornia, Dec.	27
Hayward, Cal., April	11	Hayward, Cal., Dec.	28
San Jose, Cal., April	22	Salinas, California, Dec.	29
Seattle, Wash., April	25	Santa Barbara, Cal., Dec.	30
Calexico, Cal., May	23	Rapid City, S. D., Dec.	30

T.A.J.

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NO. 47 RELEASED WITHOUT COPYRIGHT RESTRICTION November 19, 1925

KILAUEA REPORT NO 723
WEEK ENDING NOVEMBER 18, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge.

Volcanic activity remains dormant in Hawaii, but other parts of the world appear to be having large earthquakes. Three such distant earthquakes were recorded on Observatory seismographs. The one beginning at 1:34 a. m. November 16 had an indicated distance of 3200 miles, equivalent to that of Kamtchatka or Mexico.

The only changes in Halemaumau pit have been peelings of the wall at the north, at the west end of the gray sill in red ancient lavas, dumping red and gray debris on the slope below. This has cut away the shelf that formerly was topped by a high talus over the west horn of the sill. There was odor of hydrogen sulphide at the northeast rim November 17.

Eight local seisms were registered, none perceptible. One on the 13th at 5:30 a. m. appeared to originate 16 miles away by seismogram measurements. Tilting of the ground was slight to the NNE.

INTERIOR OF MAKAOPUHI CRATER

On November 16, 1925, a party from the Observatory, (Stone and Finch) visited the pit crater of Makaopuhi eight miles southeast of Kilauea. The descent into the lower pit was made with little difficulty. It is apparent that at some former time the western wall of the crater closed around what is now the eastern "mezzanine floor." The collapse which formed the present western pit exposed a section through the older floor. At the surface are four pahoehoe flows with an aggregate thickness of perhaps 20 feet underlain by a massive lava fill at least 100 feet thick. Beneath the fill is a layer of red cindery material marking the old floor. The upper part of this fill has developed a very regular, vertical, prismatic jointing; the lower portion also has prismatic jointing but dipping west as if it were normal to the former crater wall High up on the massive rock of the exposed lava fill is a patch of bright blue-green, which has given the name "Makaopuhi" ("eel's eye") to the pit. More of the green coating was found on the enormous talus blocks in the bottom of the pit and has been determined to be the basic copper sulphate, brochantite.

The flow of 1922, which issued from a straight northeast trending fissure in the western wall, covered the bottom of the pit with a jagged layer of mostly aa. Steam issues from a number of cracks and there are sulphur patches on the talus against the western walls. Several small dikes were seen low down in the southwest wall. Approximately the lower quarter of the 900-foot wall is concealed by talus, but in the remaining section no ash beds were visible. J. B. Stone.

MONOGRAPH ON TOKYO EARTHQUAKE

The Imperial Earthquake Investigation Committee of Japan has issued three volumes of its reports in Japanese on the earthquake of September 1, 1923. (Sinsai Yobo Tyosakwai Hokoku, 100A, 100B, 100E, Tokyo 1925. Professor A. Imamura, Secretary of the Committee, Imperial University, Tokyo, has already issued in English a preliminary note in Seismological Notes No. 6.)

Imamura contributes the leading article on seismology of the earthquake followed by a second statistical and mathematical discussion by Saemontaro Nakamura of the Meteorological office. These are followed by special studies of phenomena observed in different prefectures, damage to wooden buildings compared in different places by Matuzawa, aftershocks in Tokyo and Oshima by Yasuda and Seizi Nakamura, relative intensities in different places by Nasu, personal experience near Kamakura by Abe, and list of casualties

The second volume deals with geology, physical geography, land changes in elevation and triangulation, and tidal waves. Kato and Yamasaki are the leading geological authors. Seizi Nakamura presents a survey of Oshima volcano. Imamura discusses the coast line changes of the Boshu peninsula and the mud flow of the Nebukawa. The maps and charts are intensely interesting showing the changed profiles, the places where cables were broken, the numerous epicenters, the progressive changes in railway levels in all directions from Tokyo and Yokohama, the depression area in the middle of Sagami bay and the raised areas opposite the peninsulas. Faulting appears to have been complex, and of the tilted block type so characteristic of the old volcanic mountains of the Connecticut valley.

The third volume deals with an exhaustive engineering, physical and economic research on the conflagration. This ought to be translated piecemeal by insurance bureaus and engineering societies until it is well known in the American business world. Photographs are reproduced showing the terrifying heaps of tens of thousands of corpses in the Honjo yard. The succession of maps showing the fire nuclei anl the successive stages of merging conflagration, and other maps showing scores of tornadoes that developed, are most instructive. Professor Seizi Nakamura of the Physics department of the Imperial University organized students into a fire investigation corps immediately after the disaster, and his chartings form the bulkiest parts of this exhaustive work. Some of the diagrams in these volumes have English titles, a practice to be commended if such invaluable monographs are not to be issued in the English series. We hope however that the whole of it is to appear in English; it is needed by economists, geologists, actuaries and engineers. T.A.J.

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NO. 48 **RELEASED WITHOUT COPYRIGHT RESTRICTION** November 26, 1925

KILAUEA REPORT NO. 724

WEEK ENDING NOVEMBER 25, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge.

At Halemaumau, the lava pit of Kilauea, nothing new has developed. During a period of two hours on the forenoon of the 21st three slight slides from the walls in different places were heard The next day dust was seen occasionally. On the 24th in the forenoon nothing but slight trickle of gravel was noticed, but in the afternoon a dust cloud rose from the pit. Today the 25th after noon the weather was damp and clouds hung low, there was abundant vapor in and about the pit, one slide and two or three light falls of stones were seen in a quarter-hour from the northern walls, and dense steam at the south talus was hot and unusually blue with sulphur gas.

Eleven seisms were recorded for the week, six of which were of the avalanche type. All were too small to be perceptible. Tilting of the ground was slight to the SSW.

ISOSTASY

This Greek word means *the balanced stand* between the land and sea-bottom parts of the earth crust A condition of such balance is proved by gravity measurements. The continents are light and the sea-bottom rocks are heavy. Sandberg has added the notion that the loss of heat and importation of heat at different crustal blocks may effectively change gravity relations, so that an area of mountain erosion may go down beneath the sea, and one of basin accumulation of sediment under the ocean may emerge and become eroded. ("Isostasie, and the causal unity of mountain-building and volcanism," in German, by C. G. S. Sandberg, Gebr. Borntraeger, Berlin, 1924.)

The fact that such revolutions of sea and land have happened has been one of the stumbling-blocks to theory. The surface of the earth was at one time molten. It was not uniform, so that some blocks solidified first. As solid rock is heavier than its molten gassy magma it tends to sink. In the primitive paste stresses were set up between the thicker blocks that sank lowest and the later ones. There was thus a primitive topography, the lowest and thickest blocks being the ocean basins. Then came water condensation and erosion, the high lands being worn down and lightened over the paste below, the depressions being filled and weighted. The lowest and thickest blocks were thus made still thicker, and the highest and thinnest still thinner. Gravitative isostasy keeps a floating balance, and the weighted blocks sink lower and the eroded blocks rise. But geological history shows that periodically basins full of thick sediments have swollen, wrinkled, thickened and lightened, so as to rise into mountain ranges.

Here comes in thermal isostasy. The balance between heat acquired at the bottom of the crust blocks, and heat lost at the surface determines that in the erosion area the bottom of the crust is cooling. In the sea-bottom, blanketing with muds, the bottom of the crust is heating. Under the erosion area, the bottom of the crust is thickening. Under the other, its bottom is melting. Also the heated mantle of water-charged sediment expands through both rock and steam distension, increases in bulk and decreases in density. This expansion folds the strata and along with the isostatic adjustment set in motion, it lifts the area of sedimentation above the sea. The erosion area near base-level is wearing more and more slowly anyway, and the material worn off makes less and less addition to the basin. The strongly developing thermal activity is all that is needed to upset the balance. The thickened and heavier crust under what was the eroded area sinks, and the melted off and lightened crust under the basin rises. All of this imagines a definite crust and a definite pasty substratum, without attempting to define the viscosity. By "bottom of the crust" is meant the contact side of a crust block with the hot paste beneath.

Sandberg believes that active volcanism and folding of strata are both products of this heating up of sediments in basins, with the water of sedimentation furnishing physical and chemical reactions quantitatively sufficient, according to the depth of burial. He conducts experiments in the distension and folding of a sheet of asphalt, subjected to hydrostatic pressure and release. We follow him so far as volcanism applies to mountain-folded regions, but we believe there is more primitive volcanism still active in the oceanic basins, connected with the substratum itself. Sandberg illustrates mechanism whereby big overturned folds may pile up, with igneous matter at their cores. He calls this "regenerated" or "vitalized" magma. He believes that both mountain-building and volcanism would wane or disappear or become only periodic in a world losing its air and water. This he thinks happened to the moon, and he thinks the great craters on the moon themselves prove that it once had air and water. T.A.J.

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NO. 49 RELEASED WITHOUT COPYRIGHT RESTRICTION December 3, 1925

KILAUEA REPORT NO. 725

WEEK ENDING DECEMBER 2, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge.

There has been nothing whatever of volcanic activity in the Hawaiian pits for the week, other than vapor and sulphur fume as usual. Halemaumau at Kilauea continues to sleep. The pits to the east such as Aloi, Alealea and Makaopuhi, and the field of 1923 lava west of the latter, give up steam and some sulphur. The 1920 fissures in Mauna Iki in the Kau Desert are hot enough to light wood. Fissures in and near Mokuaweoweo, the summit crater of Mauna Loa, are hot and sulphurous. Tremors local to the crater regions indicate that something below stirs. No great tilt of the ground inward since the lava was in Halemaumau in July, 1924, but rather at present a tilt outward or away from the center, indicate that the underground lava is either stagnant or rising. A poised slab of the rim of pit was found to have fallen November 28th.

For the week ending this morning 14 earthquake movements were registered, all small and imperceptible, with three of the avalanche type. Coincidental with a cool spell beginning the 26th there was marked NE tilt. The net tilt for the week was strong NNE. Seasonal tilt in this direction is expectable in the winter.

INTERNATIONAL VOLCANO REPORTS

The second and third volumes of the Bulletin of the Section of Volcanology of the International Geodetic and Geophysical Union, covering the last quarter of 1924 and the first two quarters of 1925, are published. (Prof. A. Malladra, Royal Vesuvian Observatory, Resina, Naples, Italy, 30 francs a year).

The office of publication of this quarterly has now been definitely established at the University of Naples. The second volume promised that a full account of volcanology at the Madrid meeting of the Union would appear in the next volume, but it did not appear. This was in October, 1924, and the report of the general meetings has appeared, published in Toulouse, 1925, with hardly any mention of volcanology.

The articles in the second and third Bulletins are very interesting. In the second, Matsuyama reports very briefly on gravity measurement with Eotvos balance across Sakurajima and Unzen in Japan. He finds changing density, apparently across country. At Unzen these changes are not radial to the volcano, but in parallel belts NE-SW. At Sakurajima the gravity changes corresponded somewhat to the subsided areas of the eruption of 1914. He makes the extraordinary statement that the area of subsidence there, proved by precise levelling, has recovered its former level.

In the third Bulletin H. Tanakadate reviews the activity of 18 Japanese volcanoes from 1914 to 1924. Of eight recognized volcanic belts in Japan all but two have had activity in the decade that ended with the Tokyo earthquake. In the five belts of volcanoes that converge on central Japan, ten volcanoes erupted, Tarumai, Komagatake, Kattadake, Asama, Yakedake, Hakone (tremor spasm), Oshima, Bayonnaise Rock, Smith Rock, and Minami-Iwozima. In the numbers of volcanic events tabulated the maxima were in 1914, 1919 and 1923. Apart from earthquake there were 17 and 15 events in 1919 and 1923. The activities extend all the way from the Kurile Islands to the Loo Choo group.

Another paper in this volume is by A. Lacroix on the island Reunion near Madagascar. The active lava crater is at the southeastern end of the island, a U-shaped amphitheatre sloping to the sea, with numerous inner craters always different as seen by a succession of travellers. The activities are very frequent, and mostly quiet lava flows. There have been one or two explosive eruptions, very exceptional, just as at Kilauea. The flows are both aa and pahoehoe, aa being called "gratons" or scratchers. To show how frequent are the lava flows, fourteen different years exhibiting some activity are cited for the twentieth century. Most of the flows are from fissures and the top crater is a pit from 700 to a thousand feet wide and variously filled up or evacuated. All the "cow-dung" splashes of lava, bombs, Pele's hair and glassy types of basalt with iridescence are like Hawaii. T.A.J.

SUBMARINE LANDSCAPE OFF HAWAII

Hawaii is very wonderfully situated for scientific experiments with the sea-bottom. Could one look east from Hilo and drain away the ocean, a vast flattish territory would be seen 18,000 feet below and only thirty nautical miles away, with perhaps some big volcanic domes here and there like Hualalai. In the foreground would be a ragged mountain slope with remnant beach lines. The observer would be far up an enormous mountain range, bigger than the Himalaya, and he would have nose-bleed and nausea, for he would be up towards the top of the sea of breatheable air. The atmosphere would have filled up the space of the lost ocean. We could no longer live in Hilo, unless we developed the wonderful lung capacity of some of the tribes of the Andes.

We want to sound by echoes and discover those lost volcanoes. We want to bore into that great plain and get cores of the rock. Is there oil, iron, copper, sulphur, manganese, radium or selenium in vast quantities there? No man knows. No one has ever prospected the ledges of the deep sea, 72 per cent of the earth's face. If we lay a delicate magnetic instrument on the bottom, electrically connected with Hilo by cable, and thoroughly sealed, is the magnetism extraordinary? If we swing a gravity pendulum in a closed case on the bottom, is the rock enormously heavy? Pendulum work many years ago suggested that the matter under the Hamakua shore is twice as heavy as the stuff under Mauna Kea. Does it not get heavier as we go out under the sea? If with our cable attachments we operate a very delicate seismograph in a vacuum on that bottom land, so that the slightest tremblings or tilts of that wonderful country are written as autographs in the Hilo laboratory, day and night all the year around: will not this be exploration to make the north pole look tame?

Why go to remote lands when the greatest discoveries in the history of science and invention are within the reach of engineering experiment, a sampan sail of thirty knots from Hawaii? (Address Hilo Rotary Club November 11). T.A.J.

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NO. 50 RELEASED WITHOUT COPYRIGHT RESTRICTION December 10, 1925

KILAUEA REPORT NO. 726
WEEK ENDING DECEMBER 9, 1925

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge.

The past week has exhibited a marked revival of felt local earthquakes, such as has not been registered here for some months, but as yet nothing has occurred of volcanic activity on either Kilauea or Mauna Loa. There was considerable avalanching in Halemaumau before the earthquake spell began.

In a quarter-hour from 9:45 to 10 a. m. December 3 four slides fell from the western and northern walls of Halemaumau. The wind was light SSE. The walls were wet and steaming in several places though there had been no rain. The slides were small but started suddenly from high up the walls and made trails of rocks and dust, especially about the southwest rift outcrop. The walls were much more in motion than at any time recently. There were trickle cascades of sand in motion on the west wall. Soon after noon the next day big clouds of dust rose from the pit and the seismogram at 2:31 p. m. showed a long earthquake movement coinciding with an extra big avalanche.

On the 5th there was a large scar in the west wall, cascades of black sand were continuous four fifths of the way up the wall, and there was fresh red debris below and dust clear across the bottom obliterating the sulphur stains.

Two strongly felt shocks occurred about 9:30 a. m. and 12:45 p. m. each dismantling both of the seismographic instruments. The first set off a small slide at the pit, but in the afternoon the pit was very still and sleepy. On the 7th at 2 p. m. there were again sand cascades on the west wall and slides occurred several times during the day. An earthquake at 10:16 p. m. December 8 was prolonged but gentle and a lighter shock occurred at 11:48 p. m.; both of these were felt at Hilo. The indicated distance was 9 miles SE of the Observatory.

Eighteen earthquakes were recorded during the week of which one was of the avalanche type and four were perceptible. The two of December 6 appeared to have origins very near, only two miles away. A strong NNW tilt accompanied the quakes of that day and the tilting of the week was moderate NW. A dog showed alarm and pheasants squawked during the first earthquake of the evening of December 8.

TIDAL WAVES

The disastrous sea-waves that go by this name are of various origins, and they do their damage on shelving shores. The most common are occasioned by big earthquakes on the bottom of the ocean. Some are occasioned by volcanic disturbances of the sea-floor. Others are due to typhoon storms with greatly depressed barometer such as occur in the Bay of Bengal. (Materiaux pour l'etude des Calamites, No. 4, Geneva, Jan.-March, 1925, Les Raz de Maree, by C. Vallaux, p. 333).

The waves are distributed rather markedly about the Pacific and the Mediterranean belts, including the tropical East Indies and the Caribbean. The Atlantic coasts are remarkably free from tidal waves, excepting the Cape of Good Hope and Ascension Island. An active zone of submarine eruptions between Africa and South America does not, however, make tidal waves on those coasts.

Peru and Chile have suffered much from tidal waves. These are accompanied usually by earthquakes that are felt. The people pay little attention to this, but look for the "negative wave," that is, the retirement of the sea as a first sign. But frequently the first movement is a positive wave or rising water, usually smaller than the succeeding negative one. On the 28th October, 1746, a terrible earthquake that destroyed Lima in the interior, also made a terrific wave on the coast, as did the Lisbon earthquake of 1755. The Lima wave finished the destruction of Callao already begun by the earthquake. The sea retired slowly and returned with a roar. It swept everything before it. There were twenty three ships in port most crushed and sunk, but the largest were carried beyond the walls of the city, four vessels, and left in the fields. The sea swung back and forth several times. Of 4900 inhabitants, only 200 escaped. Great quantities of sand and pebbles was swept over the ruins from the wash of landslips made in the harbor islands by the earthquakes and subsequently transported by the waves.

Darwin described the tidal wave at Valdivia in 1835, again following a severe earthquake, as producing a quiet rapid rise and rapid fall. During aftershocks there were curious and complicated currents in the harbor. At the port of Concepcion, which city was damaged by the earthquake, great flocks of sea-birds were seen flying inland. Thirty minutes after the earthquake the sea retired so far as to strand ships in 7 fathoms of water. All the reefs came into view. Then the return wave poured in thirty feet above high tide. Two others followed, some minutes apart, and progressively bigger. Then for several days there were small oscillations. There were said to be eruptions out to sea.

At Arica in 1868 there was an earthquake about 5 a. m. August 13th and twenty minutes afterwards there came inward a wave two or three meters high. Then the sea went out for a mile and the inhabitants fled to the heights. An enormous wave returned more than 17 meters above high tide line and carried two ships a mile into the interior of the country. Several oscillations a quarter of an hour apart followed. This wave did damage even on the New Zealand coast across the ocean.

The two most murderous waves of this sort were the Krakatoa wave of 1883 near the Strait of Sunda on the Java shore, and the Kamaishi wave on the east coast of Japan in 1896. They drowned respectively 30,000 and 32,000 people. The Krakatoa waves appeared to be due directly to the gigantic engulfment of the island that went with the volcanic eruption, an affair of three huge explosions in two days. The waves bombarded the adjacent coasts of the strait, the largest 22 meters above tide, and a succession of them kept going about a half-hour apart. They flattened out in a very short distance, for they were not large at Batavia, just a short distance away.

The Kamaishi wave was a positive inundation of from 6 to 15 meters, the earthquake occurring far out to sea. It was not felt. The fishermen at sea in their boats knew nothing of the tragedy until they returned to their homes to find the flat shore devastated. T.A.J.

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NO. 51 RELEASED WITHOUT COPYRIGHT RESTRICTION December 17, 1925

KILAUEA REPORT NO. 727

WEEK ENDING DECEMBER 16, 1925

Issued by the Observatory, U. S. Geological Survey:

T. A. Jaggar, Official in charge.

The spasm of seismic intensity registered last week has this week died away. No activity has yet appeared in Kilauea or Mauna Loa.

Visits to the pit in dry weather have discovered much wetness of the walls with steam. Steam crack belts in and outside the pit notably accord with the southwest rift direction. Small stones fall most of the time from the north wall. Avalanche dust arose December 13 at noon. There is some sulphur odor and sulphur spots are reappearing on the bottom through the avalanche dust of a week ago. Steam is increasing at the southwest wall.

Twelve very feeble earthquakes were registered, lessening in amplitude and frequency. Microseismic motion increased about the 15th. Most of the quakes were mere tremors.

PREDICTION OF TIDAL WAVES

In the discussion quoted last week from Vallaux, (Materiaux p. calamite's No. 4), some interesting data are given about the Fosse de l'Hirondelle, a supposed submerged volcanic crater northwest of Saint Miguel in the Azores. This and other submarine volcanoes are believed to be the source of some dangerous tidal waves known as tide rips which occur on the coasts of Cornwall and Brittany. At places where the depths shallow rapidly near shore, a succession of sudden, brief, big waves develop without any relation to the weather or earthquakes. These change by interference into big swells that break on the shore, sweep everything and frequently drown people, and retire equally quickly. A family of five were drowned in this way near Land's End in 1870.

Vallaux remarks that there is no hope of predicting tidal waves successfully or of learning anything from experiment. In view of the very successful experiments on harbor reactions in Japan and of valuable forecasts from seismograms in Hawaii seven or eight hours in advance, we do not feel so pessimistic about it. (Prediction of tidal waves, by R. H. Finch, Monthly Weather Review, Washington, March, 1924, p. 147). Even with regard to long range forecasting of submarine earthquakes, there are seasonal effects which Perret has pointed out, (Science, August 28, 1908, p. 277). Vallaux thinks typhoon tidal waves are entirely hopeless, yet Father Algue' in the Philippines has repeatedly demonstrated that typhoons are entirely predictable, their courses are charted in great detail, and the waves that result are quite calculable by experience. T.A.J.

METAMORPHISM DUE TO MAGMA

Sandberg has introduced the word "magmamorphosis" into geology (Geodynamische Probleme, II, Tektonik und Metamorphose, Borntraeger, Berlin, 1924), meaning all kinds of heat and pressure recrystallization, in sedimentary rocks which have subsided and been buried to depths where the contained water was heated by magma or underground lava. This theory is in line with Sandberg's conception of a volcanic substratum everywhere under the earth's crust. (See Volcano Letter No. 48).

The remarkable accordance of the direction of strike of gneisses and schists with the margins of granite bodies, the interpretation of hornblende schists and serpentines as altered sediments rather than eruptives, the analysis of "regional metamorphism," heat metamorphism and "dynamo metamorphism," the obvious chemical relations of "contact metamorphism"—these being the different forms of recrystallization of deeply buried sedimentary rocks—all these phenomena are a part of the genesis of folded mountains, and the fundamental cause is the "activating" of magma.

All folded mountains must contain magmatic cores if we go deep enough. Magmamorphosis is the interaction of such magma with the sediments. This produces effects in both minerals and structure. The operation of magmamorphosis is strictly limited to geosynclines—that is, to troughs which have deepened while receiving erosion products from adjacent land until the sedimentary mantle itself reached the bottom region of the earth's crust. Here thermal isostasy asserts itself by rock expansion, water expansion and intrusion of substratum matter. The magmamorphism introduces an episode which itself conditions the production of mountain folds. Beyond the range of gas and hydrothermal action there may still be enormous compressions and folds due to the gliding of masses of sediments, from higher to lower positions on the flank of the swelling geosyncline. T.A.J.

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NO. 52 RELEASED WITHOUT COPYRIGHT RESTRICTION December 24, 1925

KILAUEA REPORT NO. 728

WEEK ENDING DECEMBER 23, 1925

Issued by the Observatory, U. S. Geological Survey:

R. H. Finch, temporarily in charge.

The walls of Halemaumau are again very red. The red is more extensive than has been observed for a long time and even several of the talus slopes are very brightly colored. Steam from the numerous vents in the pit has been abundant. Rock falls, especially from the northwest wall, are frequent.

Six earthquakes were recorded during the week. The one at 3:37 p m. December 19 was felt locally and at Olaa. Its indicated distance to origin, 9 miles, is the same as that of the shakes of December 8. Tilting was moderate to the southeast.

Coincidental with the beginning of the Kona wind there was a marked increase in the amplitude of the microseisms as registered by all the seismographs on the island.

THE SOUTHWEST RIFT OF MAUNA LOA

An Observatory party recently returned from spending several days on the southwest slope of Mauna Loa with E. G. Wingate, topographer of the U S. Geological Survey, who is now engaged in mapping that portion of the mountain. The Wingate camp is in a lava tube at an elevation of 9940 feet on an ancient Hawaiian trail. The trail roughly follows the 9900 foot contour and shows evidence of having been extensively used in former times.

Mauna Loa is certainly a mountain of contrasts. Starting up from sea level on the Kona or western side of the mountain one first encounters a hot arid belt. With further increase in elevation one traverses in succession a belt of moderate rainfall with a heavy vegetal growth, one of heavy rainfall with a tropical jungle, then moderate rainfall with open forests and one reaches the timber line which is limited by both cold and moisture at about 8,000 feet. The mountain is quite arid beyond the 8,000 foot level though there seems to be a slight increase of precipitation beyond the 10,000 foot contour over that of the 8,000 to 10,000 foot belt. An ohia tree (metrosideros polymorpha) over one foot in diameter was noted at an elevation of 8200 feet and smaller ones of the same variety can be found several hundred feet higher.

Leading southwest from Mokuaweoweo, the central crater of Mauna Loa, is a great belt of fissures from which have poured numerous lava flows both recently and long ago. This rift belt has a slight southerly curving tendency which is especially noticeable about 20 miles from Mokuaweoweo. Its total length is about 35 miles and in many place it is over two miles wide. The counterpart of this rift on the northeast slope of Mauna Loa seems to terminate about 15 miles from Mokuaweoweo.

Activity, marked by vari-colored cinder cones, lava spattered cracks, and long arms of aa (clinkery) or pahoehoe (smooth) lava flows, has taken place from numerous vents along nearly the entire length of the rift. While many of the lava flows reached the sea the majority issued from vents between the 3,000 and 13,000 foot contours.

The sequence of events in the 1919 flow from Mauna Loa is rather typical of the lava flows from the southwest rift. Acompanied by earthquakes the southwest rift zone became active and the ground began to crack open. On September 26 lava broke out at an elevation of about 11,000 feet. This outbreak, which lasted but a few hours was accompanied by fiery fountains and produced a very frothy lava flow. The cracking appeared to progress down the mountain and on September 29, the main lava flow broke out 11 or 12 miles from the upper site at an elevation of 7,700 feet. A stream of molten lava reached the sea, 14 miles away, in about 24 hours and continued to pour into the ocean for 10 days. Thereafter the volume of the output diminished and activity was confined to shorter flows around the source region. The fire fountains occasionally were as much as 400 feet high and built up a cone 250 feet above the former ground level All activity appeared to cease during the first week in November.

The rift belt may be reached at several places from both the northwest and southeast side without encountering much aa lava. By leaving the timber line at a point above the Komakawai water hole in Kona and travelling almost due east one reach the site of the preliminary outbreaks without having to traverse over 1000 feet of aa lava. In recent years there have been several preliminary outbreaks all the way from the 11,000 foot elevation to the summit crater. Between the 11,000 and 12,000 feet elevations the rift is marked by brilliant sulphur deposits and hot steaming cracks, and is covered by fresh pahoehoe lava

The thin covering of new lava at the upper vents appears to rest on very old lava In fact all the lava flows on the southwest half or Mauna Loa may be put into two classes —recent (within the last 100 to 150 years, say) and old. There is no uniform gradation between the youngest and oldest lavas.

Exploration of the summit of the mountain and along the rift line as low as 12,000 feet (lower when the mountain is covered with snow) is greatly facilitated by the fact that many of the cracks contain snow, ice, and water. Some are so deep and narrow that a line is necessary to lower a container to the water pocket.

The sunset effects over clouds produced by both land and sea breeze and tarde wind currents is truly wonderful. It is similar and perhaps less majestic than the view from the proposed Mauna Loa road terminus on the rim of Mokuaweoweo.

R.H.F.

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NO. 53 RELEASED WITHOUT COPYRIGHT RESTRICTION December 31, 1925

KILAUEA REPORT NO. 729

WEEK ENDING DECEMBER 30, 1925
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge.

No renewal of activity nor of seismic action heralding activity has appeared after the December solstice at the Halemaumau lava pit of Kilauea volcano. Everything remains placid at the end of the year. At 11 a. m on December 27th no rock falls were heard during a visit to the pit, and steam was abundant especially from the southwest half of the bottom region and walls. On the 29th a few small dust puffs rising from the cauldron during the day gave evidence of slides. Today, the 30th, dust in small amounts rises frequently, steam is conspicuous along the south rim of the pit and from the southwest half of the interior, and at the edge in the forenoon sulphurous odors were noticed, possibly hydrogen sulphide. On the northeastern wall above the great intrusive sill a coating of white sulphates has recently blossomed out on the face of the rock.

For the week ending December 30 nine local earthquake movements were registered on the Observatory seismographs, all too feeble to be perceptible. Tilting of the ground was slight towards the west.

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COMPOSITION OF HAWAIIAN LAVAS

In a recent copy of the Extension Letter of the University of Hawaii attention was called to the fact that contrary to common opinion most vegetables raised in Hawaii contain as much iron as vegetables raised on the mainland. When one considers that the lavas of Hawaii contain from 5 to 15 per cent of iron and that some soils show even a higher percentage, it is to be expected that Hawaiian vegetables should not be deficient in iron.

Not only are there appreciable percentages of iron in Hawaiian lavas but a great variety of other minerals is also found. The following table shows an analysis by oxides of lava dipped from a molten lava lake at Kilauea. Its composition is quite typical of most of the recent flows from Kilauea and Mauna Loa.

Silicon	49.74	per cent
Aluminium	12.36	"
Iron	11.72	"
Magnesium	8.83	"
Calcium	10.88	"
Sodium	2.45	"
Potassium	0.55	"
Titanium	2.49	"
Phosphorus	0.41	"
Manganese	0.14	"

In addition to the above a great variety of other substances are found in varying amounts. Among the more common of these substances are sulphur, copper, selenium, chlorine, nickel, chromium, strontium, barium, vanadium, and molybdenum.

Besides the commonly observed olivine, an iron-magnesium-silicate, which sometimes constitutes 60 per cent or more of some lavas, a great variety of other crystals are found. Among the other crystals augite, magnetite, hematite and feldspars are common.

Frothy pahoehoe lava may well be termed an iron-stained glass. Hawaiian lavas are classified as basaltic though some specimens have been found that approach the acid types of lava, and quartz is not uncommon on Oahu.

R.H.F.

:x:

EARTHQUAKE INSURANCE RATES

It is interesting to observe that insurance specialists have called in engineers and geologists to secure revision of earthquake rates, increasing the charges in all cases except on wooden dwellings. National Underwriter, November 19, 1925, p 10). Immediately after the Santa Barbara and Montana earthquakes the schedule adopted was short and regardless of territory. Then the only consideration was nature of buildings, in three classes. Now there are six classes of building risks, and four specified districts.

The buildings in the order from least dangerous to more dangerous are (1) wooden dwellings, (2) first class stores, (3) limited size wooden houses, (4) second rate brick and concrete, (5) factory and frame constructions of masonry and some wood, (6) soft masonry, dams, reservoirs, bridges, etc.; each of these six classes being scheduled at greater length than is shown here.

The districts for the Pacific Board of Underwriters are (1) Alaska and Nevada, lowest rate, (2) Interior counties California, next higher, (3) coast counties and Montana, and (4) Imperial, Riverside and San Bernardino, highest rate for the six classes, namely 15 cents for Class 1 buildings, and $1.40 for Class 6, per thousand dollars of insurance. For district (1) the rates of these two classes are 7 cents and 65 cents. Contents of buildings and co-insurance and rents are also scheduled.

This rapid evolution of earthquake insurance shows how little is really known of the risk, what a gamble there is in the words "Alaska, Nevada, dams, bridges," and what a splendid field of research is here for the future of science and humanity.

T.A.J.

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No. 54 RELEASED WITHOUT COPYRIGHT RESTRICTION January 7, 1926

KILAUEA REPORT NO. 730

WEEK ENDING JANUARY 6, 1926
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

The first week of the new year finds the Hawaiian volcanoes quiet. The last lava activity was at the end of July, 1924, when for a fortnight basaltic frothy lava spurted up vigorously amid the debris in the bottom of Halemaumau, the Kilauea pit. This was the return of lava through the engulfed material of the explosive eruption that had preceded. During the last year and a half the pit has gradually become quieter with respect to avalanches from the walls, and sulphurous emanations have lessened. There is no sign of new activity on Mauna Loa.

During the week at Halemaumau there have been some dusty slides. the weather has been dry and white sulphate coatings are abundant on the walls of the pit and on the 1924 ash in the desert. Flocculent steam boils out voluminously from wall and talus vents about the bottom and rim of the pit. It was discovered that a large pinnacle of the rim rock at the south edge has fallen. The taluses have grown higher during 1925. Today slight sulphur odor was perceptible at southeast rim. The north corner of the pit "works" with rock slides more than elsewhere.

Seven quakes were recorded on the 4th, 5th and 6th. Two on the 5th should have been perceptible and caused squawking of peasants. Tilt was slight NE.

HAWAIIAN EARTHQUAKES IN 1925

During the year 1925, 922 local earthquakes were registered on the observatory seismographs. Of this number only 49, or a little over five per cent were strong enough to be perceptible to human beings at Volcano House. The distribution of the earthquakes by months is shown in the following table:

Month	Number of earthquakes	Month	Number of earthquakes
January	94	July	109
February	94	August	94
March	79	September	102
April	70	October	50
May	83	November	48
June	51	December	48

R.H.F.

TWELVE YEARS RECORD OF EARTHQUAKES

From the time that seismographic records were first kept at Hawaiian Volcano Observatory, the summer of 1913, to the close of 1925, 12,264 local earthquakes were registered. The yearly totals are shown in the following table:

Year	Number of earthquakes	Year	Number of earthquakes
1913	167*	1920	211
1914	274	1921	279
1915	456	1922	921
1916	1319	1923	650
1917	207	1924	5877
1918	281	1925	922
1919	700		

*For last 6 mos. of year only.

The yearly average for the 12 complete years, 1914 to 1925 inclusive, is 1022. This value is over twice that for Italian earthquakes. (Volcano Letter No. 42, 1925.)

The majority of the earthquakes occurred in swarms at times of crises, such as outbreaks of Mauna Loa, movements along one of the Kilauea rifts, or collapses in Halemaumau. In 1922, for instance, about 645 of the 921 earthquakes for that year were due to a collapse of Halemaumau and the opening of the northeastern rift of Kilauea. If appropriate deductions for such swarms are made from the total number of earthquakes for years with molten lava in the pit the yearly average becomes about 230. The years 1917, 1920, and 1921, during which molten lava was continuously present, were without great crises and it will be noted that the 230 is comparable to their totals, 207, 211, and 279 respectively. The average per month for quiet times with lava in the pit is then about 19. 1925 furnishes a year for giving the monthly average for quiet times without molten lava and gives 77, or about the same as when all earthquakes are counted.

The greatest total for any month for the 12 years is 5313 for May. The May total is swelled by great swarms of earthquakes in three different years. Aside from the June total of 1680 which was affected by the swarms begining in May, April furnished the next monthly total with 672 shakes. The least of the monthly totals is 285 for February.

R.H.F.

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No. 55 RELEASED WITHOUT COPYRIGHT RESTRICTION January 14, 1926

KILAUEA REPORT No. 731

WEEK ENDING JANUARY 13, 1926
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

The week has had northeast winds and dry weather at the Volcano, and no activity has appeared. Avalanching in Halemaumau pit, however, has been more or less active in small slides so as to carry away much of the north wall over the west horn of the large intrusive sill. On January 9 the north station flag was in place and on the 10th it had fallen in; a big slab of rim rock 15 feet wide was left hanging out over a very precipitous bluff, backed by a large crevasse. The soil was freshly cracked 30 feet back.

Six earthquakes were registered, the one at 10:07 a. m. January 11 being felt at Hilo as a slight vertical jolt. Tilting at the Observatory was moderate NE.

PROTECTION AGAINST VOLCANIC DISASTER

Two articles on this subject have recently appeared, showing that the twentieth century has made progress in knowledge and education about volcanology. (Materials for the study of Calamities, Soc. Geog. Geneve, under the Red Cross, No. 3 A. Brun, No. 6 K. Sapper, 1924 and 1925.) Some practical results of this progress have been seen in the better handling of Vesuvian and Etnan eruptions than in the case of the Pelee disaster, and in the still better preparation and protection at Sakurajima in Japan. Also Java and Hawaii have cared for disasters with science and forethought, and all these places are giving attention to economics, transportation, construction and organization for crisis, as never before.

Brun mentions abnormal deflection of the magnetic needle in eruptions, the study of earthquakes at volcanoes, the registration of sound-waves, measurement of ground temperatures, chemical analysis of gases, the use of aviators for reconnaissance, and the steady observation of crater, hot spring and fumerole processes, as being the fundamental occupations for a volcano observatory.

Sapper states that 190,000 people have been killed by volcanoes in the last four centuries, 93 per cent of the deaths were about the Pacific, and the maximum loss has occurred at volcanoes erupting only once with such violence, and after long inactivity. Each volcanic system has its peculiar type of eruption.

Sapper does not agree that a rise of temperature, the appearance of new vents, underground noises, exhalation of gas and local tremors are themselves sufficient evidence of a coming eruption, citing Cotopaxi, Kilauea, Awoe, Kloet and others as breaking out without such signs. He thinks in thinly populated districts Brun's proposals for observatory work would be too costly. He suggests popular propaganda and education in schools concerning precautions, building regulations, sites, steep roofs to shed ash, and readiness to migrate in case of danger. Avoidance of valley bottoms is a measure suggested against possible lava flow. Famine and disease may be caused by heavy ash fall as at the Tambora eruption of 1815, 44,000 deaths, and the Laki outbreaks of 1783 when a fifth of the population of Iceland and most of the livestock were killed. This sort of happening may be met only by governmental insurance reserves, and rehabilitation as at Sakurajima. Volcanic flood waves on the shore, the boiling over of crater waters, the downrush of snowy melted avalanches, the dispersal of ash by wind, have all been the causes of immense suffering and destruction of life and property. All that can be done is to educate the populace that what has happened before may happen again, and to be ready with measures of relief. For the volcanic lands are fertile and the volcanic seas rich in food supply; people will live there.

Earthquakes and earthquake sea-waves have caused vastly greater losses of life and property than all the volcanic eruptions put together. Lava streams and their secondary effects such as melting snow floods account for only two per cent of volcanic disaster. Explosive eruption on the Pacific half of the earth has done almost all the volcanic damage.

The reviewer would summarize prediction, prevention and protection at volcanoes as requiring the following:

(1) Scientific knowledge and education; economics, construction, insurance, investigation, preparation.

(2) Forewarning, organization, administration in crisis, transportation, policing, housing and food.

(3) Protection, prevention of disease and famine, rehabilitation.

With reference to scientific research, our experience in Hawaii places first those recordings and measurements not dependent on visible lava or actual crater activity, but rather on intrusive magma always present underground; tremor, tilt, level changes, temperatures, and the chemistry of gases and salts. The position of earthquake centers and the distribution of volcanic centers for the district appear to be vital matters. It remains for geophysicists to prove whether there is any value in gravity, magnetism, sound and meteorological controls for volcano diagnosis. It remains for geologists to prove whether an explosive eruption is anything more than a big geyser due to superficial water reaching a lava chamber. T.A.J.

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No. 55 RELEASED WITHOUT COPYRIGHT RESTRICTION January 21, 1926

KILAUEA REPORT NO. 732
WEEK ENDING JANUARY 20, 1926
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

On January 14 the northeast wall or Halemauman had been working sufficiently to open new cracks in the soil ENE back from the pit rim. The N corner was making noisy avalanches. On the 16th the pit was dry and quiet. On the 18th the big sill NE and N had been peeling as shown by gray talus below.

In the very early morning hours January 19 the roars from avalanches were heard and light southwesterly wind brought the dust to the Observatory in droplets of mud rain. By daylight the east floor of Kilauea was seen to be coated with red dust. In the forenoon the northern walls were working strongly, and at 9:45 a. m. a spectacular avalanche at the north corner of the pit made a salmon-colored cauliflower cloud. There was fresh gray talus NE and red N.

Seventeen earthquakes were registered. One at 12:33 p. m. January 16 indicated origin-distance 14 miles and was plainly felt in Hilo. Thirteen of the shocks were on the 18th and 19th, when avalanches were numerous at Halemaumau. Tilting was moderate SW; seasonal change from NE to SW is expected about this time of year.

THE EARTH'S MAGNETISM

There are several reasons whereby volcanology is interested in terrestrial magnetism. At Kilauea in 1913 J. W. Green of the U. S. Coast and Geodetic Survey determined differences of declination of 16 degrees near the fire-pit, and of over 5 degrees about the greater crater. All kinds of basaltic lava fragments deflect the needle, even the Pele's hair. In 1902 when the volcanoes Pelee and Soufriere exploded violently in the Caribbee Islands, a horizontal disturbance was noted at many magnetic stations about the world starting at almost the minute of the St. Pierre destruction and lasting thereafter for several hours.

The conception of the earth as a great magnet with its poles near to its axis of rotation was long considered untenable. It was supposed the heat of the earth's interior would demagnetize it. (See D. L. Hazard, The Earth's Magnetism, Special Publication 117, 1925, U. S. Coast and Geodetic Survey). In view of current beliefs, however, in a ferruginous lava substratum and a terrestrial core of nickel-iron, and recent investigations suggesting that these materials under high pressure may have magnetic properties even though hot, magneticians are again turning to the earth-magnet idea.

What is earth magnetism, what causes it, and what causes it to change? Cathode rays, the electronic theory of matter, the constitution of the sun and the earth are all being studied in this connection. When it was thought that the hot globe could not be a permanent magnet, a mathematical analysis was made to see whether our magnetic field might be due to electric currents flowing around the earth, making the sphere an electro-magnet. Such an analysis by Bauer in 1922 showed that 94% of the field is internal, with 3% external and 3% representing a non-potential system. His results indicated that the intensity of magnetization of the earth had decreased during the last 80 years at a rate irreconcilable with the age of the earth and the present intensity of its magnetism, unless we suppose that there have also been periods of increasing intensity. This is interesting in comparison with Joly's idea of increasing evolution of the latent heat of radioactivity at long intervals. (See VOLCANO LETTER, nos. 3, 37 and 40, 1925.)

The laws governing the mutual attraction and repulsion of moving positive and negative electrons probably cause the phenomena of gravitation, and there is a growing belief that gravitation and terrestrial magnetism are probably to be traced to a common origin. As volcanism on the earth and sun is intimately associated with the physics of hydrogen, and electronic motion has a similar association, it would appear that volcanism, gravitation and magnetism may be cousins.

The variations of earth magnetism take the form of magnetic storms, diurnal variation and secular variation. Magnetic storms are irregular disturbances of short duration. They occur almost simultaneously all over the earth. Like auroras they coincide with large sunspots, but the coincidence by averages is better than that by individual cases. Magnetic storms may be due to streams of electrified particles shot out from the sun. Hale at Mount Wilson has shown that the sun has a magnetic field, and that pairs of sunspots have opposed polarity, with remarkable reversals of polarity in the two hemispheres every 11 years.

The daily variation of magetism is a function of the position of the sun above the horizon for any place, and so is independent of absolute time. The extremes occur in daytime. There is a slight effect during a solar eclipse. It is supposed a solar electrical emanation by way of the upper atmosphere affects electric currents flowing about the earth.

The secular change of terrestrial magnetism does not agree with the notion that a systematic change in the magnetic axis of the earth causes it. The periodic change every 11 years in numbers of sunspots, is paralleled by an 11-year period in the secular magnetic change. Bauer and Abbott are working toward a relation between magnetism changes and the variations in the sun's heat. Here again thermal controls, as in volcanism, may be closely related to magnetism. All three types of magnetic change in the earth appear to be related to the sun. This has given new interest to the study of atmospheric electricity and earth currents.

T.A.J.

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No. 57 RELEASED WITHOUT COPYRIGHT RESTRICTION January 28, 1926

KILAUEA REPORT NO. 733

WEEK ENDING JANUARY 27, 1926
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

As the end of January approaches nothing new has yet been inaugurated for 1926 in the way of Hawaiian volcanic activity. Seismic motion is sufficiently in evidence, with tilting of the ground and high temperatures at some places, to indicate to the observers that Kilauea and Mauna Loa are just as active as ever underground. The quiet spell that followed upon the explosive eruption of 1924 has not yet endured for any unusual length of time. The excessively hot spots where a stick may be lighted at the surface of the ground, on the summit of Mauna Iki in the Kau desert, where lava was flowing in 1920, show some sign of growing hotter. Sticks may now be lighted at two different areas. The well drilled in the Kilauea floor 80 feet deep in July, 1922, shows a temperature today, 67 degrees Centigrade, only 2° cooler than when it was drilled, and adjacent steaming cracks at 57° are 2° hotter than they were then. There is no sign of cooling or diminution of sulphur deposit at the Sulphur Bank near hotel.

Halemaumau the lava pit has been dusty with small slides from the steep north wall, but avalanches have not been so big as during the previous week. On January 23 the bottom was dusty but sulphur-stained spots on the east floor were not obscured at all. The talus slopes were red with fresh debris at the north, and with broken gray fragments of the big sill at the east. All along the wall that overlies this large intrusive sill the steepest overhang is maintained, and motion of sliding and breaking away of the edge of the pit has been stronger and more continuous there for a year than anywhere else. This dense white ledge was red hot after the 1924 eruption, and it seems as though its peeling and undermining of the wall above must be connected with its heat.

At the Observatory during the week 15 local seismic movements were registered, all small, and a few were of the type that accompanies avalanches at the pit. Tilt was slight to the SW.

A large distant earthquake was registered at 2:16 p. m. January 24, the vibrations continuing for over an hour. The distance indicated by the preliminary tremor on the gram is 3600 miles, equal to that of the ocean off Central America or Japan, or of the western Kurile Islands, the Bonin Islands or the Guam region. A tidal wave from it would have reached Hawaii about 10 p. m.

FOREWARNING OF TIDAL WAVES IN HAWAII

A terrific earthquake happened somewhere at a quarter past two in the afternoon of January 24 by Hawaiian time. It was well registered by the Kona and Kilauea seismographs of the Hawaiian Volcano Observatory. Its long slow waves exhibited on the seismogram sheets were preceded by preliminary quicker vibrations lasting 7 minutes, 25 seconds, indicating a distance of transit of the waves of compression through the earth of 5800 kilometers or 3600 miles; the origin might have been in the deeps of the Pacific off Salvador or off Japan, in which cases a water wave of 20 minutes period and over 100 miles amplitude might have been sent across the ocean. (See R. H. Finch, On the Prediction of Tidal Waves, Monthly Weather Review, March 1924, p. 147.) The time taken by the first rock vibrations to travel from the source to Hawaii was 9 minutes and 19 seconds.

The time of transit of a sea wave for approximately this distance, is dependent not only on the distance, but also on the mean depth of the ocean between the locality where the bottom of the ocean is suddenly displaced, and the coast which the wave reaches. The observed velocities of the water waves range from 3 to 8 miles per minute. From observed and computed velocities, Finch has determined in Hawaii, that the transit time of the seismic rock waves making the first preliminary seismograph vibrations, is very nearly equal in minutes and seconds to the hours and minutes taken by the water waves. Thus on the morning of February 3, 1923, a big earthquake somewhere in the north Pacific estimated 2200 miles away from Hawaii, at 5:32 a. m., made seismograph record at Kilauea 5:39 a. m., seven minutes after the shock occurred, and the water wave reached Hilo in Hawaii about 12:30 p. m., seven hours after the shock occurred. This same wave reached Honolulu's island, Oahu, thirty minutes before it reached Hilo; the distance is 225 miles northwest. The Hawaiian islands are thus a valuable gauge for the progress and direction of seismic sea waves, particularly as these waves travel all the way from Alaska to Australia, or from Chile to Japan.

Many more tidal waves may occur than are reported, when they are so small that only tide-gauges register them. The times of such tide-gauge registrations deserve more attention by seismologists than they have had, for they would yield valuable lists of transit times for water waves at different distances and through waters of different depths. These lists could be compared directly with earthquake centers, times and distances, as computed by seismograph publications.

Finch cites an earthquake in the Kamtchatka region September 7, 1918, distance 3200 miles, water wave 8 miles per minute, doing some damage in Hilo. Another southwest of Hawaii in shallower waters, the water wave reaching Honolulu at 4.7 miles per minute and San Francisco at 5.9 miles per minute. The Chilean earthquake sea-wave of November 11, 1922, travelled to Hilo at 7.5 miles per minute and registered on the seismograph early enough for a prediction of its coming over nine hours in advance. A Kamtchatkan earthquake 3200 miles away April 13, 1923, registered here at 5:17 a. m. and made a small tidal wave at Hilo at 12:40 p. m. In general the very dangerous tidal waves would be due to very big earthquakes a few hundred miles away, the water wave arriving on a shelving shore in from 3 to 6 hours, and the rock vibration arriving in from 3 to 6 minutes, thus giving several hours warning.

T.A.J.

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No. 58 RELEASED WITHOUT COPYRIGHT RESTRICTION February 4, 1926

KILAUEA REPORT NO. 734
WEEK ENDING FEBRUARY 3, 1926
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

There has been no change during the week to indicate any new activity in Kilauea or Mauna Loa craters. The pit Halemaumau gave up a dust cloud due to avalanche about noon January 28. At 1:45 p. m. slides were moving down a vertical notch grooving most of the height of the east wall athwart the end of the big north intrusive sill. This filled the air with dust along the bottom region of the east wall. The pit was dry. Nothing new was observed January 30 and February 1, no glow in the evening could be detected anywhere inside the pit, but the northeast talus was observed to be growing high and sharp-pointed. The interior surfaces were quite dusty February 3. About noon this day a rock slide fell from the west wall of the larger Kilauea crater.

Nine earthquakes were recorded during the week, one of these at 8.18 a. m. January 28 being in the perceptible class. Tilting was slight NNE. The weather was the coldest for the winter so far, and drought continues.

DAY'S THEORY OF PRESENT-DAY VOLCANISM

After quoting the evidence from Kilauea and Lassen, Dr. A. L. Day reaches the conclusion (Some Causes of Volcanic Activity, Journal Franklin Institute, August 1925) "that volcanoes are local and superficial developments representing (geologically) the last stages in crystallization in a mass of magma below, of which little remains fluid, and this in small (as geologic dimensions go) pockets, which are quite variable in gas content, pressure and conditions of chemical equilibrium." "The outstanding factor in determining the character of modern volcanism is the gas content of the crystallizing magma. If this be mainly of steam released in a closed chamber, as at Lassen Peak, then only steam explosions are to be expected as the surface manifestation of the crystallization of the magma below; if to the steam are added such chemically active gases as chlorine, sulphur, hydrogen and the hydrocarbons, then chemical reaction between these will be a sufficient cause of higher temperatures and lava flows of the character well known at Vesuvius, Stromboli or Kilauea."

The supporting evidence for this theory cited is:—The temperatures in Kilauea lava lake are very variable; the viscosity of the material in the lava basin is diversified; gases maintain fluidity remarkably and more gas brings more heat: the gases are variable and not in equilibrium; surface temperatures are hotter than those below; the Lassen eruptions on the other hand showed little red heat; they produced merely great explosions of water vapor; the Kilauea pit after the 1924 explosive eruption showed red hot crystalline bodies and possible lateral vents; on other occasions it has shown lava flowing from different levels. All this is summed up as proving that "the heterogeneous character of the gases collected, the temperature conditions within the lava basin, the appearance of the crater when free of all its liquid lava, and the dynamic relations within the lava body when present in the crater, all point to many sources rather than to a single source both of gases and of magma." Day thinks that the great Tertiary floods of lava of Africa, India and North America may have been from a crustal substratum, but that modern volcanoes have no such source. T.A.J.

THE ERUPTION OF SANTORIN

The activity of this volcano in the Grecian archipelago cited in the VOLCANO LETTER of October 22, 1925, has continued (H. S. Washington, Jour. Wash. Acad. Sci. Jan. 4, 1926) and is likely to last for a year or more. The general quality of its stiff aa lava flows and explosions recalls Sakurajima. The active central islands are in the midst of an oceanic lagoon about seven by five miles in diameter, partly enclosed by the inhabited islands Thera and Therasia; the lagoon is probably an ancient engulfment crater. The present eruption was started by small earthquakes in July, 1925 and during the first nine days of August an islet was built up in a strait between Mikra and Nea Kaimeni. By vulcanian explosions and hypersthene andesite flows this filled the strait and united these island conelets. The water was heated to nearly boiling, and 69 degrees C. was measured.

The lava piled up several meters and on October 27 the eastern flow was still moving into the lagoon. Another flow was moving on the land. Steam and sulphuretted hydrogen were given off. The lagoon water was colored orange with iron hydroxide. The new hill formed, Fouque' Kaimeni, was 75 meters high and 120 meters in diameter. It was a fissured incandescent dome continually changing with violent explosions making cauliflower clouds and throwing showers of rocks. Elsewhere there were hissing steam jets and 'coronet' jets from encircling incandescent crevices. Bluish, yellow and red flames played over the lava dome. T.A.J.

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No. 59 **RELEASED WITHOUT COPYRIGHT RESTRICTION** February 11, 1926

KILAUEA REPORT NO. 735

WEEK ENDING FEBRUARY 10, 1926
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

There has been some avalanching in Halemaumau during the week, seismic activity has been feeble at Kilauea, but an earthquake was felt in Honolulu and on Maui about 11:28 a. m. February 7.

On February 4 conditions in the pit were quiet. February 6th there was fresh talus NE, new cracks were found in the soil WNW of the pit, and small slides occurred SW and NE after 3:30 p. m. Light southerly wind caused the gas from the pit to nucleate and make visible the northerly steam jets on the Kilauea floor. This nucleation effect was noted at 5:30 p. m. February 7 in the western floor jets of the pit itself, which at first appeared feeble, then changed to densely flocculent steam tails without any apparent cause. Dust does not nucleate the steam, as shown February 10 when a northeast gale filled the pit with dust. Feburay 8th the northeast wall was dropping rock in bunches every few minutes and making red cauliflowers. The gale of the 10th, which blew down a chimney at Volcano House, did not seem to start avalanches.

Six earthquakes were registered, including a tremor simultaneous with the Honolulu earthquake, apparently a coincidence merely. Tilt was strong SSW.

DALY'S THEORY OF VOLCANISM

It would be hard to imagine any more completely different explanation for the same phenomena than is R. A. Daly's doctrine of the cause of volcanic action, as compared with the crystallization-pocket theory of A. L. Day cited last week. (Daly, R. A. Relation of mountain building to igneous action, Proc. Amer. Phil. Soc. LXIV, 2, 1925, pp. 283-307). Daly is geologist at Harvard, Day is physicist and director of the Geophysical Laboratory at Washington.

Daly makes the fundamental cause of volcanic action a rising of molten rock from the interior. Fluxing gases from such an injection are responsible for the long lives of ordinary volcanoes. Effervescence of the gas-charged slag is one of the conditions for lava outflow. Gas pressure is one of the causes for the initial rise of this material. But it is not the main cause.

The main cause is the weight of the crystalline crust of the earth, which from time to time breaks so that the continental blocks slip or glide sideways, underlain by a thick shell of hot basaltic glass, which is rigid but weak. This hot basalt, released of pressure, rises into tension cracks that open when the broken continents slide toward lower basins of sedimentation (oceans).

The migration of crust blocks of continental dimensions, over a substratum of lava-glass which is easily strained by prolonged pressure in one direction, is the Wegener "drift theory" of the origin of continents and compression of mountain chains. The existing continents broke away from an Asia-Europe center, migrating toward the Pacific both westward and eastward. The crust is some 40 miles thick. The substratum is "slippery." The continental movements have been like great landslides, leaving widening tension cracks behind, which are now the Arctic, Atlantic and Indian oceans. These have shore-lines peculiar to such origin. The Americas and the Australia-Asia blocks migrated towards the Pacific center, "folding and rafting together" the strata downstream, and so crumpled up and finally lifted the mountain ranges of the Cordillera, the Andes and eastern Asia and Australia.

The granite intrusions of the mountains are accounted for by Daly as follows. At the front of the advancing continents huge crust fragments sank in the lava substratum. There they were melted and produced solutions more siliceous than the original basic glass. New gases from limestones were introduced into the melts so formed. These account for the concentration of alkaline lavas and intrusions. This deeply assimilated matter was injected into or through the crumpled mountain sediments as granites, diorities, rhyolites and andesites.

This explanation is said to accord with the tidal-disruption theory of earth origin, which demands a primitive molten stage for the globe, and a thin crust. Proofs for the basaltic under-layer are the computed deep temperatures, too high for crystallization (See Volcano Letter No. 3, January 15, 1925). Isostatic balance implies plasticity in the substance beneath the crust (See Volcano Letter No. 48). The sinking of sedimentary basins, and their great squeezing together and shortening long before they are lifted and eroded into mountains, are facts that appear to agree with the idea that a substratum makes room for them and that something advances to crush them. The tension cracking and sinking of large areas of the crust of the earth over which basaltic floods of lava have poured out, and the repeated upgushing of black "trap rocks" as dykes in all geologic ages, are evidences of a basaltic underpinning capable of effusion when the crust breaks up above it. Such broken and flooded areas are the great rift of Africa, the Deccan of India, the Columbia basin of Idaho and Oregon, and the Bushveld of the Transvaal.

Earthquake wave caculations show sudden changes in substance, of layers of the globe 35 and 75 miles beneath central Europe. The rock is believed to change from siliceous to something heavy like basalt 35 miles down. Such a change is estimated to be only 15 miles down under the Atlantic, and is absent under the Pacific. T.A.J.

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No. 60 RELEASED WITHOUT COPYRIGHT RESTRICTION February 18, 1926

KILAUEA REPORT NO 736

WEEK ENDING FEBRUARY 17, 1926

Issued by the Observatory, U. S. Geological Survey:

T. A. Jaggar, Official in charge

There is nothing to say about the Hawaiian volcanoes for the past week to the effect that they have changed in any perceptible or measurable way. They are dormant. In Halemaumau there is moderate quantity of bottom vapor, little stones fall occasionally from the walls, no dust over the pit has indicated internal slides, and the only fresh debris on the talus is on the northeast side where there were slips last week. The vapor jets are less condensed in dry weather, and in such weather a greenish yellow sulphate patch may be seen on the lava floor.

Six local seisms were registered, very small, two of them being of the avalanche type. Long waves of a distant earthquake, of small amplitude, were recorded at 5:00 p. m. February 14. Tilting of the ground during the fore part of the week was to the NE, later to the SW, the net result being slight ESE.

HOBBS' THEORY OF VOLCANISM

Professor W. H Hobbs of the University of Michigan bases his idea of volcanic action on a conception of pockets of melted sedimentary rocks. (Earth Evolution, Macmillan, 1921.) He believes in giving up the notions of permanence of oceans, of nebular origin for the earth, of intrusive rocks being connected with a substratum, of earthquakes having an epicenter, of subterranean flow and outthrust from Asia of mountain-forming pressure, of isostasy, and of tensional stress anywhere. Compression is the rule. Strata of stiff limestone arched up over shale by compression, the rocks being restrained from melting only by pressure, relieve the pressure on the hot shale so that it melts. Laccoliths are formed by this mechanism, and according to Hobbs have no feeding dykes below.

Proofs of the hypothesis are adduced as follows: The planetesimal theory is right and calls for no molten planet. On the basis of Gutenberg's 1914 conclusions from earthquake wave velocities, the center of the earth is like the stone-iron meteorites, next outward comes a layer of heavier nickel-iron, then meteoric stone of density 3.6, and outside is a thin rind of sediments and igneous rock. The fusing point is elevated with increase of pressure. Mountain forming sediments are under great pressure and very hot. Local release of pressure will fuse them. The interior of the earth is proved rigid by physical experiments, hence cannot be molten. Water greatly lowers fusion point and sediments contain water. In pegmatites all gradations exist between water solution and rock melt. According to Hobbs less than five per cent of the igneous rocks are as heavy as the lightest of the meteorites (he appears to take no account of the possible distribution of basalt under the bottom of the sea). And finally, the average composition of shale is like the average composition of the igneous rocks.

This last argument is developed at great length, and groups of slaty sediments are said to constitute petrographic provinces just as igneous rocks do. No argument is brought forward, however, to show that any gradations are anywhere found between unmelted and melted shales in the hollows of folds.

It is granted that normal faulting means extension of earth surface area, apparently, but Professor Hobbs thinks the overwhelming proof of shortening of the surface everywhere is that rails, pipes, bridges and masonry always buckle in earthquakes and never stretch. The reviewer has before him a photograph of a curved water-pipe in Hawaii subjected to the Puna earthquakes of 1924, which was pulled out to a straighter curve, and can recall other cases of tension in earthquakes. The fallacy of the Hobbs position appears to lie in the much greater difficulty of proving tension, whereas buckling is easy and obvious. Hobbs states that in those lenticular intrusions called laccoliths, "the supposed conduit feeders have never in a single case been discovered." This is simply an error. (Laccoliths of the Black Hills, by T. A. Jaggar, 21st Annual, U. S. Geological Survey.)

Other evidences cited for the shale-melting origin of lava are that the gases in sediments are like those in volcanoes, that the limited range in chemical composition of magma is accounted for, and that this composition is systematically different in block-faulted regions from folded regions. Professor Hobbs believes that geologists have over estimated the span of geological time because the science grew up around the Atlantic where processes are slow.

T.A.J.

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No 61 RELEASED WITHOUT COPYRIGHT RESTRICTION February 25, 1926

KILAUEA REPORT NO. 737

WEEK ENDING FEBRUARY 24, 1926

Issued by the Observatory, U. S. Geological Survey:

T. A. Jaggar, Official in charge

In Halemaumau pit everything remains quiet. About the 19th sliding made fresh debris NE. During a half-hour February 22nd one slide occurred on the NW wall in the afternoon, and one NE in forenoon of February 23 while it was raining. The rain greatly augmented the steam jets in pit.

Eleven tremors occurred, six of them February 18 and 19 of avalanche type. A shake 7:39 a. m. February 21 was felt, though very small, as a single bump with a cracking noise, followed by rumble. The slip that caused it appeared to be close to the Observatory. Tilting for the week was moderate NE.

TILT AND CHANGES OF ELEVATION, KILAUEA

In VOLCANO LETTER No. 41, 1925, it was shown that there was a marked subsidence of the top of Kilauea mountain accompanying strong southwest tilt at the Observatory from 1921 to 1924 inclusive. Referred to the bench mark in front of the Volcano House one point near Halemaumau, the great pit in Kilauea crater, about two miles away, sank five feet and another nine feet. These amounts must be corrected for whatever movement took place at Volcano House.

In June 1925 R. W. Hendry, engineer, Department of Public Works, Territory of Hawaii, ran a level line to the Volcano House bench mark from a point about six miles down the mountain toward Hilo, in Puna district. Mr Hendry found that the bench mark where the Crater Hotel formerly stood, one and one-fourth miles from Volcano House, was relatively down 3 32 feet and the one at Volcano House down 3 97 feet. The ground at Volcano House sank 0.65 foot more than at Crater Hotel site. Some such difference is to be expected as the Volcano House bench mark is about one-half mile nearer Halemaumau, the place where maximum sinking is suspected, than the one at Crater Hotel. The actual sinking of the two places near Halemaumau is, therefore, about 9 and 13 feet respectively, relative to Hendry's datum mark, itself up the mountain about 24 miles from Hilo. A new level line has not yet been run all the way to sea-level. R.H.F.

BOWIE ON VOLCANISM AND ISOSTASY

The leading American expositor of the doctrine of isostasy, W. Bowie, considers volcanism superficial. (Geology from the isostatic viewpoint, Scientific Monthly, January 1926; Journal Franklin Institute, August 1924 and other papers). Dr. Bowie is chief geodesist of the U. S. Coast and Geodetic Survey. He writes "mountains are not formed where the crust is weakest, but where conditions are favorable to the expansion of crustal matter. Volcanoes are due to local causes," citing Day and the Geophysical Laboratory. "Active volcanoes seem to be only in areas of recent uplift or where uplift is still taking place. Volcanoes probably are mere incidents to the processes involved in the decrease in density and increase of volume of crustal material."

"It is probable that earthquakes are phenomena caused by local processes. Earthquakes probably are incidents to the up-movement of materials when mountains and islands are formed, to subsequent erosion, and to the sinking of the earth's crust as sediments accumulate. They are exceedingly rare in areas not subjected to the above three processes.

There are at least two statements here that geologists may take exception to. The greatest floods of lava in the world have been in regions of tension and down-break, and present-day volcanoes, since Tertiary time, are mostly breaking down and lowering. This is true of the Bay of Naples, Hawaii and most of the island volcanoes. On the other hand, where lava volcanism is in process of extinction through stages of explosive eruption, as in the Andes, elevation has occurred. This does not agree with the notion that **active** volcanoes are characterized by uplift. Moreover earthquake centers are abundant along the great deeps of the oceans, some of them extremely remote from land derived sediments. This does not agree with the statement that they are rare in regions not subjected to either erosion or sedimentation.

To Dr. Bowie the dominant crust movements are vertical. Horizontal pressures are mere lateral components of up and down stresses. The "crust" is about 60 miles thick, and below this depth the earth's material acts as though it were plastic. The dominant control of the movements today is lightening by erosion and weighting by sedimentation. The reason why a sedimentary basin sinks for a long time before the heat from below expands and raises it, is that sediments are poor conductors and there is a long lag in the heating; in the same fashion there is lag in the cooling of eroded areas, but when it is achieved the sub-crustal material that has flowed in is dense and aids contraction in bringing about final subsidence. This is much like Sandberg's view (Volcano Letter No. 48).

"The earth's crust rises under erosion areas and sinks under the sedimentary areas." Therefore the crust is very weak in yielding to long-continued pressure due to weight. It seems to the reviewer that Bowie over-accents sedimentation, and disregards the great differences in weight of quartzose continental intrusions, and iron-charged oceanic lavas and their probable enormous volume. We know nothing of the amount of sluggish volcanism going on on the ocean floor to keep it heavy and low. We do know that quartz is the commonest mineral of the continents, and that both are light and stand high. As by Bowie's own showing the deficiency or excess of mass in theoretical earth columns is far below the surface at sea-level, it would seem possible that intrusive and extrusive processes may lighten or weight the crust much more profoundly than the movement of sediments. T.A.J.

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No. 62 RELEASED WITHOUT COPYRIGHT RESTRICTION March 4, 1926

KILAUEA REPORT No. 738

WEEK ENDING MARCH 3, 1926

Issued by the Observatory, U. S. Geological Survey:

T. A. Jaggar, Official in charge

The only volcanic event of note during the week was an earthquake that appears to have centered under Mauna Loa. At Halemaumau February 25, at 5 p. m., there was some rock sliding at the west. On March 1 at 3 p. m. there was an avalanche from the SW wall and the steam vents at the base of the south wall appeared to be yellowing with sulphur increasingly.

Ten local earthquakes were registered. One at 8:20 p. m. February 24 was accompanied by a deep booming noise and felt here, origin very near station. At 6:41 a. m February 28 an earthquake generally felt on the island dismantled seismographs at Observatory and Kona and was perceptible more than 10 seconds at Kilauea. The shaking dislodged rock at Kapapala ranch which broke a water-pipe there and was the strongest felt there in two years.

Tilting of the ground at the Observatory was slight to the SSE.

J. C. Beam, topographic engineer at the station, has started surveys for a net of bore-hole locations on Kilauea floor, wherewith to determine the isothermal lines of surface temperature of the rock in the crater region by means of shallow drilling, and thermometer measurements.

THE GAS VENTS OF THE KATMAI ERUPTION

In 1919 Allen and Zies of the Geophysical Laboratory studied the fumaroles at Katmai Volcano, Alaskan peninsula (See Volcano Letter, No. 5; Technical Papers, National Geographic Society, No. 2, 1923, A chemical study of the fumaroles of the Katmai region by E. T. Allen and E. G. Zies). These gas craters at very high temperatures were mostly in the "sand-flow" of the eruption of 1912, and the following conclusions were reached:—

The vents are along deep fissures, with secondary characteristics, and temperature-pressure features partly unaccountable.

Temperatures range up to 650°C. The borders of the area are cooler.

Fumarolic activity is declining. Steam is about 99 per cent by volume of the gases, the remainder are hydrochloric acid, carbon dioxide, hydrogen sulphide, nitrogen, hydrofluoric acid and methane, with minor amounts of oxygen, carbon monoxide, argon and ammonia. Hydrogen was not determined apart from the sulphide. Sulphur dioxide was not detected. Fluorine as hydrofluoric acid occurs in amounts comparable with hydrogen sulphide and nitrogen, a quantity unheard of elsewhere.

The argon and nitrogen are largely atmospheric and the water largely from surface sources, as the fumaroles below the surface appear to be accessible to surface air and steam.

The water appears to have been vaporized and heated before it entered the fumaroles.

The heat is not from oxidation by atmospheric oxygen.

No combustible gases burn at the surface, and decrease of temperature downward in some places is due to hot lateral gas vents higher up.

Except for the soluble gases, no relation between temperature and gas composition was observed, and the Deville-Fouque' generalizations of a world-wide order of gas change with declining eruptivity, do not hold. T.A.J.

THE GEYSERS, CALIFORNIA

Steam for power is being drilled for at "the Geysers" in Sonoma County. The hot areas extend along the side of a narrow canyon, repeated at intervals for six miles. No lava or igneous products are visible, and like the Larderello power area in Italy (Volcano Letter No. 32) serpentines are present, along with sandstones, schists and shales. At the Geysers drilling reaches sandstone at less than 100 feet depth. Close to the surface the temperature is 100 degrees Centigrade. "As cracks are cut by the drill the steam flow increases and the temperature rises rapidly 25° C. or more per 100 feet in the upper strata, and measurements show that water could not penetrate to any considerable depth without being vaporized." (E. T. Allen, Jour. Wash. Acad. Sci. p. 74, Feb. 4, 1926. Further evidence of the nature of Hot Springs.)

Small hot springs are frequent, often of high mineral concentration. Their maximum temperature reaches the boiling point for the elevation 98° C. The acid springs contain sulphates of amonium and magnesium, the alkaline ones carbonate, bicarbonate and sulphate. "The evidence shows that the volatile matter is derived from volcanic gases which are escaping from springs and fumaroles," the non-volatile matter coming from serpentine and other metamorphic rocks. Oxidation is shallow as shown by fresh pyrite in the drillings; the surface water cannot penetrate deeply.

Allen accounts for the phenomena "on the assumption that superheated steam and other volcanic gases are ascending from a hot batholith" or body of intrusive magma "through a deep crack in the overlying strata; that the steam is heating surface water by condensation, and the gases hydrogen sulphide and carbon dioxide through logical chemical changes are decomposing the superficial rocks." T.A.J.

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No. 63 RELEASED WITHOUT COPYRIGHT RESTRICTION March 11, 1926

KILAUEA REPORT NO. 739

WEEK ENDING MARCH 10, 1926

Issued by the Observatory, U. S. Geological Survey:

T. A. Jaggar, Official in charge

On March 4 there was some revival of avalanching from the walls of Halemaumau. Off and on all day dust clouds were rising from the northeast side, with maximum about noon. The northern talus and walls were covered with red dust. The slides were occasionally from the west. In a steam jet at the base of the south wall sulphur stain is conspicuous. Slides continued the next two days and then diminished. The southwest and west wall showed stripping, as well as the northeast. Now the pit is quiet and dry.

Thirteen earthquakes were registered, of which two were of the avalanche type, and all were very feeble. A shock at 1:25 a. m. March 8 had distance of origin indicated at 11 miles. A few waves of a distant earthquake were recorded 11:13 p. m. March 3. Tilt for the week was very slight SW.

COMPRESSIONAL HEAT IN VOLCANIC BLASTS

An original conception of the cause of the burns to victims and shredding of tree stumps in such volcanic blasts downhill as those of Mount Pelee and Taal Volcano is presented by G. N. Cole and supported in discussion by C F Brooks. (Monthly Weather Review, Oct. 1918, p. 453).

The question is asked, "Do the hot crater gases actually sweep down the mountain as a withering blast effective for miles around? If not, the hot blast must be the result of compression on the front of the explosive wave. The fact of pressure disruption of trees, buildings and bodies indicate a pressure wave of sufficient magnitude to produce the observed heating and wind effects." Cole explains the hot blast as the passage of a tremendous compressional wave travelling at a speed exceeding the velocity of sound (335 meters per second). Brooks supposes kinetic energy moving the gas forward at a velocity exceeding the molecular velocity of air, 510 meters per second. If the second zone of air did not move while the first zone, a half kilometer thick, was driven into it, the initial temperature being 80 degrees Fahrenheit, the temperature would be raised to 621 degrees F. Even if 85 per cent of the second zone of air gave way, the temperature would still rise high enough to burn people.

Cole's analysis is as follows. The compression is called adiabatic because there is little time for dissipation of heat. The gas is compressed by three actions: (1) The crater lava is in the condition of water in an exploding boiler. The ejecta of the volacno are conceived as possibly being entirely vaporized and on condensation becoming the sand and grit that covers the landscape. This makes the first wedge to crush the air into compression. (2) The heat of this matter expands the surrounding air, compressing the air of the second zone. (3) Combustion of some of the gases may cause further heating adding to the secondary compression. This all gives rise to destruction as complete in the outer zones of action, as if done by a tornado. Both rise and fall of pressures suddenly are believed to produce phenomena observed. Trees denuded of bark, with fibre cut and shredded, are believed accounted for by "some such action as that which pops corn or puffs rice when the pressure is removed after heating." The sudden rise in pressure "must be indescribably worse on the ear drums than going through an air lock in caisson work. Lung and heart action must be stifled." Mr. Cole thinks that the only hope of protection in such countries is to have steel volcano cellars with stability, heat insulation, and pressure insulation.

The reviewer visited St. Pierre at the time of the Pelee eruption, and he has seen similar effects at Sakurajima, Bandaisan, and at St. Vincent. There may be compressional heat in volcanic blasts, but there is so much other heat not mentioned by Mr. Cole, as well as attrition and obvious asphyxiation by dust, and so little evidence of pressure, that the pressure argument seems to prove too much. Mr. Cole says that "if the pressure comes on it will heat the air of a cavern a hundred feet underground." Yet people in cellars, in steamer cabins, a sailor who wrapped himself in a tarpaulin, and Cibaris the convict cited by Mr. Cole, survived with comparatively flimsy protection. It is not a fact that at St. Pierre there was "pressure disruption" of trees, buildings and bodies. The trees were shredded by a sand blast, with the pebbles left sticking in the wood. Boiler plate was left punctured by bowlders, with the rocks left sticking in the holes. One end of St. Pierre was buried under 40 feet of gravel and dust. The heat of a burning city disembowelled bodies. There was no mystery about the deaths, to the medical officers; at the end of the town near the volcano the rock dust was incandescent and falling by tons. People and houses were burned. At the far end of the town the dust was scalding hot in a steam emulsion. Thin clothing was spared while flesh was burned. The awful cases of bronchitis in the wounded were due to nothing but hot dust. The population of St. Pierre died chiefly from instantaneous pneumonia The dust was not volatilized lava, but plain ground up rock. A mighty jungle was burned away by hot sand.

The most puzzling feature of these volcanic blasts is that they move downward and in one direction only, with dynamic effects uni-directional. Their heat is contained in ordinary volcanic ash. T.A.J.

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No. 64 RELEASED WITHOUT COPYRIGHT RESTRICTION March 18, 1926

KILAUEA REPORT NO. 740

WEEK ENDING MARCH 17, 1926

Issued by the Observatory, U. S. Geological Survey:

T. A. Jaggar, Official in charge

The week past has shown marked increase of local earthquakes and tremors. Halemaumau when visited was dry and quiet from March 11 to 13. About 10 a. m. March 14 an avalanche sent up a considerable reddish dust cloud. On the afternoon of March 15 some rocks were slipping on the west wall. Along the trace of the southwest rift dykes up and down the wall of the pit there was a dust trail clear to the top of the wall. This was interpreted to be an avalanche track; there were two such vertical markings.

Twenty-five earthquake movements were registered for the week, four of which were of the avalanche type. A felt shock at 11:51 a. m. March 14, felt also at Hilo, appeared to originate on the northeast rift of Mauna Loa, like the quake of February 28. A tremor was slightly felt about 4 a m. March 11. A shake distinctly felt at Kapapala 3:23 a m March 14 was only very slightly registered at Observatory. Tilt was moderate to WSW.

EXPLORING THE EARTH FOR MAGNETISM

The earth is a big but not very powerful spherical magnet, with both its actual poles near the earth's center. The magnetic poles are the outcrops at the surface of this interior axis The magnetic poles move, the compass direction varies with time, and there are magnetic storms which vary somehow with sunspots Not only does the compass vary in its nearness to pointing north, but it varies in the force with which it swings, and in another force which it exerts downward toward those interior poles. Of course the compass is only an indicator of a terrestrial force affecting the particles of balanced iron in the needle. Much of navigation is dependent on the forces that pull this needle There are earth-air electric currents passing from the air into the earth and vice-versa, apparently associated with the general circulation of the atmosphere, in places downward with downward positive electricity, elsewhere upward for streams of both positive electricity and of the air motion.

There has just been published the fifth of the most complete series of volumes on magnetism exploration ever produced by science. (Carnegie Institution, Ocean Magnetic and Electric Observations 1915-1921. Ault, Mauchly, Peters, Bauer and Fleming, Washington, January 1926, 430 quarto pages).

This volume describes the magnetic results obtained from cruises IV, V and VI of the non-magnetic ship Carnegie, 1915 to 1921; logs of the voyages and auxiliary observations on ice-bergs, sea temperatures and meteorology; atmospheric-electric results; and special reports on the Hudson Bay expedition, navigation of air-craft by astronomical methods, the compass-variometer, sun-spot variations in relation to atmospheric electricity, and studies of atmospheric electricity with reference to potential gradient, ionization, conductivity, current density, radio-activity and penetrating radiations.

The two vessels in this service, the Galilee and Carnegie, in nine cruises between 1905 and 1921, have spent 2668 ocean days, covering 316,536 nautical miles, making 3316 observations of magnetic declination, 2147 of inclination, and 2147 of horizontal intensity. To show the improvement in skill and instruments, the Galilee cruises between 1905 and 1908 averaged 1.8 days between observations for declination; the Carnegie averaged 0.7 day. Hence the advantage of the ship constructed without iron in its composition. The Galilee averaged 196 miles between stations for declination; the Carnegie 84 miles. The Galilee made a total of 325 observations for declination; the Carnegie, in twice as many voyages made almost ten times as many such observations.

A map of all the work on land and sea from 1905 on shows extraordinary achievement; the continents dotted with magnetic stations, the oceans zigzagged by cruises from 60° south latitude to 80° north. All of this was planned by one man, Dr. L. A. Bauer, who has directed magnetism for the Carnegie Institution from the beginning. In 1906 he wrote, "However great this task of a general magnetic survey of the earth may appear, I have now had sufficient experience to know that with good system and management, and ample funds, the work can be completed in a period of about fifteen years."

The volume before us appears to justify this forecast. So far as the discovery of the magnetic constants for all latitudes and longitudes used by mariners are concerned, the tables of figures in these volumes will correct most of the charts. Many of the charts have been wrong in their compass variations by one or more degrees. The yearly changes known as secular variation now have a basis for new reckonings in many places where before there were no data at all. This secular change is what future voyages will measure.

In reading the logs of this three hundred and seventeen thousand miles of cruising in some of the stormiest water in the world in two small sailing vessels, one is impressed with the romance of achievement in modern science. No shipwreck, no savages, no scurvy, almost no adventure. No long narratives of heroism. Continuous observations every hour with delicate instruments rain or shine away to the south of the roaring forties and away to the north of fifty-three. Computations made en route and reduced results sent home from every port, quickly corrected, and supplied to the nautical bureaus of the world. The whole world studied with one object in view, magnetism. This is the sort of thing we would like to see done for the rock bottoms of the oceans of the world, and for volcanism.

T.A.J.

SAMPLE COPY

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No.65 RELEASED WITHOUT COPYRIGHT RESTRICTION March 25, 1926

KILAUEA REPORT NO. 741

WEEK ENDING MARCH 24, 1926
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

Though the number of local earthquakes was not large, the position and intensity of some near shocks during the past week has been interesting. Nothing new in volcanic activity has happened. The increased frequency of local shocks last week and the widely felt Hawaiian earthquake of March 19 point to correspondence, with equinox, of seismic activity.

A steaming hole in the wall of Halemaumau just west of the south talus has been growing increasingly yellow with sulphur. Hot steaming cracks at the east edge of Kilauea crater next to the gravel bank have recently produced a marked increase of alum, sulphur and probably other salts which cover the surface of the lava at the contact with the underlying gravel.

An examination of the southwest edge of Halemaumau showed that the two upright white streaks there were probably produced by the avalanche of March 14, for the top of the rift notch had caved away, and also a place a few feet farther west. The material which had fallen was largely the white floury ash of 1924, there one to two feet thick at the surface, and this in falling had made a white streak on the wall below. No fresh breaks in the soil along the edge cracks were noticed farther back.

After this the only motion observed in the pit was some tinkling of stones heard falling March 22 and dust seen rising from a small slide March 24. Some fresh whitish debris was left on the northeast talus.

Twelve earthquakes were registered during the week, three of which were perceptible. A large earthquake centering some eighty miles away from the observatory was plainly felt here as a prolonged gentle swaying at 10:33 p. m. March 19. A small but perceptible aftershock from the same origin occurred at 7:27 a. m. March 20. Both of these made good records on the seismographs of Kona, Hilea and Hilo as well as at Kilauea, and from the indicated distance to origin from the three stations it appears that the disturbance was on the ocean floor 26 miles north of Honokaa, or 25 miles northeast of Kohala. At the Observatory both instruments were dismantled by the larger shock, which was felt at Honolulu, strongly felt at Kohala and Honomu, and less strongly felt in Hilo. It produced a weak rocking in Kona. Tilt was slight WSW. A small jolt occurred March 21 11:38 a. m.

THE QUERVAIN-PICCARD SEISMOGRAPH

The two professors named, in Zurich, have built a three-component seismograph with pendulum weighing twenty-one tons. By "three-component" is meant registration of up-down, east-west and north-south motion, and in this instrument all three are registered from the motion of the same suspended body. (Iberica, Madrid, No. 522, Nov. 15, 1924, Fr. M. M. S. Navarro, Meeting of the Seismologic Section, Second Assembly of the International Geodetic and Geophysical Union).

A most interesting cut is shown in this article, representing a portable seismograph made by the same investigators. It is described as designed for the registration of local earthquakes. Its plan is the same as the 21-ton instrument. The photograph shows an upright skeleton cylindrical frame on three projecting feet with levelling screws. Within the frame apparently hangs the normal pendulum and three pens write on clock-driven smoked paper. From the electrical devices indicated, apparently the damping is magnetic. Upright spiral springs appear inside the frame, suggesting that the vertical component is in some way identified with the same mass that writes the two rectangular horizontal motions. The whole instrument appears to be about three feet high and quite compact. T.A.J.

GAS WELL PIT

Dr. Sidney Powers, chief geologist of the Amerada Petroleum Corporation of Tulsa, Oklahoma calls attention to an extraordinary photograph of the pit left by a gas well blow-out. In appearance it is precisely like the Hawaiian pit-craters, subcircular, with vertical walls and internal talus and clinging rim pinnacles. The picture is published in the Oil Weekly of February 26, 1926, p. 23, and the pit appears in a wide flat terraced country, with a few trees. The walls show horizontal bedding. The caption states that this is a big gas well that blew out at White Point, South Texas. The crater developed a "vortex" in the center in which the derrick and machinery sank to unknown depths. It is said now to contain boiling water and burning gas. Perhaps there is here a lesson to be learned for volcanology, showing that pit craters are easily produced by engulfment, when deflation of something below, through loss of gas, decreases bulk locally, and a superficial pit is the result. T.A.J.

NEW SEISMOLOGICAL QUARTERLY

Referring to critical study of tide-gauge registration recommended in the Volcano Letter No. 57, Dr. William Bowie writes that for more than a year the U. S. Coast and Geodetic Survey has been examining the tidal records and every seismic sea-wave is studied with reference to the earthquake record for the same occasion. This will be a feature of a forthcoming quarterly seismological report of the bureau, the first number of which will cover January-March 1925. "Science Service" of the National Research Council so cooperates with telegraphic reports as to locate epicenters immediately. Thus Dr. Bowie has located the big earthquake of January 24 as in the Solomon Islands (Volcano Letter January 28). T.A.J.

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No. 66 RELEASED WITHOUT COPYRIGHT RESTRICTION April 1, 1926

KILAUEA REPORT NO. 742

WEEK ENDING MARCH 31, 1926

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

There is practically nothing new to record of volcanic activity in Hawaii. Halemaumau and Mokuaweoweo are dormant. The weather has been calm to southerly at Kilauea, with rain, and northerly at Hilo with fresh wind and dry weather. Halemaumau has shown much steam and the big sill northeast has caved away a little, but there have been no avalanches noticed.

Ten local earthquakes were recorded on Observatory seismographs. One at 12:34 a. m. March 29 dismantled one seismograph, and the distance to origin indicated was about 19 miles. A distant earthquake apparently 3560 miles away occurred March 27 at 12:30 a. m. Tilting for the week was slight to the SW.

Work has been begun on the Kilauea floor, with compressor and hammer drill, in making small holes at surveyed stations 1000 feet apart, to serve as permanent places for measurement of the temperatures of the bedrock.

THE WHITE ISLAND VOLCANO

In the Bay of Plenty on the northeast side of New Zealand's north island, there is an active volcano islet which strongly resembles Bogoslof of the Aleutians. This is known as "White Island" and in September of 1914 it was the scene of a frightful disaster when all the operatives of a company mining sulphur were swept away by an eruption. All that was seen from the adjacent shores of the bay was the ejection of steam clouds, but the crater lagoon appears to have been blown out after the fashion of a gigantic geyser and to have overwhelmed the camp.

The Auckland Weekly News of January 7, 1926, brings word that after some years of idleness the sulphur camp has been reestablished, not on the sand flat separating the open crater from the sea, but on the opposite side of the island more than a mile from the crater and where on the southwest side of the volcano the principal area of vegetation has developed, groves of pohutukawa (metrosideros). The crater rim a thousand feet above the camp, which is on the windward side of the island, forms a barrier between the workers and the poisonous solfataras always steaming violently on the crater side. The new camp is described as peaceful and delightful, with imported poultry, pigs and sheep, numerous buildings and huts, a fresh water supply from a natural spring which is said to contain an excess of iodine, abundant firewood, a receiving and transmitting wireless plant and a track communicating with the sulphur works at the mouth of the crater on the other side of the island. A motor boat and three row boats are kept on hand and there is a telephone between the camp and the workings. A medical officer is stationed at the plant. There is good fishing. A rookery of boobies is close at hand.

Just over the divide every vestige of life has been destroyed by the poisonous fumes of hydrochloric acid and sulphur which rise with roaring steam jets from a main blow-hole in the center of the crater floor and from lesser vents about the talus slopes.

Dr. J. Allan Thomson, director of the Dominion Museum, sends an article from "The Dominion" of Wellington, February 18, stating that the side fumeroles have from time to time been blocked by avalanches, this seeming to increase the force of the central blow-hole. About the end of January the central vent gave out "unusual volumes of superheated sulphur, the fumes carrying with them dense clouds of red oxide dust. On calm days the cloud reached measured heights varying from eight to ten thousand feet."

"Finally on the night of February 3, 1926, a fault apparently developed at the base of a 200-foot cliff on the western side of the main blow-hole, and some hundreds of yards of the cliff collapsed. The pressure of gas and steam blew forth a mass of sulphurous mud covering an area of ten acres three inches deep." A new vent broke through the disturbed earth fifty feet above the crater floor. For forty-eight hours the air was full of dust-charged steam. The main blow-hole was giving off overpowering fumes. Between it and the new vent the crater saucer was covered with massive volcanic bowlders smothered under fresh mud. When visited the place showed that a new gas vent had created the landslide, with activity very similar to the central blow-hole, sending up sulphur fume with a roar and, owing to the intense heat, not condensing its steam until the vapor reached a height of fifty or sixty feet. The steam rose to the top of the crater walls, where it was caught by the wind and blown away in clouds.

The new vent did not produce the same "nerve-wracking noise" as the central blow-hole, but it had lessened the force of the latter. "The formation of the new vent's cone is not yet permanent. Occasionally a minor landslide above the vent is blown into the air by the tremendous force, and the dust thus formed is scattered broadcast over the crater floor." The writer of the article states that the two blow-holes of the White Island crater constitute the greatest thermal activities of their kind in the world. He is of the opinion that the new eruption, by adding to the safety-valve openings "obviously has rendered the crater even safer than previously."

We would venture to caution our friends in New Zealand against putting too much confidence in this safety-valve theory. White Island has all the characteristics of a dangerous volcano like Bogoslof or like Krakatoa. The collapse above described, accompanied by red cauliflower clouds thousands of feet high, and the opening of a new wall-crack vent, means engulfment. If engulfment continues it may mean the retirement of lava lying below, at the end of a pressure cycle. If our diagnosis of what happened at Kilauea in the spring of 1924 is correct, such retirement of deep lava may take several months, and be followed by sudden collapse of the crater bottom. This we believe accounts for the considerable delay of the Krakatoa, Kilauea and Pelee eruptions after the first symptoms. Tarawera in New Zealand was a clear case of engulfment. Engulfment opens voids which fill with water, and steam explosion follows. In the event of a true explosive eruption, which can throw eight-ton bowlders three miles, a camp like that of the sulphur workers on White Island would be exposed to the first barrage.

T.A.J.

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No. 67 RELEASED WITHOUT COPYRIGHT RESTRICTION April 8, 1926

KILAUEA REPORT NO. 743

WEEK ENDING APRIL 7, 1926

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

On rainy afternoons during the past week there has been much fume and vapor at the vents in the lower walls and bottom debris of Halemaumau. Sulphur odor is occasionally perceptible. At a vent in the south wall increasing yellow coatings indicate sulphur depositing, and at the south talus there is dense blue fume of sulphur gases mixed with the steam. This blue fume is seen also near the center of the pit and at the east edge of the bottom. On April 4 new debris had fallen on the northeast talus, and a new wall scar was in evidence up and down the NNW wall. Rocks were sliding a little at the NW and NE. Such slides must have been slightly bigger about noon April 5 for dust in small amounts rose over the pit. On that afternoon the large northeast sill was steaming at a place near its east end where the rock has recently fallen away and left fresh gray surfaces.

Twenty-three local earthquakes were recorded by the Observatory seismographs during the week, all too small to be noticed. Tilting was slight to the SW.

UNITED STATES SEISMOLOGICAL REPORT

Under the title "Seismological Report" for January, February, March, 1925, by Frank Neumann, mathematician, Division of Terrestrial Magnetism and Seismology, U. S. Coast and Geodetic Survey, there has just been printed the first number of the new quarterly which marks the transfer of seismological investigations in the United States from the Weather Bureau to the Coast Survey. Formerly this matter was printed in the Monthly Weather Review. A special report will be issued to cover the six months ended December 31, 1924, during which time the Weather Bureau ceased publication. Commander N. H. Heck is chief of the Division of Terrestrial Magnetism, now made to include seismology.

The new report is in octavo form, forty-eight pages, and includes all seismological investigation in the United States, the regions under its jurisdiction, and adjacent regions. The statistical data include tables of felt earthquakes, instrumental records and a summary of current earthquakes. A special canvass was made for intensity information concerning the regions affected by the Quebec earthquake of March 1 (February 28, local time) and the Alaska earthquake of February 23. The Quebec earthquake is here considered only in relation to places in the United States. The instrumental reports use the Klotz symbols and all reports are reduced to Greenwich time.

The summary of earthquakes for the three months in lands under the jurisdiction of the United States shows only eleven days without reported shocks and many days with two to seven earthquakes. The well established locations of shocks include forty in the Philippines, twelve foreign, eleven in California, ten in Canada, and nine in Alaska. The local shocks of Hawaii are not here included, but the Bulletin of the Hawaiian Volcano Observatory is referred to. Ninety-seven earthquakes were well located, sixty-seven had positions doubtful, thirty-seven were in unknown locations, and twenty-nine were aftershocks of the Alaska and Quebec earthqaukes, making two hundred and thirty shocks in all.

The principal earthquakes were in New England on January 7, a submarine shock January 18, an earthquake February 23 centering seventy miles north of Valdez on the south coast of Alaska, the Quebec earthquake near the St. Lawrence river, and a disastrous shock March 16 in China which destroyed 5000 lives about the city of Tali in Yunnan.

The list of observatories cited in the summary includes nine in the United States, five in Canada, one in Panama, one in Guam, two in Hawaii, one in the Philippines, and one in Alaska.

Mention is made of the work of the Coast Survey in precise triangulation in California which has determined extraordinary changes in horizontal position of old stations amounting to as much as 24 feet northward near Gaviota in the Santa Barbara district. A new baseline is to be measured in that district with a view to finding out how much of this movement is an actual geographic change and how much may be ascribed to residual errors in the triangulation. A preliminary report on "Earth Movements in California" has appeared as Special Publication No. 106, U. S. Coast and Geodetic Survey. Precise leveling has been run across southern California comparing the data of 1906 and 1924. In seven kilometers distance between Santa Ana and Barstow a change of elevation of 54 millimeters was found, and between Orange and Barstow, a distance of 214 kilometers, the change was 63 millimeters.

These reports may be expected to grow in size and value, and represent the first appropriations specifically made by Congress for collecting seismological information from all parts of the United States. The Coast Survey needs the cooperation of the public. "The humblest citizen can often furnish information as valuable in its field as the technical report of the seismologist with elaborate instrumental equipment." Progress depends on cooperation. All people who keep records of felt earthquakes should send their lists to the U. S. Coast and Geodetic Survey, Washington, D. C. People in remote places are especially fortunate in situation for furnishing valuable data. Firms having organization of representatives in many places could enormously help the work by securing blank forms from the Survey and having them sent in systematically whenever an earthquake is felt. T.A.J.

SAMPLE COPY

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No. 68 RELEASED WITHOUT COPYRIGHT RESTRICTION April 15, 1926

KILAUEA REPORT NO. 744

WEEK ENDING APRIL 14, 1926
Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, Temporarily in Charge

A very diffuse blue fume was observed with the steam escaping from one of the many vents inside Halemaumau during the fore part of the week. Accompanying the numerous earthquakes attendant on the outbreak of Mauna Loa there was an increase of avalanching from the walls of Halemaumau. During the forenoon of April 10 two large slides from the wall near where the southwest rift of Kilauea enters Halemaumau were observed. Possibly this rift was in motion.

On April 11 Halemaumau was full of steam most of the afternoon and a faint odor of hydrogen sulphide was noticeable at the south rim. An occasional glimpse into the pit showed abundant floor vapor. On April 12 following the rain of April 11 the walls of Halemaumau were found to be quite red. Steam was escaping in continuous jets from a line of vents in middle of southwest talus slope. Recent movement in cracks back from the rim of Halemaumau were noticed on April 13. During the afternoon diffuse blue fume appeared to be mixed with the steam escaping from a vent in sulphur stained area on south floor of Halemaumau.

376 earthquakes were recorded during the week, 363 of which occurred during the four days following outbreak of Mauna Loa. The majority of the shakes appear to have had their origin along the extension of the southwest rift of Mauna Loa into the lower Kau country, though some appeared to originate under Mokuaweoweo the summit crater of Mauna Loa and along the northeastern rift. The net tilting for the week was very slight to the ENE. On April 13 there was a noticeable spurt of northeast tilt. A northeasterly tilt which means an increase of internal pressure of Kilauea coupled with the known sympathy of action between Kilauea and Mauna Loa indicates that Halemaumau should be watched closely.

THE APRIL 10, 1926 OUTBREAK OF MAUNA LOA

Shortly after 3:00 a. m. April 10, 1926, Mauna Loa became active after having been quiet since November, 1919. The rising fume columns illuminated by fire fountains and lava flows below cast a pinkish glare all over the island of Hawaii. Large print could be read at the Observatory 24 miles away.

The Observatory is greatly indebted to E. G. Wingate, Topographic Engineer, U. S. Geological Survey, for a very complete report of the outbreak. Mr. Wingate, who was camped a few miles from the summit of the mountain at an elevation of 11,400 feet, went immediately to the scene of action. By nightfall he had made copious notes on the activity and very accurately mapped the lava flows, the location of fountains, and active fissures.

Lava spattered from a crack over three miles long and from several places short lived flows started. The highest flow issued from near the edge of Pohaku Hanalei crater—the southern part of Mokuaweoweo. The lava both streamed down the mountain side for about one mile and cascaded over the crater rim. The southeastern half of Pohaku Hanalei crater was covered with the new lava.

Owing to lava flows along its edge observations were not made at the first of the two outer craters about a half a mile below Pohaku Hanalei. At the second of the outer craters about a half a mile below the first there was a wonderful sight. A line of fountains marked the main rift crack which cuts through this crater.

Lava was cascading into the crater from the upper edge and at the lower side there were two lava streams one running into a tunnel and the other over the surface. These two streams with others lower down fed the main lava flows which went down the mountain with branches leading toward both the Kau and Kona sides for a distance of about four miles or more. The lowest vent was at an elevation of about 12,000 feet or above the site of the preliminary outbreaks in 1916 and 1919. One branch of the flow went by the sulphur bank area which appears as a conspicuous scar when viewed from above the timber line far down the southwestern rift zone. (For a description of this rift zone, see Volcano Letter No. 52, Dec. 24, 1925).

Shortly before 8:00 a. m., as viewed from the Observatory, activity at the source vents had nearly ceased. By 8:30 a. m. the large fume cloud that was drifting to the northeast had disappeared.

There was no "swarm" of earthquakes preceding the outbreak, though they have been coming in "swarms" since. The warning quakes which were widely felt over the eastern half of the island of Hawaii occurred at 1:50 a. m. and 2:04 a. m. or about an hour before the appearance of the lava. Before the occurrence of these shakes, however, at 1:36 a. m. "harmonic tremor," a motion that is recorded on the Observatory seismographs only when there is molten lava at either Kilauea or Mauna Loa, was recorded. This type of tremor became very noticeable after the 2:04 a. m. shake and continued so for that day.

Prior to the outbreak Mauna Loa had been watched with considerable interest for three reasons: 1, there was an indication of increase of internal pressure of the volcano system as shown by a slight accumulation of easterly tilt from 1925 to 1926; 2, quite a large number of earthquakes had been occurring on Mauna Loa during the past several months; and 3, Mauna Loa had been quiet for nearly 6½ years which is rather longer than the average interval between periods of activity.

The outbreak followed one of the driest years ever noted on the summit of Mauna Loa. There was scarcely any snowfall during the preceding winter. For the last seven months the entire island of Hawaii has been unusually dry.

R.H.F.

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No. 69 RELEASED WITHOUT COPYRIGHT RESTRICTION April 22, 1926

KILAUEA REPORT NO. 745

WEEK ENDING APRIL 21, 1926
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

During the Mauna Loa eruption there has been no increase of steam or avalanche activity noted at Halemaumau. Hydrogen sulphide was smelled there on the 17th. The sulphurous steam at south talus appeared a little hotter and more flocculent.

Numbers of local earthquakes per twelve-hour interval beginning the morning of April 14 were 32, 24, 51, 32, 37, 29, 29, 16, 12, 8, 12, 8, 18, 2, the last being the night of April 20-21. The total is 310. Tilting was moderate SE with unusual daily fluctuation. Intensity of earthquakes increased as numbers diminished. Three of the quakes of the 20th were of Halemaumau origin.

PROGRESS 1926 MAUNA LOA ERUPTION

The writer explored the summit region from camp of E. G. Wingate April 11-14. The new break on the southwest rift is tangent to the two upper small pits on their east sides, and cuts across the third pit. Flows of silvery light weight pahoehoe extend from these fissures several miles south, and others have cascaded into the pits. The upper cracks are hot and vaporing in places but no longer flowing. An unusually sharp earthquake felt on the mountain the evening April 13, along with others, showed that the rift was working. Three cups on the rift east of the divide cones at about 8000 feet elevation were seen April 13 smoking with dense yellow fume, (looking down the southwest rift). April 14 about 8:30 a. m. a big brown fume column arose at that place and then others higher up the rift zone. The lava flows had started on the rift approximately 15 miles from the center of the summit crater, and five miles above Puu o Keokeo as one follows the curved rift line. At night there was red glow there and smoke all along the rift to the summit.

These observations and subsequent ones by R. H. Finch and W. O. Clark the night of April 19 in the source region above Naalehu show that the main new crack of this outbreak is several miles long and on the eastern side of the rift belt divide. In spite of this the floods of lava made their longest flow on the western side to the ocean.

April 15 observation from south of Waiohinu in evening showed the glowing front of an eastern flow in Pele o iki Kipuka high up the mountain above the Waiohinu homesteads. Beyond could be seen the lurid glare and fume column of the source fountains, and vivid glow in a long belt to the west over a flow going towards South Kona. There the cowboys of upper Papaa ranches reported the Kona branch flow as four miles from the belt road near Honomalino and progressing.

April 16 an observatory party reached the new Pele o iki eastern flow but were unable to cross it. It was aa. In the forenoon news came that the Honomalino flow was close to the road; two columns of fume showing great increase of volume and heat convection appeared over the source region. We arrived at Kaanaana's house at Honomalino 10:30 a. m. where the smoke of the burning forest at the front of the flow was visible just above. At 12:22 p m the aa flow there crashed through the guava bushes into a causeway of the road creeping as a red hot landslide of tumbling "snow-ball" block-lava 500 to 600 feet wide. Immense accretion balls or bowlders covered the surface and tumbled forward at the front. Advance across road at 1:10 p. m. was 6 to 8 feet per minute. This place was three miles above the Hoopuloa wharf and south of the Hoopuloa road. The Kaanaana house was crushed and burned.

We descended the trail to Honomalino beach, Milolii, and Hoopuloa.

April 17 at 3:30 a. m. the front overtopped the bluff back of Hoopuloa; at 9 a. m. it reached the lava flat some thousand feet back of village; the interior liquid was rolling over the front by friction with the ground, shoving forward the top layer of blocks, and maintaining a red hot talus at the lower ends of each lobe. The mass was delta shaped, 25 to 50 feet high and increased in width from 1000 to 1500 feet. Its average forward creep was 2.7 feet per minute. The middle of stream on bluff slope broke into cascades every 3 or 4 hours that night.

April 18 the front reached Hoopuloa at 4 a. m., burned houses about 5 a. m., reached sea 6:30 a. m. and in next two hours buried the town and the harbor. Clouds of steam peppered with black sand shot up, small pebbles rose in wavy trajectories, the vapor was sour with muriatic acid, and the noises were hissings and later thudding explosions and prolonged roars of escaping steam. Fish were killed by thousands.

At the road crossing a sluggish orange colored aa river pulsated within hardened lava fields. The Waiohinu flow stopped. Upper ranch buildings of Honomalino were destroyed, by branch flows. Army aviators photographed the district from the air.

April 19 about 9 a. m. the road flow stopped. Finch and Clark reported fountains at about 7600 feet elevation, activity on rift miles long, immense smoking columns and loud roar from one of them, large fountaining areas and a rived from them passing to the north of Puu o Keokeo over to the Kona side. The line of activity appeared to be 5 or 6 miles long. New cones and fountains were 50 to 100 feet high. The line is well to the east of the 1919 line.

T.A.J.

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No. 70 RELEASED WITHOUT COPYRIGHT RESTRICTION April 29, 1926

KILAUEA REPORT NO. 746

WEEK ENDING APRIL 28, 1926

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

Halemaumau continues quiet after having been inactive for one year and nine months. Today the pit floor and walls were dry and dusty with but little steam escaping.

The Mauna Loa outbreak produced no visible effects in Halemaumau save that caused by the earthquakes. There was an increase in avalanching and some of the blocks around the rim of pit were jostled so that small new cracks appeared. Some such effect is to be expected when one considers the rather unstable 1200 foot walls being jarred by earthquakes the largest of which was strong enough to overturn some objects.

During the week 46 earthquakes were recorded, 32 of which occurred on April 21 and 22. The shake at 4:32 a. m. April 22 was one of the strongest of the series and was widely felt over the island of Hawaii. The seismographs both at Hilo and Volcano were dismantled. A shake at 11:05 p. m. April 22 had an indicated distance to origin of 12 miles, equal to the distance of northeastern rift of Mauna Loa from Observatory.

The net result of tilting for the week was slight to the south-southeast.

DECLINE OF MAUNA LOA ERUPTION

The 1926 outbreaks on Mauna Loa began one year and nine months since lava activity was last seen in the Kilauea-Mauna Loa system. This is not a long interval and it is clear that the explosive eruption of Kilauea 1924 in no way interrupted the normal successsion of lava effusions. The new outburst was accompanied by a sharp change of tilt at Kilauea observatory from westerly to easterly, and a moderate change from southerly to northerly, beginning about April 11, a day after the summit outbreak. The change was from tilt towards the active center to tilt away from it. Along with this came 70 to 90 earthquakes per day, then in the second week 15 to 50, and the numbers per 24-hour day midnight to midnight beginning April 21 have been 17, 17, 6, 4, 2, 1, 1. This decline suggests a finish within three weeks of the beginning; whereas the Alika period of 1919 lasted seven weeks. But more observation of the source region is needed before this conclusion is established for 1926.

From Kilauea, glow was seen over the Kahuku lava source region April 25, also the fume cloud, and faint fume was visible April 27 and later. Fume jets had apparently developed down the rift immediately after the summit outbreaks of the 10th, gradually increasing and concentrating at about the 8000-foot level on the 13th, when the stage was set for the lava flows from the lower levels. The absence of glow at the Kilauea distance 55 miles away does not prove that small fountaining has ceased.

April 21 the cattlemen of Honomalino Ranch reported a second flow alongside of the one that had destroyed Hoopuloa moving not faster than a mile a day, and near the 1916 flow in the forest 2 to 3 miles above the belt road, in Honomalino. This stopped there, and on the 23rd they reported another branch 5 to 6 miles above the road moving 2 feet per minute, in flat country. Valuable upland paddocks in the Koa forest were destroyed.

The writer went to the flow source at about elevation 7400 feet, 3 miles north of Puu o Keokeo, and spent the night April 22-23 there on an old red cone, against the north foot of which lay the flowing streams. These streams flowed to Honomalino from a fissure line dotted with nine active cones. These made the most active part of a line of sixteen new cones visible, the lower three making pahoehoe slag-heaps of the Kilauea type, the upper ones making clouds of smoke so as to hide any others that lay farther up the rift The nine middle vents bounded the east end of the Hoopuloa source belt of fresh lava, here a half-mile wide and trending WSW. Most of this was aa, but through the southern part of it swept a gorgeous meandering river of fiery melt with rapids, and risings and fallings, and floating rafts, and overflows, all within well defined banks. This stream took its rise at the northern cones of the spectacular nine, where the hills piled up, and a spray fountain rose and fell in brilliant orange incandescence, and brooks of molten basalt fed the torrent with lava springs. With very brilliant reflection on the cloud above, the river of fire wandered off three miles across the plateau in a shimmer of western mirage and disappeared over the shoulder of the mountain towards Kona. No glow was seen in the direction of the earlier Kahuku flow towards Waiohinu. A lower cone of the nine was an open cup vomiting sluggish aa, and this went out of action during the night. The other vents were flaming or spitting or fuming fierily, and showed by the cooled field of lava from them and by their built-up flanks that they were dying remnants of what had been fountaining and flooding during the first days of eruption.

The report of a visiting party showed that the source region was still fountaining and golwing April 26th. On that day the Observatory party visited the northern sides of the Hoopuloa flow at the sea-shore and at the road, and found the former steaming feebly and the latter flaming in spots where vegetation was burning beneath. Otherwise the flow was cool and easily walked over. There is ammonia among the gases distilled. The abundant large concretionary balls of lava and the worn, lumpy aa fragments make this flow different from the rusty arborescent aa of 1919. The 1926 stream-flow was more viscous and less hot.

By analogy with former eruptions, if the Kahuku source stops action, Halemaumau may have its bottom disturbed from below, and it will be watched with interest. On the other hand the slag-heap pahoehoe in Kahuku, working sluggishly, might develop flows. T.A.J.

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No. 71 RELEASED WITHOUT COPYRIGHT RESTRICTION May 6, 1926

KILAUEA REPORT NO 747

WEEK ENDING, MAY 5, 1926

Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, Temporarily in Charge

Though there has been a decline in the number of earthquakes there has been a noticeable increase in the avalanching at Halemaumau. Many avalanches may be observed every day. Nearly all are small however. On May 3 avalanching was nearly continuous from 2:40 to 3:00 p. m. On May 5 with a high humidity there was but little steam escaping from the Halemaumau floor. The most conspicuous steam vent was near the sulphur stained area at the south side. From some places on the rim it appeared that some blue fume was mixed with the steam while at other places the apparent fume was not visible.

Eight very small earthquakes were recorded during the week. Tilting was moderate to the northeast.

THE EARTHQUAKES ACCOMPANYING THE MAUNA LOA ERUPTION OF 1926

From the time of the beginning of the preliminary outbreak of Mauna Loa during the early morning of April 10, to April 28 when shaking had practically ceased 647 earthquakes were recorded on the Observatory seismographs.

The daily distribution of the total number of earthquakes and of the number of shakes perceptible at Observatory are shown in the following table:

Day	Number of shakes	Number of perceptible shakes
April 10	75	4
11	35	1
12	81	5
13	83	8
14	60	9
15	86	13
16	61	17
17	53	7
18	26	10
19	20	4
20	23	2
21	17	1
22	12	4
23	6	0
24	4	0
25	2	0
26	1	0
27	1	0
28	1	0
29	0	0

Of the 85 shakes that were perceptible 24 dismantled the Observatory seismographs. The strongest shakes of the series were at 4:30 a. m. April 18 and 4:32 a. m. April 22. The latter dismantled the seismographs at Hilea, Hilo, and Kealakekua (See Letter No. 2, Jan. 8, 1925), and was strong enough to overturn some unstable objects though no real damage was done. A press dispatch from a Colorado seismograph station on April 10 stated that a distant earthquake was recorded whose origin was probably on Mauna Loa. The same disturbance was recorded as a distant earthquake on the several seismographs in Hawaii.

The 1926 outbreak more closely resembles that of 1916 in regard to the number of earthquakes and the time between the upper preliminary outbreak and the lower one from which the main flow issued than the 1919 one. In 1916 about 632 earthquakes accompanied the eruption or about the same number as in 1926, while in 1919 there were but 185 earthquakes. During an eruption in Mokuaweoweo in 1914 with no flow outside there were but 60 earthquakes. The time interval between the upper and lower outbreaks in 1916 was nearly three days, in 1919 about 2¼ days, and in 1926 nearly four days.

The two large earthquakes that occurred just prior to the first appearance of molten lava apparently occurred along the entire length of the southwestern rift as small tidal waves were reported from Hilo a short time afterwards and by the middle of the day of April 10 thin smoke was already issuing from a crack along the rift at an elevation of about 8,000 feet or at a distance of about 10 miles from the center of the upper outbreak.

The distance to origin as computed from the four seismograph stations located the majority of the earthquakes as occurring near Mokuaweoweo and along the upper end of the southwestern rift. There was no striking change of distance to correspond to a progressive cracking down the mountain side which has been noted at times of other outbreaks both on Mauna Loa and Kilauea.

It is interesting to note that discrepancies in the indicated distance to origin of many of the earthquakes as determined from different seismograph stations could be explained by assuming that the great faults of Mauna Loa are inclined toward the east or have an easterly dip.

R.H.F.

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No. 72 RELEASED WITHOUT COPYRIGHT RESTRICTION May 13, 1926

KILAUEA REPORT NO. 748
WEEK ENDING MAY 12, 1926

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

The change from a very quiet pit at Halemaumau through April, with the exception of the tenth, the day of the summit outbreak of Mauna Loa, to numerous wall slides beginning May 1, is the only happening of the past fortnight to suggest any sympathy between Kilauea and Mauna Loa. Kilauea motion began when Mauna Loa stopped. During the past week rock falls and avalanches have continued, and steam on the pit bottom has been thin. The northwest rim is shattered so that slides are easily started. On the tenth slides were timed, occurring at 4:30 p. m., 4:41, 4:47, 4:50, and 5:00. They were mostly from the NE and NW walls. After heavy rain this morning there is nearly continuous slipping of rocks there. Steam has ceased to be conspicuous at base of northwest talus; it is sulphurous in the center and at the south.

Thirteen very small local seisms were recorded. A small record of distant earthquake occurred 4:39 a. m. May 12. Ground tilt for the week was moderate SW.

END OF MAUNA LOA ERUPTION

At noon of April 28 T. C. White and Charles Ka of Kona reached the source cones of the Honomalino flows from the northwest by way of Kaohe and Kaapuna in South Kona. They went around the north side of the larger Alika source-cone of 1919, where they could see the whole belt of 1926 heapings along the 1926 crack a half-mile east of them. A mile up the rift were fresh openings fuming with strong sulphur gas, bordered with warm pahoehoe lava in short flows, and coated with bright yellow sulphur needles. Far up the mountain along the crack two steaming places were visible. Opposite and below the Alika vents was a string of new spatter cones for a mile and more. The upper sulphur place was at elevation 7750 feet by aneroid; a high cone in the lower series of 1926 openings gave 7280 feet. From here a small active cone was seen next south along the rift, feeding with lava a small lake a few hundred feet across. The feeding stream was about ten feet wide flowing about five miles an hour. The lake lay in the rift to the south of the feeding cone, and intermittently a big fountain of lava spouted in the southern end of the lake, the action resembling Kilauea lakes. There was no outflow towards Kona seen, and the exceedingly brilliant display which we had seen on the 23rd had greatly dwindled. White's lake appears to have been identical with the big fountain vent, at the source of our lava river. He made the direction of the 1926 rift N. 30 E. changing to approach N.-S. at its southerly end.

In the morning April 30 Honomalino ranch reported dense smoke over the source region. A Kona party of visitors to the upland the next day saw nothing glowing. On May 3 the writer rode up from Kona to the Umi Caverns next the Alika source, and camped there three nights, going by the Kaapuna trail through the On Tai Ranch, and exploring somewhat thoroughly the upper 1926 rift from the new sulphur deposits to the fountain location. All flowing lava activity had stopped, and very hot gas rose from some of the vents, which was spicy sulphur at the upper cracks and sulphur dioxide, making blue smoke, at the lower ones. It was now possible to walk right down the line of new cones, of which there were thirty below the 8000-foot level. Sixteen of these are below the big-fountain location, ending at the slag-heaps west of the 1916 cones, two miles above Puu o Keokeo. There are eight in the zone of maximum output opposite the Alika source. Above this there is a gap of a half-mile with only cracks and sulphur stain. There next occurs a group of small cones and puddled lavas, pahoehoe, and up the mountain farther the new crack occupies a valley amid old hills. The fissure has here vomited pahoehoe cascades, and the openings are coated with beautiful crystals of prismatic sulphur for several hundred feet; this marks the rift brilliantly as seen from a distance, and pale blue fume arises. This whole belt of thirty vents is about four miles long, and lies between elevations 7050 and 8000 feet. The position of the cracked zone is very near that of the 1916 rift, as though extending the latter up the mountain. The 1926 lavas in fact override those of 1916.

The belt of maximum outflow 1926, aboout elevation 7400 feet, has left a half mile of big spatter heaps of frothy pumice forty to fifty feet high in a line trending S25°W, with four or five channels on each side of the ridge leading off at right angles to unite in river beds. These made the Kahuku and Honomalino flows. On the west side the flows bent southward parallel to the spatter ridge and then united to a westerly course. On the east side they pitched down the slope in several separate rivers, and perhaps it was this separation that kept them from making any single big flow. There are large fields of new pahoehoe on both sides; the aa develops after the lava has flowed a quarter mile or more. The fountain lake is now a tumbled smoky channel full of big slabs and semi-aa rubble. This channel meanders in big sweeping curves away towards Kona. An ancient cone is split asunder where the new spatter heaps go through, and the heather bushes show charred stumps. Everything indicates that the rift opened from above downward, and the airplane photographs show that the rift developed southward between the 17th and 19th April. This developed the second Honomalino flow to the south of the Hoopuloa flow.

Looking up Mauna Loa one could see gleaming fields of new lava and two steaming areas along the rift high up. The last puffing effervescence of fume at the lower rift was seen at 9 a. m. May 4. T.A.J.

SAMPLE COPY

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No. 73 RELEASED WITHOUT COPYRIGHT RESTRICTION May 20, 1926

KILAUEA REPORT NO. 749

WEEK ENDING MAY 19, 1926

Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, temporarily in charge.

The frequent avalanching noted in last week's report has ceased. Steam from a vent near south wall and from southwest talus continues abundant. Despite the dry weather several points on the different walls appear quite damp.

Eleven earthquakes were recorded during the week. One at 1:34 a. m., May 14, was plainly felt at Waiohinu and at other points in Kau. Tilting for the week was moderate to the SW.

VOLCANOES AND AIR TEMPERATURES

In the immediate vicinity of volcanoes, fumaroles, and hot springs it is quite common to find air temperatures higher than in places more remote from the vents. Volcanoes exert a warming effect.

The amount of heat given off by Halemaumau when there is a large lake of molten lava present is rather startling. In January and Febraury, 1924, there were times when the heat escape from Halemaumau was equal to the heat produced by the complete combustion of one and a half tons of coal per second. Most of the heat quickly escapes to space but when smoke and steam clouds are present the warming effect may be noticeable for considerable distances from the vent on the windward as well as on the leeward side.

The escape of smoke, steam or water vapor and air even at moderate temperatures from fumaroles, hot springs and hot cracks tends to increase the temperature over small areas. The heating ffect of steam and warm air escaping from the many cracks in the vicinity of the Observatory is the main reason why with a heavy frost only 1500 feet away where there are no steam cracks the lowest temperature at the Observatory may be only 43° Fahr. It is possible to sleep without blankets along steam cracks at an elevation of 13,000 feet on Mauna Loa while only a few feet away freezing temperatures would be encountered.

All lava flows, of course, tend to raise the temperature in their immediate vicinity as long as they remain hot. A lava flow through a forest even after it has cooled off tends to slightly increase the average temperature by reducing evaporation. The rain quickly percolates through the lava and drains away underground and with no vegetation there is but little evaporation.

There is another and much more profound effect of volcanoes on temperatures that is just the opposite from the above—a cooling effect. The lowering of the temperature is often very widespread and in many cases the entire world is affected. The cooling effect of volcanoes is produced by violent explosions hurling great quantities of fine dust into the upper atmosphere where it may persist for several years and shut out incoming solar radiation.

One of the earliest recorded volcanic eruptions believed to have had some effects on world temperatures was that of Vesuvius in A. D. 79. Another eruption of Vesuvius in 1631 that sent up a dust cloud to a height of 30 miles was followed by cool weather in 1632 and 1633. The average of world temperatures makes the year 1785 one of the coldest on record. This cold year as well 1784 and 1786 is attributed to a violent explosion of Asama in Japan in 1783 aided by activity of Skaptar Jokull in Iceland durin gthe same year and of Vesuvius in 1785. Following the great explosion of Tomboro near Java in 1815 the whole world was remarkably cool in 1816. 1816 was frequently called "The year without a summer."

Explosions in more recent years have also produced cooling effects. The Krakatoa explosions in 1883 which sent up a dust cloud to a height of 17 miles was followed by world wide lowering of temperatures in 1884 and 1885. This dust cloud produced visible sky effects for three years. Katmai's explosions in 1912 produced a cooling effect especially noticeable in the northern hemisphere. An extensive volcanic eruption in the Chilean-Argentine Andes in December 1921 not only affected the southern hemisphere but produced noticeable results in the northern hemisphere.

Volcanic explosions may be of tremendous economic importance not only because of resulting rigorous winters in the temperate zones as in 1783-84-85, but also by the lowered temperatures greatly diminishing crop yields as in 1816.

Observed cooling effects have been such as to lower the average world temperature three degrees Fahr or more. If violent explosions from several different volcanoes should nearly coincide in time the effect might be very profound. Volcanic dust has been advanced as one of the causes of the ice ages. It is interesting to note that a lowering of the average temperature over Mauna Kea by but a few degrees would be sufficient to produce glacier conditions on that mountain. Many places now well populated might become glaciated by a lowering of the mean annual temperature only a few degrees for several years.

R.H.F.

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No. 74 **RELEASED WITHOUT COPYRIGHT RESTRICTION** May 27, 1926

KILAUEA REPORT NO. 750

WEEK ENDING MAY 25, 1926

Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, temporarily in charge.

Halemaumau continues quiet. Small rock falls are heard occasionally. On May 22 the steam vent at the south edge of the pit floor which usually omits more steam than any of the other vents was scarcely noticeable while the vents in the southwest talus and in the north floor were steaming as usual. This indicates that there is a variation in the amount of steam that escapes from the different vents. There is, of course, a large apparent variation due to variations in atmospheric conditions.

Considerable interest was taken in large white clouds that hung over Mauna Loa during the afternoon of May 24. This type of cloud may be seen quite frequently. It is primarily due to the heating of the mountain slopes during a clear non-windy day. Occasionally such clouds may be seen over Mauna Kea. The many steam vents on Mauna Loa naturally aid in the formation of such clouds.

Seven local earthquakes all too small to be perceptible at Volcano House were recorded on Observatory seismographs. This is the smallest weekly total since February.

There was a strong north-northeast tilt during the week.

BULK DISPLACEMENT DUE TO TILTING

In Volcano Letters No. 41, October 8, 1925 and No. 61, February 25, 1926, short discussions of tilting and the resulting changes of level at Kilauea volcano may be found. The exact amount of subsidence is not yet definitely known nor are the limits in distance from Halemaumau to which the subsidence may be detected by precise levelling. Determined values, however, indicate that detectable sinkings may be found 20 miles or more from Halemaumau. Preliminary values which will probably have to be increased when more determinations are made indicate that the subsidence of Kilauea during 1921-1924 inclusive ranged from 13-14 feet at Halemaumau to a tenth of a foot or more 20 miles to the northeast.

Tiltings to produce elevation changes of the above amounts and to such distance from a volcano center are not unknown. The subsidence accompanying the Sakurajima eruption in 1914 amounted to nearly nine feet at the mountain and was still large enough to be measurable over 30 miles away. At Kilauea there was a swelling up of the mountain from 1913 to the beginning of 1921 whose value probably nearly equaled that of the subsidence from 1921 to 1924. Mauna Loa appears to give surface manifestations of changes of internal pressure by tiltings of its great dome but there are no quantitative data at hand for this mountain. Shoreline elevations and subsidences have been noted at many places on the earth's surface. Elevation changes take place in regions without active volcanoes as well as in active volcano regions.

In a region like Kilauea volcano computation of the volume involved in changes of elevation is difficult unless a very elaborate net of levels are run. The value of the elevation change may jump suddenly when a zone of cracks in the earth's surface is crossed while on either side the values may change systematically. Two wide crack zones lead away from Halemaumau, one leading to the southwest and the other to the northeast.

By using the preliminary data determined for a northeasterly direction and assuming a symmetrical subsidence about Halemaumau as a center it may be shown that the volume of land withdrawn by subsidence during 1921-1924 amounted to 20,000,000,000 cu. ft. This is nearly three times the amount engulfed during the collapse of Halemaumau in 1924. If there was no compensation by elevation at other places on the Island of Hawaii it would mean that the volume of the island above sea level was decreased by the above number of cubic feet. The estimated volume displacement at Sakurajima in 1914 is about one-fourth of the above. Owing to the average porosity of the rock involved it is probable that the weight of the 20,000,000,000 cu- ft. was not much over one and one-quarter billion tons.

At times of solar eclipses the moon frequently shows an apparent error of as much as four seconds of time in her computed schedule. Dr. E. W. Brown of Yale University in discussing causes for the apparent erratic behaviour of the moon suggests that the earth my be at fault. He computed that shrinking and tumescing of the earth to the extent of a few feet in a comparative short period of years would be sufficient cause to account for the apparent failure of the moon to travel by schedule. In the foregoing discussion tumescing and subsiding have been shown to take place over small areas and it would seem to be easily possible for some such movement to take place over large areas. R.H.F.

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No. 75 RELEASED WITHOUT COPYRIGHT RESTRICTION June 3, 1926

KILAUEA REPORT NO. 751

WEEK ENDING JUNE 2, 1926

Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, temporarily in charge.

In all its recorded history Halemaumau was never more quiet than it is at present. There has been a noticeable decrease in the steaming from the vent on the south floor of Halemaumau and a slight increase at the north. Avalanching still takes places though not very frequently. Aside from anything due to the recent activity of Mauna Loa that mountain for months has been emitting more actual smoke than has Kilauea.

Six earthquakes were recorded during the week. One at 7:10 p. m. May 31 was perceptible and had an indicated distance to origin of 22 miles. Tilting was slight to the southwest.

ANCIENT VOLCANOES

In the earliest known geological ages volcanism or other forms of igneous action was very general. From these early times on there appears to have been fluctuations in volcanic activity. There were periods of great volcanic activity all over the world followed by periods of quiet. During the relative quiet periods, however, it is probable that many volcanoes showed activity. It is probable that there will be periodic fluctuations in activity in the future.

There are but few places in the world where one would have to travel far to see effects of ancient volcanism. Were there no active volcanoes in the world today one could get good impressions of how lava flows behaved and of the formation of volcanic cones by studying ancient volcanic regions.

Not conspicuous to everyone but obvious to all when the formations are pointed out is the fact that at one time there was a volcano near the site of New York city. In Auvergne—south-central France—there are many cones produced by volcanic activity thousands of years ago. These cones, as a rule, are in well defined zones showing that they were located over active fissure belts. They are among the best preserved forms of ancient volcanic activity to be found anywhere. A photograph showing several of these cones, excepting for the vegetation, looks very much like a photograph on some of the higher parts along one of the great rifts of Mauna Loa.

In Great Britain there are many remains of ancient volcanism. The subject is so extensive that Sir Archibald Geikie in writing on the subject, "Ancient Volcanoes of Great Britain," found it necessary to fill two large volumes in order to make the discussion at all comprehensive.

Pisolitic ash similar to that produced at Kilauea in 1790 and to some extent in 1924 may be found in certain strata in western Germany. This shows that explosive volcanic eruptions took place in Germany. This type of ash is produced by rain drops falling through dust laden atmosphere collecting so much dust that they fall as mud pellets. Owing to natural cementing qualities of the ash they more or less retain their round shape. There is some justification in calling pisolites, "fossil rain drops."

Probably the largest lava flow of old geologic times that may be traced quite clearly took place in India. It is known as the Deccan Trap and is still exposed over an area of 200,000 square miles. The original area was probably much greater. Its thickness varies from 4,000 to 6,000 feet.

More recent than the Deccan flows were the ones in Oregon, Washington, and Idaho which extended over an area of about 200,000 square miles. The accumulation in thickness of these flows vary from a few feet to over 2,000 feet.

Still earlier than the Deccan flows there was a flooding over a vast area in the Lake Superior region. This flow took place so long ago that its evidence is not striking. It is remarkable in having produced fills as much as 15,000 feet in thickness.

In prehistoric times but very recent there was activity in the southern part of Califorina and Arizona. Beautiful volcanic cones nearly as fresh as though they were formed but yesterday may be seen. In northern California, western Oregon and Washington it appears that there was a gradual decline of volcanic activity to present day conditions.

In the San Jose valley in New Mexico there is a very fresh looking pahoehoe lava flow. There is an Indian legend handed down for several generations of a river of fire in this valley. This legend would make the flow one of comparatively recent times. The freshness of the lava adds to the plausibility of the legend.

In recent times the most active producers of lava have been the volcanoes of Iceland. In 1783 from one volcano system, Laki, lava poured forth to the extent of 420 cubic miles.

R.H.F.

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No. 76 RELEASED WITHOUT COPYRIGHT RESTRICTION June 10, 1926

KILAUEA REPORT NO. 752

WEEK ENDING JUNE 9, 1926

Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, temporarily in charge.

During the week 11 local earthquakes were recorded on the Observatory seismographs. On June 4 at 1:53 a. m. one of the shakes was slightly felt in Hilo. Another shake at 9:35 a. m. June 9 was rather widely felt over the island of Hawaii. It was strong enough to shake objects off shelves at Kapapala and dismantled the seismographs at Volcano Observatory. The indicated distance to origin from Volcano House was 16 miles southwest. A slight record of a distant shake was written at 9:35 a. m. June 5. Tilting for the week was moderate to the south-southwest.

Halemaumau continues quiet with but few avalanches. Following the recent rains the walls are quite red.

Snow was observed on Mauna Kea during the afternoon of the 7th but none was visible on Mauna Loa.

MUD VOLCANOES

A rather comprehensive definition of volcanoes has been given about as follows: It is an orifice in the crust of the earth commonly terminating in depression or crater whose sides mark the summit of a mountain or hill. From the crater are ejected—sometimes continuously, sometimes with long intervals of quiescence—hot water, steam, gases, dust, gravel, broken stone, or molten lava. The ejection of the different kinds of materials depends upon the condition of the volcano and its age. According to the above definition lava flows, explosions, steam and gas vents, geysers, mud volcanoes, and some hot springs are but surface manifestations of more deep seated volcanic processes.

The Italians have given names to several types of decadent volcanic activity. The name solfatara is applied to vents emitting chiefly steam and sulphurous vapors. Examples are found in many active volcano regions. Soffioni is a term used to designate volcanic vents which emit steam, hydrogen sulphide and carbon dioxide. These may occur in regions of recent volcanic activity but away from present day active regions. Mofetta is a name given to volcanic discharge consisting chiefly of carbon dioxide. Examples of the latter are rather widespread, and some are quite well known such as Death Gulch in Yellowstone Park and Valley of Death in Java. In the Valley of Death not only may the bones of birds and beasts be found but also the bones of men.

The conditions necessary for the formation of a mud volcano depends largely upon the nature of the ground through which hot water and steam escapes. If the ground is of unconsolidated material like clay or tufa mud volcanoes may result and build up cones varying in height from a few feet to 500 feet or more.

Frequently, as at the Vesuvian eruption of A. D. 79, large explosive eruptions are accompanied by mud flows. Such mud streams result from heavy rains occurring at the time of the explosion mixing with the ejected dust in the air or on the ground or in both places and are not the product of true mud volcanoes.

Mud volcanoes often discharge streams of mud frequently exhibit fountaining when the vents are surrounded by a mud lake. In the northern part of Lower California near the California border rather spectacular fountaining may frequently be seen. Cheduba and other small islands in the northeastern part of the Bay of Bengal near the Burma coast contain a chain of mud volcanoes. In this chain in 1906 a new island of mud was thrown up that had an area above the water line of 600,000 sq. ft. A mud volcano, Gorela, near Kertch in Crimea with a cone 264 feet high has sent forth several streams of mud. The volume of one of these flows was estimated to have a volume of over 22,000,000 cu. ft.

Mud volcanoes are commonly located in extinct volcano regions (extinct, meaning not producing molten lava nor ash) or over rather quelt fissures in active regions. The "paint pots" in Yellowstone National Park are mud volcanoes in a region where volcanism has been extinct for thousands of years. Mud volcanoes are found on Mount Etna an active volcano region. Tikitere, a valley in New Zealand, containing many mud volcanoes is near active volcanoes.

That mud volcanoes may afford an interesting sight may be gleamed from the following description of mud volcanoes of the north of Iceland: "From the plain of mud vast clouds of steam rise into the air, while a low drumming sound proceeds from many sources. Vents are numerous but there are especially 12 large one in which the slime is boiling. In some the mud is as thick as molasses while in others it is smiply ink-black water. The thundering and throbbing of these boilers, the thud of hot waves striking banks, the scream of escaping steam at the edge of a blue-slime pond produce a horrible effect. In some places the mud is boiling furiously in others bells of black ooze rise and explode into scalding sprinkiings. The whole is a frenzied roaring pool of slush. R.H.F.

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No. 77 RELEASED WITHOUT COPYRIGHT RESTRICTION June 17, 1926

KILAUEA REPORT NO. 753

WEEK ENDING JUNE 16, 1926

Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, temporarily in charge.

At daylight the morning of May 11 and for over an hour thereafter Halemaumau was a spectacular sight. The pit was full of steam and from the rim a continuous, rather dense, steam cloud extended upward to a height of about 1500 feet. With no other cloud around and the entire column well illuminated by the sun it looked as though Halemaumau were in eruption.

The vent at the south edge of the pit floor is again emitting much more steam than any other vent inside the pit. Avalanching is rather in frequent though small rock falls at least can nearly always be heard.

During the week 10 earthquakes were recorded. All were too small to be perceptible at Observatory.

The net result of tilting was slight to the northwest. This is the usual direction of tilting for this time of the year. Tilting so far this year has been greater than during 1925. The direction of tilting during the first half of the year is normally to the south. During 1925 the accumulation of southerly tilting amounted to 7.5 seconds of arc and in 1926 it amounted to 12.6 seconds. The westerly tilt now going on will probably continue for two more months but already the 1926 westerly tilt exceeds the total of 1925 by over one second.

BORINGS IN KILAUEA CRATER

Some progress is being made in the boring on the floor of Kilauea crater. (See Volcano Letter No. 66, April 1, 1926.) One hole was drilled through rock that at the surface showed only ordinary temperatures though only 75 or so feet away there were steam cracks. After reaching a depth of about a foot a temperature of 194° Fahr was encountered. This temperature was constant for about four feet and is a few degrees higher than the natural steam vents in the neighborhood. Upon going deeper a lower temperature was encountered. At a depth of 10 feet the temperature was 172° Fahr or 20° less than at one foot below the surface. When the temperature of the hole was again measured a few days later it was found that the bottom of the hole had become slightly hotter. The amount of steam escaping from the hole when it is uncapped is very slight and the velocity of escape is low.

R.H.F.

ACTIVITY ON ISLAND OF REUNION

A. Lacroix recently reported to the Paris Academy of Sciences that a lava flow from the volcano Piton de la Fournaise, Reunion, started on December 30, 1925. The volcano is apparently in a period of active output as there was another flow in September 1924. This volcano resembles Kilauea in being classified as continuously active. It has been mentioned in Volcano Letters No. 4 January 22, 1925 and No. 24 June 11, 1925. The active cone rises to a height of 8600 feet above sea level. Glow can be seen over the mountain nearly every night. Frequently the flows that pour down the side of the mountain are of pahoehoe nature and develop lava tubes in which lava stalactites may be found.

R.H.F.

JAPAN'S LATEST VOLCANIC ERUPTION

Tokachi-dake and its companion peak Mount Iwo became active suddenly on May 24 after having been quiet for a long period. Mount Tokachi is the next to the highest peak on the island of Yezo. It rises to a height of 6541 feet above sea level.

The outbreak was heralded by preliminary rumblings so that many people in especially dangerous areas escaped. It was fortunate for those who were forced to flee and for rescue work that the outbreak occurred in the day time. A railroad train that was entering the dangerous district was turned back just in time to escape its being overwhelmed. Both lava flows and explosions accompanied the eruption. The roar from the explosions were reported audible 20 miles away. One river was damned by a lava flow and another by explosion debris. The water impounded in these damns later on broke loose and caused floods in the valleys below. The worst flood was caused by the rupture of a mountain lake which let loose a flood that rushed forward as a wall of water 30 feet high. The outbreak quickly diminished in vigor though ashes and smoke were intermittently emitted for some time after.

It is thought that about 400 lives were lost; lava flows, floods, and explosions each taking a share. Newspaper reports, from which most of the above facts were taken, state that 144 bodies were recovered within two days.

R.H.F.

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No. 78 | RELEASED WITHOUT COPYRIGHT RESTRICTION | June 24, 1926

KILAUEA REPORT NO. 754

WEEK ENDING JUNE 23, 1926

Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, temporarily in charge.

Halemaumau continues to be very quiet. Large avalanches have been rather infrequent though rock falls continue. Judging from the numerous cracks and shattered rock at many places on the rim, Halemaumau walls are still quite unstable. With the increased day temperatures during the past week the amount of visible steam escaping from the vents in the pit has lessened. A sulphur stained patch on the south-southwest wall is becoming more conspicuous.

20 earthquakes were recorded during the week. This is the largest weekly total since the eruption of Mauna Loa ceased. Only two of the shakes were perceptible at Observatory. One of these, at 4:56 p. m., June 19 with an idicated distance to origin of two miles, was preceded by a rumble. The other, at 12:46 p. m., June 22, had an indicated distance to origin of 15 miles.

Daily tilt values were small, the net result for the week being slight to the north-northeast.

VOLCANIC FLAMES

Where the recent lava flow from Mauna Loa crossed the road at Honomalino, banners of flames issued from numerous vents on each side of the flow. The flame jets varied in height from a few inches to over six feet. They were pale blue in color and at night brilliantly illuminated the approach to the flow. Through a pocket spectroscope the flames showed only the lines that are characteristic of sodium. Some of the vents from which the flames issued were 50 feet or more from the edge of the flow. The distance of the flames from the flow and the fact that they continued for hours led some people to conclude that they were of true volcanic origin arising from gases issuing from the lava. Speculations of the lava burrowing its way underground were even heard. The flow here went through a forest and, of course, the flames were of burning gases produced by distillation of vegetal matter underground. The ground is very porous and the amount of vegetal matter in it is very large. The flow crossed the road at a fill where the amount of underground vegetal matter was much more than normal. When the flames began they often issued as explosive puffs, but after a large part of the air in the underground cavities was expelled an explosive mixture was no longer formed and they issued as nearly continuous banners.

Farther up the mountain where the flames did not continue so long there were often true explosions. Occasionally small trees were blown bodily into the air and larger ones uprooted. The explosions were frequently large enough to be heard 3-4 miles away. Flames were seen to follow many of the explosions. Alongside the flow in higher and drier country near the timber line, fires ran underground as much as 300 feet from the edge of the flow and small explosions were noted at that distance.

In a flow from Kilauea in 1919 over pahoehoe lava with scanty vegetal covering, gases accumulated in small caverns and when exploded would blow the roofs of the caverns to pieces.

Along all lava flows in a region where there is any vegetation there is a distinct odor of burning hydrocarbons produced by destructive distillation of vegetal matter in addtion to the usual odor of burning wood. The odor of burning hydrocarbons near the source of the 1916 lava flow from Mauna Loa led to the conclusion that hydrocarbons in considerable quantities were a natural exhalation of Mauna Loa. Such a conclusion is probably not true as there is considerable vegetation along the southwest rift of Mauna Loa as high as 8,500 feet, or several miles above the 1916 source. The source of the main flows from Mauna Loa in 1919 and 1926 were in the same region as that of 1916 and the peculiar hydrocarbon odor was noticed in these years also. At the upper outbreak in 1926 in the neighborhood of 13,000 feet where there is no vegetation, the odor was lacking.

Flames of strictly volcanic nature have been observed on numerous occasions and at many different volcanoes. At Kilauea the flames are usually of a bluish tint, though occasionally they are of a yellowish color and often play over a vent for hours at a time. Intermittent jets of flame frequently issue from cracks in the crust on a molten lava lake. Great banners of flame a hundred feet or more in height, indistinctly seen on account of fume, have been noted accompanying Mauna Loa fountains.

Gases collected over true volcanic flames are chiefly water vapor, together with sulphur dioxide, carbon dioxide and lesser quantities of other constituents. This indicates that hydrogen may be the chief source of volcanic flames.

R.H.F.

Correction: The date "May 11" in Kilauea Report of Volcano Letter No. 77, should be "June 11."

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No. 79 RELEASED WITHOUT COPYRIGHT RESTRICTION July 1, 1926

KILAUEA REPORT NO. 755

WEEK ENDING JUNE 30, 1926
Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, temporarily in charge.

Halemaumau shows no signs of activity. The most conspicuous steaming vent in the pit is at the northwest. Faint sulphurous odors may be distinguished on the rim.

The number of earthquakes recorded during the week was 16. Four of the earthquakes were slightly perceptible at Observatory. Two that occurred at 9:20 p. m., June 23 and at 11:18 a. m., June 27 respectively, caused pheasants to squawk and had indicated distances to origin of one mile. The strongest shake of the week occurred at 3:27 a. m. June 30 and had an indicated distance of 14 miles.

A distant earthquake was recorded at 4:08 a. m. June 29 with an indicated distance of 4750 miles. A shake was reported from near Singapore about this time.

Tilting for the week was moderate to the East-northeast.

SUBMARINE VOLCANOES

It is not uncommon for sea captains to report passing through seas of pumice or turbulent waters, the result of submarine volcanoes. When one considers the number of land volcanoes and the fact that three fourths of the earth's surface is covered with water it is easy to imagine a rather large number of volcanic vents on the ocean floor.

Before a great many of the present day active volcanoes developed in height so that their throats remained permanently above water they would have been classified as submarine volcanoes. Many known extinct volcanoes passed through the submarine stage. Both Vesuvius and Etna as well as Stromboli started from the floor of the Mediterranean.

Numerous islands in the Pacific ocean are of volcanic origin. Others that are classified as coral islands may be rally volcanic with a coral cap. Islands might be covered with a coral growth either if their summits never quite reached to sea level before the volcano became extinct or if they were once higher and were eroded to below sea level. The great depth of the ocean around many of the coral atolls in the Pacific ocean points to a volcanic foundation.

The elevation of entire islands or parts of them may have been greatly reduced by subsidence. Penguin Bank west of Molokai in the Hawaiian group may have been much higher once and its elevation reduced more by subsidence as a whole than by erosion. The outline of the Bank is marked by submerged cliffs where the depth of the water abruptly changes from an average of 240 feet to an average of 1320 feet. Magnetic observations as well as topography indicates that the base of the coral atoll of Funafuti in the Ellice group is of volcanic origin. A boring in this island to a depth of 1114 feet, however, failed to reach the igneous base. The island may have been sinking coincidental with the coral growth.

The Hawaiian Island group have been elevated from a depth of 15,000 to 18,000 feet below sea level, unless we assume the rather untenable theory that the group is but a remnant of a large land mass now submerged. The volume of land of the Hawaiian Islands above water is but a small percentage of the great volume below sea level. This volume relation is true of the majority of volcanic islands because there is a great ocean deep adjacent to nearly all volcanic regions.

Occasionally at the present time new islands are born. Some live for but a short time while others make permanent additions to the land mass above sea level. An effect of the short-lived volcanic island may be the production of a shoal where once there was deep water. Graham Island was born in the Mediterranean about 30 miles southwest of Sicily in July 1831. The birth was heralded by a column of water 800 feet in diameter and 60 feet high quite suddenly appearing at a place where the Mediterranean was 600 feet deep. The water column was shortly followed by steam clouds and presently an island of pumiceous material appeared. It quickly reached a height of 200 feet with a circumstance of three miles. Within six months the island had quite disappeared though the top of its submerged remnant is but 9 or 10 feet below sea level. In 1891 there was a submarine eruption in this same general region but no island appeared. Near Bogosloff volcano in the Bering Sea an island, New Bogosloff, appeared in 1883. It appears to be a permanent addition to the land in Bering Sea. Near the Azores a short-lived volcanic island was formed in 1811. A submerged volcano near Saint Miguel in the Azores appears to be active occasionally. Several temporary islands have been reported in the Pacific. Some that persisted for a few years and were several times observed were placed on maps but later on utterly disappeared. R.H.F.

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No. 80 RELEASED WITHOUT COPYRIGHT RESTRICTION July 8, 1926

KILAUEA REPORT NO. 756

WEEK ENDING JULY 7, 1926

Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, temporarily in charge.

During the past week there has been a revival of avalanching from the walls of Halemaumau. Frequently the avalanches are large enough to send dust clouds well above the pit rim. Most of the slides have been from the north wall, usually from near the top of the wall. The echoes of the roar produced by the largest avalanches produce wierd noises.

During the recent dry spell the deposit of white salts, sulphates, have been quite conspicuous around Halemaumau pit especially on the southwest side.

The strong wind that blew on July 5 stirred up great dust clouds in the desert to the southwest of the volcano. Whirlwinds in the dust clouds greatly increased the dark appearance of the cloud. Small clouds were stirred up in the middle and southwest parts of Kilauea crater. The north end of the crater where the total dust fall of the explosions in 1924 amounted to only an inch or two is now quite free from dust. Owing to the trade winds there has been a quite constant progressive movement of the dust toward the southwest. Though it has been over two years since the explosions the appearance of the desert on July 5 closely resembled its appearance following many of the explosions.

The 12 earthquakes recorded during the week were all too small to be perceptible at Observatory. About half of them appeared to be of Mauna Loa origin.

Tilting for the week was moderate to the north-northeast. The greatest amount of the tilt occurred on the 5th and 6th of July.

THE RATE OF DISSEMINATION OF VOLCANIC DUST

The eruption of Krakatoa in 1883 not only caused widespread dust clouds in the lower atmosphere but also sent great quantities of dust into the upper atmosphere well above the level of the highest clouds. Dust was collected over 1100 miles from the vent and the dust that reached the upper atmosphere spread all over the world. Such a dust cloud in the upper atmosphere throws light on the air currents in that region. Other great explosions have occurred but few have been so widely observed. From known air currents over equatorial regions it is to be expected that the dust would spread around the world over the equator quicker than over places nearer the poles.

Professor Stentzel of Hamburg has collected data on the rate of travel of these high dust clouds and estimates the average speed of propagation to be from 85 to 125 miles per day. The actual velocity is, of course, much greater as the dust does not travel out in straight lines to all places from the explosive vent but pursues greatly curved paths before it appears over most stations.

A newspaper account reviewing Professor Stentzel's work states that the dust from the Mauna Loa outbreak on April 14, 1926 may be expected over Europe some time in July. As no dust cloud was produced by Mauna Loa this year such an expectation will not be fulfilled. R.H.F.

THE IMMANUEL FRIEDLANDER VOLCANO INSTITUTION

A discussion of The Volcanological Review and notes on some of the articles published in it were given in Volcano Letter No. 15, April 9, 1925. This review is the official organ of the Volcano Institution of Immanuel Friedlander. The institution is organized under Swiss laws and is now located at Zurich. Its work is encouraged in Italy, Swizerland, Germany, and elsewhere. The chief concern of the institution is the observatory building at Naples. Active in addition to Dr. Friedlander, the director of the institution, there is an assistant editor for the Volcanological Review, a chemist, a petrographer, a seismologist, and others. The institution is very much like the Hawaiian Volcano Research Association in its scope and supports scientific publications, trips for making scientific investigations, compilation of material, and loans instruments. R.H.F.

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No. 81 RELEASED WITHOUT COPYRIGHT RESTRICTION July 15, 1926

KILAUEA REPORT NO. 757

WEEK ENDING JULY 14, 1926

Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, temporarily in charge.

The avalanching from the walls of Halemaumau reported last week has continued during this week. Most of the avalanching is still from the north wall. On several days the avalanches, both large and small, were so frequent that when the pit was not filled with dust it was quite hazy. The scars on the walls from which avalanches broke loose are much brighter than the rest of the walls and often show considerable deposits of salts. The sulphur stained patches in southern part of the pit have been greatly dimmed by dust from avalanches. The amount of steam escaping from the pit floor does not seem to vary greatly. The steam vents may be roughly grouped into three lines that cross the bottom of Halemaumau from north to south.

Despite the large number of avalanches the number of earthquakes has not greatly increased. Of the 18 shakes recorded during the week four appeared to be of the type that accompany avalanches. The only earthquakes large enough to be at all perceptible during the week occurred at 8:15 a. m. July 12. It, apparently, caused a rather large avalanche as a dust cloud that rose well above pit rim was observed shortly after the earthquake.

Tilting for the week was slight to the south-southeast.

In answer to the question, "Is Kilauea dead?" it can be said that not only is there no evidence pointing to the fact that Kilauea is a dead volcano but also there is evidence that it is still active internally. When lava is present in the pit there is often a variation in the internal pressure of the volcano system that causes the top of the visible lava column to vary in height from 600 feet below the rim up to the rim level. An internal and unseen variation in the height of the lava column may also be possible. Records at the observatory show that the internal pressure of the Kilauea-Mauna Loa volcano system has been increasing since June 18, 1926. The increase of pressure is manifested by a swelling of Kilauea mountain that is recorded as a northeast tilt at the Observatory. There is a normal westerly tilt closely following the seasonal temperature curve from the last of winter until August. When the seasonal temperature starts to decrease in August the direction of tilting normally changes from west to east. This year not only has the westerly tilting been arrested nearly two months prior to the normal time but there has been an accumulation of easterly tilt since June 18. The 1926 tilt curve is closely parallel to the 1924 tilt curve that preceded the return of lava to Halemaumau in July of that year.

THE RETENTION OF HEAT IN LAVA FLOWS

Two and a half months after the 1926 lava flow from Mauna Loa crossed the road at Honomalino it is still quite hot. At some places even the rocks that are well exposed, as at the edges of the flow, are so hot that they hiss when water is thrown on them. Where the flow entered the sea the water is still warm. In some of the small protected arms of the sea the water is so hot that it is unbearable to the touch.

Some cracks in the Mauna Iki lava flow that poured onto the Kau desert from Kilauea in 1920 are still hot enough to ignite a stick of wood. It seems probable that a part of the heat found in lava flows long after the time of issue may be due to chemical action. R.H.F.

THE KEAIWA FLOW OF 1823, HAWAII

In Volcano Letter No. 18, April 30, 1925, attention was called to the fact that since 1920 the Keaiwa lava flow to the southwest of Kilauea which had been assumed to be of the 1868 has been correctly called an 1823 flow.

This flow is the subject of a paper by J. B. Stone in the American Journal of Science for May 1926. The flow, of typical olivine basalt, poured out along the southern half of a fissure 11 miles long. It flowed out so rapidly that a canoe was burned at Mahuku. One of the most interesting features of this flow is the "ball-lava" which may be seen at a few places in the upper portion of the walls of the crack from which the flow issued. It is assumed that the lava balls were formed by cool fragments of lava falling into the crack where molten lava was surging and after growing by acquiring coatings of molten lava during the churning action were hurled out as smooth rounded balls. Two small explosions with possibly some smaller ones marked the closing stage of the flow.

An excellent description of this flow, among other things, is contained in a paper on the above subject by H. T. Stearns in the Journal of Geology, for May-June 1926. In the abstract by Stearns he states that there is evidence that the usual fire fountains of Hawaii did not play during the eruption. Spatter that is found at the edge of the flow shows that there were rather tall fountains accompanying the eruption. Excepting for the fact that this spatter is not pumiceous the action along this crack in 1823 must have been quite similar to the preliminary Mauna Loa eruptions near the summit in 1916, 1919, and 1926. R.H.F.

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NO 82 RELEASED WITHOUT COPYRIGHT RESTRICTION July 22, 1926

KILAUEA REPORT NO. 758

WEEK ENDINIG JULY 21, 1926

Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, temporarily in charge.

There has been a considerable dimunition in the number of avalanches from the walls of Halemaumau that became especially frequent about the first of July, and continued for over two weeks. Rock falls and small avalanches may be seen and heard neraly every day however. There was a large slide from the southwest wall though the north wall still appears to be more unstable than the others.

Following moderate rains the walls of Halemaumau were quite red on July 19. The red color makes ats appearance as a series of horizontal parallel bands separated by layers of quite dense gray strata whose color changes but little. These pleasing color contrasts give Halemaumau a very striking appearance.

It has now been two years since the lava returned to Halemaumau, after an absence of about three months, to stay for only 12 days and therefore nearly two years that there has been no lava in the pit. Halemaumau was without lava duruing a large part of the thirteen year period from 1894 to 1907. During most of this period considerable smoke issued from the pit, while in the last two years there has been but very little smoking and at present practically no smoke escapes.

There has been practically no change in the location of steam vents during the past several months though the place of maximum steaming is at the northwest instead of at the south as formerly.

Earthquakes continue to be quite frequent. Twenty-two were recorded during the week. All were too small to be perceptible at Volcano House. Several appeared to have indicated distances equal to that of Mauna Loa.

Tilting for the week was slight to the north northwest. There was a strong spurt of north-northeast tilt on July 20.

LAVA TUBES

One of the most interesting and picturesque of volcanic formations are lava tubes or tunnels. Nearly every pahoehoe lava flow produces tubes, large or small.

The most common type of tube is produced by a crust forming over a lava river that initially flowed over the surface of the ground laterally confined by banks of its own making. After the crust is formed over the river the lava continues to flow underneath much as a water river does when it freezes over. When the activity ceases, the lava drains away, leaving an empty tube.

There is another type of tube that is not so frequently observed. This type is formed by lava pouring through a crack or fissure often several hundred feet below the surface. The presence of such tubes in subterranean lava flows can usually only be surmised. In the southwest wall of Halemaumau, 275 feet below the rim this type of tube is exposed. Initially this tube was but a narrow crack into which lava started pouring in 1919. A tube of considerable dimensions and over six miles long was quickly developed. The "Devil's Throat" and some similar holes, 250 to 300 feet deep in the Kau Desert southwest of Halemaumau are but breakdowns in the roofs of such tubes.

Lava rivers follow the topography just as water streams do but in several respects they are just the reverse of water rivers. The greatest volume of lava is at the source. The discharge is often through small tubes that spread out like the delta of a river. Lava tubes have been observed to be nearly horizontal, steeply inclined, and even practically vertical. The later occur where lava cascades over a cliff.

The picturesqueness of lava tubes is often increased by stalactitis and stalagmites. Two widely different types of stalactites are often present. The more common type is composed of lava and is formed by the melting action of burning gas that escapes from the lava river as it flows through the tube. In some places the roof of a tube may be quite thickly covered with these stalactites. The length of the stalactites vary from an inch or less to over three feet. Lava stalactites three feet in length with an average diameter of only half an inch have been found. Probably a large portion of the drip from stalactites fall into the lava river below but where the drip falls onto a ledge above the lava level stalagmites may be found. The stalagmite formation often resembles a bunch of petrified grapes.

The other type of stalactite occasionally found in tubes is composed of sulphates. They are formed after the tube has started to cool off but when it is still quite hot by rain water percolating through the roof of the tube and dissolving the sulphates that have been formed in the material of the roof. They often show a variety of colors and make a tube quite beautiful. Being, for the most part, quite soluble they quickly disappear when the tube cools off.

Lava tubes are found at many places in both recent and ancient lava flows. There is a lava tube on Mt. Shasta, Calif., with a roof 60 to 80 feet high. One can not travel any distance on either Kilauea or Mauna Loa without encountering lava tubes.

R.H.F.

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No. 82 RELEASED WITHOUT COPYRIGHT RESTRICTION July 29, 1926

KILAUEA REPORT No. 759

WEEK ENDING JULY 28, 1926

Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, temporarily in charge.

While there has been no surface manifestation of unusual activity at either Kilauea or Mauna Loa during the past two weeks, the Kilauea-Mauna Loa volcano system is passing through a crisis as real, from the Observatory standpoint, as though molten lava had been present. The northeast tilt that started on June 18 appears to have stopped and during the past week there was a slight northwest tilt. With the change in the direction of tilting there has been an increase in earthquake frequency. Thirty-three separate, small earthquakes were recorded. In addition to the thirty-three shakes there was a nearly continuous tremor from 9:30 a. m. to 1:30 p. m. July 22. A similar tremor was noticed for four hours during the afternoon of July 26.

During the last two or three days there has been a slight increase in avalanching from the walls of Halemaumau. All walls appear to be in motion though the greatest number of avalanches appear to have fallen from the west wall.

The fume column that can usually be seen over Mauna Loa in late clear afternoons was especially conspicuous in the afternoon of July 28. It rose as a rather narrow column at least two or three thousand feet above the outline of the mountain.

SEISMIC EFFECTS OF A SOLAR ECLIPSE

The solar eclipse of July 9, 1926, was not annular at the Hawaiian Volcano Observatory but the maximum obscuration of the sun was roughly estimated to be above 80 per cent. Such an interruption of radiant energy with its consequent lowering of ground temperatures, might well be expected to cause measurable tilts of the earth's surface. The relation between tilts and ordinary daily and seasonal temperature variations has already been mentioned in Volcano Letter No. 41, Oct. 8, 1925.

In an attempt to detect such eclipse effects the seismograms written at the Observatory during the week including the day of the eclipse were subjected to a thorough examination, and an especially sensitive optical tilt-recording instrument was put into operation for the occasion.

After some study the optical records were put aside as being too much influenced by known and suppositious accidental disturbances. From the seismograms however a good tilt curve was deduced, extending over an interval of six days. Any special tilt changes so large as one second of arc would have been unmistakable on this curve, and it is most probable that magnitudes half so great would have been correctly identified. Nothing of the kind appeared, however, which could be associated with the eclipse. One can say, then, that if eclipse tilts existed they must have been of the order of a small fraction of a second of arc.

No earthquakes were detected which could be changed in any way to the eclipse. P. H. Kirkpatrick.

ARE MAUNA LOA AND MAUNA KEA HOLLOW MOUNTAINS

Occasionally one hears the statement that Mauna Loa and Mauna Kea are essentially hollow mountains. This idea arises from the fact that when gravity observations were taken years ago on the two mountains it was found that the actual attractions of the mountains masses were less than the computed amounts based on their bulks and average specific gravits of the rock of which they are composed.

One explanation of this seeming hollow condition that has been offered is that subterranean tunnels abound in the two mountains. While such tunnels might be a contributing factor to hollowness it is probably relatively unimportant. An important factor contributing to the deficiency in the mass of the mountains is the natural voids in the lava flows of which they are largely composed. The voids in an aa lava flow may be over 35 to 40 per cent. The voids in pahoehoe flows while commonly less than in aa may still be quite high especially when the imperfect contact of one flow on another is considered. The presence of intrusive bodies of high specific gravity would tend to decrease the effects of the voids.

The crushing strength of the lava is so high that one would not expect to find the percentage of voids very greatly reduced until a depth in excess of 5,000 or 6,000 feet is reached. This becomes evident when one sees a layer of very friable pumice around Kilauea supporting compacted ash beds that in places are six feet or so in thickness. R.H.F.

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No. 84 RELEASED WITHOUT COPYRIGHT RESTRICTION August 6, 1926

KILAUEA REPORT NO. 760

WEEK ENDING AUGUST 4, 1926

Issued by the Observatory, U. S. Geological Survey:
R. H. Finch, temporarily in charge.

Earth shakings continue to be quite frequent, 34 being recorded on the Observatory seismographs during the current week. Only one of the shakes was perceptible at Observatory. It occurred at 11:02 a. m. August 3 and had an indicated distance to origin of 10 miles. This earthquake was the first perceptible one at Volcano House since the last of June. None of the 102 earthquakes recorded during July was perceptible. Usually six or seven per cent of the total number of earthquakes recorded are perceptible.

On July 30, at 2:33 p. m., there was a large avalanche from one of the walls of Halemaumau. It was the largest avalanche that has been observed for some time and sent a dust cloud well above the crater rim. Despite the large number of earthquakes avalanches have not been frequent and Halemaumau is again very quiet.

The lull in tilting noted last week continues. The net result for the week was a very slight tilt to the east-southeast.

AN EASTERN MEDITERRANEAN EARTHQUAKE

An earthquake occurred in the eastern Mediterranean Sea on June 26, 1926, that was of world shaking proportions. Three world shaking earthquakes, quite widely separated, occurred within a short time. In addition to the eastern Mediterranean shake there was a quite destructive earthquake on or near the island of Sumatra on June 27 and one in the China Sea on June 29.

The Mediterranean shake appears to have been especially severe near the island of Crete. The area over which the disturbance was perceptible was rather widespread. Minor damages were reported from Egypt, houses collapsed and at least one person was killed on the island of Rhodes, and alarm and panic was caused as far west as Malta. Ceilings were shaken down in the Archeological Museum at Candia, Crete, and considerable damage was done to valuable collections.

It is interesting to note that this shake had its origin in an active volcano region. The principal manifestation of volcanic activity in this region is Santorin. Mention of Santorin, which became active in August 1925, was made in Volcano Letter No. 43, October 22, 1925. The exact location of the fault where the earthquake occurred is not yet known but it may well pass under Santorin for, according to press dispatches, an outburst of Santorin coincided in time with the occurrence of the principal earthquake shock. Crete is but 50 or 60 miles from Santorin and the island of Rhodes but little farther.

It has been said, even by students of earthquakes, that there is but little connection between strong, widely felt earthquakes and volcanoes; that all volcanic earthquakes are small. The last statement undoubtedly does apply to the majority of volcanic earthquakes but certainly not to all of them. There are many examples of strong world shaking earthquakes accompanying volcanic eruptions, among such is the 1868 earthquake that accompanied an outbreak of Mauna Loa and the earthquakes accompanying the Katmai eruption in 1912. The June 26, 1926 shake may be another example. R.H.F.

HUALALAI

Hualalai is principally known to the majority of people who know anything at all about this mountain as the source of a very spectacular lava flow in 1801. According to O. H. Emerson who recently returned from spending a few days on this mountain there is much of interest to be seen near the summit. It is covered with cones of various types, some like those of Mauna Kea or Haleakala and some like those to be found on Mauna Loa. Cones composed of mixed lava and volcanic ash may also be found. Pit craters like those on the northeast rift of Kilauea are not uncommon. Evidence of small explosions is given by angular blocks of dense material and by layers of ash overlain by more recent lava. One gains the impression that there is a great range of age between the different formations on the summit of Hualalai. R.H.F.

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No. 85 RELEASED WITHOUT COPYRIGHT RESTRICTION August 12, 1926

KILAUEA REPORT NO. 761

WEEK ENDING AUGUST 11, 1926

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

The numerous earthquakes that marked the last three weeks still continue. During the current week 50 earthquakes were recorded. In addition to this number there were spells of very small tremors that lasted for several minutes. The only earthquake that was strong enough to be perceptible occurred at 8:24 a. m. August 6.

Tilting for the week was slight to the north northwest.

Small avalanches are frequent from the walls of Halemaumau. The walls at the north and west appear to be the most active. The odor of hydrogen sulphide can frequently be detected at south rim of pit. A crack about 250 feet back from the south rim showed signs of recent movement on August 10.

SECTION OF VOLCANOLOGY, U. S. GEOLOGICAL SURVEY

There was established on July 1, 1926, a Section of Volcanology in the Geologic Branch of the Survey. Mr. W. C. Mendenhall is Chief Geologist directing the activities of the Geologic Branch in Washington. Mr. T. A. Jaggar at the Hawaiian Volcano Observatory is Volcanologist in charge of the new Section. The Section of Volcanology is empowered by act of Congress to operate volcanologic surveys, measurements and observatories in Hawaii, including subordinate stations elsewhere, and to provide and maintain laboratories and quarters for the work, and to print reports.

This establishes a government service for continuous observation of volcanic action in the United States and its dependencies, with headquarters on Kilauea volcano. In immediate effect it enlarges the scope of the Hawaiian observatory so as to create experiment stations to study volcanism in California and Alaska, these making their reports to the Hawaiian headquarters for publication and comparison. Hitherto the Hawaiian station has been the only permanent American volcano observatory.

Lassen National Park, where was staged in 1914-15 an eruption in the northern California mountains at Mount Lassen, and where there were other eruptions from 100 to 250 years ago, has been selected for the second. This second volcano observatory will be in charge of Mr. R. H. Finch, Associate Volcanologist, who has been first assistant at the Kilauea station since 1919. His task is to establish an earthquake laboratory modelled on the one in Hawaii, equip it with seismographs, man it winter and summer, and make studies also of slow movements of the mountain, of weather controls, and of underground temperatures as shown by the springs and gas vents.

The seismographic laboratory at the Hawaiian station is placed in charge of Mr. Ronald M. Wilson, topographic and geodetic engineer. Mr. Wilson becomes geodesist and mathematician to the Section of Volcanology, as aide to Mr. Jaggar in physical investigations, and will specialize in tilt measurements and change of ground levels in relation to tide-water, and in horizontal movement determined by precise triangulation. Of late years work in Japan, California and Hawaii has proved that these slow movements are of enormous importance in relation to earthquakes and volcanoes, and that they have forecasting value.

Another officer in charge of the clerical and disbursing work of the Section of Volcanology is Mr. Richmond B. Hodges, stationed at the Hawaiian laboratories. Mr. Hodges has served through the grades of junior and assistant clerk in the Washington office of the U. S. Geological Survey. He will have charge of the records, files and accounts at the Hawaiian observatory, and of part of the drafting and editing.

Mr. Jaggar has made reconnaissance of the Lassen district in 1925 and 1926. The Topographic Branch of the U. S. Geological Survey, Colonel C. H. Birdseye in charge, is now at work making a topographic administrative map of the Lassen Park and surrounding country of the National Forests. This map will be of great importance to the volcanologists. Furthermore a monograph on the recent eruption of Lassen, by Doctors Day and Allen of the Geophysical Laboratory, excellently prepares the field for permanent studies of volcanic energy there.

For the present the program of publication of the Section of Volcanology is to issue weekly reports of earth shakings, tilts, temperatures, and other volcanic phenomena observed at all stations occupied. These are given the local press in the vicinity of each observatory, and are collected every week in the Volcano Letter for wider distribution. In the Monthly Bulletin of the Hawaiian Volcano Observatory will be published the fuller illustrated reports from each station, in this as in other things the Hawaiian laboratory becoming the mother station.

The third observatory of volcanic action planned is naturally in that wonderful region almost unknown, the Aleutian mountains and islands of Alaska. That land will be reconnoitred for the purpose in 1927, and among the many volcanoes there belonging to the United States, one will be selected for laboratory study winter and summer. Financial aid to supplement the small work that the government funds can do will be essential to any thorough research in that country. T.A.J.

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No. 86 RELEASED WITHOUT COPYRIGHT RESTRICTION August 19, 1926

KILAUEA REPORT NO. 762

WEEK ENDING AUGUST 18, 1926

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

Changes at Halemaumau pit have been slight. Six places at the bottom of the talus slopes, one of them in the rock wall itself, have developed yellow sulphur stain. These places are all east, south and southwest from the bottom area, and are distinct from the places of maximum steaming. The steaming is higher on the debris slopes, and the vapor at present is not dense.

Action is confined to small slides of rock from the walls. A wait on the rim of a half hour is usually rewarded by the sight or sound of two or three small avalanches. Usually a bunch of debris from the middle of the cliff parts suddenly from its place, without evidence of what starts it. The northern walls are the favorite places. The dust of a slide rose above the rim about noon August 17.

Twenty-six earthquakes were registered for the week, all too small to be perceptible; a weekly total much less than that of the three preceding weeks. Tilting was slight NNE.

HORIZONTAL GROUND MOVEMENT IN CALIFORNIA

An interesting report by William Bowie was published in 1924 (Special Publication No. 106, U. S. Coast and Geodetic Survey, Earth Movements in California) describing results of precise triangulation in 1922 and 1923 by reoccupation of old stations in the sections Sierra Nevada to San Francisco, San Francisco to Santa Barbara, and Santa Barbara to San Diego. The immediate vicinity of Santa Barbara itself was left to be done in 1924. The Santa Barbara earthquake occurred June 29, 1925. The published report covers the southern belt from Ventura to the base line in the mountains southeast of Riverside, and the northern belt from Gaviota just west of Santa Barbara to the vicinity of the Lick Observatory. This northern belt is referred to the base line Mount Lola—Round Top in the Sierras.

As the discussion of the author of the report was written in 1924, it does not cover the Santa Barbara earthquake and was unbiased by knowledge of that earthquake. The results of the resurvey show that in the forty years following 1880 (about), the stations of the Coast Range from Monterey to Santa Barbara moved northward respectively, taking them in order southward, 4, 7, 11, 15, 20, 22, and 24 feet, the last being Gaviota station. The results for the southern belt beginning to the southeast of Los Angeles, show that the stations progressively westward from Santiago to Ventura County, after about 1890, moved southwestward and southward 1, 2, 2, 4, 5, 6, and 7 feet, the last being Chaffee station, just east of Santa Barbara, with its motion almost exactly in the opposite direction from that of Gaviota. The changes in geographic position indicated by the resurveys are based on assumptions that the base-lines in the distant mountains stood still.

It seems to the reviewer that the various writers who have described the Santa Barbara earthquake have been unduly prejudiced by the presence of east-west faults in that region, and that they have neglected this astounding trigonometric forecast of the disaster in Dr. Bowie's survey. Professor A. C. Lawson, when he heard of the 24-foot movement at Gaviota at the meeting of the American Geophysical Union in Washington about May 1, 1924, rose and asserted that this meant a coming earthquake. A year later the earthquake came.

What was the stress acting on the under-earth at Santa Barbara in the spring of 1925? Chaffee, 22 miles to the east, had migrated south; Gaviota, 28 miles to the west, had migrated enormously north. The earth crust under Santa Barbara was strained to the breaking point, and the whole mosaic of mountain blocks suddenly yielded, with jarring, on June 29. It was not necessary that any north-south fault should show. Twenty fault-blocks may have twisted a little, a deep slab may have snapped, or deep magma may have been released intrusively.

It would appear that this work of the Coast Survey has brought earthquake forecasting into the range of quantitative measurement. T.A.J.

THE FORMATION OF AA AND PAHOEHOE LAVA

The question of how aa or clinkery lava is formed occupies considerable space in scientific literature. Nearly all of the discussions have been largely of a philosophical nature and but limited portions have been based on chemical analysis, close observations in the field, or on experiments.

A paper on "The Formation of Aa and Pahoehoe" by O. H Emerson, American Journal of Science, Vol. 12, Aug. 1926, gives a discussion of the artificial formation of aa lava. In an effort to produce aa artificially Mr. Emerson melted some powdered pahoehoe in a crucible and stirred it constantly while it was slowly cooling. While the interior remained fluid for several minutes a pahoehoe skin quickly formed on the surface. When the solidified mass was broken open it was found that the interior was essentially crystalline and that the hole formed by the stirring was lined with typical aa arborescence. Repetition of the experiment gave the same result- In one case pulverized aa was used and there was no essential difference in the result. Crystallization taking place while the flow is in motion seems to be a real factor in the production of aa. The question of the limiting conditions of temperature, gas content, and degree of crystallization in controlling types of lava flows needs more investigation.

Mr. Emerson omitted part of the history of his experiments. The method was suggested by the undersigned to see if the natural mechanical stirring in a flow was a factor in the production of aa. A first test at Hawaiian Volcano Observatory gave only pahoehoe lava because the lack of sufficient heat made it impossible to stir the melt. R.H.F.

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No. 87 RELEASED WITHOUT COPYRIGHT RESTRICTION August 26, 1926

KILAUEA REPORT NO. 763

WEEK ENDING AUGUST 25, 1926

Issued by the Observatory, U S. Geological Survey:
T. A. Jaggar, Official in charge

Changes have been very slight at Halemaumau pit of Kilauea volcano during the past week. The very heavy rain of the 20th and 21st, amounting to 8.42 inches at Kilauea Observatory, washed away much of the sulphur stain at the solfataras in the bottom, and deepened the red of the walls.

Again the seismograph shows great numbers of very feeble tremors. The total number for the week was 58. A feeble shock at 2:19 a. m. August 24 had origin at distance indicated as 18 miles. Tremors were frequent the forenoon of the 20th. Tilt was light NNW. A weak teleseism at 7:22 p. m. August 24 had distance to center indicated as 3600 miles.

LAVA DOME AT SANTA MARIA 1922-25

Santa Maria volcano in western Guatemala, after an interval of twenty years, has followed its explosive and engulfment eruption of 1902, with a lava-plug eruption of three years' duration beginning June 29, 1922. (K. Sapper, Zeitschrift fur Vulkanologie, 1926, Vol. IX, pp. 156-200, 14 plates. Die vulkanische Tatigkeit in Mittel-Amerika im 20. Jahrhundert. I Teil).

The 1902 outburst left a great hole in the southwest flank of the mountain at about 6500 feet elevation. This engulfment crater was left 3300 feet across and 800 feet deep to the geyser like lake of boiling water spouting and making sulphurous fumes until after 1906. Thereafter the volcano became quiet.

In 1922 at the end of June the same crater sent up cauliflower clouds of dust and made rumblings and small localized earthquakes and electric storms. Mr. G. Hurter of Quetzaltenango on August 13th photographed the new rounded dome of aa lava which had risen from a fissure in the bottom debris of the crater, and already had reached a height 300 feet above its lower lip. There was much growing of the heap during four months, with rumblings, fume jets, crashing of debris down slopes, and sulphurous coatings. There was glow at night illumining dust jets that were mistaken for flames. Explosive eruptions making light ash falls were frequent. October brought temporary decline.

This Cumulo-dome was of the same type as the Pelee heap of 1903, that of Bogoslof of 1907, that of Tarumai in 1909, and similar to that of Kilauea in 1888. The Lassen plug of 1915 appears to have been much the same These domes have all the features of stiff lava flows, forced by the topography to pile upward instead of streaming downhill. When the Hoopuloa flow on Mauna Loa in April, 1926 accumulated at the shore below a steep slope above, it formed a circular heap with spiny top and red hot slide slopes closely resembling the photographs from Santa Maria.

The Hurter photographs present a series of eighteen taken on successive dates for three years, wonderful pictures showing the growth of this Santa Maria lava hill, all from the same viewpoint. These are the plates in Dr. Sapper's monograph. In 1923 the flow took a fresh spurt enlarging the dome, which preserved a finely serrate profile. It had made a great growth by May. At the beginning of 1923 it was 800 feet high and 3300 feet across. It swelled further and overlapped the old crater edge. It became craggy, square-topped and massive, always fuming and glowing, in 1924. On June 1, 1924 a spine 200 feet above the top of the heap had pushed itself up through a chasm in the crest. This was quite like the Pelee tower or the Bogoslof fin. The growth stopped in 1925, leaving the new structure 1600 feet high above its base and 4000 feet across. Its top was now a wide cluster of castles, turrets, spires, domes and buttresses, surrounded by sweeping talus slopes. T.A.J.

VOLCANIC HISTORY OF OREGON

A remarkably interesting and beautifully illustrated book entitled "Mount Multnomah, ancient ancestor of the Three Sisters, by Edwin T. Hodge," has been published by the University of Oregon, Eugene, Oregon (Aug. 1, 1925). This book is for the use of geologists, mountain climbers and nature lovers, is illustrated by superb photographs and excellent block diagrams and maps, discusses the history of the Cascade Plateau, the climate, flora and fauna of the volcanoes called "the Three Sisters," and is a model of good scientific book-making, condensation, colorful writing and clear explanation. I have never seen block perspectives of landscape used to better purpose in association with photographs of the landscapes themselves.

Professor Hodge concludes that a 15,000-foot volcano once lay over the site of the Three Sisters, built above the post-Eocene Cascade fault that extends north and south along what is now the "break" between the Cascade Plateau and the rugged gorges to the west. In Oregon eighteen volcanoes lie along this fault today. In "Multnomah" a Mauna Loa of basalt was built up in Miocene time. Thereafter it collapsed or blew up or both, and enormous engulfment occurred. A circular fault eight miles in diameter bordered the sink. Streams cut back into the sink, but in Middle Pliocene two sister volcanoes were built up within it. Then more volcanoes arose, followed by glaciation. The Oregon block sank again after the Ice Age, and revivified the volcanism, which continues to the present day. T.A.J.

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No. 88 RELEASED WITHOUT COPYRIGHT RESTRICTION September 2, 1926

KILAUEA REPORT NO. 764

WEEK ENDING SEPTEMBER 1, 1926

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

Small avalanches have continued in Halemaumau pit and are notably conspicuous at present at northeast wall. These slides have undermined so as to reveal fresh rock for several hundred feet below the rim, and the ground above is heavily cracked and threatens to wreck the northeast trig station in the near future. During temporary visits about four avalanches are seen in a half hour and many falls of small stones. Some of these were observed this morning, September 1, also from the western wall, and there also the dirt is freshly cracked along fissures back from the rim of the pit. A dyke of light-colored rock was observed in the middle portion of the northeast wall. At the foot of this wall the talus heap has been growing higher during several months past, and now tends to rival the southwest heap in height. These two are just opposite each other, which suggests that the major caving away is along a line trending toward Kilauea Iki.

Recent rains have increased the volume of visible steam in the bottom of the pit, and the fuming patch at the base of the south talus appears very hot and sulphurous. Another at the base of the east talus is making yellow sulphur.

Unusually large numbers of very small local earthquakes have been registered on the seismograph. The total number counted for the week was 107. Tremors in addition to the measured movements were frequent on August 27, 28, and 29, particularly during the forenoon of the 27th. At 2:21 p. m. August 31 a faint teleseism was registered without distinct phases. The tilt for the week was slight to the SSW.

The increase in tremors may possibly forecast new activity in either Mauna Loa or Kilauea. There was a remarkable cloud over Mauna Loa at 6 p. m. August 30 that suggested volcanic fume. Some of the local earthquakes appear on the seismograms like avalanche tremors from Kilauea, others seem to indicate a Mauna Loa distance of origin.

PHOTOGRAPHIC RECORD OF LASSEN VOLCANO

In May of 1914, when Lassen Volcano, on the borderland between the Sierra Nevada and Cascade Ranges, broke into eruption, the newspapers were incredulous. It was known that at the Cinder Cone, in the eastern part of what is now Lassen National Park, there had been a lava flow some 250 years ago. Nothing is known of what then happened at Lassen Peak, a big volcano of the same class as Mount Shasta, with a shallow crater depression and pool of water in its top. It has been the custom to connect Lassen Peak with the Cinder Cone and its lava flow, but the two are 12 miles apart and there is no obvious relation between them.

In 1914, the old crater depression in the top of Lassen Peak began to eject dust and steam through small caved-in depressions of the summit. These depressions engulfed the rock of their margins until they had united into a single crater hole apparently at the junction point of several cracks in the mountain mass. The forester's Lookout House became gradually destroyed by falling stones in a sucession of explosions which increased in vigor and in numbers. The eruptions occurred every few days and rarely lasted more than 20 minutes. In the two years 1914 and 1915 the month of May appears to have been the critical one for Lassen, for the first outbreak was May 30, 1914, and the maximum explosion was on May 22, 1915.

Mr. B. F. Loomis, proprietor of the hotel at Viola, is an energetic photographer who has compiled a "Pictorial History of Lassen Volcano" (published by Anderson Valley News Press, Anderson, Cal., 1926). This book is not only a useful guide to Lassen National Park, but contains a critical review, illustrated by many photographs of the activity of 1914-15. Mr. Loomis cites the opinions of Messrs. Diller, Day, Allen, and Holway in their published statements about the Lassen eruption, and reaches some conclusions of his own, backed up by photographic evidence, that are of interest.

The chief of these is to the effect that the eruption of May 19, 1915, produced merely a flood of water and ash which devastated the northeastern creeks without throwing down trees. With this eruption there was no down-rushing blast of steam capable of melting snow to cause the flood. The much bigger eruption of May 22, on the other hand, produced a down-rushing steam blast which is photographically shown to have overturned trees and cut a V-shaped swath through the forest to the northeast for four or five miles. The action in both cases was quite like that of the volcano Pelee in Martinique, which also began with a flood and ended with a blast.

Loomis believes that both Lassen eruptions gave vent to liquid water from the mountain itself, followed by steam, and his pictures of mud torrents from the very summit appear to bear out his belief. The photographs also suggest very strongly that the plug of lava breccia which rose to fill the new crater, overflowed the west lip in a definite aa lava flow, which according to him was seen flowing and glowing. T.A.J.

SAMPLE COPY

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No. 89 RELEASED WITHOUT COPYRIGHT RESTRICTION September 9, 1926

KILAUEA REPORT No. 765

WEEK ENDING SEPTEMBER 8, 1926

Issued by the Observatory, U S. Geological Survey:
T. A. Jaggar, Official in charge

Few changes have taken place in the pit of Kilauea Volcano during the past week. Occasional small rock slides and avalanches occur at intervals, causing thin dust to rise from the pit. Dust from these slides was observed several times during the day on September 6. Dust from a slide was observed a few minutes before 8 a. m. on the 7th, at which time a spasmodic tremor was recorded by the seismographs, suggesting correlation between the two occurences.

The seismographs record 81 tremors for the week, for the most part very feeble. One exception was a local feeble earthquake at 5:38 p. m. September 1, which was perceptible to many people at the Volcano House and others in the vicinity. During the afternoon and evening of September 2 the very feeble tremors were most frequent, 27 being recorded during that time, being a third of the number recorded for the entire week. Of these, several exhibited phases indicating the distance to their origin to be about 35 miles. In contrast to this period of time with many tremors, it is of interest to note that during the 24 hours from 8 a. m. September 7, to 8 a m. September 8, only one very feeble tremor is recorded. The records show two faint teleseisms, having phases so indistinct as to prohibit the calculation of the distance to their origins, one at 5:17 a. m. September 4, and the other at 2:03 a. m. September 7.

A slight tilt to the north has accumulated during the week. R.M.W.

BORING AT CALIFORNIA GEYSERS

An article in the Oil Weekly (February 2, 1926) describes drilling for steam at the "Geysers," Sonoma County, California. A number of wells have been opened with a view to harnessing steam power to furnish electricity. J. D. Grant drilled two wells with churn rig and cable tools in something over two years. The rock is sandstone and hard serpentine. The Geysers Development Company are using a rotary drill with hydraulic feed, which permits putting extra pressure on the Hughes cone bit. A system of valves to protect the workmen and control the wind is used. Mud is pumped through the drill rod and returns through a special valve. The serpentine cap rock is said to be from 200 to 400 feet thick.

The temperature of the hole reached a dull red heat, 998 degrees Fahrenheit. Seven wells were drilled with Hughes bit to some 500 feet each in less than two months to each well, and the cone bits stood this temperature. In one well, four sets of hardened steel cones were dulled in drilling 277 feet of 9¾-inch hole in hard rock. At a depth of 451 feet such a steam pressure was encountered that the uprush of rocks, mud, and steam at the casing head wrecked the timbers.

To deal with these forces, casing is cemented from top to bottom; in the latest wells the upper casing is 15 inches in diameter, and the lower 10 inches. Steam pressure increases with the depth. The well cited above developed 67 pounds pressure at 228 feet, 169 pounds at 416 feet, and another well developed 240 pounds at 486 feet. A runway is built from the upper derrick off to the hillside, to save the derrick man in case of a steam blowout. T.A.J.

TOKYO SHORELINE ELEVATION

The Kwanto District around Tokyo and Yokohama not only had blocks of the bottom of Sagami Bay dropped and elevated hundreds of feet, at the time of the 1923 earthquake, but the land tilted This tilt was from southeast to northwest, with a depression in the interior country, and elevation of some two meters at the peninsulas. These two peninsulas, moreover, at the entrance to Tokyo Bay, have moved horizontally towards the southwest four (Boshu) and two (Miura) meters. The coasts had been sinking a half meter or so in the half century preceding the disaster. (On the Recurrence of Destructive Earthquakes in Southeast Japan during 2,000 years, A. Imamura, Proc Imp. Acad. Jap. 1926, Vol. 2, No. 6).

The tide gauges showed gradual lowering of the shore for 38 years, and sudden elevation at time of earthquake They also show nine-year and eighteen-year periodic oscillations of several centimeters.

Professor Imamura has traced old shorelines suddenly uplifted during earlier big earthquakes at Misaki on the Miura peninsula. These earthquakes occurred A. D. 33, 818, 1703, and 1923. The different benches have been allocated to their proper earthquake date by relative erosion of the standard holes in the cliff of the boring shell **Lithophaga nasuta** The shell works at sea-level. The cliff has been etched back since elevation at the rate six millimeters in 220 years. The shell holes make sea-level belts which are identifiable History records great earthquakes that check with the shell-hole-erosion data.

On this basis the bench of the 1703 earthquake was elevated 5.5 meters at the tip of Boshu peninsula, and that of the year 818 A. D., 4.7 meters—both of these more than double the uplift of 1923. T.A.J.

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No. 90 RELEASED WITHOUT COPYRIGHT RESTRICTION September 16, 1926

KILAUEA REPORT No. 766

WEEK ENDING SEPTEMBER 15, 1926

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

Halemaumau pit at Kilauea Volcano is always different from the other pits, such as Kilauea Iki and the Chain of Craters, in that the walls are sliding and the rim enlarging. The avalanches eating away the northeast rim, as noted September 1, have accomplished their threat of destroying the northeast flag station. This monument was installed last April, and was found to have gone on September 12. It was probably carried away by the morning slide of the 7th.

On September 12 slides were frequent. Today they were not observed during a half hour. There is fresh, red dust on the slopes, and a new bowlder on the floor has left a gray trail. The south talus solfatara makes blue fume in hot puffs. In many places the rock wall of the pit steams on the inner faces.

Seventy-three earthquakes were registered in the seven days prior to the morning of September 15. The frequency and intensity of instrumental earthquakes has increased since September 8. On that day there were four; on September 14 there were 17, of which three were almost big enough to be felt. Additional spells of volcanic tremor appeared on September 14 and 15. Tilt for the week was slight SSE.

NEW ZEALAND VOLCANIC ACTIVITY

Recent files of the New Zealand Herald (Auckland) beginning in April, 1926, report earthquakes and volcanic activities along the Taupo belt of the North Island from Ngauruhoe Volcano to White Island Volcano in the Bay of Plenty.

A local earthquake was felt at Christchurch March 31. April 8 there was comment on submarine disturbance near White Island causing disappearance of the fish. A cutter in 1886, during the great Tarawera eruption, in the same waters, ran into muddied sea, floating weed, and dead and dying fish. Near Mercury Bay there are hot water springs. Ngauruhoe opened a new vent with explosion and detonations April 16. The shores of the Bay of Plenty felt a sharp earthquake April 18, time said to be 10:45 p. m. at White Island. All of this was simultaneous with the outbreak of Mauna Loa in Hawaii.

From Waimarino April 24 enormous clouds of black dust along with bowlders were seen rising from Ngauruhoe for two hours. Detonations and severe vibrations were reported from other places, and brilliant glow at the crater in the evening. Campers near the mountain described shots like cannon, the noise of stones falling, rumblings, and one tremendous report after daybreak April 25 which sent up black smoke 1,500 feet. One message described "tongues of flame."

April 12 (after the activity of Mauna Loa in Hawaii had begun) earthquakes were reported from Fiji and the Marshall Islands. About May 1 the rumblings from Ngauruhoe were heard in the Gisborne district. The Tongariro National Park reported vibrations and volumes of explosion clouds from Ngauruhoe May 12. May 15 the activity increased, with loud reports, glow, and red-hot bowlders. At 7:45 p. m. a wide streak of fire extended down the mountainside. Bowlders rolling down the slopes prevented approach.

The maximum paroxysms were evidently at this time. From the railway to the west, May 17, "great gusts of light burst up from the crater." The fume column was estimated 6,000 feet in height, and was seen from Wanganui 60 miles away. Taupo reported frequent "shots" from the crater, jets of black smoke 2,000 feet high, with concussion that rattled windows, earth tremors, and "flame" visible from there.

A photographer reported May 18 a great roar, prolonged shaking, and a tremendous shot: the lips of the crater were a vivid red with flame, while bowlders of 10 to 20 tons crashed red-hot down all sides of the mountain with regular monotony. These were discernible in daytime five miles away. The snow of Tongariro was buried under the ash of Ngauruhoe. A sharp earthquake occurred May 20. Two notices of this period describe "a stream of lava through a hole in the lip of the crater," probably glowing slides of debris.

May 28 the volcano was sending white steam straight up, and was quieter. May 31 glow was still seen. June 1 a sharp earthquake was felt at Gisborne, and at the Bay of Plenty. Another occurred in the South Island June 6.

June 5 an ascent of Ngauruhoe was made; varicolored fume rose, first white, then black; there was a notch in the north lip, the crater appeared 600 feet deep, and down below what appeared to be "dark-red and blue flame" rose in glimpses 40 to 50 feet above the surface of "molten lava." The former crater floor was covered with sand and split by huge fissures which suggested coming engulfment. There was roaring noise.

July 2 a sharp local earthquake was felt at Taupo and a succession of shocks occurred July 5 in the north end of the South Island. July 8 White Island appeared to make unusual clouds of steam. July 30 a tremor was felt at Taupo and both Ngauruhoe and Tongariro showed symptoms of increased "activity" of steaming.

Such is what can be made out of press notices. It is to be hoped that the volcano observer of the Government will soon be sending us official reports; clearly there has been abundant work for a New Zealand volcanologist during the past six months. T.A.J.

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No. 91 RELEASED WITHOUT COPYRIGHT RESTRICTION September 23, 1926

KILAUEA REPORT No. 767

WEEK ENDING SEPTEMBER 22, 1926

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

On September 19 the only developments of the last week noticed at Halemaumau pit were stains of yellow sulphur and white alum on the rock slope at foot of southeast wall. On September 21 fresh gray rock fragments lay at foot of northeast wall. A line of sulphur stain at base of east talus has increased. Rock slides have not been seen lately.

Forty-four local earthquakes were registered for the week, and tilt was moderate to the NE. A distant earthquakequake was well registered at 7:38 a. m., September 16. Its preliminary phase indicated distance of origin 3,630 miles and direction southwesterly, suggesting New Caledonia. Its time of occurrence at the origin by this should have been Greenwich civil time 17 h. 59 m. 08 s. Science Service and the U. S. Coast and Geodetic Survey from records of seven stations made the origin west of the New Hebrides and the time 17 h. 59 m. G. C. T. Another weak teleseism occurred September 17, 12:59 p. m.

EARTHQUAKE IN ENGLAND

Just as the United States in 1925 was stirred by earthquake peril, so now England is in the throes of a paroxysm. The Channel Islands started the excitement August 1, with a shock in Jersey about 2 p. m. which wrecked chimney stacks and broke gas pipes. This was felt on the coasts of England and France. There were rumbling noises and rocking at Jersey that lasted several seconds, throwing over wall cases of merchandise and bringing down ceiling plaster and pictures. The vicinity of the Channel Isles is a recognized seismic center.

On August 15, 1926, a shock in the Hereford district of England, to the east of Wales, shook some 40,000 square miles of the most densely populated parts of England. Davison reviewed the happening in the Birmingham **Post** August 20. A similar but more extensive earthquake had shaken Birmingham and centered near Hereford in December, 1896, with 98,000 square miles as the area shaken, including the Isle of Man and Southeastern Ireland.

The 1926 shock produced great alarm but little damage. Chimneys fell between Ludlow and Hereford. This was the principal epicenter, and a radius of 150 miles from there probably includes all places of felt quaking. The 1896 quake and earlier ones in the same district had two centers, near Hereford and Ross, respectively, the double earthquake in each case producing maxima almost simultaneously in the two places, but stronger sometimes at the Ross center, sometimes at the Hereford. Hereford is said to be a place of faulting.

Morrell in the "Graphic" suggests that Hereford and South Wales are not far from volcanic matter below. Fifty miles to the south is Bath, where "the water constantly wells up from those superheated depths at a temperature of 120 degrees Fahrenheit. A volume of some 180,000 galloons of warm water is thus literally erupted daily, and this process has been going on for ages." Judd pointed out that this "is a slight manifestation of volcanic activity." Thirty miles west of Hereford are sulphurous wells in old volcanic rocks.

Oldham (Nature, August 28, 1926), on the basis of a formula dependent on area of felt shock, maximum intensity, and meaning of the word "perceptible," estimates the depth of origin at 30 miles; but he makes the diameter of the region of felt shock less than Davison, so that the depth may be nearer 40 miles. He makes the maximum violence number six of Mercalli's scale (Rossi-Forel seven).

The greatest of the English earthquakes was probably the Colchester shock at the east coast. 50 miles northeast of London, April 22, 1884, with twin centers near Rowhedge and Peldon, where most of the houses were damaged. Houses in 24 towns to the number of 1,213, including 31 churches, required repair. The maximum intensity was Rossi-Forel 9. The damage was greatest in low river grounds.

The area shaken was more than 100,000 square miles, and the shock was felt in France and Belgium. Sounds were heard 198 miles from the center. At London and Cambridge the intensity was R-F 6. T.A.J.

NATURAL HORSEPOWER

The horsepower in industry of the United States is 190 million ,of which 111 million is coal-produced, 67 million petroleum, and 12.3 million falling water. Great Britian uses 45 million horsepower, Germany 41.5 million, France 17.8 million, and Canada 10 million. (Compressed Air Magazine, September 1926.)

The total world horsepower resource in falling water is about 450 million, of which only 30 million is used. There is thus in sight enough water power to replace all present-day fuel when the latter is exhausted. This is without counting volcanic steam power and future development of direct solar energy and the tides. T.A.J.

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No. 92 RELEASED WITHOUT COPYRIGHT RESTRICTION September 30, 1926

KILAUEA REPORT No. 768

WEEK ENDING SEPTEMBER 29, 1926

Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in charge

The period leading up to the equinox showed a notable growth in numbers of small local earthquakes and tremors at Kilauea, but no volcanic activity has yet appeared. Beginning with the week-end August 18, the weekly numbers of shocks at the Observatory recorded by seismographs were sucessively 26, 58, 107, 81, 73, 44; and this week the number is 27. Such a curve of waxing and waning frequency has some volcanic meaning, and the weeks of large numbers showed many small avalanches at Halemaumau, which however seemed to be effects rather than causes of the shakings.

The past week has produced no slides that have been seen and no marked changes at the pit.

Besides the 27 earthquakes, microtremors were a little stronger than usual the first part of the week. There were other very minute volcanic tremors on the 22nd and the 23rd. The tilt was slight to the NNE, and during the past two weeks about two seconds of angular tilt to the east has accumulated. This is the third pronounced bend in the tilt curve away from westerly in the past six months. The first accompanied the Mauna Loa eruption. The second occurred about the June solstice. And the present one is the usual seasonal eastward tilt of the autumn.

CONCLUSIONS CONCERNING VESUVIUS

Reviewing observation of Vesuvius for twenty years as recorded in Perret's monograph (The Vesuvius Eruption of 1906; Study of a Volcanic Cycle. Frank A. Perret. Publication 339, Carnegie Institution of Washington, 151 pages, 25 plates, 1924), Dr. A. L. Day cites conclusions drawn from Vesuvius by the volcano workers of the Geophysical Laboratory. (Annual Report Director Geophysical Laboratory, 1925, Carnegie Institution Year-Book).

The pre-eruption period was 1903-06, the great paroxysm April 1906, the repose period 1906-1913, and the new eruptive period 1913-1921. Fumaroles were formed during the repose period, and the enlarged crater was gradually filled in by break-down of the walls, and after 1913 by effusion of lavas on the pit floor. The post-1913 period constitutes the beginning of a new cycle that will lead to another paroxysm.

"It is of interest to note that although lava flows developed during the eruption, the most intense activity appeared to center in the discharge of the volatile components, carried in solution in the magma in enormous quantity; and in particular with increasing concentration as greater depths within the lava column became exposed by the release of overlying pressure. It is pointed out that some, perhaps a considerable portion, of this tremendous volume of volatile material may have come from the sea nearby, and it is intimated that the gradual filling up of the crater between one extravasation and the next represents reactions in which infiltrating sea-water plays a major part, though what manner of connection exists between the sea and the volcano hearth is still unknown."

"Some years ago it was demonstrated by Johnston and his associates in the Geophysical Laboratory, that capillary forces could not properly be invoked to account for accessions of water into regions containing fluid magma; but no such limitation prevents the circulation, in appropriate channels, of (gaseous) water above its critical temperature or indeed of liquid water through supercapillary openings, such as may very well be supposed to exist near a center of explosive activity."

"It was observed further that other volatile ingredients of a chemically active kind, such as chlorine, fluorine and sulphur, were conspicuously in evidence in the preliminary stages of the eruption, but as the period of maximum intensity approached, there appears to be no evidence of any of them in quantities sufficient to affect the sense of smell. The great outpouring of volatile matter at the height of the eruption appears therefore to be water vapor, as it has also been shown to be at Lassen Peak."

Two facts emerge in this analysis, of great interest to those who studied the explosive eruption of Kilauea in 1924. One is that underground water is unreservedly appealed to as the source of volatile matter in the explosive phase of the eruption of 1906 at Vesuvius. The other is that the lava gases of the earlier phases are admittedly different, strong chemical acids. The pre-eruption period of lava flows and a full terminal crater occurred in the three years preceding the Kilauea eruption just as at Vesuvius. The forceful agent in the Kilauea explosions was pure steam, quite different from the acid gas of the great lava lake of only three months before. All of this parallels Vesuvius. But Vesuvius differed from Kilauea in that it mingled a luminous liquid-lava phase with explosion at first. Then came the paroxysmal emission of gas like Kilauea May 17-18). Then the Vesuvian "dark, ash phase" corresponding to the avalanching and earthquake maxima of Kilauea May 21 and 24.

It appears to the reviewer that this phase was a tremendous engulfment of crater rock at Vesuvius just as at Kilauea. T.A.J.

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No. 93 RELEASED WITHOUT COPYRIGHT RESTRICTION October 7, 1926

KILAUEA REPORT No. 769

WEEK ENDING OCTOBER 6, 1926

Issued by the Observatory, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

During the past week there has been no appreciable change in the pit of Halemaumau. There have been no slides or avalanches noted, nor any change in the amount of vapor. The total number of earthquakes for the week is only 25, showing that the number of earthquakes is still diminishing. The week's earthquakes have all been very feeble, of the local spasmodic tremor type, with the exception of a feeble trace of a teleseism which occurred at about 8:45 a. m. Hawaiian time on October 3. The fact that eartbquakes have been so few and feeble is probably connected with the lack of slides and avalanches. Tilt has been very slight during the week, to the NNE, but of insufficient amount to continue the eastward trend of the tilt curve that has been exhibited during the last two weeks.

THE TIDAL WAVE ON PALMERSTON ISLAND

The Sheffield "Telegraph" (Great Britain) of August 10, 1920, tells of a tidal wave on Palmerston Island, about 300 miles northwest of Raratonga, probably on May 12, 1926. Only one life was lost, but all the buildings excepting the church were swept away, and the population, about 100 in number, were left without homes and property, and with ony very scant means of sustenance. Hand-caught fish, and cocoanuts enabled them to live till relief came.

The "Telegraph" says: "The destitute condition of the inhabitants was revealed only when Sir Maui Pomare, the New Zealand Minister of Health and a Maori, on the New Zealand government steamer Hinemoa, touched there on an inspection tour. Supplies were landed and a relief ship ordered immediately from Raratonga."

The coming of tidal waves has many times been heralded by the more speedily propagated earthquake waves recorded on seismographs. Nature has thus arranged to send a message of warning, that only requires interpretation to make it possible, by preparation, to minimize the damage done by a tidal wave. The interpretation and preparation require time, and the message would hardly have been of assistance to the people on Palmerston Island without wireless. But it is conceivable that such a seismic message might still have been put to use, in suggesting to the outside world that these people were in trouble, and so have shortened their period of privation.

EARTHQJUAKE WAVES

In the Proceedings of the Imperial Academy (Japan March, 1926), A. Imamura shows that in some cases a long wave motion may preceed or travel along with the usual "P" wave in the propagation of seismic disturbances. In this paper Mr. Imamura indicates the difficulty encountered in separating on the seismograms the effect of slow motions horizontally to and fro and of tilting back and forth without horizontal motion. The trace of some of these early long waves strongly suggested the curve resulting on the seismogram when the instrument was known to have undergone sudden tilt. Mr. Imamura therefore analyzed these waves from the tilt point of view, and states that the results of his investigation appear to favor the idea of explaining them in this manner. Whether these waves of tilting are propagated in that particular form from the origin, or locally induced by the regular "P" wave, is left as an open question R.M.W.

PRECISE LEVELS ON MAUNA LOA

Lieutenant Simmons, of the U. S. Coast and Geodetic Survey, is this week begining work on the line of precise levels to be run from Hilo, via the Volcano of Kilauea, to the summit of Mauna Loa. This line of levels, in addition to making a determination of the elevation of the summit of Mauna Loa, will also provide means of establishing bench marks upon which later leveling may be done. to secure evidences of possible changes of elevation. This work should yield very interesting results when considered in connection with the tilting of the ground as recorded by the seismographs at the Hawaiian Volcano Observatory. R.M.W.

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No. 94 RELEASED WITHOUT COPYRIGHT RESTRICTION October 14, 1926

KILAUEA REPORT No. 770

WEEK ENDING OCTOBER 13, 1926

Issued by the Observatory, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

At the pit of Halemaumau there has been no activity of note during the past week, with the exception of an occasional avalanche, of which the most striking was one noted at about 9 a. m. on October 12 by a number of people at the Volcano House. The number of earthquakes for the week is only 12, being a very considerable decrease from the number of last week. This continual decrease in the number of earthquakes per week has been continuing for the past two months. There were three days this week upon which no earthquakes were recorded during the 24 hours, October 7, 11, and 12. Of the 12 earthquakes recorded there were two worthy of note. One local shock which occurred at 5:41 p. m. on October 9 was almost intense enough to be felt and lasted for nearly two minutes. The other quake is a teleseism of which the "P" wave began at 8:45:04 a. m. October 13, Hawaiian standard time. The indicated distance is 2,370 miles. Owing to the weakness of the initial motion of the "P" wave, it is difficult to estimate the direction. The entire disturbance as recorded on the seismographs lasted over an hour before the waves completely faded out.

Microseisms during the first part of the week were somewhat stronger than usual. The accumulated tilt has been only very slightly towards the west.

EARTHQUAKES AND EARTH ROTATION

In the "Transactions of the Astronomical Observatory of Yale University," Volume 3, Part VI, Dr. E. W. Brown has set forth his investigation of the constancy of the earth's rate of rotation. This is especially interesting from the point of view of Seismology and Volcanology in that the cause of these changes in rate of rotation is ascribed to geophysical changes within the earth itself. To change the rotational momentum of the earth, some gain or loss of either its mass or its impounded kinetic energy of rotation must take place. Its rotational kinetic energy is drained slightly by tidal friction. This effect is well understood and has been corrected for in the investigation. But apparently there still remain unexplained changes in the rate of rotation, in addition to the retardation explainable by tidal friction. Rate of rotation, mass and distribution of mass (moment of inertia) are factors making up rotational momentum. It is therefore possible to alter the rate of rotation, and yet retain rotational momentum and mass unchanged, by altering the distribution of the mass. Thus if the earth expands, its mass is distributed on the whole somewhat farther from the axis of rotation, its moment of inertia is greater, and therefore its rate of rotation may be slower, without loss or gain of mass or energy. An example of this effect may be had by swinging a weight on a string in a complete circle, allowing the string to wind up on the finger—the shortening of the radius will speed up rotation without the input of any more energy.

Dr. Brown suggests periodic expansion and contraction of the earth, in amount between five inches and twelve feet change of mean radius, as an explanation of the apparent fluctuations in rate of the earth's rotation. These fluctuations in rate are detected astronomically in the discrepancies developed between the computed and observed places of the moon and sun. That is, using time as derived from orbital motions and the gravitational theory the earth appears to run ahead or behind its mean rate of rotation by a slight amount, so that in the course of years a few seconds may be gained, then lost, and gained again.

If this is to be explained by the shrinking and expanding of the earth, one might expect to find evidences of it here beneath our feet. Dr. Brown reasons that this amount of change would by no means be enough, in itself, to stretch or shrink the crust of the earth to the point of fracture. But these periodic strains in the crust of the earth may be enough to liberate or shake loose greater strains accumulated almost to the breaking point through other causes—isostatic compensation for example. The investigation shows, in fact, that there is apparently a rough correlation between frequency of earthquakes and change of rate of rotation. Astronomy has, therefore, brought a direct challenge into the realm of geophysics.

R.M.W.

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No. 95 RELEASED WITHOUT COPYRIGHT RESTRICTION October 21, 1926

KILAUEA REPORT No. 771

WEEK ENDING OCTOBER 20, 1926

Issued by the Observatory, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

During the past week there have been no notable changes at the pit of Halemaumau. The seismographs show very few earthquakes, there being only 12 very feeble ones recorded for the week. On the 14th and 15th microseisms were somewhat stronger than usual, and on the 16th there were very faint evidences of occasional spasmodic tremors which have not been included in the count above. There has been moderate tilt towards the east accumulating during the week.

Last week, just as the Volcano Letter was being prepared, a strong teleseism was received which was described at that time. The records from the seismographs at Hilo, Kealakekua, and Hilea, which have since been received, also recorded this earthquake.

A letter from Mr. R. H. Finch, who is in charge of establishing the Geological Survey volcano observatory at Mount Lassen, California, has just been received. Mr. Finch states that the excavation for the seismograph cellar is well under way and he expects to have the seismographs in operation by the end of this month.

Lieutenant L. G. Simmons of the Coast and Geodetic Survey is now camped at the Rest House at an elevation of about 10,000 feet on Mauna Loa. He is endeavoring to complete the upper end of the precise level line before the coming of winter weather. This level line, as stated in a previous Volcano Letter, is to be run between sea level and the summit of Mauna Loa. The work is being done with the high degree of accuracy usual in precise levels, being run independently in both directions with a standard prism level, and level rods having the graduations on invar metal. The U. S. Coast and Geodetic Survey is also planning this winter to make observations for gravity at the summit of Mauna Loa and also to establish a standard tide gauge at Hilo. These precise geodetic surveys will be of invaluable assistance in learning more of the activities within Mauna Loa.

The University World Cruise, a floating college comprising a full faculty and students to the number of about 570 persons, visited the volcano on the 18th. On the 19th the Los Angeles Chamber of Commerce visited the volcano with 107 persons in its party. These two days, therefore, brought a flood of visitors, many of whom were much interested in seismology and volcanology.

EARTHQUAKES DUE TO COLLAPSE

An extract from the Johannesburg "Star" (Transvaal) tells of the establishment 16 years ago of a seismograph at the Union Observatory in that city. This instrument was established to study the earthquakes felt in the vicinity of extensive mines at that place, to determine whether the quakes were of natural origin or were caused by settling and collapse due to mining excavations. In the early days, before the ground had been honeycombed by mining operations, no earthquakes had been noticeable, but in 1905 earthquakes began to occur with increasing frequency. In 14 years, following the establishment of the seismograph in 1910, there were recorded 5,427 local shocks of which about one-seventh were classed as strong. These earthquakes tend to occur in series or batches, being most frequent in the dry season, perhaps due to lack of the binding effect of moisture in soil and rock. The fact is noted that the greater number of these earthquakes, and those having the greatest intensity, occurred during the early morning hours.

Realizing that these earthquakes were probably caused by the settling of the workings of the mines, more care was exercised in timbering and in refilling abandoned tunnels with waste material, to guard against collapse. A response to this care has been shown in the diminishing number of local earthquakes registered on the seismograph.

If earthquakes can be caused by artificial excavation, may it not be that some of our ordinary earthquakes are caused by the collapse of internal voids in the earth, such as might be left by retiring magma?

This idea is perhaps supported by evidence furnished in both of the recent eruptions on Hawaii; the explosive eruption of Kilauea on May 11, 1924, and the lava flow on Mauna Loa on April 10, 1926. In both of these cases it was during the waning phases of the eruptions that the maximum number and violence of earthquakes occurred. This may mean that the subsiding pressure or retiring magma, allowing the upper layers of the earth's crust to settle back, has caused earthquakes due to this readjustment.

R.M.W.

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No. 96 RELEASED WITHOUT COPYRIGHT RESTRICTION October 28, 1926

KILAUEA REPORT No. 772

WEEK ENDING OCTOBER 27, 1926

Issued by the Observatory, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

A few slides and avalanches in the pit of Halemaumau represent all the activity noted during the week. There have been 15 local earthquakes, all very feeble, and three teleseisms. On October 23 there were a few very minute spasmodic tremors that have not been included in the above count of earthquakes.

Two of the teleseisms were recorded on the 22nd and occurred almost precisely an hour apart, their maxima coming at 2:21 a. m. and 3:21 a. m., respectively, Honolulu time. These earthquakes, according to Associated Press report from San Francisco, were sharply felt in San Francisco at 4:35 and 5:36 a. m., Pacific Standard Time, which, allowing for the time difference, would be 15 minutes before they were recorded here. A peculiar circumstance is that two local earthquakes occurred almost exactly an hour apart, the first one following 16 minutes after the first teleseism, and the second local shock following the second teleseism by the same amount of time. This is perhaps no more than an interesting coincidence.

The third teleseism was on the 25th, the preliminary wave arriving at 5:26 p. m. and the main wave at 5:46 p. m., Honolulu time. The estimated distance to the origin of this earthquake is 4,440 miles. A United Press report states that this earthquake was recorded at Ewa, near Honolulu, at about 5:55 p. m., Honolulu time, the distance indicated by the record at that observatory being 4,590 miles. The accumulated tilt during the week is slightly to the SW.

AN ACHIEVEMENT

In "Science," the issue of October 1, 1926, the resolutions adopted by the American Geophysical Union are of considerable interest. That resolution concerning the determination of the value of gravity at sea is of especial interest from the point of view of seismology. It almost seems that Dr. F. A. Vening Meinesz, of the Dutch Geodetic Commission, has accomplished the impossible.

To accurately determine the value of the attraction due to gravity is a delicate operation even on land. A pendulum, swinging in a partial vacuum, is timed very carefully. The value of the attraction due to gravity is computed from the time taken for a complete swing of the pendulum, by the usual formula of phsics. But in order to attain the great accuracy necessary to discover the minute variations in gravity, there are many precautions and corrections to be applied. Rigidity of support for the pendulum, elevation above sea level, and accurate time are matters of prime importance which on land can be satisfactorily attended to. But at sea complications are introduced that seem almost insurmountable. There can be no rigid support for the pendulum—a ship at sea must always have motion that will disturb the natural swing of the pendulum. The elevation of the instrument at sea, due to tide and wave, is difficult to determine. In fact, all the complexity that attends the determination on land is many times multiplied in a determination at sea.

Dr. Meinesz conducts his observations in very cramped space in a submarine, which in itself is an accomplishment. He uses a submarine in order to get into the comparatively quiet water below that agitated by wave action. Instead of swinging one pendulum only, as in land observations, Dr. Meinesz swings three, in planes making 120° with one another. These furnish sufficient data so that the effect of the motion of the submarine can be computed and eliminated.

In the face of all the difficulties presented, the accuracy attained is comparable to that resulting from land observations. Most certainly this is an achievement of high order.

Seas and oceans cover nearly three-fourths of the earth's total area. Land gravity stations can only cover a limited part of the earth, and this method will enable studies of gravity to be made systematically over the whole earth. Dr. Meinesz hints that certain areas may show values of gravity that are not in accord with completed isostatic compensation, which would probably have a definite bearing on seismic activity.

Dr. Meinesz visited the Volcano of Kilauea about a month ago, and was very generous in telling many of his interesting experiences. R.M.W.

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No. 97 RELEASED WITHOUT COPYRIGHT RESTRICTION November 5, 1926

KILAUEA REPORT NO. 773

WEEK ENDING NOVEMBER 3, 1926

Issued by the Observatory, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

A couple of large avalanches were noted on Saturday and Sunday in the pit of Halemaumau. There have been no other notable changes or activity at the pit. Eight local earthquakes and two teleseisms occurred during the week. The local earthquakes were all very feeble, with the exception of that which came at 12:16 a. m. on October 31. This shock, apparently about 14 miles from the observatory and probably on the rift line of Mauna Loa, was of sufficient intensity so that one of the seismographs was partly dismantled. There have been no reports of its having been felt, probably due to the time of its occurrence, although its maximum acceleration indicates that it should have been perceptible.

One teleseism, which occurred at 9:20 a. m. on the 30th, was rather feeble, and no estimation as to distance and direction could be made. The other teleseism, at 3:27 p. m. on the 31st, had a maximum amplitude of 0.61 millimeters actual movement of the ground. This produced on the seismogram a record about six inches wide. In spite of the apparent size and intensity of this earthquake, no preliminary wave could be distinguished, probably being obscured by microseisms. The seismograph operated by Captain R. D. Woods in Kealakekua, Hawaii, also recorded this earthquake. A telephone message from him was the first news of the quake at the observatory, as the seismographs had not been inspected during the afternoon.

Tilt has been accumulating slightly to the east during the week.

USE OF VOLCANIC ENERGY

Manifestations of such liberal amounts of energy as occur in volcanoes, earthquakes and geysers, naturally lead to thoughts of harnessing and making use of this energy. The tides have been to a certain extent made use of in generating power, and large projects of further developments are in view. Volcanic energy is more difficult to harness, but has been successfully done.

Prince Piero Ginori-Conti, President of the Italian Society of General and Industrial Chemistry, tells (New York "Times," September 15) of using volcanic steam in the region of Vesuvius. The steam escaping from the ground is under low pressure—about 30 pounds per square inch at best, and it has been successfully utilized even when the effective pressure is as low as five pounds per square inch. It was at first an experiment. In 1903 a small engine was run at Larderello by steam escaping from a natural vent. Since that time wells have been drilled tapping larger supplies under better pressure, so that in 1914 a plant of three turbo-alternators was running with a net power output of 2,500 kilowatts.

The wells drilled are 16 inches in diameter, and vary in depth from 180 feet to 750 feet, ordinarily by using a rotary drill. In the Larderello district the steam brings with it various gases that have commercial value, as carbon dioxide, helium, and argon. Also sulphurous gas is separated from the steam before it reaches the engines.

Geysers have also been tapped, and made to deliver power. Prince Ginori-Conti says that there are in our western states geysers that are comparable to the ones that have been utilized in Italy.

In order to find natural volcano steam under pressure it is probably essential to have the surface strata sufficiently impervious to confine the steam. In the vicinity of the Volcano of Kilauea the structure of the upper layers, at least, is not only composed of a rather porous lava, but is also broken by many earthquake cracks. Thus steam that is formed underground has so many natural vents that it has practically no effective pressure when it reaches the surface. But there is aparently an inexhaustible supply, and pressure might be found by deeper drilling.

Apparently hopeful ambition is not lacking in the matter of harnessing the volcano noted in an extract from the "Madras Mail" of September 9, 1926, though in this case it seems to be to muzzling, rather than utilizing, the volcano's output. The extract is as follows:

"Farmers living near the Masaya volcano, in Nicaragua, who have clung to their homesteads in spite of damage frequently done to their crops by poisonous gases given off by the mountain, have apparently decided to muzzle their enemy.

"According to the latest report they have employed a group of German engineers, who propose to build a cap over the crater, and by the injection of certain chemicals, to neutralize the gases, which, if necessary, will be allowed to escape through a safety valve." R.M.W.

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NO. 98 RELEASED WITHOUT COPYRIGHT RESTRICTION November 12

KILAUEA REPORT NO. 774

WEEK ENDING NOVEMBER 10, 1926

Issued by the Observatory, U. S. Geological Survey:

R. M. Wilson, Temporarily in Charge

Conditions at the pit of Halemaumau remain unchanged. The steaming at the southwest talus continues, and there are still occasional avalanches.

During the week there have been eleven local earthquakes, all very feeble, and one teleseism, which occurred at 9:45 p. m. Hawaiian Standard Time on November 4. This was apparently a minor earthquake with indicated distance of 2,160 miles. During the week microseisms have been unusually strong. Accumulated tilt has been slightly to the east.

PRECISE LEVELS ON MAUNA LOA

Lieutenant L. G. Simmons, of the U. S. Coast and Geodetic Survey, now has the Mauna Loa level line completed about halfway from the summit of the mountain to the Volcano House. The difference of elevation between the summit and the Volcano House is a little less than 10,000 feet, and the distance is approximately 30 miles. In running spirit levels, level sights only are taken, and rods of 10 or 12 feet in length are used, therefore for each time the instrument is set up, only about nine feet in elevation can be gained, as an average. To make a single measurement of this difference of elevation thus requires, roughly, 1,100 "set-ups" of the instrument. But as this work is being double run—that is, each part is run in both directions—it is actually being run twice, as a check. Lieutenant Simmons will therefore have to set up, level, and read his instrument about 2,200 times to complete this section of the work. One hundred "set-ups" are considered a very fair day's work.

So far, during the progress of the work, the weather has been favorable. Rain is not so frequent on the higher part of Mauna Loa, and wind has not bothered excessively.

The party camped at the Rest House, beside Red Hill, for a while, at about 10,000 feet elevation, and then moved to the "Hotel de Jaggar" not far from the summit and at the northeast end of the Crater of Mokuaweoweo, where they stayed about 10 days. This camp is no more than a lava tube, which affords meager shelter if one is inclined to get down on hands and knees and crawl for it. A caved-in portion of the tube is the front door, which, covered with a sheet of canvas, also served as kitchen and commissary. Water in the crevices of the lava supplied the camp, though it was necessary each morning to break through an inch of fresh ice. It is a surprising fact that mice were found at this camp, easily 5,000 feet above the highest outpost of vegetation.

The party is now camped below the Rest House, at an elevation of about 6,500 feet, in comparative comfort below timber line.

THE SEISMOGRAPH STATION AT KEALAKEKUA

The Hawaiian Volcano Observatory is located on the east flank of Mauna Loa. On the west flank, in Kealakekua, is the branch station operated by Captain R. V. Woods, consisting of a single horizontal pendulum mounted in a N—S plane, being thus most sensitive to E—W motion. This instrument is of simple construction, yet during the few years of its operation has been very successful in detecting both local shocks and teleseisms. Many earthquakes have been recorded both on this instrument and on the instruments at the Hawaiian Volcano Observatory. Comparison of the records is especially interesting on account of the fact that the line between the two stations passes practically through the middle of the great mass of Mauna Loa. The two stations are also almost equidistant from the center of this volcano, and are therefore strategically placed as observation posts to study the interior workings of the mountain. Comparative study has heretofore been somewhat hampered by the difficulty of accurate time comparison. For a long time the clocks at the observatory have been corrected by the radio time signals, but at Kealakekua dependence was placed upon time secured by telephone, sometimes more than a minute in error. A radio set for receiving time signals has just been installed at the Kealakekua station. A key placed beside the radio set is connected into the station clock circuit, so that at the instant the time signal is received the key is depressed, thus recording it on the current seismogram along with the minute marks made by the station clock. To obtain the clock correction it is therefore necessary to simply measure on the seismogram the time interval between the radio time and the clock time. It is believed that time can thus be secured to within half a second or better. This will make possible the comparison of the time of arrival of shocks at the two stations with a fair degree of accuracy. R. M. W.

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No. 99 RELEASED WITHOUT COPYRIGHT RESTRICTION November 18, 1926

KILAUEA REPORT No. 775

WEEK ENDING NOVEMBER 17, 1926

Issued by the Observatory, U. S. Geological Survey:

R. M. Wilson, Temporarily in Charge

The pit of Halemaumau is still confining its apparent activity to occasional small avalanches, and continued steaming at various points on the floor of the pit and through the talus slopes. Conditions remain practically unchanged.

Rumors and reports have occasionally been heard of a glow, or smoke, being seen on Mauna Loa. Lieutenant Simmons, camped near the summit, has seen no sign of activity, nor have the seismographs indicated any unusual activity. The 1926 flow is probably still warm enough to convert into steam any rain that falls upon it, thus perhaps giving rise to rumors of smoke on Mauna Loa. The same thing happens in the pit of Halemaumau—during and after a rain the steaming is much more pronounced.

There have been but eight very feeble local earthquakes recorded this week, and no teleseisms. On the 14th of November microseisms were exceptionally strong, perhaps due to the high wind that prevailed upon that day. Tilt accumulated during the week has been moderate to the N.E., coming mostly on the 14th.

THE FIELD OF THE SEISMOGRAPH

The seismograph, as its name implies, was primarily designed to study earthquakes. That is of course its major application, but its other practical usefulness is sometimes not realized. Practically all modern knowledge of the mechanics of earthquakes and the propogation of earthquake waves has come from data furnished by the seismograph in its various forms. It is now being used not only for general study, but for obtaining information upon certain definite points of commercial and industrial interest.

In the Volcano Letter of October 21, mention was made of the use of a seismograph installed to detect local and artificial shocks due to mining operations.

Oil companies have been making successful use of seismographs to help locate oil formations. This is done by setting off charges of explosive, thus causing an artificial earthquake of which the time and place may be accurately determined. The record made on a seismograph at some distance away is then studied. The earth waves originating with the explosion are reflected back from the underground strata, and careful timing yields data from which the depth of these strata may sometimes be computed.

An instrument, operating upon the same principle as a seismograph, has been used mounted upon a railroad car, recording during the car's progress the sway caused by unevenness of roadbed.

In engineering, seismographs are adapted for use in studying the nature and amount of vibration in structures. Mounted on bridges or buildings, deflections and sway due to passage of vehicles, to variation of loading, and to wind pressure might be recorded, if these motions are of sudden or periodic nature. Slight tipping, such as might occur due to unequal settlement of foundations, would also be recorded. The effect of earthquakes on tall buildings might so be studied.

Many may be written on the use of seismographs as an aid in detecting danger to structures due to earthquakes. In the April-June, 1926, issue of the "Materiaux pour l'Etude des Calamites" (Societe de Geographie de Geneve) Dr. G. Agamennone, Directeur de l'Observatoire royal de geophysique de Rocca di Papa, writes on the menace of dams built for hydroelectric developments. There have been several calamities due to the failure of such dams, resulting in loss of life and damaged property in the flooded areas. Dr. Agamennone suggests various reasons for such failures—unusually heavy rains, poor design, undermining due to leaks under the foundations, and so on. He states that earthquakes may easily cause such failures in various ways. An earthquake may not cause an immediate failure, but may so crack the structure as to allow water to seep through and complete the destruction. Dr. Agamennone suggests that since the success of a project depends upon the care with which it is planned, that a study of the seismic conditions might well be made at a site chosen for a dam. Engineers consider rainfall, geologic structure, and many other things, but sometimes neglect seismic activity as a factor in determining the design of the dam. Frequency and intensity of local shocks should be considered, both through historical information and by setting up seismographs at the chosen site. When the dam is built, as a measure of protection seismographs should be installed at the dam.

Dr. Agamennone suggests that laws should be passed enforcing this precaution, as it would be but a small amount of insurance invested towards the safety of those living below the dam. Such instruments might give early warning of earthquakes of sufficient magnitude to endanger the dam. If mounted on the dam itself they would give warning by recording any undue vibration, settling or "giving" of the structure. Certainly these instruments would be excellent sentinels to report the coming of danger, and might easily minimize the loss of life, through warning, that would probably result should the dam fail. Sometimes legal suits result from such a failure. Seismograph records would be important evidence in ascertaining cause and blame. R.M.W.

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No. 100 RELEASED WITHOUT COPYRIGHT RESTRICTION November 26, 1926

KILAUEA REPORT No. 776

WEEK ENDING NOVEMBER 24, 1926

Issued by the Observatory, U. S. Geological Survey:

R. M. Wilson, Temporarily in Charge

At the pit of Halemaumau continued steaming has increased the yellow sulphur deposits at various places, and dust from avalanches has begun to settle on the black lava portion of the floor to such an extent as to be noticeable, causing the floor to be of a dusty, reddish tint, rather than the shiny black of the fresh lava. On November 22, at 1:20 p. m., a very considerable avalanche was noted, the dust continuing to rise in heavy clouds from the pit for five or ten minutes. An inspection of the seismogram shows a very slight tremor at that time, probably caused by this avalanche. This slide appears to have been a sloughing-off of the lower part of the wall on the north side of the pit.

There have been eighteen local earthquakes this week. All of these were much too feeble to be felt, but two of them were large enough to show definite preliminary phases indicating the distance of each to be about 28 miles. On November 20, during the middle of the day, a few very minute spasmodic tremors were noted, which have not been included in the above count. For the past several weeks the frequency of earthquakes has been very low. The number this week marks a very considerable increase. It is perhaps possible that the low ebb of seismic activity is at an end and that more frequent earthquakes may be expected.

Tilt during the week has accumulated slightly to the northwest. Tilt accumulated since the middle of September is about seven and one-half seconds of arc towards the east, and about five seconds of arc towards the north.

OCTOBER TELESEISMS

During the month of October there were seven teleseisms recorded at the Hawaiian Volcano Observatory. These were noted briefly in the current Volcano Letters. Information from other stations, not available at the time these Letters were published, has since been received. This makes possible the comparison of the various data from other parts of the world with the data recorded here.

In Volcano Letter No. 93 of October 7 a teleseism is mentioned as having been recorded at 8:45 a. m. Hawaiian Standard Time on October 3. This corresponds to 19:15 Greenwich Time. The trace of this earthquake was a feeble one and the disturbance noted at the time was probably not the preliminary wave as was then supposed. The preliminary wave probably arrived at 19:50 Greenwich Time. This earthquake apparently caused some doubt at other stations as to the position of the epicenter, and no conclusion seems to have been reached concerning it. A very uncertain estimate of the distance from this station is 5,670 miles.

On October 13, as noted in Volcano Letter No. 94, an earthquake was recorded, beginning at 8:45:04 a. m., corresponding to Greenwich Time 19:15:04. An estimate of 2,370 miles was made for the distance to the epicenter of this earthquake. From other stations come reports of three earthquakes on that day, all in the same region, near the Aleutian Islands, the one recorded here being the third. Its epicenter as computed by the central station of the Jesuit Seismological Association, St. Louis, is 51 degrees north latitude and 178 degrees west longitude. This checks with the distance from this station as estimated above. The first earthquake of this day was also recorded on the seismograph at this station, but was so faint as to have been overlooked at the time. The preliminary wave of this first earthquake was recorded at about 6:10 Greenwich Time.

The earthquakes felt in San Francisco on the 22nd of October, noted in Volcano Letter No. 96, attracted considerable notice from the press. The preliminary bulletin of the central station of the Jesuit Seismological Association makes no computation of the position of the epicenter except to say that these two shocks were apparently at approximately the same place and about 640 miles from the station at Tucson, Arizona. These earthquakes perhaps occurred two or three hundred miles off the south-central portion of the coast of California.

Another earthquake was also mentioned in Volcano Letter No. 96, recorded on the 25th day of October at 5:26 p. m., Honolulu Time, corresponding to 3:56 October 26 Greenwich Time. This earthquake apparently took place about five or six hundred miles south of the southwest end of Japan.

The earthquake which was recorded here at 9:20 a. m., Honolulu Time, on the 30th, occurred at 19:41:28 Greenwich Time, near the Queen Charlotte Islands, British Columbia, Canada. The latitude and longitude of the epicenter as given by the U. S. Coast and Geodetic Survey from combined data is 53 degrees north and 129 degrees west.

The earthquake which was recorded here at 3:27 p. m. on the 31st, Hawaiian Time, is reported as having occurred at 1:39:10 Greenwich Time on November 1 in latitude 50 degrees north, longitude 130 degrees west. This is only two or three hundred miles south of the earthquake just described above on the 30th. R.M.W.

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No. 101 RELEASED WITHOUT COPYRIGHT RESTRICTION December 2, 1926

KILAUEA REPORT No. 777

WEEK ENDING DECEMBER 1, 1926

Issued by the Observatory, U. S. Geological Survey:

R. M. Wilson, Temporarily in Charge

The pit of Halemaumau is still quiet. The steaming continues and has made a yellow deposit of sulphur at one point on the southeast talus. A new deposit of sulphur has also appeared near the foot of the northwest talus. Avalanches are infrequent.

The total number of earthquakes for the week has been nine, of which four occurred on the afternoon of the 29th of November. All of these were very feeble with the exception of one which came at 4:09 p. m. on the 29th. This was strong enough to be felt by a few persons in the vicinity, being a local shock with a maximum acceleration of about 8.0 millimeters per second per second. During the afternoon of the 29th there are evidences of occasional very slight spasmodic tremors, in addtion to the earthqaukes noted above.

Tilt has been accumulating during the week slightly towards the southwest.

SEISMOLOGY AND GEODESY

Seismology is intimately involved with many other branches of science, geodesy being one of the most important. Geodesy, dealing as it does with measurements over large areas of the earth's surface, is available as a means of discovering movements of the earth's crust due to seismic and tectonic forces. Trinagulation is used to measure the horizontal surface displacement resulting from earthquakes; precise levels to discover change in slope, or tilt, and differences in elevation due to vertical displacement. Tide gauges may record sudden or gradual elevation or depression of a shore line. Astronomical latitude and longitude observations may show change of position of great areas of the earth's surface, as in the theory of the "Drift of Continents."

Surveys of the earth's surface in general have been made to determine dimensions of areas for various civil uses, without thought that these areas may be measureably changing. The ever-increased accuracy with which geodetic surveys are being made is developing the fact that our apparently solid earth is actually undergoing surface movements that may be directly measured. Geology easily shows that the earth's surface has many times been made over. But geology deals in such vast periods of time to accomplish these changes, that an individual, in the few years given him in which to observe, must observe very closely to see the changes actually progress.

Successive surveys over the same area will always show discrepancies, even if no actual change in the area exists, as curveys and measurements can never be exact. Thus two surveys will differ, due simply to errors and inaccuracies in measurement which cannot be reduced to zero, even by the most careful work. The actual ground movements are usually small, and it is therefore difficult as a rule to separate, in the discrepancies developed by two successive surveys, the amounts that are due to measurement errors and to actual movement or change of dimensions of the measured area. If the probable errors of measurement are known, through knowledge of the methods employed, and if the discrepancies developed are considerably in excess of such probable errors, then it may be said that very likely actual movement exists.

Triangulation, by the U. S. Coast and Geodetic Survey, has successfully shown earth movement over large areas in California (U. S. Coast and Geodetic Survey Special Publication No. 106, "Earth Movements in California"), and a very comprehensive compilation of old triangulations has been made by R. H. Tucker in the September, 1926, issue of the Bulletin of the Seismological Society of America, wherein is shown the definite measurement of the relative displacement accumulated along the San Andreas fault between 1885 and 1907.

Spirit levels in Japan, re-run after the eruptions of Sakurajima and Usu, showed cases where relative differences of elevation had changed many feet in the regions around these volcanoes. Levels run in 1912 around the Volcano of Kilauea showed the presence of tilt, and more elaborate running in 1920 and 1921 apparently confirmed the idea that the elevations at this volcano are changeable, causing slight tilting or altering of grade in the slopes of the mountain.

Observations are now in progress to simultaneously establish accurate astronomic latitude and longitude stations in various parts of the world. In future years these stations may be again occupied, thus perhaps making a direct measurement of changes in latitude and longitude of a given point on the earth's surface due to its horizontal movement under the impluse of isostatic adjustment, faulting or other causes.

Therefore, in many ways are the surface motions of the earth being watched. Geology shows the results of past changes. Many of the earthquakes studied in seismology are the indication of present changes in progress—they are in fact the creaking and groaning and cracking of the earth's crust under the forces that are remodelling it. Such surveys as are here mentioned may help in the future to show where, and in what amount, this remodelling is taking place. R.M.W.

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No. 102 RELEASED WITHOUT COPYRIGHT RESTRICTION December 9, 1926

KILAUEA REPORT No. 778

WEEK ENDING DECEMBER 8, 1926

Issued by the Observatory, U. S. Geological Survey:

T. A. Jaggar, Official in Charge

During the past week Halemaumau pit has developed no volcanic activity and the Mauna Loa-Kilauea system continues quiet, though some earthquakes slightly perceptible have occurred. The earthquake reported last week, of 4:09 p. m. November 29, gave evidence on the seismographs of Kona, Hilea and the Observatory of an inward tilt towards the Mauna Loa center at these stations, exhibited as a sudden swing of the pendulums, causing off-set of the seismogram lines, from which there was no recovery afterward. This sudden tilt accorded with the accumulated southwest tilt at the observatory. This would all seem to indicate that the Mauna Loa rift belt, after the eruption of April, 1926, is still subsiding.

Halemaumau has on the south talus a bright yellow sulphur patch about 25 feet in diameter, with blackened stones in its midst. This was formerly a superheated, whitish, dry area in the midst of steam wetted talus. Prolonged dry weather has developed six other paler sulphurous patches. During 20 minutes today rocks fell twice at the NNE wall. Sixteen steam jets occur about the bottom of the pit.

Only six earthquakes for the week were registered. One of these at 1:29 a. m. December 2 was of intensity sufficient to be perceptible, and the seismogram indicated an origin 10 miles away in the line of direction N 68° W. Tilt for the week was slight to the east.

SCIENCE CONGRESS IN TOKYO

The Third Pan-Pacific Science Congress opened in the great hall of the Imperial University of Tokyo on October 30 and closed its session November 11. More than 200 delegates from overseas were present and some 400 delegates from Japan. The Congress was organized with extraordinary efficiency under the able leadership of Dr. Sakurai, and the foreign delegates were entertained lavishly by the Imperial Government and by distinguished citizens of the Empire. Excursions were provided, before the Congress opened, to the Ainu villages of Hokkaido (the northern island of Japan), to the Cretaceous and Tertiary deposits of that island, and to Tarumai volcano, which staged a small explosive eruption just at the time of the Congressional visit. Other excursions prior to Congress were to Nikko and Hakone, and these beautiful mountain districts were in the full glory of autumnal foliage. Numerous short excursions occupied the week-end of November 6 and 7, and after the Congress there were long excursions to central Japan, the Inland Sea, and the mines, hot springs, and volcanoes of Kyushu. All of this travel was furnished to the overseas delegates at the expense of the Imperial Government, and was even extended to Korea for those delegates who were headed toward China.

The countries represented in the Congress were Japan, the United States, Australia, Canada, China, France, Great Britain, Hawaii, Hongkong, Holland, the Dutch East Indies, New Zealand, Papua, the Philippines, the Strait Settlements and Federated Malay States, Russia, Sweden, Peru and Chile.

More than 400 papers were presented in English, the official language, and geophysical sciences were represented by a large number of delegates. Oceanography was accented, and the geological sciences had more representatives than any other group. Japan exhibited instruments and methods, bearing on seismology and earthquake-proof construction, greatly in advance of former practice. At Kyoto there are seismographs with magnification of 50,000, electrical transmission of the motion, and vacuum-tube amplification for registration. Remarkable new accelerographs and vertical-component instruments are under test in the University of Sendai and at the Imperial University of Tokyo. Dr. Imamura has new horizontal pendulums, designed for registering great earthquakes by reducing the amplitude instead of magnifying it, and others of extraordinarily long period by means of special adjusting screws and great height to the supporting columns.

The discussions of the Congress developed the need for more extensive translation of scientific works written in obscure languages. Resolutions were passed on motion of those interested in volcanology and local seismology, recommending (1) more published notes at short intervals, (2) more cooperation by radio, (3) more interchange of research workers, and (4) translation of far-eastern scientific books through such interchange.

It was provided that the Congress of 1929 shall be held in Java. T.A.J.

VOLCANO EXHIBIT PROJECT

The Hawaiian Volcano Research Association has now provided for an exhibition room to be built adjacent to the volcano observatory at Kilauea. For many years travelers who have visited the pit and the active lava flows have come to the observatory keenly interested to ask questions about volcanology. The new establishment is designed to meet this demand with what may be called a "live museum," that is, a place for short lectures, demonstration of maps and charts, projection of motion pictures and lantern slides and an exhibition seismograph. Plans for the building have been drawn, a curator will be appointed to care for this work, and the exhibit will be opened during the first half of 1927. T.A.J.

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No. 103 RELEASED WITHOUT COPYRIGHT RESTRICTION December 16, 1926

KILAUEA REPORT No. 779

WEEK ENDING DECEMBER 15, 1926
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in Charge

No new activity has appeared in the volcanoes Kilauea and Mauna Loa. A visit during the past week to Mauna Iki shows that the rusty spots in the top of that hill are hotter than ever. A stick thrust in a crack ignited instantly at one of these spots. Halemaumau, the lava pit of Kilauea, exhibits still further increase in the sulphur stain of the south talus. A new patch of yellow has developed at the margin of that talus, while the large yellow patch in its midst still shows strong solfataric activity. There is very little avalanching.

Fourteen earthquakes have been registered on the seismographs, all small and local except one. This last was a faintly recorded teleseism reaching a maximum at 10:25 p. m. December 9. The U. S. Coast and Geodetic Survey reports the time of occurence at the source 8 h. 37 m. 59 s. Greenwich Time December 10, and the place on the bottom of the ocean about 1,000 kilometers west of Cape Mendocino, California, at 41° N. Lat. and 136° W. Long. Tilt for the week at the Observatory was very slight to the east.

LASSEN REPORT NO. 2

The first note from Lassen Volcano Observatory in California was printed in the VOLCANO LETTER of October 21. Mr. R. H. Finch, Asscciate Volcanologist, now reports that the seismograph pendulums have been operating about a month (November 24), are still in process of adjustment, and have shown no earthquakes. Mid-November produced heavy rains at Mineral, where the volcano station is located. For several days the rainfall was three or four inches per day, and high winds blew down the big yellow pine trees with crashes like the rumble of earthquakes. The road to Mineral was blocked by fallen trees. Snow developed in the latter part of the storm.

"A man who has been cattle-ranching in the Lassen countrty for twentyfive years, told of hearing distinct rumbling from the volcano about 18 years ago. (The eruption was in 1915). The water that went down Hat and Lost creeks during the mud flows of 1914-15 was still warm 18 miles down their valleys. The Lassen edifice has certainly been getting a soaking this month."

"November 29. Winter conditions here are quite primitive. I am all by myself with the nearest neighbor about a mile away. All water has to be carried. Fortunately there is a brook about 500 feet away. So far there has been practically nothing recorded on the seismographs. They are not yet in final shape. The road to Susanville is still open, while some of the Sierra roads farther south are closed on account of heavy snow."

The Lassen Station at present consists of an office and seismograph cellar at Mineral near the Lassen Park headquarters, and a cottage for the volcanologist has been kindly supplied by the U. S. Forest Service. The seismograph cellar was started September 20 and finished October 5. The office building was finished October 19. The seismographs are of the horizontal pendulum type, built on the spot, but the time-piece is an excellent Howard seconds pendulum clock, electrically fitted. T.A.J.

EARTHQUAKE OF SEPTEMBER 16

In the Volcano Letter of September 23 we reported a big earthquake west of the New Hebrides, Greenwich time 17h. 59m., September 16, and another about five hours later. The center was located by the U. S. Coast and Geodetic Survey.

The Sydney Morning Herald of 28 September reports that the ship Mataram on that day (September 17 in Australia), was docked at Yandina, Solomon Islands. The shock was felt all over those islands, and much furniture was knocked about on the ship. On Tulagi the earthquake was very severe. Twelve distinct shocks were felt during the day, the most powerful about noon and five p. m. local time. The wharf was damaged at Makambo, and natives were panic-stricken at Viduna, a cattle ranch, where the principal shock lasted about one minute.

T.A.J.

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No. 104 RELEASED WITHOUT COPYRIGHT RESTRICTION December 23, 1926

KILAUEA REPORT No. 780
WEEK ENDING DECEMBER 22, 1926
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in Charge

The past week has been excessively rainy at Kilauea, and the only changes noted at Halemaumau pit were wetting of the walls, consequent washing-away of some of the soluble salts stained with sulphur at the solfataric areas, and a little sliding from the northern walls of the pit. As usual, the rain has increased the volume of visible vapor at the steam jets.

Sixteen very feeble local earthquakes have been registered. One at 8 p. m. December 18 indicated distance of origin as 12 miles. A prolonged tremor at 11:15 a. m. December 15, of very slight amplitude, may have been occasioned by an avalanche in the pit. No tilt was accumulated during the week.

ELASTIC-REBOUND THEORY OF EARTHQUAKES

The California earthquake of 1906 was characterized by a long, vertical rift extending northwest and southeast for several hundred miles through California. The crack passes San Francisco on the west and lies just within the coast line north of the Golden Gate, until it disappears beneath the waters of the Pacific off Cape Mendocino. The earthquake is believed to have been caused by accumulated strain on opposite sides of this crack, whereby the land to the east was moving southward, and that to the west of the crack was moving nortward, the two motions opposing each other on the rift line and demanding relief there in the course of time. When the earthquake occurred there was sudden, violent motion northwestward of the land west of the crack, and similar motion southeastward of the land east of the crack. The country on the crack itself was torn and shattered, trails, roads and fences crossing the rift zone were offset, and sod was torn athwart hills and fields and bottom lands that chanced to lie in the rift zone. The maximum was near Point Reyes, north of San Francisco, and consisted of horizontal offset of more than 20 feet. The vertical displacement on opposit sides of the gashed ground was small, only a foot or two, and the horizontal movement became progressively less along the fault zone for scores of miles to the southward. The severity of shaking was in general greatest along the rift itself, and died out away from the rift, although here were some parallel belts to the eastward which behaved like independent centers of seismic activity.

This earthquake has been reviewed. along with other great shocks, in an interesting illustrated volume entitled "Our Mobile Earth," by R. A. Daly (Scribner, 1926). In explanation of the great earthquakes of the world Professor Daly accepts Reid's theory of elastic rebound. The growing strain was resisted by the strong crust. At last at a certain moment in the year 1906, the forces reached the elastic limit of the crust. The crust broke at a point. With the speed of sound in rock, that is, at the rate of over three miles a second, this incipient fracture spread along the line of the San Andreas rift. In a minute or two of time the long fault was formed. The crust was relieved of strain which had long been growing. The crust bounded back towards its original position, and that so suddenly as to jar the whole State of California and, in fact, the whole earth. Proofs cited to confirm this theory of elastic rebound are that the belt of destruction was elongated parallel to the rift, the isoseismals or lines of equal shaking were elongated symetrically around the rift, and the shock was greatest along the rift. Eleven other great earthquakes are mentioned having faults from 12 to 190 miles long associated with them, and these faults suffered displacement both vertically and horizontally of from three to 47 feet.

A second confirmation of the theory is found in the fact that broad belts of country alongside the fault trace are permanently displaced, up and down or horizontally, at the time of the earthquake. In California this was tested by a net of triangulation stations which should have indicated a lengthening of lines where the country expanded and a shortening of lines where the country has been dilated before, and suddenly contracted at the time of the earthquake. Just such effects were discovered between triangulation stations which had been established in the 19th century, and were reoccupied after the earthquake. Moreover, the permanent displacements were approximately parallel to the fault zone, with total shifts reaching more than 15 feet and the average displacement nearly twice as much on the west as on the east with reference to a distant base line.

A fourth test of the elastic rebound theory depends on the location of the depth of the point of fracture. The principal shock is supposedly due to a sudden snapping apart of two fracture surfaces at some distance underground. Various instrumental methods have been devised for determining how deep is this point of origin, which is called the focus of the earthquake. "In general the most trustworthy determinations give depths no greater than 25 miles; their weighted average is not far from half that." This agrees with the notion that the earth's crust is only 25 to 50 miles thick and that within that thickness the fractures occur which produce big earthquakes.

The four tests proposed by Dr. Daly seem then to agree with the elastic rebound theory. They are (1) that the shock is greatest along the fault, (2) that wide areas are displaced next the fault, (3) that the land measurably contracts and expands, and (4) that the depth of focus is consistent with the notion of sudden fracturing of the crust deep underground.

With reference to volcanoes Daly concludes that they are best explained on the supposition that such deep fractures allow gas-charged lava to rise, and very often, therefore, earthquakes and volcanoes are associated. Daly considers that both quake and volcano are effects of a common cause, the sudden fracture of a strained crust. He writes: "In all this we are dealing with earthquakes of the kind that causes great destruction. The much feebler shocks, caused by volcanic explosions or by sudden injections of liquid lava into the crust, belong in a quite different category—the class of true volcanic earthquakes."

This definition of volcanic earthquakes appears dubious to the reviewer. At Kilauea neither injection nor explosion produces earthquake. Volcanic earthquakes in Hawaii are due to slipping on fault planes. These slips are of all intensities from tiny to very large. It would seem that the shift of underground magma under change of surface loading may be quite as competent to produce a big earthquake as elastic rebound. T.A.J.

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No. 105 RELEASED WITHOUT COPYRIGHT RESTRICTION December 30, 1926

KILAUEA REPORT No. 781
WEEK ENDING DECEMBER 29, 1926
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in Charge

Nothing new except the dribble of small rock falls from the walls, has been noticed at Halemaumau, the lava pit of Kilauea. Kilauea and Mauna Loa remain inactive.

The total number of earthquakes recorded for the week is 17. These were all very feeble with the exception of one which occurred at 9:26 p. m. on December 25. This earthquake was a perceptible one, and evidently shook a large section of the island, having been felt in Hilo and Waiohinu. This earthquake was recorded on the Hilo seismograph as being 46 miles from that place. It was distant 25 miles from the Volcano Observatory, probably near the summit of Mauna Loa. A few hours after this earthquake, on the 26th, between 3:57 and 4:20 a. m., the seismographs show a very feeble, but almost continuous tremor.

Tilt accumulated during the week has been moderate to the north-northeast.

THE MYSTERY OF MAUNA LOA

The terrific earthquakes and tidal wave of 1868, with landslip in Kau, lava flow in Kahuku, and collapse of the whole crater of Kilauea, seems very remote to us of the peaceful present.

On the Hilo side, we have only to quote from letters of 1881:

"Six months glided on, and still the fiery streams continued to grind on their seaward way, burning the forest through which they passed, filling up ravines, and making for themselves a vast level highway, and in places huge tunnels, through which the liquid lava flowed. It became evident that, should the awful streams unite, there would soon remain no trace of Hilo or its harbor."

"All Hilo may be said to have visited the flow during the last few days (July 6, 1881). Men, women and children, some on foot and some on horseback, have made the pilgrimage. Many in Hilo have been packing, so as to be ready to make a sudden start."

"It is almost impossible now to say when the flow will reach the sea; but all things considered, the probability is that it will take the Kukuau gulch. It is now not over one and three-quarters miles from the sea. Probably, before you hear from us again, all the lower part of the town will be destroyed."

"The lava is now only two and one-half miles from Volcano Street, and it is very liquid. It has, some part of the time, run at the rate of half a mile a day."

"Large parties of fifty to one hundred visit it daily, and some go up early in the morning and return, and again go up in the afternoon. Mr. Kennedy and Mr. Richardson are alarmed for the mills, and they have begun to pack and remove their valuable articles. Our town is greatly moved, and some have suspended all other business to watch the fires. The puffs of smoke and steam along the channel appear like the smoke of steamers descending a river. The main body of the fire is moving slowly down upon us in sufficient breadth to sweep our whole town, while the small stream is like advanced pickets on a skirmish line. Probably a few days hence we shall see its triumphant entrance into our town, about half a mile east of Church Street. It will be a grand spectacle, though full of terror."

Finally August 14th, Mrs. Luther Severance wrote:

"I know you are longing to hear about our lava flow. You will thank the Lord, as we do, that it has ceased action. It had advanced to within a mile from the beach, having travelled fully forty miles from the summit of Mauna Loa."

"We hardly can think or talk of anything else. This fiery flood, whose steady advance we have watched since last November,—that is, for nine long months—has occupied all our thoughts, and for the last two months we have spent much of our time near this terrible, fascinating monster: night and day have called us to its side." (Fire Fountains, by Lady Gordon Cumming, Blackwood, 1883.)

These human documents of forty-five years ago have very human meaning for those of us who watched the flow of 1926 invade and crush, to pulp and cinder, the village of Hoopuloa. The machinery of Mauna Loa is more than a mystery: it is an inaccessible mystery. It extends down through 18,000 feet of sea water. Skilled physicists are at this moment weighing it at a camp on the summit: is the central rock lighter than the shoreline rock? The Kilauea fountains are heavier than the Mauna Loa fountains. Cracks, mysterious cracks, extend toward Hilo and toward Kau. Where is the liquid lava now? Why do the groups of eruptions time themselves to a systematic interval? Why did the eruptions shift from the Hilo side to the southwest side; 1843, 1852, 1855, 1859, and 1881 were at the north. Now they are all at the south—1907, 1916, 1919, 1926.

The Government last year honored Hawaii by making Kilauea headquarters for widespread work in volcanology. A private corporation, the Hawaiian Volcano Research Association, has recognized the honor by financing most generously a new exhibition and lecture system for tourists at Kilauea National Park.

The Territory of Hawaii now has its chance to recognize what the Federal Government has done by building an emergency 7-foot trail up Mauna Loa in Alika. This trail, passable for low gear truck, is needed for protection of the ranches, for a scientific observatory, and to let travellers see the source fountains in that marvellou Kahuku country.

There was a summit eruption in Mauna Loa in 1903 and 1914, and damaging flows poured into the cattle lands in 1907, 1916, 1919 and 1926. There was a flow on the Hilo side in 1899. The intervals were 4, 4, 7, 2, 3, 7 years. Will the next eruption be in 1928, 1929 or 1930? Two, three or four years? Is the south side shaking now? Are the cracks growing cooler or hotter? Is the ground bending down or up?

The Alika flow did one good thing. It came against the Koa Camp road, and opened a way, only five miles long, to extend that as a 7-foot trail to the summit of the Kahuku ridge, 7,500 feet above sea-level. With that trail we will keep an observatory on the most active part of Mauna Loa. With that trail everybody can see the 400-foot fountains. With that trail we can warn the cowboys. With a telephone at the Kahuku observatory we can keep the public informed. An emergency trail need only cost about $25,000. We are going before the Territorial Legislature asking for this trail.

Mauna Loa is mysterious like the Antarctic continent. Every trail, however rough, into Mauna Loa, helps to lift the curtain and explain a mystery T.A.J.

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No. 106 RELEASED WITHOUT COPYRIGHT RESTRICTION January 6, 1927

KILAUEA REPORT No. 782
WEEK ENDING JANUARY 5, 1927
Issued by the Observatory, U. S. Geological Survey:
T. A. Jaggar, Official in Charge

At Halemaumau on December 29, at 3 p. m., there were dribbling falls of rock at the northwest wall and the southwest rift caverns. New red sand on the talus slopes showed that this had been going on for some time. The rock falls continued throughout the week, and January 5 showed a new notch at the northeast rim and new debris below. The bright-yellow sulphur at the south talus was not washed away by the heavy rains of the new year. It is noticeable that the blue sulphurous fume does not show at this place as it did formerly.

Sixteen local earthquakes were registered during the week, all very feeble Owing to northeast wind, microseisms were large after January 2. West tilt increased slightly the first part of the week, but January 3 and 4 nearly four seconds of east tilt suddenly set in, making the net tilt moderately eastward for the week.

THE INTENSITY OF GRAVITY

Lieutenants Brown and Bainbridge of the U S. Coast and Geodetic Survey have just completed "swinging a pendulum" at Kilauea and Mauna Loa. This is to determine the differences of the force of gravity at those places. Older determinations were made near Mauna Kea, and another station is to be made at Hilo.

Gravity is the resultant of the earth's attraction and the centrifugal force of its rotation. These forces change with height and distance from the equator. The same object, at sea-level, weighs one two-hundredth less at the equator than at the poles, and one two-thousandth less for each mile of elevation. If a spring balance could be made reliably sensitive to measure the tiny changes, these differences of weight of the same mass, and so the gravity variations, might be directly measured. At present, however, more delicate methods are needed.

The time of a complete swing of a pendulum (period) is dependent on its length and the force of gravity. If we measure the period and length, the force of gravity for the place of swinging becomes known. To determine the absolute force of gravity in dynes (force necessary to move a gram weight one second with the velocity of one centimeter per second) at a standard location, a double-ended pendulum is used. Adjustments that produce the same period of swing when hung from either end give precise measure of length. Counting the beats gives the other requirement, period.

Determinations of absolute gravity are made carefully at a few base stations. The force is 980.112 dynes at Washington, D. C. Field observations are made by a comparative method. The length of the field pendulum is determined by swinging and timing it at a base station of known gravity. The field pendulum is thenceforth regarded as retaining the same length, with due regard to temperature variation. A dummy pendulum exactly like the one swung, with a thermometer bulb inside its bob, is kept inside the apparatus and the thermometer is always read and temperature is recorded. From time to time the field pendulums are recalibrated at the base station.

The comparative method thus necessitates the use of only a single suspension instead of a double-ended pendulum, and the other end is a lens-shaped bob as big as a large watch. The pendulum is about a quarter meter (nine and seven-eighths inches) long with a period of a half-second. Two or more pendulums are used alternately and the results averaged. They are made of invar metal, a nickel-steel alloy that hardly expands at all with heat. An agate plane in a stirrup at the upper end of the pendulum bears upon an agate knife-edge support. An air-tight metal box holds the pendulum, which swings in a partial vacuum, having a pressure of 60 mm. of mercury, registered by means of a manometer. The box has glass windows and levers for starting the swing, and is exhausted by a hand pump. The pendulum is started through an arc of only two or three degrees, yet it will keep swinging twelve hours. Even the rigid support sways a little: an interferometer measures this swaying, and a proper correction for the period of the pendulum is computed. The pendulums are most carefully handled, as corrosion, dirt, or deformation would so alter the distribution of mass as to change their mathematical lengths.

With corrections made for amplitude of swing, vacuum pressure, temperature, and flexure of supports, the major measurements consist of swinging the pendulums through six twelve-hour intervals. Accurate time for the beginning and ending of these intervals is necessary,and may be secured by telegraph or radio, or from star observations.

An electric light flashes through a slit. A chronometer controls the flash of light every two seconds. Only when the pendulum passes the vertical a small attached mirror reflects back the light to the observer's eye. By direct observation and noting standard time, a comparison of coincident flashes is made between pendulum and chronometer. The beats of the chronometer and the wireless time-signals are recorded on a chronograph. Thus the swings of the pendulum for a few minutes, at the beginning and ending of the twelve-hour interval, are compared with standard time to within a few hundredths of a second, and this gives the number of swings. In the meantime the pendulum beats out its twelve hours unobserved.

This interval, divided by the number of swings, gives the period of the pendulum. A mathematical formula gives the force. The allowable probable error is .004 dyne. The period determination must be within one millionth second. Radio time signals are amplified and recorded on the chronograph. In Hawaii they are received from Washington, D. C., by short-wave wireless. All of this physical apparatus was set up on the top of Mauna Loa, for a week in winter, in a cavern covered by a tent.

The gravity determinations measure the earth's radius, and so determine its shape. They are used in studying isostasy, and in measuring local densities of the earth's crust. The latter use will show, here on Hawaii, what are the interior densities of our volcanoes, Kilauea, Mauna Loa and Mauna Kea. R.M.W.

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No. 107 RELEASED WITHOUT COPYRIGHT RESTRICTION January 13, 1927

KILAUEA REPORT No. 783

WEEK ENDING JANUARY 12, 1927

Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

There is nothing new to report concerning the conditions of Kilauea and Mauna Loa volcanoes. Both are dormant, Kilauea with a vast pit 3,000 feet across, inactive since August 1, 1924; Mauna Loa with a summit crater and hot rift athwart it, inactive since May 1, 1926.

For the week at Kilauea 14 very feeble tremblings were registered seismographically. Tilt has been moderate westward, about four seconds. Microseisms, after high easterly winds, were still strong January 6, but have diminished to normal.

REPORT No. 3
LASSEN VOLCANO OBSERVATORY

Mineral, California, December 29, 1926
R. H. Finch, Associate Volcanologist

About the middle of December there were press reports stating that Lassen Peak was in an eruptive stage. The reports were quite certainly based on peculiar cloud formations. On December 18 and 19 a trip was made to the National Park boundary and good views of the peak were obtained. There were no signs of unusual activity. The only clouds seen were of the cirrus type high above the level of the peak. Updrafts produced snow clouds that shot up to a height of 300 to 400 feet above Lassen Peak and adjacent peaks. Such clouds when viewed at some distance, especially by transmitted light, might easily be mistaken for small eruption clouds. The updrafts were observed to start as much as a mile below the summits. The seismographs showed nothing unusual at this time.

On December 28 the seismographs of Lassen Volcano Observatory registered their first "swarm" of earthquakes, 22 quakes being recorded on that day. The strongest shake occurred at 6:12 p. m. It was preceded by a rumble and dismantled the E-W component of the seismograph. The only other one that was perceptible occurred about an hour earlier. The majority of the earthquakes preceded the strongest one. The indicated direction was northeast at Mineral, which is southwest of Lassen Peak.

MAUNA LOA TRAIL

On January 3, 1927, Mr. Allen Burdick, Engineer of the Department of Public Works, Territory of Hawaii, accompanied by Dr. T. A. Jaggar, examined the region above the Koa Camp in Alika with a view to a trail survey. It was found that there are two possible routes from the Koa Camp to the source of the Alika flow, the one leading through the forest and old pahoehoe, between the Alika and the 1919 flows. The other route leads directly over the Alika flow, straight towards its source. The objective for the proposed seven-foot trail is the camp ground at the Umi altar, a few hundred feet north of the largest Alika source cone. There is a third possible route following the contour of the mountain about the 5,100-foot level along the trail that passes the Kaapuna Ranch house. This would lead to the north side of all the branches of the Alika flow, whence a way could be followed due east up the pahoehoe, to the top region.

It is believed that the proposed trail would serve five purposes: (1) It would assist the Board of Agriculture and Forestry in reaching the South Kona Forest Reservations with automobile trucks; (2) it would assist the County of Hawaii in time of danger from lava flow in protection and for warning given to the forest rangers and the cattle ranchers; (3) it would enable the Geological Survey to keep a seismograph station on Mauna Loa, equipped with telephones, near the sources of all the lava flows of the twentieth century; (4) it would assist the ranchers of the western slope of Mauna Loa; and (5) it would make more accessible to travelers the mountaineering and camping on Mauna Loa at all times and especially in times of splendid eruption.

Mr. Burdick is at work on an estimate for this emergency trail, and it is hoped that an act providing for its construction will be introduced for consideration of the Hawaiian Territorial Legislature through the Commissioner of Public Lands. T.A.J.

GEODETIC MEASUREMENTS ON HAWAII

To the Island of Hawaii for precise measurement by levelling came Lieutenant L. G. Simmons of the U. S. Coast and Geodetic Survey October 4, 1926. His work started from Hilo on the Hilo-Kilauea road October 4 to 14. From October 15 to November 17, with the assistance of packers and animals from Keauhou Ranch, he ran levels from Volcano House to the highest summit of Mauna Loa by way of the National Park trail and Puu Ulaula. Bench marks were placed about two miles apart. About December 18 the upper part of the Hilo-Kilauea road was levelled, completing the entire stretch from Hilo to the Mauna Loa summit. Preliminary computation indicates that the old Hawaiian survey of W. D. Alexander, which determined the height of Mauna Loa by vertical angles, differs by only about two feet from the result of precise levelling.

Lieutenants Brown and Bainbridge arrived December 15, and swung gravity pendulums at the Hawaiian Volcano Observatory, Kilauea Crater rim, December 17 to 23. By preliminary computation, not reduced to sea-level, the value of gravity at Kilauea is 978.667 dynes. These observers camped at the north lip of Mokuaweoweo, the crater of Mauna Loa, December 28 to January 7, and obtained preliminary value of gravity, not reduced to sea-level, for the Mauna Loa summit region 979.091 dynes. January 10 they began gravity observations at Hilo.

They will install at Hilo a standard recording tide gauge, to be used under the supervision of R. M. Wilson, geodetic engineer at Hawaiian Volcano Observatory, in determining a datum for the new precise levels. The gauge will also detect tidal waves. It will be operated under the U. S. Coast and Geodetic Survey by Brother J. B. Albert, Hilo seismograph observer. All this new geodetic work has been made possible by cooperation between the Coast Survey and the Geological Survey.

R.M.W.

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No. 108 RELEASED WITHOUT COPYRIGHT RESTRICTION January 20, 1927

KILAUEA REPORT No. 784

WEEK ENDING JANUARY 19, 1927

Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

There are three things happening in Halemaumau pit of Kilauea Volcano that show increase during the past week. There is a movement registering earthquakes on the seismographs: there is marked increase of avalanches in the pit; and there are yellow sulphrous patches on the debris slopes which are increasing in area. The combination means disturbance both chemical and physical, and lava eruption may follow, but the effects are not yet unusual enough to justify a forecast.

On January 13 dust from a small slide rose at 1:40 p. m. There were many small slides the next day. On the 15th dust hung over the pit after 11 a. m., and at 11:43 a. m. avalanche roar was audible at the Observatory. Small avalanches continued, dwindling in afternoon. The pit was left with northern walls scarred, and at 4 p. m. northern, western and southern walls were uneasily scaling off. Fresh debris lay on the talus slopes. The seismographs did not respond to avalanching this forenoon, but local quakes were registered the previous day, this afternoon and the day following. About 3 p. m. January 16 came a small earthquake, a big avalanche roar and a cloud of gray dust. Again the pit walls were steadily working, and a mass of red debris had fallen on the north slope. Spicy sulphur was smelled at the south rim, and the yellow solfatara below had increased in area. The slipping of rocks in the pit from the walls continued on the 18th, particularly near the Kau Desert rift tunnel.

During the week the seismographs recorded 29 local earthquakes, all very feeble. On the 13th, 14th and 15th the seismographs showed the greatest activity as on these three days most of the earthquakes for the week occurred. These three days as noted above were also the most active days for slides in the pit. One of the earthquakes, larger than the others but still not large enough to be perceptible, occurred at 5:07 p. m. on the 14th and lasted over two minutes. No avalanche was observed coincident with this quake, although it was somewhat larger than the shock above noted at 3 p. m. on January 16. There was, however, red avalanche debris produced at about this time.

Tilt accumulated during the week has been very slight to the east.

THREE PRESS REPORTS

Confirmation, denial, or explanation of the following, from those who have been there, is invited by the **Volcano Letter:**

(1) At Ballybunicn, on the west coast of Ireland, the Atlantic rollers, making great fissures by breaking down the cliffs, finally reached masses of iron pyrite and alum. Rapid oxidation took place by contact of water with these, which produced a heat fierce enough to set the whole cliff on fire. For weeks the rocks burned like a volcano, and great clouds of smoke and vapor rose high in the air.

(2) A dispatch from Dutch Harbor of December 31, 1926, states that Mount Makushin, on Unalaska in the Aleutian Islands, erupted the evening of December 30 with "fountains of fire and masses of vapor," making a spectacular display. A slight earthquake accompanied the eruption and there was fear for the safety of Makushin village.

(3) The boiling springs of Iceland are piped underground and used, not only to heat the houses, but to warm and water greenhouses and gardens. The warm water hastens the growth of flowers, vegetables, and fruits. "Near the largest geyser at Reykjavic a large greenhouse has been built." Iceland can compete with the Channel Islands in growing early potatoes, vegetables, and flowers.

We did not know the Icelandic geysers were at Reykjavic, no added facts have been seen about the Makushin eruption, and we would like to know the date and details of the Ireland story. T.A.J.

FIGHTING IN LASSEN AA

A remarkable story of the Modoc Indians is told in a popular book on Lassen National Park (The Kingship of Mount Lassen, by Mrs. F. H. Colburn; Nemo Publishing Company, 628 Mills Building, San Francisco). These Indians lived in a lava country. Captain Jack, a young Modoc chief, secreted in a lava cavern which still has a bad name, made headquarters in an inaccessible ridge of aa, flanked by deep ravines, fissures and masses of bowlders. Here with one hundred and fifty followers he conducted depredations against the whites.

Lieutenant Colonel Wheaton fought 52 Indian braves with 400 U. S. troopers January 17, 1873. He reported to the War Department that "the bowlders ranged in size from a matchbox to a church. Captain Jack's stronghold was in the center of miles of rocks, fissures, caves, crevices, gorges and ravines—some fully 100 feet deep. In my twenty-three years of service, mostly fighting Indians. I have near before encountered an enemy, civilized or savage, occupying a position of such natural strength as the Modoc stronghold. Nor have I ever seen troops engage a better armed or more skillful foe."

The fight lasted from 8 a. m. to 10:30 p. m. when the troops retreated to their camp 15 miles away. They had fought all day without seeing an Indian! Little puffs of smoke through a hole in the lava was all they had to guide their attack. Added to the difficulties was a fog so dense that the parties could not communicate. It was bitter cold. Because of the incredibly rough lava surfaces the soldiers were obliged to advance crawling on their hands and knees. It was utterly impossible to recover the dead, and they had great difficulty in removing the wounded. The attack was a complete failure.

This Lassen book contains very beautiful photographic illustrations of the volcano's eruptions and boiling springs, a life of Peter Lassen, descriptions of the country and its pioneers, and a map of the Park. Its pretensions are rather literary and poetic than geological. T.A.J.

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No. 109 RELEASED WITHOUT COPYRIGHT RESTRICTION January 27, 1927

KILAUEA REPORT No. 785

WEEK ENDING JANUARY 26, 1927

Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

The avalanching activity at Halemaumau pit reported last week did not continue. At 6 p. m. January 20 there were a few falls of stones northeast and west, some dust had been seen over the pit during the day, fresh debris lay on the northern taluses, and at 6 p. m. rocks were heard falling in the pit.

The afternoon of January 22 a few isolated rocks fell from the walls, and during a circuit of the pit it was noticed that the eastern sulphur stain is about 100 feet above the floor, and the southern larger one is at least 200 feet up the talus. No fresh cracking of the soil near the pit edge was anywhere observed. On January 26 very heavy rains had not washed away the bright yellow crystals of the south talus, though the other sulphurous spots were paler than before.

During the week 25 earthquakes were registered, mostly very feeble. On January 24 at 6:49 a. m. a shock was strongly felt in Kona, and registered at the Kilauea Observatory feebly, indicating a distance of 44 miles by its preliminary tremor, which is almost the distance to Kealakekua, Kona. At 6:54 a. m. January 25 a slight earthquake was felt at Volcano House, with maximum acceleration E-W.

A distant earthquake was registered January 23, beginning 2:45 p. m., and showing phases that indicated distance to origin 3,585 miles. Greenwich time at origin (0) should have been 1 h., 05 m., 46 s., January 24. Tilt was slight to the SE.

PROGRESS OF SANTORIN ERUPTION

Professor C. A. Ktenas of Athens describes the growth of the new lava dome surmounted by an ejection cone in the Grecian Archipelago. (Bulletin Volcanologique, Nos. 7 and 8, 1926, pp. 3-64, Naples. See also Volcano Letter Nos. 43 and 58.) His account extends to January, 1926, and the eruption had begun August 11, 1925, with the piling up of dacitic andesite lava in a sea-water channel among ancient lava cones. Santorin Volcano is in a crater lagoon enclosed by the crescent islands of Thera. August 23 a dome 73 meters high had formed, and afterwards kept about this height. Temperatures from 700° to 900° C. were measured in luminous cracks. Explosions through the dome went hand in hand with lava-flow extensions. The explosive products were of contemporaneous lava, and the gas rushes made cauliflower clouds charged with sand, pebbles and bombs.

The lava flows spread through and filled up two water channels, progressing 700 and 1,000 meters by January, 1926. The lavas expanded under a glassy carapace, and showed increase of inclination toward their fronts. The water was 10 to 50 meters deep, and the lava flows thickened to 25 to 30 meters above it. The water was heated to 65 degrees C. The lava front domed up.

The lava is glassy with plagioclase, angite and hypersthene crystals, and subordiante titano-magnetite and olivine. The composition is excessively siliceous, without quartz; silica 65%, alumina 16, iron 5, alkalies 7, and lime exceeds magnesia.

Yellowish and bluish flames were abundant on the dome, and spectroscopically showed hydrogen, sodium, chlorine and no helium. The salts showed lime, magnesium, chlorine, sulphuric acid and ammonia dominant. The fumarole gases showed dominant sulphurous acid, hydrogen, and carbon dioxide, at temperatures from 65° to 380° C. Water vapor was abundant, as shown by many explosive jets of white steam, but the gases from the lava proper showed signs of dryness. Litmus paper gave no acid reaction until it was wetted. The ashes that fell showed no acid effects until they were wetted by rain. Some of the fumaroles were anyhdrous, and some were humid. Flames during principal eruptions were several meters high. Sea salt was not deposited by the fumaroles. Sulphuretted hydrogen was notably inconspicuous, but was detected in the sea-water reactions.

The lavas were not properly aa, but formed stiff carapaces that cracked and dragged showing transverse crevasses like glacial seracs. The whole islet of the active volcano in the middle of the Thera lagoon is increased and unified on its eastern side. The lava dome developed cinder cone slopes about the central vent as the eruptions went on, the whole being called a "conodome." The explosive phenomena have increased during the development of Santorin since 1707.

The explosive activity of the period, very strong at first, reached a maximum the first half of September, and declined thereafter. There were paroxysmal explosions occasionally, and spells of waxing and waning moderate effervescence. A very interesting observation, by measurement with a micrometer scale in a field glass, records that the central portion of the dome, during a series of expulsions of gas, would rise visibly three or four meters continuously and rapidly; after the explosion this area, 50 meters across, would sink back. This oscillation repeated itself six to ten times an hour. The net result was continual change in the form of the dome. T.A.J.

CHLORINE AND VOLCANISM

Attention is called by Dr. Sidney Powers, of Tulsa, Oklahoma, to the fact that Malladra, Volcanologist of Vesuvius, and Ponte of Etna, both consider increase of chlorine in the solfataric cracks at the craters a sign of coming eruption.

The collections of gas from live Hawaiian lavas have never shown such excess of chlorine as the Italian volcanoes. Shepherd says (Bull, Hawn. Volc. Obsy. May, 1921, p. 88) "Chlorine occurs, but in relatively small amount." His analyses generally show only a few hundredths of a percent, and chlorides are rare among Kilauea salts. Muriatic acid, very conspicuous in odor and effects where the Hawaiian lava flows enter salt seawater, is comparatively unknown at the source vents. T.A.J.

SAMPLE COPY

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No. 110 RELEASED WITHOUT COPYRIGHT RESTRICTION February 3, 1927

KILAUEA REPORT No. 786

WEEK ENDING FEBRUARY 2, 1927

Section of Volcanology, U. S Geological Survey:
T. A. Jaggar, Volcanologist in Charge

An inspection of Halemaumau pit of Kilauea Volcano between 3 and 4 p. m. January 28, revealed nothing new in the condition of the bottom. There was a marked jet of steam arising from a bowlder in the midst of a dry, hot patch that extends up and down the moist middle region of the southwest talus. No slides of any size occurred at this time.

On February 1, avalanching from the northern walls of the pit was noticed, somewhat like that of a fortnight before. In the middle of the afternoon, dust from slides arose from the pit, and at 5:45 p. m. singularly white dust rose in a thin cloud from the whole pit gradually, beginning at the northeast corner. This left the air over the orifice of the pit suffused with dust for 30 minutes or more. The next day, February 2, dust rose from the north corner of Halemaumau about 7:30 a. m.

Fifteen very feeble local earthquakes, and one teleseism, have been registered during the week. Two of these indicated distances to origin of 22 and 37 miles. The preliminary wave of the distant earthquake arrived at 7 h., 36 m., 10 s., a. m., February 1. There was practically no accumulated tilt.

LASSEN REPORT No. 4

Mineral, California, January 14, 1927
R. H. Finch, Associate Volcanologist

L. W. Collins, Superintendent of Lassen National Park, and R. H. Finch, made a round trip to the summit of Lassen Peak during the three days January 11, 12, and 13. The first day was taken up in reaching camp by Supan's Hot Spring region and on the 12th the trip from camp to summit and back was made. The depth of the snow averaged between five and six feet. The places where horses are usually tied in summer ascents, about 1,400 feet below the summit, was reached at 11 a. m. Here snowshoes were left behind both because of the steepness of the slope and of the fact that it was covered with ice. About one and one-half hours were taken up in the ascent, while the descent was made in 20 minutes. Some idea of the windy conditions at the summit was obtained far down the slope by observations of swirling clouds of snow that were almost continuously blowing out from the peak. On the southeast slope, where the ascent was made, the air was still and the sunshine almost too warm. Gloves which had become wet from the explorers' going on all fours during the ascent, were almost instantly frozen in the arctic blast that greeted them as they peered over the summit. The frozen gloves were thawed out, but not dried, while lunch was eaten over a steam crack in the crater. Shortly after the start to climb out of the creater, gloves were again frozen, and at the foot of the icy slope it was found that fingers were frosted and a frosted toe was brought home as souvenir. Camp was reached shortly after nightfall.

Before starting home on the morning of January 13, the temperature of the upper Supan's Spring was taken. At a vent where the steam was escaping with a loud hiss the temperature was found to be 194° F., or about 9° F. hotter than the highest temperature reported from this spring by Doctors Day and Allen in 1923.

A perceptible earthquake that was accompanied by a loud rumble was recorded on the Observatory seismographs at 6:20 p. m. January 13.

SEASHORE OBSERVATORIES

England, the United States, and Canada are begining a definite scientific measurement of the shoreline as a sensitive marker of geophysical changes. There was a tremendous Galveston flood in 1900 from the piling-up of hurricane waters by a 100-mile gale, producing a rise of 15 feet. Galveston is now protected by a massive seawall 17 feet high. To June 30, 1925, the American Government had spent $15,000,000 in an effort to deepen and maintain the waterways leading from the ocean to eight principal cities in the region extending from Beaufort, N. C., to Jacksonville, Fla. During the 20 years 1900 to 1919, hurricanes on the coast of the Gulf of Mexico have destroyed 7,225 lives and property amounting to $105,000,000. Now comes the tragedy of Miami, Fla., more appalling than that of Galveston, and "one of the most striking examples of the helplessness of man against the unbridled elements" (R. S. Patton, "The Toll of the Waves," World To-Day, London, December 1926). Enormous sums have been spent on the levees of the lower Mississippi, which in time of flood at New Orleans hold the water so precariously that the flood patrol piles sand bags at weak places, and the water rises to within two inches of the top of the sand bags. Mr. Guy Gest, of New York, points out that an earthquake at such a moment of the kind that devasted the Mississippi valley in 1812, would wreck the whole levee system.

Mr. Patton, a British coastal survey expert, states that there are virtually no quantitative data regarding the forces which attack our beaches from the engineering standpoint. People flock annually in increasing numbers to beach resorts in search of rest and refreshment, and the beaches have become important national assets to meet the efflux of population from the over-congested cities. This is an incident to the more comfortable standards of living attained within the past few years. The coast of England between Bridlington and Spurn, a distance of 36 miles, has receded 2¼ yards annually, amounting to 3 acres lost per year. At this rate the coast, here about 40 feet high, has lost a mile since the Norman Conquest. Mr. Patton states that it is possible for engineering science to minimize or prevent this detrimental course of events, but the way to attack it is not yet clear. He cites the State of New Jersey, which has assumed jurisdiction over the entire problem and is providing for a study of basic principles of shore erosion.

The Coast Survey has just installed a tide gauge at Hilo, and nowhere is there more interest than in Hawaii in the relation of shore erosion to the rising and falling of the land. T.A.J.

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No. 111 RELEASED WITHOUT COPYRIGHT RESTRICTION February 10, 1927

KILAUEA REPORT No. 787

WEEK ENDING FEBURAY 9, 1927

Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

On February 3 small avalanches were indicated by dust rising from Halemaumau. This continued the next day, ond on the fifth, at 4 p. m., a considerable slide from the N.E. wall of the pit was seen to start under the stimulus of stones dropped by visitors. The talus below showed much fresh material. The sulphur patch at the south is spreading among the fragments. The wall and slides above this are blackened. At 5:20 p. m. a noisy natural slide fell at the N.E. wall. The steam cracks S.W. and W. of the pit are purring as though water were below, and this is true also of Sulphur Bank flat.

Only eight local earthquakes were registered for the week, none perceptible. A feeble one at 11:26 p. m. February 2 showed origin distance 45 miles. An unusual quiet interval of 60 hours, without even a tremor, occurred after 5:52 p. m. February 6, and is now in progress. Tilt for the week was slight south-southwest.

COMPRESSIONAL HEAT IN VOLCANIC BLASTS

Referring to **Volcano Letter** No. 63, March 11, 1926, I do not think there is "a tremendous compressional wave travelling at an immense speed." There is movement of air ahead of ejecta, rather than great compression. The main compression is probably at the start of the explosion, in the crater. By the time the ejecta reach the rim, the air is moving freely in front of the ejecta. The crater acts like the gun barrel. Such, at least, was my impression watching numerous explosions of Vesuvius. This I took to be proven by the height to which the material rose compared to the initial velocity. Had there been heavy compression, the air cushion formed would soon have terminated their ascent.

I happened to see a factory of high explosives blow up, one day, near Ottawa. I was looking at it at the time, from a distance of about 200 yards, across an open field. It was a thick-walled stone building. The whole building rose bodily, comparatively slowly, then the walls bulged out, and then the roof began to rise, and the whole thing flew into fragments travelling with great velocity. Judging by what I had seen at Vesuvius, I thought their velocity would take the rocks to a height of 1,500 feet, but I judged that not a single one reached 500 feet, though some travelled a long distance laterally. I expected heavy air blast, either from or toward the explosion. I felt none, though plate glass windows in Ottawa, three miles or more away, were broken **outwards**.

At the start of the explosion, there was evidently some compression, which held the light roof on to the walls—and burst the solid masonry walls before the roof went. The comparatively slow speed at first was due only partly to the time taken for complete oxidation of the explosive, but mainly I think to the retardation by the air before it began to move ahead of the material of the factory.

Similarly a large, hot-air balloon when released jumps up about 20 feet, hesitates an instant, and then shoots up like an arrow. The air compressed in front of it stops it, and then travels ahead of it.

In the Frank Landslide (Great Landslide at Frank, Alberta, by R. G. McConnell and R. W. Brock; Pt. VIII, Annual Repoort 1903, Department of the Interior, Dominion of Canada), the main peak of Turtle Mountain for a width of half a mile broke away, and fell into the valley 3,000 feet below to the N.E. Here then was heavy air compression. But it was not felt by anyone in the town on the north edge of the slide, nor could I find any trace of an air blast there. It was, however, felt by miners in the gangway of the local mine. The mouth of the tunnel was aboout 200 yards within the buried area south of the north edge of the slide. South of the edge of the slide, for half a mile down the valley, there were evidences of the air blast. The trees near the edge of the slide were overturned, and farther away were stripped of branches, and still farther, of twigs. There was great air compression, but not enough heat generated to have any observable effect upon the most delicate plants. There were no men for several miles down the valley to the S.E. I did not find any birds or field animals killed or injured by the blast. So it cannot have been very hot.

The above supports the view of T. A. J. that the destruction of volcanic blasts is due to volcanic material and volcanic heat, and not to pressure as suggested by Cole and Brooks. R. W. Brock.

MORE ABOUT SHORELINE OBSERVATORIES

The Hawaiian interest in the shore is deeply involved with the study of volcanoes. Our land is going up and down remarkably, as proved by tilt pendulums and levels. The rising goes with rising lava and the sinking with falling lava. The thing called "mean sealevel" is the only datum to refer to. If the island of Hawaii rises differently from the island of Maui, nothing will prove it unless both islands maintain tide gauges all the time, and unless "mean sealevel" is the same for both islands.

Professor Douglas Johnson (Columbia Univeristy, New York City), Chairman for Shoreline Investigations of the U. S. National Research Council (Science, January 7, 1927), has published remarkable pictures of the stages of receding shoreline at Cape Breton ("The New England-Acandian Shoreline"), and notes that the Canadian Hydrographic Office is undertaking in New Brunswick a comparison of mean sea-level with a large embayment which receives great quantities of fresh water. The tidal range is over 20 feet, and the study involves tide gauge records and the running of lines of levels. Similar studies are being made at New York City and at Eastport, Maine. Graduate students from Columbia University have also been studying the evolution of special shorelines along the Atlantic Coast.

Dr. Johnson asks the support of everyone interested in beach property and in the burdens which coast erosion throws upon the taxpayer. His committee wishes information on changes in shoreline cutting, on engineering works, on artificial beaches, and on photographing shoreline changes. T.A.J.

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No. 112 RELEASED WITHOUT COPYRIGHT RESTRICTION February 17, 1927

KILAUEA REPORT No. 788

WEEK ENDING FEBRUARY 16, 1927

Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

In Halemaumau pit on February 12 there was a new scar in the middle of the northeast wall where an avalanche has fallen. In midafternoon Febraury 14, strong, red, dust clouds rose from pit, and when Halemaumau was visited at 6 p. m., a prolonged, small avalanche was tumbling at the north corner of the pit, making a roar and sending up red dust. This slide took several fresh starts from about midway up the wali. The northern taluses were covered with fresh, red debris, and big slides had evidently fallen, for the dust extended across the bottom of the pit. On February 16, with strong south wind, nothing new was noted at the pit, but pinkish dust from the desert filled the air above Kilauea Crater.

One distant and 12 local earthquakes were registered during the week, the teleseism occurring about 3:30 p. m. February 15. Microseisms, which were strong the first part of the week, diminished in spite of the strengthening of the southwest wind. The wind squalls affected the seismogram February 16 beteewn 5:15 and 7:30 a. m., as a short-period, jerky, irreguiar vibration, the microseisms remaining normal. Tilt for the week was very slight WNW.

SUPPOSED NEW VOLCANO

Those who have studied Mexican volcanology recall the case of Jorullo Volcano, famous for having grown up under the eyes of men. A newspaper report (Minneapolis Tribune, December 26, 1926) states that in Chiapas, in southern Mexico, there is a new hill called Mount San Cristobalito. Subterranean rumblings are heard, and a "sulphurous waterfall" of curative powers has increased. German engineers are said to have pronounced the hill as a rapidly developing volcano, which began as an insignificant mound of earth about eight years ago. The statement is that "persons ascending the top of the mound are almost suffocated by the intense heat; and no one knows when the terrific subterranean pressure will blast its way through to the open air." T.A.J.

ERUPTION OF MERAPI

A wireless from the volcano service of Java states that Merapi Volcano, in middle Sumatra, has been in eruption, throwing out ash since February 5. T.A.J.

REVIEW OF HAWAIIAN EARTHQUAKES 1926

The total number of seismic disturbances registered on the seismographs during the year 1926 is 1,801. The number includes 23 teleseisms, of which eight were decipherable as to distance.

The remaining local earthquakes and tremors, individually counted, number 1,778. These may be classified by their strength, or by their kind. The greater number of them were very feeble, 90% being so classified. There were 4% of them feeble, 4% slight, and 2% moderate. The number reported as felt was 101, or 5.7% of the total.

The period of the Mauna Loa eruption, April 10 to 24, is responsible for about a third of the total, and the numbers are given day by day in Volcano Letter No. 71, as a review of the earthquakes during the eruption. The smaller disturbances are of different kinds: those caused by actual earthquakes, those accompanying avalanches in Halemaumau, and those caused by a waxing of harmonic tremor. The large count during the Mauna Loa eruption is in part due to the kind last mentioned. At times of lava flow there is a characteristic and continuous very short-period tremor registered on the seismographs. This type of tremor waxes and wanes, and many of its times of increased amplitude were counted as individual disturbances. It is interesting to note that the large number that came in April in excess of the usual average, were quite definitely confined within the period of flow from Mauna Loa, the beginning and ending of excess numbers being rather abrupt.

The number recorded for 1925 was 922 (see review of earthquakes in Volcano Letter No. 54), so that if the April excess, caused by the Mauna Loa flow, were subtracted from the 1926 total, the two years would be nearly the same.

Following is a table showing the number of local disturbances for each month:

January	54
February	32
March	68
April	761
May	43
June	56
July	101
August	254
September	240
October	62
November	46
December	61

R.M.W.

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No. 113 RELEASED WITHOUT COPYRIGHT RESTRICTION February 24, 1927

KILAUEA REPORT No. 789

WEEK ENDING FEBRUARY 23, 1927

Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

There has been no significant change in the lava pit of Kilauea during the past week. There have been the usual small slides from the walls, and the sulphur spots near the bottom of the pit on the debris slopes continue to grow, indicating that lava gas is emerging.

Seismically, the week has been extraordinarily quiet, only eight local shocks being recorded on the seismographs at Kilauea. Six of these occurred on the 21st and the 22nd, and one of those on the last date indicated by the length of its preliminary tremor a distance of origin 12 miles from the Observatory. Tilting of the ground for the week was moderate to the SSW.

EARTHQUAKE AT MORRINSVILLE, NEW ZEALAND

Disastrous earthquakes in the north-central part of the North Island of New Zealand centered about the town of Morrinsville, beginning Friday, November 12, 1926. They occurred intermittently all that day, and by the evening everyone was living out of doors. The old residents described the earthquakes as the worst they have ever known. Fire was prevented, and only one person was injured.

There was first felt a small shock at 9:01 a. m. November 12. Another came five minutes later, and another at 10:16 a. m. The big shock arrived at 10:21 a. m., without noise, swaying buildings violently, followed by a resounding thud and by numerous convulsive tremors.

Chimneys fell on the iron roofs, crockery and glassware crashed to the floors, whole shelves of goods fell in the shops, and people made a rush for the streets. The damage was particularly severe in the drug shops and liquor stores, some plate-glass windows were smashed, cracks appeared in several concrete buildings, and the top part of a granite obelisk was displaced several inches. About half the chimneys broke at about the roof level and fell.

Morrinsville lies between Hamilton and Tauranga, about 30 miles northwest of the Rotorua volcanic district. At Piako, two miles east of Morrinsville, a tank was displaced from its stand. The earthquakes were remarkably local, for in the Waikato district around Hamilton, only 18 miles west of Morrinsville, they did not cause any alarm or do any damage.

For the remainder of November 12, earthquakes continued, and according to the New Zealand "Herald" of December 23, 1926, Mr. L. I. Grange, the New Zealand Volcanologist, determined that 41 shocks occurred during the next few days. The disastrous shock was of intensity No. 8 of the Rossi-Forel scale. He believed the shocks to be of shallow origin, caused by movement of a fault on the east side of the Pakaroa Range. The Te Aroha hot springs, 12 miles northeast of Morrinsville, were unaffected by the earthquakes. One of the smaller shocks at 6:45 p. m. was described as coming without warning as a heavy, double thud, which violently shook the house, caused the windows to rattle, knocked over one or two articles on shelves, and started the people moving toward the street. Cambridge, Hamilton, and Morrinsville felt occasional small shocks during the month following the Morrinsville earthquake.

Mount Ngauruhoe, in the southern part of the New Zealand volcanic belt, was sending up steam and black smoke December 21, and on the evening of December 29 detonations were heard from the crater, followed the next morning at 4:15 by an immense volume of smoke which shot thousands of feet into the air. (New Zealand "Herald," Auckland, November 13 and December 22 and 31.)

T.A.J.

EARTHQUAKE STATISTICS

According to Professor Tondorf, of the Seismological Laboratory of Georgetown University, the frequency of earthquakes in the world was computed in 1900 by Montessus de Ballore. Aftter a close analysis of earthquake records then available, 131,292 in number, he placed the annual average earthquake occurrence at 3,830, equivalent to an earth shock every two hours and 37 minutes.

In 1904, Dr. August Sieberg, of the University of Jena, questioned the estimate as too low. A recalculation made by him in 1923 lifted the annual average frequency to 9,000, or about one every hour. Five thousand of these he indicated as being felt by human beings somewhere on earth. Violent or world-shaking earthquakes occur about every three and one-half days, either on the continents or on the ocean's bottom. Violent ones on land average one every five days.

California is visited by a shock on an average of 81 times annually. The liability of one of these shocks being heavy is about eight-tenths of one per cent. (Associated Press report January 1, 1927.)

Statistics of this kind are useful in order to stimulate thought, but the difference between the totals arrived at by Ballore in 1900 and Sieberg in 1923 is rather due to increased knowledge of the earth through human experience in the 23 years, than to any greater accuracy in the methods of Dr. Sieberg. This means that 9,000 earthquakes per annum is no nearer to the facts than 3,830 earthquakes. Neither figure means anything until we define the word "earthquake." In the Hawaiian Observatory alone we registered 5,877 local Hawaiian earthquakes in 1924, of which 3,961 were recorded during the explosive eruption in May. This is the record of only one of the 430 active volcanoes of the world. What about the bottom of the oceans, with reference to local shocks, not recorded as "world-shaking?" The ocean bottoms cover seven tenths of the earth. Clearly, then, an analysis of such few earthquakes as are recorded, is not an analysis of the terrestrial earthquakes that really occur. T.A.J.

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No. 114 RELEASED WITHOUT COPYRIGHT RESTRICTION March 3, 1927

KILAUEA REPORT No. 790

WEEK ENDING MARCH 2, 1927

Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

The changes at Halemaumau pit observed on March 1 were a fresh reddening of the whole northwest wall of the pit where a large shell of the wall had fallen. The debris slopes below were seen to be covered with reddish rocks and dust, and the dusting of the bottom of the pit extended clear across to the south taluses. Most of this had been accompanied by small slides from the decomposed rock of the northwest wall. But there had been at least one big avalanche, which had carried away the greater part of a pronounced bench at the west end of the big intrusive sill which forms the lower part of the northeastern wall. The dusting of the bottom of the pit was further evidence of a big avalanche, and the middle talus of the northeast wall showed more fresh debris. The yellowing of the southern solfataras continued to be conspicuous.

The intense oxidation of the northwestern wall beneath the former surface is remarkable, and it was here that there was excessive heat, along with blue sulphurous fume, in 1923 and earlier.

Fourteen very feeble local earthquakes were registered for the week. Ten of these came on the first two days of the weekly period, February 23 and 24. In the last issue of the Volcano Letter it was noted that a large part of last week's shocks came February 21 and 22. Thus 75% of the shocks for the fortnight occurred within a four-day spell of comparatively greater seismic activity. Three of the earthquakes of that time had indicated distances of about 13 miles, which corresponds to either the northeast rift of Mauna Loa or portions of the northeast rift of Kilauea that were active in 1923 and 1924.

Tilt during the week was moderate ENE. On February 21 the direction of tilt began to change from southwesterly to southeasterly, and by the 23rd it was nearly due east; thus a definite change in direction of tilt coincided with the time of frequent shocks.

The seismological station of the U. S. Coast and Geodetic Survey at the University of Hawaii, Honolulu, Mr. Harold McComb in charge, reports that seismometric measurements of six stations of the United States and Canada locate the distant earthquake of February 15 (noted in Volcano Letter No. 112) as 48° N. Lat. and 153° E. Long., the time at that locality being 1h., 35 m., 22 s., a. m. (G. M. T.) on February 16. The distance from Honolulu was 3,230 miles, and the epicenter is in the Kurile Islands.

EARTHQUAKE IN SCOTLAND

In view of what was said about Britain being stirred in 1926 by recognition of the earthquake peril (Volcano Letter September 23, 1926), the four columns in the Aberdeen "Evening Express" of January 24, 1927, are interesting. They announce that at 5:20 that morning the whole of the north of Scotland and much of southern Norway were shaken by an alarming earthquake, which reached intensity No. 6 (Rossi-Forel scale) in Aberdeen (Nature, February 5, 1927). The British seismographs indicate an origin outside of Scotland in the Norwegian direction. Never before has a North Sea earthquake been felt over so wide an area in Gerat Britain. The area disturbed extended all along the eastern coast of Scotland from the Orkneys to Berwick, and was probably felt in Northumberland. At the northeast end of the great Scottish rift near Moray Firth, an earlier shock the previous evening occurred at 11:05 o'clock.

The shock lasted from five to 30 seconds, and in Aberdeen people were awakened by a loud rumbling noise, doors and crockery rattled and bells were set ringing, and in some places furniture was moved. Ornaments fell from mantlepieces and shelves; doors were slammed; beds pitched up and down, and many persons were greatly alarmed; in some places plaster fell from ceilings.

The press reports from Norway state that the time was 6:20 a. m. by Norwegian Time, which is an hour earlier than Greenwich Time, and that in some towns masses of masonary crashed to the ground and other houses were cracked. People rushed panic-stricken from their homes, but there were no deaths. Three principal shocks were counted, felt from Notodden to Stavanger. The shocks were followed in Norway by terrifying rumblings which sounded like subterranean thunder. All of this indicates greater violence in Norway than in Scotland. T.A.J.

LOWER CALIFORNIA EARTHQUAKE

A violent earthquake at Calexico, on the California-Mexico boundary, occurred about 18 minutes after the midnight that ushered in the New Year (California Time.) Damage was reported at $2,000,000 throughout the entire Imperial Valley, martial law was declared on the Mexican side, and to prevent looting a special police patrol was organized on the California side of the border, with orders to shoot to kill. Many persons were cut and briused, subterranean rumblings were heard almost constantly, 50 or more shocks followed the disastrous one, and during New Years Day these diminished in intensity. At the first shock the mud houses of the Mexicans crumbled to dust, and the merry-makers of the cafes and casinos celebrating the New Year were terrified and poured into the streets. The shocks were felt from Anaheim, Calif., 150 miles north of Calexico, to Yuma, in Arizona. Damage by breakage of the water mains, followed by fire, was heavy in Mexicali. Yuma reported a succession of shocks, terminating at 6:10 a. m. The ocean at Ensenada, on the Pacific coast of Mexico, 50 miles south of the border, was thrown into extraordinary heavy swells, which prevented the launching of small boats. T.A.J.

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No. 115 RELEASED WITHOUT COPYRIGHT RESTRICTION March 10, 1927

KILAUEA REPORT No. 791

WEEK ENDING MARCH 9, 1927

Section of Volcanology, U. S Geological Survey:
T. A. Jaggar, Volcanologist in Charge

The week has been very rainy, with northeast wind, and this moisture increased the volume of visible vapor in Halemaumau. Slides have continued. One considerable avalanche was seen about 11 a. m. March 6, and another one fell with a roar at 1:50 p. m. March 9. Both of these were at the northwest wall.

Five local earthquakes and one distant one were registered during the week. The local ones were very feeble. The preliminary wave of the teleseism, here faintly recorded, arrived about 11:09 p. m. March 6, and the disturbance continued weakly for three-quarters of an hour. Allowing for the difference in time, this was probably the disastrous earthquake in central Japan reported as "Monday night" (March 7).

Tilt for the week has accumulated slightly to the south.

LASSEN OBSERVATORY SEISMOGRAPH

Two horizontal pendulum seismographs recording on a single drum by the smoked-paper method were built along with the cellar to receive them, by R. H. Finch between his arrival at Mineral, September 15, and November. The dimensions of the cellar are 10 by 10 feet, and an office room was constructed above it. The general plan of the instruments follows the lines of the Omori seismographs as they have been modified by Hawaiian experience. The time-piece is an excellent Howard pendulum clock, with seconds pendulum and eight-day movement. The upright posts, 10 by 10 inches square, rise 27 inches above piers which are 18 inches high and two feet square. The heavy masses weigh 225 pounds, consisting of cast-iron containers holding nine lead weights, each bored to take a screw-eye for convenience in handling by one man. A mental rod passes horizontally through the middle of the heavy mass and protrudes 52 inches from the center of the latter, greatly reduced in size at the outer end. The larger portion next to the post is bent slightly, and fits a niche in the face of the post, where it is held by a cardan hinge consisting of a very short piece of fine steel wire, in slots. The upper support is a piano wire with the usual adjustments at the top of the post. The sytem is damped by sheet-aluminum vanes attached to the arm, moving edge-wise in a tank of oil, supported by a removable stand in front of the pier. This permits instant lowering of the oil tank for tests of free swing of the pendulum.

The magnification of the boom is 5, and of the writing lever, 40, making the total static magnification 200. The drum is built on a steel spindle threaded with ¼-inch worm, the ends being made of 3/16-inch three-ply wood, and the cylindrical surface of pasteboard. Light-weight glassine paper is used, each seismogram being 12½ by 38 inches in size. The writing pens are of magnetized steel, lifted to make a gap in the record every minute by an electromagnet, and the pivots of the tubular aluminum writing levers and of the pen-points are made of clock and watch balance staffs. The speed of the drum is 30 millimeters to the minute, and the transmission of motion from the pendulum arm to the writing levers is by means of light metal T-bars, with points resting in sockets in the arm and the lever, respectively. A marker pen attached to the plate supporting the drum and lever system, writes a line for a few minutes once a day on the side of the smoked paper, to be used as a datum line for measurement of wandering of the pendulums under tilting of the ground. The free period of the pendulums is seven seconds.

All of this material, with the exception of the time piece, was gathered together and erected by the Associate Volcanologist, and the driving clocks for the drum were obtained from the Seth Thomas Company, having two-barrel drive and a rotation rate of the spindle of about 15 minutes, which is slowed down with the appropriate gear. The uniformity of rotation given to the drum by these clocks with a speeded balance wheel, is remarkable, and no trace whatever of jerking movement due to the ticking escapement appears in the seismograms. Hitherto, although Mineral is on the actual slope of the Lassen volcanic mass, the seismometric registration has not shown tilt and has been free from tremors of the non-earthquake type. A few tremors have been recorded that have not been identified. R.H.F.

HAWAIIAN OBSERVATORY NOTES

Since the Section of Volcanology was established (Volcano Letter August 12, 1926) the work of the central station in Hawaii has been directed to adaptation of the plant and personnel for its enlarged scope, and to systematizing of its local Hawaii work in the three branches; namely, geodetic, temperature, and seismometric measurements.

The buildings have been repaired and improved, and a new machine-shop was started in operation March 1, 1927, with F. Y. Boyrie as instrument maker. The shop contains lathe, drill presses, power hack-saw, and circular-saw table, and hereafter saving of time and money will be accomplished by machine work done on the spot.

Ground was broken for the new exhibit and lecture building of the Hawaiian Volcano Research Association February 22, and the concrete floors of the new buildings have been laid. The site selected is the actual summit of Kilauea Mountain, on top of Uwekahuna Bluff, where the view of Kilauea Crater, the Kau Desert, Mauna Loa, and Mauna Kea is magnificent. The main building will be of iron and concrete, with stone corner posts and stone benches along the outside. In front a large terrace is being built, inclosed by rough stone wall and containing stone benches. The showroom will contain an alcove exhibiting through glass a modern set of seismographic instruments in operation, as well as other instruments, and on the floor will be glass cases containing the best of the cabinet specimens collected by the Observatory. There will also be wall cases and special exhibits, roller maps illustrating Pacific geograhy, photographic prints and transparencies, and projection apparatus.

The plan of operation so far as can be foreseen is that at a certain hour in daytime the tourist groups will be received and given a short talk on the open terrace concerning the geology of the crater. They will be shown the collections, and their questions will be answered with the aid of the maps and diagrams; then a projection lecture will close the proceedings. Later there will be a National Park naturalist with office hours to meet those who are interested in the walks and rides and natural features of this volcanic park. T.A.J.

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No. 116 RELEASED WITHOUT COPYRIGHT RESTRICTION March 17, 1927

KILAUEA REPORT No. 792

WEEK ENDING MARCH 16, 1927
Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

Rainy weather has continued through much of the past week at Kilauea Volcano. Dust from slides has not been noticed at Halemaumau pit.

The total number of local earthquakes registered at the Observatory during the week was 14, all very feeble. There are also four records of blasts that were noted and timed. Tremors due to blast are of the same character as the usual spasdomic tremor; they wax to a maximum amplitude about the middle of the disturbance, and then diminish to zero, the whole lasting about 15 seconds. The source is on the Hilo road, about a mile away, where the contractor is using dynamite, approximately ESE from the Observatory, and 15 feet lower.

Probably several of the jarrings counted as earthquakes are also due to this cause, but it is not possible to tell which ones. One definite feeble earthquake had phases sufficiently distinct to indicate an origin 20 miles away. This shock was recorded at 8:50 p. m. March 12, and was also registered on the seimograph operated by Captain R. V. Woods, in Kealakekua, on the other side of Mauna Loa.

The Kona seismograph also made a feeble record of the Japanese earthquake of March 7, noted in last week's Volcano Letter.

Practically no tilt accumulated for the week, as the slight SW tilt of the beginning of the week was compensated in the opposite direction later.

THE ALEUTIAN ISLANDS

The region in Alaska which contains the largest number of volcanoes extends in a continuous curved belt from the Aleutian Range of mountains west of Cook Inlet, through the Alaska Peninsula and the Aleutian Islands, to Attu, the westernmost possession of the United States, where there are warm springs. Volcanoes that have an active record lie along a broad arc 1,500 miles long. There are at least 40 of them, ranging in height from mere islets to Redoubt Volcano, 10,200 feet high. Many of the volcanoes ore symetrically-shaped snow-covered cones, with glaciers on their flanks. All along the belt there are hot springs, and in some places sulphur springs (Mineral Springs of Alaska, by Waring, Water-Supply Paper 418, 1917, U. S. Geological Survey).

The Section of Volcanology is authorized to establish one or more volcano observatories on the Aleutian belt. The greatest recent eruption in Alaska was at Katmai Volacno, opposite Kodiak Island, in 1912. This gave vent to tremendous explosions ejecting bowlders, sand, and dust, and also a very siliceous, stiff, soda rhyolite lava, with about 77.5 per cent silica. This magma is chemically at the opposite extreme from the basic olivine basalt of Kilauea, with 48 per cent silica.

The writer criused from Unimak Pass to Atka in 1907, and learned from traders that lumps of pure native copper had been found on the shore of Copper Island, belonging to the Russians, west of Attu. On Attu is a small village of Aleuts. On Agattu there are high peaks, and all of the islands west of Buldir are believed to be pre-Tertiary rocks.

Following the chain east from here, the southern half of the island belt, comprising the larger land areas in the middle of the chain, consists of ancient igneous rocks, without active volcanoes. The northern half, on the other hand, with the dividing line sometimes in a single island and sometimes separating different islands, consists of shapely, recent, volcanic cones, many of them fuming and some the sites of eruptions during the last 50 years.

Buldir is an eroded volcanic cone, with sunken rocks to the south, where islands are said to have existed prior to eruptions that destroyed them more than a century ago. Kiska has a fuming volcano 4,050 feet high at its north end, it contains a good harbor, and its southern half is geologically different, and said to contain "mineral." Chugul and Little Sitkin are said to be fuming volcanoes, the former containing iron. Amchitka is nonvolcanic, and has good cattle feed. Semisopochnoi is covered with volcanoes, but does not smoke.

We now come to a group of large islands strongly volcanic on their north sides. Gareloi is always fuming. A smoking volcano occupies the north end of Tanaga. The north end of Kanga was very active in 1904. Great Sitkin was reported fuming in 1904, and Kasatochi is said to be the top of a volcano with a big crater lake; about 1899 the lake disappeared, and steam was rising. Copper is reported from near Salt Island on Atka, and sulphur amid the volcanoes in the north of Atka. The writer camped there in 1907, and found a boiling spring, and saw fresh volcanic cinder on snow fields.

Seguam broke into eruption for a week in December, 1891, and this was followed by a terrific eruption in the spring of 1892, making detonations heard at the native village on Atka, 75 miles away, and exhibiting two jets of cauliflower clouds. Mount Cleveland, 8,156 feet high, in the Islands of Four Mountains, was active in 1893.

This brings us to Bogoslof, Makushin, Akutan, Shishaldin, and Pavlof, well known volcanoes with an active record.

The Section of Volcanology of the American Geophysical Union (Bull. Nat. Research Council, November, 1926) conducted a symposium on scientific cooperation in the Aleutian Islands in Washington, April 29, 1926, wherein the need was urged for a permanent cooperative observatory in the large central islands, dealing with volcanology, climate, charting, the sea bottom, geology, seismology, magnetism, and atmospheric electricity. As a beginning, we shall establish a seismograph station at Kodiak in the summer of 1927, and make exploration of the eastern Aleutians. T.A.J.

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No. 117 RELEASED WITHOUT COPYRIGHT RESTRICTION March 24, 1927

KILAUEA REPORT No. 793

WEEK ENDING MARCH 23, 1927
Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

The week of the equinox has been marked in the Hawaiian Islands by an exceptionally far-flung earthquake and by some slides in Halemaumau pit. The slides in question were not wholly due to the greater earthquake, as they had been observed the day before.

On March 19 there were numerous slides at Halemaumau in the afternoon which sent up dust. At 10 a. m. of March 20 the pit was visited with a view to discovering what were the effects of the strongly felt earthquake that had shaken all the eastern islands in the early morning. There were evidences that large slides had fallen at the northeast corner of the pit, and big boulders lay on the lava floor which has displaced a very large boulder known as a landmark there previously. There were also freshly fallen accumulations of debris on the northwest talus, characterized by white salts deposited upon their surfaces. At 4 p. m. March 22 some slides were in motion at the middle of the large northeast sill.

The local earthquakes for the week registered at the Observatory were 16 in number, all very feeble with one exception, the moderate shock that occurred just before 5 a. m. on March 20.

The beginning of this shock was recorded at the Hawaiian Volcano Observatory abruptly at 4:52:00 a. m. Hawaiian Standard Time. The instruments show no preliminary phase, the motion breaking abruptly into a strong movement of about 10 millimeters per second per second acceleration. This continued for about 10 seconds, and then became stronger, dismantling the instruments, so that the maximum acceleration and the subsequent details of the shock were not recorded. The shock was perhaps the strongest and most widely felt that has occurred for a year. Reports from other islands indicate that it was felt with about the same intensity throughout the group. Its beginning was recorded in Honolulu by the seismological station of the Coast and Geodetic Survey at the University of Hawaii, at 4:51:07, reaching its maximum there as 4:51:50. That station also reports a second shock at 5:59 a. m. The extent of damage in Hilo was limited to a few broken dishes and small articles thrown from shelves in various localities.

The fact of its abrupt beginning, without preliminary phases, at any of the places where it was recorded in the islands, makes localization of the epicenter a difficult problem. It is worthy of note that Washington, D. C., reports an earthquake 4,800 miles away for the same morning, but the time is not given.

On the Island of Hawaii, the shock was recorded at the Volcano Observatory, at Kealakekua, and at Hilo. An interesting coincidence is the fact that on March 19, 1926, at 10:33 p. m., almost exactly the same date a year ago, a heavy shock occurred with almost the same characteristics. This time of year is very close to the vernal equinox.

There were several severe electric storms during the night of March 22-23, apparently centering near Hilo.

Tilt for the week has accumulated slightly to the SE.

LASSEN REPORT No. 5

Mineral, California, March 2, 1927
R. H. Finch, Associate Volcanologist

Lassen Peak Volcano again showed signs of uneasiness on March 1, 1927, after having been relatively quiet since December 28, 1926. About seven o'clock in the morning of March 1, six earthquakes followed one another in rapid succession. Two of this number were plainly perceptible, the others were detected only by means of the seismograph. At 2:26 p. m. of the same day there came another and larger shock. It was preceded by a loud rumble, and was strong enough to cause buildings to creak. It is interesting to note that "swarms" of earthquakes have been occurring at intervals of about two months.

ADRIATIC EARTHQUAKE

A severe local earthquake was described in the British press of about February 16, 1927, as occurring along the shore of the Adriatic in Jugo-Slavia, and affecting the provinces of Dalmatia, Bosnia, and Herzegovina. Near Serajevo, famous for the murder of the archduke that precipitated the world war, there were big landslides. Chimneys fell, even in Belgrade. The center is said to have been under sea, huge waves were reported on the Dalmatian coast, and ships were said to encounter gigantic seas, even in the Mediterranean off southern Italy, but the correlation of these events with the earthquake may be erroneous.

The reports stated that 19 earthquakes occurred, the first on February 14 at 4:40 a. m. by the local time, and the others during the following 20 minutes. There was said to be subterranean rumbling, and also thunder and lightning out of a clear sky. There appears to have been engulfment in some places, attributed to the underground drainage in a limestone country known to be honeycombed by solution cavities, and much subsidence due to this cause is said to have gone on in the past. The last serious subsidence was at the time of the Laibach Earthquake of 1895. The worst damage of the present earthquake is said to be in Stolac, 35 miles south of Mostar, the capitol of Herzegovina, and cracks formed in the ground.

A later report from Belgrade (Daily Telegraph, London, February 21) states that three persons were killed, 15 injured, and the damage was about $175,000. This took the form of collapsed houses, a tobacco factory destroyed, a fallen railway bridge, damage to famous historical buildings ruined from flood waves, and the crashing down of sculpture and frescoes. T.A.J.

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No. 118 RELEASED WITHOUT COPYRIGHT RESTRICTION March 31, 1927

KILAUEA REPORT No. 794

WEEK ENDING MARCH 30, 1927
Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

The week in the vicinity of the Volcano Observatory has been rainy, with light southerly winds. some thunder showers and increased snow is seen on Mauna Kea. At Halemaumau pit some small slides have occurred, chiefly from the north wall, where the rock is oxidized to a bright red color. The red debris has changed the appearance of the slope below.

After the heavy rains, the steam from vents in the lava floor and the talus has increased the visible volume of vapor clouds, and the three sulphurous patches at the south talus are growing in size. The two lateral ones have hitherto been very small, but they are now becoming large yellow patches like the big middle solfatara at that talus. It is extraordinary that the bluish fume mixed with steam that formerly was conspicuous at this middle vent, has there entirely disappeared, as though the sulphur were now deposited by a gas without the blue fume characteristic. Blue fume is seen, however, at the lower sulphur patch next the north edge of this talus. In addition to these places, white vapor rises abundantly at the center of the floor and from the southwest and northwest taluses.

There is much steam at the southwest rim cracks on the edge of the pit, and along the south wall inside the pit. An extraordinary change has happened at the southeast rim cracks of Halemaumau crossed by the tourist trail about 70 feet back of the rim. With wind in the southeast, these cracks were first observed to be free from steam March 26 and 27. They had been measured January 24, 1925, and had a temperature of 169° F., and were producing much visible vapor until recently. They have frequently been observed to yield so much steam as to be disagreeable where the trail crosses them. Now, however, the visitor may thrust his hand into the cracks, and almost no vapor is visible. Vegetation, such as lichens, mosses, grasses, and ferns, is taking hold in abundance about the openings of these cracks.

Twenty-two local earthquakes of very feeble intensity were registered at the Observatory during the week. There were two periods during the week of almost continuous tremor, apparently very much like the harmonic tremor that is the usual accompaniment to lava outbreaks. At 1:27 p. m. March 26 a very feeble tremor began, waxing gradually to a maximum at 1:37 p. m., waning, and waxing again to a second larger maximum at 1:41 p. m., and finally waning to the point where it no longer recorded itself on the seismogram at 1:48 p. m., making about 20 minutes of continuous tremor. The two maxima noted were counted as two earthquakes of the total for the week. On March 28 continuous tremor was again evident, beginning at 9:01 a. m., and continuing until 9:10, starting again at 9:16 and waxing to a maximum at 9:20 a. m., and waning to an end at 9:41 a. m.

Microseisms were rather strong on March 29.

Tilt has accumulated during the week moderately to the SSW.

LASSEN REPORT No. 6

Mineral, California, March 15, 1927
R. H. Finch, Associate Volcanologist

From March 10 to 14, 1927, the most remarkable series of local earthquakes was recorded since the establishment of the Lassen Observatory. The seismographs were dismantled three times. The strongest earthquakes were on March 10 and 11, though the majority of the entire 52 shakes were perceptible. Lyonsville, 12 miles to the southwest, also reported the strongest of the quakes. As seems to be a characteristic of Lassen earthquakes, all shakes both large and small were accompanied by loud rumbles. After the occurrence of such a series of earthquakes, it would seem indiscreet to say that Lassen Peak is dead.

CAUSE OF LASSEN MUD FLOWS

During the eruption of Lassen Peak in 1915, there were strong horizontal blasts on May 22 that denuded a section of the northeast slope of the mountain and produced remarkable mud flows down Lost and Hat Creek valleys.

It has been maintained by some that mud flowed over the lip of the crater, by others that hot water came out of the crater, and by still others that the water was derived from condensed steam and from snow melted by the steam and hot ashes. In looking over the Peak last January (Volcano Letter No. 110), it seemed to the undersigned that the source of the water may well have been due entirely to melting snow, that hot water from the crater was rather improbable, and that condensed steam, if any, played only a minor part. Snow usually accumulates on the slope in question until in March, while in the middle of January the depth of the snow—five to six feet —was sufficient to furnish water enough to account for the floods. The snow in the upper half of the comparatively narrow belt four miles long, if melted suddenly as must have been the case in 1915, could have produced steep flood waves of about the proportion of those that swept down Lost and Hat creeks. Gravel and boulders must have aided the finer particles in melting the snow and in raising the temperature of the water well above the melting point of ice. A very large boulder was still hot several days after the floods.

If the direction of the horizontal blast on May 22 was only slightly different from that of the one on May 19, as was the case, there would have been enough snow in its path to account for the minor flood that accompanied it, and the condensed steam factor may have been trivial.

R.H.F.

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No. 119 RELEASED WITHOUT COPYRIGHT RESTRICTION April 7, 1927

KILAUEA REPORT No. 795

WEEK ENDING APRIL 6, 1927
Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

Halemaumau pit at Kilauea Volacno has been visited several times during the past week, but nothing has occurred to indicate any marked change in the magma that underlies the volcano. There are usually small slides of loose rock from the walls of the pit if the visitor waits a half hour or more, but large slides have not been seen, and the sulphurous spots on the debris slopes have remained about as before. In rainy weather these solfataras give off much steam, and in dry weather the steam diminishes, but always there is some vapor at the sulphur patches. At the crack back of the southeast edge of the pit, there has been no return of steam where the trail crosses, and the winds have continued southerly. It will be of interest to observe what happens there when the northeast trade winds are resumed.

The seismographs at the Kilauea Observatory have registered a total of 16 local earthquakes, all very feeble. The only possible exception was one of these at 8:44 a. m. April 1, which appeared to be part of the faint record of a distant earthquake. Tilt for the week was moderate to the SW.

AMERICAN GEOLOGISTS

Professor E. H. Sellards, of the University of Texas, has compiled on a map the geographic distribution by states of geologists in the United States. He has presented on the same map the approximate number of papers on geological topics published in the two years 1921-1922, relating wholly or in part to each state. This figure, along with the figure showing the number of geologists, indicates to what extent the published work of the geologists concerns their own states. The list indicates all professional geologists who have worked at the science at least three years after their graduation, and at specialties that include geology, paleontology, mineralogy, petrography, engineering geology, and physiography Presumably geophysicists are distributed among several of these branches.

There are listed 1,744 geologists, and these produced in two years 1.072 scientific papers. Although the district of Columbia contains 114 geologists, only four papers were published concerning that district. On the other hand, California contains 180 geologists, who published 89 papers; and Texas 220 geologists, who published 75 papers, in each case about the state in question. New York has 171 geologists, but only 38 papers were published about New York geology. The activities of the geologists of New York and Washington, D. C., are largely in regions distant from the place where they reside.

The total number of papers for 1921-22 concerning state geology is 1,072, and of these 243 relate to the oil and copper states—Oklahoma, Texas, New Mexico, California, and Arizona. It is remarkable that of 1,744 geologists, 503, or more than one-fourth, live in Oklahoma, Texas, and New Mexico. This shows an astonishing development of geologic activity centering around oil in the last 30 years. The geologists most prolific of publications concerning their own states are in Utah, Nevada, and Oregon. In Utah eight geologists produced 32 papers, in Nevada three geologists produced 24, and in Oregon seven geologists produced 31.

Figures of this kind are very stimulating, and they mark the overwhelming domination of economic geology and especially oil geology which has grown up in connection with the vast industry of drilling and producing petroleum in the southwestern states. T.A.J.

THE TANGO EARTHQUAKE

A very severe and disastrous earthquake occurred on the west side of the Lake Biwa depression that crosses central Japan, on Monday, March 7, 1927. The principal damage was in Mineyama and vicinity, on the northwestern coast of Japan, the destruction being confined largely to fishing villages.

The Home Office on March 10 reported 2,458 dead, 4,107 injured, some 60,000 people homeless, and 88 missing. About 6,000 houses were destroyed by fire or collapse, and some 2,000 more were damaged. Airplanes were used for inspection and investigation, as railways were broken, roads were blocked, and the country at the time was suffering from floods. The misery was accentuated by snow and cold, there were numerous cracks, rumblings continued after the first earthquakes, and a flood-wave from the sea was said to have damaged Yamada and other villages. A terrific gale swept the region on March 11, adding to the misery by demolishing refugee shelters.

The earthquake was felt strongly in Kyoto, Osaka, and Kobe, but no very serious damage was done on the Pacific side of Japan. The details of the seismological data have not yet been reported outside of Japan. T.A.J.

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No. 120 RELEASED WITHOUT COPYRIGHT RESTRICTION April 14, 1927

KILAUEA REPORT No. 796

WEEK ENDING APRIL 13, 1927

Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

Halemaumau continues to show little change, but the red dust made by avalanches on the north talus has increased. On April 10 some slides were heard falling in the forenoon from the northeast wall of the pit, and at 5:15 p. m. a larger avalanche sent up a distinct dust cloud that rose above the rim of the pit and was simultaneous with a short-lived avalanche tremor registered on the seismographs at the Observatory. Heavy rain has washed away part of the sulphur and salts that were so conspicuous on the south and east debris slopes.

For the week 17 feeble local earthquakes were registered. One beginning at 9:02 p. m. April 7 continued feebly for about six minutes. Another at 2:09 p. m. April 8 had an indicated distance of origin 14 miles away. Tilt for the week was very slight to the east.

LASSEN REPORT No. 7

Mineral, California, March 30, 1927

R. H. Finch, Associate Volcanologist

Mr. Finch made a reconnaissance of the volcanic steam district of Sonoma, Napa, and Lake counties in California March 20-30. Volcanic cones are numerous in this district, and some are well preserved. A crater was found just above the petrified forest near Calistoga, which is very well preserved and shows a cone in the middle and a distinct Somma rim. The rainfall in this region is variable, so that age determinations on the basis of erosion changes affecting topography are apt to be misleading unless precipitation is considered. Thus the crater above mentioned appeared much younger than anything on Mount St. Helena. Near the petrified forest there are some interesting caves, either excavated by cliff-dwelling Indians, or else formed by erosion of softer material along an ancient lake shore that once occupied the valley.

THE UNDER SIDE OF THE EARTH'S CRUST

Seismology and the physical study of the elastic constants of rocks are making discoveries by a combination of experiments in the laboratory and measurements with the seismograph. The Geophysical Laboratory has published evidence that the earth consists almost entirely of ultra-basic rock, largely olivine, except for a thin crust and for a metallic core (Volcano Letter No. 3, January 15, 1925).

Adams and Gibson (Proc. Nat. Acad. Sci. Vol. 12, No. 5, pp. 275-283, May, 1926) have attacked the problem of what the material is under the crust of the earth. They believed it to be olivine rock or peridotite, Daly believed it to be basalt (Volcano Letter No. 59, February 11, 1926). They took specimens of granular olivine rock (dunite) from North Carolina, and basaltic glass from Kilauea, and cut a polished cylinder from each, and subjected these to pressures of from two to twelve thousand atmospheres immersed in a liquid. The changes of volume in the two substances under different pressures were determined with precision. Given the compressibility and the density, it is possible to calculate the velocity with which the preliminary and the secondary earthquake waves will be propagated through these substances.

Now in the earth itself the velocities of these two types of wave motion, the first compressional, and the second distortional, are known for various depths below the surface from seismologic data. Hence a comparison of these velocities with those calculated from the elastic constants of different rocks provides a key for elucidating problems of the earth's interior. From the seismologic data the velocity of the compressional waves increases slowly to a depth of 60 km., and at this level it changes suddenly from about 5.9 kilometers per second to 8.0 kilometers per second. The velocity in rock increases with increasing basicity and density. The pressure at 60 kilometers of depth is about 17,000 atmospheres.

Applying the formulae to the compressibility results for the granular olivine and the Kilauea basaltic glass, respectively, the investigators found that at that depth the velocity in the olivine rock for the compressional waves would be 8.4 km./sec., and for the basaltic glass the Kilauea rock would transmit these earthquake waves at 6.9 km./sec.

It is evident from this that the material at depths greater than 60 km. is heavier and more basic than gabbro, and approaches olivine in composition. With due allowance for the effects of high temperature which would probably decrease the velocity a little, the authors estimate that the material below the crust of the earth at 60 km. of depth should consist of a peridotite largely olivine, but containing some less basic silicate like hypersthene. The authors believe that measurements of the compressibility of rocks at high temperatures would enable one to make a precise estimate of the composition of the earth's crust.

The results show that the glassy, basaltic substratum under the crust of the earth, which Daly has characterized as "slippery", cannot exist there if the seismograph data are correct, and "whatever basaltic material there may be within the earth is probably confined to a comparatively thin zone." T.A.J.

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No. 121 RELEASED WITHOUT COPYRIGHT RESTRICTION April 21, 1927

KILAUEA REPORT No. 797

WEEK ENDING APRIL 20, 1927
Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

The week at Halemaumau pit has produced no important changes. At 11 a. m. April 20 the taluses showed fresh debris N, WNW, and SSW, and the sulphur patches of the eastern inner slopes showed dimming of their brilliant color through the washing of recent rains. The upper walls were dark red in color, owing to wetness. The large sulphur patch at the S talus was still bright yellow with a dark area in its center.

There has been for many weeks past a lump of red rock at the core of the west boss, an irregular dense rock mass underlain by intrusive gabbro in the middle of the western wall of the pit. This lump protruded; now it has totally fallen away, and it was evident from small slides observed three times on this morning that motion there was still in progress. The slides were very small, so that the dust from them was detected with difficulty, though the noise could be heard plainly. At 11:16 a. m. a small slide occurred NNE.

Steam appeared at the usual places in the pit, and although light NE wind was blowing, the steam cracks back of the SE station had failed to develop any return of their heat and vapor. It is evident that the cessation of steaming there, first noted about March 30, is not connceted with the direction of the wind and is more or less permanent. They are vaporing about 50 yards south of the trail, but this is quite invisible at the trail crossing, and the air rising from the cracks is barely warm.

Fourteen very feeble local earthquakes have been registered for the week at the Observatory. Tilt was slight SSW.

OPENING OF THE UWEKAHUNA OBSERVATORY

During the visit to Kilauea of the Pan-Pacific Conference on Education and Recreation recently held in Honolulu, Dr. Hubert Work, U. S. Secretary of the Interior, at 9 a. m. April 19 opened to the public the new Uwekahuna Observatory and Exhibition Room of the Hawaiian Volcano Research Association (See Volcano Letter No. 115).

Dr. Jaggar made a short address, mentioning the fact that for 11 years past it has been the hope of the workers at the Hawaiian Volcano Observatory (Bull. Hawn. Vol. Obs. Vol. 4, No. 4, 1916) that some sort of a trailside museum might be provided for which would make it possible to explain to travelers in an appropriate setting the fascinating mechanism of volcanoes, and at the same time show them pictures of recent activities and maps or diagrams illustrating the relation of the Hawaiian volcanoes to the surface features of the globe. Thanks to the liberality of Congress in creating the Volcanology Section of the Geological Survey in 1926, the Research Association supplied money for the building of a small exhibit hall equipped with electric current and projection apparatus. This is now finished, and some of the best of the collections of the Observatory have been placed in display cases, the whole room being faced with large plate-glass windows that command a magnificent view southward of the whole Kau Desert and Halemaumau pit. As the buildings and equipment furnished by the Hawaiian Volcano Research Association are all part of the plant of the Observatory, Dr. Jaggar took occasion to convey the new establishment to the use of the Department of the Interior through the two branches here presented, the National Park Service and the Geological Survey.

Secretary Work accepted the offering on behalf of the Department of the Interior, and short speeches were made also by Honorable Stephen T. Mather, Director of the National Park Service, and by Honorable Wallace R. Farrington, Governor of Hawaii.

The new buildings are of iron, with rough stone corner posts, the smaller one housing the water tank, preparation room, and power plant, the larger one standing on the highest rim of Kilauea Crater, with a terrace in front designed to display the view that on bright mornings extends all the way from Mauna Kea and Mauna Loa around past the south point of the island in panorama, and thence eastward, including all the cones and landmarks of the Kau Desert, to Halemaumau, spread out at the feet of the observer as an enormous chasm less than a mile away. Beyond it and around is seen all the detail of Kilauea Crater and the pits Keanakakoi and Kilauea Iki, while in the distance to the east lies Puu Huluhulu, that marks the site of the new Chain of Craters Road, which Secretary Work dedicated the same morning.

It is hoped eventually to install on the terrace a large Zeiss binocular telescope, and projection apparatus for lantern slides and motion pictures has already arrived, and in a short time will be installed and in operation.

T.A.J.

HILLS CREEPING IN QUEENSLAND

From Nambour in Queensland comes the report (The Argus, Melbourne, Australia, January 28, 1927) that an unusual and serious catastrophe occurred about January 26, 1927, near Perwillowan. Whole farms have moved, fissures have opened, and small earthquakes have occurred. This is a hilly country near the sea, and one farm is described as having moved a portion of its lands bodily across a road onto the territory of another farm, so as to lose part of its acreage. In one place a washout is described nine feet deep, in another place the slip of a block country 700 feet long by 60 feet deep, with a forward motion of over 600 feet, carrying banana plants on its surface. Elsewhere there is a chasm 12 feet deep and three feet long.

At Robinson's farm the roadway is reported entirely gone for a mile of length, creaking noises are heard, the hillside at the back has moved to within a few feet of the house, and the house has tilted.

At another residence on the morning of January 26, there was a landslip carrying with it trees, boulders, and earth. Culverts have been carried away or shifted. The loss in property is severe, and some families have moved into Nambour.

T.A.J.

EARTHQUAKE IN CHILE

On April 13, 1927, the press reports 50 injured and 16 dead over 1,000 miles of Chilean coast near Santiago and Valparaiso.

T.A.J.

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No. 122 RELEASED WITHOUT COPYRIGHT RESTRICTION April 28, 1927

KILAUEA REPORT No. 798

WEEK ENDING APRIL 27, 1927
Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Halemaumau, the inner crater of Kilauea Volcano, continues to evidence little change. There is no avalanching, though during a circuit of the pit on April 23 it was noticed that there are several places ready to fall whenever there is sufficient seismic disturbance. The intrusive mass at the west boss, mentioned in last week's report, has fallen away a little more, and several rock falls were heard on three visits to the pit during the past week. One of these, on April 27, 8:45 a. m., made echoes lasting for a few seconds.

White salts are seen on the walls, the sulphur patches on the talus slopes and floor remain about the same, and steam continues at the usual places. On April 25 it was noticed that the cracks near the tourist trail crossing, mentioned in Volcano Letter Nos. 118, 119, and 121, are again steaming, though very moderately.

During the week the total number of earthquakes recorded has been 19, all of them very feeble. More than half of this number occurred on the 23rd and 24th, culminating in a shock in the early morning of the 25th somewhat stronger than the rest, which had an indicated distance of 12 miles. Tilt has accumulated moderately ENE.

It has so frequently happened that either Mauna Loa or Kilauea has erupted soon after Dr. Jaggar's departure from the station, it has become almost a superstition that his leaving should be a signal for an eruption to occur. Two days after his recent departure for Alaska rumor was rampant on Hawaii that an eruption was in progress without, however, the slightest foundation in fact.

THE OCEAN

Since three-fourths of the area of the earth is covered by water, such studies as geology, topography, geodesy, volcanology, seismology, and other investigations dealing with the composition, shape, and mechanics of the earth's crust, are most easily persued over the area limited to the remaining quarter, or land area. These water-covered areas are attracting increased attention, however, through modern methods of sounding, and through evidences supplied by seismology and allied sciences.

In "La Science Moderne" (Montreal, Feb. 1927) Professor J. Thoulet writes concerning volcanic and seismic disturbances beneath the oceans. He describes the ocean depths as places of almost perfect rest. The motion of the waves and tides are for the most part surface movements and do not affect the depths, and disturbances due to diffusion must be slight, and ordinarily convection currents due to either solar or earth temperatures cannot very much disturb the deep ocean waters.

On land, geologic formations show evidences of the crust having been many times revised and made over, volcanoes are seen building new surface, and rivers are seen removing old surface. Geodesy is now a science of sufficient precision to detect progress of slow warpings and bendings. Changes must also be taking place beneath the seas, and may in time made available for study.

Volcanoes, under water, are undoubtedly producing lava flows. Lava erupting in air tends to be light and frothy due to gas expansion. But under water at great depths the pressure is so great, and cooling is so fast, that in all probability the gases are never released, and the lava is compact and dense. Thus there would be no gas bubbling to the surface, there would be no light pumice-like material ejected to float to the surface, nor any other surface indication of such an eruption, unless it might be a local heating of the water detectable at the surface—though diffusion would make this improbable.

The presence of such flows may perhaps be detected, while still fresh and unmasked by sedimentation, by sounding for character of surface. Volcanic cones and topographic shapes might become apparent with depth soundings in sufficient detail.

The U. S. Coast and Geodetic Survey has developed a sonic sounding device, utilizing a transmitted sound and a timed echo, wherewith depth measurements are possible with ease at the rate of one or more a minute, without checking the ship's speed. The sounding lead requires half an hour or more in moderately deep water, with the ship's position held. Thus it seems that here a new field of investigation is opening, through the possibility of greatly increased detail in sounding.

Earthquakes in the ocean floor are easily detected, through seismology, and their locality closely determined. But the nature of the movement producing them can only be guessed at. On land the movement along a fault can at least be measured at the surface.

Risings and fallings of the ocean's floor, of a gradual sort, defy detection, though the sudden change in depth of Sagami Bay, Japan, in 1923, was made available for study through detailed soundings in existence before the change, compared with soundings made afterwards. On land such risings and fallings of the earth's surface are made apparent through stream erosion, and if rapid, through precise leveling.

The ocean itself gives some indications of earth changes. Suboceanic earthquakes may produce tidal waves. Mean sea level, as a reference datum, has inscribed itself in geologic time as shore lines, now elevated for inspection and proof of rising of the crust. Rapid rising or falling of shore lines may be detected and measured by tide gauges, as was done at Sagami Bay.

R.M.W.

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No. 123 RELEASED WITHOUT COPYRIGHT RESTRICTION May 5, 1927

KILAUEA REPORT No. 799

WEEK ENDING MAY 4, 1927

Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Halemaumau shows no suggestion of lava activity, but slides from the walls have increased. These are taking place mostly from the northeast side, and at 10 a. m. on April 30 dust from an avalanche was seen to rise from the north corner and drift away. Later that day there were more slides, accompanied by much dust. On a visit to the pit on May 2 a large scar was seen at the north, beginning just above the west horn of the big sill and extending all the way down to the talus slope, which was coated with new debris. The wall at the other end of the sill is similarly freshly broken away, and a new boulder lies at the foot of the NNE talus. During a circuit of the pit on May 3 rocks were heard falling almost continuously from the north and northeast walls.

For the past week there have been 18 local earthquakes, all very feeble with one exception. On April 30, at 2:33 p. m., a shock occurred that was felt by a few people, both at the volcano and in Hilo. It may be classed as "slight," its maximum acceleration being about 11.0 mm. sec. per sec. The indicated distance to origin from Kilauea is about 40 miles, and from Hilo, 34 miles. It was followed by several very feeble after-shocks, one of which was of four minutes duration.

During the first part of the week tilt accumulated moderately to the south, which was recovered by northerly tilt, so that the net for the week is practically zero. The change from south to north tilting closely agrees in time with the time of the earthquake above described.

EARTHQUAKE INTENSITY

So many factors enter into the determination of the intensity of an earthquake that it is difficult to secure a scale by which the wide variety of different kinds and sizes of earthquakes may be definitely graded. The motion of an earthquake is very complicated and involved, any given point of the earth's surface traces a path which, if reproduced, would very much resemble a bad tangle in an unwound spool of thread. It is a complicated elastic vibration. The motion defies mathematical analysis. Seismographs record it ordinarily in three parts representing the three dimensions of space; for example, north-south, east-west, and up-down are the usual three components. Each of these components represents the motion back and forth in its particular direction only. In order, therefore, to unravel the actual complete motion, all three of these components must be combined, instant for instant; an undertaking of considerable complexity.

As a given point traces its tangled path, every time its motion is changed in direction or velocity, it is spoken of as being accelerated; the acceleration being ever changing in amount and direction, and its intensity being measured by the suddenness in the change of velocity or direction that it produces in the motion of the point in question. The maximum acceleration attained is the index of the power and severity of the earthquake. We feel no motion until the earth's crust is shaken or accelerated beneath us. The acceleration of an earthquake is rapidly and repeatedly reversed in its direction, producing a swaying or vibrating motion back and forth. A great acceleration means a strong starting and stopping, and re-starting and stopping again in reverse direction, of the ground beneath our feet; a harsh shaking that we feel and that tests the strength of our structures. The range of such a motion may be small—a few hundredths of an inch perhaps—but if the shaking is rapid it is nevertheless evidence of strong acceleration. If, however, the same range of motion is only accomplished through a longer period of time; say a complete cycle of motion requires fifteen or twenty seconds, as in an earthquake the origin of which is at a great distance from the observer; then the acceleration is weak and the earthquake is not felt by the observer, though the shock may be severe at its origin. Thus the intensity of an earthquake, its acceleration, its perceptibility and resulting damage, is dependent not only upon the range of motion, but also upon the rapidity with which the ground is shaken back and forth through this range. No one of the three components alone will, as a rule, show the amount of the whole acceleration; therefore, in order to compute by rigorous mathematics the value of the maximum value so as to grade the earthquake, it would be necessary to compute instant for instant throughout the disturbance the value of the varying acceleration as found from a combination of the three components, and so find where the maximum occurred. That would be an impracticable and tedious problem. Ordinarily the approximate time of maximum acceleration will be apparent in the records. The approximate maximum acceleration may then be computed for that portion of the earthquake. The same earthquake results in different action in different localities, due to distance from the origin and to the varying elastic properties of the earth's surface at different places. An earthquake is ordinarily graded, however, by its intensity at or over its origin, or where it is most severe.

Thus it is seen that it is difficult to accurately scale an earthquake, even with good records of it, and also a seismograph is not always located near the origin. The instrumental and mathematical measure of the acceleration is hardly more satisfactory as a measure of the intensity of an earthquake than is the simpler method of feeling and noting its effect on objects around us. Thus the natural scales are still in customary use. Of these natural scales the common ones are the Rossi-Forel, the Cancani, the Mercalli, and others, in general similar. These scales may be found in any textbook on seismology, but for convenience a copy of one of them will be included in next week's "Volcano Letter." R.M.W.

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No. 124 RELEASED WITHOUT COPYRIGHT RESTRICTION May 12, 1927

KILAUEA REPORT No. 800

WEEK ENDING MAY 11, 1927

Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

The activity at Kilauea is still confined to avalanching, which has diminished toward the close of the week. Small rock falls continue intermittently. Several falls were noted on May 5 and 7. On May 9 the wind was too strong to hear clearly sounds in the pit. Rain accompanied the wind, and from the dry places in the pit the hot areas could be detected. May 11 the pit was very quiet, and but a few rock falls were heard during a two-hour observation, the largest slide being one from the SSE wall, which is ordinarily very stable.

During the week ending May 11 there were 36 very feeble local earthquakes recorded. This is an increase in number over that for any weekly period since the middle of September, 1926. At that time there was a marked decrease in number, as noted in Volcano Letter No. 92. Since then the weekly average has been 15 local earthquakes, and the number per week has clung close to the average, the maximum and minimum during this time being 29 and 6, respectively. Thus the increase this week is worthy of note. One of these shocks, while still very feeble, yet plainly indicated a distance of 36 miles. On May 8 there were five cases in which the earthquakes appeared to come in pairs, the interval between the first and second tremor being in all cases close to 50 seconds. In the count for the total for the week, each pair has been counted as one. Avalanches during the first part of the week were more frequent than usual, and it may be that the second tremor in the pairs above noted are the result of avalanches precipitated by the first, and real, earthquake.

Tilt has been feeble during the week, accumulating only very slightly to the NE.

THE ROSSI-FOREL SCALE (1883)

Grades of Earthquake Intensity.

No. 1, recorded by a single seismograph, or by some seismographs of the same pattern, but not by several seismographs of different kinds; the shock felt by an experienced observer. No. 2, recorded by seismographs of different kinds; felt by a small number of persons at rest. No. 3, felt by several persons at rest; strong enough for the duration or direction to be appreciable. No. 4, felt by several persons in motion; disturbance of moveable objects, doors, windows, creaking of floors. No. 5, felt generally by everyone; disturbance of furniture and beds; ringing of some bells. No. 6, general awakening of those asleep; general ringing of bells; oscillation of chandeliers, stopping of clocks; visible disturbance of trees and shrubs; some startled persons leave their dwellings. No. 7, overthrow of moveable objects, fall of plaster, ringing of church-bells, general panic, without damage to buildings. No. 8, Fall of chimneys, cracks in the walls of buildings. No. 9, partial or total distruction of some buildings. No. 10, greater distasters, ruins, disturbance of strata, fissures in the earth's crust, rock-falls from mountains.

No. 1 grade above described is too strong in which to class the great numbers of non-perceptible tremors recorded on the seismographs at the Hawaiian Volcano Observatory, where the grading used is as follows: Very feeble, acceleration 2.5 mm. per sec, per sec., totally instrumental. Feeble, acceleration 5.0, mostly instrumental. Slight, acceleration 10, slightly perceptible. Moderate, acceleration 25, generally felt. Strongish, acceleration 50, strongly felt. Strong, acceleration 100, alarming. These terms are as used in the Volcano Letter. Dutton evaluates the Rossi-Forel grades (excepting the tenth) in terms of acceleration as follows: No. 1, 20 mm. per sec. per sec.; No. 2, 40; No. 3, 60; No. 4, 80; No. 5, 110; No. 6, 150; No. 7, 300; No. 8, 500; and No. 9, 1,200 mm. per sec. per sec. Comparisons may be made through equal values of acceleration. It is seen that "very feebly," feeble," and "slight" come below the lowest Rossi-Forel grade. Some uncertainty is introduced, as "slight" includes shocks that may be perceptible, in spite of the fact that Rossi-Forel No. 1 is intended for the lowest perceptible grade. R.M.W.

TIME

At the Hawaiian Volcano Observatory, the controlling timepiece is a Howard seconds-pendulum clock. Its correction is frequently determined by radio, and it runs in a room in which the temperature range is small. A chronometer is used in daily comparison. During the months of December, 1926, January and February, 1927, its rate was remarkably constant at -0.08 second per day. Near March 8 its rate changed to -0.66 second per day, and since then it has run at -1.71 second per day. These changes in rate are most likely due to disturbances of the clock when winding, by earthquakes, or any other of many possible causes. An interesting speculation, however, suggested by the timing of the pendulum in the gravity apparatus used here last December by the U. S. Coast and Geodetic Survey (Volcano Letter No. 106) is the possibility that the pendulum of this clock may be sensibly indicating changes in the value of gravity. Other geodetic dimensions here at Kilauea are changing—elevations through a range of about two feet, and horizontal positions as much as five feet—amounts measureable during a few months' time. Gravity would change very slightly due to the known changes in elevation, and it might also be changed by the movement or intrusion of magma in the edifice of the volcano. The value of gravity determined here in December was 978.667 dynes—not corrected for elevation, topography, etc. This value would need to change but .013 dyne and .024 dyne to produce the two changes in clock rate mentioned above.

In making the series of clock corrections observed, 82 during the period of time since the first of December, 1926, the radio signals sent out from Pearl Harbor, Hawaii, were used. It was at first thought that the clock rate fluctuated badly, but it soon became apparent that the chronometer showed precisely the same fluctuations, if the radio signals were taken as correct. It seemed inconceivable that both clock and chronometer should execute the same fluctuations, and it so became evident that the time signals themselves were in error by varying small amounts over and above the published correction. The mean rate over a long period would be practically free of these errors.

R.M.W.

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No. 125 RELEASED WITHOUT COPYRIGHT RESTRICTION May 19, 1927

KILAUEA REPORT No. 801

WEEK ENDING MAY 18, 1927

Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Halemaumau shows little change over last week, except for a nitch which has formed in the upper part of the north sill, near its west end. Small rock falls from the walls continue, and steam issues quietly from the usual places on the walls, taluses, and floor.

During the week ending May 18, there were recorded 13 local earthquakes, all very feeble with the exception of one at 7:01 a. m., which was feeble, with an acceleration of 9 mm. per sec. per sec., its indicated distance being 17 miles. It was felt by only one or two persons in this vicinity. On the same day a perceptible earthquake was reported in Kealakekua, which was recorded here as a very feeble shock at 9:01 p. m., with an indicated distance of 31 miles.

Tilt has accumulated very slightly to the west.

KILAUEAN ASHES

It has sometimes been asserted that the term "volcanic ash" is a misnomer, since it implies the false idea of a residue from combustion, and that its usage should be discontinued. Such a suggestion receives additional support from the fact that the term ash has been so widely employed and in such different senses that it has ceased to have any accurate connotation. The term, however, has come to stay in geological literature, and has its value as a general field name for all loose pyroclastic material smaller in size than a pea. When such material is compacted, it is usually described as tuff. The palagonite-tuffs of Diamond Head and of Punchbowl, on Oahu, are typical compacted ashes.

A tuff composed essentially of glass fragments is spoken of as a vitric tuff. Such a tuff results from the violent comminution of frothy lava, and is especially characteristic of viscous acid lavas, such as rhyolites. The more liquid basaltic lavas of Kilauea usually give rise to thread-lace scoriae (limu) on explosion, the vesicles being retained within delicate walls. Occasionally, however, even the liquid Kilauean basalt has been so quickly chilled and triturated as to give rise to vitric tuff, composed of angular and crescentic chips of glass. The olive-green and yellowish tuff of the 1790 eruption which rests upon pahoehoe lavas along the 1868 cracks west of Halemaumau, consists locally of over 95 per cent of glass dust, probably derived from the shattering of thread-lace scoriae. In places the upper surface of this glassy deposit is curiously channelled by sharp U-shaped valleys, occupied by the coarser ejecta of later eruptions.

When crystals predominate over glass in a tuff, the term crystal tuff is employed; when rock fragments predominate over both glassy and crystal fragments, the term lithic tuff is used. Among the later products of the 1790 explosive eruptions, lithic and crystal tuffs alternate irregularly. Much of the dark gray ash in the road cuts near Keanakakoi is almost devoid of glass, being composed of chips of olivine, augite, felspar, and magnetite.

The ejecta of the 1924 eruption are almost wholly made up of pieces of previously consolidated rocks; the ash is thus essentially lithic. Certain specimens collected from the present surface of the old "aviation field," southeast of Halemaumau, are, however, chiefly composed of glass dust, with subsidiary amounts of crystal and basalt chips. The presence of glass in the 1924 ash is more likely to be due to the trituration of old, glassy basalts than to the explosion of fresh lava froth, since bombs appear to be absent from the ejecta.

Pyroclastic materials varying in size between that of a pea and that of a walnut are classed as lapilli. Coarser materials, if composed either wholly or in part of fresh magma on eruption, are included under the term bombs; if composed of previously formed rocks, as in the 1924 ejecta, they are described as ejected blocks, pebbles, and cobbles, according to their size.

Compared with the explosive ejecta of acid volcanoes, those of basaltic character are normally of very limited distribution and of more irregular thickness. For example, the palagonite-tuffs from the craters on Oahu are notably restricted in extent, and the 1790 ash of Kilauea varies rapidly in thickness over small areas. By contrast, an acid, rhyolitic ash-band averaging only a foot in thickness has been traced for over 200 miles along the Pelly River, Yukon, and an ancient Palaeozoic acid tuff is believed to occur at intervals over an area stretching from Kentucky and Tennessee in the east to Missouri in the west, and from just south of Lake Erie to near the shores of the Gulf of Mexico.

Howell Williams.

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No. 126 RELEASED WITHOUT COPYRIGHT RESTRICTION May 26, 1927

KILAUEA REPORT No. 802

WEEK ENDING MAY 25, 1927
Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Halemaumau continues to show little change. Rocks can be heard falling nearly every time the pit is visited, and occassionally slides of varying sizes are witnessed. A rather large one occurred at the southwest rift tunnel about 9:30 a. m. May 23. The sulphur spots seem to be increasing low down on the southwest talus and on the lava floor of the pit.

There are recorded on the seismographs at this station 11 very feeble local earthquakes for the week ending May 25. On May 22 there is record of a teleseism with a vaguely indicated distance of 6,340 miles. The preliminary wave of this earthquake came at 15 minutes and 33 seconds past noon Hawaiian Standard Time, and the following phases lasted nearly an hour before the record died out completely. This earthquake was also feebly recorded on the seismograph at Kealakekua.

Tilt has accumulated only very slightly to the west.

A SIMPLE SEISMOMETER

The overthrow of columns by earthquakes long ago suggested the design of a seismometer composed of bars standing on end as a means of detecting earth shocks. Bars having very narrow bases would overturn more easily than those upon a wider footing. Bars hinged at the bottom, or resting on a knife edge, and leaning back against a rest, ladder-fashion, would be thrown over away from the support the more easily if held nearly vertical. For these types of seismometers West's formula has been used in computing the horizontal acceleration of the ground required to effect the overthrow, given the dimensions of the column. This formula is based upon an assumption that the acceleration is constant for a long enough time to allow the column to become overbalanced beyond recovery.

In "Science" of April 15, 1927, Professor Paul Kirkpatrick of the University of Hawaii has deduced a formula for the acceleration necessary to overthrow a column or bar of given dimensions, which takes into consideration the fact that the acceleration of an earthquake is not constant, even for very short periods of time, but is oscillatory. The formula contains several variables; the distance of the center of mass above the horizontal axis of rotation, the radius of gyration of the bar about that axis, the angle that the bar is allowed to lean back from its vertical against the support, the period of the oscillatory acceleration (assumed simple harmonic). From these, the value of the acceleration that will just suffice to overthrow the bar is computed. This formula suggested the design of a simple seismometer, which has been tried out on an oscillating table in the laboratory. Bars of varying form tested by accelerations of varying period and amplitude have proven the formula by experiment. Professor Kirkpatrick plans to bring the device to Kilauea to study its action in recording the local earthquakes in the vicinity of the volcano. He promises a more complete description as his experiments progress. R.M.W.

A DEFECT IN HORIZONTAL PENDULUMS

Kyoji Suyehiro, in the March, 1927, issue of the "Proceedings of the Imperial Academy," Japan, indicates that there may be an effect, hitherto ignored, that would cause the records of horizontal pendulum seismographs to be inaccurate representations of the true earth movements. Seismographs of this sort are arranged to swing about an axis that is nearly vertical. There are usually two pendulums, to record the two horizontal components of earth movement, hanging in vertial planes at right angles to each other. Thus the axis of a pendulum intended to record north-south motion is inclined slightly away from the vertical in an east or west direction in order that the pendulum will come to rest in a position at right angles to the direction whose component it is intended to record. This angle of inclination of the axis from the vertical is called the angle "I", and is assumed in most discussions to be constant, once the seismograph is set up and kept in adjustment. If this angle is changed, the period of the pendulum is changed, and if the angle is diminished to zero, the pendulum becomes unstable. A pendulum of this sort is usually regarded as being affected only by that component of the earthquake motion which is at right angles to the plane of its angle "I", which is duly recorded. If tilt is present to affect the value of "I", obviously the period of the pendulum would be changed, and if tilt were sufficient to make "I" zero, the pendulum would be unstable and would record meaningless wanderings instead of real earth motion. While tilt would hardly attain values large enough to accomplish this effect, it is shown in Mr. Suyehiro's paper that the component of the earthquake acceleration in the plane of the angle "I", supposedly without effect, may change the inclination of the effective axis of the pendulum, and so temporarily change the effective value of "I", even to the point of making it zero. Thus the pendulum would be rendered unstable, and its records might show swings of large amplitude without real earth movements to warrant them. R.M.W.

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No. 127 RELEASED WITHOUT COPYRIGHT RESTRICTION June 2, 1927.

KILAUEA REPORT No. 803

WEEK ENDING JUNE 1, 1927

Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Kilauea Volcano continues dormant, the only activity being rock falls and small avalanches from the walls of Halemaumau pit and steaming at the usual places in the pit and on the floor of the crater. On May 30 about 11:30 a. m. dust from a big slide was seen to rise on the north side of the pit and hang over it about five minutes. During a visit to the pit on the 31st new debris was noticed on the northwest talus, reaching nearly to the lava floor, and the wall above was very dusty. At 11:53 a. m. slides were heard both northwest and south. On June 1 new debris was seen on the east, north, and south-southwest talus slopes, and the wall below the west boss appeared to be more broken away.

There have been 13 very feeble local earthquakes recorded during the week ending June 1. Tilt has accumulated very slightly to the north.

The teleseism reported last week, which occurred on May 22, originated in latitude 35 degrees north, longitude 92 degrees east, at 22 h., 32 m., 48 s., Greenwich Civil Time, according to a determination made by the U. S. Coast and Geodetic Survey.

PHOTOGRAPHIC RECONNAISSANCE

The use of photographic surveying is increasing rapidly, especially under conditions that limit the time for field operations. Methods have been developed to use pictures taken from airplanes for map making, that allow tremendous areas to be covered in a short time. A recent undertaking, and one of the largest, is the U. S. Naval expedition to southeastern Alaska. This is well described in the "Scientific American" of May, 1927. Many parts of this area are very inaccessible, and mapping by ordinary ground methods is slow and arduous in the extreme. The shore lines are precipitous, and the waters rough, so that to run a ground survey along them is a serious problem. The Navy airplanes have been able to fly over and photograph, from an altitude of 10,000 feet, more territory in a day that a survey party on foot could cover in many weeks. The airplane photographs exhibit shore lines excellently, but are not so well adapted to determine land elevations and topographic shapes, especially in a country blanketed with timber. In general, aerophotography must be supplemented by a certain amount of ground work before a complete topographic map can be secured. But until such ground work can be done, the photographs furnish an excellent and useful reconnaissance map of the area.

Southeastern Alaska is not an area of volcanoes, but this work will undoubtedly be extended to other regions where its usefulness to volcanology will be more direct. Recent topographic work on the Alaskan Peninsula has brought to light volcanic craters hitherto practically unknown that would not have escaped notice in an aerophotographic survey. When the work is expanded to cover the Peninsula and the Aleutian Islands, the photographs will unquestionably yield a great deal information to those interested in volcanoes.

In a smaller way airplane photography will probably come into greater usefulness in the vicinity of active volcanoes. Already Mr. R. H. Finch has made use of airplane flights in connection with volcanologic reconnaissance both in Hawaii and in California. Photographs of Mauna Loa from the air would show perhaps more graphically than topographic maps the outlines of the more recent lava flows. In case of eruption, an airplane view of the mountain would tell much more surely and speedily the trend and progress of a lava flow than would a slow trip up the rough and forested slopes on foot. The Forest Service makes use of aeroplanes to reconnoiter forest fires, so in the same way may volcanology watch the fires of a volcano.

R.M.W.

A PRESS FANTASY

The Mauna Loa flow of April, 1926, was described in the Volcano Letter at the time. It was a spectacular cascade of lava, but was no larger than most of Mauna Loa's flows. The ribbon of new lava, from its source two-thirds of the way up Mauna Loa's 13,650 feet of elevation, down to the sea, averaged not more than a half mile in width. It covered country already rather barren, and destroyed a half mile of county roads and some twelve houses at the beach.

The "Cape Argus" (April 2, 1927), Cape Town, South Africa, excites in your imagination this terrible calamity:

"Towering 1,300 feet above the blue waters of the Pacific, Mauna Loa was covered with lush green forests and waving fern trees, with dancing streams and picturesque dwellings until the eruption of last April, when, without any warning, a sea of boiling lava eddied and surged down the mountain slopes, melting the rocks, whose grandeur of outline had been one of Mauna Loa's most arresting charms, and reducing them to a shapeless mass; destroying the bridges and transforming the forest into charred and stunted remnants.

"From the snow-capped summit great jets of black liquid spouted, the air was filled with the hissing of steam, the churning of molten lava, the fumes of sulphur, the exploding of noxious gases, and no longer did one wonder why long-dead Hawaiians called Mauna Loa the 'House of Eternal Fire'."

R.M.W.

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No. 128 RELEASED WITHOUT COPYRIGHT RESTRICTION June 9, 1927

KILAUEA REPORT No. 804

WEEK ENDING JUNE 8, 1927

Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

On the morning of June 2 a dense cloud of steam, due to falling moisture, was rising from the north side of Halemaumau pit. On June 4 the walls of the pit were seen to be colored dark red from the recent rains. No rocks were heard falling during this visit. The sulphur patch at the southeast bank appeared on June 6 to be a little brighter. A visit to the pit on June 8 discloses the fact that there has been an increase of rock falls. Both the north and the south walls are very dusty. Several rock trickles were heard from the north side, and a little dust was seen rising there.

During the week ending June 8 there have been only five local earthquakes recorded. In addition to these, on June 2 there is record of a faint teleseism, probably about 5,500 miles distant. The prefiminary wave arrived at 8 h., 53 m., 53 s. p. m., Hawaiian Standard Time, the secondary wave arriving approximately 9 minutes and 45 seconds later.

Early in the morning of June 8 several people in the vicinity of the volcano were awakened by a noise resembling the falling of a heavy weight or the striking of a heavy mass with a hammer. The effect seems to have been more a concussion than an earth shake. It is reported that this noise was also heard in Hilo. All observers have agreed as to the time close to 1:30 a. m. On the seismograph there is a very feeble tremor recorded at 1:29 a. m., but so small as to be certainly imperceptible as an earthquake. It resembles very much the records made by blasting a few miles from the Observatory. The night watchman at the hotel reports having seen a bright glow in the sky two or three minutes before he heard the noise. Indications are that this disturbance is not volcanic or seismic, having the appearance rather of an explosion of powder. But that such an explosion should occur at that time of night and be strong enough to awaken people at widely separated places is unusual. Diligent inquiry has not yet disclosed the cause of the disturbance.

SURVEYS AROUND KILAUEA

In 1920 a number of points in the vicinity of Kilauea were selected and permanently marked on the ground. These marks were then tied in both by spirit levels and triangulation, making a net covering about 24 square miles surrounding the volcano. The object is to repeat the surveys at intervals in the future to determine possible ground surface movements. Some of the points so tied in were points established by older surveys, and comparisons made it at once apparent that actual changes had taken place. Since 1920 there have been several surveys made for various purposes touching some of these points, and further movements have been disclosed. The leveling done by the Bureau of Public Roads and by the County of Hawaii in connection with new road work has yielded differences of elevation that are not the same as those secured by the 1920 work. In March and April, 1926, the Kilauea net was releveled, confirming the changes found by the road surveys. The elevation of the Volacno House bench-mark above the old Hilo datum was accurately determined by the modern precise methods of the Coast and Geodetic Survey in November and December, 1926, with results differing from the 1920 values, just as the 1920 values differed from the original 1912 level line. In May, 1926, a partial re-triangulation of the Kilauea net was made, and in December, 1926, the points were again triangulated, this time completely, the same accuracy being secured as in 1920. Another complete re-leveling of the Kilauea net is just now nearing completion, using a precise level and rods with graduations upon invar metal strips.

In studying the differences developed by successive surveys, the first question that arises is of course the accuracy of the surveys. Upon the answer to this question depends the decision as to whether the differences developed represent actual ground movements. The levelings in the vicinity of Kilauea have circuit closures averaging only about two tenths of a foot, yet successive surveys may yield relative elevations differing several feet. In the triangulation, accuracy represented by an average triangle closure of close to three seconds has been secured, yet some angles in the net of 1926 differ by several minutes from the corresponding angles of 1920. Clearly, these differences are too large to be ascribed to inaccuracies of surveying.

Results of these surveys are being computed, and work is being done towards the making of a systematic intercomparison of them all, with an attempt to correlate the changes with changes of tilt, and eruptive stages of the volcano. R.M.W.

ALEUTIAN STATION NOTES

Dr. Jaggar sends word from Alaska, telling of his arrival in Kodiak on May 12. It is his intention to spend the season making a reconnaissance of the volcanology and seismicity of the Alaskan Peninsula and the Aleutian Islands. He expects to establish one or two seismological stations, the one already temporarily decided upon being at Kodiak. The seismographs for this station were constructed in the shop of the Hawaiian Volcano Observatory, and others are now being made for a possible second station in Alaska. The instruments in Kodiak will probably be set up in the cellar of a building of the Agricultural Experiment Station, a settled structure about 10 years old, whose foundations are close to bedrock. This will have advantage over a new building in that the instruments will not require so long a time to adjust themselves to the settlement in new foundations. The location of the station in Kodiak may be temporary or permanent, as may be found advisable by further investigation of seismic conditions. The object is to go over the country more thoroughly before final selection is made for the location of a permanent station.

On May 17 Dr. Jaggar was expecting to make a trip around the Peninsula to Nushagak, probably returning to Kodiak about June 1. R.M.W.

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No. 129 RELEASED WITHOUT COPYRIGHT RESTRICTION June 16, 1927

KILAUEA REPORT No. 805

WEEK ENDING JUNE 15, 1927
Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Few changes have taken place in the great pit Halemaumau. Coatings of white salts have increased on the wall east of the lower southwest rift tunnel and down the north edge of the southwest talus. The hole formerly at the top of the northwest talus no longer exists, because the wall has broken away around where it was. Its outline, however, is still discernible on account of the difference in the color of the dirt there. New debris on the north talus indicates that recent slides have occurred from the wall above. By far the greater number of slides in the pit take place at this point. For some time this north wall has been kept red by peeling. Steaming in the pit is about as usual, increasing and decreasing according to the rainfall.

At 1 p. m. on June 10 dust from a slide at the northeast corner of the pit was observed.

The seismograph records for the week ending June 15 show 11 very feeble local earthquakes. During the afternoon of June 14 there were numerous traces of minute spasmodic tremor—so feeble that they have not been included in the count as earthquakes. Microseisms have been unusually feeble during the week. Tilt has accumulated moderately to the southwest.

LATITUDE VARIATIONS

In Volcano Letter No. 94 (October 14, 1926) a brief review was made of Professor E. W. Brown's evidence of fluctuations in the rate of rotation of the earth. There has since appeared in "Nature" (February 5, 1927) another paper by Professor Brown essentially the same as the first, but condensed. The question is attracting widespread interest, as several reviews and criticisms have appeared.

Mr. Walter D. Lambert has published in the Journal of the Washington Academy of Sciences a discussion of the possible correlation between the fluctuations in rate, and the variation of latitude of which he has made a study for the U. S. Coast and Geodetic Survey. Attention is here called to the fact that if the expansion and contraction of the earth is not uniform over its entire surface, so that the alteration is not symmetrical with respect to the axis of rotation, then the axis of rotation will seek a new position through the mass of the earth. The precise positions of the poles and the equator will therefore change, on account of this adjustment to the unbalanced moments of inertia resulting from the lopsided expansion or contraction. Latitudes are based upon the position of the poles and equator; such a change will affect the precise latitude of a given point on the earth's surface. The positions of the poles do change slightly, through explainable causes. But after the explainable causes have been computed and accounted for, there still remains a slight polar motion without apparent reason. Mr. Lambert shows that these remaining motions may thus be conveniently explained, if the expansion and contraction is not uniform or symmetrical with respect to the earth's axis. He states that there is indication of a correlation between latitude variations and changes in rate of earth rotation. He has made calculations, showing that the earth changes required to produce the unexplained latitude variations would be of the same order of magnitude as those required to produce the observed changes in rate of the earth rotation. Lopsided changes may, therefore, explain both of these effects.

The objection to the idea of non-uniform expansion or contraction is taken on the basis of sea-level. If expansion or contraction affects a part, only, of the earth's mass, the resulting elevation or depression of the earth's surface over that part should become immediately apparent through the change of its relation to sea-level.

There are, however, evidences of elevation or depression of certain sections with respect to sea-level. Geology speaks of elevated shore lines, or of drowned valleys. In Alaska, not long ago, a sudden elevation of shore line took place. This was probably an index of the elevation of a considerable area of the earth's surface. Such an elevation might represent no disturbance to isostatic compensation, yet through the increase of distance from the earth's axis, would represent a change of moment of inertia.

Here at Kilauea, it has been estimated that during the collapse that followed the 1924 explosive eruption, many times more material was engulfed than was ejected. Also, elevations have been lowered in the vicinity of the volcano. This has already been noted in the Volcano Letter (No. 74, May 27, 1926). The volume of material here locally involved is doubtless of too small an order of magnitude to produce the effects in question. But it may be that this engulfment is the result of a more general contraction, the volcano acting as a sensitive point for its registration.

A suggestion attributed to Professor J. W. Evans is that the variable amount of volume in the polar ice caps may affect the total moment of inertia of the earth. The volumes of these ice caps change through long periods of years. As they melt to their smaller volumes, water is added to the oceans, raising their level, and tending to transfer mass from the poles towards the equator, thus increasing the earth's moment of inertia, and so to change its rate of rotation. This would be a "lopsided" effect, since ocean and land areas are not symmetrically arranged on the earth's surface, and only the ocean masses would be changed. Therefore, Mr. Lambert points out, latitude variations would probably result, along with the change in rate of rotation. R.M.W.

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No. 130 RELEASED WITHOUT COPYRIGHT RESTRICTION June 23, 1927

KILAUEA REPORT No. 806

WEEK ENDING JUNE 22, 1927

Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Several changes have taken place at the lava pit, but nothing by which to predict an eruption. The solfataras are a little brighter on the floor and southwest talus; white salts are forming on the north wall; a new scar is on the south wall about a hundred feet below the rim, produced by a slide; the northern walls of the pit have avalanched considerably; and the ground at the east rim has moved inward slightly, as evidenced by a widening of the surface cracks. Probably most of the slides from the north walls took place on June 21, as dust clouds were seen rising about 9:30 a. m. There is some movement of the walls at the southwest rift tunnels, as slides were seen there on June 22 about 9 a. m.

Due to the strong northeast wind on June 17, great clouds of dust, resembling smoke, covered the Kau Desert south of Kilauea Crater.

The seismographs have recorded 15 very feeble local earthquakes during the week ending June 22. There is also a feeble trace of a teleseism at 8:40 p. m., Hawaiian Standard Time, on June 16. One of the local earthquakes (7:11 a. m. June 19) was of sufficient intensity to record indications of its distance, probably 11 miles. Microseismic motion is still very weak.

Moderate north tilt has accumulated during the week.

SOME POINTS CONCERNING 1927 OBSERVATIONS AT KILAUEA

Avalanches in the pit of Halemaumau have seemed to be more frequent in the afternoon than in the forenoon. If large enough, they undoubtedly make small records on the seismographs; and earthquakes may cause avalanches, if rock is ready to fall in reponse to a slight impulse. There is, therefore, a loose correlation between the two, especially during these quiet times when there are no larger disturbances present to mask the effect.

This suggested that the small local earthquakes recorded by the seismographs might be more frequent during some particular part of the day. Local earthquakes during the last eight months (October 1, 1926, to May 31, 1927) have been counted according to the hour of the day in which they occurred. The percetnages of the total for each of the 24 hours of the day are as follows: A. M.; 2.3, 3.3, 2.3, 3 1, 1.7, 3.5, 4.2, 2.8, 2.7, 3.8, 3.5, 8.1; P. M.; 5.6, 7.6, 6.0, 6.1, 5.8, 5.6, 4.4, 3.6, 4.2, 2.7, 3.5, 3.6. Thus it is seen that the early morning hours are the most quiet, with a slight increase in number during the forenoon. At 11 a. m. is an abrupt increase, and the following afternoon hours contain large percentages, decreasing towards evening. This irregular distribution is perhaps not due to seismic causes. Most of the disturbances counted are very feeble, and some of them may not be true earthquakes. Avalanches in Halemaumau apparently occur more frequently in the afternoons due to temperature and drying effects of the sun on the walls of the pit. During some of these eight months road construction has been in progress within a few miles of the Observatory, involving the blasting of rock. Some of the blasts are known to have caused records on the seismographs. The contractors usually tried to set off their "shots" just before noon in order that the workmen could be off work for lunch. These blasts are very likely the cause of the large percentage in the hour between 11 and 12 a. m., and others may also have added to the number of records made during the afternoon hours. Records made by avalanches in the pit also are added more to the afternoon numbers.

It seems possible that the true earthquakes may be evenly distributed throughout the twenty-four hours, and that the surpluses shown by these percentages for the afternoon hours are the result of non-seismic disturbances. This question should be considered in making use of the numbers of earthquakes given in the Kilauea Report. In times of more frequent earthquakes, and when no blasting is in progress, the proportion of non-seismic records would be so small as to be negligible.

Tilt, as given in the Kilauea Report, taken one week at a time, seems to have little significance. But at times when lava is in the pit, east tilt is observed to have correlation with the height of lava. During the 1926 eruption of Mauna Loa, tilt exhibited a rapid surge towards the east and southeast; a movement distinctly apart from its regular annual accumulation to the southwest and back. The source of the Mauna Loa flow was 24 miles from the Observatory. It seems certain that tilt changes are produced by volcanic activity within the mountains of Kilauea and Mauna Loa, even if evidences of that activity are not otherwise apparent at the surface. A review of this movement over the last six months is of interest. A surge of tilt towards the east during the last few days of February is a feature, and somewhat resembles the movement accompanying the Mauna Loa eruption. A rapid change towards the southwest beginning March 21 and ending abruptly on May 5, probably has some significance. It is interesting to note that the latter movement began practically at the time of the moderate earthquake that was perceptible throughout the Hawaiian group; a coincidence only, perhaps. Since May 5 tilt has been particularly sluggish, and the normal northeast accumulation seems to have begun. Values throughout the whole six months period are considerably more to the northeast than contemporary values of 1926, as if Kilauea were trying to gain back the east and northeast tilt lost during the 1924 explosive eruption.

The first three months (February, March and April) of records of the tide gauge installed at Hilo, mentioned in previous Volcano Letters, have been subjected to a preliminary analysis and comparison with the Honolulu records. It is the aim to detect possible seismic sea waves, and after a long period of time to detect possible shore line elevation or depression, but so far there has been no evidence of either. The records near March 20 were carefully inspected to see if the earthquake of that date had any effect, but there was none noted. R.M.W.

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No. 131 RELEASED WITHOUT COPYRIGHT RESTRICTION June 30, 1927

KILAUEA REPORT No. 807

WEEK ENDING JUNE 29, 1927
Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

The working of the walls of Halemaumau pit has continued this week, though not so actively as last week. Several small slides have occurred, and one large slide was seen at the southwest at 3 p. m. on June 26. Red dirt lies thickly on the north debris slope and at the foot of the northern and western walls. Steaming is very moderate at all the vents.

A circuit of the pit was made on June 25. At this time it was noted that the cracks back of the north and northeast rims seem to have the greater movement. One of the larger northeast cracks is very hot, but not steaming. The freshness of some of the smaller cracks give the ground a very unstable appearance. The top of a prominent pinnacle which overhung the northeast rim has slid off. This must have occurred on June 21, when there were some large avalanches on that side.

There have been only nine very feeble local earthquakes recorded during the week ending June 29. Of these, four were on June 24, and on the 23rd, 27th, and 28th there were none. Tilt has accumulated moderately NNE, apparently continuing its normal annual course.

CYCLICAL VOLCANIC ACTIVITY

Among the questions now most frequently asked by visitors at Kilauea are: "Is the volcano dead?" and "When will the next eruption be?" The Volcano of Kilauea is not dead. The second question is not so easily disposed of, as the principles involved in trying to answer it are most complicated and intricate. To be able to predict earthquakes and volcanic eruptions has long been the aim of seismology and volcanology (see "Predicting Earthquakes," by T. A. Jaggar, in Scribner's Magazine, Octoebr, 1924). The lines of reasoning that have seemed most often to hit the mark are, first, to learn through local history the habits of the area in question, and second, to observe and correlate current symptoms and phenomena. The earth's forces slowly accumulate stresses that are deep beneath the surface, of which the indications are difficult to observe. Periodicity is a good hand-hold for prediction, particularly in dealing with volcanic eruptions.

The "Second Report of the Hawaiian Volcano Observatory." by Harry O. Wood, published in 1917 by the Massachusetts Institute of Technology, sets forth in considerable detail the "Cyclical Variations in Eruption at Kilauea." Here the habits and history of activity of the volcano have been systematically studied. A great number of natural phenomena have definite periods; cycles of similar action repeated again and again. Most familiar to us are day and night, summer and winter, high and low tides. Volcanic activity is probably the result of a combination of causes, many of which are of periodic nature. Tides are caused in the waters of the ocean by the gravitational attraction of the sun and moon. In the earth's stiff crust stresses are set up to resist these deforming attractions, in spite of which a slight tide also exists in the solid earth. These earth stresses and tides doubtless affect volcanic action, and have seasons of greater intensity just as the ocean has spring tides. If the action of a volcano depended upon only one such simple periodic cause, it would perhaps erupt with perfect regularity. But there are probably many causes, some orderly and periodic and some irregular, few of them well understood, and it is the combined result of them all that is reflected in volcanic action. Cycles of gas pressure accumulation and release, of chemical reaction, and of geyser-like action in slow subterranean flow of viscous magma; slow changes due to isostatic adjustment; accidental effects as choking of vents, or draining off of lava through newly formed earthquake cracks; these are some other suggested causes. Periodic effects combined, in general, yield a periodic resultant with a cycle long in time, as only occasionally will the individual effects work together in harmony. Thus if observations are studied over a considerable length of time, and periodicity is discovered, periods of equal time may be projected into the future as a basis for forecasting.

Tidal effects, semi-monthly and semi-annual in period, are to be expected, and appear to have been recognized in observation. Thus Mr. Wood suggests that early summer and winter are times favorable to eruption, while early spring and fall induce quiet. An effect having a seven-year period seems to exist, perhaps being correlated with latitude variations (see Volcano Letter No. 129, June 16, 1927). The combined resultant of these and other periodic effects has been estimated to have a cycle 130 years long; a result derived by independent investigators, and apparently justified by observation.

The history of Kilauea reveals other quiet periods like the present one. Old residents here remember the relatively dormant period between 1894 and 1907, when people were asking then, just as they are now, "Is the volcano dead?" Could they have then foreseen the high lava activity of 1920, and the explosions of 1924, the question would have seemed ridiculous. The present quiet phase is but part of the cycle of the volcano; history repeating itself. As time goes on, a longer recorded history will be available for the study of periodicity; the symptoms of accumulative and accidental effects will become better understood; causes will be recognized, and forecasting will rest on a firmer foundation. R.M.W.

ALEUTIAN STATION NOTES

From Alaska, Dr. Jaggar reports favorable weather and convenient transportation. The cooperation of other Government Departments, and of individuals, is making a success of his reconnaissance (see Volcano Letter No. 128, June 9, 1927). His trip is covering the Aleutian Islands and the Alaskan Peninsula as thoroughly as may be in the time at his disposal, both by land and water. The Coast Guard cutter takes him to Attu and to the Pribilof Islands, arrangements have been made to go to the far west Aleutian Islands. He will go around Pavlof Bay by power boat, and expects to explore Pavlof Volcano. He has been into Bristol Bay and back to False Pass. It is expected that a second seismograph will be installed at Unalaska. R.M.W.

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No. 132 RELEASED WITHOUT COPYRIGHT RESTRICTION July 7, 1927

KILAUEA REPORT No. 808

ENDING JULY 6, 1927

Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

New lava began to flow into the pit just before 1 a. m. on the morning of July 7. The Kilauea Report, as follows, had been prepared but had not been sent to press. It applies to the last week, and is here presented as a preface to the events of July 7:

Avalanchings have continued this week at Halemaumau, particularly at the northeast, where cave-ins have formed a large bay. Dust from slides can very frequently be seen there. The northeast talus has much new debris. Many slides are also occurring at the southwest rift tunnels. Several wide, gray streaks on the south-southwest talus, three of them reaching to the foot, mark the courses of tumbling bowlders. The north wall of the pit has fresh scars. A pinnacle and several overhanging blocks at the north-northeast are about ready to fall.

The cracks developing parallel to the east and northeast rims of the pit of Halemaumau, first mentioned in Volcano Letter No. 130 of June 23, have continued to widen steadily. These cracks in which movement has been noted vary in distance from the edge of the pit, few of them being back more than 50 feet. There is about 1,500 feet of ground along the rim that has shown motion in this manner. Avalanching has been considerable during the past months at the northeast rim of the pit, and it seems as if the ground that has been gradually falling away there has been acting as a keynote to the horizontal arch of the pit walls. The gradual disintegration of this keynote has thus allowed this long section to slump inward slightly. The widening of these cracks suggests the probability of increasing avalanching on the east and southeast sides of the pit, which have heretofore been more stable than the other sides. This is the part of the rim most frequented by visitors, and it has been thought advisable to warn them to cross these fresh cracks with caution. Measurements are being made to determine the rate of motion.

During the week ending July 6, the seismographs have recorded 10 very feeble local earthquakes. In addition to these, on July 3 at 12:15 a. m. Hawaiian Standard Time, there is a very faint trace of a teleseism. No phases are distinct enough to indicate the distance.

Microseismic motion has been somewhat more feeble than normal. Tilt has accumulated slightly towards the east.

The foregoing report was prepared on July 6. Early in the morning on July 7 the night watchman at the Volcano House saw a glow at the pit, and awakened the people at the hotel. Mr. James K. Tsuchiya spread the news through the neighborhood. The lava probably came into the pit shortly before 1 a. m. People who were awake at midnight have reported nothing unusual. There was no disturbance to awaken people, and the fountaining in the pit probably began gradually. The seismographs show two very feeble local earthquakes at 11:12 and 11:46 p. m. July 6, which in no way differ from the many recorded during the last months. Harmonic tremor commenced rather definitely at 12:32 a. m. July 7, and probably marks the beginning of release of lava, though perhaps at the very beginning it was coming up through cracks or loose talus, so that glow was not immediately visible. The night watchman was inside the hotel until nearly one o'clock, when he was due to make his regular inspection of the premises. He saw a rather faint glow, which brightened rapidly as he watched it, and he then notified the manager of the hotel. By a few minutes after one, there were many witnesses, and the first cars reached the pit at about 1:40 a. m.

There are four fountains of lava, nearly in the line of the 1920 rift; that is, along the NE and SW diameter of the pit. The one to the southwest is a short distance up the talus slope, just beneath the 1920 rift tunnels. From it a river of lava is running down the talus to the lake forming on the floor of the pit. The second fountain is near the base of the big SW talus, and from it two short lava rivers are flowing down. The third fountain, smaller than the others, is near the edge of the lake, and at the bottom of the same SW talus. The fourth fountain is on the other side of the pit, near the bottom of the NE talus, and its source is below the level of the lake. The three larger fountains are spouting lava over 100 feet into the air, and all are rapidly building spatter cones. The level of the lake, now of irregular shape, is about 1,500 feet long and 900 feet wide. It is slowly rising, as the fountains feed it. The surface is rather placid, being broken by the usual red cracks between the slowly moving blocks of the cooler crust. Around the rim of the pit, new "Pele's hair" can already be found, and a small amount of light, forthy spatter has been brought up by wind and deposited near the edges of the pit.

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No. 133 RELEASED WITHOUT COPYRIGHT RESTRICTION July 14, 1927

KILAUEA REPORT No. 809

WEEK ENDING JULY 13, 1927
Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Lava is still flowing into the pit, though perhaps with diminishing activity. The flowing from the southwest cone is gradually filling the lake through channels that are crusted over and invisible. The flow shows glowing cracks, and occasional red toes of liquid lava are thrust out. At night the crack patterns are most interesting. There has been only a little glow from the pit during the latter part of the week.

The seismographs have recorded 20 earthquakes during the week. One of these, at 3:21 a. m. July 7, a little over two hours after the outbreak of lava in the pit, was moderate; all the others were very feeble. The moderate shock had an indicated distance of 35 miles. It was reported as felt in many parts of the Island of Hawaii. A perceptible earthquake was reported in Kona at 20 minutes after midnight, July 7. A preliminary trace of harmonic tremor occurred at 10:55 p. m. July 6, and lasted 17 minutes. Harmonic tremor definitely began at 12:32 a. m. July 7, and the lava broke out a few minutes later. At 1:25 a. m. July 8 the harmonic tremor faded out, though there were a few recurrences for a few minutes at a time during the rest of that day. It has not been strong enough to show anything but very feeble traces since the 8th. Tilt has been slight to the NNW.

NEW LAVA IN HALEMAUMAU

The coming of lava into the pit of Halemaumau occurred just in time so that the beginning of the flow was described in the last number of the Volcano Letter. The lava spouted into the pit very vigorously during the first few hours, but began to show diminishing energy during the day, and the small fountain ceased action about 5 p. m. July 7. The lake formed on the bottom of the pit rose to an elevation of 2,480 feet above mean sea level, the old floor level being at 2,392 feet. The lava in the lake was quite fluid, as the waves induced by the convulsions of the northeast fountain could be seen to cross to the opposite side of the lake. During the early morning hours of July 8 two more fountains ceased action, and the molten lava of the lake partly drained out, perhaps flowing down the vent of the northeast fountain when the active lava retired at that place. When daylight came, it was seen that the cooled surface of the lake had collapsed about 10 feet, leaving a shore line bench around the edges. A sector of spatter on this bench and adjacent talus indicated about where the northeast fountain had been. Two little cones mark the site of the short-lived small fountain, and a larger spatter cone, whose summit elevation is 2,520 feet, marks the position of the fountain at the base of the southwest talus. These cones are above the lake, so that the collapse did not disturb their formations as it did in the case of the northeast vent. The remaining action was confined to the southwest fountain, which had built around itself a spatter cone about 40 feet high above the talus upon which it is built, and its summit elevation was then 2,602 feet. Down the side of this cone, from a low edge of the hole in its summit, lava was pouring in a large, steady stream. The lava was building a steep delta down to the edge of the collapsed lake, and was beginning to flow out on top of the depressed lake surface.

The more quiet phase thus begun on the morning of the 8th has continued since. Lava has been flowing uninterruptedly from the cone, but it has been becoming less and less spectacular. The spatter from the fountain encased within the cone has built the cone higher, and it has capped itself over. The lava stream gushing forth from the base of the cone has gradually built itself a roof. Occasional interesting action is seen when this stream becomes clogged and the lava breaks out and flows on the surface for a while; or when the cap of the cone collapses or is blown off, and a glimpse is obtained of the energetically boiling lava within. The lava from the cone forms a miniature pahoehoe flow which is gradually covering the surface of the collapsed lake. The front of this flow has progressed slowly, by uneven spurts, so that by July 13 it has reached the site of the dead northeast fountain, and has covered most of the surface of the collapsed lake; the northwest bay being still uncovered. The southeast shore line bench of the lake has been covered by the flow, as the flow is higher here near its source. The flow has not yet reached the elevation of the bench at the east and north sides of the lake, though the collapsed part of the lake is covered on these sides.

Action so far is of a minor sort only, when compared to the usual lava displays of Halemaumau in past years. The new lava in the bottom of the pit, including lake, cones and delta, covers an area of but 30 acres. This outbreak is much the same as that which occurred in 1924, about two months after the explosive eruption. At that time lava came into the pit on July 19, spurting from a source on the southwest talus. Lava continued to flow, but with diminishing vigor, till July 29, when it ceased, and there has been no active lava in the pit until the present outbreak. The present active cone is not far from the position of that of 1924.

The very energetic manner in which the lava first appeared a week ago perhaps represents the effervescence due to the sudden release of pressure upon breaking through into the pit. The steady persistence in the activity of the one remaining cone is an encouraging sign for continued activity, though action does not seem as strong on the 13th as during the preceeding days of the week.

R.M.W.

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No. 134 RELEASED WITHOUT COPYRIGHT RESTRICTION July 21, 1927

KILAUEA REPORT No. 809

WEEK ENDING JULY 20, 1927
Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

The flow of lava into the pit of Halemaumau has been diminishing during the week. The volume of new lava poured into the pit on July 7, the first 24 hours of the outbreak, represents about half of the total accumulated to date. The flowing from the southwest cone has been continuous, though fluctuating in amount, until July 19. The top of the cone has in general remained open towards the southwest, parts of its walls or roof being blown off from time to time. On July 19 the flow ceased during part of the day, though lava flowed from the cone at 3 p. m. and during the evening at about 9 p. m. Inspection of the pit on the morning of July 20 showed no lava flowing; no active lava was visible down the throat of the cone, and only a very thin trace of blue fume was issuing from its mouth.

The number of earthquakes recorded during the week ending July 20 is 18. These were all local and very feeble. Harmonic tremor does not show on this week's seismograms. In addition to the above local earthquakes, a feeble teleseism is recorded; its long wave beginning at about 1:34 p. m. July 14. Tilt has accumulated moderately towards the northwest.

SOME ALEUTIAN VOLCANOES

In a wireless message from Dutch Harbor, Alaska, Dr. Jaggar tells of a most interesting fortnight spent in the western Aleutian Islands. He went with the Coast Guard Cutter to Attu, and returned to Dutch Harbor July 8, having seen some 20 big volcanoes on the trip. He is high in his praise of the region as a field for volcanological study. Gareoli, an island-volcano over 5,000 feet in height, is a cone from which yellowish steam is issuing. Tanaga, a wonderful composite cone covered with cinder, is the eastern neighbor of Gareoli. Semisopochnoi, to the west of Gareoli, is shown on the chart as having "burning volcanoes." The present report speaks of sedimentary rocks, such as sandstones and conglomerates, in abundant occcurrence on the south side of this Aleutian belt, which are perhaps comparable with the rocks found near Unga.

Bogoslof Volcano is of especial interest. The island, which is the top of the volcano, has changed its formation many times. Passing ships have reported from time to time the appearance of new summits, or the disappearance of old ones, and an occasional eruption has been witnessed from a distance. Sidney Powers, in the "Geographical Review" September, 1916, gives a brief sketch of the history of the volcano. He gives the date of the first formation of the island as 1768. Another island developed nearby in 1796, and still another in 1883. These were at first separate islands, the last mentioned being a precipitous plug pushed up from a volcanic orifice to a height of 800 feet above sea level. These islands changed in form during the years up to 1906, when another plug, 2,000 feet in diameter and 400 feet in height above the ocean, was pushed up into the group. A few months later this was partially blown away, and still another plug rose by its side, being in turn partly destroyed by an explosion in 1907.

In the Technology Review, Vol. X, No. 1, is the "Journal of the Technology Expedition to the Aleutian Islands, 1907," of which expedition Dr. Jaggar was himself in charge. Bogoslof was visited in August, 1907, and the Journal has a number of photographs of the steaming summits, which at that time had become joined together by volcanic additions and by sand and gravel bars into a single island. Sketch maps show the development of the island as reported by various observers up to that time.

Activity since 1907 has been only casually observed by passing ships or by distant witnesses on the nearer neighboring islands, Unalaska and Umnak. Dr. Jaggar's recent visit has shown him the result of the many active phases since 1907. He reports a new steaming lava dome, 1,200 feet in diameter and 200 feet high, which is surrounded by a salt lagoon, in which the water is warmed to 75° Fahr. Around the lagoon is a complete ring of gravel and sand, which forms the connecting link between the summits that were separted by open channels prior to 1906. New Bogoslof or Grewingk Island, the northern peak that appeared in 1883, he reports much changed in form since 1907. Old Bogoslof, the peak of 1796, is now surrounded by a high bank of gravel. The island is tenanted by great numbers of sea-lions, a count up to 400 having been made. Murres and other nesting birds are present by the million. The latest phase of volcanic activity probably began about July, 1926, and increased thereafter with occasional explosions which were seen from distant villages on the neighboring islands. This recent activity was probably very similar to the eruption of 1906. There is no continuous accurate record being made of these phenomena.

This is all but a sample of the area of volcanic and seismic activity that the region has to offer. Katmai and the Valley of Ten Thousand Smokes, Pavlof Volcano and many others are available for study and research. Dr. Jaggar suggests that Dutch Harbor, on Unalaska Island, is an ideal place for a Government scientific research station, not only for the study of volcanology and seismology but also geology, biology and botany. For these investigations, and for coast, geodetic and topographic surveys, such a station would be an admirable base for the whole Aleutian belt. R.M.W.

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No. 135 RELEASED WITHOUT COPYRIGHT RESTRICTION July 28, 1927

KILAUEA REPORT No. 810

WEEK ENDING JULY 27, 1927

Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

There has been no renewal of flowing lava in Halemaumau pit. Glow and fumes are absent from the southwest cone, but at night there is still some glow to be seen in the cracks of the pit floor. Steam vents in the pit are quite active, particularly on the south and northwest taluses.

There is considerable working of the walls of Halemaumau, most of this being on the northeast side. The ground back of the north-northeast and northeast rims is breaking up, forming many small new cracks as well as widening the old ones. Debris falling from this side of the pit has covered a very large section of the new floor and partly filled the depression between the north-northeast and northeast taluses. Frequent avalanching has occurred. On July 21 at 9:10 a. m. a cauliflower dust cloud rose from the pit, hanging over it for about five minutes. At 2 p. m. July 22 there was dust from slides at the west boss, and stones could be heard falling there. On July 24 dust hung over the pit in varying quantities all day, and there was almost constant avalanching from the north-northeast wall. The two bowlders on the north-northeast talus, which have served as landmarks, have disappeared under new debris.

This spurt of avalanching, together with the widening of old cracks and the opening of new ones around the rim of the pit, is similar to the action noted in Volcano Letter 130, on June 21 and 22, which was at that time considered due to natural disintegration of the walls. There was then a very slight increase in the frequency of earthquakes, of which two gave indicated distances of 11 and 25 miles. About 16 days later lava came into the pit, and it seemed that in some way the presence or release of active lava stabilized the walls, so that instead of the increased avalanching expected from the development of the cracks, there was in fact a decrease of avalanching. An avalanche was reported on July 18 in Makaopuhi Crater. On the 19th lava ceased to flow into Halemaumau. Now, on the 23rd to the 25th comes another spurt of avalanching and development of cracks at the rim, which is in turn about 16 days after the outbreak of lava. This time the avalanching is accompanied by a swarm of earthquakes, two of them feeble and three slight, definitely drawing attention to the presence of volcanic forces. Whether the possible changes in conditions at the pit will be towards increase or decrease remains to be seen.

During the week a total of 21 earthquakes have been recorded. On July 24 at 6:05 a. m. there was a slight shock that may have been felt. The next day, at 2:07 a. m. and at 6:13 a. m., there were slight shocks that were felt at the volcano and in Hilo, and possibly elsewhere. On the same day also, a feeble shock occurred at 11:56 a. m. On the 26th another feeble earthquake occurred at 1:29 a. m. All others in the above total were very feeble. Three of the stronger shocks had indicated distance of 25 miles. Tilt has accumulated very slightly to the west.

COAST RANGES FROM THE AIR

Through the courtesy of Major General J. L. Hines, Commander of the Ninth Corps Area, U. S. Army, San Francisco, California, the undersigned was permitted to make an airplane trip over the Coast Range mountains between San Francisco and Clear Lake during the forenoon of April 4, 1927. The plane was very successfully piloted by First Lieutenant H. A. Moore. The course taken was to Calistoga and thence just to the east of Mount St. Helena and north to the southeastern part of Clear Lake, Mount Konocti, with a fairly distinct crater remnant in its southern peak, was passed, and the return to San Francisco was made about 18 miles west of the outgoing course.

Deep erosion valleys that trend the same as the mountain ranges, that is, northwest-southeast, showed up very distinctly. Layers of rock that showed up as systematic bands were noted on the east slope of Mount Konocti. From the varying extent of the erosion it appeared that there was considerable difference in age between the different mountains. Most of the mountain ranges appeared to have steeper slopes on their western sides than on their eastern sides, as though they had been formed by some mighty force shoving at the country from the east.

The airplane method of making a reconnaissance in this country is especially time-saving, as on foot one encounters dense underbrush of live oak, manzanita, and poison oak.

R. H. Finch.

SAMPLE COPY

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No. 136 RELEASED WITHOUT COPYRIGHT RESTRICTION August 4, 1927

KILAUEA REPORT No. 811

WEEK ENDING AUGUST 3, 1927

Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Avalanches continue to be rather frequent at Halemaumau, some of them making considerable noise and dust. Slides are occurring on all sides of the pit, though the largest seem to come from the north walls. Steam vents are moderately active, the one on the northwest talus being very flocculent.

A circuit of the pit was made on August 3. A close view of the northeast wall, from the north side, reveals many loose blocks in the vicinity of the northeast dike.

During the week ending August 3, there have been 18 local earthquakes recorded. Of these, there were four that were perceptible, all the others being very feeble. The perceptible shocks were recorded at 11:31 a. m. July 29, 2:14 a. m. on the 31st, 8:40 p. m. August 1, and at 9:42 a. m. on the 3rd. The first three were of the barely perceptible sort, having indicated distances of 39, 16 and 15 miles, respectively.

The fourth earthquake, on August 3, was the heaviest registered or felt at the Volcano for some time. Both seismographs were dismantled, and the disturbance was felt by nearly everyone. Windows were rattled slightly, and a moderate avalanche which occurred at the time was probably precipitated by the shock. Captain R. V. Woods reports that his seismograph in Kealakekua, Kona, was also dismantled, and the earthquake was pronounced there the strongest for some time. It was strongly felt in Hilo, causing considerable excitement and a small amount of damage due to merchandise being thrown from shelves in a store. The seismograph at the Brother's School was dismantled, first indicating a distance of 34 miles from Hilo to the origin of the earthquake. The indicated distance from the Volcano was 16 miles. These distances are misleading if the origin of the shock was a general slip along the main Hawaiian rift. Other reports have not yet had time to come in, but it was undoubtedly felt throughout the Island of Hawaii, and probably on the other islands also. This earthquake seems upon preliminary inspection to have characteristics similar to that which occurred on March 20, 1927, and is perhaps stronger than that one. In both cases the seimographs failed to record the maximum intensity, as the early movements of the shocks dismantled the instruments. One of the seismometers that is being developed by Professor Kirkpatrick (see Volcano Letter No. 126 of May 26, 1927) indicates maximum acceleration in the E-W component of between 50 and 90 mm. sec. per sec.; degree of perception also suggests intensity No. 3 on the Rossi-Forel scale.

Since July 24, beginning as noted in the last issue of the Volcano Letter, there have been nine shocks of sufficient intensity to be perceptible. This is a very distinct and sudden increase in earthquakes of this type. Most of them have been felt all over the island. This latest shock is perhaps but one of the series, being featured by greater intensity.

There has been no sign of return of lava. Both Mauna Loa and Kilauea are being closely watched for symptoms that may be correlated with this increase of seismic action.

Tilt has accumulated moderately to the NW.

HOT SPRINGS IN THE COAST RANGES NORTH OF SAN FRANCISCO

A considerable portion of Napa, Sonoma, and Lake counties, north of San Francisco Bay in California, is covered with lava of comparatively recent geologic age. The lava caps most of the Coast Range mountains which traverse this region. At many places hot springs and geysers are to be found. The geysers, for the most part, are not natural in that their vents were formed by drilling through the material that confines the steam and hot water.

To ascertain whether there is any appreciable variation in the temperatures of the hot springs, it is a part of the work of the Lassen Volcano Observatory to make systematic measurements of their temperatures. The temperatures of nearly all springs in California were measured several years ago, and appear in Water-Supply Paper 338, Springs of California, by G. A. Waring, U. S. Geological Survey. There is thus a basis for comparison already established.

The temperatures of a majority of the hot springs in the above mentioned region were measured in March, 1927. It was found that some of the springs were hotter and others colder in 1927 than when they were measured by Mr. Waring in 1908.

Varying rainfall and weather conditions affect the temperature of many of the springs. In order to accurately detect slight variations in temperature the measurements should be taken at about the same time each year.

R. H. Finch

THE CHINESE EARTHQUAKE

The death toll, at first exaggerated, of the Kansu Province earthquake has recently been before the public eye in the papers. It has taken over two months for the details to get out to civilization. Seismologists the world over knew of the occurrence of the earthquake, and knew its position, within a few hours after it happened (see Volcano Letter No. 127, June 2, 1927). R.M.W.

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No. 137 RELEASED WITHOUT COPYRIGHT RESTRICTION August 11, 1927

KILAUEA REPORT NO. 812
WEEK ENDING AUGUST 10, 1927

Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

The pit of Halemaumau is now comparatively quiet, conditions being apparently much the same as during the months before the July activity. Avalanching has been quite frequent, and new scars can be seen on nearly all sides of the pit. Cave-ins have so undermined the northeast wall that more or less continuous avalanchingg can be expected there for some time. On August 7 an observer on Uwekahuna Bluff saw blocks dropping from the usually stable southeast wall.

During a circuit of the pit on August 9 strong odor of sulphur dioxide was noticed at the north rim. This odor has been noticed at th s point many times before, but not so strongly. The bowlder marking the north rim station has fallen in.

The new lava floor is stained white at the foot of the southwest talus. Steam vents in the pit do not seem to change in any way.

Fourteen very feeble local earthquakes have been recorded during the week ending August 10. In addition to these local shocks, there is a feeble record of a distant earthquake at an estimated distance of 4,250 miles; the arrival of the preliminary wave recorded at 3:17 a. m. Hawaiian time, August 9. Two very faint traces, probably teleseisms, are recorded at 11:43 a. m. on the 5th, and at 1:45 a. m. on the 10th.

Tilt accumulated slightly towards the south during the first part of the week, but the motion then reversed, so that the net accumulation for the week is practically zero.

MIGRATION OF EARTHQUAKE REGIONS

The systematic progression of the epicenters of successive major earthquakes in a definite direction in the same zone has been many times observed. Along the whole length of a given fault or rift zone in the earth's crust stresses may slowly accumulate, finally producing fracture at some weak point. Such an earthquake releives the stress at that particular point, only to add stress at adjacent localities each way along the line of weakness. The next fracturing stress will so accumulate in one of these adjacent regions, making the progression along the fault. Thus the Kansu Province earthquake of May 22 is found to be in about the same latitude, but some 250 miles to the west of the similar great Chinese earthquake of Dec. 16, 1920. The westerly progression checks with the known east and west direction of the main faults.

A more general analysis suggesting the migration of whole seismic zones is briefly set forth in the paper "On a Long Period Fluctuation in Latitude of the Macroseismic Zone of the Earth" by Torahiko Terada and Naomi Miyabe (Proceedings of the Imperial Academy, Japan, May 1927). Earthquakes in certain regions have been divided into groups of fifty years each, and the mean latitude for the shocks of each group computed. Graphs of these means for the past several hundred years have been plotted for the following regions: (1) Eurasia; (2) North and Central America together with the West Indies; (3) South America; (4) China, by itself; (5) Japan. For comparison, there have also been plotted on the same time scale a curve representing tree growth and the curve representing the fluctuations in the rate of rotation of the earth as given by Prof. E. J. Brown (Volcano Letters No. 94, Oct. 14, 1926, and No. 129, June 16, 1927). Graphs (1), (2) and (4) are in remarkable agreement, showing most clearly a dim nishing north latitude from about 1725 to 1825, followed by increasing north latitude to the present time. Graph (3) seems to exhibit correlation if decrease of north latitude is accepted equivalent to increase of south latitude, suggesting migration of the same direction in the two hem.spheres. The curves representing tree growth and earth rotation also show remarkable correlation, as if the long period fluctuations in earth's atmosphere rate of earth rotation and position of earthquake zones may all be inter-related in some manner. Perhaps latitude variation and the long period of variation in volcanic activity may also be involved with the same suggested relation. The migration of the earthquake zones in Japan is represented by two graphs, giving the fluctuations in both latitude and longitude. The latitude graph does not show direct correlation with the others mentioned above, but a suggested explanation is given. R.M.W.

A MUSEUM FOR LASSEN NATIONAL PARK

A museum to make better known the natural history of Lassen National Park was opened with a formal dedication ceremony on July 4, 1927. It is located near the northwestern entrance to the Park. The museum was erected by Mr. and Mrs. B. F. Loomis as a memorial to their daughter Mae and they plan to turn it over to the National Park Service as soon as the boundary of the Lassen National Park is extended to include the area in which the museum is located. The most striking part of the exhibit is the pictoral history of Lassen Peak. There are pictures showing the condition of the peak prior to the outbreak in 1914, numerous ones showing the progress of the eruption, and others showing Lassen as it is today. There is a good display of the different kinds of lava to be found in the park and the mounted wild life exhibit is quite complete. R. H. Finch.

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No. 138 RELEASED WITHOUT COPYRIGHT RESTRICTION August 18, 1927

KILAUEA REPORT No. 812
WEEK ENDING AUGUST 17, 1927

Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Halemaumau pit has evidently settled down for a quiet period, following the spell of avalanching of several days ago. Four visits to the pit during the week fail to reveal any striking changes. There are a few new scars on the north and northeast walls, and the northeast talus overlaps the new floor a little more. Several bowlders have also rolled out onto the floor. Small slides can frequently be heard, but seldom can they be seen unless they make dust. The white stain on the lava floor has increased, some of it being slightly tinged with yellow. Steaming is very moderate.

During the week ending August 17 the seismographs have recorded but seven earthquakes, all local and very feeble. Tilt has accumulated slightly NNW.

WHAT IS EARTHQUAKE INTENSITY

The Rossi-Forel scale for grading earthquakes according to their intensities (see Volcano Letter No. 124 of May 12, 1927) illustrates the century-old practice among seismologists of making and using such classifications. The practice has been supported by some investigators and decried by others, but that it is generally accepted is shown by the fact that more than 27 such scales, all different, based upon seismographic measurements, arbitrary mechanical effects or personal emotions, have been constructed and used.

This confusion of scales would have been avoided if the makers had had any definite agreement or perhaps more definite ideas as to what they were attempting to grade. "Intensity," as applied to earthquakes, at first appeared to be a term without precise meaning, but the later scale-makers all agree that it is the destructive mechanical effect, rather than the degree of ensuing panic, which properly characterizes the intensity of an earthquake. But how is the destructive power of an earthquake to be stated numerically? Holden, in 1888, on the authority of Milne and other workers in Japan, introduced the idea that a destructive intensity scale was the same as a scale of maximum accelerations. The argument for this view was partly theoretical and partly the result of some approximately successful Japanese experiments. Accordingly Holden devised an absolute or dynamical scale, in which each degree meant an earthquake having a certain, stated, maximum acceleration.

Since Holden's work, scales similarly based upon maximum acceleration have been brought out by Omori, Cancani, Wood, Milne, McAdie, and perhaps others, but no one offered a conclusive demonstration that maximum acceleration and destructiveness really do go hand in hand. This is an important postulate and would seem to deserve investigation. As it is, the scales furnish us with many different answers to the question of what acceleration will be required, say, to knock down a given fence. One feels that there would not be so many if it had first been more critically asked whether or not there is any one unique acceleration which is necessary and sufficient to accomplish this destruction. The present writer believes that there is not, but that the acceleration required all depends upon the circumstances of its application; that is, upon the period and amplitude of the disturbance which brings it.

For example, let us consult some of the scales to learn what maximum acceleration will suffice to destroy an average frame house. Omori puts it at 4,000 millimeters per second per second; Wood gives from 1,200 to 3,000; Holden 1,200, as nearly as can be interpreted; while Cancani apparently considers 500 to 1,000 as sufficient. Nothing is said about periods or amplitudes. Now with these figures in mind take a C tuning fork, vibrating 512 times a second, and apply its stem to a door panel or a wooden table top. The wood is thrown into vibrations which can readily be felt with the fingers. With a little trouble the amplitude of vibration can be measured. It may be one one-thousandth of an inch or more, but to be on the safe side we shall here assume that it is only one tenth of this amount. Putting this into millimeters, and applying a formula well known to physicists, we obtain as the maximum acceleration of the wood particles 26,400 millimeters per second per second, or more than six times the highest estimate above for the destruction of wooden structures. It may be noted that the door or table survives the experiment unharmed.

This extreme case shows that the intensity-acceleration proportionality is certainly not of general applicability. A big accereation with a small period is harmless. Apparently the period should be given seperate consideration in the establishment of the true meaning of intensity. It would perhaps be more nearly correct to define intensity as a quantity proportional to the product (maximum acceleration) x (period). It is easily shown that this is the same thing as putting intensity proportional to the ratio of amplitude to period. This tentative suggestion, with any others covering this same question, await a test which can only come by systematic observation of the destructive effects of a large variety of accurately measured earthquakes.

Paul Kirkpatrick.

HAWAII TERRITORIAL FAIR EXHIBIT

At the Territorial Fair, which opens in Honolulu on August 29, there will be an exhibit of photographs and lava specimens from the vicinity of Kilauea Volcano. The Hawaii National Park will exhibit jointly with the Hawaiian Volcano Observatory. The Observatory will show a seismograph which was constructed in its own shop, and there will be a short moving picture shown of the 1926 Mauna Loa flow. In order to furnish information to those not already acquainted with the history and work of the Observatory, the Volcano Letter for next week will deal briefly with these subjects. A number of extra copies will be printed and furnished for free distribution to those interested at the Fair.

R.M.W.

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No. 139 RELEASED WITHOUT COPYRIGHT RESTRICTION August 25, 1927

KILAUEA REPORT No. 813
WEEK ENDING AUGUST 24, 1927
Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Kilauea Volcano continues dormant, and very few changes are to be noted in the lava pit, Halemaumau. During a walk around the pit on August 18 a faint odor of sulphur dioxide was noticed at the fourteen-ton bowlder on the east rim and also at the north rim, and a few rock falls were heard. On August 23 the only changes appeared to be an increase of the white salt coatings on the north and northeast walls and of the white and yellow stains on the lava floor. A crack at the southeast rim seemed to have been in motion. Steaming was very slight. On August 24 there was increase of steaming due to the wet weather.

During the week ending August 24 there have been 26 local earthquakes recorded, all very feeble except one which was registered at 9:22 p. m. August 23. This was feeble and hardly strong enough to be perceptible. Its indicated distance from the Observatory is 25 miles. On August 17 a swarm of very feeble tremors was recorded, and a similar swarm came on August 20. Faint traces of tremor, occasionally visible between the counted earthquakes, suggests that each swarm represents a continuous though very feeble disturbance, perhaps similar to harmonic tremor. Very slight south tilt has accumulated during the week.

THE HAWAIIAN VOLCANO OBSERVATORY

The Hawaiian Volcano Research Association was founded in 1911 by business men of Honolulu as an organization to promote volcanological research, and to establish the Observatory at Kilauea. Professor T. A. Jaggar of the Massachusetts Institute of Technology was secured to take charge of the work; and additional funds towards the support of the project were also furnished through the Institute. The seismograph cellar and the main laboratory building were constructed in February, 1912, and detailed routine records of activity have been kept ever since. The station was transferred to the United States Government in 1919, and was operated under the Weather Bureau until 1924, when through governmental reorganization it was changed over to the Geological Survey under the Department of the Interior. The Research Association has continued its full collaboration throughout these different transfers. The Hawaiian Volcano Observatory, therefore, now represents this combination of interests. Professor Jaggar has remained in charge since the beginning; he is now Chief of the Volcanology Section of the Geological Survey, and a director of the Research Association. In the former capacity he is also in charge of volcanologic stations in California and Alaska. Under his direction the Observatory operates subordinate seismological stations at other places on the Island of Hawaii.

Kilauea Volcano is an excellent subject for volcanological study. It is an active volcano, yet being ordinarily non-explosive, it is relatively safe and may be studied at close range; it is accessible; its activities are confined to a region conveniently within the scope of a single station; Mauna Loa, also active, is close by and furnishes additional phenomena for study; there are great numbers of local earthquakes as clues to its moods; it is in the middle of the wide circle of earthquake zones defined by the shores of the Pacific Ocean; it is American territory.

The aims of the Observatory are: To keep detailed records of Hawaiian volcanism; to attract to Hawaii volcanologic specialists and scientists interested in allied subjects; to make available elsewhere the knowledge gained in Hawaii concerning volcanoes and earthquakes. The work of the Observatory is under the general heading of Geology. The mountain's structure, its features and faults, its interior mechanism, statistics of its eruptive habits, details of its individual lava flows and eruptions, the character of its ejected material—these are all main lines of investigation under the general heading. Various branches of science are used as tools for observation. Seismology is most important, as the local earthquakes and tremors are in fact the heart-beats of the volcano, and tilt is its respiration. Chemistry gives the analysis of lavas and gases, and is a key to some of the reactions within the volcano and to the behavior of lava at the surface. Astronomy, through the tidal effects of lunar position, helps in the study of the periodicity of eruptive phases. Geodesy provides methods for measuring the stretching, warping and bulging or collapse of the ground surface near the volcano, and also checks the tilt; gravity measurements indicate interior densities. Meteorology suggests correlations such as weather and barometric pressure with volcanic activity. Hydrography and topography show the shape of the volcano, and the former includes knowledge of tides and fluctuations in mean sea level. Engineering is represented by the boring of wells and holes in the crater floor, for the study of sub-surface strata and temperatures. Photography, microscopy, radio, all do their part.

The cooperation of the U. S. Coast and Geodetic Survey has been very valuable in furnishing precise levels from Hilo to Mauna Loa, in making gravity determinations at Hilo, Kilauea and on Mauna Loa, and in establishing a tide gauge at Hilo. The regular operations of that Survey, and of other organizations and individuals, give much data useful to the Observatory along the lines suggested above.

Results of the study of special problems, tabulations of routine observations and discussions concerning them, are printed in the regular publications and reports of the Observatory, or appear as articles in the scientific periodicals and bulletins. The Hawaiian Volcano Research Association has recently financed the erection of a Lecture and Exhibit Hall. Lava specimens, photographs and charts are exhibited here, and illustrated lectures are given by the Hawaii National Park and the Observatory in cooperation so that visitors may be as fully informed on the points of local interest as is possible in their sometimes too brief stay.

Kilauea and Mauna Loa are active volcanoes. Its history shows that Kilauea is visibly active during the greater part of its time. Most of the lines of investigation outlined above are important even though molten lava or other spectacular surface activity is absent. The volcanoes are at present quiet, and no "fire" is visible, so that visitors now seeing them for the first time are led to the conclusion that the preponderance of pictures of activity is deceptive. Photography is obviously most extensively used during the spectacular phases. The present quiet period seems long, but it is only a short phase when counted in terms of the active age of these volcanoes.

R.M.W.

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No. 140 RELEASED WITHOUT COPYRIGHT RESTRICTION September 1, 1927

KILAUEA REPORT No. 814
WEEK ENDING AUGUST 31, 1927
Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Very few changes have taken place in Halemaumau pit. Conditions remain practically the same, except for occasional rock falls and avalanches. At 2:30 p. m. August 28 gray debris lay on the northern taluses, and at 3:10 p. m. a large avalanche dust cloud rose from the northeast corner of the pit. Two other slides just previous were noted by observers on Uwekahuna Bluff. At 11:50 a. m. August 29 avalanche dust clouds rose from the north, northeast, and east sides of the pit, and hung over it for several minutes. On August 30 at 9:35 a. m. a large, gray streak from a slide was seen to extend all the way from the west rim to the pit floor, and the northern walls were freshly peeled in several places. Rather continuous slides were occurring at the lower northeast corner of the pit. A section of a ledge southeast has fallen. A visit to the northeast rim August 31 shows the ground to be very loose there.

During the week ending August 31 the seismographs recorded 17 local earthquakes. One of these, at 8:10 a. m. August 28, was feeble and apparently not more than two miles from the Observatory. There are no reports of its having been felt. The other 16 shocks were all very feeble. There has been no accumulation of tilt during the week.

A REVIEW

The Bulletin of the National Research Council, Number 61, reporting the transactions of the American Geophysical Union at the meeting of April, 1927, contains a number of papers of very considerable interest. Already these papers are but brief abstracts, so that this still more brief review can hardly aspire to be more than a mere list of the subjects introduced. This Bulletin also contains the report of the delegates of the American Geophysical Union who went to the Third Pan-Pacific Science Congress at Tokyo in October, 1926.

The papers presented are grouped under general headings. Meteorology is represented by a "Symposium on Some Factors of Climatic Control," and by a number of papers on particular features. Terrestrial Magnetism and Electricity are discussed, and so is Oceanography. Volcanology, Seismology and Geodesy are of particular interest to this Observatory, and some of the features brought up by the papers under these headings are here outlined.

Under Volcanology comes a discussion of the investigation of hot springs by the Geophysical Laboratory. Phenomena in California, in Lassen Park and at the Geysers; in the Katmai region in Alaska; in the Yellowstone National Park; are compared as to range of seasonal temperature and as to materials brought to the surface with the water and steam. These considerations open the way for deductions on subterranean formations and conditions. Another paper points out the part played by gases in the phenomena of volcanism, commenting on the hypotheses of gas-heating and gas-fluxing, and refers to conditions at Kilauea. The presence of metals in various deposits placed by volcanic steam is touched upon. A discussion of conditions on the Moon is given, particularly the low value of lunar gravity and the lack of atmosphere, and the effect of these conditions upon the probable method of formation of the Moon's craters.

Reports of the work being done and the progress made in seismology by various organizations occupies considerable space. Improvement of instruments and the substitution of more modern seismographs for those of older design, the establishment of new stations, cooperation in centralizing the data, and early publication of results and summaries of earthquake information, seem to be the main lines of progress. The investigation of shifts and motions of the Earth's crust in relation to earthquakes is shown to be important, as through such measurements it may be possible to keep watch over dangerous fault zones. There are discussions of the travel of seismic waves through the Earth's surface layers, and concerning new phases observed in teleseismic registration.

The papers relating to Geodesy are numerous. Mention is made of triangulation by the Geodetic Survey of Canada at two places where the object is to discover and study earth movements in connection with seismic disturbances. The statement is made that "The geodesist has proved the theory of isostasy to be a scientific fact . . . . " The earthquakes of the St. Lawrence River Valley are supposed to be due to the recovery, by isostatic adjustment, of the area relieved of the weight of ice of the glacial period. A brief description is given of the methods, accuracy and preliminary results of the World Longitude-Net operations. In this work automatically recorded time signals and refined star transit observations were used simultaneously at stations scattered all over the world; the many different longitude differences to be harmoniously adjusted. The probable errors of these individual longitude differences, expressed in time, are given as amounting to only a few thousandths of a second. An interesting feature is brought out in the description of an adjustment made in the North American level net. The whole net was adjusted without the introduction of conditions for ties to sea-level. The result seems to indicate that according to spirit-leveling, mean sea-level is about a foot higher at Portland, Maine, than at St. Augustine, Florida; and nearly a foot higher at Seattle, Washington, than at San Pedro, California. The first order triangulation covering the western half of the United States has been re-adjusted, and one paper tells briefly of the loop closures; the mean of all the closures being about one part in 450,000, representing an error of about 14 inches per 100 miles.

In many of these abstracts reference is made to publications wherein these subjects are dealt with more in detail, and there are frequent references to forthcoming publications along the same lines which will soon be available. At this April meeting a resolution was adopted to find a way to have translated into English the many and valuable publications in Japanese that represent the current investigations in seismology in Japan. It is to be hoped that this may be done. R.M.W.

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No. 141 RELEASED WITHOUT COPYRIGHT RESTRICTION September 8, 1927

KILAUEA REPORT No. 815

WEEK ENDING SEPTEMBER 7, 1927

Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

There has been considerable working of the walls of Halemaumau during the past week. One very large avalanche occurred on the northeast side at 2:20 p. m. September 1. On September 2 two large scars were seen where the northeast wall had peeled, and from 9:30 to 10 a. m. small slides were almost continuous on that side. At 3:45 p. m. the pit was full of dust from slides. A large avalanche dust cloud was reported to have been seen about 6:45 a. m. September 4. On the 5th new debris lay thickly on the north-northeast, northeast, and south taluses. Steaming activity varies little.

On September 2 the crack at the southeast tourist station had widened very perceptibly, and there were several small new cracks nearby. The following day several crack measurements were taken, and the large southeast crack was found to have widened more than half a foot since July 11. Another crack had widened nearly as much in the same period of time. While other cracks in the vicinity had opened, their movements were not as great. On September 5 the small new cracks were more pronounced.

Six very feeble earthquakes occurred during the week. In addition to these there was a swarm of very feeble tremors on September 1. Minute tremors came also on the 2nd, 3rd, 4th, and 5th. Accumulation of tilt during the week has been negligible.

JAPANESE SEISMOLOGICAL INVESTIGATIONS

More than any other nation, perhaps, Japan is vitally interested in earthquakes. The high activity of its seismic zones, bringing heavy earthquakes into densely populated regions, makes earthquake knowledge actually a life and death matter. It is the business of the Japanese seismologists to examine in detail the circumstances and meaning of every shock, to delineate the active faults, to detect where the accumulating forces and stresses may next produce fracture with resulting damage to life and property. On March 7, 1927, an earthquake occurred in Tango Province, Japan. It was recorded on the seismographs of observatories in many places, and the press reported it rightly as disastrous. In the "Proceedings of the Imperial Academy," 3 (1927), No. 4, Japan, is an abstract of the seismological investigation of this earthquake by A. Imamura and Nobuji Nasu. There were two faults produced at right angles to each other, the vertical and horizontal displacement along each one being measured at the surface. Changed elevations along the sea coast were also noted. These are not unusual movements and changes to be produced by an earthquake. One feature that seems particularly interesting is the reported apparent temporary lowering of sea level, two or three feet in amount, which took place two hours and a half before the earthquake. In the analysis of the shock, the authors explain this to be a temporary elevation of the ground, caused by the up-tilting of a block of the earth's crust under accumulating stress. This stress was then expended in producing the fracture, generating the earthquake and allowing this area to resume its former position without the permanent displacement exhibited at other places. Three portable seismographs were set up at the corners of a triangle covering the epicentral region. These instruments began recording only four or five days after the earthquake, and the after-shocks that were still occurring were carefully analyzed. It was thus possible to estimate the boundaries of the disturbed block and to suggest the sort of mechanism involved.

A few months ago Mr. Imamura published a description of a horizontal pendulum seismograph which could be adjusted to a free period as long as three and a half minutes. In a more recent paper in the "Proceedings" (3, 1927, No. 5), with the title, "On the Observations of Slow Earthquake Motions," he describes certain earthquakes as recorded on this instrument. The very slow natural period of the instrument has apparently made it sensitive to long period motions that have heretofore escaped notice in teleseismic registration. There are several records reproduced in the paper, plainly showing waves having periods in the various cases between 53 and 220 seconds, ordinarily with an amplitude of from 0.3 to 0.6 mm. These long period waves may be thought to be a result of the very long period of the horizontal pendulum making the records. It is hard to believe that this is so, however, when the period of the waves is not the same as the period of the pendulum. Mr. Imamura, in fact, discards one well-marked wave which has a period about the same as the pendulum, suspecting that it may have been caused by instrumental resonance. He then turned his attention to the records of ordinary seismographs for the same earthquakes, and found in several cases that the ordinary instruments showed traces of these long waves when attention was called to them by the records of the special instrument. This would seem to make it certain that the long waves so recorded are not fictitious phenomena resulting from the peculiarities of the instrument itself, but are in fact representations of real earth movement. R.M.W.

THE UWEKAHUNA SEISMOGRAPH

When the Uwekahuna Observatory was built, provision was made for setting up an exhibition seismograph. A small alcove at one side of the main room contains a pier which is founded upon solid rock and which does not in any way touch the foundations of the building. This space has so far not been utilized as the seismograph has not been ready. This instrument is one of modern Japanese make that was ordered by Dr. Jaggar when he was in Japan with the Third Pan-Pacific Science Congress last October. Delivery has been slow as Dr. Jaggar requested the makers to substitute cardan hinge supports for the heavy masses in place of the cup and pivot supports used in the stock instruments of this type. The seismograph has arrived in Honolulu, and will be set up at Uwekahuna in the very near future. It will be run continuously, and its records will be filed at the Observatory. It is expected that a study of these records will yield interesting information as to the seismic conditions at that place, which is much nearer to the pit than is the present seismograph station. R.M.W.

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No. 142 RELEASED WITHOUT COPYRIGHT RESTRICTION September 15, 1927

KILAUEA REPORT No. 816

WEEK ENDING SEPTEMBER 14, 1927

Section of Volcanology, U. S. Geological Survey:

R. M. Wilson, Temporarily in Charge

The avalanching activity at Halemaumau has continued with increased vigor. Probably the largest avalanche was one that occurred at 9 a. m. September 9 from about the center of the wall just west of the Kau rift tunnels, leaving a scar several hundred square feet in area. The many tons of debris dislodged have partly buried the southwest cone. This section of the wall is usually quiet, and avalanching there may be considered significant inasmuch as it may mean that the northeast-southwest rift line was in motion.

Many new scars made by slides are to be seen all over the northeast, north, and northwest walls. Some very large slides have come from the northwest wall which, until recently, has been very quiet. A rather loud avalanche was reported to have occurred from the north wall about 9:30 p. m. September 12; also continuous small slides on that side. On the afternoon of the 13th several noisy slides from the north wall were seen from the Uwekahuna Observatory.

A circuit of the pit made on September 12 disclosed a few changes. An immense bowlder that hung under the northeast rim has fallen, and nearby is a slim pinnacle which appears ready to topple over. Dirt has been dislodged by the widening of a crack through the north-northeast fault cliff.

During the week ending September 14 there have been 19 very feeble local earthquakes recorded on the seismographs. Tilt has accumulated moderately to the NNE.

THE HILO SEISMOGRAPH STATION

The Hawaiian Volcano Observatory has for several years operated subordinate seismological stations on the Island of Hawaii. They have been found very useful in locating the epicenters of near earthquakes. The instruments at the Observatory usually give the distance to the origin of an earthquake, but only in exceptional instances can reliable direction be derived from the records. Thus the actual position is difficult to definitely determine from the records of a single station. But with other stations recording distances to the same shock, it is possible to quite accurately plot the position of the origin. The value of the data supplied by these outlying stations certainly warrants the making of any improvements possible in them.

About the first of this year a well equipped machine shop was added to the facilities of the Observatory. Among other things this has made possible the construction of better seismographs for these subordinate stations. A reasonably simple design was adopted for a two-component type, and already three sets have been made, and a fourth is partly constructed. The first of these three is the one installed by Professor Jaggar this summer in Kodiak, Alaska; the second is being held for a probable second station in Alaska; the third has just been installed in Hilo, Hawaii. One of these instruments was placed on exhibit at the recent Territorial Fair in Honolulu. In these instruments the heavy mass is a 27 inch long section of 8 inch iron pipe, with end plates welded top and bottom, and filled with sand, weighing approximately 225 pounds. The mass is slung as a horizontal pendulum by means of short piano-wire links at the top and bottom. These links on the base side are fastened into an upright bar which is in turn supported by a plate arranged to be bolted to the wall. The bar can be adjusted to secure the proper inclination of the support axis. The center of gravity of the upright heavy mass is out 8 inches in front of the axis of support. To the front of the heavy mass is bolted a tubular aluminum boom 41 inches long with wire guys to stiffen it, and with a fine pivot at the outer end. The recording mechanism consists of an aluminum drum about 11 inches in diameter and 12½ inches long, to carry smoked paper. The drum is rotated by an escapment clock, which gives the paper a speed of 30 mm. per minute. Both components of the seismograph record on the same drum. The writing point is a fine steel needle in jewelled bearings that rests upon the smoked paper with its own weight only, and is fastened to the long arm of a magnifying lever. The short arm of the lever is coupled to the pivot at the end of the heavy mass boom by a light aluminum bar with jewelled bearings. The pendulums will first be tried with a free period of seven seconds. The magnification is 160. Oil damping is employed to steady the heavy masses. These instruments are intended to be hung on the wall, so that the only pier necessary is the one to support the recording mechanism.

The single component instrument that has been in operation for six years at the Brothers' School in Hilo has been replaced by one of these two-component instruments just described. Brother Albert will continue in charge of this station. A completely new housing has been made in the back corner of the school grounds, far from the disturbances of street traffic and school activity. This new seismograph cellar is reinforced concrete of monolithic construtión, walls and roof being five inches thick. The inside dimensions are eight by nine feet, and the floor is about seven feet below the outside ground surface. The walls are set on solid rock, as is also the pier in the middle of the room which carries the recording mechanism. The building is turned so that its 9 foot length is in a northeast-southwest direction. A flight of narrow stairs, partly outside and partly inside, leads down through a low door into the cellar. The instruments are hung in the corners of the room; the east-west component pendulum in the south corner, and the north-south component in the west corner. The axes of the instruments are therefore at 45 degrees with the walls of the building. A ventilator is arranged to carry off the smoke from the smoking lamp. The temperature of the room seems to vary through a daily range of only about five degrees Fahrenheit. Notes as to the behavior of this new installation will appear in future issues of the Volcano Letter. R.M.W.

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No. 143 RELEASED WITHOUT COPYRIGHT RESTRICTION September 22, 1927

KILAUEA REPORT No. 817
WEEK ENDING SEPTEMBER 21, 1927
Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Numerous slides have occurred from nearly all sides of Halemaumau pit. Most of them have been from the north and northeast walls, though the northwest wall has also been very active. Crack measurements taken on September 17 showed that there has been a general increase in the width of all cracks on the east side and that the southeast ledge was fast separating from the main rim, having moved about eight inches in a week. The observer could see the dirt settling into the southeast crack and hear the rocks adjusting themselves to the movement. At 1:30 p. m. September 19 the ledge fell with a roar resembling an explosion, tearing away a great strip of the rim. A disturbance recorded by the seismographs about this time may have been caused by this avalanche. This and several other avalanches were seen and heard from the Uwekahuna Observatory.

The walls of the pit are very dark and reddish from the recent rains. Steaming is moderate at all vents.

There have been 28 very feeble local earthquakes recorded on the seismographs during the week ending September 21. One of these was an extended disturbance of small amplitude covering more than four minutes of time, which occurred at 5 p. m. on the 14th.

During the week no material tilt accumulated up to the 17th. On this day a definite spurt to the south-southeast began, lasting for two days, making the net accumulation for the week moderately south-southeast. On these same two days the records show the presence of an unusual amount of short-period tilting, causing the seismogram lines to crowd and overlap.

LOCAL SEISMIC PERIODICITY

A few weeks ago a rough analysis was made to determine whether the very feeble local earthquakes recorded at the Hawaiian Volcano Observatory inclined to a greater frequency at any particular time of day. The afternoon hours seemed to contain the greater percentages, as was stated in a previous issue of the Volcano Letter.

During the last ten months these feeble disturbances have seemed to come in waves of increasing and decreasing frequency, the time interval from crest to crest of increased frequency being about two weeks. So another preliminary analysis has been made to determine whether these recurring waves show real periodicity. It is a question whether the investigation should be based merely on the number of shocks, or whether intensity should also be considered. One heavy shock probably releases as much accumulated stress as would several smaller ones. No attempt has been made therefore, in this rough review, to make a quantitative computation of the energy displayed by the various disturbances. Instead, the crests of seismic activity have been selected merely by inspection of the records to find at what times activity is most apparent.

The short period of time covered by the inspection, and the crudeness of the method used in reducing the records, prohibit a definite and final statement of results. It seems apparent however, that there is a true periodicity present, and there seems to be a correlation with the phases of the moon, as would be expected if luni-solar gravitational attraction is considered as a factor. The maxima of this periodic local seismic activity seem to come when the moon is at first or last quarter, and the times of lesser activity when the moon is either new or full. July 7, 1927, when new lava came into the pit of Halemaumau, seems to be timed as one of these crests of activity. The evidence of periodicity seems more pronounced since the July eruption, and the last noted crest of seismic activity occurred about September 16.

R.M.W.

HORIZONTAL GROUND MOVEMENTS

An interesting development in the recent work of the Observatory is the detection of horizontal earth movements in the vicinity of Halemaumau. Marked points located in 1920 have been re-surveyed during the last year. Progress of the work has been mentioned from time to time in the Volcano Letter. Preliminary computations have just been completed, and comparison made between the 1920 and the 1926 results. It has become apparent that motions of considerable magnitude have taken place during this six-year interval of time. The points surrounding the pit have converged, agreeing with the general collapsing of the region around the pit that has already been detected by the re-running of spirit-level lines. The horizontal movements of the ground, within a zone of two miles radius about the pit, do not in all cases converge radially towards the center of the pit. This would be expected if the collapse were centralized at the pit. Instead the movements seem to indicate that the collapse was more probably along an elongated belt, perhaps determined by a fault line. The points within this zone show movements of from two to five feet. There are two points near the pit, less than a mile apart, that have approached each other, one moving three feet and the other five feet, so that the distance between them has become eight feet less than before. The line between these two points forms one side of a triangle that was used in the triangulation. In the triangle, the angle opposite this side has changed more than two minutes of arc. Since in both the 1920 and the 1926 surveys an accuracy represented by an average triangle closure of three seconds was attained, it is evident that real motion has taken place. This line is the one that joints the marked point at Uwekahuna and the one near Little Beggar, and the angle is that measured at the mark at the Observatory between these two points. If motion of the same sort continues, or if the movement reverses, it is evident that a re-measurement of the angle at the Observatory will detect it. If the approaching together of these two points represents a collapse of the area around Halemaumau, as seems to be the case, then variations in the angle spanning them should immediately indicate further collapse or recovery. In other words, fluctuations in this angle should be an important clue in detecting changes of volcanic phase in Halemaumau.

R.M.W.

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No. 144 RELEASED WITHOUT COPYRIGHT RESTRICTION September 29, 1927

KILAUEA REPORT No. 818

WEEK ENDING SEPTEMBER 28, 1927

Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Avalanching at Halemaumau has continued to be frequent. There has been so much sliding since the July lava activity that the new floor of the pit is now well overlapped with debris on all sides. The slides have occurred mostly from the northern walls, eating away the rim to such extent that the pit is constantly enlarging itself in the direction of Volcano House.

At 5:20 p. m. September 21 the prolonged roar of an avalanche was heard from the Observatory, but the weather was so foggy that no dust could be seen. The next day new scars were seen on the south, east, northeast, north, and northwest walls, and a coating of new debris lay on the north-northeast talus. A section of the east rim has collapsed. On September 24 more new debris was seen on the northern taluses.

On September 26 the pit was quiet and steaming was very slight. The character of the weather has a great deal to do with the amount of steaming. On September 28 a light rain was falling, and there was a considerable increase in the volume of steam escaping. The wet weather also has its effect on the colors of the walls, so that on this day there were very pleasing contrasts of deep red and light and dark gray colorings. A large scar near the top of the north wall may have been made at 1:10 p. m. September 26 when dust was observed. There were also fresh scars on the northeast wall.

Twelve local earthquakes have been recorded during the week ending September 28. These were all very feeble, excepting two which occurred at 3:03 p. m. and 4:11 p. m. on the 27th. The first of these was feeble, its origin apparently about 28 miles from the Observatory. The second was slight, its origin being about 14 miles away. There have been no reports yet received that these shocks were generally felt, though the latter was noticed by a few persons in Hilo. Microseisms were slightly stronger than usual on the 26th and 27th. Tilt has accumulated moderately to the NNE.

LASSEN REPORT No. 11

Mineral, California, September 7, 1927

R. H. Finch, Associate Volcanologist

A description of two lava flows from Cinder Cone, about 10 miles northeast of Lassen Peak, was made by J. S. Diller as far back as 1891. Diller stated that the youngest of the flows occurred in the 19th century something like 50 years previous to his writing. There are indications that there were at least three flows, and Diller's conjecture that the youngest occurred about 100 years ago is probably correct. The age of the oldest of the flows is not known, although it may be about 300 years. One of the older flows crossed a lake, making two new ones—Butte Lake and Snag Lake. The latter takes its name from the many snags still standing in the water, though snags are also found in Butte Lake. The bed of the old lake that shows in many places well above the level of the present lakes indicates that the ground in the vicinity of Cinder Cone was first upheaved and later sank. The weight of the lava flows, in places over 100 feet thick, might well be the cause of a sinking.

The last flow covers but little new ground, lying almost entirely on preceding flows. Both weathering and tree growth point to the fact that there were at least three flows and that the youngest might possibly have occurred within the memory of some people still living. A preliminary investigation by Mr. A. E. Jones, who worked as seismologist at Lasse Volcano Observatory during the summer of 1927, by means of the magnetic properties of the flows ("Telling the Age of Old Lava Flows," Volcano Letter No. 45, November 5, 1925), places the youngest flow about 1832, and the next youngest about 1795.

R. H. Finch

EARTHQUAKES AS CATASTROPHIES

A short review of the notable catastrophies that occurred in the world from September 1, 1924, to August 31, 1926, appears in "The World's Health" (Paris, July, 1927). M. Raoul Montandon, the editor-in-chief of "Materiaux Pour l'Etude des Calamites," in this review distributes according to time, and according to place, 551 disasters that have afflicted mankind in this two year period. In kind, they are represented as follows: Earthquakes, 66; volcanic eruptions, 4; avalanches and landslides, 9; floods, 197; cyclones, hurricanes, typhoons, 148; droughts, 23; tidal waves, 8; fires, 48; famines, 17; plagues of locusts, 31. Their distribution is given as: Africa, 35; North America, 75; Central America, 19; South America, 38; Asia, 97; Europe, 249; Oceania, 38. Summer is apparently the most hazardous season.

These figures are based upon reports published in the press, and Journalism is prone to inaccuracy in stating damage to life and property. It is therefore difficult to draw a fine line in selecting the happenings that are of sufficient magnitude to be classed as catastrophies. Yet in the case of the earthquakes, the figures above agree remarkably well with the statement of Montessus de Ballore that of the 30,000 earthquakes which may occur in a year, 31 will be to some extent destructive.

In dealing with a summation of calamities of such varied kind, it will be difficult to make correlations as to general cause, though it is suggested that solar activity and sun spot years may have something to do with some of them. There is of course one factor that must be considered in connection with all catastrophies; that is, the density of population. A tremendous earthquake, an extensive flood or a violent hurricane can only be counted as a catastrophy when man and the works of man are present to suffer destruction. This factor probably accounts for the large percentage of catastrophies that these figures give to Europe.

R.M.W.

Professor Jaggar has completed his season of volcanologic reconnaissance in Alaska. He made a short visit to the Lassen Volcano Observatory in California, and is now in Washington. It is probable that he will arrive in Honolulu on October 18.

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No. 145 RELEASED WITHOUT COPYRIGHT RESTRICTION October 6, 1927

KILAUEA REPORT No. 819

WEEK ENDING OCTOBER 5, 1927

Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Halemaumau pit has taken on a somewhat new phase in regard to the restlessness of the walls. The heavy avalanching so prevalent during the period of the equinox has practically ceased, and now there are only numerous small slides. These are rather continuous, often so small as to be barely perceptible. They seem to be occurring from nearly all sides of the pit, but are concentrated mostly southeast and northwest. The fine material thus deposited on the northwest talus has made a wide streak its full length. Slides at the top of the northeast talus have eaten a hole into the wall similar to that just above the northwest talus.

Few other changes have taken place in the pit. The white and yellow stains on the floor increase in the vicinity of the southwest cone. Steam escapes from the smaller cone in irregular puffs, and all vents are moderately active.

During the week ending October 5 the seismographs have recorded 22 very feeble local earthquakes. On September 30 there was a period of continuous harmonic tremor, beginning feebly at 9:30 p. m. and increasing in strength until about 10:40 p. m., when it began to fade out, disappearing from the records at 10:50 p. m. This type of disturbance is of especial interest, as in the past it has been closely associated with the presence of active lava. There are, however, no other symptoms of renewed activity. It is interesting to note that this spell of harmonic tremor, with the small group of very feeble spasmodic tremors that closely preceeded it, represents another crest of seismic activity that comes just two weeks after the last crest noted, confirming the idea of periodicity (see Volcano Letter No. 143, September 22, 1927).

The two earthquakes on September 7, mentioned in last week's Kilauea Report, were also well recorded on the seismographs in Kona and Hilo. The plotting of distances has shown that the second one originated not far from Ainapo, on the southeast slope of Mauna Loa.

Tilt for the week has accumulated very slightly to the east.

VOLCANOES AND SUBMARINE EARTHQUAKES

Disturbances of the surface of the ocean, attributed to volcanic or seismic causes, have been noted at various times. In the "Bulletin Volcanologique" (Italy, 1926, Nos. 9 and 10) is given a series of reports of such occurrences, and other instances are noted in the Seismological Report Supplement for 1924, published by the U. S. Coast and Geodetic Survey. These phenomena are observed and recorded by ship's officers or other persons aboard vessels at sea. Some of the descriptions are very meager, merely mentioning that shocks were felt, or that the surface of the ocean was disturbed. It seems doubtful that the vibrations of an earthquake, which are elastic vibrations in a solid body, could be propogated through sea water and reach a vessel as a perceptible shock or tremor unless the water were shallow or the disturbance great. It is easier to understand that a submarine eruption should disturb the surface of the sea, causing it to heave or seethe, and perhaps bring up sediment from the bottom. In two of these reports the heaving, seething and discoloring of the ocean's surface is described, but in neither one is the feeling of shock or tremor mentioned. Those reports mentioning perceptible shocks say nothing of the water surface, or say that nothing unusual was observed.

It is difficult, save in one or two doubtful cases, to correlate these disturbances with earthquakes as recorded upon seismographs at the time. A volcanic eruption might well be a slow outpouring of lava, producing convection currents with resulting disturbances at the surface, yet which would not send out seismic waves of sufficient intensity to be recorded at any great distance. On the other hand, a tectonic earthquake violent enough to be felt as a shock through any great depth of sea water should certainly send out seismic vibrations (along the earth's solid crust) over distances great enough to record on many of the world's seismographs.

When the ocean surface shows disturbances, as seething or sediment, water temperatures should yield interesting information. In the few cases here reviewed no such temperatures were recorded. R.M.W.

AN ELECTRICAL ACCELEROMETER

Juichi Obata (Proceedings of the Physico-Mathematical Society of Japan, May, 1927) describes an electrically recording accelerometer. Minute earth tremors can be detected with this instrument, as the magnification can be made great. A simple pendulum is held about 10 degrees out of vertical by a prop bearing against a thin metal diaphragm. Horizontal acceleration of the apparatus in the plane of the pendulum and prop will cause the prop to bear more or less heavily against the diaphragm which is used as one element of an electrical condenser. The second element is so placed that any variation of the pressure of the prop will vary the distance between the elements, and so vary the capacity of the condenser. The condenser is connected up electrically as part of an oscillating circuit containing an ordinary radio vacuum tube. Changes in the capacity of the condenser induce changes in the grid potential of the tube, thereby altering the plate current and causing a galvanometer to register.

The dispalcement of the diaphragm necessary to register on the galvanometer is so slight that relative motion within the apparatus may be neglected and the readings may therefore be regarded as representations of true acceleration. The sensitivity of the arrangement in this simple form is stated to be such that one millimeter galvanometer deflection is produced by an acceleration of 0.4 cm. per sec. per sec. Greater magnification may be secured by the use of additional tubes to amplify the electrical impulses issuing from the first tube, just as in a radio receiving circuit. R.M.W.

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No. 146 RELEASED WITHOUT COPYRIGHT RESTRICTION October 13, 1927

KILAUEA REPORT No. 820

WEEK ENDING OCTOBER 12, 1927

Section of Volcanology, U. S. Geological Survey:

R. M. Wilson, Temporarily in Charge

Conditions at the volcano are much the same as last week, with numerous small slides from the walls of Halemaumau pit and only an occasional avalanche. These slides are mostly from the northwest side, where they can be heard nearly continuously, and much fine material lies at the foot of all the walls.

Yellow stains are quite pronounced on the smallest of the cones active on July 7, and in spots on the south and east taluses. A bright yellow area of sulphur crystals lies at the foot of the south talus. Higher up this talus is streaked with wet steaming places.

There were 23 very feeble local earthquakes recorded on the seismographs during the week ending October 12. One of these, at 10:25 a. m. October 5, was recorded just at the time of a large avalanche in the pit, and is probably a record of the vibrations caused by the falling rocks. Microseismic motion has been normal. Moderate tilt towards the NNW has accumulated during the week.

ISOSTASY AND GRAVITY

If the earth were so simply constructed as to have no irregularities of surface or composition; if it were a perfect mathematical body, then many present scientific problems would not be crying for solution. It might then be a true spheroid of revolution, all its surface at a single elevation, and, at any particular point on its surface, its radius, its curvature, the value of gravity, would all be easily computed by simple formulae dependent upon latitude. Such is not the earth upon which we live. Science does use, however, as a basis for many calculations, an imaginary mathematical spheroid, chosen of such dimensions that it represents as nearly as possible our actual earth in shape.

Mean sea level represents the nearest natural approximation to the spheroid. Imagine perfectly calm oceans, and think of their surfaces as continued even under the land areas at the same natural level that the water would assume if it had free passage there. This smooth and continuous sheet of water surface would be the geoid, and is the surface of zero elevation. The geoid is the slightly irregular figure of which the spheroid is the idealized mean. At all points on the geoid the plumb line hangs exactly perpendicular to its surface. The plumb line is deflected from the true vertical by certain local conditions. Thus at one side of a high mountain range, a plumb bob would be subject to greater horizontal components of gravitational attraction toward the high country than toward the lower country on the other side. This implies that the geoid surface would slope up toward the high country, relative to the spheroid. In general the geoid surface would thus be above the spheroid for land areas, and would be below the spheroid for ocean areas. Dr. William Bowie gives the result of a computation along 700 miles of a parallel of latitude, one end over land and the other over water, taking account of land elevation, ocean depth, and isostasy. It appears in this particular case that the geoid should be some 60 feet below the spheroid at the water end of the line, and 15 feet above at the land end.

Isostasy, briefly, tells us that in general the earth's crust considered for a thickness of some 60 miles, is of the same weight per surface area, everywhere. While high elevations like mountain regions imply thicker crust, the thickness is compensated by lesser density. It is thought that this crust rests upon a layer in the earth's structure that is, through heat and the tremendous pressure upon it, maintained in a state of high viscosity. This layer must be elastic, as it transmits earthquake waves, but because of its viscosity it slowly flows as a very thick fluid under the great pressures put upon it. If a mountain range could be lifted from one place, and set down in another, it would press down the crust of the earth under its new position, forcing out from underneath some of this viscous layer, which would flow beneath the area relieved of the mountain's weight, lifting this place and again restoring balance. Mountain ranges are not moved outright, yet through long ages great amounts of material are shifted from place to place on the earth's surface through stream erosion and deposition. This accommodation of the crust and its supporting layer to such shifts of weight is called isostatic compensation. The crust, being brittle, yields by successive fractures to these deforming forces, causing earthquakes.

On a perfect earth, such as that suggested above, the value of gravity would be easy to compute for any chosen point, once fundamental values were determined. Observed values would agree with computed values everywhere. Such simplicity is not attainable on the real earth. Thus when a value of gravity is observed (see Volcano Letter No. 106, January 6, 1927), there must be many corrections applied; for the elevation of the station, for local topography, for general irregularities of the earth's surface distant even to the antipodes, and for crustal density as suggested by isostasy. An observed value, so corrected for all known variations of the real earth from the perfect one, should agree with a value computed for the corresponding point on the perfect earth. A discrepancy represents, probably, the omission of some unknown factor in applying the corrections to the observed value. Such discrepancies are called the anomalies of gravity. Dr. Bowie indicates that the correction for the elevation of a gravity station should not be the elevation above mean sea level, or the geoid, but should be taken as the elevation above the true spheroid (see American Journal of Science, September, 1927). The corrections show isostasy and gravity to be in harmony.

A very real usefulness of gravity observations comes through the study of these anomalies. For, if a corrected observation gives a value too great, so that the anomaly is positive, it is an indication of a geologic formation of unusually great density not far beneath the surface, or of unusually small density if the anomaly is negative. In Japan, earthquake regions are so investigated to search for hidden faults and dykes, or to detect shifts or intrusions of magma beneath a volcano. R.M.W.

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No. 147 RELEASED WITHOUT COPYRIGHT RESTRICTION October 20, 1927

KILAUEA REPORT No. 821

WEEK ENDING OCTOBER 19, 1927
Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

Recent visits to Halemaumau show the pit to be quiet. Slides are not so numerous as last week, and steaming changes little. At 10:20 a. m. October 17 there was a small slide at the north corner which made dust, and about 3:30 p. m. October 19, slides occurred at the south corner making a bright red scar visible from the Uwekahuna Observatory. There is fresh yellow sulphur at the base of the southeast talus.

Crack measurements along the east rim of the pit show little movement, but on October 19 small new cracks were seen in the dirt back of the south station.

The seismographs have recorded 18 very feeble local earthquakes during the week ending October 19. A perceptible shock occurred in Kona, local to that place, at 6:01 p. m. on October 16. Tilt has accumulated slightly to the NNW.

ERUPTION OF MAGEIK IN ALASKA

The Seattle "News-Tribune" carries an Associated Press dispatch of the date September 30 stating that Mageik Volcano of the Katmai group erupted explosively "late in August" (1927). The authority quoted is Captain Harry W. Crosby, President of the Crosby Fisheries, who spent the summer aboard his schooner-cannery "Salmon King" in the northeast arm of Uganik Bay on the northwest side of Kodiak Island. Mageik and Martin were two volcanoes seen by Dr. Jaggar to be steaming, looking northwest from Shelikof Strait on May 18, 1927. Both took part in the great Katmai eruptions of 1912. Mageik is forty nautical miles from the middle of Shelikof Strait, and sixty miles from the Crosby anchorage in Uganik Bay.

Thousands of tons of pumice stone and ashes were reported by Crosby as showered over an area 50 miles square. The article quotes him:

"We were about 50 miles off the Alaskan Peninsula in clear weather, when suddenly we noticed a gigantic puff at the top of Mageik. Soon the air was filled with volcano ash, and it began to rain pumice stone. After the explosion, the volcano smoked like a factory chimney. A short distance from the ship we found large quantities of pumice stone, some pieces as big as your first, floating on the ocean.

"We scooped up a bushel or more of the stones and brought them to Seattle. For five days the eruption continued, and the mountain was still smoking when we left for Seattle.

"Each morning while we were off the Alaskan Peninsula, the decks and rigging of the ship would be covered with the fine powdered volcanic ash, some of it so white that it resembled snow. The first duty of the crew in the mornings would be to sweep the decks clear and to dust off the rigging.

"The eruption followed a period of unusual weather, a great calm with scarcely a breath of air, and a depressing atmosphere. The air was full of white volcanic ash for a week, and thousands of tons of pumice stone fell around us."

No dates or ship's positions appear in this article, but apparently the vessel did not sail until five days after the major explosion. Captain Crosby is a reliable commercial man, navigator and fisherman of many years' experience in Alaskan waters. T.A.J.

ALEUTIAN VOLCANOLOGY

The foregoing account illustrates how much is needed a reliable scientific station for collecting and verifying reports of activity from the forty-five potentially eruptible volcanoes of the Aleutian volcano chain, extending from Mount Spurr to Buldir. When Dr. Jaggar was at Naknek May 24, 1927, the teacher there, who had been to the Valley of Ten Thousand Smokes, reported that a trapper in January, 1927, had seen an ash eruption from one of the Katmai hills, and that two trappers were missing who had gone into that region. This is in the same district as Mageik.

Here, then, are two accounts, both incomplete as to hours and dates and places, suggesting that ash and pumice eruptions are being renewed in January and August, 1927, for the Katmai volcanic system.

Bogoslof was found in lava eruptivity when Dr. Jaggar on the "Unalga" visited and made landing on the islet July 6, 1927. This was in the technical sense that a pile of steaming hot lava was slowly heaving itself from the submerged crater above the sea-water. The salt lagoon surrounding the lava heap was warm. Fresh bombs and bomb-pits lay about. The records of mariners for a year past told of explosions in July, August, September, and November, 1926, at Bogoslof.

After this visit came a telegram from Captain Cochrane, commander of the Bering Sea Patrol, dated July 27, saying, "One of Akutan whalers reports Bogoslof active on July 26." The word "active" here certainly means another explosion. Where was the whaler; how far away; what direction was the wind; what was the hour; what happened? Such are the details needed by science.

Now we get Mageik exploding a month later. Fortunately a small sidelight is thrown on this volcanic action of the Katmai group by the new seismograph at Kodiak village. While it was being installed, July 30, at 7:10 a. m. Kodiak Time (ten hours slower than Greenwich), a local earthquake was sharply felt. At 5:52 a. m. August 11 a slight east-west swaying shock was felt and was registered by the seismograph so as to indicate an origin distance of 35 nautical miles; duration of registered motion three and one-half minutes.

Coinciding with "late August" of the reported Mageik eruption, the Kodiak seismogram of 7:18 a. m. August 28 exhibits a feeble local earthquake with preliminary phase indicating a distance of 30 nautical miles; duration of motion about one minute.

Summing up, we have (1) Bogoslof piling lava July 6 and exploding July 26: (2) Earthquakes at Kodiak originating 30 to 40 miles away at intervals of 12 and 16 days after July 30: (3) Explosion of Mageik the end of August and first days of September. Kodiak is 93 nautical miles from Mageik and about 35 miles from Shelikof Strait, where there is probably a northeast-southwest fault. T.A.J.

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No. 148 RELEASED WITHOUT COPYRIGHT RESTRICTION October 27, 1927

KILAUEA REPORT No. 822

WEEK ENDING OCTOBER 26, 1927

Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

There are evidences in the Halemaumau walls of slides west and northwest during the past week, and some dust has been seen rising once or twice. In general, however, the pit has been very dry, quiet and free from steam.

During the week ending October 26 there were 20 local earthquakes recorded, and one teleseism. All the local shocks were very feeble, with the exception of one which was feeble, yet perhaps of sufficient strength to have been felt, though no reports have been heard of it. This one took place at 6:20 a. m. October 24, possibly through trigger action, superimposed upon the diminishing waves of the teleseism.

Tilt has accumulated moderately to the ENE during the week.

RECORD OF ALASKAN EARTHQUAKE

The preliminary phase of the distant earthquake recorded at the Kilauea Observatory has a feebly registered beginning at 5 h., 37 m., 48 s. a. m. October 24, and confusion at the beginning suggests that there were two individual shocks at the origin, separted by a few minutes of time. The distance to the origin, doubtfully indicated, is 2,800 miles, and the time of the shock at that place approximately 5 h., 30 m. a. m. A report from Petersburg, Alaska, states that an earthquake occurred there at 6:51 a. m., which appears to check closely with the computed time and distance above, and broke windows at that place.

The long wave phase here was large, lasting more than an hour and a half. The records indicated a heavy shock, which if under the ocean would have caused a tidal wave. Warning was therefore issued, but no tidal wave occurred, as the epicenter was not under the ocean.

This earthquake was well recorded on the newly established seismograph in Hilo, and also on the instrument on the other side of the island in Kona. These three instruments agree in showing a waxing and waning in amplitude of the long wave phase, periodic in nature, approximately two and a half minutes in cycle; the effect persisting through several cycles. This perhaps has meaning if the shock was a double one, as it suggests interference between two wave trains of slightly differing periods, starting from the two separate shocks. R.M.W.

THE ULTRA-BASIC MAGMAS

A generalization of far-reaching importance to volcanology is made by N. L. Bowen (American Journal of Science, August, 1927) to the effect that the porphyritic crystals in a basaltic lava, calcic feldspar and olivine, are virtually foreign to the liquid magma in which they occur, considered as a liquid melt. That is to say, all approach to ultra-basic chemical composition in porphyritic lavas, glassy rocks and fine grained dyke or sill rocks, resides in the effect of these phenocrysts on the analysis. The lavas of glass or fine-grained uniform crystalline material without phenocrysts, equivalent to the groundmass of the porphyries, never "remotely approach ultra-basic compositions."

The larger or more crowded the phenocrysts the more the approach to such extreme rocks as peridotites or anorthosites. When the crowding reaches the stage of a completely crystalline gabbro extremes of basicity may be attained never approached by effusives. Here the porphyritic and gabbroid rocks of Mull, for instance (see Volcano Letter No. 7, February 12, 1925), show feldspar phenocrysts four-fifths anorthite feldspar. Normal basaltic feldspar is only fifty per cent anorthite. Likewise normal basaltic olivine reaches only ten per cent of the rock. When an extreme type from Juan Fernandez analyzes 53 per cent normative olivine, it proves to be crowded with great porphyritic crystals of olivine, in a matrix of plagioclase and augite.

Bowen concludes that "the process of accumulation of crystals is not supplemented by significant re-solution of the accumulated crystals." He believes that ultra-basic liquids do not exist, corresponding in composition with the coarse granular or porphyritic rocks. Liquidity ceased with the crystallizing out of the porphyritic or coarse granular basic plagioclase and olivine. These represent chemical excesses incompatible with flowing liquids. "As the amount of accumulated crystals increases the mass becomes less capable of being poured out as a lava and to some extent of forming minor intrusives, and the extreme types occur only as a major intrusion." Only some pocket or part of a major intrusion can be the locus of accumulation of basic plagioclase crystals or olivine crystals.

Speaking of the feldspar, the following is Bowen's conception of how crystal accumulation starts and how it feeds the flow of porphyries. A rock that is "always porphyritic in its finer crystallizations" has no liquids corresponding to it in bulk composition. No matter how rapidly chilled and solidified, some of the feldspar remains as porphyritic crystals. These never were in solution in the matrix liquid that forms the groundmass. They were once in solution in some large mass of liquid of another composition, where they crystallized out and accumulated, presumably by a movement of crystals under the action of gravity either upward or downward. "No doubt other crystals were separating at the same time, but their motion differed either in magnitude or in direction."

"If the mass thus enriched in accumulated crystals is injected into surrounding rocks, or is poured out," it gives a basalt with porphyritic crystals. "If on the other hand it cools where it had its origin, or is moved elsewhere as a large mass, the continued outgrowth of crystal boundaries gives a gabbro" with porphyritic tendency lost or obscured.

The meaning of this for Hawaiian lava flows which show large porphyritic white feldspar crystals or green olivines, is that these minerals are lifted in a current of normal basaltic liquid from a region of partial crystallization deep underground. And that when the Kilauea lava lakes or the Mauna Loa fountains are fluid and splashing, if we could strain the molten glass through a metal screen, we would capture these crystals completely formed and probably not forming at all at the moment of capture. Both Kilauea and Vesuvius show included large lumps of granular crystalline olivine. These must be pieces of completed segregations of the excess basic matter of the deep major intrusion. All of this entirely agrees with the presence of crystalline olivine gabbro and porphyry so abundantly shown at the bottom of Halemaumau after the collapse of 1924. T.A.J.

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No. 149 RELEASED WITHOUT COPYRIGHT RESTRICTION November 3, 1927

KILAUEA REPORT No. 823

WEEK ENDING NOVEMBER 2, 1927
Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

Changes in Halemaumau have been slight. On October 29 in the early afternoon the pit was dry and sunny, and the rain of the previous night had not increased the visible steam. There were slight steam jets in the upper parts of the northern, western, and southern talus slopes. The north floor cone steamed a little and showed increase of yellow stain. The middle cone showed only once a slight vaporing. Some feeble rock sliding was heard towards the north. On October 31 dust from numerous northern avalanches was observed at the pit morning and afternoon. In rainy weather, which brings out the rock colors, at 2 p. m. November 2, the pit wall was very brilliant with red oxides in contrast to the blue black of the new lava floor. The central and northern cones were giving off vapor, and the vapor on the debris slopes was condensing. Some sliding was heard at the southwest. The walls show more iron oxide color at the bottom than at the top, and more of this red dust on the lower western wall than on the eastern.

The number of earthquakes registered on the seismographs at the Observatory during the week ending November 2, is 9. Seven of these were very feeble. One which occurred at 2:38 a. m. October 28 was recorded as feeble here, but was stronger in Kona, being felt there as an 8-second tremble with a rumbling noise. It was recorded on the Kealakekua seismograph, and also on the Hilo instruments, the combined records showing that the origin of the shock was about four miles east of Kailua, Kona, on the southwest slope of Hualalai. Another earthquake was 19 miles from the Observatory. Tilt during the week has accumulated slightly towards the SW.

CRATERS MADE BY METEORITES

A remarkable report from Russia ("Science" Oct. 14, 1927, p. 352) states that the Soviet Academy of Sciences "has discovered the resting place of a large meteorite, estimated to weigh nearly half a million tons, which fell in a remote district of Yenesei Province, Siberia, in the summer of 1908. The site of the fall occupies over a mile in diameter in almost inaccessible terrain in a marshy forest. The meteorite fell in pieces, so that the ground is pitted with deep funnels from 50 to 100 feet in diameter. The forest for over fifteen miles around the place was completely leveled and the fallen tree trunks scorched. The fall, nineteen years ago, was registered on the seismographs at Irkutsk, 900 miles away, and in the towns of Kirensk and Ilimsk, about 250 miles distant. T.A.J.

SILENT ZONES AROUND EXPLOSIONS

It has been known for many years that great volcanic eruptions are sometimes heard several hundred miles away, when at places near at hand almost nothing is heard. Dr. Omori mapped these phenomena as recorded at various distances from Asama Volcano, and discovered that there are zones of audibility and zones of silence at different distances. Experiments are now to be made in England by firing big guns and broadcasting the sound by radio ("Science" July 15, 1927, p. xiv). People at all distances who are equipped with radio receiving sets may hear the guns by radio and then several minutes later hear the actual sounds as they arrive through the air. Dr. Whipple, of the Kew Observatory, reports that at a place 80 miles from the guns he has heard the sounds about 11 minutes after the firing. He says that it is agreed that such long-range sound records are produced by a layer of the atmosphere some 25 miles or more above the earth's surface, where the temperature is relatively high, and the sound waves are refracted down to earth again. The so-called Heaviside layer is known to reflect radio waves from the upper atmosphere, and this sound effect may depend on something similar. Through such a layer a sound inaudible 20 miles away might by reflection and refraction be heard at a distance of a hundred miles. During the Pelee eruptions in Martinique of 1902, it was positively proved that explosions from the volcano unheard at Fort de France, 12 miles away, were heard at Barbadoes, 150 miles away directly to windward.

T.A.J.

A VIBRATION MICROPHONE

"Science" reports (July 15, 1927, p. xiv) that the Type H inertia microphone of the Bell Telephone Research Laboratories has been modified so as to record selectively minute vibrations of the walls of a safe, while refusing to pick up sound waves or such noises as are made by a heavy truck rumbling by the building. It is said that when this instrument is placed in a bank vault, it is unaffected by subway trains rumbling by, but is instantly affected by anything which touches the safe itself, however slight. The instrument is said to be small and compact, several may be placed at strategic points liable to burglarious contacts, and the slightest local disturbance summons the police.

It may be inquired whether this instrument would not be of great value in local seismometry so as to transmit, say from small drilled wells in the rock, the times of first vibration of earthquake at different places to a central station. T.A.J.

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No. 150 RELEASED WITHOUT COPYRIGHT RESTRICTION November 10, 1927

KILAUEA REPORT No. 824

WEEK ENDING NOVEMBER 9, 1927

Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

There has been little in the behavior of Halemaumau pit to justify the excessive spasmodic trembling of the seismographs. On November 5 in clear, dry weather, the pit was quiet with only small patches of visible vapor Slight sulphur stain has developed at a wet steam vent 200 feet up the south talus. In the afternoon there were slight slippings of debris at the south and north walls. On the 7th at 1:15 p. m. a considerable avalanche fell at the northeast. At the same place another sent up dust about 8:30 a. m. the 8th, the dust hanging over the pit for a quarter hour. Today, the 9th, there is new debris on the NE, N and SSW slides, and some dust has arisen at the north.

During the week the Observatory seismographs have recorded 68 very feeble local earthquakes, and one moderate distant earthquake. The number of local shocks is a definite increase over the general average for the past months. The numbers increased during the first days of the week, reaching a climax in frequency on the afternoon and early evening of November 5, this swarm then coming to a surprisingly abrupt halt at 9:40 p. m. On the 6th there was none recorded. The 7th and 8th together produced but six shocks, suggesting a return to the same general average as before.

The teleseism occurred in the early morning of November 4. The preliminary was recorded at 3:28 a. m., the ensuing phases suggesting a distance of 2,400 miles. The other instruments on this island, at Hilo and Kealakekua, also have good records of the shock. Before news of the earthquake was issued, a report came from Hilo that at 9 a. m. there was observed at the end of the breakwater a slight unusual rise and fall of water level. This may perhaps have been a small tidal wave resulting from the shock, though the tide gauge records have not yet been inspected. Press reports indicate that the shock was strongly felt in California, and that trains were delayed for an hour or so north of Santa Barbara.

Tilt during the week has accumulated very slightly to the south.

ISOSTASY, EARTHQUAKES AND VOLCANOES

Referring to Omori's view that earthquake centers are not deeper than 27 kilometers below the surface of the earth, William Bowie writes (Isostasy in Geophysics and Geology, Journal of the Washington Academy of Sciences, March 4, 1927):

"The four major causes of earthquakes would seem to be (1) the breaking of crustal material caused by the weight of sediments, (2) the breaking of rock as the crustal material is pushed up under the area of erosion to restore the isostatic balance, (3) the breaking of the rocks as the result of the expansion of the crustal material under an area which had previously undergone heavy sedimentation, and (4) the breaking of rock caused by the contraction of crustal material under an area which had previously undergone erosion during an extended time.

"According to the Pratt theory of isostasy, the overflow of lava from a fissure or from a volcano is probably caused by an expansion of the crustal material below. No extra mass has been added to the prism of the crust involved. It is merely a case of fluid material from some depth within the crust being raised to the surface, increasing the volume of the prism and decreasing the density. Whatever processes cause the uplift of a mountain system undoubtedly cause the volcano and the lava overflow.

"It would seem that the earth is gradually losing heat as the result of erosion and sedimentation. As the eroded material is carried away, the prism of the crust beneath is forced up to restore the equilibrium. Erosion may have occurred to the extent of five or ten miles before an uplifted area is baseleveled. In such a case every element of the crust beneath would have been raised to a position approximately equal to that distance and would have been brought to a region having a much lower temperature than that of the region from which it came. Eventually there would be a loss of heat at the surface, and the material of the prism would be cooled down by 100° to 300° C., depending on how far the crustal material had been pushed up. That heat lost would not be compensated by heat gained in other places. The areas of heavy erosion later become synclinoria into which sediments are deposited. The sediments accentuate the synclinoria, resulting in a pushing down of crustal material into hotter regions. Eventually this material takes on the temperature of its new position, expands to form mountain systems or plateaus, and again loses heat at the surface. What maintains the heat of the earth no one knows. There have been many theories, including the one now advocated by many, that the disintegration of radioactive materials replaces heat in sufficient amounts to cause the surface of the earth to remain at a practically constant temperature. Be this as it may, we cannot escape the conclusion that the raising up of crustal material under areas of erosion brings hotter material to the surface with a consequent loss of heat.

"It is rather difficult to see how a volcano could come into being out in the middle of an ocean, but, in general, volcanoes are merely a part of a region that is higher than the surrounding bottoms of the ocean. The Hawaiian Islands, for instance, occupy a long stretch extending for some 1,200 kilometers, while the average width of the pedestal on which the islands rest is of the order of magnitude of 140 kilometers. There must have been light crustal material where the islands now are at the beginning of the sedimentary age, and the uplifts and subsidences of the Hawaiian area have been the result of erosion, sedimentation, and to a certain extent of the accumulation of rock from coral growth. It is very difficult to explain a chain of islands out in an ocean without assuming under it crustal material which has been lighter than normal density from the beginning of the sedimentary age."

The recent determinations of gravity on the Island of Hawaii by Major Bowie's associates have shown positive anomalies or excess densities everywhere on the island, anomalies growing greater at the summit of Kilauea than at shoreline, and still greater at the summits of Mauna Kea and Mauna Loa. Dr. Bowie points out that there is an outstanding average positive anomaly over the sea bottoms as shown by reductions of Dr. Meinesz's pendulum work in a submarine. The Island of Hawaii, then, shows gravity conditions similar to those of the great ocean bottoms. This does not quite agree with the above assumption of "crustal material lighter than normal density." It may be, however, that the Hawaiian ridge began with the piling up of light siliceous lavas, and is now subsiding with heavy gabbros crystallizing in its core.

T.A.J.

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No. 151 RELEASED WITHOUT COPYRIGHT RESTRICTION November 17, 1927

KILAUEA REPORT No. 825

WEEK ENDING NOVEMBER 16, 1927

Section of Volcanology, U. S. Geological Survey:

T. A. Jaggar, Volcanologist in Charge

The "blue black" of the new lava floor of Halemaumau, described on November 2, was obliterated under tan-colored dust about November 10. In the night between November 10 and 11 numerous earthquakes were registered, and at 2:40 p. m. of the last date rocks were sliding from the south wall, which was streaked with dust, and the lava floor of the pit was thickly coated with it, especially at the south. The northeast corner showed a new scar. A crack had widened at the east rim. At 2:50 a somewhat continuous slipping of stones occurred at the south, at 3:10 bowlders tumbled the full length of the south talus, and 10 minutes later there was more active sliding of fine and coarse material at the south. Much gray dust arose. The middle and north cone vents were steaming, and the southwest cone steamed in puffs.

At 11 a. m. November 13 the pit was quiet, but the floor dust was very thick under the southwest rift tunnels. A few stones were in motion at the south. The sulphur patches east were still yellow and not dust-covered. At 9:40 p. m. a noisy avalanche was heard, followed by a smaller one.

Today, the 16th, there was a little sliding south and northwest, but the conspicuous feature was the cracking of rim ground for fifty feet back at the south, with hanging edge blocks and freshly broken soil.

Evidences of increased local seismic activity continue. There have been 62 local earthquakes recorded during the week ending November 16, and one feeble teleseism. The local earthquakes were all very feeble with the exception of the one which was felt in Hilo at 6:10 a. m. on the 11th. This one was slight in Hilo, and even weaker at the volcano, being barely above the very feeble class at the latter place. It appears to have originated beneath the east flank of Mauna Loa. The shocks included in the above count show character in that they tend to come in swarms, and many are of the small spasmodic tremor type. One such swarm, five tremors within ten minutes, culminated in the earthquake just described. Another more marked swarm, between 1 a. m. and 1:50 a. m. November 16, includes 21 separate very- feeble earth quakes. The distant earthquake is too feebly recorded to indicate the epicentral distance; the preliminary phase apparently began at 10:07 p. m. on the 24th. Microseismic motion increased in strength during the 15th, and was still strong on the morning of the 16th. Tilt during the week has accumulated moderately to the northeast.

FALCON ISLAND

Press reports in England describe new heaping-up of the volcano Falcon Island in the Tonga group, about 30 kilometers north of Honga Hapai. The British warship "Laburnam" on October 8 describes the volcano erupting every 20 minutes, and forming an island 1,730 yards long N-S and 1,430 yards E-W. The crater is said to be 305 feet above sea level. The eruptions each last about one minute and consist of "columns of steam and lava." The sides have a gradual slope.

Falcon is like Bogoslof in its record of rising and being washed away repeatedly. It was a shoal in 1867, smoking 10 years later, erupting 11-13 October, 1885 along a northeast line two miles long, with great ejections of cinder and ash. The island formed was 150 to 300 feet high and over two miles long. In 1889 it had a cliff 150 feet high, in 1892 it was only 27 feet high, and in 1894 it was a mile and one-half long 20 to 50 feet high, and very hot in places, with a lake in the center four to five feet deep. In 1898 and 1900 it was only a shoal, and it was reported to have disappeared in 1913 (J. A. Thomson, N. Z. Journ. Sci. & Tech., Dec. 1926). T.A.J.

VIENNA EARTHQUAKE

The press reports a strong shock in Vienna at 8:49 p. m. October 8, upsetting old houses, stopping clocks, breaking chimneys, cutting off telephone and telegraph communication, stopping tramways, and starting panic in the theaters. An oil fire was started in a suburb. Village houses were damaged in lower Austria, and the people camped in the open.

An earthquake in a large city like Vienna always leads to thoughts of New York, and the following is of interest in this connection ("Gas Logic," published by the Consolidated Gas Company, New York, October, 1927, page 13):

"The nearest Manhattan ever came to the source of an earthquake was the tremor which shook Long Branch, New Jersey, on June 1, 1927. But it was the Charleston, South Carolina, quake of 1886 that destroyed New York's equilibrium. The upper west side of the Island was greatly affected ,especially in Harlem, where entire blocks of buildings shook to such an extent that mortar dropped from the brick walls, furniture rocked, and pictures fell from the walls." T.A.J.

THE ALASKA EARTHQUAKE OF OCTOBER 24, 1927

Seattle newspapers report that this earthquake was severe in Juneau and Sitka, with north and south movement at Juneau lasting 30 seconds and followed by three lesser shocks. Sitka reports two heavy shocks at 6:59 a. m. and five minutes later, respectively. The Sitka seismograph pens were flung to the southeast. Windows were broken at Petersburg. Telegraph cables were broken near Wrangell and between Juneau and Skagway. The epicenter is located on land in the basin of the Alsek River, about 100 kilometers east of Yakutat (Jesuit Seismological Association, Preliminary Bulletins). The various northwestern American seismographs were dismantled, and seismometrically the earthquake was very big. The two shocks check with interference phenomena shown by our record at Kilauea (Volcano Letter No. 148). Apparently heavy fault movements occurred from the Fairweather Range southeastward, and our expectation of a tidal wave would have been abundantly verified if the disturbance had been under the ocean a few miles to the west. T.A.J.

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No. 152 RELEASED WITHOUT COPYRIGHT RESTRICTION November 24, 1927

KILAUEA REPORT No. 826

WEEK ENDING NOVEMBER 23, 1927
Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

Halemaumau remains dormant and the spell of excessive seismicity has waned, probably following the fortnightly law (see Volcano Letter No. 143, September 22, 1927). Some noise has been heard and avalanche dust has been seen over the pit, but mostly it has been quiet.

On November 19 at 4:15 p. m. rocks were heard falling once or twice at the north, and fresh brown debris lay on the northeast talus. Recent rains had washed into puddles some of the floor dust which had discolored the lava. Much dust was seen blowing away in clouds at this time, for several days, at the west rim of Kilauea Crater, owing to strong northeast wind.

Today, the 23rd, a little steam is rising at the hole in the middle floor cone, and the northeast talus has fresh dark red fragments from a wall scar of the same color above. It is noteworthy that the cracks of 1924 at the road terminus now steam hardly at all.

The seismographs at the Observatory have recorded 33 very feeble local earthquakes and one teleseism during the week. On the 17th, at 5:02 a. m., and again at 5:50 a. m., there occurred prolonged tremors, lasting about 5 minutes in each case. At 3:55 p. m. on the 18th, and at 12:11 p. m. on the 19th, there were other similar tremors of several minutes duration. These seem to suggest disturbances due to avalanches rather than harmonic tremor. The distant earthquake was very feebly recorded, its long wave phase beginning at about 8:45 p. m. November 18. No estimation as to distance could be made. Microseismic motion was strong on the 16th and 17th, but diminished to normal amplitude during the following days. Tilt has accumulated moderately to the NNE during the week.

GASES OF MT. PELE'E IN MARTINIQUE

Thorough chemical analysis of five specimens (Gases of the Mt. Pele'e Lavas of 1902, by E. S. Shepherd and H. E. Merwin. Journal of Geology, February-March 1927) representing the old and new lava of Mt. Pele'e for the great eruption of 1902, which destroyed St. Pierre, reveals remarkable uniformity of siliceous hypersthene andesite, with free silica in the form of tridymite in the groundmass. The analyses show almost no change of composition as between the old peak and the fresh lava of 1902. The glassy forms of the rock contain more gas than the crystalline ones. Silica averages 63 per cent, and the normative quartz 21 per cent. It was found that the determination of water from rock powder gave excessive values as compared with melting chips in vacuo. The powder takes up water.

The total volatile constituents amount usually to from 5 to 7 Cc. per Gm. of rock, one exceptional glassy shell of a bread-crust bomb giving 26 Cc. per Gm. Water vapor averages about 80 per cent of the total gas volume at 1,200° C., and carbon dioxide 9 per cent. Chlorine is 0.6 per cent, fluorine 2 per cent by volume, large because of its small atomic weight, though amounting to only 0.005 per cent of the weight of the rock. Sulphur and carbon monoxide are about 1 per cent each, and hydrogen about 0.3 per cent. Hydrogen is notably more abundant in the glassy specimens. Water is at a maximum in the glassy shell of the bomb (96 per cent). At 1,000° C. each cubic meter of issuing lava has 50 cubic meters of gas, or a minimum partial pressure of 50 atmospheres. Even the pumice contains nearly 7 Cc. of gas to the Gm., showing that it had not yet parted with all its volatile constituents.

The excessive gas in the shell of the bread-crust bomb reverses Lacroix's explanation for the cracked crust. He thought the shell cooled suddenly, expelled its gases, and so produced shrinkage cracks. Shepherd and Merwin explain the bread-crust as having cooled before vesiculation gets under way, so as to imprison the gases. The more slowly cooling interior allows vesicles to go on forming with a swelling which cracks the shell. This gas evolution in large blocks may continue for days and reduce them to piles of detritus. Crystallization throughout the mass may liberate heat and so maintain the vesiculation temperature. Such a rock would be instable if suddenly erupted into a region of low pressure.

"The conditions under which bread-crusting can occur are very limited. Possibly a temperature change of 100° or less determines whether a bomb shall develop a bread-crust surface, or completely expand to pumice."

The fluid mobility of a glass is much greater when it contains gases, and gas-charged glass will flow at about 900° C, whereas the hardened threads left after frothing require 1,250° C. to melt them.

"It will be noted that the relationships between temperature, viscosity, volatile content, and gas pressure in relation to the magma, are complex. Increased concentration of volatiles implies a reduction in viscosity accompanied by an increased pressure if the temperature remains constant. Increase of temperature implies rise in pressure and decreased viscosity, and vice versa. A crystallizing rock, by concentrating volatiles in the mother-liquor, raises the pressure and lowers the viscosity, with, however, two opposing forces: the increase in viscosity due to lowering temperature and in some cases increased silica content of the mother-liquor." The increase of silica increases viscosity unless the glass is at the same time enriched in gases.

The authors explain the down-rushing ash clouds of Pele'e as having at least 70 cubic meters of gas at a pressure of 50 atmospheres at 1,200° C. for each cubic meter of lava. The gas was chiefly steam. The heavy rumbling explosions accompanied a forceful ejection laterally of a momentarily glowing mass of lava from the wall-crack where the lava dome made contact with rock substratum. This emulsion "was possessed of ample energy to keep it well stirred and prevent its coming to rest until the gas evolution had quieted down by cooling." The internal partial pressures of the volatiles in the glass are estimated at over 100 atmospheres where they lifted the heavy spine that rose continuously in the Pele'e dome.

"For its explosive impetus each eruption depended upon the available mobile vesiculated lava and carried with it material less vesiculated which supplied energy gradually to the cloud after it detached itself from the peak." This shows the importance of preliminary vesiculation to produce the phenomena of eruption. T. A. J.

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No. 153 RELEASED WITHOUT COPYRIGHT RESTRICTION December 1, 1927

KILAUEA REPORT No. 827
WEEK ENDING NOVEMBER 30, 1927
Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

Halemaumau pit remains quiet. Visits to the pit November 27 and 30 in the forenoons showed that rain produces visible vapor from the rock walls in places and great increase of visibility of floor vapor. There have been little slides making dust from time to time, chiefly from the northern walls.

During the week the seismographs recorded 20 very feeble local earthquakes.

Tilt during the first part of the week accumulated moderately to the SSE, but partly recovered this motion on the 28th and 29th, so that the net accumulation for the week is only slightly to the SSE.

KODIAK STATION REPORT
October 31, 1927

The first shocks recorded on the seismograph installed in Kodiak, Alaska, last summer, were mentioned in Volcano Letter No. 147, October 20, 1927. The instrument was started August 8, and there were four earthquakes recorded during the remainder of the month. In September, there was but one very feeble shock recorded. Microseismic motion is usually slight, but occasionally increases in intensity over a period of one or two days. Thus September 2, 17 and 23 were days which show records of strong microseismic motion, perhaps caused by wind or stormy weather.

October was a more active month. There were 11 local earthquakes recorded, and an excellent record was obtained of the big earthquake which occurred in southeastern Alaska on the 24th. The local shocks were perhaps too small to be perceptible, though the ones which came at 1 a. m. on the 23rd and at 11:50 p. m. on the 31st may have been felt. These earthquakes appear to have taken place 28 miles and 22 miles, respectively, from Kodiak. Some of the others showed distances of 30, 37, and 101 miles to the epicenter. During the month there were three periods of increased microseismic motion, perhaps caused by stormy weather. These came on October 3, 14 and 27.

The earthquake of October 24 recorded its preliminary wave at 6:01:44 a. m. Kodiak time (16:01:44 Greenwich Civil Time). The secondary wave came at 6:03:12, the long wave began at about 6:03:41, and the maximum motion was at 6:07:30. The resulting indicated distance is 510 miles from Kodiak to the epicenter, which is in good agreement with the scaled distance to the origin as now known. The indicated time at origin of the shock is 5:59:56, which also is in very good agreement with the time determined by the various other observatories. Details of this earthquake have been mentioned in Volcano Letters Nos. 148 and 151. R.M.W.

LASSEN REPORT No. 12
Mineral, California, November 18, 1927
R. H. Finch, Associate Volcanologist

A wireless set for time service was installed in June at the Lassen Station, through the good offices of Charles A. Huff of San Francisco. During the summer months many tourists visited the observatory. Mr. Finch worked on construction of a portable seismograph for installation eventually near Lassen Peak. The National Park road to the peak is advancing rapidly. Messrs. C. A. Anderson and Howell Williams, graduate students in geology from the University of California, were among the visitors to the laboratory, and Mr. Williams spent three weeks at work in the district, studying the petrography and mapping Chaos Crags and Chaos Jumbles near Viola. Mr. Austin E. Jones on July 9 became temporary assistant and seismological observer, remaining until the end of August .

During July and August explorations were made and photographs taken by Messrs. Finch and Jones at Lassen summit, Brokeoff Mountain, Magee and Prospect Peaks. Notes were made on faults and fresh-looking lava flows, having in view the mapping of several of the latter. It looks as though there had been one or more lava flows per century in the Lassen country for many hundred years past. Measurements were made of temperatures of hot springs at Supans, Bumpass Hell, Morgan's, and in the Upper Warner valley. Mr. Jones made preliminary tests of the age of the Cinder Cone lava flows by magnetic methods (see Volcano Letter No. 144, September 29, 1927).

It is planned to equip the observatory at Mineral with a new two-component Hawaiian seismograph uniform in mechanism and constants with the instruments at Hilo and Kodiak, and to make the present Lassen seismograph, built by Mr. Finch, an exhibition instrument in the Loomis Memorial Museum at Manzanita Lake.

Among the activities of the Lassen Volcano Observatory is weather recording, a matter of considerable importance in relation to hot spring work, seismology, and on account of the excessive snow falls of winter. The U. S. Weather Bureau has kindly furnished the equipment of a regular cooperative observing station; maximum and minimum thermometers, and a rain gauge. The road between Mineral and Red Bluff was kept open in 1926-27, excepting for two weeks in February. The inner roads were blocked with snow between mid-January and April 25, sometimes five feet deep. This winter marked the opening of Mineral as a place for winter sports, the Sunday afternoons showing 50 or 60 cars parked by the store, whither people from the valley came for snowshoeing, sledding, tobogganing, etc.

The Lassen seismographs gave very large records of the Alaskan earthquake of October 24, 1927, as well as the one off the coast of California on November 4. The needles of each component went clear off the sheet during the two earthquakes. The Omori tables seem to work for California earthquakes as the distance indicated from the Mineral seismographs agreed with the records from Berkeley and Santa Clara. The depth of the California shake appears greater than the average for this region.

On October 20, 1927, three sharp local shocks occurred. The first was the strongest and made windows rattle and buildings creak within a range of 15 miles from the peak. All shakes were preceded and accompanied by rumbles. These shakes occurred distinctly before fall rains had set in. The earthquakes mentioned in first Lassen report occurred on October 13, 1926, after there had been some heavy rains, only a few days before the shaking. There is a saying current here that with a wet fall there are many earthquakes and with a dry fall but few. The saying may be founded more on fancy than on fact.

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No. 154 RELEASED WITHOUT COPYRIGHT RESTRICTION December 8, 1927

KILAUEA REPORT No. 828

WEEK ENDING DECEMBER 7, 1927

Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

Two visits to Halemaumau show little change over last week. No avalanches have been noted, and only a few slides have occurred. One small slide was observed at 11:40 a. m. December 6 at the lower part of the northeast wall. The north wall has a few new scars. At 10 a. m. December 7 the pit was quiet, wet from the recent rains, and full of color. Steam vents were very active, particularly at the center cone.

The week ending December 7 is of considerable seismological interest. The instruments recorded 98 local earthquakes during the week, of which two were slight but perceptible, the rest being very feeble. This unusually large number is due to a series of small shocks of the spasmodic tremor type, beginning at 5:58 a. m. on December 3, increasing in numbers on that day to a maximum frequency at about 6:30 p. m. At this time they were occurring at fairly regular intervals, on an average of six minutes apart. They then became less frequent, but the series persisted during all of the next day, coming to an end at 2:27 a. m., December 5. These spasmodic tremors were on the whole very similar to one another in character, intensity and individual duration, though toward the end of the series their intensity was somewhat diminished. The total number of tremors counted in the series was 76, of which 47 came on December 3. This is the greatest number for any one day since the tremendous numbers which occurred during the Mauna Loa eruption in April, 1926. Treated as earthquakes, some of them displayed a preliminary phase from which distance could be estimated. From the average of these it would appear that the disturbance was about 18 miles from the Observatory. Phenomena of this type are distinctly of volcanic origin. Careful attention was therefore paid to Mauna Loa and Kilauea, for other possible symptoms of outbreak. No other signs of activity were observed, however. The fact that harmonic tremor, which comes hand in hand with eruption of lava, was totally absent from the records, served to diminish the idea of immediate activity. The suggested crisis is apapparently past, as the instruments are now recording nothing unusual. The occurrence of such phenomena, however, is sure evidence of volcanic life within the mountains of Mauna Loa and Kilauea, which in time may be expected to display itself at the surface.

The two earthquakes that were of slight intensity, and were perceptible, came at 10:09 a. m. December 1, and 7:37 a. m. December 6. The first of these was reported felt both in Hilo and at the volcano. It was well recorded on the seismographs at these places, and a very feeble record was made on the instrument in Kona. These records combine to indicate that the origin was near the Puna rift line ,about 12 miles east of the volcano. The second slight shock was apparently local to the volcano, as the motion broke abruptly into maximum amplitude, without appreciable preliminary phase. It was felt by a number of persons in this vicinity, and was accompanied by a rumbling noise. It was followed four minutes later by a very feeble after-shock.

Microseismic motion has been normal during the week, and tilt has accumulated moderately to the NNW.

HILO STATION REPORT

A description of the Hilo seismographic installation appears in Volcano Letter No. 142, September 15, 1927. The instruments are of the same type as those installed at Kodiak, Alaska. The more important recordings of the Hilo station have been mentioned from time to time in the Volcano Letter, when they have had a bearing on the data obtained at the Hawaiian Volcano Observatory. The Hilo station is about 23 miles in air line distance from the Observatory, so that in general the stronger local shocks are recorded at both stations. This is a convenient arrangement, since by plotting indicated distances it is possible to determine the point of origin of many of the local earthquakes. The plotted distance from the Kona station aids in such determinations. This is a well known method, and has been used for a number of years here. The new installation at Hilo is somewhat more sensitive than the old instrument, making possible the plotting of more of the feeble shocks.

During the month of October, 1927, there were recorded at Hilo 13 local shocks and one teleseism. The recording of the distant earthquake (October 24) has already been described in Volcano Letter No. 148, October 27, 1927. None of the local earthquakes was reported as perceptible there ,and they were with one possible exception of the very feeble class. Of the 13, nine were recorded at the Observatory also. There was strong microseismic motion on the 17th and 18th.

The November records show 12 local earthquakes, 10 being very feeble. The other two were slight, but were perceptible in Hilo, and occurred at 6:12 a. m. November 11, and at 9:13 p. m. on the 21st. There were nine of the 12 recorded also at the Observatory. In addition to the local earthquakes, there were three teleseisms recorded, one at 3:35 a. m. November 4, which has already been mentioned, another very feeble trace is shown at about 9 p. m. on the 17th, and the third was a slight but definite record of long waves at 8:48 a. m. on November 18.

The Hilo records are exceptioanlly free from such bothersome disturbances as diurnal tilt, traffic movements, or pen displacements due to room or instrument temperature changes. The massive construction of the concrete walls and roof of the seismograph cellar, combined with the fact that the structure is set deep into the ground and is in a location shaded by trees, is perhaps responsible for the small temperature range within the instrument room. The situation is distant from any highway, and local external disturbances are infrequent.

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No. 155 RELEASED WITHOUT COPYRIGHT RESTRICTION December 15, 1927

KILAUEA REPORT No. 829

WEEK ENDING DECEMBER 14, 1927

Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

At Halemaumau on December 10, at 2 p. m., one small slide of rock was heard. A slide was heard from Uwekahuna December 13 at 3:55 p. m. Today, December 14, about noon small rockfalls occurred every 5 or 10 minutes at the northeast, north and south walls. The air was perfectly still, and no other noise, such as hissing, was heard. Recent avalanches have scarred the walls all the way to the upper edge NW, NE and SW. The heavy rains now wet the entire north sill, which was formerly so hot that it resisted soaking. There are, however, large dry patches at the top of its east end, in the wall above that point, and on the north side of the west boss.

The total number of earthquakes registered on the seismographs at the Observatory during the week ending December 14 was 21. These were all very feeble at this place. One at 4:13 a. m. on the 10th had an indicated distance of 37 miles, and was reported as perceptible in Hilo.

LASSEN REPORT No. 13

Mineral, California, November 25, 1927
R. H. Finch, Associate Volcanologist

Between 9 and 11 p. m. November 24, nine local earthquakes were recorded on the Mineral seismographs. Three were perceptiple. The perceptible quakes and some of the unfelt ones were accompanied by deep rumbling noises. The occurrences of single earthquakes seem to be well distributed throughout the year, while the earthquake "swarms" appear to be confined to the winter months. It will be interesting to watch in the coming years to see if this relation continues.

CENTRAL OREGON VENTS

Dr. E. T. Hodge, investigating fossil forests in the volcanic strata of central Oregon (New York "Times," October 2, 1927), doubts the evidence reported in the nineteenth century by Russell that the lava welled from fissures, and says that "with the exception of one place in the eastern John Day country, he has not found any of the postulated fissures." Instead of this, the lava welled from craters, and in some instances the flow virtually buried these craters, erosion removing further evidence. He pointed to the many craters in the Deschutes country as proof of the crater theory. T.A.J.

ERUPTION OF SOLFATARA

The report in the newspapers (Seismological Despatches, Georgetown University) dated at Pozzuoli, Italy, August 1, 1927, is extraordinary if true. It states "in sympathy with Vesuvius, the volcano known as the Solfatara today resumed violent activity for the first time recorded since the year 1198. It hurled skyward from the center of its semi-extinct crater quantities of blazing hot, but dry, sand." T.A.J.

THE PALESTINE EARTHQUAKE

A very serious earthquake in the Holy Land occurred just at the time when Kilauea was last in action. The "Richmond River Express" of September 16 (Richmond, Australia), cites a letter giving details. The writer, Mrs. Drayton, had been having her house newly decorated; "we had just finished putting up a bed, when there was a most terrific noise like hundreds of tube trains approaching at once. The house commenced to rock, and I was thrown over against the wall—gazing upwards. Saw the ceiling at an angle of about 45 degrees. The plaster began to fall. We bolted for the children, fled from the house, and stood in the road.

"When we eventually crept gingerly back again we discovered that we had not one whole wall or ceiling, and all our six weeks decoration had gone for nothing in 10 seconds—less than 24 hours after the work had been completed. It was a very upsetting experience. I am quite certain that I had never before felt real fear—air raids in London and submarines left me cold compared to this. The casualties are 200-odd killed and 385 seriously injured, and about 100 minor injuries in Palestine. Then 68 killed in Trans-Jordania, and about 500 injured.

"Nablus suffered very heavily. Government House, on the Mount of Olives, was damaged to the extent of £50,000. Lord Plumer was on leave, and if he had been here would probably have been killed.

"We had another less severe shock on the following Sunday, the 17th, and several minor tremors. Although the loss of life was not very severe in Jerusalem, the damage to property was considerable, the houses of three senior British officials fell down and others have been condemned. In the Bennetts' house, on the opposite corner to ours, the cistern burst and the place was flooded, they being away on leave." T.A.J.

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No. 156 RELEASED WITHOUT COPYRIGHT RESTRICTION December 22, 1927

KILAUEA REPORT No. 830

WEEK ENDING DECEMBER 21, 1927

Section of Volcanology, U. S. Geological Survey:

T. A. Jaggar, Volcanologist in Charge

At Halemaumau pit December 12 at 2 p. m. there was nothing new in evidence, no slides were heard and the slopes appeared undisturbed after excessive recent rain.

During the week there were 37 local earthquakes recorded on the Observatory seismographs. All of these were very feeble with the exception of one which occurred at 3:37 p. m. on the 18th. This one was feeble, but was felt locally; the origin of the shock was apparently within two miles of the Observatory. Two earthquakes were felt in Hilo on the 15th, one at 2:07 a. m., the second and stronger one being at 6:01 p. m. Distances indicate that these shocks originated on the northeast rift of Mauna Loa.

Tilt has accumulated during the week moderately toward the NE.

A WHEELED BOAT FOR VOLCANO EXPLORATION

Aleutian Island explorations in 1907 led the writer to wish for a wheeled boat that would beach itself. The father to the wish was the experience in a schooner of nearly landing at Vsevidof Volcano, finding no anchorage, and being forced to go to sea. In 1927 he tried a low-geared small motor car with balloon tires on tundra and beach of the Alaskan Peninsula. Traveling was practicable, but inlets, rivers, and rocky stretches were obstacles. Again the beach boat became desirable, a boat motor-car that would launch itself, and resume land travel along favorable beaches. The beaches in many volcano lands are nearly continuous, and the shore line is a natural highway. Where storms and fogs are frequent, life at a shore camp, with gasoline power, electric lights, electric or gasoline heating, and tent extension of the vehicle, is more flexible than in a boat cabin restricted to safe anchorages, which are few and far between.

Numerous patents have been obtained for amphibious boats, and the Mobile-boat of Powell in Chicago is to be tried out next summer in Alaska. This is a Ford truck chassis with steel boat body and twin screws. At the observatory shop at Kilauea, we have converted the Alaskan motor car of 1927 into a car-skiff for experiments in traveling along the shores of Hawaii and camping on the beaches. The principles of the new beach boat differ from that of Powell: a 16-foot flat-bottomed skiff by Kneass of San Francisco has a Ruckstell-Ford car chassis of 1926 mounted on oak timbers inside, and a Smith "Formatruck" chain drive rear axle has been adapted to support a stern extension of the skiff on double springs, using the Ford wheels. The Ford front axle and steering-gear are adapted to the bow of the boat. We thus get a substantial lorrie with a skiff body.

For the water drive, the counter-shaft holding the front chain sprocket of the driving mechanism carries two light steel paddle wheels 24 inches in diameter expected to be about one-third immersed. These paddles are removed and carried inboard during land traverses. The balloon-tired land wheels will be largely submerged when the boat is in the water, the rear ones continuing to revolve. The land wheels necessarily cut down the speed in water, but act somewhat as low ballast, and the disc surfaces oppose lateral leeway. The disc front wheels act as rudders in the water with the same steering wheel as on land. By jacking up the boat in shallow water, removal of 10 bolts aft and five forward, sets free all the running gear, which may be left on the beach or stored inboard for a long water run at higher speed than otherwise.

Tests of the boat-car on land have been satisfactory, and the water test will be made in a few days. There remain the various adaptations to sounding, camping, cooking, protection against the weather, winch, stake, and cable contrivances for hauling the car over steep or rough land, and tests of caterpillar chain treads, mud hooks and the like for driving through soft ground. All of this work, under the Hawaiian Volcano Research Association, is in sequence upon a long series of experiments in driving over desert and lava whereby cross-country cars have been used for many years at the Observatory. Much of this work was necessitated by the requirements of drilling for temperature measurements. Heavy drill rigs of three different types have been hauled, and 34 bore-holes have been made, mostly on the lava floor of Kilauea Crater.

It is planned to do practical work in exploring the Kona coast with the beach-boat. There is great volcanologic interest in sounding and dredging at Hoopuloa and Alika where the recent Mauna Loa flows entered the sea, and it is reported that the U. S. Coast and Geodetic Survey is about to begin operation with the U. S. S. "Guide" mapping in detail the west Hawaii harbors. The best of these is Kealakekua, where in 1876 there was submarine eruption, and pumice was reported to float up hot. Dredging would be of interest here. Echo and wire sounding admit of important experimental work in volcanology, with a view bottom such as the Alika flow, what is the character and density of the underwater rock, and how can it be diagnosed by sounding apparatus as different from the sea-bottom round about? If by noise, or feel, or sampling such a flow can be outlined, an important scientific advance can be made. For where are there other such submarine lava flows? They may be found off the Puna and Kau coasts. There have been many occasions when the sudden drainage of lava from Halemaumau pit led to suspicion of submarine quiet flow. Here is where it behooves volcanology to join hands with oceanography.

The first Kona expedition will be directed to exploring and collecting the Hualalai and Mauna Loa lavas of North Kona where the many flows have entered the sea. For this country now the Geological Survey has admirable topographic maps, and there are numerous beaches here and there to serve as landing places for making camps. The 1859 flow built out much new land and its lower fields have never been explored geologically. T.A.J.

The "Palestine Earthquake" described last week occurred July 11, 1927, at 1:10 p. m. Greenwich time (3:10 p. m. Palestine).

SAMPLE COPY

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No. 157 RELEASED WITHOUT COPYRIGHT RESTRICTION December 29, 1927

KILAUEA REPORT NO. 831

WEEK ENDING DECEMBER 28, 1927

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

After a week of excessive rainfall, wherein Halemaumau pit has been continuously full of vapor, the scene from the edge today, December 28, at 3:15 p. m., was of a faintly visible cauldron with hundreds of vapor jets on the bottom blown from the west, and many others on the walls. Avalanches were almost continuous, several moderately strong ones occurring within a 15-minute stay. They were mostly from the northern walls, but occasionally rocks fell at the south. The bottom did not appear changed in configuration, and the rock sliding was probably due to undermining occasioned by the excessive washing-out of the finer material.

During December to date rainfall has amounted to 42 inches at the Observatory, and the daily rainfall, beginning December 21, was 1.85, 3.00, 0.95, 2.00, 7.80, 4.50, and 7.45 inches. This was one of the heavy winter "Kona" storms from the southwest.

The Observatory seismographs have recorded 30 local earthquakes during the week. These were all very feeble with the exception of one, classed as feeble, which occurred at 8:57 a. m. December 21; its origin was about 14 miles from the Observatory. It has not been reported as perceptible. In addition to these local shocks, there was a period of definite though very feeble continuous tremor, beginning at 1:38 p.m. December 21 and lasting 25 minutes. A teleseism was recorded on the 28th, the preliminary wave beginning at 7:59:12 a. m. Other phases indicate the distance to the origin to be 3,440 miles. The time at origin, in Greenwich Civil Time, resulting from this data, would be December 28, 18:20:10.

Microseismic motion showed increase on the 25th, reaching its maximum amplitude on the 27th, although on that day the wind had moderated locally. Tilt has shown a strong spurt toward the SSE, the accumulation for the week being approximately 3.0 seconds of arc in that direction.

MUD RAIN DROPS FROM BRISBANE

Richards and Bryan describe (Proc. Roy. Soc. Queensland XXXIX No. 5, 1927, 54-60, 2 plates) lithified tuff or ancient volcanic ash containing "mud balls." The Brisbane turf is Upper Triassic, unconformable above schist. The base of the section is an agglomerate with schist and rhyolite fragments. The tuff is well known about the city of Brisbane, but the pisolites are found only at Castra, 12 miles away. Portions of the tuff are believed to be water-laid, for it is underlain by fresh water lacustrine sediments and grades above into shales. The pisolitic ash described and figured is in all respects exactly like the modern hardened mud raindrops that accompany such explosive eruptions as those of Kilauea in 1790 and 1924, or Vesuvius in 1906. It is of great interest to find it in ancient fossilized form in hard rock.

The Brisbane pellets are compared with marbles or beads. The largest are 25-30 mm. diameter, and these are abnormal. (Compare Bull. Haw'n Volc. Obs'y June, 1921, Fig. 21 and p. 102.) The balls occur scattered in the lower and middle portion of the Castra section, crowding certain layers. (Compare 1790 ash with [illegible] nts, Kilauea, Bull. Haw'n Volc. Obs'y, July, 1921, Fig. 22 and p. 114.) Most of the Brisbane spheroid[illegible] were 3 9 : m. diameter, some are flattened and egg-shaped, internally they are concentric layered, the skin is often discolored and harder than the rest, and the grain is finer than the matrix tuff. (Compare "Kilauea pisolites," Fig. 2, F. A. Perret, "Some Kilauean Ejectamenta," Amer. Jour. Sci. Art. LII, June, 1913, p. 612.)

The authors find parallels to the Australian mud-balls in the ejecta of Taal Volcano, 1911, and the mud-drops of Pelee in Martinique, 1902. These comparisons are entirely justified, and it may be said that all "cauliflower cloud" eruptions of recent observation have produced mud rains when the atmospheric condensation accompanied dense floury ash accumulation in the rain clouds. The condition for preserving layers of pisolites is when stiff mud-drops fall in light dry dust beds of previous eruption, and it is possible that the baking the dust has been subjected to, accounts for its cement-like quality in rapid hardening. The pisolitic ash of 1790 at Kilauea, where the footprints were hardened, was a mud when the footprints were made, and its upper surface crusted to preserve the footprints like a weak cement.

The presence of pisolites is a sure proof of direct subaerial ash fall, and each layer usually means a separate mud-rain shower. Such mud rains may occur many miles away from the volcano. T.A.J.

HEAT BY LAVA CIRCULATION

After discussing gas-heating and gas-fluxing, which he believes to be reasonable, but perhaps unnecessary, Shepherd (Section of Volcanology, 1927, Bull. Nat. Res. Counc. No. 61, p. 262, Washington, D. C.) suggests that these hypotheses were invented to explain an undrained lava lake, a closed system. If we assume the Kilauea lava lake to be a bubbling spring with many subterranean outlets, not from one magma chamber, but from numerous roots, he believes that the required heat could easily be supplied by "the rise of a few cubic meters of lava per second with only a two-hundred degree drop in temperature." The basaltic roots go to considerable depths, the acid volcanoes taking their origin among the more superficial roots.

In this connection a quotation from Tempest Anderson (Volcano Matavanu in Savaii, Quart. Jour. Geol. Soc. LXVI, 1910, London, p. 637) is relevant: "Matavanu is certainly a (lava) river. Kilauea may be a river, but is more probably a boiling pot. Does the lava of Kilauea at the times when the lake empties itslf periodically, say once in five years, also discharge itself into the sea?" T.A.J.

ERRATUM

In Volcano Letter No. 156, fifth paragraph of the article, fifth sentence should read: "Echo and wire sounding admit of important experimental work in volcanology, with a view to identifying a lava-flow bottom. Taking a known basalt bottom such as the Alika flow," etc.

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No. 158 RELEASED WITHOUT COPYRIGHT RESTRICTION January 5, 1928

KILAUEA REPORT No 832

WEEK ENDING JANUARY 4, 1928

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The week following the storm of the solstice season has been characterized at Halemaumau pit by many avalanches, tremors, and strong WSW tilting. Recorded avalanches were at 8:15 and 10 a. m. December 29, 10:02 a. m. December 31, and just after 9 p. m. January 2 and preceded by felt jarring. Dust rising over the pit was repeatedly seen, and several people reported avalanche roaring.

Measurements about 3 p. m. December 29, at 15 places along large cracks close to the east edge of the pit, showed that the cracks had widened two to four inches during December. All the talus slopes show fresh debris, and the falls of rock are particularly conspicuous along two vertical solfataric zones at the east and west ends of the big northeast sill. These appear to be ancient wall cracks where the pit wall shows a U-shaped cross-section of an ancient pit. The lava floor shows no changes other than fresh overlapping of extending talus debris, notably at the northwest.

There were 84 earthquakes registered during the week. One at 9:56 p. m. on December 30 was feeble; it has not been reported as felt. All the others were very feeble. On January 1 at 8:04 a. m. a tremor almost large enough to be classed as feeble was recorded, and at the same time a heavy avalanche was noted in the pit. Another heavy avalanche followed a few minutes later, but its recorded tremor was not nearly so pronounced.

Microseisms continue moderately strong.

NEW ZEALAND-TONGA VOLCANOES

A suboceanic ridge connects New Zealand and Tonga, and east of this is a narrow, almost linear, trough in the ocean bottom over 4,000 fathoms deep in two places (Volcanoes of the New Zealand-Tonga Volcanic Zone, by J. Allan Thomson, New Zealand Journal of Science and Technology, December, 1926, p. 354-371). West of the Kermadec Islands the submerged region descends gradually to depths of over 2,000 fathoms. The Tongan Plateau bears the inhabited islands of Tonga on its eastern higher side, composed of submarine tuffs and coral limestone. On its westward lower side there are small volcanic islets and submarine volcanoes. Similarly in New Zealand there are sedimentary rocks in the northeastern part of the country forming a raised mountain axis, while in a relatively depressed belt, next to the west, lie the volcanoes. In the Kermadecs the volcanoes lie close to the edge of the ocean trough, but there are granite fragments in the tuffs there of continental origin.

The volcanoes from Ruapehu in New Zealand to Fanua Lai in Tonga lie in a northeastward-trending straight line parallel to the ocean deep east of them. Farther north the lines of botb plateau and trough swing to the northwest toward the discontinuous platforms which support the Ellice, Gilbert, and Marshall groups of islands. The active volcano line also bends, ending with Niuafou.

Andesitic lavas and ashes dominate throughout the entire chain of old and new volcanoes, only the Kermadec Islands and Niuafou showing basalt in addition. This andesitic composition and the linear arrangement make the whole system one volcanic group.

To the east of this group all the Pacific islands consist only of basalts and their derivatives characteristic of the Pacific basin proper, while to the westward, as the active volcanoes are mainly andesitic, the New Zealand-Tonga line is believed to be marginal to the Pacific, particularly as many of the islands are partly composed of continental plutonic, and sedimentary rocks.

"There are at present two competing theories as to the origin of andesitic magmas. Daly, who believes that a universal layer of basaltic composition everywhere underlies other rocks, considers that andesite is best regarded as a direct derivative of common basalt by the removal through sinking of the heavier constituents in a column of slowly cooling liquid basalt. Hobbs, on the other hand, considers that andesites are formed by the simple melting of shales under up-folding arcs of the crust owing to the relief of pressure caused by the arching." After pointing out some objections to both these theories, Thomson concludes: "Probably a combination of Hobb's theory with Daly's theory of a universal underlying layer of basalt comes nearer the truth. Under the up-rising arcs there is a melting both of shales and other continental rocks and of basalt and an admixture, resulting in an andesitic magma. Within the Pacific basin proper, where the basalt layer forms the surface of the crust, a remelting forms only a basalt magma, from which trachytes and alkaline rocks are formed in small amounts by differentiation."

Dr. Thomson's paper is in the main a record of eruptions of this whole line of active volcanoes Forty explosive outbreaks are recorded since the beginning of the 19th century, the only records of lava flows being those of Ngauruhoe of 1869 and 1881, both of which are disputed. However, all the larger cones show lava flows in section. "Either flows are relatively so infrequent that nearly a century can pass without one, or there has been latterly a change in the mode of eruption by which the lava has become more explosive." This all sounds very much like the eruptive history of Lassen Volcano and the Aleutian and Japanese cones ,and as the list of Tongan outbreaks is admittedly incomplete, it is probable here as elsewhere that many of the lava flows are from the lowest vents and consequently submarine.

This accents the importance of what has become increasingly evident at the Hawaiian Volcano Observatory, namely, to devise geophysical methods for studying movements of magma underground. This means investigation of tilt, tremor, magnetism,gravity, horizontal and vertical shift of benchmarks, and changes of solfataric chemistry. A combination of these processes, rapidly at times of explosive crisis, and slowly at other times, is what must form the basis for diagnostic measurement in volcanology. Intrusion is the greatest volcanologic process; it is in action today, and this fact is insufficiently realized by geologists. There is no field more hopeful for development of precise methods along these lines than the volcanic districts of New Zealand, where a new volcanologic service has been inaugurated. T.A.J.

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No. 159 RELEASED WITHOUT COPYRIGHT RESTRICTION January 12, 1928

KILAUEA REPORT No. 833

WEEK ENDING JANUARY 11, 1928

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

This week has ended with a small gush of lava in the bottom of Halemaumau, but it is very doubtful whether this is anything more than a squeezing-up by pressure of remnant liquid lava from the July eruption of 1927.

The week has been fine, ending with strong northeast wind. At the end of last week there was almost continuous uneasy sliding of small rocks from the west, northwest, and north walls of Halemaumau. This is usually started by a big rock falling from high up the wall. The July floor has been greatly overlapped with debris, especially under the northwest talus cone, the top of which has been incessantly added to so as to bury the niche formerly seen there.

A traverse of the south and west edges of the pit the afternoon of January 7 showed that the flag at the west-northwest rim was in a precarious position, and new cracks were giving up hot steam for 50 feet back of this flag. So fresh were the cracks that fern and grass sods watered by the recent rains were torn asunder, and some of the fissures were more than three feet wide. Numerous small slides were falling under this place.

On January 9 new measurements along the cracks back of the east rim showed progressive widening of the principal crack northward to a maximum of five inches increase of width over the measurements of December 29. Leveling across Kilauea Crater floor from the south gravel ridge to the vicinity of the pit revealed a lowering in eight months of the Halemaumau rim region of 0.4 foot. Six notable slides occurred just after noon.

On January 10 avalanches increased all day at the northwest, and from 4:30 to 5 p. m. big slides indicated that the WNW wall was undermined and in process of falling. A large wet scar in the high wall lay over wet new-fallen fragments below. There was some sliding on all sides of the pit, as though the bottom plug were lowering under the debris slopes.

At 12:26 a. m. January 11 there was a prolonged avalanche roar heard, and then a moderate rosy glow appeared over Halemaumau. When the pit was reached about 1 a. m. there were three glowing areas of fresh incandescent lava on the floor, a long curved western band, a small central pudding, and a smaller fiery pot at the site of the north floor cone of July, 1927.

It was evident that new lava had spouted up, but in addition a light-colored landslide area covered the whole northwest floor. The rosy glow above the pit as seen from a distance had entirely disappeared in 20 minutes; the new lava was no longer bright, but consisted of a filigree of cooling flows with a suggestion of blue flame at the northern cone. There was little observed motion, no hissing or fountaining anywhere, but sliding continued from all sides, particularly northwest. The high, dark, avalanche scar in the WNW wall was now extended up to the top, and steam was seen on the face of the wall next to the north.

A circuit of the pit during the forenoon showed that the main new flow was not visibly incandescent by daylight, and consisted of black "sharkskin" lava in a crescent around the south side of the northwest pool of 1927. It lay just outside of the sunken crust of that circular pool, which had been surrounded by a raised bank separted by cracks from the subsided inner shell. The new lava had come up these cracks in three places, the flows merging outside of the bank to make the crescent, which was about 500 feet long. At its northeast end, near the center of the pit, was a small, ragged, lava patch, which had flowed from another crack eastward.

All of this appeared to have been occasioned by the landslip of the northwest debris slope. The tumble of rocks had ridden over and weighted down the whole of the crusted pool, breaking up the crust, as shown about the edges, and apparently squeezing up live lava from below, which emerged at the border cracks. Apparently this "lava floor," seemingly dead since last July, was really a stagnant lava puddle, still liquid below. It had been about 70 feet deep.

The northwest floor area was all covered with lobate heaps of red bowlders, the lobes convexed to the southeast. The northwest talus was completely stripped, revealing a rock slope lying at a flat angle. An immense avalanche from the edge of the pit had carried away the WNW flag, made a new notch in the pit edge just where the opening cracks had predicted collapse, and the crash had precipitated the landslide at the bottom.

The fire pot at the north cone had merely sent out a little trickle of black lava, stimulated by the same landslide pressure on the crust as at the other places. During the day the slides seemed to subside.

All this history pointed to a collapse rather than a rising, as shown by the slides and inward tilt of the past week. The load of tumbled rock revealed and squeezed up a little remnant lava. There was no harmonic tremor and no hissing was heard, both of these being characters of gas-charged lava when it is vigorously tumescing and ready to make fountains.

There were 58 local earthquakes recorded during the week. All were very feeble with the exception of one, at 1:07 p. m. January 4, which was a moderate shock felt in Hilo, South Kau, and other places, as well as locally. The distance to its origin from the Observatory is indicated as 21 miles. A number of the very feeble local tremors occurred coincidently with avalanches in the pit. For many avalanches the time was not noted. It is probable that if more avalanche times had been noted, there would have been a greater number of the recorded tremors matched with coincident avalanches. During the night of January 10-11 a very heavy avalanche occurred, probably at 12:26 a. m., if the tremor recorded on the seismographs at that time can be regarded as the resultant disturbance. This tremor was more strongly recorded on the Uwekahuna seismograph than at the Observatory, which is to be expected; the distances of the two stations from the pit being 0.9 and 2.2 miles, respectively. The tremor as recorded at the Observatory was almost strong enough to be graded above the very feeble class, being nearly large enough to be perceptible. It was preceded by four more feeble preliminary tremors, the first of which was recorded at 12:19 a. m.

Microseisms were slightly stronger than usual during the middle part of the weekly period. Tilt accumulated moderately toward the WSW during the week.

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No. 160 RELEASED WITHOUT COPYRIGHT RESTRICTION January 19, 1928

KILAUEA REPORT No. 834

WEEK ENDING JANUARY 18, 1928

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Succeeding events confirm the belief that the lava gush of January 11 was only a squeeze by landslip on remnant liquid lava under crust. There has been no more flowing, and all the seismic, avalanche and tilt disturbances of the first of the year have ceased. There is nothing new at Halemaumau.

The number of earthquakes recorded on the Observatory seismographs during the week is only 15. They were all very feeble. Of this number, nine came on the first two days, leaving only six for the rest of the week. Microseisms were moderately strong on the 13th and 14th. Slight east tilt has accumulated during the week.

LAVA AND ASH OF KILAUEA

In 1925 Dr. John B. Stone, Bishop Museum Fellow of Yale University, made a geological investigation of the rock materials and structural relations of Kilauea Volcano, which he presented as his dissertation for the doctorate. (Products and Structure of Kilauea, Bishop Museum Bulletin 33, Honolulu, 1926; 59 pp., 2 pl., 7 fig., and bibliography.) This essay is an admirable introduction to the discussion of the difficult interpretation of field facts concerning the relation of Kilauea to Mauna Loa. Dr. Stone examines without prejudice the specimens he collected himself, giving full credit to all earlier workers. He makes use of block diagrams to exhibit the structure and topography of Kilauea Crater and Kilauea mountain. He gives special attention to the boundary line between Kilauea flows and Mauna Loa flows, and concludes that a volcano in the general vicinity of Mauna Loa was older than Kilauea. On the basis of the evidence presented, this conclusion appears to the reviewer to be still in doubt, as it seems to him not unlikely that the ancestral volcano under the Mauna Loa-Kilauea complex was a ridge connecting the present Kilauea sink with the Waiohinu district by way of Wood Valley and Mohokea, all of these places being engulfment remnants of ancient craters.

Stone makes the following wise comment: "It is generally assumed in discussions of Hawaii that the island has been built by the five recognized volcanoes, but this is by no means certain. An old land mass underlies Kilauea and at least part of Mauna Loa. That this land was built by the present Mauna Loa is quite possible. but not proven. The evidence of extensive faulting along the southern coast and probably also along the northern side of Kohala suggests that there may have been older volcanic centers of which nothing is known, now sunk beneath the ocean or buried by the later volcanoes." It seems to the reviewer that Wood Valley and Mohokea are physiographically much too important as probable old volcanic centers to justify the statement that "nothing is known" about them.

The petrography of Kilauea indicates that all specimens are basalts, with labradorite basalts most abundant and containing only one per cent of olivine. There are some olivine basalts, and from the deeper mountain gabbroid explosion blocks have been thrown up which are picrite basalts containing 15 to 40 per cent of olivine. The minerals are olivine, pale brownish augite, rare hypersthene, calcic plagioclase feldspar, magnetite, ilmenite, and brown glass containing apatite. Cristobalite was found in vesicles of some of the coarser rocks. Sulphur and sulphates have been formed by fumarolic action. The textures of the rocks range from intersertal to diabasic when they are crystalized, porphyritic crystals are olivine, feldspar, and pyroxene, and the tops of the flows have a black, glassy ground mass.

Typical feldspar basalts of Kilauea Crater contain weight percentages of minerals as follows: Olivine, 1; augite, 54; labradorite, 31; iron ores, 13; glass, 1; and the specific gravity is about 3. Dikes are rare, and when found have chemical composition like the flows. Gabbroid intrusions are common in the bottom walls of the innermost craters, showing percentage compositions as follows: Olivine, 40; augite, 31; laboradorite, 37; iron ores, 2; apatite, 0.3; and specific gravity, 3.

The ash beds make up less than five per cent of the section of ancient lavas exposed on the fault cliffs near the sea southeast of Kilauea. There are interbedded with the lavas five layers, 15 to 20 feet thick, of reddish yellow stratified ash here, which are quite fresh. On top of these older lavas and underneath the veneer of recent flows which have cascaded over the Kilauea slopes, there is a bed from 20 to 60 feet thick of alternating yellow and gray ash containing lapilli. This occurs at the top of the pre-Kilauea series in the big fault cliffs, and is correlated by Stone with the so-called "yellow ash," from 28 to 95 feet thick, in the Pahala and Kapapala districts. Stone states that the yellow ash of Kapapala contains bands of lapilli and is pisolitic. He classifies as a single stratum marking an episode in the geological history of the country the red and yellow clays of Glenwood and the Bird Park, the beds of the southeast fault cliffs, and the ocher soils of Pahala.

There are ash beds at the base of the Uwekahuna cliff west of Kilauea Crater, and others forming the surface soils around Kilauea. These last range in thickness from one to 30 feet, and contours drawn by the reviewer on Dr. Stone's map of thicknesses show that the surface ash is at its maximum just south of the crater and is distributed northeast and southwest from there in belts of decreasing thickness.

The thread-lace scoria, or basaltic pumice, which lies at the base of these ash beds, ranges in thickness from one to 18 inches, the thickest exposures adjoining the north side of Kilauea Crater. The contours indicate a symmetrical development around this part of the crater with widest belts at the north, as though a south wind were blowing when lava fountains in the northern part of the crater ejected this material.

Four intervals between ash eruptions are indicated by fossil sod layers in the beds above the thread-lace scoria, and Stone considers only the coarse upper layer to be the product of the eruption of 1790. The ash beds contain mineral and glass fragments, sometimes the one and sometimes the other being dominant. The 1924 ash consists almost entirely of mineral fragments. T.A.J.

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No. 161 RELEASED WITHOUT COPYRIGHT RESTRICTION January 26, 1928

KILAUEA REPORT No. 835

WEEK ENDING JANUARY 25, 1928

Sectior of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Nothing has happened during the week to change Halemaumau pit. A little dust from slides was seen rising January 24. The seismographs at the Observatory recorded 25 very feeble local earthquakes. On the 24th, beginning intermittently at 5:12 p. m. and becoming continuous at 5:18 p. m., there was a very feeble protracted tremor, very much resembling harmonic tremor in appearance on the record. It waxed and waned, so that there were five distinct times of maximum amplitude, which have been included in the above count for the weekly total. The greatest of these maxima occurred at 5:37 p. m., and the tremor itself continued until 5:46 p. m. before the last trace died out.

Microseisms have been normal during the week, and tilt has accumulated very slightly toward the ENE.

LASSEN REPORT No. 14

Mineral, California, January 15, 1928

R. H. Finch, Associate Volcanologist

There have been several reports recently concerning activity of Glass Mountain, a peak about 7,850 feet high and about 75 miles north of Lassen Peak, in the Modoc lava beds. Rather new lava flows are to be found nearly all the way between Glass Mountain and Lassen Peak. Forest Service officials report about half an acre of land covered with pumice which is very hot. By digging but a little way into the pumice, much higher temperatures can be reached. Near this pumice bed there is a deep fissure from which steam issues.

According to George W. Courtright, a rancher and trapper residing about 12 miles east of Glass Mountain, the heat of the mountain has been known for years. The local Indians, ever since the country was settled, have been known to say, "Glass Mountain no good place." Mr. Courtright reports that numerous earthquakes occurred in January and February, 1910, and that during the shaking flames were observed over the mountain. In the spring of the same year he reports finding "blue mud" on vegetation on the mountain slope. Earthquakes originating in the mountain and accompanied by rattling noises have been noted by Forest Service officials for at least 15 years. Similar noises and shakes have been observed by Mr. Courtright for a much longer period. Near the northern end of the lava beds to the north of the mountain, a fissure about one-half mile long opened up during a very pronounced shake in 1910.

The writer and Mr. George L. Collins of the National Park Service endeavored to make temperature measurements and to take photographs on the mountain January 13, 1928, but were driven back by a heavy snow storm. It is planned to conduct further explorations in the spring.

VOLCANO-GLACIER FLOODS

The effect of volcanic heating on glaciers in Iceland is of great interest in comparison with what may happen on the glacier-covered volcanoes of Alaska. This melting was supposed to happen on the snow-covered Lassen Volcano of California. It may even have happened some thousands of years ago in Hawaii, when glaciers lay on top of Mauna Loa and Mauna Kea. This may account for some Hawaiian tuff deposits. The heat of the eruption melts the snow and ice masses, and the warmed water melts out gorges in the glaciers, increases in volume, and mixes with volcanic and glacial debris so as to make collossal torrents carrying icebergs out over the lowlands. These glacial floods are common in Iceland, where they are known as "Jokulhlaup" or glacier rushes. (Vulkankunde, by Karl Sapper, with petrographical introduction by A. Bergeat; 32 text figures, 30 plates, and 4 colored maps; 1927, Engelhorn, Stuttgart.)

At Katla, Iceland, in 1918, several openings trending SW-NE, about 1,000 meters above sea level, went into action along this crater which had become buried under ice since 1823, when it was last active. At 2 o'clock in the afternoon of October 12, 1918, after a swarm of weak earthquakes, steam clouds shot up, and for three nights thereafter these were full of electric fireworks. Human electrical operations, such as telegraph and telephone, were interupted. There was much rumbling, and heavy ash-fall occurred and shrouded much of the land in darkness. This continued off and on for 20 days, with maxima about the 10th and 21st day. In a radius of one kilometer 698,220,000 cubic meters of ash fell.

The warm water streams from the melting of ice reached a depth of from 60 to 70 meters, and the masses of sand and mud which the glacier rush carried with it were so extensive as to build out the coast line.

The first glacier rush happened an hour and a half after the eruption began, and flooded a sandy waste at the foot of Katla. Spectators saw the flood, overhung by steam and dust clouds, laden with gigantic icebergs, rushing down a valley, and in a short time the sea nearby was covered with large and small bergs. At 5:30 that afternoon, a new glacier rush started in farther to the east, and continued most of the night, as shown by the roaring of the waters and the crashing and rumbling of colliding icebergs. This torrent spread out over a flat area of about 125 square kilometers, carrying thousands of ice slabs, the larger ones becoming stranded on the sandy waste. At one place the torrent rushed against a cliff 60 meters high, so that ice fragments and water shot into the air like a gigantic surf on a sea shore. By the next morning most of the flood was finished, but there were several smaller out-breaks on later dates. Farming lands were damaged, and many animals were killed. A visit to the crater after the eruption revealed heaped-up ash and great clefts 500 to 800 meters long, 40 meters wide, and 25 meters deep. Two great gorges had been eroded out of the glaciers by the floods.

This review will be continued. T.A.J.

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THE VOLCANO LETTER

A Weekly news leaflet of the Hawaiian Volcano Research Association

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No. 162 RELEASED WITHOUT COPYRIGHT RESTRICTION February 2, 1928

KILAUEA REPORT No. 836

WEEK ENDING FEBRUARY 1, 1928

Sectior of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

There has been nothing new observed at Halemaumau pit. The week has been stormy with northeasterly wind and rain. A little sliding from the walls was observed January 28, and sulphur is reappearing at the bottom of the talus E and SE. Today there is increased avalanching on the north walls of the pit. Thirty very feeble local earthquakes have been registered at Kilauea for the week. Microseisms have been normal.

LASSEN REPORT No. 15

Mineral, California, January 16, 1928

R .H. Finch, Associate Volcanologist

On December 21, 1927, the temperatures of Morgan's main hot springs varied but slightly from previous measurements of October. Some of the smaller springs near Mill Creek channel show increase of temperature and decrease of outflow. In one of these in October, some larvae of presumably a large fly were living in water at a temperature of 168 degrees F. In December there were still more larvae, and the temperature was 195 degrees F. On each occasion the larvae appeared very much alive.

At 8 a. m. December 30, R. H. Finch and O. H. Emerson left Mineral to try for an ascent of Lassen Peak. The cabin at Supan's solfatara was reached at 2 p. m. While the snow was not as deep as last year at a corresponding date, snowshoes were needed all the way. At Supan's (the 'Sulphur Works"), the snow was about four feet deep as compared with about six feet last year. All small streams showed less volume than a year ago. Owing to high wind and dense steam clouds, a satisfactory temperature reading of the largest steam vent at Supan's was not obtained, but indications were that it was as hot as when measured in October, 1927 (240° F.). Owing to heavy snow storm, no attempt was made to complete the ascent, and Mineral was reached on the return December 31 at 2 p. m.

AGE OF LASSEN CINDER CONE LAVAS

By AUSTIN E. JONES

The following preliminary notes on rough field application of the Chevallier method (Volcano Letter No. 45; Nature, October 3, 1925, p. 515) to Lassen lavas are of interest. The method assumes the magnetic declination of the outcrop to preserve the declination of the year of solidification. Mr. Finch writes that Mr. Austin E. Jones, assistant at the Lassen station, and he had found evidence of a source fissure in this flow marked by a NW-SE line of cones. Mr. Jones writes:

"August 30, 1927, I made rough experiments with a Forest Service surveying compass by Keuffel and Esser. (Lat. 40° 32′ N., Long. 121° 15′ W. Magnetic declination 19° E.). Loose lava blocks showed magnetic declinations varying up to 20° from the earth's field here. A traverse was run, checked by backsighting, to a large reddish outcrop on the east side of the lava beds between Butte Lake and Snag Lake. The magnetic field of this outcrop was found to have a declination of 14° 9′ east of north. This was close to a small red cinder cone on this edge of the lava beds.

"Traversing across the beds, a black rock was found giving declination 16° 7′ east of north. This had smooth surfaces and was part of a fissure eruption frozen in place. The ridge had precipitous sides 20 to 40 feet high, was 50 feet thick, and indicated a former fissure for more than 100 yards.

"Assuming equivalence to Redding, California, the nearest magnetic station, and extrapolating for the declinations at ten-year intervals 1810 to 1920 (Smithsonian Physical Tables), the older rock cooled between 1794 and 1797. Interpolating for the newer rock, it cooled in 1832. The probable error is within 10 years.

"If the lava underlying the Cinder Cone ash were examined, it should prove much older than either of the other two flows, and should help date Cinder Cone itself."

ALASKAN NOTES

Associated Press notices of December 7, 1927 (Seismological Dispatches of Georgetown University) say that many square miles of land are rising in upper Cook Inlet. Small boats here have gone aground in waters formerly deeper, and places formerly covered by several feet of water at low tide are now only reached by the highest tide, which has a range of 34 feet at Anchorage. (The same thing has been observed in eastern Japan.)

A notice of December 8 states that two volcanoes on Unimak had been smoking for ten days, after a season of unusual activity in the Aleutians. The smoke and vapor is stated to be "in comparatively small quantities."

Lake Kenai, 20 miles northwest of Seward, is reported to have been severely shaken by three earthquakes December 9. Cabins swayed, but no damage was done. Juneau experienced a rattling earthquake for 30 seconds at 10:02 a. m. December 31. T.A.J.

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No. 163 RELEASED WITHOUT COPYRIGHT RESTRICTION February 9, 1928

KILAUEA REPORT No. 837

WEEK ENDING FEBRUARY 8, 1928

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Halemaumau pit remains the same, no noticeable changes having occurred since the "activity" of January 11. There are occasional slides from the walls, sometimes large enough to send a little dust above the rim, but no large avalanches have been observed. A visit at 5 p. m. February 8 showed a few wall scars north, northeast, and east. There was very little steaming, but the wet steaming areas on the taluses were very conspicuous. The crack at the southeast trail, about 75 feet back from the rim, has widened.

Twenty-five earthquakes were counted on the seismograph records, of which 21 were very feeble and four were feeble. One of the later group, at 2:24 a. m. February 6, had an indicated distance to origin of 20 miles.

VOLCANO LORE

A very important book on geographical volcanology has just been published by Professor Karl Sapper, in charge of the Department of Geography at the University of Wurzburg. (Vulkankunde, von Karl Sapper, with petrographical introduction by A. Bergeat; 32 text leaves, 30 plates, and 4 colored maps; 1927, Engelhorn, Stuttgart.) Dr. Sapper is well known for his extensive studies of the statistics of eruptions and the distribution of volcanoes on the earth, and he has made extended journeys, especially among volcanoes of Central America and Iceland. This book is a readable text on the geographical distribution, significance, and forms of volcanoes on the one hand, and on the mechanism of volcanic eruption in its relation to mineralogy, physics, and chemistry on the other. No attempt is made to expound the mathematical aspects of the subject in relation to geophysical processes, but a very complete chapter on the history of volcanologic investigations is presented from the time of Aristotle to the days of such modern theorists as Daly and Joly.

The petrographical introduction by Dr. Bergeat presents current notions concerning the minerals in volcanic rocks, the classification of such rocks, and the distinction between the intrusives and the effusives. This chapter hardly goes beyond 19th century petrography.

Chapter II, on the gas-content of magma, is very modern, and contains a full discussion of the recent work on collection and analysis of gases and the studies of lava temperature which have been made by American investigators, especially in Hawaii, California, and Alaska.

Chapter III deals with the meaning of "magma" and a discussion of basaltic substratum in its relation to such conceptions of the motion of the crust of the earth as have been expounded by Daly, Wegener, and von Wolff. With reference to von Wolff's book on "Vulkanismus," Dr. Sapper expressly states that he does not attempt to double on the geophysical data set forth in von Wolff's book, but wishes rather to supplement it with a text which is expressly geographical.

The fourth chapter, on the "Nature of Volcanic Activity," is illustrated by descriptions and pictures of the wonderful eruptions of Santa Maria Volcano in Guatemala, which have come under the direct observation of the author, and also such recent happenings as the eruption of San Borin in 1926, the explosive eruption of Kilauea in 1924, and the remarkable Icelandic eruption of Katla in 1918. This chapter is necessarily one of the most important in the book, 90 pages long, and deals with the forewarnings and accompaniments of what are called eruptions, and then discusses these phenomena under the headings "Subaerial Eruptions, Subiacustrine, and Submarine Eruptions; and finally pure effusive outbreaks, which are treated somewhat more completely than other phases of the subjects because of the fact that they are less well known than explosive eruptions.

The history of Masaya is traced from the sixteenth century on, this Nicaraguan volcano having exhibited a lava lake, lava flows, gas outbursts, and many moderate explosive eruptions with ejection of ash, sand, lapilli, and scoria. Some of these were disastrous.

Sapper next describes Kilauea, treating in order the visit of Ellis in 1823, Daly's work in 1909, the work of Brun, in 1910, who obtained the impression of a continuous lava stream or spring passing under the pit, only a part of which was revealed by the opening. It should be said that Tempest Anderson, in 1909, had a similar notion about both Halemaumau and the volcano on Savaii, and it is interesting to note that Shepherd's recent suggestion of heat by lava circulation (Volcano Letter No. 157, December 29, 1927) contains the elements of a similar conception. Perret's work is given much attention by Sapper, who has evidently studied exhaustively his description of observations made in the summer of 1911, which were the beginning of what has since developed into the Hawaiian Volcano Observatory. Sapper points out that whereas W. L. Green considered the lava process a hydrostatic one, Daly added the conception of gas frothing to establish a convectional circulation, and then Perret added the notion of a continuous gas combustion, which has been carried still farther by Jaggar.

The next purely effusive volcano to be discussed is Matavanu, on Savaii, in the Samoan group, which developed a lava lake and sent a flood of basalt over several villages into the ocean for six years—1905 to 1911. The condition in successive years is reviewed largely from the data published by German observers, making the most complete condensed statement of the succession of events in that remarkable Samoan eruption which has yet appeared.

This review of Dr. Sapper's book, the first article of which appeared under "Volcano-Glacier Floods" in Volcano Letter No. 161, January 26, 1928, will be concluded next week. T.A.J.

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No. 161 RELEASED WITHOUT COPYRIGHT RESTRICTION February 16, 1928

KILAUEA REPORT No. 838

WEEK ENDING FEBRUARY 15, 1928

Sectior of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Conditions at Halemaumau show no change over last week. A slide from the east wall at 9:30 a. m. February 12 was reported. A visit at 11:30 a. m. on the 13th showed new fine material at the bottoms of the NE, N, NW, and SW walls. Measurements show pronuonced widening of the east rim crack from the 14-ton bowlder to the edge of the pit.

The number of earthquakes recorded on the Observatory seismographs during the week ending February 15 shows a very considerable increase over the numbers for the last few weekly periods. The records show 61 local earthquakes, all very feeble with one exception. The earthquake recorded at 10:06 a. m. on February 11 is graded as feeble, and may have been perceptible to some people in the vicinity of the volcano. The indicated distance to the origin of this shock is 28 miles. It has been reported as felt in Hilo. A few minutes after this earthquake there was a prolonged tremor lasting about four minutes. Aside from the fact that this perceptible earthquake and prolonged tremor occurred on the 11th, this day also had more than its share of the very feeble earthquakes, 16 being recorded during the 24 hours.

Microseismic motion was somewhat stronger than usual on the 9th and 10th. There has been practically no accumulation of tilt during the week.

VOLCANO LORE

(Conclusion)

It is pointed out that lava volcanoes occasionally produce intense explosive phenomena, and in this connection the explosive eruption of Kilauea in 1924 is carefully reviewed. Masaya is quoted as having behaved like Kilauea in ejecting pumice and breadcrust bombs at the end of a lava flow period.

The classification of eruption types is considered, as for instance in the four categories of Lacroix; namely, the Hawaiian, Strombolian, Vulkanian, and Pele types. The Hawaiian type has great fluidity of magma, seldom exhibits explosive paroxysms, and characteristically produces glassy black slags and fibrous spun glass. The Strombolian type exhibits basaltic magma, more viscous, resisting the explosion of gas, so as to make heavy explosions common, with ejection of magma bombs. The Vulkanian type has very stiff magma, which becomes fully solidified between explosions, so that when an explosion occurs cauliflower clouds are the rule, with ejection of angular stones and breadcrust bombs. In the Pele type, glowing clouds of dust are ejected explosively, with extreme restriction in the orifices, viscosity of the underground magma is at a maximum, and down-rushing torrents of debris are common.

Finally, the subject of phreatic or water-made explosions is treated, and in this connection there is cited an explosion that took place in the lava fields of Matavanu in May, 1908. A great opening was made in the lava field of 50 meters diameter, great quantities of mud were thrown out a hundred feet into the air. At first it was thought that a new crater had formed. The place was in the midst of the former town Saleaula, where there had been a stream of water. Similar explosions have been described in Mexico, in the Aegean Sea, and elswhere.

The aftermath of volcanic activity is next considered, as shown in the activity of solfataras, geysers, mud streams, gas craters, and the like. Next comes the genetic morphology of the volcanic edifices, and the destruction of the same through atmospheric erosion, chemical action, the work of the winds, and other processes.

The geography of active volcanoes is Dr. Sapper's specialty, and this book presents more fully than any of its predecessors the facts known concerning the distribution of volcanoes, the amount of materials ejected, the frequency of eruptions, and the geographical significance of these facts with reference to the activities of men and in relation to the other geophysical processes of the crust of the earth. There follows a condensed list of active volcanoes, and their several histories are treated by means of formulae, such as were instituted first by de Ballore. This treatment promises much for volcanologic science as it makes possible the condensation of a vast amount of information in a single letter. Thus Kilauea is described for the year 1822 "a^2", which means lava flows of greatest magnitude exceeding two cubic kilometers in bulk. So the letter "b" stands for ejection of ash, sand, lapilli, and scoria; "c" stands for ejection of deep magma, and "d" for explosive ash eruptions involving chiefly surface material.

The review of volcanology at the end of the book is eclectic, and covers with the same thoroughness and brevity that appears in all the other chapters the progress of volcano theory during the growth of civilization, and ends with the statement: "The most important goal for the future of volcanology is to obtain new collections of fact and make them available, for only by such procedure can a substantial basis be made for more satisfactory theories than have hitherto been evoked." T.A.J.

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No. 165 RELEASED WITHOUT COPYRIGHT RESTRICTION February 23, 1928

KILAUEA REPORT No. 839

WEEK ENDING FEBRUARY 22, 1928

Sectior of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

It has been a week of avalanching at Halemaumau pit, with the accompanying tremors recorded on seismographs. On February 17 at 8:30 a. m. and at 10:15 a. m. light avalanche dust clouds were seen NE and NW respectively. All the forenoon of the 18th the north wall was working, and dust clouds went up at intervals. At 1:30 p. m. there was a big dust cloud at the north, but when the pit was visited all was peaceful both that afternoon and the next day.

February 20 at 8 a. m. a large dust cloud rose at the north corner of the pit and hung in the air for 20 minutes. Other avalanche clouds followed, and a climax of sliding sent up such a cauliflower that the column of dust rose several thousand feet and was visible from Hilo, starting rumors of an eruption. Between 9:30 and 11 a. m. only minor avalanches occurred N and NW, and there were others in the afternoon. The pit floor was covered with red dust on its north side, and the big cloud had stained the outside Kilauea floor there also. On February 22 the roar of an avalanche was heard about 3 a. m., small slides were seen NE at 8:30 a. m., and on visiting the pit at 2 p. m. I found little motion. The bench at the west end of the big north sill is gone, and there is a break in the wall west of there. The northeast corner had been sliding, as shown by fresh avalanche debris.

During the past week there have been recorded on the Observatory seismographs 52 very feeble local earthquakes and one very feeble teleseism. The avalanching at the pit is probably responsible for many of the small tremors recorded on the seismographs. Avalanching began during the early hours of the 20th, apparently working to a climax at 8:57 a. m., when an avalanche occurred that made a definite record on the instruments. At 3:05 a. m. February 22 there was heard a roar of an avalanche, and a corresponding tremor appears on the seismogram.

The teleseism was very feebly recorded, a phase that may be the beginning of either the secondary or long wave is shown at 9:42 a. m. February 21. No estimate of distance could be made.

An earthquake reported felt in Hilo at 6:55 p. m. Febraury 15, is represented only by a very feeble tremor shown on the Observatory seismogram.

Tilt during the week has accumulaied modrately towards the SSW.

EXPLORATION OF WEST COAST OF HAWAII

The wheeled boat "Ohiki," described in Volcano Letter No. 156 December 22, 1927, traveled 30 miles to the beach at Ninole lagoon December 21, and successfully propelled itself in the water and landed itself on two beaches. It went forward and backward as required, taking up motor-car propulsion when the wheels touched bottom. The freeboard was raised, the paddle-wheels enlarged, an extension of the boat aft and water fenders were built, a winch and cable were mounted in the bow, and tests on Hilo beaches were made with increasing success January 17 and 20, and Febraury 4. A large outboard motor was added to the paddle-wheel propulsion, and a speed in water of four miles per hour was attained. The machine weighs 3,800 pounds, and is 22 feet long, with 5 feet beam, and overall width of 7 feet at the paddle boxes.

Thus equipped, an expedition was conducted to the west coast of Hawaii. The scientific party consisted of L. A. Thurston, President of the Hawaiian Volcano Research Association; T. A. Jaggar, R. M. Wilson, and T. Dranga, the personnel varying during the fortnight. The machine in the guise of an automobile truck left Kilauea Observatory February 8, the party of six camped at Waiohinu Homesteads that night, proceeded overland to Hookena, remaining there one day making beach and sea tests. We then went overland to Keauhou February 11, and camped there four nights, making sea trips south to Kaawaloa and Napoopoo, and north to Kailua, returning in each case overland. The boat was run with outboard propeller alone, paddles alone, and both together, and landings were made on rocks, pebble beaches, and sand.

Crew and load were reduced to four men, Thurston, Jaggar, Dranga, and Tahara, and a minimum of equipment, extra washboards were built amidships, and a voyage off the wild shoreline of northwest Hawaii was undertaken from Kailua to Kawaihae, a distance of about 40 miles. Camps on beaches were made at Makalawena, Kiholo, and Puako, and landings on other beaches at Kukio and Kalahuipuaa. Kawaihae was reached without accident at 11:30 a. m. February 19, the boat again became a truck for the steep hill road of 2,600 feet rise to Waimea, where the night was spent; and the next afternoon a land journey of 69 miles brought the party to Hilo via Hamakua and eastern Hawaii. February 21 completed the circuit of the island to Kilauea, making the whole journey by amphibian 208 miles by land and 58 miles by sea. Boat, engines, and running gear were all strong and in running order. The runs overland all made elevations of from 1,000 to 3,900 feet.

Geological features of interest observed on this journey were the lava cascades of Hookena, what appear to be fault cliffs at Hookena, Kaawaloa, and Keauhou, the 1801 flow north of Kaupulehu, mostly aa at its sea-front, the 1859 flow at Kiholo, where it is black pahoehoe of very fresh aspect, and the Kaniku flow in South Kohala, mostly aa lava equally new in appearance but of unknown date. At Puako are brown soils more than 10 feet deep, which appear to be freshet deposits, and a flat of this material heavily forested with algeroba extends more than three miles southwest of Puako, suggesting the yellow tuffs, of southern Kau, the glacial outwash of Mauna Kea near Humuula, and the North Kohala soils. The thickness of such deposits, remote from the volcanoes, more and more appears to suggest a glacial outwash origin rather than ashfall. (See Bull. Hawn. Volc. Obs'y October, 1925, p. 76.) T.A.J.

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No. 166 RELEASED WITHOUT COPYRIGHT RESTRICTION March 1, 1928

KILAUEA REPORT No. 840

WEEK ENDING FEBRUARY 29, 1928

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The notable avalanching described last week at Halemaumau pit came to an end, and during the current week very little has occurred in Kilauea Crater with the exception of a seismic flurry of felt earthquakes on February 26.

A visit to the pit at 2 p. m. February 25 revealed no motion of sliding from the walls, nothing new in the bottom, and more yellowish green sulphur stain near the base of the talus slopes east and southeast at spots which have exhibited such solfataric action for a long time past.

On February 26, after the two felt earthquakes of the night and morning hours hereinafter recorded, along with the southerly tilt which might have presaged subsidence in Kilauea, there was no conspicuous rock sliding to justify such a conclusion. Only one small fall of rocks that made dust occurred between 11:30 a. m. and 1:15 p. m. At 1:40 p. m. there was a slide at the north corner of the pit, and the niches in the wall northwest and north were working a little. On February 29 in the afternoon there was no change in the pit, but the eastern sulphur patches, after a spell of dry weather, appeared a little brighter colored.

There were 29 local earthquakes recorded by the Observatory seismographs during the week. Two of these were perceptible; the others were all very feeble. The two perceptible shocks occurred during the morning hours of February 26, the first one at 1:41 a. m. is classed as slight, and the second one, which came at 7:16 a. m., is classified as of moderate intensity. The first awakened a number of people from sleep, and is reported by some as accompanied by an earth noise. The second was of greater intensity than the first, and was felt as a single jolt by nearly everyone in the vicinity of the volcano, even though some were on their feet and walking at the time. A single bursting noise came with it. This second shock in its first movement dismantled both seismographs, so that after the first movement nothing was recorded till the last small dying out tremors, which show on the record after the instruments were set to rights three minutes later. When the pen was again set on paper, there was a definite tilt of about two seconds of arc disclosed, probably representing an actual tipping of the ground remaining from the disturbance of which the earthquake was the indication. The preliminary movement of both of these shocks was toward the southwest, in the direction of Halemaumau, and owing to the total lack of preliminary phases, both shocks were apparently strictly local.

Microseisms were somewhat stronger than normal on the 26th. Accumulated tilt during the week is strong toward the south, being due almost entirely to the sudden occurrence of south tilt during the second perceptible shock, as noted above.

LASSEN REPORT No. 16

Mineral, California, February 8, 1928
R. H. Finch, Associate Volcanologist

On Saturday, January 21, 1928, a rather sharp earthquake shock was plainly felt at Mineral. Within a few minutes two more smaller shocks occurred. All appear to be Lassen earthquakes. Sixteen inches of snow fell January 22-23, making it necessary to plow out the road.

In the library of the California Academy of Science an account of the last lava flow at Cinder Cone, Lassen Park, dates the flow during the winter of 1850-51. Other notes say January, 1851. According to the field evidence, there is nothing to refute the date 1850-51.

Newspapers have reported a new geyser at Calistoga. Examination showed in a new drilling, when the steam-producing depth of adjacent wells was reached, a temperature of 230° F. was measured. Before drilling was resumed, the well blew off and steam rushed up around the casing and eroded a crater before the well was cooled off with cold water so that the casing could be cemented in. Now the well is capped, and the steam supply is used in one of the bath establishments. The old, much advertised geyser well has been drilled deeper, and now it spouts about every minute instead of every four minutes.

On February 8 at 7:55 a. m. at Mineral there was a perceptible earthquake accompanied by loud roaring.

EAST INDIAN VOLCANO BULLETIN

A new monthly publication in English, the Bulletin of the Netherlands East Indies Volcanological Survey, was begun in November, 1927. It will be sent to those interested by the Survey in question, Bandoeng, Java.

There 58 volcanoes in the East Indies which have been in eruption since 1600 A. D., and 45 others in fumarolic activity. Sixteen volcanoes have erupted in Java. Observatories are in operation on seven Javanese volcanoes. The research carried on concerns seismologic, meteorologic, temperature, and chemical measurement, and depth soundings in crater lakes. Each Bulletin reviews the volcanic phenomena of the month, lists publications, and No. 2 contains an interesting table and map summarizing all the volcanic activity of the East Indies. T.A.J.

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No. 167 RELEASED WITHOUT COPYRIGHT RESTRICTION March 8, 1928

KILAUEA REPORT No. 841

WEEK ENDING MARCH 7, 1928

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On March 4 at 3:10 p. m. there was a slide in the lower northeast corner of Halemaumau. On March 6 at 11:25 a. m. and again at noon thin dust from slides rose from the north corner. On March 7 at noon the pit was without change, rocks dribbled occasionally from the north wall, and a slide at 12:20 p. m. fell at the south.

The Observatory seismographs have recorded only nine very feeble local earthquakes during the week ending March 7. In addition to these there were two pronounced spells of continuous tremors, 3:04 to 3:14 p. m. on March 1, and 4:10 to 4:23 p. m. on March 2.

Microseisms have been slight. Tilt during the week shows only a slight accumulation towards the SW.

NEW KRAKATOA ERUPTION

Just after the December solstice Krakatoa, in the Straits of Sunda, between Java and Sumatra, broke into activity. Krakatoa is the volcano which in 1883 started activity in May and reached one of the greatest explosive climaxes in history in August, blowing away the side of the island, and making a flood wave in the sea which drowned some 35,000 people on the neighboring shores of the strait.

A Reuter dispatch of January 5, 1928, states that Dr. Stehn, head of the Java volcanological service, had led an expedition to Krakatoa and reported the active crater to be under water, ejecting columns of water, steam, lava, and ashes 250 to 650 feet high. The activity on that date had greatly increased within the preceding 24 hours. A press dispatch of January 26 stated that an eruptive outburst occurred that afternoon, that the volcano was almost submerged in the sea, and that its activity had been increasing during the preceding few weeks. A message of January 28 stated that the eruption had been violent in recent days, but was apparently dying out, with submarine rumblings still persisting, and only the exhalation of fumes and gas for the preceding 12 hours.

Details reported in the Paris "Times" of January 24 are that the refugees from the southwestern coast of Java were coming into Batavia, that the government had sent a naval vessel for rescue and investigation, and that an enormous column of steam and fire was rising 200 to 300 yards above the top of the crater. Terrifying rumblings were heard under Sunda Strait on all sides of the Krakatoa island-ring. Natives were said to be standing in terrified awe, assembled in groups along the coast of Java and Sumatra, panic had caused the inhabitants of Coneet Bantam in southern Sumatra to flee into the high regions inland, the men venturing back to the coast only during daylight, and local insurance companies have increased their rates for volcanic insurance.

On January 25 it was reported that the government was broadcasting warnings to the population and that the main crater had been building itself up to the surface of the sea for the past five days.

"For the past five days 300 eruptions a day have taken place between 8 o'clock in the morning and noon. A tenth of these are more than 300 meters high. The highest column of burning ashes on January 21 reached 1,200 meters into the air."

Then follows an obscure statement to the effect that if the three active craters became closed, or if the crater became built up above the ocean, an explosive disaster might occur. T.A.J.

LONDON EARTHQUAKES

A curious note in the "Evening News" of London, England, March 9, 1927 ("When London Quakes," by Mary Morrissey), states that an earthquake occurred in London in April, 1580, which knocked pieces off St. Paul's Cathedral, set the church bells ringing, caused people to rush out of the theaters and taverns, and led Queen Elizabeth to order a special prayer against earthquakes to be used nightly by every household.

In 1692 an earthquake in London filled the streets with terrified crowds. On February 8, 1750, there was a sharp shock, accompanied by a roar, thought to be the blowing-up of powder mills. Just a month later another earthquake broke crockery, caused bells to ring, made the dogs howl, and fish were said to jump clean out of the water.

Then as now quackery in seismological forecasting was rampant, and a weak-minded soldier foretold a third and worse earthquake to occur the night of April 5. On the evening of that day there was a fashionable exodus, the roads out of London were thronged with vehicles, some contenting themselves with spending the night in their coaches in Hyde Park, with cards and candles to pass the time, while others went "to an inn 10 miles out of town," says Horace Walpole sarcastically, "where they are to play brag until 4 o'clock in the morniing and then come back, I suppose, to look for the bones of their husbands and families under the rubbish."

But the earthquake never came, and the soldier was shut up in a mad-house. T.A.J.

AN EARTHQUAKE IN PARLIAMENT

A curious interlude in the New Zealand Parliament (N. Z. Herald, 12th October, 1927) occasioned by an earthquake, occurred October 12, 1927, when a seismic spell began, leading to a violent shock October 15 at New Plymouth and a number of shocks November 8 and 9 in northern New Zealand. At an evening session of the Parliament at Wellington, a sharp earthquake shook the building, produced a buzz of murmuring that almost drowned the voice of the Member speaking, and caused an immediate evacuation of the galleries. Later a debate was just starting when the electric lights failed. Pending the arrival of candles there were vain attempts to relieve the gloom with song. With candles business was resumed, then the lights flashed on again. Members had hardly settled down to business, however, when the lights failed a second time, and the leader of the opposition suggested adjournment. Discussion of this was arrested when the lights once again appeared with their usual brilliance. T.A.J.

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No. 168 RELEASED WITHOUT COPYRIGHT RESTRICTION March 15, 1928

KILAUEA REPORT No. 842

WEEK ENDING MARCH 14, 1928

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

On March 10 at 11:30 a. m., dust arose from slides at Halemaumau on the northeast corner of the pit. At 3 p. m., and again between 4:25 and 5 p. m., several slides occurred, those during the last period being observed at the edge of the pit. The falls of rock were from places halfway up the cliff on the northeastern and northwestern walls, sometimes occurring simultaneously at two distinct places, and obscuring the pit with thin dust clouds.

On March 13 there were avalanches during the forenoon which sent up dust clouds chiefly at the northeast corner of the pit, and about 1:50 p. m. a prolonged roar of an avalanche was heard at the Observatory, a thick cloud of dust rose at the northeast so as to cut off the view of the pit, and this gradually thinned and disappeared in the course of a half-hour. At 3 p. m. there was more dust from the same place.

On March 14 thin dust clouds rose occasionally from the pit, and a new scar was observed from Uwekahuna Bluff on the southeast wall of Halemaumau not far below the upper edge of the pit.

The seismographs at the Observatory recorded 17 very feeble earthquakes during the week ending March 14. There were two that had the indicated distances 23 and 9 miles. On March 13 the big avalanche in the pit caused a decided tremor to be recorded at 1:53 p. m.

Moderate NE. tilt has accumulated during the week.

WORK OF THE SECTION OF VOLCANOLOGY 1927

In 1926 various phenomena in Halemaumau indicated the probability of the return of quiet lava through the bottom talus, and this happened July 7, 1927. The end of 1927 showed no reaction of subsidence, and hence it was expected that at decreasing intervals lava would return. That eruptible lava was close to the bottom of the pit was verified January 11, 1928, when a landslip forced liquid melt to come up through cracks.

The routine of the Hawaiian staff involved new features as follows: Compiling of Lassen and Kodiak reports, measuring seismograms from Kodiak, study of tide gauge records, supervision of a machine shop, and increased precision in measurement of horizontal and vertical movements at Kilauea Crater. The staff operated the Uwekahuna Museum until December, when it was turned over to the National Park Service. Field work has included exploration of Mauna Loa trails, continuation of drilling for temperature measurement, tests of a special motor boat for shore exploration, establishment of the Kodiak Station, and exploration of the Aleutian Islands.

Additions to the plant in Hawaii were a new seismograph and its cellar in Hilo, motor car radio receiving sets for time signals, and various machines. The Uwekahuna Observatory and Museum was finished in April and opened to the public, and this establishment forms an addition to the scientific equipment in that a high-class Japanese three-component seismograph has been added to the recording mechanism of the Observatory at a point nearer to the pit than ever before.

Collaboration in Hawaii has been largely through the Research Association, as will be detailed next week. The Alaskan Branch of the Geological Survey has cataloged and stored the collection of Aleutian specimens, and has furnished valuable cooperation in Alaskan volcanology. The topographic maps of Hawaii, now nearly finished by Captain Burkland's topographers, are invaluable as a basis for extending geologic and volcanologic surveys. The Bishop Museum has published an excellent bulletin on the geology of Kilauea by Dr. Stone. The National Park Service has given every assistance, and is now relieving the Observatory of labor and expense in operating for the public service the Uwekahuna Museum. The Coast Survey is doing work closely linked to volcanology in precise triangulation, leveling, magnetism, gravity measurement, hydrography, and computations of theoretical isostasy. The Observatory has furnished the Coast Survey with an Hawaiian seismograph for use at Sitka, Alaska. The National Geographic Society has authorized Dr. Jaggar to explore the Pavlof Volcano group on the Alaskan Peninsula in 1928, and will finance the expedition. The motor boat amphibian, subject of construction experiments and field tests in Hawaii under the Research Association, is a collaborative effort coordinate with the National Geographic project. The Coast Guard furnished invaluable service in transporting the Volcanologist to Attu Island and back to King Cove, and in offering every facility for exploration and for developing a collaborative Government project for Dutch Harbor. The United States Army, through Major General E. M. Lewis, in command of the Hawaiian Department, has assisted the Observatory with the loan of important equipment, and both the Army and Navy have taken great interest in the possibilities of assisting volcanology with airplanes.

It is hoped that in the future several scientific bureaus of the Government will make a united effort, from Dutch Harbor as a base, to map the Aleutian Islands, explore their natural resources, and conduct geophysical work in that land of abundant earthquakes, remarkable weather phenomena, unusual tides, and superb transitions in geological process.

Outstanding events of the year, in addition to the volcanic activity above noticed, were the opening of the Uwekahuna Observatory by the Honorable Hubert Work, Secretary of the Interior, on April 19; and the exhibition by the Observatory with the assistance of the Hilo Chamber of Commerce of a working seismograph, motion pictures, and photographs of active eruptions, at the Hawaiian Territorial Fair in Honolulu in September.

Associate Volcanologist R. H. Finch discovered spells of seismic activity at Lassen Park, explored the steam district northwest of Calistoga, measured temperatures of hot vents, mapped recent lava flows and faults, and investigated earth movements at Supan's Springs by installing a line of stakes at the sulphur bank there. The Kodiak seismograph station has been operated efficiently by Mrs. E. M. Floyd. An eruption of Mageik Volcano, in the Katmai group, occurred in August, and a heavy Alaskan earthquake in October.

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No. 169 RELEASED WITHOUT COPYRIGHT RESTRICTION No. 168

KILAUEA REPORT No. 843

WEEK ENDING MARCH 21, 1928

Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Two visits to Halemaumau this week disclose no important changes. Exceedingly dry weather has been prevalent, and there has been a minimum of slides in the pit. At 4:15 p. m. March 18 a few stones were heard falling, and the south cone was steaming freely. Considerable debris had fallen on the east floor from slides of the preceding week. The southeast sulphur spot was entirely obliterated, and the east sulphur spot was dimmed. Large new scars showed on the face of the northeast wall, and there were streaks made by slides north-northeast. The rim has receded very noticeably at the 14-ton bowlder. During 15 minutes just before 10 a. m. today not a sound was heard, and steaming was very slight at all vents. The whole pit interior appeared very dry, dusty, and peaceful.

During the week ending March 21 there were 20 very feeble local earthquakes and one teleseism recorded on the instruments of the Observatory.

The record of the teleseism showed fairly definite phases, the preliminary being at 6:40:26 p. m. on March 15, the secondary coming at 6:47:59 p. m., and the long wave beginning at 6:56:03 p. m. The beginning of the preliminary wave was of the gradually emergent type, so that the distance indicated by these times of arrival, 3,685 miles, is probably slightly too small. This earthquake was also well recorded on the seismograph in Hilo. At this station the preliminary wave showed a more definite beginning, and the somewhat greater indicated distance of 3,720 miles is probably more nearly correct.

The accumulation of tilt during the week has been slight toward the SW.

WORK OF THE RESEARCH ASSOCIATION 1927

In the course of 1927, the Hawaiian Volcano Research Association has accomplished through the Hawaiian Volcano Observatory the following:

(1) Construction and opening of the Uwekahuna Observatory and Museum, now serving the public through the National Park Service.

(2) Establishment, manning, and maintenance of the useful instrument shop.

(3) Manufacture and output of three seismographs, two now in operation at Kodiak and Hilo, and one shipped to the U. S. Coast and Geodetic Survey for use at Sitka, Alaska.

(4) Continuation of boring experiments on the floor of Kilauea Crater, so that in all 34 holes for measurement of temperature have been drilled.

(5) Continuation of seismometric recording at Hilo and at Kealakekua in West Hawaii, and establishment of a new station, equipped with a three-component instrument of Japanese manufacture, at the Uwekahuna Observatory on the high bluff west of Kilauea Crater.

(6) Continuation of publication of the Monthly Bulletin of the Observatory and of the Volcano Letter.

(7) Building and testing a wheeled boat.

The Uwekahuna Observatory is a success, and travelers find in the motion pictures, the exhibits, the explanations, and the splendid view a compensation for what is missing when the lava pit is inactive.

For the winter of 1927-28 the drilling apparatus is laid up, and the work connected with temperature measurements on the holes and points located and on the cracks adjacent to the 132 surveyed stations of the Kilauea floor.

The seismological registration done by the stations under the Research Association is incessantly improving as to quality of instruments and time service, and it will not be long before all stations have instruments of the same quality as those at the Observatory.

Under the Research Association, F. Y. Boyrie has worked continuously from March 1 to December 31 as machinist in the shop equipped here by the Association. He has constructed seismographs, repaired instruments, set up the electric plant for projection apparatus at the Uwekahuna Observatory, installed all the machinery in the shop itself, kept the drilling apparatus in order, and assisted by F. F. Fischer and S. Oda, has built the wheeled-boat. Professor Paul Kirkpatrick was employed by the Association from July 1 to August 14 to act as lecturer, in cooperation with the National Park Service, at the Uwekahuna Observatory, and to carry on seismological research. He devised special projection for the motion pictures at the Territorial Fair, and had charge of the Observatory's exhibit at the Fair. Captain R. V. Woods and J. B. Albert continued to do good work as seismograph operators in Kealakekua and Hilo, respectively. The station at Hilea, under A. D. Williams, was temporarily discontinued on May 15 until such time as a better istrument is available.

The Hawaiian Volcano Research Association has added to the plant complete tool equipment of a power machine shop, including gasoline engine, automatic hack-saw, large and small machine drills, a machine grinder, a circular-saw table, and a forge. A large lathe was obtained and added to our shop. New parts for this lathe were obtained through the Government in October, and this tool, supplementing the small Barnes lathe and the still smaller jeweler's lathe already on hand in the Observatory, equips the establishment with turning tools sufficient for all present need. T.A.J.

STATION NOTES

On March 15 Dr. T. A. Jaggar left this station, beginning his trip to Washingtoon, D. C. In Washington on April 5 he will deliver a lecture before the National Geographic Society, and will then start for Alaska as leader of the National Geographic Pavlof Volcano Expedition.

Mr. F. Y. Boyrie terminated his services as machinist for the Observatory on March 15. In his place Mr. Tai On Au has been engaged to continue the construction of other units of the Hawaiian type seismograph and to carry on the miscellaneous machine work of the station. Mr. Au is a resident of Hilo, and comes to the Observatory after three years training in the machine shop of the Smith-Hugh Vocational Training School. R.M.W.

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No. 170 RELEASED WITHOUT COPYRIGHT RESTRICTION March 29, 1928

KILAUEA REPORT No. 844

WEEK ENDING MARCH 28, 1928

Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Conditions at Halemaumau remain practically the same as last week, except a slight increase of steaming due to recent light rains. There were three floor vents emitting steam this morning, two of which mark the sites of two of the lava fountains of last July. The vent of the small twin fountain, at the center of the pit floor, had the densest vapor. There has been no avalanching and very little sliding. Two or three small slides were observed March 24 and 28.

Crack measurements taken on the 24th show varying differences over measurements of February 13 of from seven-eighths of an inch to three and three-quarters inches. Four of the original 15 marked measuring points along the east rim have become unavailable through caving or becoming too wide to be reached.

During the week ending March 28 the Observatory seismographs have recorded 12 very feeble local earthquakes and one teleseism. The teleseism is recorded on March 21, its preliminary wave beginning at 5:56:50 p. m., the secondary wave at 6:04:39 p. m., and the long wave at about 6:14 p. m. The indicated distance is 3,875 miles. A notice from Lieutenant J. H. Peters, in charge of the field station of the U. S. Coast and Geodetic Survey in Honolulu, gives as the preliminary determination of the epicenter Lat. 28° N., Long. 96° W. By the same authority, the teleseism mentioned in the Kilauea Report last week, which occurred on March 15, was in Lat. 23° S. and Long. 170° E. These preliminary notices are obtained from the records of different observatories, assembled and computed through the cooperation of Science Service, the Jesuit Seismological Association, and the U. S. Coast and Geodetic Survey.

Tilt has accumulated only very slightly to the south during the week.

REVIEW OF HAWAIIAN EARTHQUAKES OF 1927

The total number of seismic disturbances recorded on the seismographs of the Hawaiian Volcano Observatory during the year 1927 is 1,168. This number includes 19 teleseisms, of which seven were decipherable as to distance.

The remaining local earthquakes number 1,149. These grouped by their intensity are as follows: 1,121 were very feeble, 16 were feeble, 9 were slight, and 3 were moderate. All of the slight and moderate shocks and five of the feeble shocks were reported as perceptible, being 17 in all for the number of earthquakes felt here during the year.

The following table gives the number per month of the local shocks for 1925, 1926, and 1927. The numbers for 1925 and 1926 have been included here for the sake of comparison, and were copied directly from Volcano Letters Nos. 54 and 112, respectively, in which the earthquakes for these years were reviewed.

Month	1925	1926	1927
January	94	54	85
February	94	32	46
March	79	68	63
April	70	761	68
May	83	43	82
June	51	56	45
July	109	101	72
August	94	254	75
September	102	240	103
October	50	62	76
November	48	46	191
December	48	61	243

The number in April, 1926, is swelled due to the shocks accompanying the eruption of Mauna Loa. The very feeble earthquakes here counted are probably not all true earthquakes. Many of the records are too faint to distinguish the character of the shocks. While most of them are real earthquakes, some are caused by avalanches in the pit, some are the waxing to maximum amplitudes of a more continuous tremor of the harmonic type which may be present, but for the most part may be too feeble to record, some are volcanic spasmodic tremors, and a few during February and March, 1927, were probably caused by blasting in the vicinity.

There are certain features of interest that stand out during the year 1927. The regular recurrence of times of increased local seismic activity cannot be set aside as accidental. These crests of activity come at intervals of about two weeks, near the times of the first and last quarter phases of the moon. This feature has been mentioned in Volcano Letter No. 143, September 22, 1927. The records for October, November, and December continued to show the same effect.

On March 20 the heaviest earthquake of the year duplicated the one of March 19, 1926. It is a coincidence perhaps that these two big earthquakes should fall almost on the same day of the two years, though the proximity of the equinox may have been the inspiration in each case. The outbreak of lava in July was oddly enough almost wholly unaccompanied by seismic activity. There was one perceptible earthquake just after the appearance of lava differing in no way from other shocks that occurred during the year. The only definite seismic accompaniment was the presence of harmonic tremor during the first day of the eruption of lava.

A group of seven perceptible earthquakes, with two more almost strong enough to be felt, occurred in the period between July 24 and August 3. This is a large share of the heavier shocks for the year, and their grouping within these few days undoubtedly has some significance. On December 3 and 4 there occurred an extraordinary series of spasmodic tremors clearly volcanic in origin. In this series there were about 75 individual tremors which have all been counted in the total number of earthquakes for the month, swelling that total considerably above its normal amount.

R.M.W.

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No. 171 RELEASED WITHOUT COPYRIGHT RESTRICTION April 5, 1928

KILAUEA REPORT No. 845

WEEK ENDING APRIL 4, 1928
Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Scars on the Halemaumau walls indicate that slides have occurred at various places. The largest of these is at the southwest, and extends the full height of the wall. Appearances seem to indicate that great rim blocks have tumbled down the face of the wall, gathering material to such extent as partly to bury the southwest cone. Just as the cone of July, 1924, was buried by debris of the southwest talus, it now appears that the big cone of July, 1927, is to share the same fate.

During the week ending April 4 the Observatory seismographs have registered 20 very feeble local earthquakes and one teleseism. Two of the local earthquakes were of the protracted tremor type, one beginning at 10:26 a. m. on the 29th being 12 minutes long, and the other beginning at 9:29 p. m. on the 31st being three minutes long. One earthquake at 5:38 p. m. on the 28th was registered here as very feeble, but was perceptible in Hilo. The teleseism is very faintly recorded, the preliminary wave beginning at 6:45:38 p. m. without other distinguishable phases.

Tilt has accumulated during the week moderately toward the ENE.

EARTH MOVEMENTS IN JAPAN

The great Kwanto earthquake of September 1, 1923, is well known as a classic among the great earthquakes of the present age. Accurate surveys existing before its occurrence have fortunately made possible the discovery and study of earth movements of a most surprising magnitude resulting from it. In 1925 a report published by the Imperial Earthquake Investigation Committee showed that the floor of Sagami Bay had suffered serious deformations. Depressions of the bottom of the bay amounting to as much as 400 meters, and elevations as great as 250 meters, were shown to have occurred. In a very general way the depressions and elevations exist in alternate parallel belts as if caused by a wrinkling of the original surface.

There has recently been published (Proceedings of the Imperial Academy, Tokyo, February, 1928, Vol. IV, No. 2) three papers of considerable interest dealing with additional information on the effects of this great earthquake. The elevations and depressions above mentioned seemed so great and out of reason that a careful study was made of the data used in obtaining them. Possible errors in making the soundings were discussed, and while it is admitted that some of the values showing extreme change may be improbable, yet for the most part the differences originally obtained seem unassailable.

By re-triangulation a study has been made of the horizontal movements in connection with this earthquake. An analysis has been made to show where the greatest horizontal stresses existed in the earth's crust. This analysis tends to show that the maximum horizontal compressional stress accumulated some distance to the northeast of Sagami Bay; yet the maximum effects appear to have occurred in the bay itself.

The suggestion is made that the land areas are more rigid than the area of the earth's crust underlying Sagami Bay. Thus under the horizontal pressure shown by the triangulation, it is perhaps possible that the entire land block in the region of the greatest stress moved forward, the force expending itself in crumpling the more plastic crust under the bay. This idea is supported by the fact that no visible faults were made on the land area, indicating that whatever motion in which the land block took part, it moved as a whole. The relatively small horizontal displacements shown by the triangulation may have easily occasioned the much larger vertical displacements in the wrinkling of the bottom of the bay. This may be easily illustrated by noting the height to which a piece of paper will buckle up from a flat surface if its ends are forced only slightly nearer to each other.

It therefore seems that the area beneath Sagami Bay is a weak spot in the earth's crust which was compressed and deformed by the earth stresses accumulated in the more rigid surrounding regions.

There are also two other papers in the same publication dealing with certain interesting cases of land elevation and depression due to other earthquakes, detected by re-running spirit level lines. A tabulation is given showing the results of re-leveling over or near the epicenters of eight different earthquakes where changes of elevation were clearly shown. The Kwanto earthquake above discussed produced changes of elevation on land amounting to as much as two meters, which is the greatest amount shown in the list.

Much of this re-leveling over old lines was done several years after the original leveling was completed. The results may be questioned, therefore, in that the changes disclosed may not all be due to the single greatest earthquake occurring in that interval of time. Slow tiltings are known to exist, and the changes may be due in part to these slow motions instead of to the one earthquake suspected. There is one interesting case quoted, however, wherein the vertical changes discovered can be definitely attributed to a given earthquake. The running of a spirit level line was in progress when a sharp local earthquake occurred back on part of the line only three months completed. The portion of the line passing over the epicenter was immediately re-run. It was discovered that over the epicenter the earth's crust had bulged up an amount of over 2 cm. in a distance of only 4 km.

That motions of the ground are not all sudden and accompanied by earthquakes is shown by the last paper, dealing with a spirit level line run over older work after an interval of 35 years. In the region covered during this period of time there were no major local earthquakes. The line crossed several land blocks surrounded by known fault lines, and it was found that the blocks had suffered a general depression. In each case the west side of the block had fallen more than the east side. In one block the west side was depressed 9.4 cm., while the east side showed a depression of only 3.8 cm. In the adjoining block the west side was down 9.6 cm., while the east side had been elevated 0.4 cm. These two land blocks are being independently tilted towards the west.

The study of such earthmovements gives information that is valuable in the prediction of earthquakes. For the most part the cases above are movements that took place at the time of occurrence of earthquakes. But if slow movements can be detected, and their mechanics correctly interpreted, it may be possible with increased knowledge along these lines to tell where earth stresses are accumulating, and to so predict an earthquake before the actual fracture takes place. Work is being done along these lines in California and Japan, so that in the future it may be possible to detect the development of potential earthquakes.

R.M.W.

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No. 172 RELEASED WITHOUT COPYRIGHT RESTRICTION April 12, 1928

KILAUEA REPORT No. 846

WEEK ENDING APRIL 11, 1928

Section of Volcanology, U. S. Geological Survey:

R. M. Wilson, Temporarily in Charge

Halemaumau on April 6 at 9 a. m. was comparatively quiet, although the southwest wall was still dusty from slides of the preceding week, and the south and center cones and other vapor vents were steaming profusely. On April 7 the pit began a spell of active avalanching, when at 7:07 a. m. a very prolonged roar of falling debris was heard by occupants of cottages in the vicinity of the Observatory. Reference to the seismogram showed that this avalanche set up strong tremors lasting two minutes. About five minutes later a thin cloud of dust arose and rolled along the crater floor and up the north ledge. At 7:14 a. m. there was another avalanche roar, and thick dust ascended. Other large slides followed from time to time, also evidenced by rising dust clouds. The slides appeared to come from the north and northwest walls.

On April 8 there were slides NE. at noon, and at 3:15 p. m. the southwest wall was still dust-coated. Rock falls were heard N., NW., and SW. On April 10 thin white dust was seen at intervals over the north corner of the pit. On April 11 the pit was free of steam and quiet, except for a dustless slide of rocks in the north corner at 8:50 a. m., a few invisible falls of stones from different walls, and a slide at 11:25 a. m. at the NW. New debris lay on the NW. talus.

A visit on April 1 to Mauna Iki, the Kau Desert flow of 1920 from Kilauea, showed that there are still several spots hot enough to ignite dry sticks.

The number of local earthquakes recorded during the week ending April 11 was 24. All of these were very feeble with the exception of one at 7:13 a. m. on April 7. This one was still a feeble shock, but larger than the others and almost strong enough to be perceptible. It followed by six minutes the heavy avalanche above described, and more rocks were heard to fall at about the time of the shock.

The acumulation of tilt during the week was moderate toward the WSW.

On April 2 Messrs. G. E. Josephson and W. E. Bonsey, of the faculty of Kamehameha Schools, Honolulu, walked to the Rest House on Mauna Loa, the following day going to the Crater of Mokuaweoweo and returning to Kilauea. This trip to the top and back within two days is somewhat of an accomplishment. They reported steaming in the southwest end of the crater, with a suggestion of yellow sulphur stain and fume. Conditions in Mokuaweoweo, however, are probably normal.

SUN SPOTS AND VOLCANIC ACTIVITY

Various correlations have been attempted between recurrences of volcanic activity and other phases of earth condition. In Volcano Letters No. 94, Octoper 14, 1926; and 129, June 16, 1927, it was suggested that there is a definite connection between fluctuations in the rate of rotation of the earth and latitude variations with changes of volcanic activity. The effect of lunar phases and solar season has been many times discussed. These causes have their effects on volcanic and seismic activity through possible stresses set up in the earth's crust due to earth tides or to slight periodic expansion and contraction of the earth as a whole.

In "Technology Review" of January, 1928, Dr. Charles G. Abbot gives an interesting description of his experiences and general results in the study of the sun. The sun's control of the earth is manifest in several ways, and it may easily have a periodic effect on volcanic activity through its radiations as well as through its gravitational attraction. Of particular interest is the 11-year cycle in the waxing and waning of sun-spot numbers. Perhaps there is a correlation between this sun-spot cycle and the 11-year cycle of volcanic activity that has been suggested as existing at Kilauea. The volcanic cycle still needs some years of observation before the fact of its existence is made certain and its phase and period fully determined. Yet a rough histrocial review detects years of high activity about 1896, 1908, and 1919. High sunspot years came about 1918 and will again be due about 1929.

The variation of solar radiation also shows a shorter cycle of a little over 25 months in period, which probably produces response in conditions on the earth. These changes in solar condition have already been found to affect climate and weather, and their study is proving useful to meteorology. Volcanology may perhaps also derive benefit from the investigation of these changes in the sun's radiation .

Such far reaching problems as earth rotation, latitude variation, earth tides, sun-spot variations, isostatic adjustment of erosion, long-period climatic changes of the earth's atmosphere, and periodic phases of volcanic activity, are delicately inter-related, so that the study of each involves consideration of the others.

NOTICE TO NON-SUBSCRIBERS

The Volcano Letter mailing list is being revised to effect as much economy in mailing as possible. We are very glad to send the Volcano Letter free to libraries of educational institutions, professors of geology, etc., but we suspect that there are recipients of this publication that may no longer be interested in it. We shall be deeply appreciative if those no longer desiring it will please send notice to the Hawaiian Volcano Obseravtory, Volcano House, Hawaii.

TITLE PAGE AND INDEX

Those who have saved their copies of the Volcano Letter for binding will be interested to know that the Hawaiian Volcano Observatory is preparing three annual title pages and indexes of the articles appearing in the issues of 1925, 1926, and 1927. These will be printed and mailed in the near future.

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No. 173 RELEASED WITHOUT COPYRIGHT RESTRICTION April 19, 1928

KILAUEA REPORT No. 847

WEEK ENDING APRIL 18, 1928

Section of Volcanology, U. S. Geological Survey:

R. M. Wilson, Temporarily in Charge

The volcano continues inactive and without phases to indicate the possibility of reappearance of live lava in the near future. Visits to Halemaumau were made on the mornings of April 13, 16, and 18. On the 13th the pit was quiet and dry, and there was very little steam. Stones were heard rolling occasionally on the north wall, and there were one or two small dusty slides atop the west end of the northeast sill. The most noticeable fumarole was at the center of the southwest talus. On the 16th the wind was too strong to hear sounds within the pit. There were indications of ground cracking in the vicinity of the south station. On the 18th no changes were noted, except a quantity of dark-colored bowlders scattered down the south talus. The two 1927 cones were steaming. The yellow stain at the base of the east talus seemed deeper, but the south and southeast sulphur spots have not yet reappeared.

During the week ending April 18 the Observatory seismographs registered 11 local earthquakes. All were very feeble with the exception of one which occurred at 1:43 a. m. on April 16. This one was slight, but was felt by many people in the vicinity of the volcano. Its origin is shown to be five miles from the Observatory, the direction suggested being SE.

Slight ENE. tilt has accumulated during the week.

THE CHAIN CRATERS ROAD

The Hawaii National Park on April 15 opened its new road along the chain of craters southeast and east of Kilauea. Work on this road was commenced in April, 1927, and its cost as now given to the public is $158,083. It starts from the Volcano House-Halemaumau road at a point one-half mile east of the Summer Camp, and follows in general the route of the old Cocktail Trail, crosses the old Keauhou Road, and continues on through the general region traversed by the Kalapana Trail, ending at the southwest side of Makaopuhi Crater. Its length is 6.95 miles. It is throughout a first-class, modern, gravel surfaced, automobile highway.

The craters from which the road takes its name are in a sweeping curve along the Puna Rift line, and give evidence of both ancient and recent volcanic activity along that crack in the mountain structure. Out-pourings from this same rift line where it curves still farther east and northeast beyond Makaopuhi, have built the ridge of Puna, marked by its line of cones. The Puna ridge probably continues even beyond the easternmost point of the island, though it there disappears into the sea. The road may some day be continued down into Puna to make another most interesting route between Hilo and the volcano.

Starting at the point of departure from the older Volcano House-Halemaumau road, the new road passes at 0.5 mile, 1.0 mile, and 1.6 miles the three craters Lua Manu, Puhimau, and Kokoolau. At 2.3 miles is the Devil's Throat, and at 2.4 miles the cinder cone. Two more craters, Heake and Pauahi, are next passed, the first at 2.7 miles, and the highway follows the rim of the second between 3.4 and 3.6 miles from the beginning of the road. At 3.8 miles the old Keauhou road is crossed, and then comes Aloi Crater at 4.6, where is the steaming area and the road's nearest approach to Puu Huluhulu. Between 5.5 and 5.7 miles the road follows the edge of Alealea Crater. At 6.0 miles is the entrance south to the very interesting 1923 miniature lava flow. The end of the road is reached at Makaopuhi Crater, 6.95 miles.

Justice cannot be done in describing these points of interest in so small a space; a brief review must suffice. The craters are members of the same family which includes the Crater of Kilauea, Kilauea Iki, and Keanakakoi. They are the stand-pipes where in times past the lava rose and fell as it was forced into or allowed to drain from the great crack called the Puna Rift. The benches and mezzanine floors in some of the craters represent lava lake levels that were maintained long enough for the lava beneath parts of them to harden. Those parts of a cooling lake where lava still remained soft enough to drain away when the release of pressure came, would then collapse, leaving these benches high and dry.

The Devil's Throat is like the Pit Craters in the Kau Desert. These deep well-like holes are the cavings-in of the roofs of lava tubes or chambers, weakened by heat or earthquake cracks; the falling debris perhaps being removed by the flow or heat of lava beneath to make room for more and still more caving-in till finally the very top surface falls in. Near the Devil's Throat is an interesting cinder cone, of which the inner construction has been exposed by the cutting for the road. The road throughout its length exposes by its cuttings interesting shallow sections showing the thickness and composition of the region's surface layers.

The steaming area at Aloi Crater gives evidence of rock beneath the surface still hot enough to turn back as steam the ground water that comes in contact with it. In the steaming area is an interesting ridge of hard, dense, bluish rock very different from the usual vesicular and frothy types of lava.

Of special interest are the miniature lava flows of 1922 and 1923. The little flows in Makaopuhi Crater of May 28, 1922, and on the brink of Napau Crater which oozed out the next day, are the clues that indicated how the lava was draining from Halemaumau during its great collapse of that month. Halemaumau refilled its lava reservoir during the next 15 months, but again movement along the Puna Rift occurred, as evidenced by earthquakes, opening the way for the lava to drain again from the pit during August, 1923. In this case the clue was the small flow of August 25, 1923, just south of the new road, at the 6.0 miles point. Here can be seen how lava issued from a long crack in the ground, spattering up into the trees and flowing down through the forest for a few hundred feet, making interesting tree moulds. Halemaumau partly recovered from this second collapse, then in April of 1924 came the earthquakes and subsidence in Puna, at the lower part of the rift line, followed by the great explosive collapse of Halemaumau in May. This time no lava appeared along the rift, but evidence seemed ample without it that once more the same crack was responsible for the wasting of Kilauea's fire.

Thus the Puna Rift is easily seen to be an important part of the volcano. The new road now makes it more accessible for study, so increasing the knowledge of the volcano as well as making available to the pubilc a region of great interest and scenic beauty. R.M.W.

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No. 174 RELEASED WITHOUT COPYRIGHT RESTRICTION April 26, 1928

KILAUEA REPORT No. 848

WEEK ENDING APRIL 25, 1928

Section of Volcanology, U. S. Geological Survey:

R. M. Wilson, Temporarily in Charge

Halemaumau is quiet, and there has been very little working of the walls and little change in steaming. The coatings of white salts have increased on the north and southwest walls. Two noisy slides from the ledge at the middle of the south wall were observed at 8:50 a. m. April 25, and the quantity of debris on the talus below indicated that there has been other slides. There is no new surface cracking about the south rim.

The east rim cracks were measured on April 21, but little difference was found over the measurements of March 24.

The Observatory seismographs have recorded 12 very feeble local earthquakes for the week ended April 25. Tilt has accumulated slightly WNW. during the same period.

ECHO SOUNDING

In Volcano Letter No. 122 of April 28, 1927, mention was made of sonic or echo sounding for ocean depths. The U. S. Coast and Geodetic Survey S. S. Guide has for the past few weeks been operating along the Kona coast of the Island of Hawaii, making standard charts in the region of Kealakekua and Kailua bays. The writer was given opportunity to go aboard and witness the sounding operations, seeing the fathometer in operation.

This device is simple in principle and most efficient in operation. The hydrophone, a part of the apparatus, is placed in contact with the water on the ship's bottom. This is a metal diaphragm, which is caused to vibrate by means of a powerful electro-magnet, like a giant telephone receiver. The sound thus transmitted to the water travels to the ocean's bottom, and is reflected back again as an echo. This faint echo is then received by a microphone and is electrically amplified by vacuum tubes to such strength that it will operate a magnetic relay. The speed of sound in sea water is known. The timing of the sound's journey from the ship to the ocean's bottom and return is therefore a measure of the depth. The whole operation is made automatic. A disk revolving behind a fixed scale carries upon it a contact device and a neon tube. When the neon tube passes the zero point of the fixed scale, contact is made causing the hydrophone to start the sound waves on their downward journey through the water. The return echo is signaled by the operation of the relay, which causes the flash of a spark through the neon tube; but during the journey of the sound to the ocean's bottom and return, the neon tube on its revolving disk has traveled along the scale from the zero point where operations were started, so that the flash of the spark occurs at a distance from the zero point of the scale corresponding to the time elapsed. The flash of the spark is instantaneous, but due to the persistence of the image in the retina of the eye, it appears to remain stationery for a fraction of a second at some part of the scale where its position may be read. The scale is graduated to read directly to fathoms, so that one needs but to glance at the instrument, noting where the spark flashes occur on the dial scale, to be immediately informed of the depth of water beneath the ship.

The work of the vessel includes the taking of other data of all sorts. Direct wire soundings are frequently made with a lead which brings back samples of the bottom. Water samples are taken from near the bottom at the same time. Thermometers are lowered which record temperatures.

In order that the positions of the soundings may be plotted upon a chart, the ship's position is known at will by three-point locations read upon shore objects, when the work is within sight of land, as is usually the case. The position of the ship is thus determined for each sounding made. The frequency with which these soundings are made and plotted is dependent upon the distance out from shore, the regularity of the bottom, or the importance of the area being covered and the amount of detail desired in the chart. In contrast to the older method of lead and line soundings, the use of which demands that the ship be nearly stopped each time a sounding is taken, this sonic method allows soundings to be taken at any speed the ship may be making. In chart making the only reason for diminishing speed is to allow the observers time to record the depth and position data. In the shoal water near land where the ship cannot be taken, small motor boats are used, with ordinary lead and line, to fill in the shore details of hydrography. Topographic parties on shore add other information for the chart.

The interest of volcanology in this work can be understood when it is realized that the volcano is not all above sea level. One too easily thinks of the base of this island volcano as being at sea level. As a matter of fact its base is where its slopes first start upwards from the great general plains of the sea bottom. The average sea bottom of the Pacific about Hawaii is easily as much below the sea surface level as the summit of Mauna Loa is above it. Thus in height the whole lower half of our volcano is under water and not available to direct observation. On the slopes of Mauna Loa that are above sea level, which we are able to study directly, we find many points of interest to volcanology. There are lava flows, cones and volcanic vents, rift lines, and fault scarps. These features obviously must exist on those parts of the mountain's slopes covered by sea water, though perhaps in changed form. This speedier and easier method of taking soundings that has been developed in the last few years should teach us much about these inaccessible lower slopes of the mountain. It may be that further developments in echo sounding will enable those operating the apparatus to tell by the quality of the returned echo what the character of the sea bottom is. We may thus be led to discover and be enabled to chart submarine areas freshly covered by lava. Increased detail of shape of the ocean's bottom discovered by greater numbers of soundings will perhaps disclose cones or volcanic topography of other sorts. In last week's Volcano Letter mention was made of the possibility that the great Puna rift extends on to the northeast after it dips into the water. The few scattered soudings taken for the older charts confirm this idea, showing a ridge extending on down the submerged flank of the island. Detailed soundings here might easily show interesting features which would reveal the history of this ridge.

R.M.W.

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No. 175 RELEASED WITHOUT COPYRIGHT RESTRICTION May 3, 1928

KILAUEA REPORT No. 849

WEEK ENDING MAY 2, 1928

Section of Volcanology, U. S. Geological Survey:

R. M. Wilson, Temporarily in Charge

Halemaumau remains unchanged except that steaming has increased in the pit due to the rains of the past two days. Most conspicuous is a wet steaming area on the north-northwest wall.

There were evidences on April 28 and May 2 that the north wall had had slides. Dust from a slide at the north corner was observed at 11:30 a. m. on the latter date. For some time there has been a slight accumulation of yellow stain at the site of the southeast sulphur patch, which has long been buried under debris, and on April 28 this stain was so plainly perceptible that it was thought that sulphur crystals were forming. Today, however, no yellow stain or crystals were to be seen.

The Observatory seismographs have recorded 20 earthquakes during the week. All of these were very feeble with the possible exception of one at 5:01 p. m. April 27. This one, while still feeble, might perhaps have been felt. Several of the others were large enough to show themselves plainly as true earthquakes rather than as small and distinctly local spasdomic tremors.

Tilt accumulated slightly to the south during the week.

THE THREE-YEAR CRUISE OF THE "CARNEGIE"

On May 1 the yacht "Carnegie" was scheduled to start upon its seventh cruise. This vessel of the Carnegie Institution of Washington is in charge of Captain J. P. Ault, and during the next three years is to engage in investigations of terrestrial magnetism and electricity, marine, biology, meteorology, and oceanography.

Work in magnetic observations at sea was first begun systematically by Halley in 1698. Other observations were made casually by various ships until in 1905 the "Galilee" was started out specifically for magnetic observations. The "Galilee" had iron in its hull that was found to be disturbing to the observations, but it was used until 1909, when the present vessel, the "Carnegie," was completed. The "Carnegie" started its first cruise in August of 1909, and has now traveled about 290,000 miles. This seventh cruise, which is starting, will add about 110,000 miles to its record. The proposed route for the present cruise is to start with a circuit in the North Atlantic Ocean, after which the vessel will go through the Panama Canal to the South pacific, then into the North Pacific, and will be near Hawaii about August, 1929. The route then goes through the South Pacific, and eastward once and a half around the world in the south latitudes, then up through the Atlantic and back to Washington, reaching the starting point about July, 1931. (See Journal of the Washington Academy of Sciences, Vol. 18, No. 5; or Scientific Monthly, February, 1928.)

With the experience furnished by the "Galilee," the "Carnegie" was built with as little iron and steel in its construction as possible. It is a two-masted sailing ship with an auxiliary engine of 100 horsepower capable of driving it without sail at the rate of six knots. The engine is constructed for the most part of non-magnetic metals, only a few essential parts being of steel. There is practically no other iron or steel on board. The vessel's anchors are of bronze, with manila cables. There are seven men on the scientific staff, and 17 in the crew.

The study of terrestrial magnetism has been and still is the major aim of the vessel's journeys. Observations for compass declination or deviation are systematically made ,and the secular or annual variation is determined for the different parts of the oceans. Seasonal and daily changes are also observed. From this information accurate isogonic charts are made enabling navigators to correct for compass errors. It is interesting to note that here again the eleven-year cycle of sun-spot activity has an effect. It has been found that there are changes in terrestrial magnetism that correspond to these changes in solar radiation.

On this cruise the vessel will undertake new work, the study of terrestrial electricity. This includes the measurement of atmospheric charges and potential, and leads to better understanding of conditions affecting radio transmission and of the Heaviside layer. Marine microbiology and chemistry will be studied, and other branches of marine life will be observed. Tow nets have provided for the collection of samples of ocean living organisms, and a laboratory on the ship provides the means for analysing or preserving the samples brought in. Another new laboratory has been added to accommodate the radio apparatus and the electrical depth sounding equipment. Marine meteorology is given attention. At sea, meterological observations and investigations of terrestrial magnetism and electricity are free from the many disturbing influences that exist on land.

Oceanography receives its share of study. Deep sea soundings are made, deep and shallow water temperatures are observed, bottom samples are collected, by a line run out to depths as great as 20,000 feet. In order that the line may go straight down and not be slanted in the water by the ship's motion, the vessel is stopped every other afternoon, or about every 150 or 200 miles, for the purpose of making these observations. The vessel is equipped with echo sounding appartus, as described in last week's Volcano Letter. Captain Ault remarks that the topographic features of the bed of the ocean must be as interesting to the geodesist and seismologist as are the features on dry land.

Results of some of the observations will be computed on the vessel and transmitted for publication when various ports are touched. The information is disseminated to all nations, and for this reason the vessel is a welcome visitor to ports all over the world. R.M.W.

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No. 176 RELEASED WITHOUT COPYRIGHT RESTRICTION May 10, 1928

KILAUEA REPORT No. 850

WEEK ENDING MAY 9, 1928

Section of Volcanology, U. S. Geological Survey:

R. M. Wilson, Temporarily in Charge

A few changes have taken place in Halemaumau. The wet steaming area of the north-northwest wall has become less conspicuous. The coating of white salts on the north wall has entirely peeled away. Dust was seen there on May 5 and 6, and stones were heard rolling at that side on other visits.

A survey of locations of various steam vents was made on May 7. They are as follows: Back of N., NW., and W. rims; below edge of E. rim; middle of NNW, wall; both side edges of NW. talus; center and south top of SW. talus; three places on SE. talus; below east end of NE. sill; middle of NNE. talus; two floor fumaroles at foot of N. talus; the south and center cones.

The southwest talus, by far the greatest debris slope in the pit, has some interesting phases. Slides rarely occur from the wall above it, and it is the only talus that has not overlapped the lava floor formed last July. This indicates that the talus has remained stationary and without change for about a year. For some time, however, a crack just below the upper edge and parallel to the wall has been developing, and may mean that the talus as a whole is slipping, perhaps to slide down onto the lava floor as did the northwest talus, which by this mechanism caused the squeezing up of liquid lava in Halemaumau on January 11 last.

During the week ending May 9 there have been recorded on the Observatory seismographs 35 earthquakes. One of these was a very feeble teleseism of which the preliminary phase began at 6:24:39 p. m. May 7. The record was so feeble that other phases could not be distinguished, and no estimate of distance could be made. Of the local earthquakes all were very feeble with the exception of one at 4:41 p. m. on May 5. While this shock was still feeble it may have been strong enough to be perceptible. The distance to its origin is indicated as 19 miles from the Observatory. On May 2, at 2:45 p. m., there was a protracted tremor which lasted for four minutes apparently of volcanic origin.

It was stated last week that there had been several earthquakes somewhat larger than the usual run of very feeble tremors. Most of them were not large enough to rise above the "very feeble" class, but were strong enough to indicate distance. This series of earthquakes has continued through this week also, so that the fortnight shows a very definite feature of seismic activity. An attempt to determine the epicenters of some of these earthquakes has shown them to have been rather scattered and without indication that any particular locality is responsible for the disturbances.

Tilt has accumulated during the week slightly to the south.

EARTHQUAKE BELTS

There is published in the "Scientific American" for April, 1928, a decidedly interesting and easily understood article on the world distribution of earthquakes. This article is by Professor Bailey Willis, and therefore carries with it the weight that can be expected from an authority on the subject.

The necessity for earthquake-proof building is emphasized. Here again is pointed out the fact that very few parts of the earth are absolutely free from earthquakes. The limited areas that we consider as liable to earthquakes are merely those in which earthquakes are relatively frequent. Those which are usually considered free from earthquakes are the spots on the earth where earthquakes are less frequent, but where shocks are by no means impossible.

The risk of earthquake damage increases as density of population increases. A great earthquake may occur under the ocean and pass completely unnoticed by mankind, except by seismographic records: yet a smaller earthquake taking place at a great center of population sometimes brings with it tremendous damage.

Professor Willis calls attention to the fact that buildings may be made more earthquake-proof at very little additional original cost. Great buildings are erected with careful consideration paid to the various forces that may affect them. Their design is calculated to make them strong against wind pressures, to enable them to carry loads of snow, and to make them proof against the disintegrating effect of weather. Much attention is paid toward making them fireproof. But in many places earthquakes happen so seldom that risk of damage from that cause is ignored completely, and in the design of buildings no features are included to guard against the earthquakes which the place must some time expect.

The article gives a table headed "Annual Frequency of Earthquakes in the More Seismic Regions." Some readers here in Hawaii have noticed and commented on the fact that Hawaii is omitted from this table. There are here great numbers of volcanic earthquakes, particularly on the Island of Hawaii. These are for the most part the accompaniment of movements in the mechanism of the volcanoes. They are not deep-seated nor far-reaching in their effects. The type of earthquake with which Professor Willis deals is the more far-reaching tectonic kind. Tectonic earthquakes are slippings in the earth's crust when it yields suddenly to stresses which have accumulated through ages, and do not necessarily occur in volcanic regions only. Such shocks are so heavy and deep-seated, involving the sudden shifting of such large volumes of the earth's crust, that they are recorded sometimes by seismograph stations throughout the world. Here in Hawaii our seismographs frequently record such distant earthquakes, which we call teleseisms. But it is very seldom that we transmit answers to these messages from distant parts of the earth. Tectonic earthquakes of sufficient depth and power to be recorded away from Hawaii seldom occur here. Practically all of our earthquakes are so purely local that they pass unnoticed by seismographs in other parts of the world.

R. M. W.

NOTES

A radio message from Dr. Jaggar, at Squaw Harbor, Alaska, has just been received. He states that he has arrived there safely with his outfit, and that the tests of his new amphibian automobile-boat have proved satisfactory. When Dr. Jaggar was in Washington, the National Geographic Society, under whose auspices this expedition is being made, saw the necessity of and made appropriations for a topographer to accompany the party. With tests completed, the expedition will start in actual work of reconnaissance within a week.

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No. 177 RELEASED WITHOUT COPYRIGHT RESTRICTION May 17, 1928

KILAUEA REPORT No. 851

WEEK ENDING MAY 16, 1928

Section of Volcanology, U. S. Geological Survey:

R. M. Wilson, Temporarily in Charge

The north and northwest walls of Halemaumau have been sliding, and several clouds of dust, made by avalanches, were seen rising from time to time. One from the north wall at 6:13 p. m. May 11 made vibrations which were recorded by the seismographs. There have been no changes in the pit except the difference in the amount of steaming under varying weather conditions.

During the week ended May 16 the seismographs at the Hawaiian Volcano Observatory recorded 32 very feeble local earthquakes. A teleseism was also recorded, the preliminary wave arriving at 11:57:01 a. m. on May 14; the secondary showing itself 10 minutes and 16 seconds later. The estimated distance to the epicenter is 5,580 miles.

Microseismic motion, which has been unusually feeble for some weeks past, increased to moderate amplitude during this week. Tilt has accumulated slightly WSW.

THE CRUST OF THE EARTH

Mau's burrowings into the crust of the earth by means of shafts and tunnels barely scratch its surface when the depths so reached are considered in terms of the dimensions of the crust itself. Information as to composition, consistency, and temperature at greater depths must be obtained by indirect observation. In 1914 Michelson conducted experiments to measure the periodic tiltings of the earth's surface which he translated into earth tides. These tides, similar to ocean tides but of smaller amplitude, resulting from the attractions of the sun and moon, gave a measure of the rigidity of the earth by showing how much the earth's structure yields to these deforming forces. His experiments showed that the earth is a whole is somewhat more rigid than solid steel.

Geology, by the study of strata that have been laid bare by ages of crust folding, up-thrust and erosion, by analyses of volcanic ejecta and extrusives, has arrived at certain conceptions of the construction of the earth's crust. Seismology has yielded up most important evidences since the path and rate of travel of earthquake waves are dependent upon the density and elasticity encountered along their routes. These earthquake wave paths penetrate most parts of the earth, and serve to probe its inner condition. Thus it has been found that at a depth of some 50 or 60 km. there is a level of change of condition; earthquake waves are reflected from this level of discontinuity, or if they penetrate it are found to travel at much greater speeds below it than in the upper levels. Geophysicists have been making tests of the compressibilities of various rocks. Isostasy gives data as to the relative distribution of density with depth.

Geologists, seismologists, isostasists, experimental geophysicists, each have their particular ideas of exactly what is beneath us in the earth's crust, based on their individual lines of observation. How do successive layers vary in composition, density, temperature, conditions of rigidity and elasticity? Professor Reginald A. Daly, in an article published in the American Journal of Science, February, 1928 has assembled these various data and ideas with the aim of producing harmony among them.

Professor Daly shows that while the paths and velocities of earthquake waves are dependent upon conditions of density and elasticity, yet it is dangerous with information at present available to assume that the rocks which we believe to have those conditions of density and elasticity are thereby identified as those actually traversed. The preliminary earthquake waves travel at speeds of from 5.4 to 6.0 km. per second in the upper layers of the earth's crust, and the secondary waves travel from 3.2 to 3.5 km. per second; but below the layer of discontinuity the preliminary waves attain a speed of about 7.9 km. per second.

To try to determine what particular rocks these earthquake wave speeds represent, geophysicists have made compressibility tests of various constituents of the earth's crust. Specimens have been subjected to careful measurement under great pressures. But these samples are generally tested at our ordinary living temperature, and are tested in small pieces only. Daly's article points out that the results of these tests for a given material may not accurately apply to the higher temperatures and greater bulks of the same material at the depths in question. Also it is known that constants of rigidity and elasticity of many materials are not the same for great stresses as they are for small stresses, nor are they the same for stresses applied and released quickly as they are for stresses held through long periods of time. The vibrations of an earthquake wave are rapid, and their stresses are slight. In response to these vibrations perhaps different constants of rigidity and elasticity apply than those secured in making the tests or in computing from the static conditions of great pressure within the earth's crust. It therefore seems doubtful that it is yet possible to take the constants derived by timing earthquake waves to identify any particular rock or mineral.

Taken without these reservations ,the compressibility tests seem to preclude the possibility of a basaltic layer underlying the earth's crust. The idea of its presence there, however, is desirable to geologists and isostasists. The article here reviewed suggests that if basalt could be tested under the conditions existing at that great depth, that it might be found to have constants which would make it the proper medium to carry earthquake waves at their observed speeds.

R. M. W.

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No. 178 RELEASED WITHOUT COPYRIGHT RESTRICTION May 24, 1928

KILAUEA REPORT No. 852

WEEK ENDING MAY 23, 1928

Section of Volcanology, U. S. Geological Survey:

R. M. Wilson, Temporarily in Charge

On May 19 yellow stain was strongly noticed at the site of the southeast sulphur patch, and on May 21 the area of stain, as seen from the opposite side of the pit, appeared to have increased. Apparently sulphur crystals are again forming at this place.

A circuit of the pit on the 21st showed considerable change in the rim contour due to avalanches. On May 22 several slides occurred, one from the south corner about 9 a. m. making considerable noise. Dust was seen rising from the north and northeast corners during the day.

The east rim cracks were measured on May 23, but very little difference was found over the measurements of May 7 .

The seismographs at the Observatory recorded 13 local earthquakes during the week ended May 23. One at 7:43 p. m. May 18 was feeble, but may have been perceptible; all the others were very feeble.

Microseismic motion diminished during the week to an amplitude somewhat less than normal. Tilt accumulated slightly to the SSW.

The teleseism of May 14 mentioned in last week's report is given a tentative origin in Lat. 8 degrees S., Long. 80 degrees W. (north coast of Peru). This position results from a preliminary combination of reports from several stations, assembled and computed by the U. S. Coast and Geodetic Survey, the Jesuit Seismological Association, and Science Service in cooperation.

Thousands of sailors from United States battle squadrons now in Hawaiian waters are visiting the volcano.

ANCIENT PHILIPPINE EARTHQUAKES

A recently published catalog of historic earthquakes in the Philippine Islands (Seismologiacl Bulletin of the Weather Bureau, Manila, for 1926) gives 32 pages of very interesting descriptions of some of the greater ancient earthquakes and volcanic eruptions there. The time included is from 1585, when the first shock was recorded after the discovery of the Philippine Islands, to 1865 when the establishment of a government bureau began the more systematic collection of data. The descriptions of earthquakes are for the most part from writings of the priests, and frequently mention the damage to churches and parish houses. More damage occurred to such buildings because of their masonry construction than to the native buildings of loosely built wood, bamboo, and thatch.

It is suggested in the preface that the seismicity was probably about the same then as now; the number of earthquakes chronicled being then about as great as the numbers noted in recent years.

The descriptions are very graphic and interesting, and are set forth as the personal experiences of the various authors. About all the different effects that earthquakes produce are mentioned. Landslides and mud flows, shaken and broken buildings, earth cracks large enough to engulf human beings, changed river courses, ejections of mud, sand and water, darkness caused by dust of destroyed buildings or by clouds of volcanic ash, general destruction of towns, subsidence and flooding of land by sea water, tidal waves, and many other things are mentioned in the descriptions.

Many references are made to improved building construction with the aim to minimize the amount of earthquake damage. One writer says: "In spite of all these (experiences) the vanity and forgetfulness of men left them unconvinced that high houses are more subject to a great ruin. After the said earthquakes numerous houses were again built in the city, most of them of cut stone, as if all had forgotten the former disasters. Against all good architectural rules, walls fourteen to twenty meters high and less than a meter thick with a foundation about two meters deep were raised. Moreover these high and thin constructions had not any buttress as support or reinforcement; the mortar was of very poor quality made of little and weak lime and sand carelessly applied by unscrupulous Chinese, but yet our citizens pretended to have lasting buildings." Can it be said that even now in modern times with all this experience available to us that enough consideration is given to earthquake-proof building construction? Their experiences in those earlier years led finally to the building of wooden columns into masonry walls to prevent the falling-in of roofs should the masonry be shaken down. They also took such precautions as adding buttresses to building design, and building thicker wails and wider foundations. There is occasional note that damage was greater near a river than distant from it, perhaps having to do with the known increase of earthquake effects on buildings situated upon beds of alluvium.

The terror and grief among the people during these great earthquakes, and the ensuing pestilences and famines, are listed among the most serious effects of the shocks. Thus was Manila visited by disaster in the great earthquake of November 30, 1645: "The horrifying spectacle of that night was made more terrible by the distracted and precipitous wandering of the people through the darkness, blackened by the dense cloud of dust covering the city, the yells of the terrified multitude and the cries for help of the victims crushed and buried in the ruins."

The question of "earthquake weather" is mentioned by one writer as follows: "On the date of the main earthquake the weather was calm, the sky cloudy and dull, the air hot and heavy with puffs of wind and drizzling at intervals." These are indications, that author remarks, of impending earthquakes. There seems to be persistent belief throughout history that so-called "earthquake weather" exists as a forerunner of great seismic disturbances. This question is still open for science either to prove or disprove.

R. M. W.

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No. 197 RELEASED WITHOUT COPYRIGHT RESTRICTION May 31, 1928

KILAUEA REPORT No. 853

WEEK ENDING MAY 30, 1928

Section of Volcanology, U. S. Geological Survey:

R. M. Wilson, Temporarily in Charge

Halemaumau continues quiet. A few small slides have occurred. On May 26 the north wall was streaked from slides. The southwest sulphur patch has again been obliterated by fallen debris.

Rumors of recent widening of cracks at the 14-ton bowlder proved false, although this place presents a dangerous appearance.

An extraordinarily strong northeast wind on May 25 made dense dust clouds on the south Kilauea floor and over the Kau Desert.

Eleven very feeble local earthquakes were recorded on the Observatory seismographs during the week ending May 30. There was also a very feeble record of a teleseism on May 26, of which the secondary and long waves are doubtfully identified at 11:37:50 and 11:46:24 p. m.

During the first part of the week there was a sharp spurt of tilt toward the NE., with an equally definite recovery, so that the net tilt accumulated for the week is but very slight toward the N.

GEODETIC WORK ON THE NORTHWEST HAWAIIAN ISLANDS

The U. S. Coast and Geodetic Survey S. S. "Guide," after completing the work of charting on the Kona coast of the Island of Hawaii (Volcano Letter No. 174, April 26, 1928), proceeded to the northwest islands of the Hawaiian group. The work there is the beginning of an extended program of latitude and longitude observations, determinations of gravity, measurements of magnetic declination and intensity, charting and topographic mapping. These small islands have needed such observations in order that they may be accurately charted. Their positions have heretofore been located for the most part by sextant observations only.

The geological aspect of these islands has been considered by Professor Harold S. Palmer in Bulletin 35 of the Bishop Museum. They are uninhabited, and have been given but little attention in the way of scientific investigations and surveys. It is believed that these are the older islands of the Hawaiian group and that they were at one time high volcanic cones, now reduced by erosion to projecting fragments and shoals.

The "Guide" has just completed the first trip of three weeks to Nihoa and Necker islands and to French Frigates Shoal. On Nihoa an astronomic station was occupied, where latitude, longitude, and azimuth were determined. Observations were also made for gravity and for magnetic declination. A topographic map of the island was made on the scale of 1:2,500. Some difficulty due to heavy seas attended the first attempt to go ashore on the island. The boat carrying the scientific party with instruments and supplies was capsized during the landing, but the instruments were for the most part recovered and there were no casualties.

Observations were to have been made on Necker Island, but rough weather made landing there impracticable. The ship therefore proceeded to French Frigates Shoal, where on East Island the same observations were made as on Nihoa. Triangulation was also started, and more complete magnetic observations were made at this place.

The ship returned to Honolulu for supplies and fuel, and has just started on a second trip to these islands. Another attempt will be made to occupy Necker to make there the same observations that have been completed at Nihoa and French Frigates Shoal, and to continue the triangulation work at the latter place.

The program contemplates continuing these observations on through the islands to the northwest as far as Ocean Island, if conditions permit, perhaps representing several seasons' work. For the longitude and gravity observations radio time signals are received direct from the Arlington station near Washington, D. C. Lieutenants Brown, Bainbridge, and Simmons, who did geodetic work on the Island of Hawaii about a year and a half ago, are the observers in this present work. R.M.W.

THE BALKAN EARTHQUAKES

The destructive earthquakes which occurred last month in Bulgaria and Greece filled the columns of the press at the time with descriptions of death and destruction. A series of pictures appeared in the "Illustrated London News" of May 5, 1928, giving very graphic evidence of the damage which the earthquakes accomplished.

Reports from the scientific investigations by seismologists and geologists as to just what occurred will be some time getting into print, due to the time that the necessary observations must take. A short preliminary discussion by Dr. Charles Davison of this group of earthquakes and their aftershocks has already appeared in "Nature" of May 5. That there will be many points of interest to scientists is evident from the number of observed geological effects mentioned in the press. The migration of focus during the series of earthquakes has attracted attention. The great area disturbed in the Bulgarian earthquakes and the lesser area disturbed by the Grecian shocks has already suggested that the former had a greater depth of focus. Changes of land elevation, tidal waves, the opening of great cracks in the earth, altered volume of flow in mineral springs with changes in the temperature of the water, are all things which will supply a wealth of material for scientific study. There is mention made of electrical displays noted before the occurrence of the first shock, suggesting forewarning phenomena, though science still doubts the existence of such effects. Mention is also made of investigations immediately started to discover the effects upon buildings, thus to learn more about details of design which will minimize damage by future earthquakes.

The scientific discussion of such calamities must be made the most of to increase knowledge toward lessening the loss of life and property in the future. R.M.W.

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No. 180 RELEASED WITHOUT COPYRIGHT RESTRICTION June 7, 1928

KILAUEA REPORT No. 854

WEEK ENDING JUNE 9, 1928
Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

Practically no changes have taken place at Halemaumau in the past week. On June 2 and 5 there were avalanches, dust from one of them at 1:45 p. m. on the former date rising in a peculiar compact cloud. The odor of free sulphur was noticed very slightly at the southeast rim at 11:30 a. m. June 6.

During the week there were 14 very feeble local tremors recorded on the Observatory seismographs. One of these, an earthquake slightly larger than the others, exhibited phases indicating a distance of nine miles to its origin. On June 5 there were two periods of continuous tremor, the first one beginning at 7:53 a. m. and lasting six minutes, and the second one beginning at 8:03 a. m. and lasting four minutes. These two spells of tremor perhaps represent the same disturbance, as they were separated by only a four-minute quiet interval.

During the first part of the week microseisms were somewhat more feeble than normal. On June 2 and 3 there seemed to be evidences of a vibration of longer period than the normal microseisms. Their period was about 7.2 seconds, and they could be detected in the records at intervals during the greater part of these two days. Microseismic motion again became normal by the end of the week.

Tilt has accumulated slightly to the southwest.

AERIAL PHOTOGRAPHS

In the current issue of "The Military Engineer" there is another article describing the campaign of aerial photography in southeastern Alaska. This project was described some time ago in the "Scientific American," and was mentioned in Volcano Letter No. 127, June 2, 1927. The recent article gives reproductions of some of the excellent photographs secured and briefly describes the field program and the subsequent compilation of the pictures into maps. Some of the country covered is so inaccessible to people on foot that it has not been thoroughly explored, and some lakes that were heretofore unknown were discovered in the photographs. Much valuable information was thus obtained in the matter of possible power sites and water supplies. Sets of these photographs are on file in the Geological Survey offices in Washington and in the office of the Forest Service at Juneau, Alaska.

During the 1926 outbreak of Mauna Loa in Hawaii, aerial photographs were for the first time used here to record progress of lava flows. The value of their use in this connection cannot be over estimated, both for the collection of scientific data and as a safety measure for the protection of human lives and property. At times of Mauna Loa eruptions, with the consequent lava flows down the slopes of the mountain, automobiles carrying sightseers in great numbers have crowded in to the flanks of the flow from both directions on the belt road running around the island. The traffic congestion resulting has usually been considerable, although during the last outbreak police organization kept everything well in hand. But with such congestion on this road there is grave danger that a lava flow coming down from above may split and isolate some of these sight-seers in a dangerous predicament. Some of the regions on the mountain slopes above the road are almost impenetrable, and it is difficult in the extreme for men on horseback or on foot to keep close watch on all the developments of the flow that might prove dangerous to those below. Periodic flights of an airplane over the flow, with the photographs that might be taken on such flights, would easily show the development of any dangerous aspects of the outbreak. A series of such pictures would constitute a most valuable scientific record of the flow. R.M.W.

THE FAILURE OF THE SAINT FRANCIS DAM

There has just been issued the report of the commission appointed by the Governor of California to investigate the failure of the Saint Francis dam, which occurred shortly after midnight on March 13, 1928. Defective foundations is the cause given for the collapse of the structure. Part of its length was built on a geologic formation which appears like solid rock when dry, but was found to lose much of its strength when water-soaked.

The body of the dam crossed a geologic fault which has been termed "dead." Motion along this fault line might easily have caused the failure of the dam. Careful investigation showed no sign of movement, however, and the nearest seismographs showed no earthquakes anywhere near the time of the calamity. In Volcano Letter No. 99, November 18, 1926, an article by Dr. G. Agamennone is reviewed in which he laid emphasis upon the necessity of an installation of seismographic instruments as a safety measure at all large dams. Stresses to the point of failure in these great dams probably do not accumulate suddenly. The softening of the foundation may have allowed this dam to settle or yield a little, perhaps with slight internal fractures, even some days before it actually collapsed. A seismograph installed upon the dam might have detected these slight preliminary motions, recording them either as tremors or as slight tiltings.

The failure of the dam in this case is not ascribed to actual earthquakes, but the use of seismographic instruments might nevertheless have given warning of the coming collapse, possibly several days in advance. The cost of installation of these instruments would seem to be a very slight amount to pay for the possibility of detecting the danger of such a calamity. R.M.W.

ERRATUM

The number of the preceding issue of "The Volcano Letter" was transposed. The correct number is 179, not 197. Recipients are urged to make the correction on their copies to avoid confusion in filing.

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No. 181 RELEASED WITHOUT COPYRIGHT RESTRICTION June 14, 1928

KILAUEA REPORT No. 854

WEEK ENDING JUNE 13, 1928
Section of Volcanology, U. S. Geological Survey:
R. M. Wilson, Temporarily in Charge

The volcano is quiet. There have been a few light slides, mostly from the south wall, but none has been noticed that was large enough to cause clouds of dust to rise. The weather is extremely dry, resulting in diminished steaming activity. There are no phases apparent which may indicate a change in volcanic conditions, but with the approach of the summer solstice close watch must be kept for anything that may be significant.

Twenty-three very feeble volcanic tremors were registered at the Observatory. One of these lasted for four minutes beginning 12:26 p. m. June 6. Microseismic motion is slight. Tilt accumulated slightly to the WSW.

MAKAOPUHI CRATER

The new Chain Craters Road in the Kilauea Section of Hawaii National Park, which at present ends at Makaopuhi Crater, has brought this interesting piece of scenery more under public observation than before. In Volcano Letter No. 47, November 19, 1925, there are notes of a visit to the bottom of this crater by Dr. John B. Stone, and Mr. R. H. Finch of the Observatory. Dr. Stone remarks that the eastern part of the crater was originally inclosed by a complete oval wall, the western part of which was destroyed when the collapse making the western pit occurred. This exposed a section down through the lava fill of the original eastern crater, which now forms a mezzanine floor to the western pit. The small spot of green salt part way up on the cliff on the east side of the deeper pit, and other small spots of the same salt appearing on bowlders in the talus slide below. Dr. Stone identifies as the basic copper sulphate, brochantite. The green spot upon the wall of the crater has been called the "eel's eye," whence comes the Hawaiian name of the crater, Makaopuhi.

On June 6, 1928, another trip was made to the bottom of the crater by Messrs. W. O. Clark, G. W. Russ, R. M. Wilson, and others. Some additional interesting features were noted. The ridge-like block above the north end of the cliff of the mezzanine floor appears to be part of the original northwest wall of the crater, which at some time has tilted forward and down. This is shown by the fact that the strata exposed in the surface of this block are tilted down at a considerable angle, while those in the undisturbed wall are nearly horizontal. The steep gully filled with talus just to the west of this tilted block is the crack formed when the block separated from the main wall. This apparently occurred some time during the life of the crater before the formation of the western pit.

The present bottom of the crater is a fill of ordinary aa lava which flowed down the western talus from the fissure vent of 1922. Looking down at this floor from the lookout point on the southwest rim of the crater, the lava appears smoother than it really is when one attempts to walk across it. From the same rim viewpoint the larger rocks which form the talus slopes do not appear to be as large as 8 to 10 feet in diameter, as is actually the case.

Below the lookout point, and low down on the southwest talus of the deeper pit of the crater, is a sulphur patch very similar to those seen in the pit of Halemaumau.

This double crater is slightly over 5 000 feet long east and west, and about 3,200 feet wide north and south. The rim elevation opposite the end of the road is slightly over 2,900 feet above sea level, and the bottom of the deep pit is a little less than 2,100. The mezzanine floor is about 2,500 feet in elevation. R.M.W.

EXPLOSIVE ERUPTION OF TOKATI-DAKE

In the "Bulletin Volcanologique" Nos. 13-14, 1927, is given a description by Hidezo Tanakadate of the explosive eruption phases of Tokati-Dake beginning December, 1925. The first explosions seemed to differ in character from those which followed nearly a year later. The first phases showed no sign of new lava in the ejectamenta, and it is suggested that the explosions were caused by water heated in the upper strata of the plug of the volcano by the gradual rising of the lava column some distance below. That these eruptions were rather shallow in origin is also attested by the fact that the tremors and earthquakes which they inspired were not severe nor recorded at any great distance.

The second phase which occurred after several months of quiet brought to the surface lava bombs and fragments at such high temperature that a nearby wooden cottage took fire from the bombardment. The description suggests that these explosions of the second phase originated deeper in the throat of the volcano and were perhaps caused not only by the conversion of ground water into steam at high pressure, but perhaps also by the liberation of actual volcanic and explosive gases. R.M.W.

JAPAN'S LATEST EARTHQUAKE

Deep down in the Pacific Ocean east of Japan was the center of a severe earthquake recorded by seismographs throughout the world on Sunday, May 27. The epicenter was 39° north latitude and 149° east longitude, according to computations of the U. S. Coast and Geodetic Survey after a study of records from seismograph observatories in Samoa, the Philippines, Canada, and the United States. This is in the Tuscarora Deep, which is north of a ridge along the bottom of the Pacific Ocean extending northward from Tokio. Seismologists recognize this region as one of the world's great earthquake belts. (Daily Science News Bulletin, May 28, 1928.) R.B.H.

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No. 182 RELEASED WITHOUT COPYRIGHT RESTRICTION June 21, 1928

KILAUEA REPORT No. 856

WEEK ENDING JUNE 20, 1928

Hawaiian Volcano Observatory, U. S. Geological Survey

R. B. Hodges, Temporarily in Charge

There is nothing new at Halemaumau. A few slides have occured, but for the most part the pit is very quiet. A spot of yellow-green sulphur stain is plainly visible at the lower edge of the southeast talus. The solfatara on the east talus remains the same. Steaming has not increased. The weather remains fair, but the velocity of the northeast trade winds has increased considerably.

The east rim cracks, measured on June 18, show an extremely slight increase of width in the neighborhood of the 14-ton bowlder.

Thirty-two very feeble local earthquakes were recorded. In addition is the record of a distant shock beginning at 4:58:55 p. m. June 16 and continuing for about 2 hours and 20 minutes. The distance to origin appears to be 3.914 miles. This is very probably the earthquake at Oaxaca and Mexico City, mentioned in news dispatches.

There is steady tilting, in moderate amount, to the WSW, which is unusual at this time of the year.

PISOLITES

Pisolites, or mud rain drops, are commonly found in areas that have experienced ash fall, yet there has been comparatively little attention directed to them. Probably the earliest public mention of them was made by Dr. Edward Otis Hovey, following the explosions of Mont Pele in 1902. A few geologists have given them some attention, and recently they have been studied by Dr. J. Allen Berry, of Napier, New Zealand.

The mud balls are extremely hard and formed in layers, which give the term "pisolite." They vary somewhat in size, the largest being comparable to a marble or a large pea. A simple explanation as to how they are formed is given by Finch, in Volcano Letter No. 75, June 3, 1926, who states: "This type of ash is produced by rain drops falling through dust-laden atmosphere and collecting so much dust that they fall as mud pellets. Owing to the natural cementing qualities of the ash, they more or less retain their round shape.". Jaggar, in Volcano Letter No. 157, December 29, 1927, adds: "The condition for preserving layers of pisolites is when stiff mud-drops fall in light dry dust beds of previous eruption, and it is possible that the baking the dust has been subjected to accounts for its cement-like quality in rapid hardening." Dr. Berry, in the "New Zealand Herald," Auckland, March 24, 1928, likens their formation to hailstones, as follows: "In the formation of hailstones it is well known that the laminated structure they present is due to ascending currents of air causing the hailstone to be surrounded by alternate layers of ice and snow, due to its being carried up into layers of the atmosphere having varying degrees of temperature. In the same manner, these masses of mud were carried up into a layer of pumice dust, where there was not much water vapor, resulting in a dense lamination. As the result of increased weight, or a diminution in the velocity of the ascending currents, and these ascending currents are quite common, they fell back into the layer of pumice dust containing a large quantity of water vapor, and a less dense lamination resulted. This process of ascent and descent repeated several times would result in the formation of what is called chalazoidites, from the Greek words meaning 'stone resembling hail'."

Continuing to quote from the "Herald:" "Dr. Berry has shown from staining and X-ray methods that these laminations are characteristic of these bodies; in fact they are very similar to the layers of an onion. Although these pumice bodies, or chalazoidites, must in New Zealand have a widespread distribution, no geologist has previously directed attention to them. It is also remarkable that although they are probably a concomitant of every great volcanic eruption in any part of the world where dust with large quantities of water vapor is being ejected, the references to their occurrence in the literature are remarkably few.

"Dr. Berry has recently discovered that chalazoidites fell during the eruption of Vesuvius which overwhelmed Pompeii in 79 A. D., and that they were similar to specimens which have been found in Napier and Taupo."

Large quantities of pisolites are found on the lee slopes of Kilauea, obviously a product of the great eruption of 1790. They formed to a certain extent in the explosions of 1924. Other places where this type of ash is known to occur, other than those mentioned, are Brisbane, western Germany, Japan, and the Philippines. Doubtless it exists also in Alaska and other volcanic regions. It may occur many miles from a volcano. In the case of Napier it is 80 or 90 miles from the probable origin.

R.B.H.

NOTES

R. M. Wilson is temporarily absent from headquarters in order to install a new seismograph at the Kona station. A description of the installation will appear in the next issue of the Volcano Letter.

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No. 183 RELEASED WITHOUT COPYRIGHT RESTRICTION June 28, 1928

KILAUEA REPORT No. 856

WEEK ENDING JUNE 27, 1928

Hawaiian Volcano Observatory, U. S. Geological Survey

R. M. Wilson, Temporarily in Charge

No changes have been detected at the pit. There are only infrequent slides and a slight increase of steaming following recent rains.

There were 18 very feeble local earthquakes recorded on the Observatory seismographs during the week ending June 27. Two teleseisms were also recorded, both on the 21st. The preliminary motion of the first one arrived at 12:18:27 a. m., and the indicated distance to its origin is 3,120 miles. The beginning of the preliminary wave of the second teleseism was recorded at 6:05:07 a. m., with 2,900 miles as the indicated distance. Both of these records were feeble, but the phases were fairly distinct.

Accumulation of tilt during the week was slight toward the east.

THE PAVLOF VOLCANO EXPEDITION

A brief radio message from Dr. T. A. Jaggar dated May 15 gave his address as King Cove, Alaska. Some additional news has now come from him in a letter of the same date written from his camp at Squaw Harbor. The expedition arrived at that place on May 9, camp was established, and the equipment tried out.

The "Honukai of Hilo" is the amphibious boat in use by the party, and was built for the expedition by the Powell Mobile-Boat Corporation, Chicago, Illinois. The name "Honukai" comes from the Hawaiian for "sea turtle." Photographs of the vehicle have appeared occasionally in the daily press during the last few weeks. It is in principle similar to the "Ohiki," described in Volcano Letters Nos. 156 and 165. The "Honukai" is a metal boat built upon a truck chassis for land travel, and is propelled in the water by twin screws as an ordinary motor boat. The amphibian was tested in Puget Sound before it was shipped to Alaska. Dr. Jaggar speaks highly of its behavior during the test and during the first days of work in establishing camp in Alaska. He states that it is tight and dry, its canopy top furnishing good protection from the weather. It is sufficiently seaworthy to navigate easily in moderately rough weather when white caps and ground swells are running. It can be "navigated" right up out of the water over the stony beaches and tundra directly to the camp site or elsewhere, and promises to be very useful and practical. Its power and speed in the water is augmented when necessary by the use of a Johnson outboard motor.

A sloop with a 5 h. p. motor has been hired locally as an auxiliary in water transportation. Two pack mules, towed upon a scow from base to base, are used when the party wishes to make expeditions inland into the mountains beyond the range of the "Honukai."

At the time of writing, it was planned to start work at Canoe Bay, at the head of Pavlof Bay, about May 18. The expedition is under the auspices of the National Geographic Society. The scientific data collected, the maps and photographs obtained, and the experiences of the party, we hope will appear in the National Geographic Magazine soon after the season is ended. R.M.W.

KONA SEISMOGRAPH STATION

The Monthly Bulletin and the Volcano Letter of the Hawaiian Volcano Observatory have from time to time mentioned the records of the seismograph that has been operated in Kealakekua since March 4, 1922. This single-component instrument has furnished data of great value. The usefulness of the station can be understood from the fact that it is directly on the other side of Mauna Loa from the Observatory, and is therefore in a strategic position to supplement the records of the Observatory in the study of that active volcano. The air line distance between the two stations is 43.6 miles, affording an excellent base from which to triangulate the epicenters of Mauna Loa earthquakes.

One of the new Hawaiian type two-component instruments has just been installed in place of the older and smaller seismograph that has so well demonstrated the value of seismic observations on the west side of the island. The new instrument is the same type as the one installed last summer in Hilo, except that the magnification is slightly reduced. The same concrete pier that was used for the old instrument is being used, with a few alterations, for the new installation. It is founded on solid pahoehoe lava, and is well protected from temperature changes in an insturment room built in a sheltered basement. Captain R. V. Woods remains in charge of the station. Operation of the new instrument was begun on June 22.

Surveys show the station to be at latitude 19° 31′ 18″ N. and longitude 155° 55′ 20″ W. Its elevation is about 470 meters above sea level. Using these coordinates, computations show this position to be 70.2 km. N. 81° 30′ W. of the Hawaiian Volcano Observatory. The summit of Mauna Loa lies almost exactly midway, in line, between these two stations.

The instrument has inertia masses of about 70 kilograms, and records on smoked paper. The static magnification is 120. Both N-S and E-W components have been adjusted to a free period of 6 seconds, and are oil damped to a 3:1 ratio. The recording drum is driven by an escapement clock mechanism, giving the paper a speed of 30 millimeters per minute. Time used is Hawaiian Standard, 10 h. 30 m. slower than Greenwich. The time clock is corrected by radio signals from U. S. Naval Radio Station NPM at Pearl Harbor. R.M.W.

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No. 184 **RELEASED WITHOUT COPYRIGHT RESTRICTION** July 5, 1928

KILAUEA REPORT No. 857

WEEK ENDING JULY 4, 1928

Hawaiian Volcano Observatory, U. S. Geological Survey

R. M. Wilson, Temporarily in Charge

Observations at Halemaumau fail to show any indication of changes in volcanic phases. Falls of rocks occur at infrequent intervals, but few of them are large enough to cause dust clouds. Wet weather has deepened the colorings in the wall stratification.

The Observatory seismographs have recorded 24 very feeble local earthquakes during the week ending July 4. One teleseism was also recorded on June 29, with its preliminary phase beginning at 12:28:15 p. m. The record was very feeble, so that all the phases as read from the record are doubtful. The indicated distance is therefore doubtful also, but is apparently 3,400 miles.

Tilt has accumulated slightly to the north-northeast during the week.

ACTION OF IRREGULAR IMPULSES UPON SEISMOGRAPHS

The general theory of seismographs is based upon the assumption that earthquake motion is simple harmonic. This is natural since the motion is an elastic vibration, but it is in fact the resultant of many simple vibrations in different directions and of many different periods. The actual net result is, therefore, a very complicated motion which defies mathematical analysis. In applying such formulas as are deduced by considering the earth's motion to be simple harmonic, it is to a certain extent unknown what errors are introduced due to this complication of motion that actually exists. The records made by seismographs cannot be expected to represent true earth displacements, motion for motion. The indicated accelerations probably roughly represent ground accelerations in order of magnitude only, except perhaps for very slow and simple movements and vibrations.

Some welcome investigation seems to have been undertaken by T. Terada and U. Nakaya to determine the effect of a series of irregular impulses upon an oscillating mechanism. In Volume IV, No. 5, of the Proceedings of the Imperial Academy (Japan) is a brief abstract describing the experiments made by these investigators. An oscillating system somewhat similar to an ordinary seismograph with its recording apparatus was arranged to be acted upon by streams of shot, so that impacts would result irregularly from opposing directions. The records made by these irregular impulses were then studied.

There are many factors entering into the action of a seismograph as ordinarily installed for the study of earthquakes. First there is the natural period of the seismograph itself; and the damping and friction attendant upon its mechanism. These are the usual instrumental constants determined by computation and experiment. Some individual parts of the seismograph, such as the recording levers or the wire suspensions of the heavy mass, perhaps have natural periods of their own which through the action of resonance may have a marked effect upon the action of the instrument under certain conditions. The foundation of the instrument may also have a natural period, and the very ground upon which the station is built may respond more easily to vibrations of certain frequency. Thus even if the earthquake motion were simple harmonic, its recorded result after passing through these various parts of the installation might easily yield a record of considerable complexity. And since actually the earthquake motion is itself complicated, its relation to the resultant motions of the recording pen is entirely too involved to be subject to exact analysis.

The records secured by the experiments here described show a remarkable resemblance in character to the usual seismographic records of real earthquakes and microseisms. In these experiments it is possible to govern the average frequency and intensity of the impulses given to the mechanism. A comparison of actual earthquake records with the records artificially obtained should show to what intensity and frequency of impulse the actual earthquake may correspond. The character of the earthquake may so perhaps be determined without the necessity of the long train of mathematical reasoning that must fall short of true results at the best.

The authors promise a more detailed description of the experiment, with discussions, to appear in Volume V of the Bulletin of the Earthquake Research Institute of the Tokyo Imperial University. R.M.W.

GENERAL DIMENSIONS OF HALEMAUMAU

The approximate center of the pit of Halemaumau is in latitude 19° 24′ 34″ north, and longitude 155° 17′ 10″ west. In its present condition it is almost circular in shape, though the northeast-southwest diameter is slightly greater. Its diameters are 3,420 by 3,980 feet. The perimeter is 1.96 miles. The depth of the lowest part of the floor below the average rim elevation is 1,170 feet. The summit of the southwest cone is 160 feet above the lowest part of the floor. The debris slopes or taluses repose at an angle of about 30° from the horizontal, which is about a 58% grade. The steeper walls stand at about 80° from the horizontal; while the average slope of the northwest wall is about 53° from the rim to its lowest toe. The area of exposed lava floor and the cones with their spatter is now about 19 acres. The horizontally projected area of all the taluses is 87 acres, and the area of the horizontal projection of all the walls is 81 acres; the slope areas are of course much greater. This makes the total area of the pit 187 acres. The southeast station at the "Halemaumau sign," which is the point from which the pit is most often viewed, is about south 30° east from the center of the pit, and the elevation of the bronze mark there is 3,651 feet above mean sea level. R.M.W.

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No. 185 RELEASED WITHOUT COPYRIGHT RESTRICTION July 12, 1928

KILAUEA REPORT No. 859

WEEK ENDING JULY 11, 1928

Hawaiian Volcano Observatory, U. S. Geological Survey

R. M. Wilson, Temporarily in Charge

Halemaumau is still very quiet, and there is nothing to indicate that any changes are about to take place. Activity of the walls is so slight as to be practically negligible. The only variation in conditions occurs when there is increased steaming in wet weather and a corresponding decrease in dry weather. Reddening of parts of the walls also occurs during rains.

Twelve very feeble local earthquakes and one faint teleseism are shown on the Observatory seismograms for the week ending July 11. The record of the teleseism, July 9, is too faint to show phases, and therefore distance to origin cannot be computed. The first sign of the preliminary phase is shown at 11:02:50 a. m.

Tilt has accumulated moderately toward the WNW.

CONTINENTAL DRIFT

The "Theory of Continental Drift," a symposium recently published by the American Association of Petroleum Geologists, Tulsa, Oklahoma, assembles the modern conceptions regarding the earth's outer layers, and digests them to brief outlines and discussions for application in this particular question. Dr. van der Gracht gives as introduction an outline of Wegener's theory of continental drift, setting forth the major evidences in its favor. Following this are comments by such authorities as Bailey Willis, Rollin T. Chamberlin, John Joly, G. A. F. Molengraaff, J. W. Gregory, Alfred Wegener, Charles Schuchert, Chester R. Longwell, Frank Bursley Taylor, William Bowie, David White, Joseph T. Singewald, Jr., and Edward W. Berry. Dr. van der Gracht then adds a few paragraphs in reply to these comments which are for the most part not in favor of the theory. Many modern ideas over a wide range of subjects have been brought forward as weapons with which either to support or to attack the theory. The discussions are of great interest not only to one who is concerned alone with the study of continental drift, but also to anyone interested in geology or geophysics in general.

Dr. van der Gracht added very materially to the strength of Wegener's theory by utilizing the calculations of Joly. These calculations tend to show that by radioactive disintegration enough heat is generated in 31 km. of depth of the earth's crust to about equal the amount of heat which that thickness of crust is capable of transmitting to the surface. This means that such a thickness of crust is a perfect blanket, and any heat generated below cannot escape through it. Joly suggests that the effect of this condition is the slow accumulation of heat, particularly under the continents, until the under part of the crust is brought to melting point. More and more of the earths under crust is fused until some escape for this heat is provided. Van der Gracht believes that this melted layer allows the continents an easy base upon which to slide and that the tidal effects of luni-solar attraction in such a liquid layer may produce the tangential power to effect the motion.

As evidences that this has happened, it is shown that the Atlantic coast lines of the Americas would approximately fit against the Atlantic coast lines of Europe and Africa. Other apparent parallelisms of coast lines would suggest that at one time there was only one great continent and one ocean, and that the continent was rifted and torn apart by these forces, the present continents being the separated fragments of the original one. The mountain ranges parallel to coasts are taken to be the crumpling of advancing edges of the continental masses as they meet with resistance in front of them. The theory attempts to plot climatic zones as defined by fossils, which existed in the geologic past about a different polar axis than the present one. These zones now seem to occur in separated arcs, but plotted on the re-assembled original continent become more perfectly arranged as true earth belts.

In a note by Wegener himself sent to be included in this symposium, it is suggested that a definite test of the theory will come from periodic remeasurements of geographic longitudes at various places. There is cited the case of the apparent change of relative longitude between Greenland and northern Europe amounting to as much as 1,190 meters in the interval of time between 1870 and 1907. Unfortunately this comparison depends upon longitudes obtained by lunar observations, which are subject to considerable error. The more recently determined longitudes by radio time signals throughout the world will establish a very definite base upon which continental movements may be checked.

Arguments against the theory are many. The most common one appears to be the doubt that there are available horizontal forces sufficient to accomplish these great results, even though great lengths of time are given these forces in which to act. It is suggested that the apparent agreement of coast lines supposedly left by the separation of continents once adjacent, is as conveniently explained as accidental. This is borne out by rock analyses taken from corresponding parts of these separated coast lines which should have been, according to the theory, at one time very close together. These analyses, made by Washington, fail to check as would be expected if the coast lines had once actually fitted together. The theory postulates that the continents are floating masses supported by a yielding layer, a condition somewhat similar to that called for by isostasy. The crust underlying the Pacific Ocean is supposed to yield slowly to the advancing continents, its action in yielding being considered more as a viscous yielding than one of crushing and fracturing. Yet it is pointed out that tectonic earthquakes occur under the Pacific, which would not be the case if the crust there could yield as a viscous layer.

The theory is based on considerable thought and the assembling of a great deal of data. Many vexing geologic problems might be solved by its acceptance. But the general opinion of those making comment upon it, however, is that the theory is not yet sufficiently well founded to accept.

R.M.W.

ERRATUM

In the "General Dimensions of Halemaumau," as given in last week's Volcano Letter, the pit diameters should be 3,420 by 2,980 feet. The latter was given too great by 1,000 feet through a typographical error.

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No. 186 RELEASED WITHOUT COPYRIGHT RESTRICTION July 19, 1928

KILAUEA REPORT No. 860

WEEK ENDING JULY 18, 1928

Hawaiian Volcano Observatory, U. S. Geological Survey

R. M. Wilson, Temporarily in Charge

Conditions have not changed at Halemaumau. Rockfalls are infrequent, and steaming is slight.

The seismographs of the Volcano Observatory have recorded but seven earthquakes during the week ending July 18. This is the smallest number for any week since June, 1927.

Tilt has accumulated slightly toward the east.

LASSEN REPORT No. 17

R. H. Finch, Associate Volcanologist

U. S. Forest Service Ranger W. J. Brokenshire and other Forest Service officials found a considerable quantity of lava in the top of a fir snag when it was felled during a forest fire in the latter part of May, 1928. The find was made on Sugarloaf Mountain near some fresh looking lava flows that are just to the east of Magee Peak. The lava specimens are covered with sulphate deposits, and some pieces contain charcoal. The snag, which appeared to have been dead for many years, was about 30 inches in diameter. A volcanic explosion may be offered as a possible explanation for the location of the lava specimens.

THE PAVLOF VOLCANO EXPEDITION

In Volcano Letter No. 183, June 28, 1928, there were notes on the progress of the Pavlof Volcano Expedition of the National Geographic Society, based upon letters from Dr. Jaggar dated May 15 in Alaska. At that time the party was organized in camp, and work was just beginning.

Another letter dated June 13 has just been received telling of the exploration accomplished up to that time. The amphibious autoboat "Honukai" is proving itself most practical and useful. Its weight is about the same as the "Ohiki," but it is more protected against weather and does not leak. The experiments with the "Ohiki" of the Hawaiian Volcano Research Association (see Volcano Letters Nos. 156 and 165) here in Hawaii furnished experience which has proved of the utmost value in handling the "Honukai" in Alaska. The woven steel mats first used with the "Ohiki" are being used with the "Honukai" frequently and with great profit. These mats when placed under the wheels of the vehicle allow it to be taken over soft sand and muddy places without difficulty. The "Honukai" is doing full duty both on land and water in hauling freight and passengers, firewood and camp material, in trolling for fish, and in bringing down from the foothills such game as is shot; Dr. Jaggar speaks of using five bullets to kill a 10-foot bear. As a boat it is not particularly fast, but has been found very seaworthy in heavy seas and in strong currents and tide rips, and has been found able to land successfully through fairly heavy surf. On land it is taken along the beaches and over the tundra quite easily. It makes excellent sleeping quarters for two men whether on land or on sea.

Mr. C. P. McKinley, the topographer furnished by the Geological Survey, had mapped 600 square miles of the mountain country on a scale of 1:180,000. He has used the mules to make topographic side trips up into the mountains. The rest of the party have been collecting and pressing plants and sea weeds, and at the time the letter was written had already taken about 150 excellent photographs.

Dr. Jaggar states that the geology of the region is very interesting. Some fossil leaves and shells have been found. A mountain north of Canoe Bay which is 4,300 feet in elevation has been identified as a new volcano. It has a large crater and a lake in its summit and Dr. Jaggar proposes to name it Dana Volcano.

The weather had so far been good, and on some days the temperature reached almost 70° in the sun. At that time of writing, the expedition was preparing to start on a somewhat pretentious overland trip with the "Honukai" across the foothill country on the east part of the Pavlof Bay-Bering Sea isthmus. The object was to get into a chain of lakes on the Bering Sea side.

It was expected that wild flowers would soon be out in great profusion. Specimens will be collected, and many color photographs will be taken. Already 1,500 feet of motion picture film have been taken and shipped out.

R. M. W.

LAVA SLICKENSIDES

In the New Zealand Journal of Science and Technology, Vol. X, No. 1, May, 1928, is a brief description of an igneous dyke recently exposed in a quarry at Aukland. The faces of the dyke show striations, which were apparently formed when the mass was still soft, and was being forced up into the volcanic debris and scoria in which it was founud. The writer suggests that had striated blocks from such a dyke been found in a talus deposit, or in less obviously associated surroundings, they might easily have been taken to be of glacial origin.

R. M. W.

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No. 187 RELEASED WITHOUT COPYRIGHT RESTRICTION July 26, 1928.

KILAUEA REPORT No. 861

WEEK ENDING JULY 25, 1928

Hawaiian Volcano Observatory, U. S. Geological Survey

R. M. Wilson, Temporarily in Charge

An avalanche from the northeast wall of Halemaumau occurred on July 20 at 4 p. m. Dust resulting was seen above the pit rim about five minutes later. On July 21 two dusty scars showed on the northeast wall, and a heap of new debris lay at the foot of the wall between the northeast and north-northeast taluses. The north wall is quite red from wetting. No other changes have been observed.

One feeble and 15 very feeble local earthquakes were registered during the week. The feeble shock occurred July 21 at 1:05 p. m., and had an indicated distance to origin of 15 miles. There was also the faint record of a distant earthquake beginning at 8:47:36 a m. July 18.

There was a slight accumulation of SSW. tilt.

Microseismic motion was slight throughout the week.

THE ISOTHERMAL SURFACES OF THE EARTH'S CRUST

In the American Journal of Science of June, 1928, is a discussion of isogeothermal surfaces by Van Ostrand. This represents a more general attack on the problem inspired by the various local investigations at different places for oil bearing formations. Mr. Van Ostrand applies formulas for conductivity of heat through earth crust materials, and works out the thermal gardients that would result if the earth had cooled to its present condition by conduction and radiation from an original state of high and uniform heat. The result of this mathematics is a set of perfectly regular isothermal surfaces. But actually these surfaces are irregular, conforming to local conditions of structure, conductivity, moisture content, and geologic formation. The oceans carry off heat from the underlying crust by convection, and therefore the isothermal surfaces in low latitudes are depressed under the oceans. It is supposed, however, that these isothermal surfaces are in general smooth and without abrupt variations.

In the discussion an important place is not given to the possible heat generated by radioactive decomposition, as suggested by Joly (see Volcano Letter No. 185).

The general problem when modified by the effects of surface configurations such as mountains, valleys, or oceans, by known details of geologic structure, and by known mean surface temperatures, will give the expected variation of temperature with depth Thus when abnormal temperature conditions are encountered, they may in many cases be used as indications of local irregularities of some sort in the earth's crust. It is found that the salt domes of oil bearing areas are associated with elevation of these isothermal surfaces and this principle is taken advantage of as an aid in determining the extent and shape of such formations.

This line of investigation would probably have application in the vicinity of a volcano to determine at least where the most recently active parts of the structure might be. It is known that heat flows slowly through rock, and it is probable that the intrusion of magma into a region could not be detected by changes of temperature at any great distance except after the passage of a considerable period of time. This assumes, however, that the layers blanketing such an intrusion are not cracked or punctured in any place to allow convection.

The temperature borings undertaken in the vicinity of Kilauea by the Hawaiian Volcano Observatory represent a still more localized application of the problem. Here the different strata have been laid down in very recent times at high temperatures. The entire floor of the crater is broken up by many cracks which furnish means of escape of heat from the lower layers by convection as well as by conduction. Since here the temperatures involved are great and the distances small, a great precision of temperature measurement is not so esseutial as in the case of the more thoroughly adjusted areas existing in older regions. Isothermal surfaces determined in the lava fill of Kilauea Crater should indicate by their shape the position of those parts most recently deposited, and should show where cracks are allowing heat to escape by convection.

R. M. W.

GEOPHYSICAL PROSPECTING

The use of specially designed seismographs in prospecting for oil bearing formations has been discussed occasionally in preceding issues of the Volcano Letter. The development of geophysical methods toward the particular end of commercial prospecting is receiving considerable attention, as may be judged by an article in the New Zealand Journal of Science and Technology for May, 1928, by Donald C. Barton. The use of the Eotvos balance is given the most important place among the methods he mentions. The seismic method comes next. There follow the methods using tests of the earth's crust for electrical conductivity, and for magnetic properties.

These methods of prospecting are considered sufficiently important to oil companies so that the expenditures in our southern oil producing states is estimated to be $400,000 a month on geophysical investigations alone. Other countries have been using the same methods in a lesser degree. The discovery of several oil fields and the mapping of others has come about through the use of these investigations.

The demand for their use has been greatest in the field of oil prospecting. There is no reason, however, why these methods, which are now so well developed, may not be used in prospecting for ores or other resources hidden beneath the earth's surface. Their application has already been used in Japan to account for certain details of seismic and volcanic mechanism. There is possibility that with more development it may yet be possible through their use to discover more definitely and more in detail the structure and mechanism of a volcano.

R. M. W

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No. 188 RELEASED WITHOUT COPYRIGHT RESTRICTION August 2, 1928

KILAUEA REPORT No. 862

WEEK ENDING AUGUST 1, 1928

Hawaiian Volcano Observatory, U. S. Geological Survey
R. M. Wilson, Temporarily in Charge

Wet weather at Kilauea Volcano on July 26 and 27 increased considerably the activity of steam jets in Halemaumau and on the outer crater floor. There have been a few slides from the pit walls caused by visitors rolling bowlders over the edge, but no natural ones of any size. Slight fresh cracking of the ground has occurred about the south rim station. Dusty slides at the south corner were noticed on July 19.

Several patches of buff colored ash of 1924 are still noticeable in depressions on the crater floor.

Measurements of the east rim cracks on July 30 showed a few minor differences.

The seismographs recorded 28 very feeble local earthquakes during the week.

Tilt has accumulated moderately NNE.

Recent surveys around the pit show that there have been four major cave-ins from the rim during the past 12 months. One strip about 400 feet long just to the northwest of the 1920 rift tunnels has fallen in. Directly over the northwest talus a strip about 700 feet long and containing nearly an acre has fallen in since the surveys of last year. The falling in of this part of the rim very likely represents the avalanche which caused the squeezing up of liquid lava on January 11, 1928. Another piece is gone from the north-northeast rim, just over the north end of the intrusive mass; probably the accumulative result of the minor avalanching that has been going on there so frequently during the past year. A long narrow strip having an area of about 0.7 acre has also fallen in from the east-northeast rim.

THE CALDERA PROBLEM

Several theories have been advanced to explain why many volcanoes are encircled by outer craters of which the diameters are great if compared to the apparently localized centers of activity. These calderas, sometimes with extended flat bottoms, are usually supposed to have been caused by volcanic explosion or by subsidence and collapse. Thus a volcano may build itself up as a perfect, sharp cone, with only a small summit crater, until an explosion causes its top to be blown off, thereby creating a summit crater of greatly enlarged proportions. This summit crater may then gradually fill, resulting in a large caldera with only localized activity within it. Again a volcano may proceed to build itself as a perfect cone until such time as the lava column retires and allows the summit portions to collapse inward upon the descending lava. This again would result in an enlarged summit caldera.

A new idea has recently been advanced by Sandberg, Koninklijke Akademie van Wetenschappen te Amsterdam, who believes that neither of the above ideas is the true one. He suggests that the explosion theory would not necessarily leave the inner walls so nearly perpendicular and so nearly circular in shape, as is the usual case. He believes that the large volumes represented by some of these calderas could not have collapsed into a comparatively restricted volcanic throat. The new theory is that these large calderas, which are usually circular and have steep inner walls, actually represent the tops of former great volcanic throats extending in undiminished size down into the volcano. Thus these "cone pipes" measured by the diameter of the outer caldera would suggest older volcanic activity on a greatly enlarged scale. As volcanic activity decreases, the volcanic throat diminishes in diameter until the remaining activity occupies a comparatively restricted area within a greater encircling caldera. As so many volcanoes now show smaller cones and throats within greater encircling calderas, it is taken as evidence that volcanism has diminished by that ratio within rather recent geologic time.

At Kilauea Sandberg describes the larger crater, which is approximately oval in shape and 3 by 2 miles in length and width, as being the top of the original "cone pipe" of Kilauea Mountain. The walls of Kilauea Crater, would, according to this idea, continue almost vertically downward nearly to the bottom of the mountain structure. Later activity having diminished, this large pipe has filled, and the activity has become centralized at Halemaumau, which now represents in turn the size of the reduced volcanic throat in which the lava column rises.

The explosive eruption of 1924 was a comparatively small one of its kind, as is testified by the much thicker beds of older explosive ejactamenta underlying its debris. During this eruption, the explosions which threw material from the pit, the avalanches from walls rendered unstable upon the retirement of the lava, and the material engulfed which followed the lava as it retired, enlarged the pit to double its former diameter. Geodetic measurements have shown that at this time the central parts of the floor of Kilauea Crater surrounding the pit settled by as much as nine feet in places with respect to the surrounding country. Thus even this small eruption did a great deal toward working the walls of the pit back and forming a larger caldera. Had the processes of this eruption been continued through longer time and in greater violence, the entire floor of Kilauea might have been eaten away and either engulfed or thrown out as ejected material. Had the processes continued still farther, the walls of Kilauea Crater itself might have been eaten back from their present position. The present position of the walls of the crater probably represent the limit of action of such a destructive phase in the history of the volcano. Evidences of this exist in the number of down-faulted blocks around the rim, which seem very suggestive of the method of development and enlargement of the great crater. These down-faulted blocks would have no place in the large volcanic pipe theory suggested by Sandberg.

R.M.W.

SAMPLE COPY

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No. 189 RELEASED WITHOUT COPYRIGHT RESTRICTION August 9, 1928

KILAUEA REPORT No. 863

WEEK ENDING AUGUST 8, 1928

Hawaiian Volcano Observatory, U. S. Geological Survey

R. M. Wilson, Temporarily in Charge

There has been slightly increased avalanche activity at Halemaumau during the past week. The slides occur mostly at the north end of the northeast sill. No other noteworthy changes have been observed.

Twelve local earthquakes and one distant shock were registered on the seismographs. One of the local earthquakes, classed as feeble, occurred at 7:50 p. m. August 7, and was felt by a few persons in the volcano district. The teleseism recorded very faintly, the preliminary wave beginning at 8:06:24 a. m. August 4.

Tilt was moderate to the SW.

POWER FROM NATURAL STEAM

The development of power from natural steam issuing from the ground has been for some time a fact in Italy (Volcano Letters 32 and 97). Development of natural power of this sort has now been made in California at The Geysers. A brief description is given in the July 7, 1928, issue of "Nature" by Allen and Day of the Geophysical Laboratory of Washington. Experiments were started there about six years ago in a small way, until outside capital became interested, making possible a more complete development of the power at hand. The area which shows signs of abnormal surface temperature is a narrow strip about 25 miles long, but the more intense thermic activity is limited to a smaller area only about six miles long and one-quarter mile wide. Wells have been sunk to various depths from 400 to 650 feet by allowing cold water to flow into the well while the drilling operations were in progress. This cold water condensed the steam and so reduced the steam pressure, allowing the operations to proceed without undue difficulty. The steam pressure made available in five new wells varies from 95 pounds to 276 pounds per square inch, and issues in such volume as to make available for power an average per well of about 1,000 kilowatts. The wells are rather close together, the distance between them varying from 50 to 175 feet, yet apparently there is no lessening in steam pressure of any of these wells due to the discharge of steam from the others. The original two wells which were drilled before the advent of outside capital were utilized to operate the electric lighting plant for the inn and cottages located nearby. Plans have been made for the commercial use of the increased power available from the newer and larger wells.

It is pointed out that in all probability this steam comes directly from underlying masses of hot magma. The steam is superheated to such high temperatures that the idea of its coming from an underground water reservoir does not seem reasonable. Additional evidence is the fact that the gases brought up with the steam are those that would be expected to issue from hot magma. These are particularly carbon dioxide, hydrogen sulphide, nitrogen, and argon, and traces of other gases. Thus these indications seem to point to hot magma as the origin of the virgin steam, rather than to the mere heating of infiltrated surface water by hot strata. It is noted that here again heat at the surface in the form of natural steam or hot springs is probably an indication of the presence of a deep fault. R.M.W.

PREDICTION OF EARTHQUAKES

The daily press is prone to give considerable space to those who desire to predict calamities. The predictions of Professor Raffaele Bendandi, of Faenza, Italy, have been given considerable publicity. It is the habit of this forecaster to make frequent and rather vague predictions as to coming earthquakes, tornadoes, and tidal waves. Earthquakes occur in considerable frequence on our world, which may yet pass unnoticed except by seismologists, unless they happen to occur in some thickly populated area where damage to humanity results. It is safe to prophesy a great earthquake at almost any time one may wish, and then afterward to point to a selected earthquake which may appear to justify the prophecy, if one is not too particular as to precise time and locality. The prophecies of Professor Bendandi have been subjected to analysis by Mr. James Young, of Toronto, Canada, who has found that no more of these prophecies have been properly fulfilled than would be expected from the laws of chance, merely. He points out that many of the earthquakes selected by Bendandi as justifications of his prophecies, while they may occur within a few days of the time set, often fail by whole continents to agree with the prophesied locality. It is also pointed out that several of the greatest and most disastrous earthquakes were not predicted at all. Thus it would seem that Professor Bendandi may make his prophecies merely at random, afterwards making use of a far fetched chance method to justify them.

Earthquake prediction by conventional scientific methods is by no means impossible. The tiltings, changes of level, and horizontal creeps of the earth's crust discoverable by geodetic measurements are apparently proved to be forewarnings of earthquakes by a number of actual observed cases in Japan and California. These movements probably represent elastic crust yielding before earthquake fracture occurs. RM.W.

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No. 190 RELEASED WITHOUT COPYRIGHT RESTRICTION August 17, 1928

KILAUEA REPORT No. 864

WEEK ENDING AUGUST 15. 1928

Hawaiian Volcano Observatory, U. S. Geological Survey

R. M. Wilson, Temporarily in Charge

Halemaumau presents an extremely quiet and peaceful appearance, and there is absence of any indication of volcanic activity in the near future. Slides were noted at 2:40 p. m. August 9, 3:15 p. m. August 11, and 9:15 a. m. August 15. Steaming is extremely slight in the pit.

Fourteen very feeble local earthquakes were registered on the seismographs at the Observatory. It is interesting to note that nine of these occurred on August 8, and that one shock was a three-minute tremor coming just after noon. Beginning at 9:51:21 p. m. August 11 is a brief disturbance, presumably a faint trace of a teleseism.

Microseismic motion is considerably below normal.

The net accumulation of tilt for the week is strong to the NNE.

SOUTH AMERICAN EARTHQUAKES

The following extract from "Harper's Weekly" of December 5, 1868, indicates that inhabitants of the Pacific Coast region of South America must always have lived in fear of disastrous earthquakes.

"The Spaniards in South America were not without early intimation of the insecurity of the soil. Lima was founded in 1535, under the high-sounding title of Ciudad de los Reyes, or City of the Kings, since altered to its present name. In 1582 Lima had its first recorded attack of earthquake. The centre of the shock, however, was lower down along the coast, in the neighborhood of Arequipa, founded by Pizarro some twelve months after the establishment of Lima. Arequipa was laid in ruins then as now; but Lima escaped with a warning. Lima's turn, however, was not long in coming. Four years afterward it was laid prostrate; and so great was the catastrophe, even in that land of catastrophes, that the anniversary of that destruction is solemnly commemorated to the present time, on the day of the Visitation of Elizabeth. Lima had its third attack in 1609. In November, 1630, there was another earthquake; but so many of the citizens contrived to escape that they, then and there instituted the Festival of Nuestra Senora del Melagro, which is celebrated annually to this day.

"Thenceforth, earthquake and city may be truly said to have entered into contest for possession of the soil. Earthquake returned to the charge in 1655 with such violence that, for the first time, the citizens camped for several days in the country districts around. When they returned they found no stone standing on another; nevertheless the city rose again. After this there was no earthquake for some twenty years. Again, ten years later, in 1687, at four o'clock in the morning, houses and public edifices came tumbling down without the least previous intimation, the inhabitants, as usual, rushing into the squares and open spaces. The miserable consolation, however, of looking on in safety was this time denied them. At six in the morning the earthquake repeated its attack with renewed vigor, and the sea, retiring and rising in a wall of inky waters—as it did in the great earthquake of this year (1868)—dashed back with overwhelming force over the land. Callao, which had arisen as the port of Lima, a few miles from it, was entirely destroyed, and most of the inhabitants were carried away by the receding waters. The local records, preserved to us by Don Antonio de Ulloa, captain of his most Christian majesty's navy, mention this as the most disastrous visitation to that date. December, 1690, September, 1697, July, 1699, February, 1716, January, 1725, December, 1732, were all earthquake months in Lima. In 1734 and 1745 there were more earthquakes. On the 28th of October, 1746, at half past ten at night, the first shock was felt of another earthquake, and within the space of three minutes all the buildings in the city, great and small, public and private, were heaps of ruins, burying with them those inhabitants who had not been quick enough in escaping to the squares. Then succeeded a moment's calm, as when the heavy ordnance has opened the battle, and the lighter, but more numerous, musketry prepares to follow. Soon it began again, and the houseless, homeless inhabitants counted two hundred distinct shocks within the following twenty-four hours. These shocks continued until the February of the following year, and were computed at four hundred and fifty in all. On this occasion the port of Callao sank quite down below the level of the sea. Nothing was left standing save a piece of wall belonging to the fort of Santa Cruz, on which twenty-two persons contrived to save themselves. Of the twenty-three ships then in port, nineteen were wholly sunk, and the remaining four carried a considerable distance inland. Of the four thousand inhabitants which the port of Callao then numbered, only two hundred survived. In Lima thirteen hundred dead bodies were excavated from the ruins, exclusive of great numbers of maimed, who afterward died of their hurts. Commander Wilkes, of the United States exploring expedition of 1849, was able in that year to define the site of the old port of Callao beneath the sea." R.B.H.

THE HAWAIIAN SEISMOGRAPH

Another set of instruments, of the type developed and manufactured in the laboratories of the Hawaiian Volcano Observatory, is being tested prior to shipment for installation at Dutch Harbor, Alaska. This is the sixth set of instruments of the series built at the Observatory. The other five sets are distributed as follows: Hilo and Kealakekua, Hawaii, stations operated by the Hawaiian Volcano Research Association; Kodiak, Alaska, station, and Lassen Volcano Observatory, Mineral, California, operated under the Section of Volcanology, U. S. Geological Survey; and U. S. Coast and Geodetic Survey, Washington, D. C., for test before installation at Sitka, Alaska. A description of the instruments appears in Volcano Letter No. 142. R.B.H.

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No. 191 RELEASED WITHOUT COPYRIGHT RESTRICTION August 23, 1928

KILAUEA REPORT No. 865

WEEK ENDING AUGUST 22. 1928

Hawaiian Volcano Observatory, U. S. Geological Survey

R. M. Wilson, Temporarily in Charge

At 9:50 a. m. August 18 the north wall of Halemaumau was working very slightly. Two falls of rocks were heard in 10 minutes from that side, and another from the northeast corner. The north wall and talus gave the appearance of having had numerous small slides. During the "Pageant to Pele," presented to a large audience at the side of the pit from 9 to 11 p. m., there was nearly constant avalanching, filling the air with dust, and at times drowning the exercises. By daylight August 19 could be seen heavy coatings of red dust on the floor and walls of Halemaumau and on the south Kilauea floor. The avalanching continued at irregular intervals, coming from blocks tumbling from the north rim, and gathering debris along their course. Examinations show that widely cracked areas formerly back of the north rim have gone in, and that there are numerous fresh cracks of varying sizes. Many of the new cracks are emitting steam, and several of those that are dry are allowing the escape of heat. At the present time there is still some sliding from the north rim.

The Observatory seismographs have recorded nine local tremors during the week ending August 22. These were all very feeble with the exception of one which occurred at 10:47 p. m. August 18. This one is classed as feeble, and was apparently caused by an unusually large avalanche in the pit of Halemaumau. Tremors of this magnitude can very seldom be ascribed to avalanches, yet the evidence points to the fact that this one is the result, and not the cause of an avalanche. The amplitude increases gradually to the maximum, and fades out again gradually; there are no phases to be recognized, as would be the case in a true earthquake. The record of the same disturbance from the Uwekahuna seismograph is 25% greater in amplitude, in spite of the fact that the magnification of that instrument is less than the corresponding factor for the instruments at the Volcano Observatory. This is easily explained in the case of an avalanche tremor by the fact that the Uwekahuna instruments are but 0.7 mile from the pit, while those at the Volcano Observatory are 2.6 miles away. This tremor was the climax of a series of five avalanche tremors, of which the first was at 9:41 p. m. Thus the Observatory seismographs bear witness to exceptionally heavy avalanching during the evening of the 18th, when there were present at the edge of the pit well over a thousand spectators who had come there to see the entertainment furnished by the program of the Cook Sesquicentennial.

Microseisms throughout the week have been normal. Slight tilt has accumulated toward the northeast.

THE PAVLOF VOLCANO EXPEDITION

A letter from Dr. Jaggar dated July 11 gives us additional notes of the progress being made by the National Geographic Pavlof Volcano Expedition, of which he is the Director. The letter was written in camp at the north end of Pavlof Bay, just east of Pavlof Volcano. The party had just completed a trip into the interior of the Peninsla, where two comps were made on the northeast base of the volcano. From these camps a nine-day side trip was made to the region north of the mountain, where an interesting bit of volcanic topography was found similar in nature to the Chaos Jungle at Viola on Mount Lassen, California. A view into the crater of Pavlof was had, and two inner cones were seen. In the crater there was also visible an old lava flow and considerable steam from a number of solfataras. No hot springs were found, but mineral springs were discovered on two occasions.

The topographic section of the expedition had mapped 2,000 square miles of country. The expedition had taken 225 photographs and a considerable number of color plates. Wild flowers are there in abundance, and specimens of the different kinds have been collected and pressed. Dr. Jaggar says that fossils have been found and that the geology of the region is very interesting. The geologic details, however, must wait for a more thorough investigation by some geologist in the future who will be able to base his work upon the present reconnaissance and the topographic maps being made by the party.

The weather has been bad, especially from the point of view of the topographic party, who need clear weather for long distance photography and plane table operations. There have been hundreds of caribou seen, and 25 to 30 bears. The expedition has had no difficulty in keeping its larder stocked with meat, fish, and clams at all times. Salmon have been caught with a small seine operated by the "Honukai."

The "Honukai" is still holding its place as one of the most useful units in the expedition's transportation. It traverses the beaches with ease, and can go over the greater part of the dry tundra country. Swampy tundra and "niggerheads" have at times caused it to turn back, however. The use of the steel mats in soft places, as suggested by the experience with the "Ohiki" in Hawaii, has proved valuable in the extreme.

At the time of writing, the expedition was planning to go westward to Volcano Bay as the last lap of the season's explorations.

A radio message has just been received from Dr. Jaggar stating that the work was completed and the expedition was starting back home from Alaska on August 16.

R.M.W.

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No. 192 RELEASED WITHOUT COPYRIGHT RESTRICTION August 30, 1928

KILAUEA REPORT No. 866

WEEK ENDING AUGUST 29, 1928

Hawaiian Volcano Observatory, U. S. Geological Survey

R. M. Wilson, Temporarily in Charge

There was rather active avalanching from the north wall of Halemaumau on August 24. Since that time the wall has continued to be restless with numerous falls of rocks and an occasional dusty slide. The south wall has had a few slides recently, as shown by streaks in the heavy dust coating of the south talus. The whole pit interior is still thickly coated with dust from the avalanches of August 28.

There have been eight very feeble local earthquakes and one teleseism recorded on the Observatory seismographs during the week. The record of the teleseism was feeble; the arrival of the preliminary phase is shown at 11:23:00 a. m. on August 24. Subsequent phases suggest a distance of 2,800 miles to the origin.

Microseisms have been more feeble than normal. Tilt has accumulated moderately toward the NW.

THE ISOSTASY OF HAWAII

An article of exceptional interest to the Hawaiian Volcano Observatory has appeared in the American Journal of Science of August, 1928, by Roy W. Goranson. The primary object of the investigation outlined was to discover the density of the island mass of Hawaii. The method of attack, through the use of gravity observations, has also developed some interesting conceptions as to the state of isostatic adjustment of the island.

The first part of the paper outlines briefly the method of computing theoretical gravity. Correction for isostatic adjustment is given considerable space, and it is shown that lack of knowledge of the true distribution of mass in the earth's crust leads to a rather wide range of possible values in arriving at this correction. Isostasy is accepted as a fact, but its precise mechanism is not fully determined. Geology and seismology may eventually yield data which will determine how the variations of density are distributed in the isostatically adjusted earth crust. Another problem of isostasy which has a direct bearing on the calculation here discussed is the strength of the earth's crust. How large may an uncompensated topographic mass be and still be upheld by this crust?

The large values, all positive, of the local anomalies of gravity have led this investigator to believe that the island of Hawaii is for the most part not compensated. That is to say, the island mass is present as an isostatically unbalanced load upon the earth's crust, its excess of matter causing the large values in the observed gravity.

To put this in figures, the island is resting on the ocean floor with a pressure amounting to 9,700 pounds per square inch over an area of about 19,000 square miles. If this great mass is not isostatically compensated, it is being supported simply by the strength of the earth's crust which forms the ocean floor. It is suggested that this load is just about the greatest that can be so supported. Isostatic adjustment is probably attained only with the passage of geologic time, so that it is conceivable that this island has been volcanically built at such a rate as to be still largely uncompensated. He believes that the island of Hawaii is even now gradually accomplishing its adjustment by gradual sinking and downfaulting. This might easily account for the downfaulting areas around the coast of the island as in Puna, Kona, and perhaps Hamakua and northeast Kohala

Again to express this in figures. it is suggested that if the island as it now stands is not at all compensated, and if the earth's crust beneath it has no strength it would be expected that the island as a whole would settle downwards 11,000 feet to accomplish total isostatic adjustment. This would leave the tops of Mauna Kea and Mauna Loa projecting above the ocean as small islands with summit elevations of only about 2,800 and 2,600 feet above sea level. This of course represents the extreme case. Presumably isostatic adjustment is already partly accomplished, and it is known that the earth's crust has considerable strength, so that perhaps a sinking of only 8,200 feet should be taken as an estimate.

It is suggested that this mechanism explains the general progressive diminishing elevation of the islands of the Hawaiian group towards the northwest which may once have been as high as Hawaii. These islands perhaps increase in age toward the northwest; they have had more time to settle and to more completely accomplish their isostatic adjustments. This may also be an explanation of the gradual sinking of basaltic ledges in the ocean with the coral growths on their tops having to grow higher and higher to maintain their position at the ocean surface.

The object of the calculation was primarily to discover the density of the bulk of the island. H. S. Washington is quoted as giving a density of 2.96 for the average value of Hawaiian rock material. As it lies in place the apparent density of the rock would be considerably less, perhaps as little as 2.0, due to its vesicularity and loose bedding. From the evidence furnished by gravity stations on the side and top of Mauna Kea, Goranson calculates 2.12 as the density of the upper part of the cone of Mauna Kea. Similarly, the upper portion of Mauna Loa, lying above 4,000 feet of elevation is given a density of 2.52, resulting from the use of gravity determinations at Kilauea and at Mauna Loa summit. For the whole island cone from its base on the ocean floor to the summit he gives an average density of 2.69. Thus it is apparent that the densities at higher elevations are smaller. This would be expected due to the compacting by pressure of the lower layers and the probable intrusion of dykes of denser material in the lower structure. Summing up, the density of the mountains of Hawaii is given as lying between 2.40 and 2.63, the probability favoring the lower value. R.M.W.

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No. 193 RELEASED WITHOUT COPYRIGHT RESTRICTION September 6, 1928

KILAUEA REPORT No. 867

WEEK ENDING SEPTEMBER 5, 1928

Hawaiian Volcano Observatory, U. S. Geological Survey

R. M. Wilson, Temporarily in Charge

Avalanching from the north wall of Halemaumau is not so active; only a very few small slides now occur. Dusty slides were rather frequent on August 30 and 31. New cracks back of the north rim appear to have widened slightly. The odor of chlorine gas was noticed in that area during a circuit of the pit on August 31. There are scattered new coatings of white salts on the north wall.

There have been recorded only seven local tremors during the week. One at 11:04 p. m. on August 30 was classed as feeble, but was reported perceptible to a few people in the vicinity. All the others were very feeble.

Microseismic motion has been more feeble than normal during the past weeks, but increased slightly in amplitude on September 4. Tilt has accumulated slightly toward the NE.

TILT

Ground movements are becoming increasingly important as indications of forces acting beneath the earth's surface. Pressures set up by volcanic action or by the stresses accumulating in the earth's crust which tend towards earthquake conditions may be thus sometimes detected at the surface. Triangulation for measurement of horizontal displacements has yielded interesting data in a number of places, notably in the areas of the major faults in California, and in Japan in the region shaken by the great Kwanto earthquake of 1923. Leveling has shown vertical displacements largely resulting from earthquakes, in cases too numerous to mention. Triangulation and leveling are expensive operations, and cannot be used as a means of keeping continuous watch over ground movement. The accumulated movements during a period of months or years may be discovered by retriangulation or releveling over an area, but the day by day development of movement cannot be watched by these methods.

Tilt, or tipping of the ground surface, must obviously occur in a region where change of relative elevation takes place. Occurrence of tilt may therefore be taken as an indication of ground movement involving changes of elevation. It is possible to make continuous record of tilt. Omori, some 20 years ago, started the recording of tilt in Japan with a pair of long period horizontal pendulums. In fact, most horizontal pendulum seismographs are competent to record it with greater or lesser degrees of accuracy, according to their design. A clinograph designed by M. Ishimoto is a small bi-filar horizontal pendulum, optically recording, which has been used to some extent in Japan specifically for measuring tilt. Temperatures of ground and instrument affect all such arrangements to a certain degree. The most precise tilt measurements so far made perhaps resulted from the experiments of Michelson and Gale; these observations were so accurate as to detect tiltings due to the earth tide, for which purpose they were made.

Continuously recorded tilt as observed at the Hawaiian Volcano Observatory has been most valuable in the study of the volcanic phases of Kilauea (see Volcano Letter No. 41, October 8, 1925). Tilt as considered in Japan in connection with great earthquakes is briefly outlined by Imamura and Haeno in "Proceedings of the Imperial Academy," Tokyo, IV, 1928, No. 4. Here it seems possible that continuously recorded tilt may be the key to the foretelling of earthquakes. Stations near or in an area wherein ground stresses are accumulating would be expected to record the bending and elastic yielding of the rock crust caused by such stresses before their release in fracture and earthquake. It would not be difficult to maintain a considerable number of tilt stations scattered over a suspected region.

A number of cases in Japan are cited where abnormal tilt actually occurred and was recorded before an earthquake. The Kwanto earthquake of 1923, with its many and great upheavals of the earth's surface, would doubtless have been very rich in data of this sort had there been more stations to record the tilt. As it was, a slow shoreline subsidence was noted preceding the earthquake which must have meant the presence of very considerable tilts. Seismographs in Tokyo actually did record some of these precursory tilts. From July 30 to August 17, 1923, a definite surge of abnormal tilt was noticed, and then after an intermission of two weeks a very sharp surge of tilt in the same direction began and continued for eight hours, at which time the earthquake occurred. There are no less than nine other cases where abnormal tilts of from 7 to 30 seconds were observed as preliminaries to major earthquakes. The earthquakes followed the recording of these tilts after a period of from four days to two weeks.

The Advisory Committee in Seismology of the Seismological Society of America emphasizes the importance of tilt by making it one of the four subjects important for future attention.

With instruments of the horizontal pendulum type, and perhaps with others when they may be designed, the changes of air and ground temperature at the station cause trouble in recording tilt. Most records show cyclical variations, diurnal and annual, which are in all probability not caused by the volcanic or seismic tilt which it is desired to study. It is sometimes difficult to separate from the composite motion recorded the components which are due to these particular movements. Most types of tilt recording instruments are not provided with methods for absolute check whereby the accumulative instrumental errors may be eliminated. Thus an instrument may gradually settle on its foundation, and so record false tilt. It cannot be known whether this is true tilt unless it is determined that the ground upon which the instrument stands has partaken of the same amount of motion. This is a function of precise leveling in connection with tilt; that is, to analyze the apparently accumulated tilt. By leveling, or other outside observations, it may be possible to see whether the accumulation shown by the instrument over a long period of time is an actual accumulation of tilt or merely an accumulation of errors and instrumental change. R.M.W.

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No. 194 RELEASED WITHOUT COPYRIGHT RESTRICTION September 13, 1928

KILAUEA REPORT No. 868

WEEK ENDING SEPTEMBER 12, 1928

Hawaiian Volcano Observatory, U. S. Geological Survey

R. M. Wilson, Temporarily in Charge

Halemaumau has been quiet during the past week. A few slides have occurred, but no notable changes have been observed. Crack measurements on September 10 show a few minor differences.

There have been 24 local earthquakes and one teleseism recorded on the Observatory seismographs during the week. One of the local shocks, at 2:27 p. m. on September 11, is classed as feeble, but was felt by a number of people in the vicinity. The distance to its origin is 14 miles from the Observatory. All the other local shocks were very feeble. The teleseism, also on September 11, made only a feeble record, and the phases could not be definitely distinguished. The beginning of either the secondary or the long wave is shown at 2:20:06 a. m. Hawaiian standard time.

An earthquake reported felt in Kona at 8:30 p. m. on September 4, whose origin was indicated on the seismograph there as being seven miles from Kealakekua, was recorded at the Hawaii Volcano Observatory as a very feeble tremor.

Microseismic motion was slightly stronger during the first part of the week; and tilt has accumulated moderately toward the SW.

MICROSEISMIC MOTION

Microseisms are found to exist at practically all seismological stations, and it is presumed that all parts of the earth's surface are subject to these slight but continuous vibrations. They probably act differently in different localities, and have their origin in various causes. In general these oscillations have periods of from 2 to 10 seconds, and amplitudes of motion of from 0.02 mm. to 0.5 mm. They are usually continuously present, but wax and wane in amplitude. It is sometimes difficult to read from seismograms the weak preliminary motions of a true earthquake when microseisms are thus being continually recorded, as they frequently mask the earthquake motion which it is desired to observe.

Considerable study has been given to microseismic motion to determine its nature and cause, but a direct and satisfactory explanation has not yet been reached. An enlightening investigation by Takeo Matsuzawa is described in Volume II, Part 5, of the Journal of the Faculty of Science, Imperial University of Tokyo. This investigator in studying the types and causes of microseisms at Tokyo remarks that his results must of necessity be influenced by the particular locality. Studies carried on at other places would presumably develop individual microseismic characteristics. His suggestion is that each small part of the earth's crust composes a local oscillating system, having in each place its own characteristics as to natural period and ease of oscillation. Such a system, depending upon local topographic shape, density, material, geologic structure, etc., would naturally be very complex, and would probably respond to a number of different natural periods, together with their harmonics. Microseisms at stations only a few kilometers apart have different characteristics, while those recorded at stations close together usually appear to be somewhat similar in period and amplitude.

At Tokyo Omori found three particular types of microseisms, perhaps resulting from the more outstanding natural periods of vibration of the particular locality. For the first of these types Matsuzawa gives periods of from 2 to 3 seconds, with normal range of motion of about 0.02 mm.; the second type has a normal period of 4 seconds, and range of motion of 0.05 mm.; and the third has somewhat irregular periods ranging between 6 and 9 seconds, and sometimes attains a range of motion amounting to 0.5 mm.

As to the agencies inspiring these vibrations, those suggested are changes of atmospheric pressure, changes of temperature, wind, ocean wave action on nearby coasts, ocean tides, precipitation. This investigator considers change of atmospheric pressure the chief cause of microseismic motion at Tokyo. Wind produces certain effects due to the shaking of the buildings which shelter the instruments, but apparently affects true michroseismic motion only to a limited degree.

The correlation between changes of barometric pressure and the amplitude of microseismic motion seems well established at Tokyo. Many cases are cited wherein the general presence of barometric depressions due to cyclones has produced definite increase of amplitude of microseisms. Conditions of barometric pressure less violent than those accompanying cyclones, such as the presence of steep pressure gradients merely, have been also shown to swell the microseisms. Studies of these correlations have progressed so far that the character of response of microseismic motion has been found to depend upon the character and location of the atmospheric disturbance. Thus it is stated that apparently at Tokyo the more rapid microseismic motions are inspired by atmospheric disturbances in the northeast part of Japan, while the slower motions are inspired by disturbances to the southwest. It has also been noticed that where a marked barometric depression travels from west to east, there is a time lag in the climax of microseismic motion produced thereby amounting to three or four hours after the nearest approach of the depression. On the other hand, if the depression is traveling from east to west, the maximum microseismic motion appears to occur coincidentally with the nearest approach of the disturbance. This perhaps has something to do with a difference of effect of the barometric depression on land areas and on water areas. In general, the coming of a time of increased microseismic motion is heralded by the development of the quicker motions first, while the waning phases are marked more by the predominence of the slower motion.

Whether or not atmospheric pressures produce microseisms through a direct mechanical compressing or flexing of the earth's crust is not definitely known, but is suggested as what may possibly happen. Thus perhaps the pressures and impulses applied to the earth's structure are causing it continually to vibrate and to ring like a great bell.

The discussion suggests that if it is true that each particular locality has its own natural periods of vibration, that very probably the recording of earthquakes is affected thereby. Thus a natural period of a locality would tend to control the period of the earthquake as transmitted and recorded. It would seem that the care taken to design seismographs which will not impose their proper periods upon their records is somewhat lost if the natural period of the locality, which cannot be controlled, is to impose its effect on the recorded results anyway. R.M.W.

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No. 195 RELEASED WITHOUT COPYRIGHT RESTRICTION September 20, 1928

KILAUEA REPORT No. 869

WEEK ENDING SEPTEMBER 19, 1928
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Heavy coatings of white salts formed on the fresh surfaces of the north wall during the week. Today, however, they have disappeared after a night of rain. The thick layer of dust on the Halemaumau floor is finally being washed away, and yellow-stained areas are again showing. Steam vents are all mildly active.

There were 20 very feeble local earthquakes recorded at the Observatory during the week. Microseismic motion was normal, and tilt accumulated slightly towards the N.

PROJECT FOR ALEUTIAN GEOGRAPHIC OBSERVATORY

By T. A. Jaggar

The writer on September 7, 1928, addressed the Seattle Chamber of Commerce on a proposed Aleutian Geographic Observatory to be established at Dutch Harbor, Alaska. This project is formulated in extension of a report on a possible Alaskan volcano observatory, revising somewhat and broadening the project. (Volcano Letter Nos. 116, 128, 134 and 147.)

Experience shows that mapping should be the main aim, and that all sciences should be represented. The founding of the Hawaii observatory by the sugar and other industries through the Volcano Research Association, with government collaboration, suggests that the fish, fur, and shipping industries might do something effective for southwest Alaska.

Modern exploration and discovery is extended by each new invention. Montana and Arizona have been "discovered" to be garden spots through irrigation and agricultural machines. The "Carnegie" is mapping all the oceans with echo sounding and new electrical instruments (Volcano Letter No. 175, May 3, 1928).

The advent of the salmon canneries, of Diesel engines in 60-foot boats of 2,000 miles fuel radius, of radio communication, and of some new maps, have greatly improved the Alaskan field for the explorer.

It is proposed that the observatory be at Dutch Harbor as a fixed home for land and sea mapping and for measuring geophysical, biological, and chemical processes along the arc of the Alaskan peninsula and the Aleutian Islands. The station will work in concert with eight scientific bureaus of the government, seven civil offices, and two outside institutions. It is called geographic, because it will study that part of the earth in relation to man.

It will measure and secure data all the year around concerning the weather, tides, currents, magnetism, earthquakes, volcanic activity, crust upheaval, animals, plants, fish, natives, and commercial needs.

For the summer half of the year, the observatory will maintain expeditions to collect land and marine organisms, minerals, rocks, and human antiquities; to map the lands, the geology, the depths of the sea, the air currents, temperatures and pressures, and such earth activities as magnetism, tremor, tilting, and changes of mean sea level. The snowy craters of the big volcanoes will be explored and photographed with the aid of alpinists and aviators.

It is a land of ancient inhabitants who linked America with Asia; it contains the greatest craters on earth; it exhibits volcanic activities that should throw light on the origin of the earth and the origin of ores; on the mainland there are known occurrences of gold, silver, lead, copper zinc, sulphur, petroleum, and coal, and the numerous big western islands have not even been prospected.

It is a grassy country without trees. Sheep, reindeer, and cattle are grown there, but ranching is a new industry. There is much fur produced, largely foxes, mink, and land otter. The Aleutian land is one of the great breeding grounds for the study of migratory birds.

There has come recently a demand for scientific study of the Aleutian lands from numerous scientific institutions and conventions, so that the matter is being pressed by the National Research Council of the United States. The writer has reconnoitered the field by three expeditions devoted primarily to volcanology.

The proposal is to place four workers at the main station winter and summer, equipped with a powerful Diesel yacht and small boats, also laboratories, shop, quarters, dock, and photographic dark room. The station will keep in radio communication with its yacht and with existing stations. It will provide a base and a boat for the Coast Survey and the Geological Survey in mapping the coasts and interiors. It will publish weekly and quarterly reports.

The substations will work from April to September, and each summer will produce a new substation, for intensive geophysical measurements, photographing, and collections, on a volcano for instance, setting up a seismograph and weather instruments, and keeping a journal. The summer staff will be eight persons, and the substation will report to the main station. The substation camp will be left for future use. Specialists in all sciences will be imported from outside institutions for work at the substations.

The observatory vessel will carry the observers, the pack horses, and the camp equipment to the substation site, and the base camp may be moved by boat as often as necessary, when the substation work is in the nature of an exploring expedition. It will probably be advantageous for the first established substations to work in conjunction with map-making expeditions.

It is useless to establish such an institution without adequate funds. The following is the estimated cost of equipment and operation:

EQUIPMENT		ANNUAL UPKEEP	
Boats	$25,000	Salaries	$22,200
Houses	12 000	Station Upkeep	6,000
Horses	400	Boat Upkeep	4,200
Apparatus	1,000	Food Supplies	3,500
Contingent	8,600	Travel & Freight	3,000
		Contingent (Incl. publications)	11,100
	$50,000		$50,000

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No. 196 RELEASED WITHOUT COPYRIGHT RESTRICTION September 27, 1928

KILAUEA REPORT No. 870

WEEK ENDING SEPTEMBER 26, 1928

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

There have been no changes in Halemaumau. The bottom region is remarkably dry and free from steam.

During the week 27 local earthquakes and one teleseism were recorded on the Observatory seismographs. One of these local shocks, at 10:02 a. m. September 20, although feeble was yet possibly strong enough to have been perceptible. All the others were very feeble. The teleseism made a weak record from which the distance could not be estimated. The beginning of either the secondary or the long wave is shown at 9:21:54 p. m. on September 21.

Microseismic motion was normal throughout the week, and the accumulation of tilt was moderate towards the NNE.

THE 1928 OUTBREAK OF KRAKATOA

The volcano Krakatoa in the Sunda Strait between Java and Sumatra consisted of an old engulfment crater in the sea prior to August, 1883. The crater rim protruded above the water as the islands Verlaten, Lang, and Krakatau. The latter was the largest, five miles long, consisting of three cones, the basaltic Rakata the largest, 2,623 feet high, the other two smaller and andesitic named Danan and Perboewatan. These two last occupied the extension of Krakatoa island from the region of the ancient andesitic crater rim, on which Rakata was built, northwestward to the site of the ancient crater center.

The colossal eruption of 1883 followed two centuries of quiet. Danan and Perboewatan became explosively active in May, and on August 28th, 1883, one of the most enormous volcanic explosions ever recorded occurred. These two cones were engulfed completely, leaving water 900 feet deep, columns of ash and pumice went miles into the air, and the engulfment wave drowned 36,417 people in the low coastal villages of western Java and southern Sumatra. Rakata was left with a sector of its cone gone, and a great bluff reaching to sea level like the northeast side of Molokai.

Krakatoa since then has been quiet. A new submarine eruption about the center of the triangle made by the three remaining islands began December 29, 1927. Fishermen reported columns of smoke rising from the sea sixty feet or more, with bombs that glowed at night. Gas bubbles had been seen here earlier in 1927.

Early in January, 1928, feeble eruptions every half-minute or minute culminated in a repose interval of 5 to 8 minutes every quarter hour, and this was followed each time by unusually heavy explosions. The water would rise in a dome. Out of this a black mass of ashes and bombs, clinging together, emerged in tree-like forms. The sea in contact with the incandescence boiled, surrounding the ash column with a wreath of steam. When the ash reached its greatest height, the black color disappeared in rocket trails of white steam and gases. A few bombs floated for awhile buoyed by gas. A white central steam column remained, encircled by the wreath at its base. The relapse of the water dome made a wave, and the ring of falling matter made other waves, felt at some distance as a swell. Sometimes the eruptive material was ejected obliquely in several directions. There appeared to be six crater orifices below sea level. The photographs taken are very striking, showing the central column like a lily, and the basal wreath like a flower pot.

The sea water was made turbid by the ash. Water temperature was 103° F. 1,600 feet away, the normal water being 84° F. The glow of the ejected bombs could be seen at night. The width of the eruption center on the water was 2,000 feet in a WNW.-ESE. direction. The sea had been about 600 feet deep where the eruption occurred.

A temporary observatory, with seismograph and radio sending apparatus, was set up on Lang Island. Others on military motor trucks were maintained on the mainland to receive warnings for the populace. There were tremblings and rumblings. The first eruptions were only 200 feet high. After January 13 glowing masses were thrown up occasionally 4,000 feet. Regular observations were inaugurated night and day. After January 26 the activity dwindled. On that date the new crater rim appeared above sea level and reached in a few days a height of 10 feet and a length of 570 feet, consisting of loosely piled cinder. The waves quickly washed this away. On February 4 only three eruptions occurred and 11 rumblings were heard. The next day one eruption and two rumbles. Nothing but seismographic shakes and gas bubbles with sulphuretted hydrogen occurred after that date in February.

In March a thorough survey was made. A depth of 113 feet of water was sounded at the new crater. The bottom temperature was 97° F. There is a cone on the bottom at the wall-crack region of the submarine engulfment pit of 1883, steepest toward the deeper pit-center. There was a small eruptive revival the end of March, and another the last half of April. Some sulphurous gas bubblings in the sea several miles apart were found in Sunda Strait spread over 500 square yards, off Tjarita, and have been noticed by fishermen for some years. (Bull. Neth. East Ind. Volc. Surv. 1927-28 and Overdruk Leidsche Geologische Mededeel., 1928, pp. 325-329: articles by Ch. E. Stehn and J. H. F. Umbgrove.) T.A.J.

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No. 197 **RELEASED WITHOUT COPYRIGHT RESTRICTION** October 4, 1928

KILAUEA REPORT No. 871

WEEK ENDING OCTOBER 3, 1928
T. A. Jaggar, Volcanologist in Charge

Halemaumau has been particularly quiet throughout the week. During the first part of the week the pit was dusty from previous avalanching, and steam vents were only slightly active; but with the southerly rainstorm of October 1 the pit walls and floor were washed clean of the dust coatings, and steaming was very noticeably increased, particularly at the fountain vents of July, 1927. Ocassional small rock falls are difficult to locate because of the lack of dust to mark them.

The Observatory seismographs have recorded 18 very feeble local earthquakes during the week. Microseismic motion was normal at the beginning and end of the week, but was more feeble than normal on September 29 and 30. Tilt accumulated very slightly towards the east.

THE HALEMAUMAU SEISMOGRAPH

The seismograph installed at Uwekahuna, the west wall summit of Kilauea Crater, in December, 1927, has in general recorded the same earthquakes shown on the records of the instruments at the Volcano Observatory. As would be expected from its magnification, most of the Uwekahuna earthquake traces are smaller in amplitude. But a few which apparently originate at the pit of Halemaumau are shown larger on that instrument, perhaps due to the fact it is nearer to the pit than are the Observatory instruments. To carry the idea thus suggested still farther, a seismograph has recently been installed close to the edge of the pit. It is expected that this will record tremors due to avalanches that are too feeble to be recorded on the more distant seismographs at Uwekahuna and at the Volcano Observatory. By comparison it should then be possible to discover definitely which of the tremors recorded at the Observatory are caused by avalanches.

Spirit leveling near the pit has made it apparent that the tilting motions there are large. It is perhaps these tilting movements and the corresponding change in inclination of the pit walls that are the cause of periodic spells of avalanching that have been evident during the past years. This tilting measured close to the vent of the volcano may prove to be a more sensitive key to the movements of the lava column, just as the tilts at the Volcano Observatory are known to be correlated when the lava level is visible within the pit and the tiltings are correspondingly stronger. This new seismograph is in a position to pick up the first feeble indications of returning activity.

The installation is distant 1,900 feet radially from the center of Halemaumau in direction S. 34° 05′ E, and is back 450 feet from the edge of the pit along the same radius extended. This places it a little north of the trail from the automobile parking place to "Halemaumau sign," and it is about 300 feet from the shelter hut. The elevation is approximately 3,635 feet above mean sea level. A shallow depression was dug in soft pahoehoe lava till a more stable layer was reached, upon which was founded a pier for the recording drum and a column for the support of the pendulum. The pendulum axis is approximately parellel to the pit edge to make it sensitive to shocks and tilt from the direction of the pit. The shelter hut is 4 by 5½ feet, inside dimensions, and is about 4½ feet from floor to roof in the highest part. Its walls are of one-inch boards, with tar paper both inside and out, and with rocks and gravel piled against the outside up to the eaves. The roof is double, with a four-inch space packed with sawdust. It is further protected from rain and sunshine by a corrugated iron roof with a ventilated air space beneath it. The floor is of gravel and asphaltum so sealed as to prevent steam from rising inside the chamber from the floor, as this area of the crater is porous with small steam ducts rising through it almost everywhere. The building was constructed during the first two weeks of September, and the instrument was first set up on September 12. Operation was experimental for several days, the useful run beginning on the 18th.

The seismograph used is the one removed from the Kona station when the larger Hawaiian type seismograph was installed there this summer. This instrument has been overhauled and somewhat revised. It is a single component horizontal pendulum, with suspension similar to the Bosch-Omori. The boom axis hangs from the column to the drum in a direction S. 78° 45′ W. The inertia mass is 30 kg., and static magnification is 70. It is at present adjusted to a period of nearly seven seconds, and the damping ratio is 2.6. Sensitivity to tilt is 2.5 seconds of arc for one centimeter displacement of the null point of the writing pen. Recording is on smoked paper, which moves about 23.5 mm. per minute. The instrument will run nearly 60 hours without attention. Before it was installed at the pit its constants of magnification and sensitiveness were tested on the oscillating table at the Hawaiian Volcano Observatory.

The records so far accumulated do not cover a long enough period of time so that deductions may be made from them. The useful run of the instrument began on the 18th, but was interrupted during the first few days by lack of proper adjustments. From that date up to and including October 1, there were 13 very feeble tremors recorded. It seems so far that this new instrument is recording an entirely different group of very feeble tremors than those recorded at the Hawaiian Volcano Observatory. None of the 13 recorded is identified as recorded at the Obeservatory. There has not yet occurred a heavy enough shock to be recorded on both instruments.

Large tilting movements close to the pit are to be expected, and the seismograph is apparently to bear out that expectation. From September 28 to October 2 there was recorded no less than 10 seconds of arc tilt away from the pit. This is perhaps not due entirely to volcanic causes, however, as the instrument may not yet be fully settled on its foundation. On October 1, beginning at 3:54 p. m. and ending at 6:45 p. m., there was an apparent surge of tilt which accounted for more than half the amount above noted; but this interval of time represents very closely the time and duration of a very heavy shower of rain. In this instance the pen movement was probably caused by wind, temperature, or other effects of the shower, rather than by actual ground tilting, though there was evident no tendency for the pen to return to its former position after the effects of the shower had ceased.

R.M.W.

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No. 198 RELEASED WITHOUT COPYRIGHT RESTRICTION October 11, 1928

KILAUEA REPORT No. 872

WEEK ENDING OCTOBER 10, 1928

T. A. Jaggar, Volcanologist in Charge

The past week has developed no changes at Halemaumau. Fresh wall surfaces are conspicuous north and southeast, but no slides of magnitude have been observed.

On October 6, during a visit to Mauna Iki, the lava cone of 1920 six miles southwest of Kilauea, temperature measurements taken at the second hot area with a 550° C. thermometer, showed a temperature at the first vent of 260° C., and at the second vent 275° C. (527°F.). At the latter place a stick caught fire.

The Observatory seismographs have recorded 16 very feeble local earthquakes during the week, and one teleseism. The teleseism was on October 8, with its preliminary phase recorded at 4:40:47 p. m. The indicated distance to its origin is 3,815 miles, suggesting another earthquake off the Pacific coast of Mexico to add to the series that has been taking place there during the past year.

Microseismic motion was strong during the first part of the week, but diminished to normal during the last part. Tilt accumulated moderately toward the NNE.

EQUATORIAL BELT HAS THE MOST EARTHQUAKES

A remarkably interesting statistical investigation of violent earthquakes has been made by Charles Maurain showing gradual diminution in frequency from the equator to about 50 degrees of latitude, and very rapid diminution thence to the poles. ("On the Distribution of Earthquakes by Latitude," Comptes Rendues del l'Académie des Science, Paris, Vol. 184, 1927, p. 612; Matériaux pour l'"Etude des Calamités, Geneva, April-June, 1928, p. 90.)

The investigation is based on seismograph records locating big distant earthquakes made by stations all over the globe during the first two decades of this century. The most modern group concerns 542 shocks reported by the International Seismological Summary between 1914 and 1920, and secondly 1,009 earthquakes listed by John Milne between 1903 and 1910. These 1,551 great earthquakes are distributed as follows among zones of 10 degrees of latitude from the equator northward or southward; and the third column takes account of the surface area of these different latitude belts:

Latitude (Northward or Southward)	Nos. of Earthquakes	Nos. of Earthquakes Per 10,000,000 Square Kilometers
0°–10°	450	50.8
10°–20°	329	38.3
20°–30°	244	30.4
30°–40°	258	35.4
40°–50°	152	24.1
50°–60°	87	17.1
60°–70°	21	5.6
70°–80°	9	3.9
80–°90°	1	1.3

This list shows strikingly that large earthquakes have greatest frequency in the equatorial belt, and are remarkably few in number near the poles. An examination of the 542 more modern records (1914-1920) indicates that the earthquakes are distributed almost equally between the north and south hemispheres (273 north of the equator, 264 south of the equator), and five actually equatorial. The statistics of the first decade show a larger number in the northern hemisphere than in the southern. Of the whole 1,551 shocks for both decades, 927 are at the north and 624 at the south.

It seems likely to the reviewer that the greater number of northern earthquakes registered in Milne's time was due to the scarcity of instruments in the southern hemisphere, a defect which was later remedied.

Maurain concludes that the distribution of mass in the crust of the earth may be sufficiently uneven with reference to the equilibrium between centrifugal force and terrestrial gravity to produce tensions greatest at the equator, and diminishing from the equator to the poles, Other investigators have shown that the strongest seismicity is in regions where geological movements such as volcanism and mountain building are most rapid. If we combine these two things, centrifugal stress and geological activity, the greatest sensitiveness would be in the equatorial belt, and this would account for the increasing earthquake frequency in that direction.

With reference to the influence of volcanism on the distribution of big earthquakes, it is interesting to compare Maurain's results with the tables of volcanic outbreaks between 1801 and 1914 compiled by Sapper (Zeitschr. Vulk., Aug. 1917, p. 130; also Volcano Letter No. 4, Jan. 22, 1925):

Latitude (Both North and South)	Nos. of Eruptions	Nos. of Eruptions Per 10,000,000 Square Kilometers
0°–10°	944	107.0
10°–20°	826	96.5
20°–30°	238	29.6
30°–40°	437	60.0
40°–50°	157	24.9
50°–60°	101	19.7
60°–70°	47	12.4
70°–80°	115	49.5
80°–90°	0	—

T.A.J.

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No. 199 RELEASED WITHOUT COPYRIGHT RESTRICTION October 18, 1928

KILAUEA REPORT No. 873

WEEK ENDING OCTOBER 17, 1928

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

There has been an increase of avalanching at Halemaumau. Probably the greatest slide was on October 11, when a dense cloud of dust rose out of the pit about 4:15 p. m. An avalanche of large size occurred also on October 13 at 3 p. m. from the north wall. It was followed a few minutes later by a smaller slide from the south wall. The north wall has had numerous slides for two months past.

On October 15 at noon much steam was rising from Halemaumau following several hours of rain.

There have been 16 local earthquakes recorded at the Observatory during the week. Two of these were feeble, but were a little larger than the others, which were all very feeble. The first of the two larger shocks was caused by a big avalanche in the pit at 4:07 p. m. on the 11th. The second shock at 4:11 a. m., October 12, apparently originated a few miles south of Kilauea, and was felt by a number of persons at Kilauea and in Hilo. This earthquake was recorded on the seismographs at the Observatory, at Uwekahuna, at Halemaumau, in Hilo, and in Kona. The indicated distances from these stations, in the order given, were 11, 15, 11, 29, and 49 miles.

On the 14th, at 10:30 p. m., there is recorded a very faint disturbance that is probably the long wave of a teleseism.

Microseismic motion was slightly stronger than normal during the first part of the week. Tilt accumulated moderately toward the east.

POSSIBLE 1851 LAVA FLOW AT LASSEN CINDER CONE

The evidence of two flows from Cinder Cone, the small recent volcano 10 miles northeast of Lassen Peak in California, is very clear. The older flow is covered with volcanic sand, and the newer flow overlies the sand. The locations of trees that existed before the sand eruption are still plainly marked by depressions in the sand.

There are several small cinder cones to the southeast of the main one. Where the lava flow is crossed along the line of these small cones, it quickly appears to an observer that the so-called younger flow might itself really be two flows.

The writer knew that Doctors Day and Allen had dated the last flow over 250 years ago, and during his own trip, made to take photographs, the evidence of the presence of three flows came as a complete surprise.

Later Mr. A. E. Jones, who worked as seismologist at Lassen Volcano Observatory during the summers of 1927 and 1928, provisionally dated the last two flows as of 1795 and 1832 approximately, with a probable error of 10 years more or less, measuring magnetic declination of fixed ledges. This is on the theory that the declination constant of the ledge preserves record of the earth's regional magnetic field at the time the lava congealed. (Volcano Letter Nos. 45, 144, and 162.)

The magnetic work thus suggested a possible lava flow eruption in the middle of the nineteenth century. Dr. H. A. Harkness, for whom is named Mount Harkness in the southeastern part of Lassen Volcanic National Park, wrote an account of activity at Cinder Cone (Cal. Acad. Sci. Proc. Nov. 2, 1874) said to have occurred during the winter 1850-51. Dr. Harkness made the mistake of attributing all the lavas and ejecta of Cinder Cone to 1850-51, a contention that can easily be shown to be in error. His evidence was unacceptable to Dr. Diller and to Drs. Day and Allen, and by them was dismissed. Diller however (Lassen Peak Folio 15, U. S. Geol. Survey), writing in 1894, states that the second or effusive eruption was much later than the first. "but certainly more than 50 years ago, and was of such a character as not to attract attention."

I read the account by Dr. Harkness at the library of the California Academy of Science in January, 1928. The following statements are taken from his article:

Lights were observed apparently by different observers to the east of Lassen "Butte" from time to time from 1850 to 1854. The Indians of that country were hostile, so no attempt was made to ascertain the source of the light.

Dr. Wozencraft from above Red Bluff observed a great fire to the eastward of Lassen during the winter of 1850-51 which continued for many nights without change of position. He dismissed the Indian camp-fire theory. Dr. J. B. Trask at Rich Bar on the north fork of the Feather River, to the southeast of Lassen, also saw light for many nights.

Mr. Charles Gibbs with a party of miners saw the same lights and reported them as due to a volcanic eruption. Miners arriving at a hotel near Georgetown, El Dorado County, during the summer of 1851, reported passing an active volcano and hot rock, their location of which agrees exactly with that of Cinder Cone.

The same miners gave a description of Boiling Lake and the geyser near Drakesbad, features of the present Lassen district, and their description would apply at the present day were the activity at those places a little greater than at present. R.H.F.

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No. 200 RELEASED WITHOUT COPYRIGHT RESTRICTION October 25, 1928

KILAUEA REPORT No. 874

WEEK ENDING OCTOBER 24, 1928
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

At Halemaumau avalanches were noted at 9:35, 9:40, and 9:45 a. m. October 18, so that dust was rising rather steadily at the north rim at 10 a. m. On October 20 at 11:20 a. m., thin dust filled the pit, and this recurred in the afternoon. At 2 p. m. fresh debris was observed on the SW., S., and SE. bottom slopes. The pit was very dry, only slight vapor appearing at the center cone and the SE. and S. taluses. At 9 a. m. today fresh rocks were seen on the north talus, and the noise of falling material was heard at the west.

During the week ending October 24 there were 20 local earthquakes recorded on the seismographs of the Volcano Observatory. Two of these, at 10:41 a. m. on the 21st and at 9:56 a. m. on the 22nd, while feeble, may have been felt. The distances to the origins of these shocks were 13 and 12 miles, respectively. All the other earthquakes recorded were very feeble.

Microseismic motion was normal during the week. Tilt accumulated moderately toward the north.

RECENT ACTIVITIES IN NEW ZEALAND

We are indebted to Mr. Birch of the New Zealand Herald, published at Auckland, for clippings noticing a number of earthquakes in the spring and summer of 1928.

Opotiki, on the shore of the Bay of Plenty opposite White Island Volcano, reports earthquakes as follows: A slight shock January 16 at 1:18 p. m., a sharp shock February 5 at 1:30 p. m, a sharp tremor February 16 at 3:30 a. m., another February 19 at 3:30 p. m., a short and very snappy shock on June 20 at 1:10 p. m., another more severe at 5:50 a. m. July 11; and at Waihi, on the west side of the Bay of Plenty, an earthquake at 6:10 a. m. August 13 seemed to travel in a north and south line, sufficiently pronounced to awaken many persons. All of these shocks are of interest as occurring in the northern part of the belt of active volcanoes, and close to White Island, reported as showing some activity in June.

Other earthquakes have been felt in various parts of the North Island, and at least two in the South Island. Mercer, south of Auckland, felt a slight shock at 6:55 a. m. February 17. March 7 produced a really severe earthquake in the city of New Plymouth at 6:50 a. m. This seemed to come from the slopes of the great volcano Mount Egmont, 8,260 feet high, immediately adjacent to New Plymouth on the south, and the damage was greatest in the southeastern quarter of the borough.

Chimneys went down in all parts of the town, and the shocks were said to be the most severe felt there for many years, lasting about 30 seconds, working up to a climax, and then dying away. The damage was estimated at many hundreds of pounds. Shops suffered severely, goods being shaken off of shelves and falling in show windows. In one grocer's shop everything on the eastern wall fell, resulting in many broken bottles, but the other walls were not damaged, and generally the drug stores appear to have escaped. In one shop a plateglass window was cracked. There was a landslip on the Frankley road which barely missed a passing motor truck. The villages at the northeast base of Mount Egmont all experienced the earthquake, but were not severely damaged.

The capital, Wellington, felt a slight earthquake at 7:27 a. m. March 16, and another at 5:15 a. m. July 31.

On June 12 the volcanic belt at its southern end, between Lake Taupo and the Rangitikei River, was shaken. Taihape reported tremors preceded by heavy rumbling which lasted for several seconds about 5:30 a. m. Presumably the same earthquake reported as about 6 o'clock was felt in the Rangitikei district accompanied by a rumbling sound which made a rapid crescendo and then diminished. The north end of Lake Taupo reported an earthquake at 9:25 a. m., with vibration from east to west. This was not noticed at the south end of the lake.

On the evening of July 17 Raetihi, southwest of the Ngauruhoe group of volcanoes, felt two shocks, the first reported severe and accompanied by a loud rumbling noise and lasting about 30 seconds. The second tremor was mild, only a few seconds long, and occurred only 10 minutes after the first shock.

For the South Island Oamaru on the southeast coast reported a series of severe shocks in the Ben Avon district for the fortnight preceding February 7 which had set rocks tumbling down the hillsides and terrified both the cattle and the inhabitants. The convulsion was confined to a limited area. Greymouth, near the state collieries on the northwest coast of the South Island, felt slight tremors shortly before 9:15 a. m. March 25, and these were followed by a greater shock progressing apparently from northwest to southeast. T.A.J.

On March 3 Ngauruhoe began to rumble after smoking and steaming all day, and at 6 p. m. threw up rocks to a height of 500 feet. One rock dropped outside the crater and rolled down the slope, and glow was seen over the summit at night. The rumbling resembled thunder. At 10 a. m. March 4 the thundering began along with ejection of great clouds of white and blue vapor, and lasted five minutes. Heavy sulphur fumes rolled down the slopes of the cone. Twenty minutes later, and again at 10:30 a. m., loud explosions occurred, accompanied by jarring which shook the mountain huts at Whakapapa, and the smoke column rose 2,000 feet while showers of rock rolled down the northern slope, where dust arose as the material slid. Far away at Opotiki a severe earthquake occurred this day at 3:30 a. m., preceded by a prolonged rumble. A thick column of black smoke was rising at 5:50 p. m. March 9, reaching a height of about 8,000 feet, and spreading to drop a shower of ash over Tongariro Volcano to the west. Glow was seen over the crater March 9 and March 10.

The White Island activity was said to have begun in June with excessive steam as seen from Opotiki which died away during the following week. It was believed some sort of an eruption occurred during the night June 24-25, for the next day the volume of steam from the blowhole was enormous, rising to a height of 2,000 feet in clear frosty air, and stretching away in a long white cloud for a mile. The local radio station reported hearing nothing from the sulphur workers on the island.

As no news since June is presumably good news, it may well be that all of this excessive steaming seen from Opotiki did not really amount to an eruption. T.A.J.

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No. 201 RELEASED WITHOUT COPYRIGHT RESTRICTION November 1, 1928

KILAUEA REPORT No. 875

WEEK ENDING OCTOBER 31, 1928

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Kilauea Volcano continues to remain in repose. A few slight avalanches from the northeast and east walls of Halemaumau were noticed. They caused dust clouds during the forenoons of October 30 and 31. Dense steam was rising from the fire pit following rains on the latter day.

The number of local earthquakes recorded on the Observatory seismographs during the week is 15. They were all very feeble.

Microseismic motion became somewhat stronger than normal toward the end of the week.

Tilt accumulated only very slightly to the south.

POISONOUS GASES IN JAVA

Beginning in the autumn of 1927 the East Indian Volcanological Survey has produced in English, a monthly bulletin of volcanic activities. The excellent volcano service of the Dutch East Indies has erected observatories on the volcanoes Semeroe, Tangkoeban Prahoe, Papandajan, Merapi, Keloet, Lamongan, Idjen, and Karmodjang. Most of these have permanent observers, five of them have seismographs, five report thermometric measurements of gases or hot springs, two report chemical tests, and six make meteorological measurements. In two of the volcanoes crater lakes are sounded occasionally, and 10 other active volcanoes are visited from two to four times a year. (Bull. Neth. East Ind. Volc Surv. Nos. 1 to 11, Nov. 1927 to Sept. 1928, Bandoeng, Java).

The word kawah means crater, and Tangkoeban Prahoe, in west central Java, has seven vents. In three of these craters after August, 1927, increased solfataric action produced the suffocating gases carbonic acid and hydrogen sulphide. Throughout 1927 the locality known as "Death Valley, outside of the Ratoe vent of this volcano, had its gases sampled by means of the Bunte burette. At the same time the temperature was taken, and such weather conditions recorded as might influence the gas measurement, such as air temperature, humidity, pressure. cloudiness, and wind. Carbonic acid in August varied from 36 to 69 per cent, in September from 46 to 78 per cent; hydrogen sulphide, in August, between 7 and 16 per cent. and in September between 4 and 15 per cent.

In Papandajan, of southwestern Java, the hottest place is the Kawah Mas, where a self-recording electrical thermometer automatically registers the temperature every 12 minutes. The maximum reading was 372° C. September, 1927, and the highest temperature during that year was 420° C.

Here also suffocating gases are abundant in the Roeslan Valley, named after a native observer who was suffocated there December 18, 1925.

In October, 1927, "Death Valley" gave from 59 to 75 per cent carbonic acid, and 10 to 12 per cent hydrogen sulphide. Observed at a place where at the end of June 1923, three high school boys had met with sudden death caused by asphyxiating gas, the measurements showed a decline of the percentages, especially in the case of carbonic acid. On September 13 the sum total of both gases had been 35 per cent, whereas on October 29 it was 18 per cent.

At Papandajan, in the Kawah Mas, maximum temperatures were higher in October, and minimum temperatures lower, than in the preceding month. The highest temperature recorded was 379° C. In Roeslan Valley carbonic acid varied from 20 to 42 per cent, hydrogen sulphide from 7 to 12 per cent. The crater Nangklak No. 4 gave carbonic acid 4 to 33 per cent, hydrogen sulphide 2 to 11 per cent.

In December, 1927, cold carbonic acid gas was coming out at Death Valley, and a spring showed sulphur in suspension. In Roeslan Valley hydrogen sulphide varied between 10 and 20 per cent. carbonic acid between 41 and 51 per cent. At another crater of Papandajan, Nangklak No. 4, hydrogen sulphide varied from 10 to 12 per cent, and carbonic acid from 43 to 68 per cent.

In January, 1928, Roeslan Valley on Papandajan gave hydrogen sulphide 16 to 17 per cent, carbonic acid 47 to 49 per cent. Nangklak No. 4 gave hydrogen sulphide 6 to 9 per cent,carbonic acid 43 to 49 per cent.

Papandajan in February, 1928, showed higher temperatures, and along the banks of a small brook traversing the volcanic crater hydrogen sulphide developed in a new place near an old camp, so that a native who passed the place swooned.

In March Tangkoeban Prahoe increased its gas pressure, and in a ravine between two of the craters suffocating gas appeared in such high concentration that one of the dogs of the observatory was choked. The carbon dioxide there was found to be 75 cm. deep, by the capacity of the gas to extinguish a flame.

In April Bromo Volcano in eastern Java was reported as having been active since the middle of March when the eruption had begun with loud explosions, the ejection of big stones, and ash clouds of reddish color. A light ash fall continued, and a sulphurous smell was perceived some miles away. At Papandajan in May a blow-hole in the Baroe Crater threw up black sulphurous mud, staining the whole region round about. In central Java a sudden eruption occurred near Batoer, a well known tobacco producing center. Strong earthquakes occurred May 4-13, and then an explosion amidst the tobacco fields, where three vents opened, a dull noise occurred, and the material thrown up was saturated with water and flowed south in three hot mud streams, while the stones ejected destroyed a large part of the hamlet Timbang. One man was killed by a falling stone, there were new cracks in the ground the crops and vegetation were destroyed and highly concentrated suffocating gases came forth.

In July these gases were investigated, and carbon dioxide was found escaping from fissures under high pressure along the road from Batoer to Dieng. The gases streamed down drainage ditches, forming a layer 20 cm. deep, which would extinguish a candle flame 60 meters away from the vent. On June 13 a light wind blowing up the grade depened the gas until it was 16 cm. deep (5 feet ,and so was dangerous. The gas layer became visible by condensation, and produced giddiness, high pulse, and heavy pressure at the back of the head. Birds were killed. and the lush bamboo vegetation, as well as fields of tobacco, withered from exposure to the gas. T.A.J.

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No. 202 RELEASED WITHOUT COPYRIGHT RESTRICTION November 8, 1928

KILAUEA REPORT No. 876

WEEK ENDING NOVEMBER 7, 1928

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

In Halemaumau pit at noon of October 31 a slide was reported, and beginning at 9 p. m. of November 1, a series of heavy avalanches occurred repeatedly for about two hours. In the still night air these were distinctly heard at Volcano House. An especially heavy slide at 10:30 p. m. was registered on the several seismographs. Dust from avalanches at the northern wall of the pit was seen at 8:30 a. m. November 2, and at 4 p. m. November 5 thin dust from slides rose above the pit in a veil.

Examination of the walls at 3:30 p. m. November 3 indicated that the avalanches had fallen mostly at the north and northeast corners of Halemaumau, making red debris on the two talus cones at the ends of the large intrusive sill.

For the week ending at 8 a. m. November 7 the Observatory seismographs have registered 17 very feeble earthquakes. A tremor at 2:37 a. m. November 1 has the gradual development to a maximum, followed by similar gradual decline, which is characteristic of avalanche tremors. Throughout the week microseismic motion was strong, but is now decreasing.

Tilt accumulated moderately to the north.

ERUPTIONS OF ETNA

Press reports indicate that the volcano Etna in Sicily is giving vent to a lava flow. The last lateral eruption was in June-July 1923. Since that time activity has been confined according to last reports to jets of vapor and dust from the summit crater. (1926 Bulletin Volcanologique, Nos. 9-10, Etna From August 1923 to the end of 1925, By G. Ponte.)

The activity of Etna, according to Perret, has been marked by eruptions during the past 300 years at intervals averaging about six years, making some 17 eruptions per century. It is a volcano in many ways resembling Mauna Loa. In the surrounding country have occurred some of the most disastrous earthquakes of history, notably at Messina, and the volcano itself has occasioned serious loss of life.

The observatory stands about 1,000 feet below the summit, where there is a central crater, but just as in the case of Mauna Loa, the serious eruptions of modern times do not occur at this crater but rend open the flank of the mountain. The observatory was originally designed for astronomical observations, but is now assigned to the Volcanologic Institute of Catania University.

A small eruption occurred on the 29th of April, 1908, which lasted only 12 hours, following upon a repose period of 16 years. Such a long sleep required greater relief than this, and therefore the succeeding months were considered a time of anxiety. This was justified by the terrible earthquake at Messina on December 28. After the earthquake both Etna and Stromboli diminished in activity, as though the earthquake had relieved a subterranean strain. Finally, however, March 23, 1910, a greater eruption occurred, and still another in September of 1911. The lava of 1910 flowed at the speed of 11 miles per hour from a vent which threw up spatter to a height of about 150 feet. Mr. Perret obtained a photograph of a remarkable smoke ring which floated upward over 5,000 feet and expanded until it was about a quarter mile in diameter. The lava of Etna is basaltic containing from 44 to 49 per cent of silica. From a chimney at the vent Perret observed banners of flame due to burning gas rising 10 or 15 feet. Rafts were observed floating down the lava stream, the latter was from 6 to 12 feet in depth, and as the big masses on top of the stream were carried along at about four miles an hour they gave the impression of big barges floating past. The color of the hotter parts of the flow at night was a golden yellow, estimated to have a temperature of about 1,200°C. Lava tunnels were found, through which the stream poured, and the lower portion of the flow was typical aa lava.

Mr. Perret makes the point that tunnels very commonly form along the line of the fracture or fissure through which the lava flow pours, and the lava tunnel left exposed extended from crater to crater along the rift, and was revealed only after the slope of the mountain slumped away near the lowest crater at the end of the eruption. The entrance to the tunnel was a perfect arch 12 feet high, and in the interior it was 25 feet high in places. All this closely resembles the lava tunnels of Ki'auea and Mauna Loa, where the flows are smooth and slaggy near the source vents in the portions of their courses where the tunnels are formed, but farther down the mountain the lava turns to clinker. It will be remembered that the tunnel now exposed in the southwest wall of Halemaumau is a true rift tunnel, through which poured the lava flow of Mauna Iki in 1920. (The Eruption of Etna in 1910, by F. A. Perret, Science Conspectus, Massachusetts Intitute of Technology, Vol. I, No. 3, Feb. 1911.) T.A.J.

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No. 203 RELEASED WITHOUT COPYRIGHT RESTRICTION November 15, 1928

KILAUEA REPORT No. 877

WEEK ENDING NOVEMBER 14, 1928

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Conditions at Halemaumau do not change materially. Rains of the past few days have not soaked the pit to any great extent. The areas of steaming are conspicuous through being wet, in contrast to surrounding dry areas. The south and central cones steam thinly, and other vents are more or less flocculent.

The week has been particularly quiet seismically, only three very feeble local earthquakes having been registered. Microseisms appear normal, despite a strong, steady northeast wind.

Tilt is strong to the northeast.

HORIZONTAL MOTION IN JAPANESE EARTHQUAKES

The work of the United States Coast and Geodetic Survey in reoccupying triangulation stations in California after the great earthquake of 1906 showed that horizontal motion had shifted large blocks of country. The triangulation stations east of the fault had moved south; those on the west had moved north. This agreed with observed displacement of fences, trails, and roads, which were offset over 20 feet north of the Golden Gate.

The same method has now been applied to Japan. In the case of the Tango earthquake (Volcano Letter No. 119, April 7, 1927), the Gomura fault exhibited dislocation on the ground of as much as eight feet. The fault trends NW-SE, and the country round about contains bench marks placed during trigonometric surveys made between 1884 and 1888. These stations were retriangulated in June and August 1927, some months after the earthquake. It was found that the stations east of the fault line had moved north several feet, while those to the west had moved south.

A geometric method was devised for platting on a diagram the amount of displacement of those bench marks lying nearest to the fault plane on both sides of the rift, and then projecting on the line representing the fault the amount of the several displacements so as to obtain a figure representing the total offset along the fault trace. Just as in California, the basis for displacement of any station was a base-line connecting two distant monuments that lay outside the area affected by the fault.

The results indicated that the total offset shown by triangulation is about 2.4 meters, while the maximum movement measured directly was 2.7 meters. In general the amount of shift of the triangulation stations is the greater, the nearer the station lies to the rift.

It next became of interest to apply this triangulation method to the great Kwanto earthquake, which produced the terrible Tokyo-Yokohama conflagration of 1923 (see Volcano Letter No. 171, April 5, 1928). The actual fault in this case trends NW-SE in the middle of Sagami Bay, where, it will be remembered, there was actual deepening of the soundings by from 400 to 600 feet along the zone of fault blocks which subsided at the time of the earthquake. As this fault plane had no marked extension on land, and yet the bay is surrounded by lands containing trig stations, it is clear that in order to find out the horizontal displacement on the rift, the triangulation method is the only one available.

The whole Tokyo area has been retriangulated, and the stations lying in the Misaki and Boso peninsulas nearest to the rift on the east side, all show strong displacement to the south. On the other hand the bench marks on Oshima Island and the Izu Peninsula, west of the rift, show still greater displacement northward. The base line used lies 90 miles to the north between Teruisiyama and Tukubasan.

Using the same graphical method as before, platting the line of the fault, and the line at right angles thereto on which are laid off the several distances of the trig stations from the fault trace, and then projecting on the fault trace the displacements north of the western stations and the displacements south of the eastern stations, it is found that the net offset or shift horizontally along the rift amounts to eight meters, or over 26 feet.

This triangulation was all carried out by the Military Land Survey Department. An extraordinary feature of the map exhibiting all the displacements around Sagami Bay, which represent the changes between the surveys of 1884-1899, and the post-earthquake surveys of 1924-1925, is that the land stations appear to have shifted somewhat uniformly in a circular arc around the west, north, and east sides of the submarine earthquake center. That is to say, Sagami Bay is an indentation in the southeastern coast of Japan, and the land southwest of it has moved north, the land northwest of it has moved northeast, the land north of it has moved east, and the land northeast of it has moved southeast. Here again, as in the Tango earthquake, the maximum displacements are at those stations nearest to the rift, and the amount of displacement diminishes quite consitently in proportion to the distance from the Sagami Bay center. The map gives one the impression that the land has executed this rotation around Sagami Bay almost as though it were plastic. (A. Imamura and F. Kishinouye, On the Horizontal Shift of the Dislocations Accompanying the Recent Destructive Earthquakes in the Kwanto District and in Tango Province, Proc. Imp. Acad. Japan, IV, 1928, No. 3.) T.A.J.

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No. 204 RELEASED WITHOUT COPYRIGHT RESTRICTION November 22, 1928

KILAUEA REPORT No. 878

WEEK ENDING NOVEMBER 21, 1928

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Volcanic conditions at Kilauea have not changed. There is very little working of the walls, and earthquakes are very infrequent, only eight very feeble shocks having been registered during the past seven days. Tilt accumulation is moderately northwest.

THE ERUPTION OF ETNA

The volcano Etna occupies an oval tract 30 miles long in a north south direction, and 23 miles wide, on the north-eastern coast of Sicily. The city Catania is at the southern edge of the mountain, and was destroyed by earthquake in 1169 and invaded by lava in 1669. A railroad connecting Catania with Messina follows the coast line east of Etna. Taormina lies northeast of the mountain and Messina is 35 miles farther to the northeast on the strait that separates Sicily from the mainland of Italy. Etna is 10,758 feet high, and its height was reported to have decreased 112 feet between 1861 and 1900. The circumference of the mountain is about 91 miles, and its area about 460 square miles. The summit is truncated, and an inner cone rises from the summit plateau containing the large crater. East of this is the Valle del Bove, a vast desert gulf three miles wide, bounded on three sides by cliffs 2,000 to 4,000 feet high, and constituting apparently a collapsed area much like the crater of Haleakala.

Numerous lava flows have poured out in the Valle del Bove, and others have come from the flanks of the mountain on other sides, forming minor craterlets below the base of the large central cone. Historic eruptions of Etna are reported as far back as 693 B C.

The lower belt of vegetation to about 3,000 feet of elevation is the zone of cultivation, where vegetables are grown, and in the drier upland vines and olives flourish. The slopes are densely populated, having 930 inhabitants per square mile below elevation 2,600 feet, and more than 3,000 inhabitants per square mile in the southeastern sector. The highest zone is wooded up to elevation 6,800 feet. For much of the year the summit region is covered with snow.

The present eruption began about November 1, and from press reports we learn that four streams of lava started about elevation 3,000 feet on the east flank. This appears to mean north of the lava flows of 1811 and 1852, near the north rim of the Valle del Bove. Mild earthquakes preceded the eruption, and one flow appeared to be headed in the direction of Sant Alfio and Giarre which is east of the mountain, on the railroad. On November 4 Pontanazzo, with a population of 2,000, was threatened, 22 farm houses on its outskirts had been engulfed, and officials were causing evacuation of the danger zone.

It now became apparent that the flows were moving more to the north, road traffic was disrupted, and on November 5 the large town Mascali was being deserted.

November 8 the eruption was said to be spreading destruction comparable to that of the great flows of 1169, several hamlets had been destroyed, the flow was widening as it reached lower levels, and hundreds of persons were reported homeless. At this time three men who had returned to their homes to rescue household goods and had decided to sleep there overnight, were said to have been surrounded by lava flows so that fellow townsmen looked on helplessly as the molten slag engulfed the victims.

On November 9 Mascali was invaded, although the three principal streams seemed to be diminishing in volume. The central stream had advanced several miles, and two other flows had gone less than a mile. By November 11 the largest flow was said to be moving toward the shore at the rate of 15 feet an hour, with a front two miles wide and 16 feet high. Twelve thousand persons were homeless and being cared for in schools, churches, and railway stations. Villages, cultivated fields, and orchards had been destroyed, and the government was preparing to provide measures of relief. The railroad was overwhelmed by the flow, trees were blazing, the torrent was following the valleys and factories and mills were being dismantled. A roaring noise was heard, the usual explosions occurred about the front of the lava, where coal gas from burnt vegetation was mixed with air in caverns, and out of the cracks came forth the odor of hydro-carbons.

By the 13th the speed of the flow had greatly decreased. Relief funds were appropriated by the Mussolini cabinet. The Italian press estimated damage to agricultural lands at three million dollars, and to habitations, roads, railways, bridges, and engineering works, 15 million dollars. Only 50 out of 800 houses are left standing in Mascali, and 100 houses are reported destroyed in Serrageano. Other places mentioned as suffering are Annunziata and Carraba. Earth rumblings were heard as far as Messina and the explosions from the lava caverns are reported as hurling up flakes of stone, just as they do about the front of Mauna Loa flows when the lava enters a forest. The last report from Rome (November 12) states that 4,000 acres have been laid waste, 700 houses destroyed, and 5,000 persons made homeless. It is worthy of note that this eastern region has hitherto been mostly free from lava flows of historic dates, so that the mountain is merely fulfilling the law of symmetrical cone-building. T.A.J.

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No. 204 RELEASED WITHOUT COPYRIGHT RESTRICTION November 29, 1928

KILAUEA REPORT No. 878

WEEK ENDING NOVEMBER 28, 1928

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Dense steam was rising from Halemaumau on the afternoon of November 22 due to falling moisture. On November 24 at noon there were no changes whatever in the pit that could correlate in any way with numerous earthquakes registered in the early morning. A slide from the northeast wall made dust at 8:20 a. m. November 26. Nothing new was seen today.

Earthquakes increased materially during the week, a total of 36 having been registered. Twenty of these were recorded between 5:17 and 5:43 a. m. November 24, and five of this number were of sufficient intensity to be felt locally. Two shocks, slightly larger than the others, had phases indicating distances to origins of 0.4 mile and 1.3 miles from the Observatory.

Tilt for the week accumulated SSW. As most of this took place on November 24 and 25, the earthquakes seem indicative of a partial collapse of the center floor, possibly due to subsidence of the lava column.

CRATERS OF THE MOON NATIONAL MONUMENT

The large basaltic areas of the Snake and Columbia rivers have long been considered flows that emerged from obscure fissures. Gradually the fracture lines that constitute the vents are coming to light. One of these is the rift zone trending NW.-SE. lying Southeast of the White Knob Mountains in Idaho, which has been set aside as the Craters of the Moon National Monument, including about 80 square miles south of Arco, Idaho. The reservation is about 23 miles long by 8 miles wide, and stands between 5,000 and 6,000 feet above sea level in a semi-arid district. A roadway penetrates the northwestern end of the Monument, and the whole district is in every way similar to the Kau Desert southwest of Kilauea, or the Puu o Keokeo desert of the southwestern rift of Mauna Loa.

There are both aa and pahoehoe lava flows, many horseshoe-shaped cinder cones made by fire fontains at the sources of the flows, numerous lava caverns in the pahoehoe, which become natural bridges were these are partially broken down, and a large number of tree moulds and lava trees. There are also ice caves and water holes, all of which owe their existence to ground ice. (H. T. Stearns, Bull. Idaho Bureau of Mines and Geol. No. 13, July, 1928, Moscow, Idaho.)

There are yawning crater pits, and many spatter cones, and the floods of lava for six miles against the southern spur of the White Knob Mountains filled the valleys as if they were bays, and left the spurs like projecting headlands in a black sea. These mountains are of granitic rocks, and when in recent geological time the great rift opened on their slope, and thick jagged lava flows poured to the south and east, there were left small and large fragments of granite that broke off from the roof of the lava reservoir and floated upward in the molten lava during the eruption. Obsidian occurs among these older eruptions, and this was quarried by the Indians to make arrow heads.

A second series of eruptions broke out making many of the large cinder cones in the middle of the Monument area. The third and last eruptive epoch gave vent to barren black lavas which form the latest veneer over much of the area, these flows in many places surrounding the earlier cones. Altogether about 35 cones and vents and 30 different lava flows are found in the Monument. Everything indicates that the actiivty was accompanied by quiet fountaining of vesicular lava, with much foaming and great quantities of gas, but without explosive eruption such as would spread volcanic dust for hundreds of miles. The bombs are of the spindle, ribbon, and bread-crust types associated with the ejection of clots of liquid lava.

The rock is basaltic, with 51% of silica, 14% alumnia, 15% iron oxides, 6.5% lime, 2% magesia, and 6% alkalies.

Pahoehoe flows cover about half the area, often with blue glassy crusts and billowy, ropy surfaces, these flows being filled with caverns. The caverns invariably occur in pahoehoe and not in aa. The aa flows. just as in Hawaii, are in many cases produced where pahoehoe changes to clinker some distance away from its source, but the aa never changes back into pahoehoe. Some of the aa lava flows are 25 to 100 feet thick, and have moved several miles out on the plain.

The cones of the Craters of the Moon area are large cinder heaps about 450 feet high, or lines of smaller spatter cones about 50 feet high and 100 feet in diameter, or lava domes rising 30 to 50 feet above the surrounding country, and sometimes surmounted by tiny spatter heaps less than 10 feet high. These lava domes are compared with Mauna Iki, which was formed in 1920 at Kilauea.

The tree moulds vary from a few inches to three feet in diameter, and are sometimes 10 to 20 feet deep. Sometimes the liquid lava flowed into the checks or shrinkage cracks in the charred surface of a log, forming a checker pattern, easily mistaken for bark impressions. Lava trees rising one to five feet above the general surface occur where part f the lava flow has drained away, leaving the mouded trunk in relief.

The abundant water holes are due to the freezing period, which at this elevation in Idaho covers about seven months in the year. This is much like the summit regions of Mauna Loa and Mauna Kea. The caves and cinder heaps act as heat insulators, and in one place called Ice Cave a heap of ice and snow 20 feet thick is found even in summer. Fifteen perennial water holes are listed. The temperature of the water rarely exceeds 34° F.

Stearns concludes from the evidence of pine trees and other vegetation growing on the flows that the youngest cones in the area are over 400 years old. The charred wood seen in many places was set on fire artificially or by lightning, and was not fired by hot lavas. There is some very fresh pahoehoe lava which may be little more than 250 years old, and there are obscure Indian traditions of fire seen in the region. All of this resembles similar evidence concerning the Lassen country, and indicates the possibility of other eruptions yet to come near the Craters of the Moon National Monument. In detail the photographs of stalactites, shore-line marks of lava in caverns, festoons, pits, and the rift landscape in Mr. Stearns' report are extraordinarily like Hawaii. T.A.J.

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No. 206 **RELEASED WITHOUT COPYRIGHT RESTRICTION** December 6, 1928

KILAUEA REPORT No. 880

WEEK ENDING DECEMBER 5, 1928

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

There are no changes at Halemaumau. Some large slides occurred on the forenoon of December 3. At 10:55 a. m. there was a big avalanche at the north, with a column of dust spreading NW.-SE. rising from the pit. The debris fell from the north rim, in the region of the active avalanching of last August. The north wall is thickly coated with white salts, and much white material covers the north talus.

A section of the southeast rim near the tourist outlook has caved away. It is still very unstable, and further slides will occur there until all the loosened area goes.

Crack measurements along the east rim show practically no changes in nearly three months.

The count of earthquakes for the week is but three very feeble local shocks. One of these at 6:17 p. m. December 3 had an indicated distance to origin of 9.3 miles.

Tilt accumulated moderately to the NE.

WHITE ISLAND VOLCANO

It will be recalled that White Island, in the Bay of Plenty, near the north island of New Zealand, is an active volcano which has a sulphurous crater nearly at sea level, surrounded by fuming cliffs, and separated by only a bar from the ocean. On the back-slope of the cone, away from the crater, dwell the operatives of a sulphur-mining company, equipped with a launch, wireless, and a tramway to the workings at the crater. In the second decade of this century (1914) a former group of sulphur workers, who lived on the lowland between the crater and the beach, were all exterminated by an evisceration of the crater which no one survived to describe. The wreckage suggested an explosive eruption and a flood.

In Volcano Letter No. 200 of October 25, 1928, we described White Island activity in June, 1928, seen as excessive steam from Opotiki on the neighboring coast.

On September 1, 1928, a new eruption of White Island occurred. This "was accompanied by a phenomenon in the form of a sulphurous dust cloud," believed similar to the one experienced some days earlier by the steamer "Emlynian" in the Netherlands East Indies, about 30 miles north of Flores and 200 miles east of Java. It appears that this dust cloud in both cases coated the decks of ships. In White Island it swept south, across Crater Bay, where the company's launch, the Whaakari, was moored, and dusted it without arousing the men sleeping on board. (New Zealand Herald, September 13, 1928.) It should be pointed out that the "Emlynian" was close to the volcano Rokatinda, which has just had a disastrous eruption.

The men in the camp, which is removed from the active area of White Island, were unaware that anything unusual had taken place during the night. The telegram to the head office of White Island Products, Ltd., Auckland, from the island, was as follows:

"A minor eruption occurred in the active crater area about 1 a. m. on Saturday, September 1. Series of new vents formed from two to four chains from the main blow-hole in the direction of 'Lot's Wife'."

"The whole of the upper crater area is covered eight to 24 inches deep with very fine blue-gray dust. Stones and bowlders up to two and three hundredweight were scattered in a radius of about 200 yards around the activity. We have not yet been able to make a full inspection, but from the edge of the activity it appears that the force has subsided, although steam is blowing over an area of about half an acre. The chief trouble is that we are completely cut off from the sulphur suppiles, as the road is impassable."

Professor J. A. Bartrum, geologist of Auckland University College, considered that the main interest of the White Island activity lay in whether the activity was caused by avalanching from the crater walls at the back of the main blow-hole, believed to have caused the 1914 eruption, or whether there was some other cause. Mr. Welsh, the general manager of the company, stated that slips had not caused the recent eruption. Professor Bartrum thought that " in that case the occurrance is certainly a little disconcerting, and the tendency to any special activity needs watching.

We previously reported earthquakes about the Bay of Plenty in January, February, March, June, July, and August. A sharp earthquake was felt at Opotiki shortly before 1 p. m. September 12, and Rotorua reported several shocks after 1:30 a. m. on October 2. They terminated at 3:15 a. m. with the heaviest shock experienced here for many years. All the geysers at Whakarewarewa were very active in the early morning. At Tauranga, again on the Bay of Plenty, a sharp earthquake shock was felt at 5:17 a. m. November 6, and the tremor was felt at Te Puke. All of these jarrings, throughout the year, around the bay in which White Island is situated, make that volcano an interesting object, especially as it has had two reported outbreaks, one just at the June solstice, the other just before the September equinox. (See Volcano Letter No. 66, April 1, 1926.) T.A.J.

ERRATUM

The previous issue of the Volcano Letter should be numbered 205, instead of 204.

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No. 207 RELEASED WITHOUT COPYRIGHT RESTRICTION December 13, 1928

KILAUEA REPORT No. 881

WEEK ENDING DECEMBER 12, 1928

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

There is nothing new to report about Halemaumau pit of Kilauea Volcano. There has been little avalanching, and the visible vapor from the cones on the bottom and from the vents about the border talus varies with the weather. After excessive rain such as has fallen during the last twenty hours vapor fills the pit, but there is equally great increase of vapor from the cracks of the floor and rim of the greater crater.

Sixteen very feeble local earthquakes were registered during the week ending at 8 a. m. December 12, including two continuous tremors each of about 2½ minutes duration, both on December 11, beginning respectively at 10:31 a. m. and 11:19 a. m. Tilt for the week was slight to the NE. Microseisms were normal.

THE ROKATINDA ERUPTION

A newspaper report of August 9 stated that the eruption of Rokatinda killed a thousand people, injured 600 with flying rocks, and in addition six villages were wiped out by eruptions and earthquakes, and a large section of the seaboard had been submerged and recurrent waves of enormous size had caused the sinking of nine vessels.

The exact facts of this eruption have now been investigated by the volcanologists of the Netherlands East Indies and it appears that 226 people were killed, of whom 128 perished by flood waves caused by landslides at two places on the southeast and south coasts of the island. Four villages were covered with ash and pumice, and two others were partly destroyed.

The volcano Rokatinda is on the southern flank of the circular island Paloeweh which lies north of Flores in the eastern part of the Javanese Archipelago. The eruption occurred in the night August 4-5. It was preceded by local tremors which increased in intensity from July 25 on. Many of the inhabitants of the southern villages near the crater fled to the northern part of the island. The greatest destruction was between 10 p. m. and midnight. Great masses of new material in the form of pumice and ash were thrown out, and of old material in the shape of lava blocks. The new craters were enlarged by subsequent explosions. The red hot stones could be seen far away from the north coast of Flores. As this is the dry season the grass and trees were fired by the incandescent material so that the southern half of the island was ablaze.

Three new craters were formed, some 500 meters apart, one 400 meters in diameter. During the violent eruptions of the first few days ash and pumice to a depth of from one to two meters accumulated at a distance of one kilometer from the craters. Large blocks fell 1.5 kilometer away from the center. These blocks were as big as a man's head and made large impact cavities in the ground. Pumice fell all over the island. Ash, carried by the prevailing wind covered the southwestern part of the island with a thick mantle of light gray dust. On August 5 and 6 this ash fell on Bali and on East Java.

On August 8 only white clouds of steam were issuing from these pits. In the large southern crater a plug had appeared consisting of coarse loose porous light gray block lava containing many inclusions. After this conditions were tranquil the crater could be approached without danger, one of the smaller craters threw off some ash, another went out of action at the end of August, and on September 9 a new craterlet was formed throwing out stones in the immediate vicinity of the vent and fine ash that fell all over the island.

This new eruption ceased September 25 and thereafter only white steam clouds were emitted. The three earlier craters had thrown out light gray ash, whereas the later crater ejected dark gray ash and angular blocks of old material.

A beach on the southeast shore of the island disappeared, and a steep bluff was formed by sinking of the seacoast on the south shore. Fumeroles and solfataras are found on several parts of the island about lava flows, old domes and fissures, and some of these as well as the elevated fringing reef around the island, indicate that the island is subject to fracturing by uplift. There is no previous historical record of eruption on Paloeweh.

It is of interest to note that Krakatoa was still showing recurrent volcanic activity at its submarine vent in between the three islands, as seen from the observation post and seismograph station which was established in January to keep track of the eruptions. August 25 there were 19 explosions, three upwellings and ten tremors. August 27 tremors were recorded. August 28 there were 21 explosions and tremors were increasing day by day. August 31 produced 15 explosions, seven upwellings and 12 tremors. (Bull. Neth. East Ind. Volc. Surv. No. 12, Oct. 1928.) T.A.J.

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No. 208 RELEASED WITHOUT COPYRIGHT RESTRICTION December 20, 1928

KILAUEA REPORT No. 882

WEEK ENDING DECEMBER 19, 1928

Section of Volcanology, U. S. Geological Survey

E. M. Buckingham, Temoprarily in Charge

No new phases have been discovered at Halemaumau. Conditions remain unchanged. Ocassional rockfalls are heard. Fresh wall scars north and northeast were observed today.

Only five very feeble local earthquakes were registered during the week. Microseisms were very slight. Tilt accumulated very slightly to the SW.

WORLD EARTHQUAKES

The literature of seismology is hopelessly dry. It consists of long lists of figures. Moreover the figures are technical and the headings of columns quite incomprehensible to the layman. There is great value however to the lists of figures for the interested experimenter, who possesses a delicate pendulum swinging free in a quiet basement room, which has suddenly begun to swing in long sweeping strokes at a certain hour of a definite date, and has then written an autograph lasting over three hours. It is unfortunate that the fascination of building and using seismographs has not taken hold of amateurs the way the construction of telescopes has done. If we had more amateur seismologists the science of the earth would progress faster. We believe the dryness alluded to above could be remedied, and that hundreds of persons might be led to take an interest in recording earthquakes and reporting on their findings, if some of the many organizations for popularizing science would start a campaign for popularizing seismology. This would be particularly welcome in such earthquake lands as California, Japan, India, Italy, New Zealand and western South America, and a comparatively simple instrument might be placed in the hands of hundreds of persons who are interested in local earthquakes by reason of their habitat.

Two documents have come to hand recently, issued by the British Association for the Advancement of Science. One is the 33rd report of the Committee on Seismological Investigations, of which the astronomer, Professor H. H. Turner, is chairman. The other is a catalogue of earthquake as registered by seismological observatories all over the world for seven years between 1918 and 1924.

The notes show that earthquakes are apt to recur at the same epicenter. In one case the same epicenter has done duty for thirty-four earthquakes. Most earthquakes are believed by measurement to originate at approximately the same depth below the earth's surface. By this is meant big shocks. Most seismologists believe this depth to be about thirty miles down. According to Professor Turner there is evidence that a certain number of earthquakes are above the normal depth in their origin, while still stronger evidence shows that some earthquakes are touched off from very deep foci, and so shake a very large area of the surface of the globe.

In the Committee report we learn that there is not a single day during the whole seven years on which no earthquake was recorded, though there are many days on which shocks were recorded at one or two observatories only.

The monthly counts of epicenters show that twenty-nine large earthquakes occur somewhere in the world most months, and that September for this group of seven years has more earthquakes than any other month. The figure for September is fifty-one, even leaving out the exceptional year 1923 when came the Tokyo disaster with its many aftershocks in September. To judge by the table of averages shown, there are more in spring than in winter, more in summer than in spring, more in September than in summer months, and then a gradual decline to a low level in frequency in January.

There is an interesting note on vertical component seismographs. It is well known that the elasticity of a suspension spring is liable to changes when temperature varies. With the Galitzin vertical pendulum a change of 1° C. in the temperature of the apparatus is sufficient to put the instrument out of action.

At Strasbourg a spring made of elinvar, an alloy with a low-temperature coefficient for elasticity, has been in use for some time. Such a spring tested at Kew Observatory is found to yield continually under the load, but the effect of ordinary temperature change is almost eliminated.

The work of the International Seismological Summary published by the British Committee every quarter is a very useful and valuable adjunct to every earthquake station. It must be very laborious to compile. The seven-year catalogue is a digest of this summary, and is intended to reach geologists and geographers, so as to interest them in using the statistics of latitude and longtitude and numbers of earthquakes, in connection with their field knowledge. We believe that this catalogue would be still more popular if it could have two columns added to the tables; one to express the general locality of the epicenter in a geographical name; and another to express the probable intensity or "size" of the earthquake in terms of its seismographic range. It is true that the number of stations represented is somewhat a measure of extent but it would seem that an obvious aftershock ought to be labelled as different from a world-shaker. T.A.J.

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No. 209 **RELEASED WITHOUT COPYRIGHT RESTRICTION** December 26, 1928

KILAUEA REPORT No. 883

WEEK ENDING DECEMBER 26, 1928

Section of Volcanology, U. S. Geological Survey

E. M. Buckingham, Temoprarily in Charge

There has been a slight increase in the working of the Halemaumau walls. It is believed that this is due to possible fluctuations of the Kilauea floor as indicated by tilt measurements.

On December 20 considerable steam was escaping from the south cone and a vent on the SSE. talus. On December 23 an avalanche from the NNE. wall was observed at 3 p. m. On December 26 there was evidence of avalanching from the north and east walls, and dust from two slides was seen. Several falls of rocks were heard.

There were six very feeble local earthquakes registered during the week. In addition were two perceptible shocks having epicenters from 10 to 12 miles southeast of the Obseravtory. The first, at 8:43 p. m. December 24, was accompanied by a tilt at the Observatory of seven seconds to the north. The second shock occurred at 10:13 p. m. December 25. Tilt for the week accumulated slightly northeast.

Measurements made at the Halemaumau seismograph station on December 19 and 26 indicate a tilt of 10 seconds away from the pit during this interval. Tilt has been slowly accumulating in this direction since the early part of November.

EXPECTED HAWAIIAN ERUPTION

In 1912 the writer wrote that Mauna Loa should become active before 1915; it broke out in 1914. In 1917 he wrote that a great crisis in Hawaiian volcanism should come around 1920; both Mauna Loa and Kilauea had flank outflows within the twelve month preceding July 1, 1920, and a great explosive crisis came in 1924. In 1923 he wrote that the nine year cycle following 1913 would probably be unusually long and representative of one of the long term intervals such as 1868 and 1790 had illustrated; the 1924 engulfment accompanied by shore collapse at Kapoho was a close parallel to 1868. All of these tests of reasoning with reference to forecast are merely based on observation and experience, coupled with a logical deduction from the records of the nineteenth century.

Experience has shown that in Japan, Italy, Hawaii and the Caribbee Islands, one hundred and thirty years or some such figure is a common interval between either big eruptions or big earthquakes near eruptive centers, or both. On the other hand Vesuvius and Kilauea both exhibit a minor interval of from nine to ten years, and the larger volcanoes Etna and Mauna Loa tend to average their outbreaks at intervals of one half this period, or about four and one half years. Mere charting of the facts for the last thirty years has shown a distinct tendency in the pit-lava of Kilauea to rise when Mauna Loa breaks out, and to sink when Mauna Loa stops action. These things are not invariably observed, for the simple reason that the Kilauea lava column is not always visible.

It is not permissible to say that Kilauea and Vesuvius shall break out every nine years, or Mauna Loa and Etna every four and a half years. A volcano is not a clock. The interval theory is based on averages, and the averages are based on certain laws of nature such as those that determine the space intervals of ripple marks in the sands of the sea or the time intervals of waves when they break rythmically on the beach. The lava under a volcano has been pressing upward for ages through a crack of a certain size. It has blocked or impeded that crack with its own heap of lava and so has forced itself to adopt a rhythm or interval like the puffs from a steam engine. If it has several vents, these divide responsibility for the interval, and if one vent is low and close to the water table, while the other is high and far above the ground water of the island, the probability of explosion is greater for the lower vent. This is because a sudden drop in the lower vent may place the lava column below the water table and so develop a steam chamber. This is the situation of Kilauea as compared with Mauna Loa.

The whole great edifice or volcanic system is itself involved in responsibilities to large masses of lava underground which it perhaps shares with other active or half extinct volcanic systems along the same rift or crack, and these responses may demand certain major eruptions or major dormancies at very long intervals of time, when the whole crust of the earth for that part of the world is disturbed to an unusual extent. It is like the intake and outgo of a large corporation, itself made up of the accounts of smaller stores. One must know all the books or the accounts will not balance. So when we argue about the expectancy of eruption at Kilauea, we must take account not only of average small intervals and average great intervals but also of the volume of output of lava in relation to the intervals as compared with the volume expected by analogy with average eruptions in the past.

As compared with the outpourings of 1852, 1855, 1859, and 1868 the lava output of the island of Hawaii in the last eighteen years has been very small, unless there has been an enormous unseen lava flow under the ocean. Yet there are many features of the flows of 1914, 1916, 1919 and 1926 from Mauna Loa, and the intervening effusions about the crater of Kilauea, that closely resemble the double cycle that followed 1850. We have platted a curve of the combined activities of Mauna Loa and Kilauea, which shows a pronounced low level about December of 1913 and December of 1924, and a remarkable high level about December 1919. The lava of Kilauea rose rapidly after 1913 with arresting depressions after each Mauna Loa flow. After 1924 the lava has risen slightly in the bottom of Halemaumau pit and Mauna Loa flowed vigorously in 1926. If the curve of rising now continues comparably to what happened after 1913, it is logical to expect activity from either Kilauea or Mauna Loa in 1929. T.A.J.

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No. 210 RELEASED WITHOUT COPYRIGHT RESTRICTION January 3, 1929

KILAUEA REPORT No. 884

WEEK ENDING JANUARY 2, 1929

Section of Volcanology, U. S. Geological Survey

E. M. Buckingham, Temporarily in Charge

The week has been very quiet at Kilauea, with only two very feeble earthquakes and very little change at Halemaumau. The tilts noted last week have dropped back to nearly the values shown prior to those accumulated at the time of the two perceptible earthquakes of December 24 and 25.

VOLCANIC ACTIVITY NEAR TONGA

From the Apia observatory, Dr. Andrew Thomson Director, came news under date September 24, 1928, that Falcon island, the newly formed volcano fifty miles to the nortwest of Nukualofa in the Tongan islands, continues to give off steam with an occasional expulsion of a mass of cinders and ash. Its activity had diminished during the previous six months.

Dr. Thomson writes, "There is a rather striking difference between the Tonga and Samoa volcanoes, in the materials ejected. In all recent eruptions in Tonga, ashes, cinders and scoria have been thrown up, while in Savaii lava only has been ejected. The volcano Maugaloa in Savaii, which threw out such enormous quantities of lava from the Matavanu vent during 1907-11, has become dormant. The steam column, which used to issue from a vent, became smaller in size, then came only at irregular intervals and it is now several years since it has been seen at the Government residency about five miles away."

The same observatory reports a probable new submarine eruption about 120 miles farther to the northwest indicated by fields of floating pumice first observed by the S.S. Carisso, October 3, 1928, about 240 miles east of Suva, Fiji. (Science, p. XIV, Nov. 9, 1928.) During that night patches of pumice ,each covering several miles, were seen along a course 70 miles to the southwest of the first patch. The S.S. Veronica sighted a patch a mile wide 30 miles farther to the west October 7, over water more than 1200 feet deep, and a very large field of pumice was found farther to the east many miles in length in an N-S direction and about a half mile wide.

The pumice first seen was at 17° 25′ south latitude, 176° 09′ west longtitude. If the vent is on the bottom of the sea near this place, it is an area in deep water of great seismic activity where ten violent earthquakes occurred between 1913 and 1920 and one of the epicenters lies about 75 miles north of where the pumice was seen. There are two principal earthquake centers, and it is a remarkable fact that all of this seismic and volcanic activity is on the line between the active volcano island Niuafou and the Tonga volcanoes further to the south. Niuafou is about 100 miles north of the region in question.

The activity of Falcon Island is well described in the December, 1928, National Geographic Magazine (Hoffmeister and Ladd, Falcon the Pacific's Newest Island, p. 757). These authors landed on the revived island in May 1928, discovering strong hydrogen sulphide fumes, no red glow at night, a roundish island with crater close to the shore on the southeast or windward side, and the greater part of the heap built to leeward of pumice, cinder, lava fragments, bombs and ash to a height of 365 feet. The island is about two and a half miles across in an east-west direction, clouds of steam and sulphur fume rise from the crater, the surface is rill marked and washed into gullies, and steep cliffs have already been cut by the sea along the windward side of the island.

The present eruptive period of Falcon Island began with its most violent eruption on record in October 1927, and minor eruptions from time to time have added to the heap since. It is an old volcanic shoal first reported in 1865 and occasionally active since.

The north shoreline consisted of coarse black cinders and pumice banked at 70°, and the ground was made up of fine ash mixed with sharp fragments of cinder, pumice and lava, with only trench-like gullies to break the uniform curve of the ridges. The profile of the island shown in a photograph exhibits a distinct wave cut platform at the east The bottom of the crater is elliptical, covered with a boiling lake, some parts of which boil incessantly, while other places bulge upward periodically, when black sediment is brought up from below. The water varies in color from milky green to yellowish white. The lake is surrounded with ash and sulphur flats, dotted with steam jets, and the steep walls of the crater are vertically fluted, with steam vents rising from the depressions which have deposited sulphur and other substances coloring the gullies yellow, orange or white in contrast with the drab ridges.

There is a younger crater with steep sides, and an outer crescent ridge, with a gulch between the two that has drained into the lake to form a low delta built out into the lake from its eastern side. The crater wall is largely fine ash and scoria but there are numerous volcanic bombs and blocks. The bombs are spindle shaped, were thrown out in a liquid condition, are often exceedingly porous, in other cases they show concentric structure. Some of the blocks are three feet in diameter, made of agglomerate or of either dense or porous lava. The vent noises are of sputtering and whistling, the lake waters have a vile taste, and sulphur dioxide appears to have been dominant, as the eyes smarted and breathing through cloth gave relief.

T.A.J.

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No. 211 RELEASED WITHOUT COPYRIGHT RESTRICTION January 10, 1929

KILAUEA REPORT No. 885

WEEK ENDING JANUARY 9, 1929

Section of Volcanology, U. S. Geological Survey

E. M. Buckingham, Temporarily in Charge

Beginning January 5 there was a marked increase in avalanching in Halemaumau pit, all from the south, and southeast walls. Since that date avalanching has been practically continuous, and a large part of the south rim has disappeared. Half the lava floor of the pit is buried under debris from a big avalanche occurring at 7:40 a. m. January 7 and carrying away the south station. The area around the tourist stand is badly shattered and has settled noticeably, rendering the bench mark at the edge of the pit valueless. Crack measurements in the vicinity show a widening of 0.8 foot in one of the cracks between December 4 and January 7, with an additional widening of 0.3 indicated by a measurement on January 8.

The avalanching is progressive and appeared to originate about one-third of the way down from the southest rim, undermining the top and lossening the lower sections by impact, and spreading progressively from south to southeast.

The seismographs at the Observatory recorded 16 very feeble earthquakes, 12 of them occurring during the interval from January 5 to 6:30 a. m. January 6. Beginning at noon of January 5 the instruments recorded a very faint continuous tremor which lasted, with varying amplitude, throughout the remainder of the week. Many of the counted earthquakes are hardly more than pronounced increases in the amplitude of this tremor.

MORE ABOUT ETNA

The eruption of Etna is said by Professor Ponte, Director of the Etna Observatory, to be much bigger than those of 1910. 1911 and 1923 (London Times, Nov. 12). The eruption started November 1 and on the 6th the velocity of the lava increased and the stream was only 200 yards from the Circum-Etna Railway at 9 a.m. The volume of lava had been increased suddenly by three arms which had been flowing separately uniting as they approached the hamlets before Mascali, and this produced accelerated movement. At one place the flow formed a huge cascade. An iron bridge began to sink at the approach of the lava, and was simply fused when the lava reached it. The spectacle is described as ominous and terrifying. Trees suddenly take fire and flare up, and orchards disappear in flames. The people in the villages continually formed processions and carried religious banners, pictures and even statutes before them while praying fervently. The preceding night big explosions were heard, with loud subterranean rumblings (Daily Telegraph, London, Nov. 7).

On November 7 Mascali, a town of 7000 inhabitants, had been destroyed, and The Illustrated London News of November 17 carries remarkable pictures showing the lumpy aa lava in the midst of this masonry town with the dome of a large church still standing. A message of this date said, "the main body of the parish church, its belfry and the new War Memorial, the last three structures standing collapsed at three o'clock this afternoon and the village is now entirely obliterated." The pictures give a vivid idea of what a Mauna Loa lava flow would do if it were to invade the newer masonry structures of Hilo such as the business blocks and the Federal Building.

Vehicles of many kinds were brought in to carry away the inhabitants. The correspondent writes "during the night the lava stream steadily advanced, obliterating house after house, and this morning (7th) when I tried to approach the town, the heat prevented me from getting within 300 yards of the last group of houses, which were already surrounded by a burning mass."

"The town hall was one of the last buildings to remain standing. For some time as the lava rose all around it the walls offered stubborn resistence. Suddenly, however, they collapsed and mingled with the mass of melted rocks."

"Several secondary craters opened on the 2nd and 3rd and on the 4th they formed one vast crevice on the side of Monte Frumento, from which poured out huge volumes of lava."

Along the eastern railway there was dense fume for more than a mile making breathing very difficult. The lava near Mascali was moving about five feet per minute but it was certain to reach the railway. The breaking of an aqueduct by the lava caused serious inconvenience and destruction of road bridges interrupted traffic. An attempt to divert the main lava stream and open an artificial outlet to the sea to prevent the destruction of important towns was being planned (London Telegraph, Nov. 8).

By the end of November 7 the flow had gone 300 feet beyond Mascali. It had now cooled sufficiently for a hard, dark crust to form on its surface. It therefor no longer presented the appearance of a river of fire, but looked rather like an enormous pile of coal. It was twenty-five feet high where it entered Mascali. Cracks appeared in the flow, revealing its fiery interior and as it advanced it made a horrible crunching noise. At night, by contrast with the surrounding darkness, it resumed its fiery aspect. The stream now stretched about ten miles from its crater. (London Daily Mail, Nov. 8).

On the 8th digging and mining new channels to lead the lava away from the large town Giarre were occupying the attention of the authorities. The most tragic scene at Mascali was the engulfment of an aged couple who had fallen asleep after nights of anxious vigil At three o'clock in the afternoon, when the lava had surrounded them, they were suddenly seen on their roof imploring help. A crowd of spectators 500 yards away were terrified and realized that help was impossible. Then the walls fell in and the unfortunate couple disappeared.

After the little church had crumbled in, the campanile or bell tower stood. It was observed to lean first in one direction and then in another and suddenly the bells rang out. The crowd was deeply affected and many of the old folk fell on their knees and prayed. The bells were still heard long after dark, and at eight o'clock the tower fell and the bells rang no more. (London Telegraph, Nov. 8).

On the ninth a huge cascade of fiery liquid rock was pouring uninterruptedly into the valley of Bove, where a lake of lava had been formed three-quarters of a mile wide, feeding the torrents that descended to the lowlands. On the 11th the railway bridge at Mascali was destroyed and the railway was obliterated. This finished the second railroad interrupting all traffic at the east end of Sicily. (London Telegraph, Nov. 10 and 12.) T.A.J.

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No. 212 RELEASED WITHOUT COPYRIGHT RESTRICTION January 17, 1929

KILAUEA REPORT No. 886

WEEK ENDING JANUARY 16, 1929

Section of Volcanology, U. S. Geological Survey

E. M. Buckingham, Temporarily in Charge

The avalanching which began last week reached a climax at noon of January 10, when a section of the southeast rim about 100 feet long fell into the pit, carrying away the 19th hole golf tee. Since that time there have been only occasional small slides, although another section of the southeast rim appears to be slowly loosening.

The continuous tremor which began at noon of the 5th died out in the afternoon of the 9th. During the week there were recorded eight very feeble local earthq akes and one teleseism, which occurred on January 12 from 1:42 to 2:14 p. m. The strongest of the local shocks was coincident with the landslide at Halemaumau on Janury 10.

MAKING ARTIFICIAL EARTHQUAKES

The Hawaiian type seismograph (described in Bull. Hawn. Vol. Obsy. vol. XV, No. 11, Nov. 1927) has been mentioned in the Volcano Letter as an instrument designed especially for local earthquakes from experience at the Hawaiian Volcano Observatory. Six pairs of pendulums of this design have been built in the Kilauea shops and set up at Hilo and Kealakekua, Hawaii, at Kodiak. Alaska, and Cheltenham, Maryland, at Mineral, California and Dutch Harbor, Alaska. The last is still in process of being installed. A seventh instrument is now set up in the Observatory shop, and is being subjected to tests with experimental earthquakes.

The readers of the Volcano Letter may be interested to know how that can be done. The late Professor Omori of Japan made a shaking table on wheels actuated by a connecting rod from the driving wheel of a steam engine. With this he set up various brick, stone and cement columns clamped to the top of the table, and then subjected the machine to rhythmical jerks or accelerations applied by the engine. By increasing the period and amplitude of these jerks to the critical value that led to the overturning or fracture of the columns, he learned much about the strength of masonry suitable for an earthquake land. Similar experiments were conducted in the engineering laboratory of the Massachusetts Institute of Technology about 1911 under the guidance of Professor C. M. Spofford and others.

The problem before us in the Hawaiian laboratory is different, in that it is desired to imitate feeble earthquakes such as frequently affect seismographs in a volcanic land, and to provide devices on the oscillating table for setting up such a seismograph with its full recording mechanism. In the summer of 1928 Mr. R. M. Wilson designed and built such an oscillating table, having the property of reducing the amplitude of motion of the machinery to which it was attached to microscopic proportions, while retaining with scientific accuracy a constant reduction ratio. This ratio is approximately 1/29, so that when the motor moves back and forth 1/10 of an inch, the shaking table moves 1/290 of an inch. Earthquakes of this small amplitude in actual motion of the ground are very common at Kilauea, and produce on the Observatory seismograph an autograph about a half inch in range of back and forth motion of the writing pen on the smoked paper.

The tool used for giving harmonic motion to the table is the chuck of a machine lathe holding an adjustable crank to which is attached a connecting rod that may be set at any desired distance from the lathe center. The other end of the connecting rod operates two upright levers attached to long steel rollers that bear the weight of the table. The table is a T-shaped body of massive concrete weighing about 800 pounds with a post of concerte rising at one end to hold the pendulum of the seimograph. At the other end is a platform to hold the clockwork and recording drum. The crank radius in the lathe chuck can be easily changed to give the required amplitude to the table, and the desired period of oscillation is obtained by changing the lathe speed, which may be governed through a wide range of motions with the belt pulleys, the speed gears, and the throttle of the power plant.

The Hawaiian seismograph is a horizontal pendulum with mass weighing 80 pounds, hinged above and below with short links of piano wire, operated usually with a free period of about seven seconds, and damped with light aluminum vanes dipping in oil near the outer end of the boom. The lever magnification is about 130 times and the time is marked on the smoked paper by a lift of the pen tips once a minute electro-magnetically. The paper speed is 1¼ inches per minute.

An account of the first tests of the Hawaiian seismograph with artificial earthquakes will appear in the August Bulletin of the Observatory (Vol. XVI, No. 8). These tests were made by Mr. Wilson with a view to checking the theoretical magnification with the observed magnification for various amplitudes and periods of forced vibration communicated harmonically to the oscillating table. The result was a magnification curve of great interest showing that oscillations representing periods between one and four seconds most nearly conformed to the theoretical curve, and indicated a magnification about 113, instead of 130 as computed from the lever system.

The effects of solid friction in relation to viscous damping and to the energy of the impressed motion were conspicuous, as usual with smoked-paper seismographs. The elimination of friction in instruments with pivoted levers entirely omitted is now being tested with interesting results. T.A.J.

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No. 213 RELEASED WITHOUT COPYRIGHT RESTRICTION January 24, 1929

KILAUEA REPORT No. 887

WEEK ENDING JANUARY 23, 1929

Section of Volcanology, U. S. Geological Survey

E. M. Buckingham, Temporarily in Charge

There have been noticeable changes at Halemaumau during the week. A small area of the south wall, at about the point where the recent sliding originated, has been emitting a moderate but constant volume of steam since the sliding began, and may furnish the key to the cause of the sudden failure of that section of the rim.

There were 21 local earthquakes recorded during the week. Only one, occurring at 6:02 p. m. of the 20th, was strong enough to be perceptible. Its indicated distance was 19.5 miles from the Observatory. At several times during the week a very feeble continous tremor was noted. Microseisms increased noticeably toward the end of the week.

MUD VOLCANOES

A combination of natural gas and muddy water rising through cracks in formations where hydrocarbons are abundant may produce fields of mud and clay, with little cones and craters which simulate volcanoes in form. Otherwise they are not volcanoes at all. These mud and gas cones occur in many parts of the world, especially in the vicinty of petroleum-bearing strata.

A recent dispatch from Australia states that at Lake Victoria, nine miles from Paynesville, a small island was thrown up last January so as to stand about 3 feet above the surface of the lake. This was nearly washed away, but in the summer some 2000 cubic yards of slimy black clay was brought up by a combustable gas so as to make a new island at the same place 60 feet long and 30 feet wide. This stood about 4 feet above the water and contained much fibrous material resembling decomposed vegetable matter. The lake here was 12 feet deep. Gas rose through two big cracks in the island. Gas bubbles have risen through the lake in the past.

Burma is a land of mud volcanoes and the rising gas is sometimes very hot. An extraordinary report of the 29th of July, 1926, stated that at 2:10 a. m. a large flame was seen rising several hundred feet high, burning for about fifteen minutes, and then jetting up again ten minutes later. This was in Kyaukpyu township. It proved to be a mud eruption a half mile north of the village of Kin which built a considerable hill and buried many acres of cultivated land. Many young plants were distroyed by the heat. A similar eruption had occurred here forty-eight years earlier, preceded by rumbling, when a large volume of fire and smoke came forth and fine debris fell miles away from the center. There was excessive heat and leaves were scroched.

The Minbu district of Burma, 300 miles north of Rangoon on the right bank of the Irrawaddy river, is an area of blue and green Miocene clays and soft sandtones. These contain traces of oil. From small holes in the ground mud oozes out along with inflammable gases. Mud is cold and smells of petroleum. Gradually a small cone is formed with a crater. The biggest crater is six feet across. The bubbling of thick viscous mud inside is incessant and one after another bubbles two feet or more in diameter form and burst so as to splash the mud round about. Occasionally there are subterranean gurglings which alarm visitors. There are many such mud cones in different stages of development over a few acres of land near Minbu. The mud is salt. (Indian newspapers, 1926.)

In central Java 50 miles northeast of Solo there is an elevated mud plain two miles in circumference, in the center of which salt mud is thrown up to a height of from 10 to 15 feet in the form of globes which burst and emit white smoke. Two bubbles observed rose and burst seven or eight times to the minute. Some times these vents throw up two or three tons of mud. The fumes smell like gunpowder. When the bubbles burst, they throw the mud out from the center and there is a loud noise as it falls on the surrounding surface. The ground is all a quagmire round the active vents.

The smaller bubbles heave and swell, and when they burst the mud falls in concentric circles, the intervals between explosions being from a half minute to two minutes. In other places the mud is rocketted up to a height of 20 or 30 feet accompanied by vapor. This mud was too stiff to be blown into bubbles. The mud was all cold at the surface, but it is said to be warm underground. In this immediate vicinity there are salt lakes and bubbling pools with cold water of offensive smell and bitter, salt and sour taste. Here there is a mud cone and crater with bubbling mud inside. This mud is very liquid and when it rises there are rumbling noises. At several large springs in the vicinity there is gas effervescence with strong odors of hydrocarbons. The ground is hot and the boiling can be heard 30 yards away. (The Family Magazine, 1843.)

Near Turbaco, a few miles from the north coast of Colombia, there are lowland thickets on a rectangular plain where the soil is dark brown clay and there are open areas of mud volcanoes separated from one another by irregular clumps of sedges. Here there are fifty or sixty active craters in conelets two to four feet high. The craters are from one to five feet across filled with cold creamy liquid mud continously bubbling and sometimes overflowing the lip and running down the sides of the cone to harden in the hot sun. The gases are hydrocarbons with more or less carburetted and sulphuretted hydrogen and nitrogen. (The Scientific Monthly, July 1928, p. 42.)

T.A.J.

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No. 214 RELEASED WITHOUT COPYRIGHT RESTRICTION January 31, 1929

KILAUEA REPORT No. 888

WEEK ENDING JANUARY 30, 1929

Section of Volcanology, U. S. Geological Survey

E. M. Buckingham, Temporarily in Charge

There were no changes at Halemaumau during the week.

The seismographs at the Observatory recorded 10 very feeble earthquakes. Continuous tremor was still present at times, but became much fainter and died out about noon of the 28th.

Microseisms were unusually large in the early part of the week, but became normal on the 25th.

POSTSEISMIC BLOCK MOVEMENTS IN THE TANGO DISTRICT

An article in the November "Proceedings of the Imperial Academy" (Tokyo) by Chuji Tsuboi on the postseismic block movements in the Tango earthquake district presents data which may shed considerable light on the completeness of the isostatic adjustment of the earth's crust. Immediately after the Tango earthquake of March 7, 1927, the Japanese government began a network of precise levels, to be repeated periodically, to determine what earth movements, if any, were taking place in the final adjustment after the earthquake. Three surveys have been made on April 12 to June 16, 1927; June 1 to July 31, 1927; and March 3 to April 20, 1928.

While the discrepancies between these surveys are of the order of millimeters, their peculiar grouping indicates that they are actual earth movements and not instrumental errors. The movements were plotted against a projection of the lengths of the level lines and connected by a series of straight lines. A study was then made of the known fault lines of the region, and it was found that in every case discontinuities in the plotted points fell across known faults, showing that each block or group of blocks moved as a unit with an upheaval, subsidence, or tilting which was constant throughout that block.

The changes between the second and third runnings were not all of the same sense as between the first and second, showing that in some cases the forces causing movements actually reversed themselves, relative to each other if not absolutely.

The average distance across blocks is the neighborhood of four kilometers. While this cannot be taken as the width of the maximum area which will remain isostatically uncompensated, it does give an indication of the extent to which adjustment proceeds once the rigidity of the crust has been destroyed by a major earthquake. An interesting check on this deduction is seen in the system of parallel fault scraps in the neighborhood of Kilauea, which in one place reach a frequency of four faults of relatively large displacement in a distance of about two miles.

A vertical displacement on a land area of 40 feet in one movement is exceedingly rare, even with an earthquake of the first magnitude. It would therefore seem, if complete adjustment attains after each major shock, that a topographic feature of any size cannot remain uncompensated, and that isostatic compensation must be very complete indeed. E.M.B.

INTERNATIONAL CONGRESS OF OCEANOGRAPHY MARINE HYDROGRAPHY AND CONTINENTAL HYDROLOGY AT SEVILLE

Notice has been received of a meeting of the International Congress of Oceanography, Marine Hydrography and Continental Hydrology to be held at Seville, Spain, May 1-6, 1929. The subjects for discussion are:

Section of Oceanography and Marine Hydrology.

1. Relations between the vitality and the oxygen of the seas.
2. Study of the straits as means of communication between the seas.
3. Modern methods for the determination of the relief of the sea-bottom.
4. Aereous currents in the equatorial regions of the oceans.
5. Relations between oceanography and navigation of the air.
6. Cooperation in an international map of the scale of 1/1,000,000 and consideration of the suitability to complete same by a map dividing the oceanic and continental regions, including in the latter the continental plain.
7. Relation between the currents and emigration of fishes.
8. Influence of the arctic ice on the climate.
9. Methods for the determination of the density of sea-water.

Section of Continental Hydrology.

1. Solid stock.
2. Formation of bancs and deltas.
3. Methods for precise measurements of the hydraulic yield of turbines.
4. Investigations with reduced models and their laws of analogy.
5. Subterranean waters.

Persons interested should address the Secretary of the Organizing Committee, Instituto Espanol de Oceanografia, Calle de Alcala, 31, Madrid. E.M.B.

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No. 215 RELEASED WITHOUT COPYRIGHT RESTRICTION February 7, 1929

KILAUEA REPORT No. 889

WEEK ENDING FEBRUARY 6, 1929
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Examination of Halemaumau February 2 showed the rim gone to a depth apparently 15 feet more or less south and southeast, carrying away such landmarks as the old burned boards of the 1918 outhouse and the pinnacles just inside the rim, as well as the south station. The bronze datum bench mark southeast is on cracked dangerous ground at the extreme edge of the pit. A new tourist platform for viewing the pit has been built at the east rim. The south talus was struck by the great avalanches and set in motion as a landslide so as to cover the whole south half of the lava floor. This is much like what happened just a year ago. January 11, 1928. At that time, however, liquid lava was pressed up.

There is a little steam high on the south and southwest taluses, and from the cavity in the central lava cone. Some minor wall cracks are steaming, and the SSE. rim cracks steam vigorously and show fresh soil breaks 40 feet or more back from the rim. Rocks were sliding a little on the lower south wall. February 3 and 4 a little dust rose from slides at the north corner of the pit, and gravel was heard slipping at the south. On February 5 the strongly felt earthquake of 2:25 a. m. appeared to produce little effect at the pit.

Nine very feeble earthquakes were registered at the Observatory during the week, and in addition one strongly felt earthquake (intensity IV Rossi-Forel scale) occurred at 2:25 a. m. February 5 so as to awaken sleepers generally. This shock was felt strongly also at Hilo and Kohala, appeared to be local at Kilauea seismographically, and hence may represent a deep earthquake under the east side of the island

Tilt for the week was moderate ENE. All the seismographs showed an apparent easterly tilt at Kilauea during the earthquake. This suggests that if subterranean lava was concerned with the earthquake at all, the lava movement was one of rising. Microseisms for the week were ordinary.

THE BALI ERUPTION 1926

On the ilsand of Bali, next east of Java, there is a volcanic rift line trending northwest and southeast carrying two larger volcanoes, Batoer on the northwest and Agoeng on the southeast. The latter is believed extinct, but Batoer has had lava flows in 1849, 1888, 1904, 1905, and twice in 1921. In August, 1926, a new and extensive lava flood destroyed the village Batoer with its Brahman temple.

Dr. C. E. Stehn, in charge of the Volcanologic Service of the Netherlands East Indies, has produced an interesting memoir on this eruption, with 67 pages of text, 47 photographs, 10 map plates and 14 text figures (Vulk. en Seismol. Mededeelingen No. 9, 1928, Bandoeng, Java.) There is an abstract in English, and the plates have both Dutch and English legends. Contour maps on large and small scales are presented, showing fissure eruptions, details of cones, craters, and flows, and lava tunnels which are all like Hawaii in topographic arrangement, but there is ash ejected with the lava outflow, and this is uncommon in Hawaii. The lava is an olivine-bearing pyroxene-andesite, or basalt, carrying about 52% of silica, and therefore is somewhat more acid and refractory than the Hawaiian basalt.

The upper part of Mount Batoer is an oval sink, larger than the Kilauea crater, with NW.-SE. axis 8½ miles long, and the other dimension 6 miles. Inside this there is a second cauldron 4 1/3 miles across, merging into a crescent-shaped crater lake at the southeast end of the greater caldera. This lake is 200 to 260 feet deep.

On the floor of the inner crater stands a mixed cone rising 2,000 feet above its base and 5,600 feet above sea level. This is some 1,300 feet below the highest rim cone, Mount Abang, at the southeast end of the outermost ring wall. The greater ring crater is closed with its drainage inward to the lake, and in this respect differs from Asosan, in Japan, which it somewhat resembles. The inner volcano, here as at Aso, is the scene of activity, and the historic lava flows have been filling the southern half of the inner wall valley from 1849 to the present.

Batoer is the name of the inner volcano, which has two summits, several groups of craters, and fracture lines mostly radial, which are followed by the crater cones and pits. There are some fractures which are concentric, and one that crosses the flank of Batoer. The summit pits of Batoer are 160 and 650 feet deep, and gave vent to lava flows in 1905.

Twenty-two groups of parasitic cones and craters have been found, partly built of ash and partly of lava scoriae, either loose packed or sintered together.

The eruption of 1926 began in the night of August 2, was preceded by earthquakes, and opened a long radial fissure at the southwestern base of the inner volcano Batoer. Hot slag was thrown up, and lava flowed southwestward. The following night the fracture opened to a length of 4,200 feet northeastward in the direction of the peak. The lava flow divided into two streams flowing north and south when the confining wall of the inner sink was reached, and the southern branch overwhelmed the village completely by August 27.

The progress of the eruption greatly resembled a flank eruption of Mauna Loa. At first there were 20 spurting jets along a continuous crack. After August 10 three groups of active mouths became segregated, containing 8 to 10 craterlets each. These built up in the course of the month so as to make the highest cones of ash at the northeast or highest group of vents. The middle group produced blocks, bombs, and cinder, and built cones of intermediate height. The lower openings of both groups produced lava flow with a temperature from 1,100 to 1 200° C. Lava fountains were observed. Gases escaping at the border of the lava field as late as May, 1927, still had temperatures up to 575° C. The lowermost group of vents was some 1,600 feet down the rift from the others, and during the eruption it would fling up large blobs of glowing lava from 30 to 60 feet into the air.

The uppermost lava flow was a foamy pahoehoe near the vent. The lower one was a scoriaceous aa, and both streams flowed together as a rough clinkery lava in the lower parts of the flows. Large rafts of plastered clinker 20 feet high and 40 to 50 feet across were observed on the surface of the flow transported 1¼ miles. In its upper course the lava flowed 20 feet a minute on a slope of five degrees; farther down on a horizontal floor 1.8 miles from the source the lava field was 26 feet thick and progressed 139 feet in 24 hours (Aubust 9-11). August 28 a velocity of 39 feet per hour was measured two miles from the source. Approximately 741 million cubic feet of lava was produced, the outflow ending September 21.

This memoir is of great interest in showing true lava eruptivity in the East Indies. T.A.J.

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No. 216 RELEASED WITHOUT COPYRIGHT RESTRICTION February 14, 1929

KILAUEA REPORT No. 890

WEEK ENDING FEBRUARY 13, 1929
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The lava pit of Kilauea has exhibited no conspicuous change during the past week. Occasionally rocks have been heard to fall from the walls, and the rainy weather has produced more visible vapor than is seen during dry weather.

Seven very feeble earthquakes have been registered on the seismographs at the Kilauea Observatory, and one short period of spasmodic tremor occurred on February 9 about 12:52 p. m. Two local earthquakes on February 8, at 11:17 a. m. and 6:48 p. m. both indicated an origin approximately 18 miles from the station. This origin is probably in the direction of Mauna Loa, as these earthquakes were similarly registered in Kona. The strongly felt earthquake of February 5 appears to have originated under the southern part of Kilauea Mountain, as shown by measurement of the seismograms of Hilo, Kona and Kilauea.

Tilt for the week was moderate to the SSE. at Kilauea. Microseismic motion was slight.

NGAURUHOE ERUPTION OF MARCH 1928

Ngauruhoe is a steep-sided symmetrical cone rising 7,515 feet above sea level, in the national park near the southern end of the volcanic belt that traverses the north island of New Zealand. The 1928 eruption is the eleventh recorded outbreak since 1839. The known eruptions have ejected blocks of augite hypersthene andesite. A dark colored aa lava flow found at the foot of the mountain is reported to have been poured out in 1869 (Eruption of Ngauruhoe, March, 1928, by L. I. Grange, N. Z. Jour. Sci. and Tech., Vol. X, No. 3, Oct. 1928, page 143).

On the morning of March 4, 1928, the volcano rumbled, and there were two vertical shots from the crater with an interval of half an hour between them. Blocks of lava were ejected and rolled down the side of the mountain, and black clouds of ash were blown toward the south. The rumbling and belching continued in the afternoon, and two more shots occurred in the evening. At 6 a. m. March 5 a big shot was accompanied by earthquakes that shook the Whakapapa huts, about six miles away. Twice that day the volcano roared, and for the rest of the week the mountain was clouded over. On March 11 Mr. Grange, the Government Volcanologist of New Zealand, at the foot of the mountain could sometimes hear the roar of gas vents. The crater was reached March 12 and found to be a flat-floored depression surrounded by steep walls, and partitioned into east and west divisions, with a small shallow crater occupying a part of the rim at the north. The main crater is more than 200 feet deep and about 650 feet in diameter, the inner walls exposing beds of scoria and lava flows. There were three small vents on the bottom, the central one being active, and small steam vents occured in several places in all the craters and some sulphur was being deposited.

The active vent was a conelet about 70 feet in diameter where red-hot lava could be seen below a surface covering of stones that had fallen back during the eruptions. It resembled a quiescent blacksmith's fire. The lava appeared viscous, to judge from the sharp edges, smooth faces, and open contractive cracks of the hot, fresh blocks. Blue smoke was escaping with a tremendous roar,and at times there were bursts of gas darkened by ash. Sometimes the roar would cease for several seconds. The first of the gas jets was inclined west, but after 20 minutes the inclination shifted to the southwest. Red-hot fragments of lava were thrown up 50 feet. Once there was a sharp, loud explosion, throwing blocks above the rim of the main crater, into which they all fell back. In the afternoon black cauliflower clouds rose several times from the crater, and at night a red glow was reflected from the fumes. It appears that on February 21, 1928, the lava surface was about 80 feet below the rim of the vent, and descriptions of the crater floor by observers at other quiescent times indicate that the active vent has changed position. T.A.J.

VOLCANIC TREMOR AT VESUVIUS

The annual of the Vesuvian Observatory for 1925 contains an analysis of the seismograms registered during paroxysmal explosions in the crater for 24 hours November 30-December 1, 1923. (G. Imbo, Annali, del R. Osservatorio Vesuviano, Vol. II, 1925, page 149.)

Harmonic continuous vibrations and more rapid spasmodic occasional ones are distinguished at Vesuvius, just as at Kilauea. There are also longer period wave movements, and very feeble local earthquakes usually not stronger than Grade II of the Cancani scale.

The active date in question followed about three months of moderate activity. The Vesuvian crater was floored over with an active conelet on the high bottom. At 4 p .m. November 30 a lava flow poured from the west base of the conelet to the north wall of the crater, and the conelet produced nearly continuous explosions accompanied by projection of lava shreds. Scoriae were thrown up over 300 feet. By 4 p. m. of the next day a million cubic meters of lava had been produced, it ceased flowing, and the vent activity became normal.

The Vesuvian Observatory maintains a vertical component seismograph with heavy mass weighing 200 kilograms, period 2.11 seconds, and lever magnification 170. Horizontal tremor is indicated by an Agamemnone instrument.

About 724 explosions were registered in 24 hours, and the frequency exhibits three decreasing maxima and three decreasing minima. The microtremor waxed in somewhat similar pulsations to a high maximum, and then declined.

Professor Imbo on February 5, 1926, carried an accurate timepiece to the crater and compared the time of explosion with the seismograph records for 10 explosions. The mean time of propagation was 5.9 seconds for a distance of 2,670 meters, showing a superficial velocity of 456 meters per second. Probably the distance from the deep explosion was less than this over a more horizontal course. It was estimated that the depth of the explosion source was 312 meters, reducing the angle of the line from source to observatory to 4.8°; the angle from conelet to observatory is 11.2°. T.A.J.

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No. 217 RELEASED WITHOUT COPYRIGHT RESTRICTION February 21, 1929

KILAUEA REPORT No. 891

WEEK ENDING FEBRUARY 20, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Until midnight of Tuesday, February 19, nothing whatever was noticed in Halemaumau pit at Kilauea Volcano to make certain the immediate approach of a new lava eruption. There was merely the expectation as reported in Volcano Letter No. 209 of December 26, 1928. The past week has been quiet at the pit, a survey party noted that the steam rising from the northwestern floor was a little bluish the forenoon of February 19, and a few rocks fell from the northern walls.

About 12:30 a. m. February 20 frothy fountaining lava gushed up a new crack athwart the 1927-28 lava bottom of Halemaumau, at the base of the northwest talus.

The seismographs exhibited 17 very feeble earthquakes for the week at the Observatory. One at 10:08 p. m. February 13 gave distance to origin 24 miles. Fourteen of the shocks were just before the lava outbreak between 10:47 p. m. February 19 and 12:28 a. m. February 20. Continuous volcanic tremor began 12:46 a. m. on the 20th. Microseisms for the week were slight. Tilt for the week was moderately strong to the NNE. The pit seismograph showed a first tremor at 10:27 p. m. the 19th, accompanied by tilt away from the pit (SE.); other tremors followed each with a tilt, and continuous tremor began at 12:44 a. m.

HALEMAUMAU OUTBREAK FEBRUARY 20

In view of the forecast of December 26 (Volcano Letter No. 209) it was satisfactory to find molten lava gushing up the peripheral wall-crack of the bottom of Halemaumau northwest just after the midnight preceding February 20. This inaugurated a new eruptive spell quite like those of July 19, 1924 at 1 p m., July 7, 1927, at 1 a. m., and 12:26 a. m. January 11, 1928: but the new eruption appears more vigorous and voluminous than any of those. All four followed either midnight or midday, as though a solar influence might be present. In none of the four was a witness actually present at the first gush of gas. The 1924 eruption lasted 12 days; 1927, 13 days; 1928. 1 day.

The watchman at Volcano House and some others saw glow over Halemaumau about 12:30 a. m. The volcanic tremor on the seismograms became continuous, after some scattered trembling spells before and after midnight, at about 12:45. Strong tilt away from the pit in trembling spasms was registered at the pit seismograph 1,900 feet southeast from the center of Halemaumau. These spasms finally became continuous trembling of the ground.

A rift broke open through the lava floor and base of the talus slides, 1,370 feet long, trending N. 63° E., about 270 feet out from the northwestern edge of the floor proper. By analogy with 1927 what happened was the rush of blue sulphurous gas, carrying with it increasingly incandescent basaltic foam, until spray fountains of melt were jetting up from 100 to 300 feet all along the crack. The eruption was of Mauna Loa type. Only thin fume arose. In the first hour and a half a lava lake was formed covering all the floor except the central cone summit to a depth near 30 feet. The average rise of the lake for 11 hours was more than 5 feet per hour.

At 2 a. m. there was a group of big fountains at the north with one great jet like an upturned hose shooting 225 feet into the air; this was reduced to 100 feet by 12 noon. Next southwest came a smaller fountain building a cone. Next was a long nearly straight line of violently boiling fountains across the west side of the lake roaring like a surf for a length of 1,000 feet. The great north fountain, just under where the avalanches have been numerous for years, and about where the old Postal Card fissure was 10 years ago, is the source of a wide lava stream out into the lake.

Around the line of perpetual fountains, which played up 50 to 100 feet, at the west, the lake quickly filled in to submerge their vent fissure. These fountains were thus out in the lake with the lake surging about them making a concentric elliptical pattern in the crusts. These crusts streamed in toward the fountain line and foundered. The rest of the lake cracked in radial bright lines toward the east. Glowing lava toes pushed from under the skirt of skin around the lake edges, and the talus shores steamed a little.

The lake at noon February 20 was 1 500 feet long and 1.000 feet wide. and shaped like a properly oriented map of Australia. The old central cone at first made a crescent island with horns turned south, but was submerged by 10 a. m. By 4:30 a. m. the lake touched the rock wall northwest. The high south-southwest cone of 1927 stood 83 feet above the lake at noon February 20.

There was a little avalanching at the east in the early morning, but this was exceptional. The tremor, and the reverberation of the rumbling fountains increased as the day wore on, and as the heavy viscous lake tended to restrain the gas of the rising foam. By evening the line of fountains made thudding detonations and reddish yellow flames rose as the huge gas bubbles burst in quick succession through the boiling western part of the lake.

By 5 a. m. the northern fountains were building cones and ovens, with glowing grottoes inside, and cascades of glowing slag poured down from the higher ones. Thin blue fume, brown in transmitted light, rose from the big pit. and reflected the light of the slag pool below so as to rival the moonlight. The steady roar could be heard at Volcano House. Gray or salmon colored moisture clouds billowed up rapidly hundreds of feet above the fume veil: these were made of atmospheric humidity drawn in by convection.

Needles of lava glass and wisps of Pele's hair, along with pellets of pumice, fell to leeward and in the Kau desert. Rampart shores of the lake were forming southwest and southeast during the day. Small fountains in the lake itself became more numerous as the vent fountains diminished. At first the spray banks to leeward of the north fountains were of greenish brown pumice, later of black glass. In daylight the lava lake surface acquired a leaden color with a blocky pattern. T.A.J.

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No. 218 RELEASED WITHOUT COPYRIGHT RESTRICTION February 28, 1929

KILAUEA REPORT No. 892

WEEK ENDING FEBRUARY 27, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

In Halemaumau pit of Kilauea Volcano a new eruption of gas charged lava, which began near 12:45 a. m. February 20, and continued its fountaining throughout that day and the first half of the next, went out of action about 1:15 p. m. February 21 so far as fountains are concerned. Since that time a heavily crusted lake, with glow cracks seen at night, has remained in the bottom of the pit, and all around it stands a rampart approximately 8 feet high above the lake sufrace This implies that the lava lake subsided by shrinkage and loss of gas about 8 feet below its highest stand, and this subsidence was mostly accomplished during the 24 hours following noon of February 21. The average diameter of the new lava fill is approximately 1,600 feet, and its average depth about 64 feet. These figures give 128,680,000 cubit feet (3,640,000 cubic meters) of new lava.

The report of the watchman who saw the first evidences of the eruption from the northeast rim of Kilauea Crater, 2 miles away, was to the effect that a dark cloud arose, then a white steamy cloud, and then the glow of spouting lava. The fountaining rift in the bottom of the pit for the first 12 hours was described in Volcano Letter No. 217. The heat of the big lake on February 20 made whirlwinds at the south edge of the pit which carried needles of lava glass and small lapilli. A long rampart was building at the lake edge toward the west, and a smaller one appeared at the southeast. During the next day this rampart formed all around the lake.

At 7 p. m. February 20 the big north fountain had built a high spatter wall and oven, the lake was in contact with the northwest wall of Halemaumau, and a line of grottoes had appeared under the west rampart.

The rumbling thud of the long line of fountains west and the big geyser of slag at the north had become deep and heavy, with occasional detonations. Along with this all the seismographs showed stronger volcanic tremor, which had increased since the morning. The pattern of bright lines was concentrically elliptical around the belt of western fountains, and zigzag radial lines extended E., SE., and S. The spray from the north fountain was sometimes 100 feet high.

On February 21 after an earthquake felt about 3:33 a. m., the lava was sinking, and avalanches were sliding at the north about 10 a. m.; the west fountains, beginning at 10:30 a. m., dwindled to small spurting at the east end of their crack, and the big north jet lessened. This last had built an "armchair" grotto. At 11:30 a. m. the west fountains went out of action, seismometric tremor decreased, and about this time the lake was receding. At noon there was no trace of the line of western fountains, and it was evident that the active north fountain had built its niche by lowering and causing its cone to cave in. The second northwest conelet of the 20th was gone. The coarse blocky crust pattern showed no trace of the radial lines. In a few places the crust cracked, and glowing melt welled up. The border rampart was complete, 7 feet above the lake, with an overflow margin outside. At 1:10 p. m. the north fountain stopped, and at 1:13 p. m. a slide occurred NE.

At 8:30 p. m. a long oval glow area was defined at the west, and a glowing cove at the east, with sluggish lava welling up along the outlines. The rest of the lake had a dull cherry red pattern like a bed of coals. There was the grinding noise of foundering crusts. A northwestern slide occurred at 8:50 p. m. During the night the dark red glow on the clouds decreased. Another earthquake was felt at 12 midnight.

The forenoon of the 22nd showed brown fume hanging under the rain clouds far to the SW., but the pit appeared clear. After this the lake changed little, avalanche debris rested on the new pumice bank at the north and on the eastern talus, and glow cracks were still visible at night. On the evening of the 23rd the hot air rising above the new lava made a rain cumulus with long tails leading down to the pit. On the 24th fifteen spots were counted on the lake crust where the last lava trickles had welled up. After rain, steam had increased at the top and bottom of the south talus and at the N. edge of the new lava. Small slides at the north were heard the forenoon of the 25th, and yellow stains at the north fountain locality were seen on the 26th.

The seismographs at the Observatory registered 5 very feeble and 3 slight local earthquakes for the week, and one weak teleseism at 10:50 p. m. February 25. The felt earthquakes of February 21 at 3:33 a. m. and 2:00 p. m. indicated origins 13 miles away, and the earthquake felt at 4:51 p. m. February 24 showed distance 14 miles. Both the last named were felt at Pahala, and the first two were felt in Hilo. Volcanic tremor began 12:46 a. m. February 20 and ended 11:30 a. m. February 21. At the pit seismograph it continued until about 1:00 p. m. Tilt at the Observatory was strong SSW. Microseismic motion increased at the end of the week.

The Halemaumau seismograph, recording only NW.-SE. tilt (to and away from rim), registered 11 seconds angle of tilt to the SE. between 9:15 a. m. February 19 and 12:45 a. m. (time of outbreak) February 20. Five seconds of this accompanied small earthquakes between 10:06 p. m. the 19th and 12:35 a. m. the 20th. The rim region then tilted back to the NW. 6 seconds between 12:35 a. m. the 20th and 2:23 p. m. the 22nd; tipping was strongest between 8 a. m. and 1 p. m. the 21st. At that time there was thus a net gain of 5 seconds (11 minus 6) tilt away from the pit.

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No. 219 RELEASED WITHOUT COPYRIGHT RESTRICTION March 7, 1929

KILAUEA REPORT No. 893

WEEK ENDING MARCH 6, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The lava activity that was observed in Halemaumau pit Febraury 20 has entirely ceased, and there remains the frozen lava lake with virtually no motion of any kind. The incandenscent pasty lava undoubtedly exists under the crust, but the shell on the lake has become too thick to show any further glow or gas action. On March 1 at 11 a. m. fresh debris lay on the eastern taluses, and there was also slight change in the northern and southern slopes. A slide was heard at the southwest. Sulphur stain was increasing near the north spatter cone, and a new patch had appeared at the south edge of the lava floor, which was steaming. At the west a crack in the floor was seen, and the south side of the lava area appeared to be settling more than elsewhere. White stain suggests fumarole action on a large red rock in the gravel near the bottom at the east. White stains are increasing on the lava crust. Columnar fluting is conspicuous at the southern end of the east sill, where also there is steam from the wall.

On March 2 the strong earthquake at 10:24 a. m. dislodged a small slide at the east wall of the pit. At 11 a. m. March 3 a little sliding was heard, there was a line of steaming up and down the top of the south talus, and fresh avalanche debris had increased at the east.

In the forenoon March 4 slides were common N. and NE., and about noon visitors throwing rocks at the edge NNE. started a slide that made a red scar in the wall, put numerous white rocks on the talus below, and made a cloud of dust. March 5 there were small rock falls N. and SE.

The seismographs registered only 6 local earthquakes for the week, 4 very feeble, 1 feeble at 10:19 a. m. March 2, and 1 slight and locally felt 10:24 a. m. March 2 of intensity III R. F. The last two indicated a distance from the Observatory of 17 miles, probably in the Kapapala direction, making the center somewhere between Kilauea and Mauna Loa. Tilt for the week was moderate to the north, and microseisms were normal.

MOUNT SHASTA MUD FLOWS

During the summers of 1924 and 1926 there were floods from Mud Creek, which drains the Konwakiton Glacier on the south slope of Mount Shasta. Owing to the depth of the mud deposited by the floods, trees were killed over hundreds of acres, roads buried, and railway traffic interrupted, while the drainage system into which Mud Creek flows was contaminated by mud for over 75 miles.

The floods were due to the rapid melting of the Konwakiton Glacier. The glacier rests on a thick deposit of unconsolidated volcanic ash. Mud Creek always carries a great amount of this ash. Light snowfalls of the winters preceding the mud flows allowed the summer sun to cause more rapid melting of the glacier than is common. The floods in Mud Creek were the result.

Some press reports, written by correspondents a considerable distance from Mount Shasta, attribute the rapid melting of the glacier to an increase in the volcanic heat of the mountain. Nothing has been found to support such a contention. The hot springs on the summit of Mount Shasta are steaming much the same as they have been for years. The highest temperature found at these springs on June 18, 1928, was 180° F., or a little below the boiling point for an elevation of 14,000 feet. R.H.F.

EARTHQUAKES ON ISLAND OF HAWAII 1928

The total number of seismic disturbances registered by the seismographs of the Hawaiian Volcano Observatory during the year 1928 is 1,053. Of these 1,034 were local earthquakes and tremor swarms.

Of the local earthquakes, the grouping by intensity is as follows: 1,004 were very feeble and so registered only by instruments; 25 were feeble, making a clean-cut earthquake seismogram, and felt by some persons; 3 were slight, making strong seismograms, and generally felt, except by persons in motion; 2 were moderate and strongly perceptible. The latter were January 4 and February 26.

The total of local shocks compares as follows with the three previous years: 1925, 922; 1926, 1,778; 1927, 1,149; 1928, 1,034. The average then is about a thousand per year at present, as 1926 was the exceptional year of the Mauna Loa outbreak, when there were 761 shocks in April alone.

The number of teleseisms for 1928 is 20, of which 4 are near the March equinox, 8 before and near the June solstice, and 8 near the September equinox.

An interesting feature was the notable increase of tremor swarms, lasting each from 2 to 34 minutes. They were conspicuous in January, March, June, and December, and were identified with pit avalanches in the late summer and autumn. T.A.J.

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No. 220 RELEASED WITHOUT COPYRIGHT RESTRICTION March 14, 1929

KILAUEA REPORT No. 894

WEEK ENDING MARCH 13, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Halemaumau continues quiet. On March 8 there was some sliding of rock from the north wall and also March 12, but in less amount On March 13 at 11 a. m. fresh red debris was observed on the east talus from a newly stripped portion of the wall two-thirds of the way down, above the big sill. A few stones were heard slipping twice during a visit of a half hour. Some stones from slides had rolled out over the new lava southeast.

The weather being sunny, no vapor was detectable rising anywhere from the new lava floor, not even from the stained area at the south edge. From the slide rocks outside the southeast edge of the floor, and from a wet spot at the top of the south talus, vapor was rising. There was also steam and moist ground at the lower ledges southeast whereas most of the talus slopes appeared dry. Hot vapor rose from fissures inside the south wall of the pit, near the top.

Four very feeble local earthquakes were registered at the Observatory during the week. A large distant earthquake began about 3h. 11m. 22s. p. m. March 6, and the long waves threw the writing pens off the drum. The indicated distance was 3,650 km., corresponding to the north side of the Aleutian Deep south of Amukta Pass. This origin was confirmed by radio report from Alaska. Small seismic sea waves were registered as following this earthquake in Hilo Harbor at the tide gauge between 7:45 and 10 p. m. March 6.

Tilt for the week was slight SSW and microseismic motion was very slight.

SEISMIC SEA WAVE MARCH 6

The large, distant earthquake registered at the Hawaiian Volcano Observatory as beginning 3 h. 11 m. 22 s. p. m. March 6, Hawaiian Standard Time (G.M.T. 1 h. 41 m. 22 s. March 7) exhibited on the seismogram very clear preliminary tremors lasting 5 minutes and 26 seconds and a well marked beginning of secondary waves, which merged without distinction into such large long waves that the writing pens of the seismographs at Kilauea and at Hilo swung off the smoked paper. These seismograms indicated an earthquake of great magnitude at a distance approximately 3,650 kilometers, or 2,270 statute miles from the Observatory. The seismogram showed signs of the return wave that had passed around the crust of the earth on the side of the globe remote from Hawaii about four hours after the start of the record. Calculation showed that the time of the actual shock at the epicenter was 6 m. 52 s. before the registration began; that is, the seismic waves through the rock under the bottom of the sea took a little less han 7 minutes to travel 2,270 miles.

This distance is slightly less than that of California from Hawaii, and the indication from the direction of first disturbance and from the excess of long wave motion in the north-south direction implied an earthquake origin lying probably either NNW or SSE from Hawaii. Toward the south this would be near the Marquesas Islands, and toward the north it would mean the well known earthquake region of the extremely deep trough (over 4,000 fathoms) that lies about 125 miles south of the Aleutian Islands. Everything indicated that one of the big Aleutian earthquakes was in progress.

In accordance with previous experience at this station (Volcano Letter No. 57, January 28, 1926) the big submarine earthquakes from Alaskan waters and also those still farther away from the sea bottom off Chile are liable to create flood waves in the ocean that may do some damage on the eastern side of the large Hawaiian Islands. The experience of February 3, 1923, had shown that a large earthquake south of the Alaskan Peninsula could make a disastrous tidal wave which arrived at Hilo about seven hours after the shock was registered at the Kilauea seismographs. Accordingly, in the present instance a tidal wave warning was sent to the harbor masters at Hilo on Hawaii, and Kahului on Maui, and through the Naval Radio to the Commandant at Pearl Harbor in Honolulu. It seemed probable that the water wave would reach Hawaii about 10 p. m., by analogy with the transit time of the sea wave of 1923.

The speed of travel of such waves is comparable to that of the wave represented by the normal daily tide, and this speed has nothing to do with the violence of the resulting shore waves, which are compounded with the natural period of the local harbor or basin, and usually keep swinging back and forth for hours at intervals of 15 or 20 minutes. The speed of the free wave in the open ocean is for the Atlantic tides about 500 miles per hour, and for an earthquake wave in the Pacific 300 miles per hour, more or less.

On March 6 the event proved that a great earthquake had occurred at the north edge of the Aleutian Deep approximately 100 miles south of Amukta Island, as reported by Japanese steamers in that vicinity, which felt the sharp bump of the quake. Also Dutch Harbor reported severe shaking. The surging waters began to swing in and out of Hilo Bay about 7:45 p. m., as recorded on the tide gauge at Pier 1 back of the breakwater, with a range of motion of something over a foot and an interval of about 15 minutes between crests. In the Wailoa River at the head of Hilo Bay the harbor master reported 16 inches between high and low level swings. I watched these swings as follows:

8:20 p. m.,	current	inward
8:27 p. m.,	"	outward
8:31 p. m.,	"	inward
8:34 p. m.,	"	outward
8:38 p. m.,	"	inward

With higher tide the surges were watched between 9 and 11 p. m., and the intervals grew longer. The S. S. Haleakala at Pier 2 broke stern lines as result of the surging motion. The maximum was between 8 and 9 p. m., and about 10 p. m. the surges dwindled. It was evident that the speed of propagation of the water movement must have been over 400 miles per hour.

The correspondence of location of earthquake, and of sea wave as registered on the tide gauge, with published expectation in accordance with seismogram data, was completely satisfactory. The time of transit of sea wave appears to be less than that of 1923. Its resultant surges in Hilo Harbor were much lower than in 1923, when disastrous wave action reached heights about 15 feet above normal. As the earthquake of 1929 appears to have been equally intense, and the position only a few hundred miles farther west, it seems likely that local surging must depend on wave resonance with the stage of the tide, and the effects of winds and waves over the ocean intervening between the earthquake origin and the port. T.A.J.

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No. 221 RELEASED WITHOUT COPYRIGHT RESTRICTION March 21, 1929

KILAUEA REPORT No. 895

WEEK ENDING MARCH 20, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

No volcanic changes have been observed at Kilauea or Mauna Loa indicating anything unusual. Some rapid tilting, accompanied by tremor, at three seismograph stations in and around Kilauea Crater has interested the observers because of its resemblance to similar movements incident to the eruption of February 20. This interest is reinforced by prolonged tremor spasms at the Observatory March 15, 17, 18, 19, and 20, two of these accompanied by east tilt.

On March 15 at Halemaumau a small slide was heard about 9 a. m. toward the north, and the falls of rock during the forenoon were very slight. The next morning, March 16, there was very little steam in the pit, and only a few slides. March 18 at 9 a. m. there was a very little sliding at the northwest. Yellow sulphur has appeared in cracks at the stained whitish spots along the north and south edges of the new lava. The downfaulted bench around the edge of the subsided lava lake is in steps. A little steam shows sometimes quite suddenly at the north sulphur spot as though nucleated by invisible gas blown over the place from a nearby orifice. There is vapor high on the west and south taluses, on the lower east talus, and at the top of the talus NNE. On March 19 just before 6 p. m. red and gray dust rose from avalanches in Halemaumau.

Seventeen very feeble earthquakes were registered at the Observatory, of which one at 9:05 a. m. March 13 indicated origin distance two miles away, and another, 11:14 a. m. March 19, origin distance 11 miles. The tremor spasms above mentioned are not included with these earthquakes. Tilt for the week was strongish WSW., several of the shocks of March 17 until 4:14 p. m. exhibiting westerly tilt simultaneous with the tremor. Microseismic motion was normal.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION 1928

The work of the Association is divided between general furtherance of the progress of the Hawaiian Volcano Observatory and the specific tasks of maintaining seismograph stations and issuing publications. The Board of Directors are L. A. Thurston, W. F. Dillingham, F. C. Atherton, L. T. Peck, W. W. Thayer, W. R. Castle, A. L. Dean. The Honolulu office is 1031 Fort street, L. W. de Vis-Norton, secretary. The Association is incorporated, and has about 180 patrons and members, and a mailing list of about 600 institutions, libraries, and individuals.

The division of work between the United States Geological Survey and the Association at the Kilauea observatory is broadly on the line between salaries and equipment: the permanent salaries are Governmental. Outside of the observatory, the Research Association employs the seismograph observers in Hawaii, and occasionally other persons on Research Fellowships.

The Observatory was founded by the Research Association in 1912, and has gradually acquired increasing Government aid. The collaboration may be compared with the demands of manufacturing associations on the Bureau of Standards. The Association has supplied shops, instruments, laboratories, expeditions, researches, books, specialists, vehicles, and machines, that have made possible path-breaking investigations which could not have been attacked under Government alone, owing to the restrictions that control Government funds.

The work of the Association in 1927-28 in seismology illustrates perfectly its influence and results. The Association built the Uwekahuna Observatory, for use as a trailside museum by the National Park Service; equipped it with a seismograph for both exhibition and research, and placed the best collections on exhibition. This accomplished three distinct advances: it provided a new seismograph and observation station in a new place; it gave the public a museum and relieved the Observatory of exposition duties; it provided the National Park with motion picture hall and apparatus for exhibiting to travelers volcano activities of other times. Government staffs immediately assumed operation expense.

The Association at the same time equipped and manned a machine shop for making seismographs. Seven instruments have now been built in that shop, new ones are installed in Kona and Hilo, many other tools and machines have been built, and the machinist is now a Government employee. The old seismograph released from Kona was rebuilt and installed in a small roofed cellar near the Kilauea pit: this instrument showed remarkably instructive tilt and tremor in the Halemaumau eruption of February 20, 1929.

In the summer of 1928 the seismologist built an oscillating table for mounting and testing seismographs by imparting to them artificial earthquakes. The "Ohiki," wheeled boat built by the Research Association and tested in a longshore trip on Hawaii, was the experimental basis of a successful season with an amphibian in Alaska.

The published work of the Association in 1928 concerns volcano notes from many lands, the weekly reports from Kilauea, Lassen Observatory notes from California, reviews of volcanologic books, popular statements of the technical work in progress on local shocks, tilt, microseismic motion, distant earthquakes, tidal waves, temperatures of borings, work of the several seismograph stations, notes on explorations, new methods and cooperative work of other bureaus, some National Park enterprises, addresses and articles on borings, Coast Survey work, gravity measurements, and on tide gauge measurements and station installation.

The improved registration of earthquakes by the Association seismographs was never better demonstrated than during the last three months, when the local earthquakes that preceded and followed the February eruption were well recorded at five stations, and all five also made record exhibiting data that bear on distance of origin, direction, and intensity, for the great Aleutian earthquake of March 6, 1929. To the radio equipment installed at Kilauea and in Kona the Observatory owes increasingly accurate time service, the time signals being sent out from Washington, D. C., and from naval stations in California and Hawaii. T.A.J.

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No. 222 RELEASED WITHOUT COPYRIGHT RESTRICTION March 28, 1929

KILAUEA REPORT No. 896

WEEK ENDING MARCH 27, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Avalanche dust rose from the northeast side of Halemaumau at 3:10 p. m. March 20. In the forenoon of March 23 what appeared to be a fresh scar on the north wall of the pit was observed, and a very few small slides occurred. About midday March 25 the pit was quiet, except that a slide occurred at the north end of the large northeastern sill about 1 p. m.

At 8:40 a. m. March 27 the pit was very quiet, no stones fell, there was steam back of the upper edge E., N., NW., and W. outside of the pit, but the floor was not steaming. There was the usual vapor from the taluses. About 11 a. m. some dust rose from the pit.

At the Observatory 20 very feeble earthquakes occurred, and tremor in irregular recurring spasms, also very feeble, as follows: March 28, 8 to 10 a. m., 8:50 to 10:45 p. m.; March 21, 6:30 to 8 a. m., and irregularly in the afternoon; March 23, irregularly 10:12 a. m. and 3:25 p. m.; March 24, irregularly 6 to 7 a. m.; March 25, 9:34 to 9:37 p. m.; March 26, 8 of the earthquakes above mentioned, between 3:19 p. m. and 4:50 p. m., may be expansions of tremor too feeble to register continuously.

Microseisms were normal, diminishing during the week. Tilting of the ground was slight to the south.

VOLCANOES IN CHILE

The following notes from a letter received from Mr. John B. Stone are of great interest as they are written by a geologist who worked five months on the geology of Kilauea Volcano in 1925 (Bulletin 33, B. P. Bishop Museum, Honolulu, 1926).

"I have recently returned from a vacation trip to Chile" (Mr. Stone is engaged in mining geology in Peru) "during which I went as far south as the island of Chiloé. One of the objects of my trip was to get some information on the volcanoes in that region.

"In Santiago the director of the seismological service stated that the volcanoes in north Chile are not active, but that those in the region between Santiago and Chiloé are active intermittently. There are others farther to the south, but the country is almost uninhabited and little is known about them. Among the volcanoes are Llaima, near the town of Temuco; Villarica and Pueyhue, near Osorno; and Osorno Volcano, Calbuco, and Tronador, near Puerto Varas on Lake Llanquihue. These volcanoes are on the west side of the central valley of Chile (which is beautiful farming country), and are easily accessible from the excellent railway running south from Santiago to Puerto Montt."

A short time before the first of December, 1927, there were earthquakes along the coast of Chile, and at the same time several volcanoes of the southern Andes were active.

The volcano Llaima began erupting violently about November 29, 1927. Enormous flashes and a great quantity of smoke, lava, and cinders came out of the crater. Llaima is some 65 kilometers from Temuco, and it is not more than 3,000 meters high. It has two craters, and is covered with snow all the year round. It lies in latitude 38 degrees 44 minutes. The volcano had a violent eruption in 1864, and flashes of fire have frequently been seen in its craters. There are said to be 34 volcanoes between the latitudes of 24 degrees and 42 degrees.

"I went south from Valparaiso by sea, and on arriving in Puerto Montt on January 6, 1929, found that the volcano Calbuco was in eruption. The air was full of light ash, but only steam was issuing from the volcano at noon of that day. I went in an automobile to Puerto Varas, but was unable to get closer to the volcano than six or eight miles. According to the people there the eruption began about 1 a. m. January 6, 1929, and the outbreak was accompanied by a slight earthquake. The volcano then threw out ash until about 6 a. m., and there was another smaller earthquake about 4 a. m. For the rest of the day there was a fine steam plume from the peak, and once or twice I thought I saw small, dark puffs that could have been ash. Faint steam or smoke was rising over a large area of the woods at the foot of the volcano. I thought it might be caused by the fall of hot ash, but there were reports of a lava flow. On January 7, 1929, I saw the volcano from a different angle, and there appeared to be two steam jets. The only press report of the eruption that I saw was much exaggerated.

"It would be possible for an observer with headquarters at Puerto Varas, or possibly at Osorno town, to keep half a dozen volcanoes under fairly close observation. The eruption that I saw is probably typical, consisting of a short ash ejection, possibly accompanied by lava flows. The country is far more accessible than Alaska, and except for the heavy winter rains is a most agreeable place to live in. Puerto Varas, I judge, is only about 200 feet above sea level, and Calbuco volcano would appear about 5,000 feet high" (1,738 meters or 5,700 feet, according to Sapper). "I think that an expedition less expensive than those to Alaska could get important results in two or three months. December-January is the best season.

"At the Braden Copper Mine at Sewell, I found that the Talca earthquake of about December, 1928, had lasted one minute and a half and had destroyed the tailings dam at the mill, thereby causing a rush of mud that killed 43 people. A new Chilean law has established a Department of Public Works, which has as one of its chief duties the supervision of buildings to make them more nearly earthquake-proof." T.A.J.

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No. 223 RELEASED WITHOUT COPYRIGHT RESTRICTION April 4, 1929

KILAUEA REPORT No. 897

WEEK ENDING APRIL 3, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

During a half hour at Halemaumau pit about 2:30 p. m. March 29 no slides were heard. Fresh debris was observed on the north and northeast talus slopes, and scars were visible half way up the wall above both places. A ranger reported that the northeastern slide occurred about 2:30 p. m. March 27.

Measurement of cracks near the tourist outlook on the eastern rim of Halemaumau indicated that little or no change had occurred since January 18. At the former tourist outlook, farther south, where so much avalanching occurred in January, a rim crack was found to have widened 0.13 foot.

On March 30 at 8:30 a. m. a small slide removed rock from the eastern rim, and another was reported the next morning farther south. At 10 a. m. March 31 everything was quiet at the pit, and nothing new was observed. At 3:45 p. m. that day an avalanche sent up dust above the rim level.

Sixteen very feeble earthquakes were registered on the Kilauea seismographs, and irregular tremor occurred at intervals throughout the week, but very feebly. Tilt was moderate to the SSE., and microseismic motion was slight.

EARTHQUAKE INTENSITY SCALES

The attempt to define the size of an earthquake has led to making scales of earthquake severity. Where a large country is involved these scales have been based on popular reports. For scientific comparison with other places the size of the earthquake at any place ought to be expressed by a number. Just as four pounds of sugar ought to be four times as big as one pound, so a number four earthquake should be four times as big as number one. Herein lies the difficulty.

The Rossi-Forel intensity scale in common use is numbered 1 to 10, the numbers are defined by such expressions as "recorded only by seismographs," "cracking of plaster," "fall of chimneys," and by such adjectives as instrumental, moderate, and disastrous. The trouble with such a scale is that a nervous, sensitive person not used to earthquakes considers a feeble shock "stong." On the other hand, the average psychology of many people is a vaulabe criterion of intensity. The five grades (1) not felt, (2) felt by people at rest, (3) felt by everyone, (4) causing general fright, (5) causing consternation and panic, are definite.

The scientific basis of intensity, from a pendulum swinging in oil and scribing the length and time of its swings, or better, the length and time of the maximum swings of the earth while the pendulum stands relatively still, is called an "acceleration" or jerk. It is measured in rate of change of motion, millimeters per second change of motion per second (mm./sec.^{2}). The mathematical expression for this involves the square of the velocity of the earth particle divided by the amplitude of its motion. The changes of motion involve changes of direction as well as of speed. But for measurement it suffices to consider earthquake vibration a simple to and fro swinging. The seismograph pendulum assists this conception, for each instrument translates the earthquake motion into harmonic vibration in one direction only.

The Cancani intensity scale is based on a range of accelerations for each of 12 grades. The first 3 grades, from 1 to 10 mm., are instrumental only, and grade 12 would make a terrible catastrophe, reaching the acceleration due to gravity, 9,810 mm. per sec.^{2} Each grade doubles the value of the next preceding grade, expressed thus in millimeters (2½, 5, 10, etc.).

The Rossi-Forel scale, when reduced to accelerations, has values in terms of grade I as unity.

Grade	I, barely felt	equals	1
"	II, felt by few	"	2
"	III, felt by several	"	3
"	IV, feebly felt generally	"	4
"	V, felt by everyone	"	5.5
"	VI, alarm	"	7.5
"	VII, panic	"	15
"	VIII damage	"	25
"	IX, destruction	"	60
"	X, catastrophe	"	125

It is thus arithmetically good from 1 to 4, and thereafter is an ascending curve. Grade I Rossi-Forel equals Grade IV Cancani.

The following are the grades of the Mercalli scale, abridged to show human effects:

I, INSTRUMENTAL, not felt.
II, VERY SLIGHT, felt by very few.
III. SLIGHT, felt by several.
IV, MODERATE, felt by many, no alarm.
V, RATHER STRONG, felt generally, some alarm.
VI, STRONG, felt by nearly everyone, many with fright.
VII, VERY STRONG, flight from houses, some damage.
VIII, RUINOUS, great terror, some wounded, much damage.
IX, DISASTROUS, a few lives lost, general ruin.
X, VERY DISASTROUS, great loss of life and utter ruin.

In the writer's tests, and Professor Mercalli among Italian peasants evidently had similar experience, ignorant persons in city or country can understand a human scale. They usually distort or exaggerate physical effects on masonry, water, trees, chimneys, etc., because they have no training in measured or judicial statement. T.A.J.

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No. 224 RELEASED WITHOUT COPYRIGHT RESTRICTION April 11, 1929

KILAUEA REPORT No. 898

WEEK ENDING APRIL 10, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Halemaumau, the inner pit of Kilauea Crater, has been almost motionless during the past week, and the new floor of black lava which was poured out February 20, 1929, appears almost as fresh as the day it solidified. In the forenoon of April 3 vapor rose over the whole pit after light rain. At 10:30 a. m. April 6 a small slide occurred at the north wall. At 8:05 a. m. April 9 light dust arose at the northeast side of the pit. On this day white salts were noticeable on the walls and talus blocks after two dry days following rain. The next morning, when there was a little drizzle wetting the stones, much of the whiteness disappeared.

The seismographs registered five very feeble local earthquakes during the week. One at 10:13 p. m. April 3 had indicated distance 11 miles from Observatory. The spasms of tremor were not observed after April 6. Tilt was slight to the south, and microseismic motion was normal.

THE ORIGIN OF LASSEN MUD FLOWS

By R. H. Finch

The cause of the mud flow from Lassen Peak on May 19, 1915, has been disputed. Drs. Day and Allen in their book, "The Volcanic Activity and Hot Springs of Lassen Peak," attribute the flow to melting of snow by a hot blast of gas, a deposit of hot volcanic ash, and hot rain. Loomis in his book, "A Pictorial History of Lassen Volcano," contends that hot water came out of Lassen Crater.

It is hard to believe that hot water came out of the crater, and Day has shown that the mud flow started some distance below the crater rim. The hot water theory may be dismissed. The writer agrees with Loomis that there is not sufficient evidence to indicate the occurrence of a hot blast or any considerable explosion just prior to the mud flow of May 19. There was only one flood on this date, excepting the possibility of a small one below the western flow, while the known explosions on May 22 produced several small mud flows. If there was no explosion and no hot blast, then there would not have been any hot ash deposit nor warm rain. Even if there had been an explosion, any rain accompanying it would probably have been but little warmer than any other rain—certainly not hot. It is also doubtful under the conditions existing on Lassen Peak at that time whether a rainstorm, unless of very unusual intensity, could cause a flood of the magnitude observed.

The flood originated in an embayment on the northeast slope of Lassen Peak that was uniformly covered by snow with a depth of several feet over most of the area. Now it is known that a few feet of snow of uniform covering can absorb several inches of rainfall so that the rain produces but little immediate run-off. If there had been bare spots in the snow field, then water could have run under the snow in considerable quantities and, in a place as steep as the Lassen slope, started avalanches. A hot blast, unless long continued, or a slight deposit of hot volcanic ash would produce much the same effects as a rain—a melting of superficial layers of snow and an absorption of the water by lower layers. A hot blast or a hot ash fall on a steep slope not uniformly covered with snow could, as in the case of rain, start streams under the snow and also cause avalanches.

It would seem, then that the Day and Allen theory as to the cause of the Lassen mud flow on May 19 may also be questioned.

An examination of enlargements of the photographs taken by Mr. Loomis immediately after the mud flow on May 19, and of the material transported by the mud flow, indicates that a large volume of hot lava poured through the eastern notch of the crater. There is much new lava that was carried in fragments down the flood. This flow was not only much more voluminous than the one through the western notch, but as would be expected, it was probably, as a whole, more molten. The lava flow could easily have melted the snow down to the ground and sent a stream of warm water under the snow lower down the slope. An avalanche mixed with hot rock could easily have been started in this way and produced a flood of the magnitude observed.

Minor mud flows did accompany the explosions on May 22. There was a horizontal component or this explosion that was parallel with the course of the upper part of the mud flow on May 19. The area affected by this blast was much wider than the area devastated by the mud flow of May 19 and accordingly encountered snow banks with exposed edges. Considerable hot ash was also thrown out by this eruption. The largest mud flow that accompanied this explosion followed the course of the one on May 19. At places where there was still uniform snow covering, the mud flows occasioned by hot ash and perhaps mud rains of this explosion for the most part stayed on top of the snow.

TITLE PAGE AND INDEX

The Title Page and Index for 1928 is now published and has been mailed to the regular list. It will be sent to anyone desiring it.

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No. 225 RELEASED WITHOUT COPYRIGHT RESTRICTION April 18, 1929

KILAUEA REPORT No. 899

WEEK ENDING APRIL 17, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

At Halemaumau on April 11 at 3 p. m. bluish vapor was noticed rising through the talus at the east edge of the new lava floor and staining the rocks yellow. At a sulphurous patch on the north edge of the new lava, yellow vapor was observed in a jet, by one of the park rangers. Fresh red debris was observed on the north talus slope. At 3:07 p. m. a small slide occurred at the south, and some very feeble sliding of sand occurred there almost continuously.

On April 13 at 10:15 a. m. a red scar was noticed above the east end of the big sill on the eastern wall, and fresh debris lay on the talus below. The pit was visited about 9 a. m. April 15, 16, and 17, but nothing new was observed and the walls were quiet.

At Kilauea Observatory nine very feeble local earthquakes were registered during the week. One at 4:48 p. m. April 13 was felt in Hilo and indicated a distance of 11 miles from the Observatory for its origin. Another at 12:17 p. m. April 14 was weaker, and indicated a distance of eight miles. Tilt was slight to the north, and microseismic motion was normal.

SECTION OF VOLCANOLOGY 1928

The Section of Volcanology of the United States Geological Survey makes headquarters at the Hawaiian Volcano Observatory on the northeast brink of Kilauea Crater. Its work in Hawaii is greatly assisted by the Hawaiian Volcano Research Association (see Volcano Letter No. 221). It maintains in addition the Lassen Volcano Observatory at Mineral, Californfnia, has placed a seismograph in the Loomis Museum at Viola, California, and another at Kodiak, Alaska. Service of the Kodiak instrument had to be discontinued temporarily after the closing, in August, 1928, of the Agricultural Experiment Station, where the seismograph was operated. Another seismograph with its time clock and other appurtenances has been deposited at Dutch Harbor in the Aleutian Islands. This station will be started and the Kodiak station revived in 1929.

The report of the Volcanologist for 1928 stated that "it is logical to expect activity from either Kilauea or Mauna Loa in 1929." This has been verified by the outbreak of Kilauea February 20, 1929. The new cycle of lava activity in Hawaii has proceeded with lava in Halemaumau pit in 1924, 1927, 1928, and 1929, and lava from Mauna Loa in 1926. The cycle should be half finished by January of 1930, and so approaching its maximum of lava gas pressure at that time, equivalent to that of 1919 for the last cycle.

The routine in Hawaii in 1928 consisted of mapping changes in Halemaumau, operating seismographs at the pit, Uwekahuna, the Observatory, Kona, and Hilo, measuring crater rim fissures and temperature of bore-holes, keeping track of Mauna Loa, studying the seismograms and also those of Kodiak, publishing Volcano Letter and preparing Monthly Bulletin, experimental work with new seismographs and the oscillating table, building seismographs, keeping up the office work and records, operating tide gauge and maintaining time service by radio. The routine in Lassen National Park is similar in seismological work, but includes measurements of hot springs, of marked landslip areas, and of magnetism in lava flows, and geological mapping.

The personnel in Hawaii included T. A. Jaggar, volcanologist; R. M. Wilson and E. M. Buckingnam, engineers; R. B. Hodges, clerk; F. Y. Boyrie and Tai On Au, machinists; and H. Yasunaka, janitor. The Kona station was operated by R. V. Woods, the Hilo station by J. B. Albert and the Kodiak station by Mrs. E. M. Floyd. The tide gauge was operated by M. F. Lacerdo. Additional employees were S. Oda, J. H. Tahara, and Aiu Ahoi. The Lassen station was in Charge of R. H. Finch, associate volcanologist; assisted by A. E. Jones and C. A. Anderson, who made special investigations. Mr. Howel Williams also worked on Lassen geology. Mr. B. F. Loomis built a very substantial concrete and stone seismograph exhibition building next the museum at Manzanita Lake, where was installed the Finch seismograph, that had been replaced at Mineral by the Hawaiian type of instruments.

The Pavlof Expedition of the National Geographic Society under T. A. Jaggar materially advanced the exploration of Aleutian volcanoes. This has been given further impetus by the Federal Relations Committee of the National Research Council, which has formed a group of federal representatives of government scientific bureaus interested in the Aleutian Islands, to formulate a project for collaborative study of that region.

The shop of the Hawaiian Volcano Observatory has now produced eight pairs of seismographs, the wheeled boat "Ohiki," the oscillating table, special drilling apparatus whereby 34 bore-holes are now available as temperature stations, and machines for various physical experiments. T.A.J.

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No 226 RELEASED WITHOUT COPYRIGHT RESTRICTION April 25, 1929

KILAUEA REPORT No. 900

WEEK ENDING APRIL 24, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

At Halemaumau at 2:40 p. m. April 17 thin clouds of avalanche dust were arising over the pit. A more concentrated cloud rose at the north side, and the field glass showed that men were standing at the NNE. rim, probably dropping rocks and so starting the slides. At 3:15 p. m. both the dust and the visitors were still present. On the 19th at 2:30 p. m. the cleft above the north talus was seen to be somewhat enlarged, and a fresh scar was identified west of it. Apparently a thin layer of surface debris from a comparatively large area of the wall had caused the slides of the 17th. On this day there were occasional falls of single rocks from the northern wall, and at 2:35 p. m. dust from a slide appeared in the cleft above the NNW. talus. At 10 a. m. April 22 the pit was quiet, dry, and sunny, and exhibited no change. At 9:30 a. m. April 24 artificial slides on the north side of the pit were occasioned by men dropping rocks. At 1:10 p. m. thick, reddish dust arose at the north.

The seismographs registered eight local earthquakes, or tremors, all excessively feeble except one on April 20 at 10:21 p. m., which was very feeble but indicated distance of origin about 16 miles from the Observatory.

Tilt was pronounced to the SSW. Microseismic motion was slight.

A NEEDED SHOCK RECORDER

Seismoscopes that show whether a local earthquake has occurred were invented centuries ago. Seismographs which write earthquake autographs with pencil, ink, a scraping pen on smoked paper, or a light beam on photographic paper are mostly the product of the last century.

It was an effort of the staff of the Kilauea Observatory from 1911 to make a simple local earthquake instrument. But it proved difficult. It is easy to place a marble on top of a pillar: an earthquake rolls it off. It is easy to set up a pencil on its end on a glass plate: an earthquake rocks it or topples it over. Both require watching or they tell little about the time, duration, and size of the shock. And if they are found upset, a spider or a cockroach might have done it. If they require a strongly felt earthquake to upset them, what use are they? If they are too sensitive to tell how large a big earthquake is, again what use are they?

In short, the effort to record time, duration, and size appeared to require a masonry cellar at constant temperature, timekeeping like that of an astronomer, clockwork of the finest, observers directed by physicists, and five or six seismographs of different sensitiveness to be ready for big earthquakes, medium earthquakes, and little earthquakes. The Tokyo laboratory has 15 or 20 working instruments.

The object is to secure cheapness and attractiveness, in order to get records of local motion from many places and to interest many people. This is what, for meteorology, makes the thermometer and the rain gauge so useful. There is an enormous moral and ethical inertia, and even resistance, to be overcome, in order to make the discovery of the distribution of small local earth motions interesting to the man on the street. Recently the presidential addresses of the Seismological Society of America, the work of several associates of the Hawaiian Volcano Observatory, an appeal from the president of a leading insurance compay, and a letter from the Scientific American, have set the writer to experimenting, and the Jaggar Shock Recorder is the result.

The problem boiled itself down to the question, "What have we really got from our outlying seismograph stations, after running them for 10 years." We have a list of earthquakes, identifying the same ones at four different places, showing others strangely limited to single places, showing how long the jarring lasted at each place, and how great was the amplitude or back-and-forth motion of the levers. The timekeeping was not accurate beyond that of central telephone stations appealed to by the seismograph operators. The amplitudes were comparable only to such extent as the pendulums were built alike, tuned alike, and set up in like directions. Artificial jarrings were possible, from locomotives and trucks and school children. Directions of maximum motion, where a pair of pendulums is used, are of doubtful value; the reason is that each instrument place is likely to have its own swaying habit in all earthquakes, strongest always either east-west or north-south; every hillside is a pendulum. And finally, the magnification is so great in these instruments that strong shocks merely dismantle them.

Determination of distance of origin by study of the preliminary tremor is the one thing for which distributed good seismographs are important. This, however, requires expensive instruments, wireless timekeeping at each place, paid observers, and continuous attention by a central observatory. And even then, many shocks occur without good preliminary tremors, and the distance determination of centers tells nothing of how deep underground were the bumping, or gaping, or scraping fault surfaces that made the shock.

The seismologist says, "I wish I had sure knowledge of the measured size of that shock at plantations and ranches all around Mauna Loa." Then he could check up his theoretical place of origin by knowing where the shock was strongest. For this he needs a shock recorder, easy as a thermometer to read, working night and day, kept by the planter and the rancher. The need for this has grown, rather than lessened for we have recorded an astonishing number of little earthquakes felt all over the island of Hawaii.

The instrument that I have been working in the Kilauea station is made of a lead cylinder, hinged with two hacksaw blades, and writing on the face of an alarm clock. It produces an eight-inch paper disc with a line written round it like a gramophone record. The operation is no trouble at all. The paper is smoked, runs a week, and is then dipped in dilute shellac. Any quiet corner away from machinery receives the box, about three feet long, which is screwed down. It is sensitive so as to show our feeblest instrumental Kilauea earthquakes. The time is recorded by a dial printed on the paper. The cost will be about $25. When interesting earthquakes occur, any number of copies of the disc seismogram may be printed on blue paper like any engineer's drawing. In this way, if purchasers of a shock recorder care to send us their record discs, we can send them blue prints to keep of any earthquakes that interest them.

We shall be glad to correspond with any prospective purchaser of one of these instruments. T.A.J.

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No. 227 **RELEASED WITHOUT COPYRIGHT RESTRICTION** May 2, 1929

KILAUEA REPORT No. 901

WEEK ENDING MAY 1, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Halemaumau pit has been remarkably quiet during the past week with slight slides from the walls observed between 9 and 10 a. m. April 25 and about 11 a. m. May 1. These were quite possibly occasioned artificially.

Eight very feeble local earthquakes were registered at the Observatory. On the 24th of April there was very faint tremor at intervals.

Tilt for the week accumulated slightly WSW. Microseisms were normal.

GEOGRAPHICAL SHIFT OF EARTHQUAKES

Professors Terada and Miyabe (A Long Period Fluctuation in Latitude of the Seismic Activity on the Earth, Bull. Earthq. Res. Inst., Tokyo Imperial Univ., March, 1929, Vol. VI, pp. 333-343) have investigated how big earthquakes have shifted from south to north and back again in the course of five centuries on both sides of the equator.

The inquiry was suggested by successions of disasters in Japan lying on a line progressively farther north. Then it was found that in the 19th century maximum of average frequency of Eurasian earthquakes lay about latitude 35° N., whereas in the 20th century they cluster about latitude 40° N.

This led to platting mean frequency of severe world earthquakes by latitude belts. It was found that:

(1) A southing of latitude in the 16th century in Japan and Eurasia equalled a northing in the southern hemisphere for South America.

(2) A northing in Eurasia about 1600 equalled a southing in South America.

(3) A southing about 1700 in Eurasia equalled a northing in South America early in the 18th century.

(4) A northing about 1800 in Eurasia equalled a southing early in the 19th century in South America.

(5) Approaching 1900, Eurasian earthquakes moved south and South American earthquakes moved north, both starting to change direction in the 20th century.

The listing of Central American earthquakes showed some correspondence of latitude fluctuation with South America, and North American earthquakes exhibited a curve somewhat resembling the rest of the northern hemisphere. China and Japan were platted separately, and were found to have in common an east-west component of shift as well as a meridional one. In both, the successive displacements of earthquake activity are in the direction SW-NE. This corresponds in general with the axes of the great deep, the island arcs, the inner seas, and the continental structure of eastern China. For either hemisphere there is suspected from all the curves a period of about 200 years between like phases of the fluctuation. It should be remembered that these are curves of fluctuation of latitude for earthquakes where 1,000 or more casualties are reported. The curves have no bearing on general relative frequencies for latitude belts, where the epicenters are determined instrumentally (see Volcano Letter No. 198).

Seeking a cause for the northing and southing of earthquake frequency periods, the authors compare the deviation of the moon's longtitude from 1640 to 1925 with the earthquake curves (see Volcano Letter Nos. 94 and 129). De Sitter and Brown have suggested that the changes in the length of day are due to actual change in the earth's radius, and so to change of its moment of inertia. The maximum moment of inertia was near 1786 and the minimum 1897. The earthquake frequency reached higher latitudes about 1800, and moved toward the equator about 1900.

Terada and Miyabe find it easier to conceive increase and decrease in the equatorial protuberance and the polar flattening, than to assume expansion and shrinkage of the whole earth. The greatest shearing stress would be in the middle latitudes and so express itself in seismic activity. The simultaneous poleward and equatorward shifts of seismic frequency in the two hemispheres suggest that in some way the change in ellipticity of the globe shifts the earthquake latitudes.

There was an acute change in the length of day observed in 1918, believed by De Sitter as possibly explained by a general shrinkage of the earth's radius. Moreover, he considers the curve of the centuries as consisting of a succession of straight lines, changing suddenly. T.A.J.

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No. 228 RELEASED WITHOUT COPYRIGHT RESTRICTION May 9, 1929

KILAUEA REPORT No. 902

WEEK ENDING MAY 8, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Halemaumau has remained very quiet throughout the past week, with practically no changes. Only one slide was observed, occurring from the north wall at 9 a. m. today. The debris fell from near the top of the wall to its lowest point of contact with the north talus.

On May 6 fresh red scars were noticed north.

There has been a slight increase of white stain at the foot of the south talus, and some increase in the yellow stain at the west end of the spatter formed by the big fountains of February 20-21, 1929.

Four very feeble local earthquakes were registered at the Observatory. One of these was strong enough to rattle a window of one of the nearby cottages.

There was a slight accumulation of tilt to the southeast. Microseismic motion was slight.

MECHANISM OF TOKYO EARTHQUAKE

The disaster of 1923 contained as main facts:

(1) Great earthquake at Sagami Bay September 1, 1923.
(2) Coast uplifted 1 to 2 m., Oshima volcano island stood still.
(3) Bottom of bay subsided between 1912 and 1923 up to 210 m.
(4) An earthquake sea-wave flooded the coast.
(5) Region around Bay suffered clockwise horizontal displacement of vortical aspect between 1884 and 1924 as shown by triangulation.

The subordinate facts were:

(1) Land subsided and beaches retreated for 20 years before the earthquake; amount of subsidence 10 cm.
(2) The shoreline has been upheaved in ancient times.
(3) Westerly tilt was measured of 1.7 seconds July 30 to August 17, 1923.
(4) Four small faults and one big crack system were formed.
(5) The isoseismals were radial, irregular and extended to the NW.
(6) The direction of earthquake motion was somewhat vortical.
(7) Submarine cables were snapped.
(8) Deep sea fish floated dead.
(9) Landslips were common west and northwest.
(10) Mineral Springs, lakes, and wells changed.
(11) Aftershocks occurred in several zones.
(12) Decrement of aftershocks was irregular.
(13) Epicenter determinations of the great shock were conflicting, and indicated a "seismic domain."
(14) Distribution of the initial motion, somewhat doubtful, made the center probably on land due north of Sagami Bay.

The theories to account for the disturbance were as follows:

(1) Upthrust, suggested by T. Kato.
(2) Block movement, suggested by N. Yamasaki.
(3) Submarine fault, suggested by A. Imamura.
(4) Subterranean fault, suggested by S. Nakamura.
(5) T-shaped fissure, suggested by T. Shida.
(6) Plutonic intrusion, suggested by T. Ogawa.
(7) Linear rebound, suggested by M. Matsuyama.
(8) Horizontal folding, suggested by T. Terada.
(9) Vortical action, suggested by K. Suda and S. Fujihara.
(10) Magmatic action, suggested by H. Nagaoka.

S. Fujihara and T. Takayama now present somewhat fully in English the conception of a vortical shear. (On the Mechanism of the Great Sagami Bay Earthquake on September 1, 1923; Bull. Earthq. Res. Inst., Tokyo, March, 1929, Vol. VI, pp. 149-176). A vertical surface of discontinuity is believed to extend along the Japan coast with southwesterly motion on the Pacific side and northeasterly motion on the land side. A rotational motion of crustal blocks is believed to have taken place about Oshima as a center. The volcanoes have been notably rigid when other formations shifted. Oshima resisted the shear and a horseshoe distribution of stress has accumulated about Sagami Bay. This stress was last released in 1853-54. Discontinuous yielding occurred again September 1, 1923, There was a sudden warping of the horseshoe, which the authors illustrate by a model consisting of a circular rubber plate laid horizontally. An eccentric clamped vertical axis corresponds to Oshima. A tangential horizontal pull southward on the east side of the disc wrinkles it appropriately and rotates all points on the surface as the triangulation bench marks found to be moved.

The great subsidence of the bottom of the bay is believed to have been a warping for 11 years past, accelerated at the time of the earthquake. Rotation clockwise accompanied by convergence was computed for the bay, and a rotation in opposite seuse for a region next to the northeast, accompanied by divergence. The primary epicenter lay in between. T.A.J.

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No. 229 RELEASED WITHOUT COPYRIGHT RESTRICTION May 16, 1929

KILAUEA REPORT No. 903

WEEK ENDING MAY 15, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Halemaumau pit, the inner vent of Kilauea Crater, has remained quiet. Between 9:30 and 10 a. m. May 15 there was only one vigorous steaming area, namely at the top of the south talus. The north wall appears more freshly stripped than the others, but no slides have been observed during the week.

The upright cracks parallel to the eastern rim of the pit, and back from the edge, were measured May 15, and the 11 marked stations along the fissures showed very slight widening since March 29, 1929, the greatest movement amounting to 0.11 foot. This was at station No. 14, near where the opening crack extends tangentially into the pit wall.

Seven local earthquakes have been registered for the week, of which six were very feeble. One at 5:54 a. m. May 12 indicated an origin very close to the Observatory and was felt, the intensity being No. 3 Rossi-Forel. Microseisms for the week were slight, and tilt moderate to the northeast.

MECHANISM OF EARTHQUAKES

"A great earthquake is accompanied by topographic changes; such changes have been particularly remarkable in the three last great earthquakes that have happened in Japan. The study of these shakings has led to the conclusion that the change in the surface of the land is not such as would result in seismic rays radiating out in all directions."

"We may now consider proven the existence of blocks and block movements, using the evidence of measurements made by means of precise leveling. These measurements have demonstrated that the motions of these earth blocks are so independent that there exists little correlation between them, and there is deduced the existence of a malleable layer under the groups of blocks."

"The fact that the atmospheric pressure gradient plays an important part in the incidence of an earthquake, suggests the existence of a mobile stratum within which viscous matter is present, easily displaced under the action of differences of barometric pressure."

"Studies of the properties of magma, such as the phenomena of differentiation, the rapidity of magmatic intrusion, etc., permits us to consider the origin of seismic waves as result of shock provoked by sudden change in the kinetic moment of an intrusive."

"In the case of a feeble earthquake, there will be only the shock induced by the intrusion itself. But in the case of a big cataclysm there may be formed actual fractures in the terrestrial crust, resulting from the enormity of the disturbance."

"We have, in fact, many aftershocks following a great earthquake, which may be explained as injections of magma in the fissures formed by the first big disturbance. The topographic changes of level or of horizontal position are then accounted for as resulting from movements tending to readjust the isostatic equilibrium of the block."

"Seismic wave motion tends in fact to die out in passing a fault plane, whether that fault were the direct result of seismic happenings or other tectonic cause. The anomaly exists in the fact that seismic intensity diminishes when elastic waves pass athwart a fault plane standing perpendicular to the directions of propagation."

"In introducing magma as a cause, we can more easily explain other facts that accompany earthquake." (On the mechanism of production of seismic waves, by Misiho Ishimoto, in Japanese, abstract in French, Bulletin of the Earthquake Research Institute, Tokyo Imperial University, March, 1929, Vol. VI, pp. 127-147.)

The author discusses the relation of dykes, faults, and existing igneous outflows to earthquake rifts, presents maps and a diagram exhibiting the relations of dyke intrusion to time, specific heat, conductivity, density, thickness, distance, and temperature, and quotes Barrell (Professional Paper No. 57, U. S. Geol. Surv. 1907, pp. 157-159), to the effect that "the extension of dyke intrusions resembles volcanic eruptions in that both take place in an intermittent and paroxysmal manner."

It would appear from the facts of volcano research that lava outflow, magmatic intrusion, and swarming of earthquakes may all correlatively take place in an intermittent manner, which is cyclical and not at all paroxysmal. Paroxysm is nothing more than occasional acceleration.

T.A.J.

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No. 230 RELEASED WITHOUT COPYRIGHT RESTRICTION May 23, 1929

KILAUEA REPORT No. 904

WEEK ENDING MAY 22, 1929
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The past week at Kilauea and Mauna Loa has exhibited suggestion of movement on the flow rifts of the latter mountain. Kilauea has been notably quiet.

At Halemaumau about sundown May 15 a ringing noise of snapping was heard in the new lava bottom like deep cracking due to cooling as the sun's rays left the surface. On May 17 about 4 p. m. a slide occurred at the east rim. On the 19th a little dust rose at the north corner of the pit about 9 a. m., and a very small fall of rock was heard during a visit at 2:30 p. m. May 20-21 it was noticed that the wall gulches above the north and northwest taluses are deepening toward each other, as though a slab of that wall might some day fall. Some stones now lie on the east side of the 1929 floor.

About 6 p. m. May 15 a smoky film of cloud was observed above the normal rain cloud that lay over Mauna Loa. At 8 p. m. May 17 Honomalino Ranch reported Mauna Loa to be smoky. The Puu o Keokeo district, about the 8,000-foot level of the southwest rift of Mauna Loa, was examined by ranchmen, and nothing new could be found on the mountain. The sulphur patch of 1926 was fuming slightly. Mauna Loa was absolutely clear in brilliant sunlight this morning, May 22.

Only three local earthquakes, all very feeble, have been registered, but two of these indicated a distance of origin appropriate to the south end of Mauna Loa; namely, 9 a. m. May 19, distance 34 miles, and 1:45 a. m. May 20, distance 28 miles. It may be added that two small earthquakes registered last week were: 6:16 a. m. May 14, felt at Honomalino, distance from Observatory 38 miles; and 12:05 a. m. May 15, distance 31 miles.

Tilt for the week was strong WSW., and microseismic motion was slight.

ACTIVITY OF KRAKATOA IN 1928-29

Krakatoa, in Sunda Strait between Java and Sumatra, was in new activity between December and April, 1927-28, as previously reported (Volcano Letter Nos. 167, March 8, and 196, September 27, 1928). The outbreak of 1928 was in the ocean between the three islands that had been left by the gigantic eruption of 1883, and a cone was built up on the sea bottom which was piled above sea level occasionally in 1928, and then washed by the waves. The third phase of activity was in April.

This third phase was characterized by a series of little eruptions lasting until May 15. From 6 a. m. May 14 till 8 a. m. May 15 a total of 7164 jets occurred, and 14 of these reached a height of 100-400 meters. Dr. Stehn reports that on May 1 after 7 p. m. strong glare was seen above the crater in the ocean accompanied by steam, which he attributed to the flowing of lava over the rim of the submarine crater. Flames were also seen above the vent of orange-yellow color, making the surface of the sea look as if it were ablaze. The flames rose about 10 meters and were suspected as being due to hydrogen.

The fourth phase of activity lasted from May 18 to May 27. An ash eruption rose 500 meters. Each period of activity was preceded by volcanic tremors registered on the island seismograph. The directions of motion of the seismic components suggested an inclined vent underground and some slow displacement of the position of maximum action.

June 1 and 2 there were slight eruptions. The submerged crater rim lay from 5 to 10 meters below sea level. The fifth phase of activity began July 6 and ended July 13, with small eruptions reaching a maximum height of 250 meters. Soundings indicated a lowering of the submerged cone. Explosions and tremors were renewed at the end of August and early in September. In October Krakatoa was quiet except for bubblings of gas and tremors recorded by the seismograph. Many audible explosion noises were heard in November, and seismic activity was renewed. The noises are described as peals, reports, and rumblings. The shaking was strong enough to cause noteworthy avalanches from the summit of Rakata Peak. Small eruptions occurred in December, one on the 20th throwing up ashes and bombs 80 meters with glow and rumblings.

Except for tremors, Krakatoa was quiet at the beginning of January, 1929. The seventh phase of activity began on January 12 with steaming above the eruption point and bombs of old pumice material floating about as long as they remained hot and charged with gas. Activity slightly increased, reaching a maximum January 20-21, when 8817 separate jets were counted within 24 hours, the maximum height being 1100 meters. On that day the crater rim was built up above the sea as a loose pile of bombs and blocks. Only a strong surf marked the spot the next day. Then the activity decreased somewhat, but after January 25 the eruptions increased and created a new island called "Anak Krakatau," meaning child of Krakatoa. Enormous masses of solid material were thrown out from two or three crater openings, eruption columns reached 1,200 meters in height with a width of 500 meters, and the photographs presented show a crescent-shaped island with magnificent explosive jets of dark material radiating upward surrounded by a wreath of white steam at sea level.

The greatest number of separate jets was counted February 3-4, amounting to 11,791 spurts within a period of 24 hours. On Febraury 9 the new island was 21 meters high, and on Febuary 18, 38 meters. Electric discharges were sometimes observed in the eruption columns. The building up of the island wall around the crater cut off the view of minor eruptions from the station on Lang Island, as did the dust cloud when the wind was unfavorable. Pauses in activity increased from February 4 to Febraury 18, when the seventh phase of explosion ended. The island was examined from an airplane, the horns of the crescent pointed WSW., and the length was about 250 meters. (Bulletin Netherlands East Indian Volcanologic Survey No. 17, March, 1929, and preceding numbers.)

T.A.J.

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No. 231 RELEASED WITHOUT COPYRIGHT RESTRICTION May 30, 1929

KILAUEA REPORT No. 905

WEEK ENDING MAY 29, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Halemaumau has remained quiet during the past week, and nothing more has been heard from Mauna Loa. The afternoon of May 24 showed a few rocks on the new floor at the southeast and some appearance of fresh debris of large size at the top of the north talus, with appropriate fresh red scars in the wall above. A small slide at 12:05 p. m. May 27 and another at 1:35 p. m. sent up dust at the north corner of the pit.

Seven very feeble local earthquakes were registered for the week, of which one at 4:07 a. m. May 28 was felt in Hilo and Papaikou, the seismogram at Kilauea indicating distance of origin 21 miles. A big distant earthquake beginning 12 h. 17 m. 34 s. p. m. Hawaiian Time May 26 gave evidence of origin about 6,800 kilometers from east Hawaii, or something over 4,200 English miles. As Honolulu recorded 6,500 kilometers, the possible location might have been anywhere in the belt extending north and south through Japan Otherwise the distance would correspond to the ocean north of New Zealand or to Central America.

Tilt was moderate WNW., and microseismic motion slight for the week.

TEMPERATURES OF CRYSTALLIZING MINERALS

The older text books possessed little information about the temperatures of mineral formation, and so the loose generalizations of the 19th century imagined that basaltic lavas were cooler than deep-seated magma like granite. which was conceived to crystallize under enormous temperatures and pressures. The facts almost completely reverse this, and extensive laboratory work has thrown light on the temperature meaning of the mineral crystals found in the rocks. Besides the direct measurements of temperature of lava at craters, we now have many measurements of the melting temperatures of minerals, the inversion temperatures of minerals which change from one crystalline form to another, like quartz to tridymite, and to cristobalite, the melting temperatures of mineral mixtures, the temperature at which a mineral decomposes, and the effect on fusion or on chemical reaction of increased pressure in depth and of included gaseous mineralizers. (The Temperatures of Magmas, by E. S. Larsen, The American Mineralogist, Vol. XIV, pp. 81-94, 1929.)

Rocks crystallize from a liquid condition, or melt from a solid condition over a temperature interval which is greatly affected by the pressures involved and by the presence of steam or other gaseous ingredients which exist in the deep magma underground when the paste is congealing, but do not exist in the powdered rock of the open crucible heated in a furnace. Basalt melts through a temperature interval from 980° to 1,260° C., and granite 1,215° to 1,260°. Obsidian or rhyolite, the lava equivalent of granite, with much water in its composition melts easily until it loses its water, but thereafter it can be made liquid only at a much higher temperature. The two forms of quartz, the commonest mineral of granite, are stable up to 870°, above that to 1,470° silica becomes tridymite, and above that to 1,720° it becomes crystobalite. Quenched at any higher temperature silica takes the form of glass.

The apparent discrepancy between the higher melting range of the granitic magma as compared with basalt, and the much lower crystallizing range of temperatures which are evidenced by its minerals, can be explained as due to the gases in solution which are in the granitic magma, but are not in the rock when it is melted in a crucible. The slow cooling of a magma intermediate between rhyolite and basalt shows first the crystallization of lime-feldspar and dark minerals. leaving the remaining liquid richer in the material for quartz and orthoclase feldspar. There is finally left a liquid with a composition near that of pegmatitic granite. The original magma with the composition of basalt required a higher temperature to keep it liquid, and the granitic material was liquid at a lower temperature. The conclusion is that rhyolite or granite crystallize at the lowest temperature of the group. The magma in the throat of a volcano may be excessively hot owing to gas reactions and surface oxidation. When a mineral crystallizes from a solution, the temperature must be below the melting point of the mineral. But that does not tell how much below, as most of the rock minerals are in a condition of what is called "solid solution" and the crystallizing temperature differs with the composition. Most basaltic magmas remain almost completely liquid at a temperature below 870°.

The following is a summary of conclusions: (1) Rhyolitic magmas have lower temperatures than basaltic magmas. (2) Measurements of the basalt of Kilauea vary from 750° to over 1,200°, those at Vesuvius vary nearly as much. (3) The melting temperatures of minerals yield only maximum temperatures. Some biotite mica must form below 850°. (4) The inversion temperatures of silica show that some basalts and most rhyolites and quartz latites are nearly completely liquid at temperatures below 870° and probably all magmas crystallize above 570°. (5) Common hornblende inverts to basaltic hornblende at a rising temperature of 753°. Hence most hornblende rhyolites and quartz latites and many andesites containing common hornblende, crystallize below that temperature. (6) Since the inversion of quartz inclusions to tridymite or cristobalite is very rare, and this inversion takes place without a flux at an appreciable rate at 1,250°, very few magmas have so high a temperature. (7) The lack of fusion of most granitic and arkose inclusions indicates a temperature below 1,150° but mineralizers would permit fusion at much lower temperatures. (8) The results show that some basalts have temperatures below 870°, many are below 1,000°, very few are as high as 1,260°, and most are not far from 800° to 900°. (9) Rhyolite or granite magma has lower temperatures. in the range between 573° and 870°. Most of these rocks crystallize below 850°, the temperature of decomposition of biotite, and below 750°, the changing point of common hornblende, for they contain both these minerals. Hence most rhyolites or granites had temperatures between 600° and 700°.

T.A.J.

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No. 232 RELEASED WITHOUT COPYRIGHT RESTRICTION June 6, 1929

KILAUEA REPORT No. 906

WEEK ENDING JUNE 5, 1929
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Examination of Halemaumau pit at 5:50 p. m. May 30 showed that the whole northwest talus was covered with new gray debris, this overlapped the lava floor of 1929, and the wall showed fresh breaks above this talus clear to the top. Sliding at the north corner had been observed the previous day. On June 3 at 8:45 a. m. a large dun colored dust cloud from an avalanche was seen to rise over the northwestern half of the pit.

Eight very feeble earthquakes were registered for the week, one of these coincident with the above mentioned avalanche cloud. Tilt was moderate NNE., and microseismic motion was slight.

OCEAN SALTS FROM VOLCANOES

Visitors to the sulphur bank near the hotel at Kilauea have been impressed with the heavy layers and beautiful crystals of sulphur, with steam at 96° C. puffing up and smelling of sulphur dioxide. In the summer 1922 Dr. E. T. Allen determined that the vapor from the bore-holes has the following composition by volume:

Steam	96.2
Fixed gases (nitrogen etc.)	3.7
Sulphur dioxide	.096
Sulphur vapor	.004
Hydrochloric acid	trace
	100.00 percent

In one or two years the big iron pipes that encase the bore-holes become lined with an inch or so of compacted crystals of pure sulphur over a thin layer of sulphide of iron, a black coating that is next to the metal. All of this, and the heavy banks of sulphur that cover the old ash deposits, are laid down from .004 per cent sulphur vapor in the steam. (Bull. Haw'n Volc. Obsy. Vol. X, No. 8.)

Dr. E. G. Zies determined at the Valley of Ten Thousand Smokes near Katmai, Alaska, that the fumaroles gave off 26 million liters of steam per second containing about 0.2 per cent of hydrochloric acid, hydrofluoric acid, and hydrogen sulphide. Figuring the volumes given off per year and reducing to weights, this amounts to 1,250,000 tons annually of hydrochloric acid gas, 200,000 tons of hydrofluoric acid gas, and 300,000 tons of hydrogen sulphide gas.

The temperatures of these gases in 1919, seven years after the eruption, exceeded 500° C., the incrustations lining the cracks showed how powerful had been the solvent action of the gases, indicating the power of such an agency to concentrate valuable ore deposits.. At the Kilauea sulphur banks there is abundant pyrite, a product of the action of the fumarole gases on the lava.

The power and rapidity of this deposition, despite the tiny percentage of the ingredients in the steam, only appears when we consider the agregate quantity of even the least significant of the acid gases when continually discharged into the atmosphere at these rates. The average river contains insufficient chlorine to convert its sodium into salt; the ocean contains much more chlorine than sodium. One hundred million tons of hydrochloric acid is the annual requirement to account for the saltiness of the sea. In about 40 inches of world-wide rainfall this would amount to one-fifth of a millionth part of chlorine. Yet in ordinary chemical determinations one part in a million is considered insignificant. Hence we see what a large part can be played by volcanic steam which never ceases.

Of this 100 million tons of hydrochloric acid gas the Katmai area alone of the 450 active volcanoes of the world was contributing more than one per cent in 1919, and Kilauea, with its bare trace of chlorine, contributed about 30,000 tons. Many volcanic districts discharge acid gases. It appears that volcanoes, of which also there are many on the sea bottom mostly unknown, are quite competent to supply to the ocean the excess of chlorine needed for its salt.

The fluorine content of seawater is only one-twenty-fourth that of chlorine. The fluorine becomes locked up in the incrustations, and when it gets into the sea is absorbed into the bones and shells of marine animals, all of the phosphate beds of the vast ancient oceans showing a fluorine content of from 1.0 to 1.5 per cent. This element forms an insoluble compound with calcium, in contrast to chlorine which with sodium forms the highly soluble common salt. This disparity between the amounts of fluorine and chlorine in sea water, and the relatively large amounts of fluorine given off by volcanoes, disposes at once of the argument that volcanoes get their chlorine from the sea. Everything indicates that both these halogen gases are derived from the lava itself. (Annual Report Director Geophysical Laboratory, Year Book No. 27, 1928 Carnegie Institution, page 81.)

Sea water contains calcium carbonate as well as other salts. This is secreted from the water in the body of globigerina, a tiny organism ceaselessly dying and depositing billions of skeletons that make chalk on the ocean bottom. Locally the ocean floor is built up a foot per annum. Ten thousand years would shoal the ocean, but there have been millions of years, and the ocean is still deep.

The accumulation of heavy chalk or globigerina ooze is partly kept low by isostasy, the crust sinking and the continents rising. But this could not take care of millions of years of globigerina hailtsones. And what furnishes the lime to the salt water? Shifting shorelines and erosion of limestones on the land has furnished new lime to the rivers and the sea. But has the amount of rising limestone equalled the vast seabottom, which covers seventenths of the surface of the earth?

But though globigerina is everywhere in the upper waters, two-thirds of the seabottom has no chalk. What could account for chalk banks being absent? The chalky bottoms are where the ocean is not so deep. It was found that where the ocean is more than two and a half miles deep, where the pressure approaches three tons per square inch, sea water can readily dissolve the chalk skeletons. And so, with the circulation of the oceans the lime salts are brought back and secreted over again by the live organisms. (Liverpool Echo, January 26, 1929, citing J. Stanley Gardiner, professor of zoology, Cambridge.) T.A.J.

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No. 233 **RELEASED WITHOUT COPYRIGHT RESTRICTION** June 13, 1929

KILAUEA REPORT No. 907

WEEK ENDING JUNE 12, 1929
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Halemaumau remains practically unchanged, with occasional slides from the walls. Debris from recent slides was noticed on the northwest talus June 5, at 2 p. m., with larger bowlders on the lava floor. A small slide was observed on the south wall at 9:30 a. m. June 8. The pit otherwise was very quiet. On June 9 nothing new was seen. There was a small rockfall north about 10 a. m. today. Very thin dust from a slide rose north at 2:15 p. m.

Twice as many earthquakes were recorded this week as for the preceding week; namely, 16 of very feeble intensity. The accumulation of tilt was slight to the northwest Microseismic motion was normal.

WEATHERING OF HAWAIIAN LAVA

Many people who visit Hawaii ask the question "How long does it take for these fresh lava flows to make soil?" The first of a series of papers on the chemistry of decomposition of basaltic lavas in Hawaii (The Composition of Lavas and Soils from Kauai, by N. E. A. Hinds, Am. Jour. Sci. April, 1929) has been published by Professor Hinds, including reviews of many analyses made by Kelley, McGeorge, and Thompson, Bulletin 40, Hawaii Agricultural Experiment Station.

On all the islands there are astonishing differences of rainfall and of climate, wet on the side of the trade winds, dry on the opposite side. On the dry sides lava remains unaltered, on the wet sides it breaks down rapidly.

The predominant lavas of Kauai, the western of the larger islands, are olivine basalts, composing 85 per cent of the dome visible above sealevel; next come augite andesites and olivine augite andesites, while subordinate in amount are the basic lavas largely augite and olivine and some rare nephelite and melilite basalts.

Olivine is very conspicuous in most of the rocks as large and numerous visible crystals. Hinds found these in approximately 92 per cent of 400 specimens. Most of the lava is of the blocky or aa type, the ratio of aa to pahoehoe (smooth lava) being about 3 to 1. The chemical composition of the Kauai lavas when fresh, (and the smaller island Niihau to the west is very similar,) is as follows: Silica 40-49 per cent, alumina 8-14, iron 11-14, magnesia 7-16 lime 9-12, alkalies 2-5, water 0.30-1.00, and titanium oxide 2-3.

Rainfall on windward Kauai varies from 50 to 100 inches along the eastern and northern coasts, and from 10 to 30 inches on the western coast which is 12 to 15 miles from the summit of the single volcano dome that makes up the island. This summit, slightly over 5,000 feet in height, is possibly the rainiest locality in the world, where for a seven-year period the extraordinary average of 473 inches per annum of precipitation was measured. The main average temperature yearly for elevations varying from 14 to 300 feet ranges from 68° to 79° F.

Most of the weathering is chemical. There is a little frost on the uplands, and the detritus is moved by streams, landslides, and ocean waves, but the mineralogical and chemical changes in the soil vary mostly with the climate of different sections of the island. There are no analyses as yet from the swampy region of the summit plateau. The soils and subsoils are in the main from decomposition in place of lavas and agglomerates, the latter from local vents where this material has been dumped about subsidiary cones on the weathered lavas. There are some alluvial soils at the mouths of rivers, and some coral detritus near the shores.

Throughout the Hawaiian islands rock alteration varies with the climate and the age of the domes. Younger domes are Haleakala, Mauna Kea, Hualalai, Mauna Loa, and Kilauea; older ones are Kauai, east and west Oahu, east and west Molokai, west Maui, Kohala, Niihau, Lanai, and Kahoolawe. The last three have dry climates and are less dissected and better preserved than the wet islands. The stage of topographic evolution therefore is not a measure of age.

Some weathered lavas and their disintegrated products from Oahu yield the following:

	Lava (Per Cent)	Disintegrated Product
Silica	52	20
Alumina	11	38
Iron	10	18
Lime	10	0.33
Magnesia	6	0 20
Alkalies	3	0.50
Titanium ox.	4	4.7
Water	1	17

On Kauai bright brick-red soil is found in the dry regions, brown and dark red soil in the wet, the powdered and clayey decomposition material passing downward into brown, yellow, gray, or green rotten rock in marked contrast to the soils and subsoils, for the latter retain none of the original texture. In the lower zone are great numbers of concentrically weathered bowlders (onion structure), having spherical or ellipsoidal masses of relatively fresh rock at the core. Going down farther we come to relatively unaltered rocks, the depth of the weathered zone depending on the amount of rainfall.

An average of eight soil analyses from Kauai gives percentage of insoluble residue, mostly silica 39, alumina 17 iron 14, magnesia 3, lime 0.89, alklalies 0.42, titanium oxide 2.3, water 12, averaged from a range of from 4 to 19.

The mechanical analyses of a typical soil gave in percentage volatile matter 19, fine gravel 0.02, coarse 1.57, fine sand 5.48, silt 6.449, fine silt 33.40, clay 33.50. The content of water in soils and subsoils is about the same, an average of 26 soils and subsoils together giving 8.6 per cent, of eight subsoils alone 8.14, and of 26 soils alone 9.16. T.A.J.

NOTE: Address of Secretary, Hawaiian Volcano Research Association, is 300 James Campbell Building, Honolulu, T. H.

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No. 234 RELEASED WITHOUT COPYRIGHT RESTRICTION June 20, 1929

KILAUEA REPORT No. 908

WEEK ENDING JUNE 19, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

On June 13 at noon the north wall of Halemaumau was dusty with fresh red and gray scars and new material on the northwestern talus appearing fresh. There was other new red debris northeast, from the middle of the wall above. On June 18 the felt earthquake at 8:42 a. m. produced some sliding in the pit, but much stronger sliding was occasioned by the earthquake of 9:31 a. m. when much dust rose above the pit. Examination showed a gouge down the middle of the west wall where large fragments of rim rock had fallen so that broken debris lay on the lava floor below. At 11:40 a. m. rocks were heard and seen falling at the north, west, and south walls of the pit. On the west wall of Kilauea Crater north of Uwekahuna a fresh avalanche scar was produced by the large shock, with new talus below. A party near the Halfway House in the Kau Desert noted the earthquake of 9:31 as a shock accompanied by a rumble, and sufficiently strong to cause the trees to wave back and forth. At the Observatory the dominant effect was a slow east-west swaying with creaking of the building. The high magnification seismographs were dismantled.

It is worthy of note that this seismic disturbance occurs close to solstice, and that the press reports an eruption of Komagatake in the north island of Japan, and a disastrous earthquake in the southern district of New Zealand.

The seismographs registered for the week two distant earthquakes, two moderate local shocks, several very feeble local shocks, and one tremor lasting two minutes. The first of the two strongly felt Hawaiian shocks, at 8:42 a. m. June 18, indicated distance of origin 11 miles, and the second one, much stronger, at 9:31 a. m., 44 miles. The tremor following this lasted 10 minutes. The first distant earthquake was weakly recorded about 11:06 p. m. June 12. The second was more pronounced, beginning 12h. 28m. 46s. p. m. June 16. The indication of distance is 8,100 kilometers, and possibly this was the New Zealand shock.

Microseismic motion was light throughout the week. Tilt accumulated, moderate to the WSW.

ENGULFMENT AT KRAKATOA 1883

An important review of the history of the Krakatoa group of islands, bringing up to date the geology and the eruptive history, has just been published by the Volcanological Survey of the Netherlands East Indies as a special report for the Fourth Pacific Science Congress, Java, 1929 (The Geology and Volcanism of the Krakatau Group, by Dr. Ch. E. Stehn). The following is a summary of the constructive and destructive periods in the building of what is now a group of three islands at the corners of a triangle, with a new eruption in progress building a new islet in the sea between them (Volcano Letter No. 230).

I. Formation of a hypothetical ancient single volcano about 2,000 m. high of which the last lava streams and ejecta were hypersthene andesite with tridymite, and a microlithic devitrefied glass. The period involved the destruction of this volcano, leaving four remnant islands, with a sea basin in the center.

II Formation of an eccentric basaltic volcano covering the southern Rakata remnant, 800 meters high.

III. Submarine activity of two andesitic volcanoes, Danan and Perboewatan. Formation northward of an island, Krakatau proper, which joins up with the basaltic volcanic cone of Rakata. The same magma penetrates into the Rakata cone through a dyke fissure. Fresh activity in May, 1680.

IV. May 20, 1883, commencement of a new eruption which continued with short pauses, and became the gigantic famous eruption.

August 26-28, 1883, the greatest activity. Considerable increase in size of Rakata, Verlaten Eiland, and Lang Eiland from ejecta of andesitic magma, obsidian, pumice, and older rocks. Terminating with destruction of the volcanoes Perboewatan and Danan and half the basaltic cone of Rakata Peak. Formation of a basin 279 m. deep between the three islands left.

V. Severe abrasion by ocean waves especially on the west coasts, and extension of the low northern portion of Verlaten Eiland by the building of a spit.

VI. Submarine activity beginning June, 1927, and becoming an eruption December 29, 1927. Submarine cone of basaltic bombs, ashes, and old material appeared above the surface of the sea January 25, 1928, and later washed away. Submarine lava streams. The submarine crater rim appeared again January 28, 1929, forming new basaltic island "Anak Krakatau."

From May to August, 1883, smaller eruptions left their products close to the active craters and threw out much pumice. The paroxysm came on August 26 and thereafter. On August 27 Perboewatan subsided and a severe explosion followed, directing its discharge eastward. In no case were collapses preceded by explosions.

Fresh subsidences took place associated with tidal waves which formed bluffs. About six hours after the first subsidence August 27 came the gigantic collapse, followed by an explosion which piled unsorted pumice to thicknesses of 100 meters, strewed ash over 827,000 square kilometers, ejected ash clouds over 70 kilometers high, and made noises heard in Australia.

More subsidences and fractures occurred involving the basaltic Rakata Peak, and a second explosion that followed within an hour of the big one was believed to destroy Danan Volcano as shown by the sequence of the present strata. This disrupted the remainder of the big island and part of the sea bed, left a submarine ridge between the two explosion centers, and deposited some shells and coral in the strata. More fractures followed and another engulfment of the northeastern part of Rakata and the south part of Lang Eiland, causing the last tidal wave.

Verbeek in 1885 prophesied "In any renewed activity of the volcano, islands will arise in the middle of the sea basin, just as formerly the craters Danan and Perboewatan formed in the sea within the old crater wall." This is just what is going on now.

In the light of what was observed showing engulfment the dominant process at Kilauea in 1924, Dr. Stehn's conclusion that collapse was the dominant process at Krakatoa in 1883 is of fundamental interest in volcanology.

T.A.J.

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No. 235 RELEASED WITHOUT COPYRIGHT RESTRICTION June 27, 1929

KILAUEA REPORT No. 909

WEEK ENDING JUNE 26, 1929
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The week at Halemaumau has produced very few changes. On June 20 all was quiet. One or two rocks fell south at 3:45 p. m. There was nothing new in the bottom or on the walls. On June 24 with a stiff NE. breeze, dust was disturbed on the northeast and south walls. Light rock falls were heard south and southwest. A dusty slide occurred northeast at 11:55 a. m. At 5 p. m. more dust was observed thinly spread over the pit. Today at 2:45 p. m. was seen the scar of slides from midway the north-northeast wall, and a pile of new gray debris at the foot. The ground back of the southeast rim shows very slight signs of caving at the cracks which opened in January, as though further movement had occurred there.

Earthquakes registered by the seismographs at the Observatory included seven very feeble local shocks, one two-minute tremor beginning 12:16 a. m. June 22, and one moderate earth shock also on June 22 at three minutes past noon. This earthquake, which was felt locally, had an indicated distance to origin of nine miles.

Tilt for the week accumulated moderately NNW. Microseismic motion was very slight.

NEW INVESTIGATIONS

Section of Volcanology.

Changes of personnel at the Hawaiian Volcano Observatory have recently occurred, and new investigations are now beginning. Mr. R. M. Wilson rejoined the Topographic Branch of the Survey in California in November, 1928, and Mr. Earl M. Buckingham was temporarily appointed in his place as topographic engineer at the Observatory. Mr. Buckingham made a new map of Halemaumau after changes in the walls had been made by the avalanches of January, 1929, and a new lava floor had been created by the eruption of February 20. He also continued investigations which had been started by Mr. Wilson dealing with mean sea level at Hilo, and with tilting of the ground at the Observatory as determined with level-bubble. Mr. Buckingham also joins the Topographic Branch of the Survey in California on July 1, 1929. Mr. Howard A. Powers, instructor in petrography at Harvard University, has been appointed Junior Geologist on the Survey as chief assistant at the Hawaiian Volcano Observatory, beginning July 1, 1929. Mr. Powers will specialize on the study of minerals in the rocks of the Hawaiian Islands along with mapping of the geologic formations on the basis of the excellent topographic maps of Hawaii made by the Topographic Branch in cooperation with the Territory under Captain A. O. Burkland. These atlas sheets are now finished and in process of engraving for the whole of this island, and some geologic work has already been started by the Survey. This will now be carried forward, and the specimen collections of the Observatory will be subjected to microscopic and chemical examination. For the first time the Observatory will enter on the field of investigation of the older lavas of the island and their relation to the past history of the volcanoes.

For continuation of the seismologic work started in the Aleutian belt of Alaska, Mr. Austin E. Jones left Seattle on the Coast Guard cutter June 8, 1929, for Kodiak and Dutch Harbor, and in both those places he will establish seismograph recording. A new observer will be found for the seismograph at Kodiak, the service of which was discontinued in August, 1928, and the Hawaiian type seismograph now stored at Dutch Harbor will be set up in a cellar constructed for the purpose and operated in connection with the Naval Radio Station at that place. Mr. Jones is now at work building the cellar.

Hawaiian Volcano Research Association.

Professor Chester K. Wentworth of Washington University, St Louis, has been appointed Research Fellow of the Association for the summer months of 1929, and is now at work investigating the volcanic tuffs soils, wind-blown deposits, and other related loose materials on the island of Hawaii. His special topic is the origin of the yellow tuff so well known in the Kau district from Pahala to South Point. These tuffs are important in that district as marking a dividing line between older and newer series of lavas. Mr. Wentworth will subject the specimens to microscopic investigation and also make comparisons in the field of the relationships of these deposits to the surrounding rocks in the different districts of Hawaii where they are found. It is hoped in this way to determine the meaning of an important dividing line in the volcanic stratigraphy of Hawaii.

Dr John B Stone now with the Cerro de Pazco Copper Corporation in Oroya, Peru, has been appointed Research Fellow of the Association to make an exploration and report in Chile during the winter months of 1929-30. The investigation has in view a study of the volcanoes on the west side of the central valley of Chile with especial reference to the beautiful cone of Osorno and the recently active volcano Calbuco on Lake Llanquihue. Dr. Stone will make a volcanological reconnaissance of the region with the special object of securing photographs and specimens and of bringing the Hawaiian Volcano Observatory in closer touch with the volcanologic work of Chile. This country is little known, but is important because of its many earthquakes and numerous volcanic vents.

Dr. Stone and Professor Wentworth have both done geological work in Hawaii in the past. Dr. Stone investigated the products and structure of Kilauea during the summer and autumn of 1925 under a Bishop Museum fellowship awarded by Yale University (Bulletin 33, Bernice P. Bishop Museum, 1926.) Mr. Wentworth was Bishop Museum Fellow 1923-24 investigating the sediments of the Pacific islands and published studies of the geology of Lanai and the pyroclastic geology of Oahu (Bulletins 24 and 30, Bernice P. Bishop Museum, 1925 and 1926.) T.A.J.

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No. 236 RELEASED WITHOUT COPYRIGHT RESTRICTION July 4, 1929

KILAUEA REPORT No. 910

WEEK ENDING JULY 3, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The Kilauea lava pit has remained quiet throughout the past week. At 9 a. m. June 29 a compact cloud of dust from an avalanche rose near the northeast rim. Because of its whiteness, the dust at first had the appearance of a cloud of steam. At 10 a. m. July 1 Halemaumau was so densely obscured in rain and fog that observations were impossible. All was quiet and no sounds were heard. A light dust cloud from a small slide was seen at 2:30 p. m. from near the Halemaumau seismograph station on the Kilauea floor.

Eight very feeble local earthquakes were registered on the Bosch-Omori seismographs at the Observatory. One of these, registered at 5:14 a. m. June 28, had an indicated distance to origin of 17.3 miles. In addition is the feeble record of a distant shock, beginning at 2:36:52 a. m. June 27.

Microseismic motion continued to be very slight, although a little stronger near the close of the week. Tilt accumulated slight to the WSW.

LASSEN REPORT No. 18

Lassen Volcano Observatory, Mineral, Calif.,

R. H. Finch in Charge

HOT SPRINGS OF THE COAST RANGES

The following table shows the result of hot springs measurements together with the Waring (G. A. Waring, Water-supply Paper 338, U. S. Geological Survey) data for comparison. (See Volcano Letter Nos. 120, 135, 136.)

Location	Temperature	1927	Waring Data
Calistoga:			
Throat of Plummer's Geyser	218(F.)	Mar. 22	
Pool at Plummer's Geyser	143		Highest of
Pacheteaus, side of capped geyser	213.5		natural vents, 173
Well back of Calistoga Hotel	143		
Harbin Hot Springs:			
Entrance of bricked-in pool	119	Mar. 26	122
Anderson Hot Spring: (Practically abandoned as a resort.) Highest temperature found in a board-covered spring on east side of hot spring canyon	116	Mar. 26	146
Castle Springs:			
In storage tank a little way from intake	152	Mar. 26	164
Seigler Springs:			
Magnesia	61	Mar. 27	72
Arsenic	96		90
Hot Iron	106		100
Sulphur	106		
Near Sulphur	118		119
do	125		126
Howard Springs:			
Borax	91	Mar. 26	95
Iron sulphur	110		110
Magnesia	108		102
Iron soda	88		
Excelsior lithia	72		
Sulphur Bask:			
Pool in old shaft near road	106	Mar. 27	120
Highland Springs: (Appeared to be abandoned.)			
Magic Bath	78	Mar. 28	
Diana Spring	78		80
Skagg Springs:			
Upper	132	Mar. 28	120
Middle	120		122
Lower	128		135

The average rainfall for the area in which the above springs are located is 48 inches, though the amount varies greatly from year to year.

The most recent volcanic activity in this section of the Coast Ranges took place at the Sulphur Banks, to the east of Mt. Konocti. Becker thought it might have occurred within the last 1,000 years, and mentioned Indian tradition of activity at Sulphur Bank. Judging from erosion, Mt. Konocti may have had its last activity much more than 1,000 years ago. The remnant of a crater is still discernible, however, on the south peak of Mt. Konocti. In the hills to the east of the Sulphur Bank there is a fairly well preserved crater. As one goes south from Clear Lake there appears to be a progressive increase in the ages of the last lava flow that capped a good deal of the country. There is, however, a well preserved crater above the Petrified Forest to the west of Calistoga. Considerable volcanic ash is found in its vicinity that has been faulted since its deposition.

The rock mass of the Coast Ranges in this vicinity has been greatly faulted, folded, and crushed, with the main faults trending northwest-southeast, the direction of the main valleys. Folds in the rock appear to be better preserved in the region to the southwest of Clear Lake than farther south.

From the summit of St. Helena, Napa Valley might once have extended much farther north, and drainage from the north was interrupted by lava flows from a small cone to the southwest of Mt. St. Helena. There appears to have been another interruption a little farther north caused by lava flows or upheaval. Above the Palisade Mine there is well preserved evidence of a fissure eruption. Judging from the numerous faults and the recentness of the last activity, it is surprising that this section of the Coast Range has so few earthquakes.

R.H.F.

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No. 237 RELEASED WITHOUT COPYRIGHT RESTRICTION July 11, 1929

KILAUEA REPORT No. 911

WEEK ENDING JULY 10, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

No noteworthy changes have taken place at Halemaumau. On Sunday, July 7, avalanches occurred, one about 12:30 p. m. filling the entire interior of the pit with dust. There were other slides later in the afternoon.

Observations on July 8 showed that the top fourth of the north talus was covered with fresh material. The north wall appeared to be the only site of avalanching.

On July 10 thick steam was rising out of the fire pit during the forenoon after several hours of good rain. Prior to this there had been a long dry period at Kilauea. At 3 p. m. it was noted that there were many very active steam jets in the Halemaumau bottom, making an interesting sight as they projected straight upward. A southerly rainstorm was in progress.

During the week there were registered on the seismographs 28 very feeble local shocks, one feeble earthquake at 11:04 p. m. July 9 with an indicated distance to origin of 23 miles, and three teleseisms. This is the greatest number of earthquakes registered in one week since the week ending November 28, 1928, when 30 very feeble local shocks were recorded.

Two of the teleseisms occurred on July 5, one at 3:57 a. m. and the other just after 4:08 p. m. They were not well enough recorded to distinguish phases. The third teleseism began at 11:01:06 a. m. July 7. A preliminary determination of distance to epicenter is 7,480 kilometers from Kilauea.

Tilt for the week was moderately south-southwest. Microseismic motion was very slight.

LASSEN REPORT No. 19

Lassen Volcano Observatory, Mineral, California,

R. H. Finch in Charge

Lava Flows

There are several post-glacial lava flows in the vicinity of Lassen Peak in addition to the three at Cinder Cone and the small one that started through the western gap of Lassen Crater in 1915. There is a series of flows along a north-south line extending south from Tamarack Peak.

Another fresh-looking flow had its origin between the two Prospect peaks. Another flow originates near the northeastern corner of the park east of Cinder Cone. The above flows were not very fluid and consist of broken blocks. A typical basalt flow that was quite fluid extends for miles in Hat Creek valley just below the Hat Creek fault scarp. It contains a great many lava tubes. About 15 miles to the east-southeast of Mineral there is a flow that contains both aa and pahoehoe and formed lava tubes.

Lassen Peak

An ascent of Lassen Peak was made on August 5-6, 1927, supplies being carried on a pack animal. Camp was made inside the main crater about 30 feet below the western rim, above and to the west of the lake in the crater. Rock falls from different walls were frequent. By 7 p. m. ice was forming over the lake, though at the camp, about 50 feet above the lake, the lowest temperature during the night was 46° F., and on the crater rim the temperature was still higher. Steam cracks afforded an easy method of heating food. Lassen Peak may be thought of as being composed of three lobes.

When the doming pressure incident to the 1914-15 activity became sufficiently great, the north lobe cracked away slightly from the other two and opened an east-west crack that probably was very superficial. From the gaps that already existed in the crater wall, it seems that the cracking was along an old break. A massive layer with scars shows that material broke off from it both into the crater and down the outer slope. The layer was in the same plastic condition when it was deposited as was the incipient flow that went through the eastern and western gaps. The flow through the eastern gap was blown or slid on down the mountain side while that through the western gap is still in place.

The flows had probably just started when the explosion blew away the source material. Mud deposits in the Lost Creek Valley indicate that there have been one or more explosions and mud flows from Lassen within the last 500 years. The 500-year limit was obtained from the conditions of preservation of tree trunks buried in the mud flow and recently unearthed by stream erosion.

Dacite pumice in the ash material of the 1915 eruption was scattered over a wedge-shaped area extending from Bumpass Hell nearly to Chaos Crags and from the Peak itself for 12 miles to Butte Lake on the northeast. Just to the north of Hat Mountain, near the center of the area, the ground appears to have been covered with the pumice. Great quantities of this pumice are to be found on the summit of East Prospect Peak, the rock of which is basalt.

Glass Mountain

Following several newspaper accounts of Forest Service officials discovering activity at Glass Mountain, which lies about 70 miles north of Lassen, and after telephone conversation with a Forest Service supervisor familiar with that country, it seemed advisable to investigate the acitivity. Accompanied by G. L. Collins of the National Park Service, an attempt was made to photograph and take temperature measurements at the scene of activity, but we were forced to go back on account of heavy snow. Contact was made with G. L. Courtright, of Dry Lake, about 12 miles east-northeast of Glass Mountain, and from him was obtained an account of an explosion on Glass Mountain in 1910. (Volcano Letter No. 144, 1928.) From other people was obtained an account of a small lake that had formerly existed on the mountain. Mr Courtright said that he is now unable to find this lake. An explosion under the lake could account for the mud reported on vegetation after the explosion, as well as for the disappearance of the lake. R.H.F.

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No. 238 RELEASED WITHOUT COPYRIGHT RESTRICTION July 18, 1929

KILAUEA REPORT No. 912

WEEK ENDING JULY 17, 1929

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

There appear to have been no volcanic changes at Halemaumau throughout the past week. No slides have been noticed, nor are there signs indicating that stripping of the walls has occurred.

On July 13 a semicircle of moisture was noted at the top of the big west talus. This was like an arch just under the uppermost point of the talus which as a whole is shaped like an inverted V. The effect is as though a crescent-shaped crack marks a deep break in the talus cone. The crack emits some vapor, and there are steaming spots in the middle of the talus below. The south talus shows a linear up-and-down fissure steaming at its top.

A slight increase of steam at the center of the west talus was observed at 3 p. m. July 17.

A total of 18 local earthquakes was registered by the instruments at the Observatory during the week. Two of these were felt locally, one on July 10 at 1:27 p. m. and the other July 15 at 10:02 a. m. The felt shock of July 10 had an indicated distance to origin of 10 miles; that of July 15 had no distinguishable phases on account of being immediately preceded by the waning tremor of a very feeble earthquake. There was continuous tremor July 17 from 5:14 to 5:16 a. m.

Tilt accumulated moderately strong SSE. Microseismic motion was extremely slight.

LASSEN REPORT No. 20

Lassen Volcano Observatory, Mineral, California
R. H. Finch, In Charge

The following measurements refer to landslipping in progress at Supan's steam holes, Lassen National Park, and to temperatures at various hot springs. (Compare Day and Allen, 1925, Volcanic Activity of Lassen Peak, Carnegie Institution.)

The line of stakes across new cracks that was placed 50 feet apart in November, 1927, parallel with the valley containing the sulphur works was retaped on July 27, 1928. The following table shows that there was downhill slipping in the upper part of the 1,00-foot line that was practically compensated by over-riding lower down.

	Stake Intervals	New Measurement	Change
	0— 1	50.1 feet	+0.1
	0— 2	100.1 "	+0.1
	2— 3	51.4 "	+1.4
	3— 4	51.3 "	+1.3
	4— 5	50.0 "	0.0
	5— 6	49.4 "	—0.6
	6— 7	49.6 "	—0.4
	7— 8	49.8 "	—0.2
	8— 9	49.8 "	—0.2
	9—11	99.5 "	—0.5
(Note: †10 moved)	10—11	49.9 "	—0.1
	11—12	50.2 "	+0.2
	12—13	49.6 "	—0.4
	13—14	49.9 "	—0.1
	14—15	49.9 "	—0.1
	15—16	49.8 "	—0.2
	16—17	49.9 "	—0.1
	17—18	50.0 "	0.0
	18—19	50.0 "	0.0
	19—20	†20 moved	

The line was extended 300 feet and three lines run across the valley by transit: one at the upper end of the stake-line, one near the middle, and one at the lower end.

Temperatures of Hot Springs

Supan's.

The highest temperature found at the "Big Steamer" at Supan's solfatara on July 28, 1928 was 240°. The same vent on September 5, the driest part of the season, was but 235°. As the temperature of such hot springs varies inversely as the amount of water discharged, the slight cooling of the spring was contrary to what was expected.

Morgan Hot Springs, August 7, 1928.

No.		Fahr.	No.		Fahr.
1		177	12	muddy water	188
3	middle pool	185		mud	172
	lower "	196		clear water	195
	north "	190	14		178
4	middle "	168	17		201
	south "	176	19		144
5		172	20		200
6		176	Between 12 and 14 in black earth		160
7		196	23		192
8		156	24		198
9		106	Geyser		200

Live, wiggling larvae in mud algae at No. 3 with temperature of 120°. When temperature was 140° the larvae was dead.

Boiling Lake, August 11, 1928.

Water north end of lake	130 Fahr.
Mudpot north end of lake	198
Milky pool southwest edge of lake	192
Site of Cornpopper, south end of pool	204

(The ground at this site sank several feet since the fall of 1927.)

Devil's Kitchen.

Bluish-gray pool of water near northwest end	171 Fahr.
Deep pool just above one with stream flowing through it near upper end of "kitchen"	195
Splashing pool upper north side	169
Yellow pool northwest end	189
Pool in rock southwest edge	198
Small splashing vent southwest	199
Large splashing pool southwest	199

Bumpass Hell, September 5, 1928.

No. 8		194 Fahr.
9	mud pot	194
10	pool	174
11	steam vent	192
13	" "	194
14	east side	190
16		194
17		195
Several small vents depositing sulphur crystals		195

The highest temperature observed at Bumpass Hell in 1928 was considerably lower than the highest for 1927.

R.H.F.

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No. 239 **RELEASED WITHOUT COPYRIGHT RESTRICTION** July 25, 1929

KILAUEA REPORT No. 913

WEEK ENDING JULY 25, 1929

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

A quiet flow of lava broke out in the bottom of Halemaumau about 6 a. m. today. The flow at first was from two fountains loudly splashing just above the lower edge of the big west talus. About 8 a. m., before the new lava had covered the floor formed last February, a crack opened athwart its center with much gasrushings, releasing a line of fountains in direction approximately northeast-southwest. The fountains are about 200 feet high.

The eruption is one of a series of minor, short-lived flows characteristic of this period of cyclical events at Kilauea. It can not be stated how long the flow will continue, though at the present time it is strong.

The last activity in Halemaumau occurred on February 20 and 21, 1929. It filled the bowl-shaped bottom of the pit with lava to a depth of about 60 feet, forming a floor a little less than 1,200 feet below the rim. Few changes occurred at the volcano since that time. No great avalanches took place that might denote a great subsidence of the lava column, and it was therefore thought that magma lay not far below the surface of the volcano edifice, and another eruption during 1929 was accordingly considered possible.

The usual harmonic tremor indicative of flowing lava is registering on the seismographs at the Observatory. This began to be somewhat steady at 6:46 a. m. Beginning at 8 p. m. July 24 there were spells of tremor fairly regularly every 16 seconds and lasting nearly an hour.

The earthquakes for the week ending July 24 at 8 p. m. total 19. These were all of very feeble intensity and not large enough to be felt. At numerous times throughout July 21 the seismographs registered short spells of microscopic tremor. The seismograph on the crater floor near Halemaumau did not record this tremor, however.

Tilt accumulated moderately NNE. Microseismic motion remains very slight.

VESUVIUS IN JUNE 1929

The following is quoted from Nature, June 15, 1929, showing that Vesuvius has recovered from its 1906 engulfment to the stage where it makes external lava flows:

"After the great paroxysmal eruption of Vesuvius in 1906 there followed seven years of obstruction and comparative repose. In 1913 the conduit became open and the normal type of external activity began. Since then the crater has been steadily filling from a succession of central conelets, and at intervals in recent years there have been minor crescendos of explosive and effusive activity. By far the greatest and most spectacular of these broke out in the early hours of June 3. The outburst began with tremendous explosions and the hurling into the air of masses of incandescent material. The central conelet split and collapsed. As it fell back into the crater lava welled out and occupied the northeastern quadrant of the crater. (This was the lowest lip left in 1906. T.A.J.) Professor Malladra announced on June 3 that he considered the eruption to be one of the periodic recrudescences of activity; that it was unlikely to last more than two or three days; and that a disastrous eruption of the culminating type—such as those of 1872 and 1906—was not yet to be expected.

"On the morning of June 4 it became clear that for a minor eruption the manifestations were more than usually violent. The interior of the crater now became a lake of effervescing lava some 500 yards in diameter. The lava overflowed into the Valle dell Inferno and escaped down the outer slopes into the valley of Cuppaccio and towards the little town of Terzigno, following the course of the 1834 lava stream. After a short interval of quiescence from 2:30 to 7:30 p. m. there was a sudden paroxysm of activity for three-quarters of an hour. Incandescent matter rose 1,500 feet above the crater and fell in glowing showers on the slopes of the volcano. Afterwards there were loud and frequent explosions, followed by an ash cloud that rose to still greater heights. From 11 p. m. on June 5 to 3 a. m. on June 6 there were further tremors and explosions, and columns of lava were thrown into the air to break into incandescent bombs. Since then there have been (at the moment of writing) no further reports of activity. The lava stream has extended five miles down the southeastern slopes, widening to a frontage of 900 yards, destroying 110 acres of cultivated land and wiping out three small hamlets. Although Terzigno was evacuated with the prompt aid of the military, the township itself has fortunately been spared, the lava having halted 300-400 yards from the houses. It is estimated by Professor Malladra that the volume of lava approaches half that emitted during the 1906 eruption." T.A.J.

THE NEW ZEALAND EARTHQUAKES OF JUNE 1929

On Hogben's map (Geography of New Zealand, p. 243, by P. Marshall, Christchurch, Whitcombe and Tombs) of larger New Zealand earthquakes, eight principal shocks appear in the middle belt between the north and south islands, only two in the northern region of active volcanoes, and four in the southern mountains and fjords. The Wellington earthquake of 1855 elevated the shoreline. Now comes a series of disastrous shocks in the north mountains of the south island, the region extending southwest from Nelson, with the worst damage at Murchison, which was virtually destroyed.

The new series began on June 17 in the Buller Gorge, but within three months there had been another serious earthquake with many landslides in the Otira Gorge. These are sites of two of the south island's famous roadways. The new crash occurred all along the route between Greymouth and Westport, on the west coast of the north end of the South Island, and the north coast at Nelson, seat of a college. The college, a large masonry building, was wrecked. The roads were split open in huge crevasses, landslides wrecked quarries, railways, and homesteads, some peole were killed and wounded, even frame houses were lurched and collapsed, communications were destroyed, roads disappeared, bridges collapsed, and railway tracks were warped, twisted, and destroyed. (Auckland Weekly News, June 26, 1929.) All the chimneys came down, telephone poles fell over, and trains were derailed. Valleys were blocked and lakes formed. People were thrown off their feet. The time of the major shock was about 10:25 a. m. local time June 17.

Riverview Observatory at Sydney calculated the epicenter 100 miles east of the South Island, but the Wellington seismograph station did not agree to this: field evidence indicated an epicenter in the mountains. Messrs. Ferrar and Grange of the Geological Survey of New Zealand are investigating the movement, which is believed to be a fault displacement. T.A.J.

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No. 240 RELEASED WITHOUT COPYRIGHT RESTRICTION August 1, 1929

KILAUEA REPORT No. 914

WEEK ENDING JULY 31, 1929

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

The lava activity reported last week as beginning about 6 a. m. July 25 continued until 7:42 p. m. July 28, when all fountaining ceased. The lake formed during the flow reached a maximum depth of 94 feet in the center of Halemaumau, and nearly buried the south cone of 1927 which was well up the talus slope prior to the eruptions of 1929.

Following the cessation of flow there was still some activity in the lake as the sluggish liquid continued to seek its level, but cooling of the crust was rapid. The crust settled, and the cracking noises of this process can still occasionally be heard. There is glow at night from numerous scattered points. No avalanching has followed the eruption.

Seventeen very feeble local earthquakes were registered by the instruments at the Observatory. In addition was the harmonic tremor accompanying the lava activity. This tremor was continuous after 6:32 a. m. July 25, although the fume was first noticed at about 6:10 a. m. The tremor waxed and waned at times, but grew stronger on July 27. Fountain action was also stronger. About 7 p. m. July 28 the tremor weakened and after 7:11 p. m. it was unsteady. It ended entirely at 7:42 p. m., when the fountains also went out of action.

There was moderate WNW. tilt during the two days preceding the eruption, slight SSE. tilt during the flow of lava and until July 29, and very slight WSW. tilt for the next two days. The net accumulation of tilt for the week was moderate to the south. Microseismic motion is still very slight.

HALEMAUMAU OUTBREAK JULY 25-28, 1929

Halemaumau has again been the scene of volcanic activity. The eruption began on the morning of July 25 and continued until the evening of July 28. It was one of a series of short-lived, quiet rises of magma which has characterized the present cycle of activity in Kilauea. The lava column attained a maximum height in the pit of 2,640 feet above sea level, a gain over the fill of February 20-21, this year, of 94 feet.

The first indication of the renewal of activity was a series of very small earthquakes a few minutes apart beginning at 4:35 a. m., each accompanied by a slight tilt to the east. The shocks and the tilt made only a slight record on the north-south component of the instrument. They were followed by spasmodic tremor, caused by fountain action, which became stronger and continuous after 6:30 a. m. and lasted so throughout the eruption.

The first observed activity was a cloud of smoke noticed by the machinist of the Observatory at 6:10 a. m. At 6:40 a. m. two fountains of lava were spurting from vents above the lower edge of the middle of the large western talus bank. A high column of blue smoke, pungent with the odor of sulphur dioxide, rose continuously from the fountains, and occasionally spurts of brown sulphur fumes were mixed with the smoke. By 7 a. m. a moisture cumulus had gathered over the pit.

The fountains strengthened rapidly so that by 7:20 a. m. they were throwing pumice and bombs at least 200 feet in the air, and two-thirds of the old floor was covered with new lava.

At 7:45 a. m. steady blasts, sounding like gas rushing through small orifices, were audible above the pounding of the lava fountains. These increased until, at 8 a. m., several small lava fountains, yielding brown fumes and apparently flaming, broke through cracks at the eastern edge of the old floor. Simultaneously, the western fountains lowered slightly, though their fuming increased. A little later the rapidly foundering old floor west of the new fountains was split by a large crack. By 10:20 a. m. it was covered by a lava lake, but its position was marked by a linear fountain, most active at its eastern end.

The filling continued steadily until, at 12:45 p. m., the old floor was nearly covered by a lake 25 feet deep over its lowest points. Fountaining continued with increasing vigor in the western and central areas, but the gas blasting had ceased. Blue smoke still issued from the fountains, but little brown fume was in evidence. About this time two phenomena became evident which, with the fountaining, characterized the remainder of the activity, namely, the cracking and foundering of the surface crust, and the pouring of cascades over ramparts built up near the margins of the lake.

The western fountains gradually strengthened at the expense of the central fountains until, at 6 p. m., 12 hours after the start of activity, spouting was confined to the western marginal fountains. These remained constant and strong (throwing material 300 feet high) until the morning of the fourth day, July 28. During this day the vigor showed periodic increase and decline. About 4:30 p. m. fountaining ceased entirely for 15 minutes, then increased suddenly to nearly the former vigor. Spouting continued with constant force until about 7 p. m., then gradually decreased until it stopped completely at 7:42 p. m.

The influx of lava continued constantly during the life of the fountains. The margins of the lake were extended during the rise by cascading over the marginal ramparts. Tilting of the bench lava beneath the lake, and convection currents in the lake influenced the advancing of the lake margins in such a manner that cascading and spreading was strong first on one side of the lake and then on the other.

During the first 24 hours the lava rose 44 feet above the level of the old floor. At the end of 48 hours the depth had increased to 77 feet, and on the morning of the fourth day, Sunday July 28, the pit had been filled 88 feet. The maximum elevation of the lake surface, reached July 28 after 85 hours of flowing, was 2,640 feet above sea level, 94 feet above the old floor.

The lake, shaped somewhat like an ivy leaf with the broad stem lying toward the southwest, has a maximum width of 1,700 feet and a length of 2,100 feet. Its area is approximately 50 acres.

Soon after the cessation of activity, withdrawal of the supply of molten lava and some shrinkage accompanying crystallization of the crust permitted the surface of the middle of the lake to settle. A survey of the pit made the next day shows that the existing floor has an elevation above sea level of 2,600 feet. This central floor is bounded by in-facing fault scarps from 20 to 30 feet high. The narrow lake margin, between these scarps and the walls of the pit, varies in elevation from 2,615 to 2,630 feet. From these data it has been estimated that approximately eight million tons of rock have been left in the bottom of Halemaumau by this eruption. H.A.P.

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No. 241 RELEASED WITHOUT COPYRIGHT RESTRICTION August 8, 1929

KILAUEA REPORT No. 915

WEEK ENDING AUGUST 7, 1929

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

There has been no renewal of volcanic activity at Kilauea. Appearances at the fire pit indicate that there will be several weeks of quietude before another flow of lava occurs. A few slides have fallen north and east, but otherwise Halemaumau remains unchanged.

Recent measurements of the east rim cracks show no significant changes over the measurements of May 15, the largest amount of movement being 0.135 foot.

A substantial increase in the number of earthquakes during the past week may mean slight subsidence of the invisible lava column. Twenty-seven very feeble local shocks were registered at the Observatory. In addition there was a two-minute period of microtremor 5:14-5:15 a. m. August 7; also two felt earthquakes, one at 10:43 p. m. August 5 and the other at 2:42 a. m. August 7. The distance to origin of the former can not be determined because the preliminary phase was destroyed by the minute mark; the latter shock originated about nine miles from the Observatory.

Microseismic motion was slight throughout the week except for a temporary feeble increase early August 2. The accumulation of tilt was slight to the NNE.

FOURTH PACIFIC SCIENCE CONGRESS

Mr. R. H. Finch, Associate Volcanologist in charge of Lassen Volcano Observatory in California, was delegated by the United States Geological Survey to attend the Fourth Pacific Science Congress as representing the Section of Volcanology of the Survey. In this journey he received assistance also from the Hawaiian Volcano Research Association as their delegate.

Mr. Finch reports that Dr. Maclawin of New Zealand represented the New Zealand Government so as to be able to give advice on extending the observations on New Zealand volcanoes. At a Japanese dinner in Singapore Mr. Finch met Dr. H. Tanakadate, volcanologist of Sendai University. The return trip from Java May 31 was on a Japanese freighter passing by Borneo and Celebes, and through the Sulu Archipelago and Sulu Sea. Most of the large islands of the Philippines was seen, as well as the southeast side of Luzon. A small fume cloud was observed over Mayon. Dr. Kozu from Sendai, and S. Kunitomi, seismologist of the Central Meteorological Observatory of Tokyo, were passengers. The program of papers at the Congress was serious and of sustained high quality. Mr. Finch feels that he benefitted much by his contacts at the Congress. He reports:

"The opening meeting of the Fourth Pacific Science Congress was held in Batavia, Java, on May 16, 1929. The Congress then moved to Bandoeng, Java, where in the delightful climate appropriate to an elevation of 2,000 feet the scientific sessions of the Congress were held from May 18 to May 24.

"The Congress was organized under the supervision of the General President, Dr. O. De Vries and Dr. H. J. Lam, General Secretary. About 250 foreign delegates were present, as well as a strong delegation from the Dutch East Indies. The delegates came from 24 different countries, with South American countries and Mexico not represented.

"One of the most interesting excursions prior to the opening of the Congress was to the volcano Krakatau. With the steamer 'Rumphius' provided by the Royal Packet Navigation Company (K.P.M.), excellent views were obtained of the three older islands of the Krakatau group. Landings were made on these islands, as well as on Anak Krakatau (Baby Krakatau), the island that was formed by explosions early in 1929. Exhibitions of native dances and native industries of the principal tribal groups of the Dutch East Indies were other outstanding features of the entertainment provided before the Congress opened. Both foot and airplane trips were made during the session of the Congress to Tangkoeban Prahoe volcano. After the Congress adjourned on May 25, there were excursions until June 4, many of which were to active volcanoes.

"For the most part papers were not presented before the Congress by the authors themselves. Papers on closely related topics were grouped and reviewed by one person. The time saved by this method was devoted to open discussion. Printed abstracts of most of the papers were available before they came up for review and discussion. The papers will be printed in full in the proceedings of the Congress.

"There were four sectional meetings under the head of volcanology. Many questions of interest to volcanologists were discussed in the sections of seismology and petrology. Of especial interest under seismology was the evidence offered on the occurrence of earthquakes with a focal depth of from 180-240 miles. The papers of Dr. Kozu on the influence of temperature upon the volume of granite and some lavas given under petrology proved of great interest to volcanologists.

"The invitation of Canada to hold the next Congress in Vancouver, B. C., in 1932, was accepted." R.H.F.

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No. 242 RELEASED WITHOUT COPYRIGHT RESTRICTION August 15, 1929

KILAUEA REPORT No. 916

WEEK ENDING AUGUST 14, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Dust from slides in Halemaumau was seen at various times during the forenoon of August 8, possibly caused by persons dropping rocks.

On August 11 it was noted that slumping since the July eruption leaves a terraced fault bank high along the west side where the deeper conduit was. The deeper withdrawal occurred there, and the deepest part of the slump appears to be at the northwest in the floor surface. There is little change of the east side of the bottom. Twenty or more hummocks are at the west. One of these is open and round like a tree mold, and stands up like a huge pipe 20 feet across. There are avalanche rocks on the steep down-faulted terrace at the edge of the floor under the northwest talus.

Blue smoke continues to come from the east rampart, and there is the usual steam from vents in the west and south taluses.

Earthquakes for the week number 28. None was felt, all being of very feeble intensity. Two of the shocks were of the continuous tremor type, one occurring 12:45 - 12:47 p. m. August 7 and the other 10:43 - 10:53 p. m. August 10.

Tilt accumulated slight to the NW. Microseismic motion was slight, with a little strengthening on August 10.

VOLCANIC LIGHT, HEAT AND POWER

In view of the possibility of warming the rooms of the hotel at Kilauea Volcano by natural steam with the aid of a hot water radiator system, it is of interest to learn what has been done in other places. At Kilauea the four bore-holes at Sulphur Bank close to the hotel yield constantly great quantities of steam at 96° C. If this were passed through a tubular boiler containing the water circulation for the hotel radiators, with the pipe properly insulated, every room might contain an adjustable heater filled with pure water from the tanks. There would thus be no waste of water. The slight corrosive effect of the acid steam would be met by building the boiler of a suitable resistant metal. The hot water system would be a great comfort to many guests in cold, rainy weather and by drying the building would act as a preservative against mildew.

Even in ancient times it was the dream of mankind to utilize volcanic heat. This does not mean harnessing the eruptions of volcanoes, but rather making use of the fumaroles and boiling springs generally found in volcanic districts. For many years the steam of fumaroles has been used in Iceland for the heating of schools and other public buildings. In Japan there is a village heated in winter with the aid of volcanic steam led into the buildings. Most of this is the steam of ground water brought to the boiling point through the agency of underground magma or of volcanic gases. The latter are dominantly hydrogen, carbon, chlorine, and sulphur, and their compounds through union with oxygen of the air.

Even farmers have made use of volcanic energy to assist them in agriculture. On the island Ischia, near Naples, the peasants make use of numerous fumaroles to warm their tomato plants and so make them sprout sooner. On the bottom of the extinct Agnano Crater a gardener found the volcanic heat useful in order to keep his vegetable crop producing all the year around by distributing his sowing and his harvesting in accordance with an irrigation system dependent on hot springs. Recently a company has been formed that makes use of volcanic steam for the warming of hot houses where useful plants are produced.

It is well known that in many places in Iceland, North America, the tropics, and New Zealand hot springs are used as laundries, and of course they have been used from time immemorial as baths beneficial in certain diseases.

Near Lardarello in Tuscany boric acid has been produced from scalding natural steam for more than a century. Prince Ginori Conti began there in 1904 to operate a small steam engine by curbing a natural steam vent. Further development of the steam power was hampered by the low pressure and temperature of the surface steam and the rapid eating away of the metal by the acid vapor.

In order to obtain higher pressures and temperatures, bore-holes were drilled which yielded a rush of steam at 190° C. and 14 atmospheres of pressure. There was finally obtained at Lardarello from several bore-holes 250,000 kgs. of steam per hour averaging two atmospheres of pressure and a temperature from 120° to 190° C.

In order to avoid the corrosion of expensive machinery, the high-pressure natural vapors were condensed under pressure, the fixed gases were assembled and conserved as by-products, and pure water was heated above the boiling point in a low pressure boiler so as to make steam, utilized by expanding it in low pressure turbines.

At Castel Nuovo a well 130 meters deep operates three turbo-generators of 2,000 kilowatts capacity. At present the plant yields some 12,000 kilowatts and no exhaustion of the resources of the ground has yet appeared.

In Java experiments at Kawah Kamodjang Crater with a bore-hole 128 meters deep yields a volume of steam at six atmospheres pressure estimated capable of producing 900 kw. At the Geysers in the St. Helena Range in California a great store of hot steam has been revealed by drilling, and this increases with depth. Borings for power have been made here discovering temperatures from 99° to 173° C. and pressures from 60 to 169 pounds. The wells vary in depth from 154 to 636 feet. Both temperature and pressure increases with depth. These wells also have been harnessed for power. The geological conditions indicate that the region overlies intrusive volcanic magma. (Volcanoes which heat Towns, by Dr. L. Steinberg, Weser Zeitung April 26, 1929, Bremen. Steam Wells at the Geysers, California, by E. T. Allen and A. L. Day, Carnegie Institution Publication No. 378, 1927.) T.A.J.

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No. 243 **RELEASED WITHOUT COPYRIGHT RESTRICTION** August 22, 1929

KILAUEA REPORT No. 917

WEEK ENDING AUGUST 21, 1929
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

A slide was reported at the north wall of Halemaumau about 3 p. m. August 16, and the next morning a fresh scar was observed there. Notably little visible steam appears about the new lava floor. A small crack at the east edge of the floor yields blue fume, and on August 17, at 9:45 a. m. the upper edge of the northern grotto niche at the west side of the floor began to yield blue smoke. This was very slight and diminished on succeeding days. The talus slopes make a little vapor visible on cool, moist days.

Nineteen very feeble earthquakes were registered at Kilauea and one feebly perceptible shock at 12:38 p. m. August 14. This had indicated distance to origin of 30 miles. Microseismic motion increased slightly during the nights of August 15-16 and August 19-20.

Tilt accumulated moderately NNE.

THE RISING LAVA IN HALEMAUMAU

The three short-lived eruptions which have occurred in the inner pit Halemaumau since 1925 have brought into the bottom of the pit a total of 8,692,000 cubic yards of solidified lava and have filled the bottom to a depth of 210 feet. Expressed in terms of the old Halemaumau which was overflowing in 1921, and was a much smaller shaft, this volume of lava would have meant in the old pit a rise of level of 350 feet.

Because of the fact that the dimensions of the pit have been increasing owing to the breakdown of the walls, and also because the bottom has been changing, it has been necessary from time to time to revise the topographic map of the actual pit crater. By keeping this map up to date it has been possible to compute with fair accuracy the actual amount of lava added during each eruptive period.

Before the outbreak of July 7, 1927, the bottom of Halemaumau stood at an elevation of 2,390 feet above sea level. It was 1,260 feet below the observation station on the southeast rim. During the 1927 eruption the level of the lava rose to an average elevation of 2,500 feet above sea level, and the total area of the new surface was 30 acres. After making proper allowance for the slope of the containing walls, the volume of new lava was computed to be 85,430,000 cubic feet.

Heavy avalanching during the months following, and other avalanches at the time when an internal landslip in the pit in January, 1928, was accompanied by an upward squeezing of red hot lava, produced burial of much of the 1927 lava floor beneath debris from the walls.

A new eruption of lava came February 20, 1929, pouring its floods over 19 acres of the 1927 lava that still remained unburied by debris. During the 36 hours of activity, a lava lake was formed which had an average depth when frozen of 45 feet, a surface area of 40.5 acres, and a total volume of 51,900,000 cubic feet. The new floor thus formed had an elevation of 2,546 feet above sea level and was 1,104 feet below the rim at the observation station.

The last eruption which began on July 25, 1929, and continued for 85 hours built up the floor of Halemauamu to a point 1,050 feet below the observation station. The total volume of this lava of July, 1929, in the new floor is 97,350,000 cubic feet and the surface area is 54 acres.

The figures given for the volume of each flow represent only the actual amount of lava which remained in the pit after activity had ceased. In each case a great deal of the frothy liquid material extruded during the eruption was either withdrawn from the lake when the lava column sank into the earth at the end of the active period, or else contracted by loss of gas. During the eruption of July, 1929, the inflated lava lake at the time of maximum activity before any recession contained a total volume of 126,850,000 cubic feet of molten lava.

A tabulation of these data facilitates comparison:

	Depth	Area	Volume
July, 1927	110 ft.	30 acres	85,430,000 cu. ft.
Feb., 1929	45 "	40.5 "	51,900,000 " "
July, 1929	55 "	54 "	97,350,000 " "

H.A.P.

THE NEW CYCLE IN HALEMAUMAU

The above figures computed by Dr. Powers exhibit the facts of a true rising of the lava column of Kilauea since the explosive eruption of 1924. After that engulfment the funnelling talus had its lowest point 1,330 feet below the observation station. The depression of the bottom was diminished by 70 feet with the lava filling of July, 1924. by 110 feet with that of 1927, by 45 feet with that of February, 1929, and by 55 feet with the eruption of July, 1929. As the talus of the bottom opens out funnelwise at an angle of 30 degrees, the areas have increased and in general the volumes have increased. The duration of eruption in the two outbreaks of 1929 was less than in the outbreaks of 1924 and 1927, while the volume of inpouring per day was much greater. The 1924 eruption lasted 10 days and the 1927 eruption 13 days, while the two outbreaks of 1929 each stopped suddenly at the end of a day and a half and three days and a half, respectively.

The fountaining at the beginning of all these eruptions was of the Mauna Loa type, throwing up basaltic pumice. The fountains of 1924 were estimated to be 150 feet high, those of 1927 125 feet high, those of February, 1929, 200 feet high, and those of the last day of the July eruption, 1929, reached maxima of 300 feet at times. The 1927 eruption was estimated to pour out 50 per cent of its volume during the first hour, and something similar was true in 1924. Both these eruptions built up cones at single vents, whereas the two 1929 eruptions opened fissures at the floor margins, and the largest fountains left only niches. This history seems to indicate that the intensity of gas action and the freedom of flowing has increased in 1929, and at the same time the interval between outbreaks has decreased.

A platted curve of the rate of rising now in progress, with an average fill of about 70 feet for each eruption, and a diminishing interval between eruptions, should make the next inflow of lava take place some time between now and November, 1929. This expectancy might be interfered with if Mauna Loa should erupt, but that would be an equally satisfactory demonstration that the Hawaiian lava column is alive.

T.A.J.

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No. 244 RELEASED WITHOUT COPYRIGHT RESTRICTION August 29, 1929

KILAUEA REPORT No. 918

WEEK ENDING AUGUST 28, 1929
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The pit Halemaumau at Kilauea Volcano has shown no movements of interest during the past week. A round convection cloud hung over the pit during the night August 23-24, gradually vanishing with forming and reforming as the sun's heat dried the air about 8 a. m. On August 25 at 2 p. m. the weather was rainy and this developed steam at hot places in the wall of the pit above the northeast and southwest taluses and on the talus slopes. Blue vapor rose from the crack at the niche at the western edge of the floor where the northernmost source fountain had been in July, 1929.

Sixteen very feeble earthquakes were registered at Kilauea, including several spells of spasmodic tremor August 21, mostly during the noon hour and possibly occasioned artificially. One slight perceptible shock occurred at 1:45 a. m. August 28 with origin not more than four miles from the station according to the seismographic evidence.

Microseismic motion was slight, with some increase August 21-22. Tilt to August 24 accumulated moderately SSW. Tilt measurement was temporarily interrupted thereafter by repairs to the seismograph basement.

MEASURED DEFORMATION FROM TOKYO EARTHQUAKE

Tanakadate calls attention to the fact that regional deformation by uplift, sinking, or sidewise motion of the land has only been measured in relation to earthquakes within the last 40 years. (Geomorphology of the Kwanto Earthquake in Japan—in Italian—by H. Simotomai Tanakadate, R. Accad. delle Sci. Fis. e Mat. Napoli, December 3, 1927.) This has been done for the San Francisco earthquake 1906 and, for the Japanese Empire, in the cases of the earthquake of Nobi 1891, of Omati 1918, Kagi in Formosa 1906, and the recent Tango earthquake.

After the great Kwanto earthquake of September 1, 1923, the Naval Institute of Hydrography measured the bottom of Sagami Bay in comparison with soundings of 12 years before, and found enormous changes. A belt extending SSE. from the central part of the bay had lowered from 110 to 210 meters, and a horseshoe of the bottom enclosing this on the northwest had been lifted or shallowed to a maximum of 250 meters. The maximum subsidences were, in a pocket near the head of the bay of 300 meters, and in the channel leading to Tokyo Bay of 400 meters. The biggest belt of sea bottom elevation trends northwest along the northeastern half of the bay, and the biggest belt of sea bottom depression trends out to sea from the southern half of the bay, interrupted by a belt of 100 meters of elevation, between the active volcano island Oshima and the mainland northwest of it.

In other words the belts of elevation and depression are along northwest-southeast axes alternating, with the southern elevation axis lying along the active volcano line Oshima-Fuji. Although the entire northeastern belt of elevation exhibits such positive uplifts as 100, 180, 230, and 250 meters, which cannot possibly be accounted for by the filling of bottom depressions by submarine landslip, the immediately adjacent shorelines rose only one or two meters. The same may be said of the Idu Peninsula on the opposite side of the bay, immediately adjacent to the undersea ridge raised 100 meters and undersea depression from 100 to 300 meters; this shoreline moved hardly at all. The bottom of the bay appears to be sharply differentiated mechanically from the solid rocks of the shore.

The area of the sea bottom region lowered was 700 square kilometers and the bulk displaced 50 cubic kilometers. The area of the sea bottom region elevated was 240 square kilometers and the bulk displaced 20 cubic kilometers.

Coming now to the shoreline, it was mostly elevated somewhat, at the instant of the earthquake, from the head of Tokyo Bay to the mouth of Sagami Bay. A region back in the interior, extending northeastward from Fuji Volcano, was slightly depressed. The axis bounding these two belts is northeast and southwest, or about at right angles to the Sagami Bay axis. Precise levels run by the Military Institute of Geography immediately after the earthquake discovered elevations of one or two meters or less at the southern end of the Boso Peninsula east of Sagami Bay, and at the extreme head of the bay near Kodu. The maximum uplift was at Hemuro Mountain 21 kilometers north of Kodu amounting to 2.65 meters. This maximum land uplift was a localized hump clear inside the Fuji belt of depression. The subsidences in this last belt were small, of the order of tens of centimeters.

The relative horizontal movements of bench marks relocated by precise triangulation in 1924-25, compared with the geodetic net of 1884-89 from base lines measured in 1882 and in 1924, reached a maximum on the volcano Oshima, of 3.78 meter, in a direction N. 8° E. In general the displacement is at a maximum around Sagami Bay of the order of one or two meters, and is north on the west side of the bay, eastward to the north of the bay, and southeastward to the northeast of the bay. This encircling movement diminishes in the interior country. The displacement at Oshima island is toward the bay.

The country has been shown to be broken up into small fault blocks and the two peninsulas where the maximum shore movements occurred consist of lithified tuffs of Tertiary age excessively dislocated from that time to the present, and much of this dislocation extends into broken shore terraces directly related to Quaternary and recent earthquakes. Tanakadate shows that by investigation of the tide gauge at the Miura Peninsula, nearest to the earthquake center, the shore had been gradually sinking about 10 centimeters in the last 23 years. Before that, on the authority of researches by scientists, and of a careful investigation of 150 fishing villages, the evidence shows that prior to the earthquake of 1923 there had been gradual lowering of the shore, and encroachment of the sea, of the order of three feet in 65 years. This applies especially to the two peninsulas. The evidence goes to show that in just such measure as the subsidence prior to the earthquake had been greater, so much the higher was the elevation or springing up of the ground at the moment of the earthquake.

A great earthquake in the same region in 1703 produced elevation of the Boso Peninsula and lifted dry land areas unknown before, said to have been from one to four kilometers wide, at different places along the shore. Accordingly it seems likely that from Tertiary time to the present this has been a region of "hereditary earthquakes," like southern Italy, where magmatic invasion brings about elevation, eruptions, and earthquakes. T.A.J.

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No. 245 RELEASED WITHOUT COPYRIGHT RESTRICTION September 5, 1929

KILAUEA REPORT No. 919

WEEK ENDING SEPTEMBER 4, 1929
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On August 29 dust rose from Halemaumau pit at 1:30 p. m. in two small clouds separated by an interval of about one minute. At 12:05 p. m. August 30 a large dust cloud rose from the east side of the interior of the pit with protuberances projecting upward, an indication that a strong avalanche had occurred. The pinkish dust hung visibly over the pit for many minutes. The effects of this were seen at 10 a. m. August 31 in that the north side of the new lava floor was dusted by the outward projections from a big avalanche that had fallen from the north wall, and that corner of the pit was still sliding. There were some large stones on the north side of the floor. Much fresh rock was in evidence on the northeast talus. Above the northern niche at the edge of the floor west, blue smoke appeared as though puffing. Small patches of milky stain lay on the edge of the floor south and north-northwest.

Fifteen very feeble earthquakes were registered. The day records of August 30 and September 3 were interrupted by repairs. Microseismic motion was slight.

MURCHISON EARTHQUAKE, NEW ZEALAND

At 10:17 a. m. June 17, 1929 New Zealand time (11h. 30m. faster than Greenwich) a disastrous earthquake struck middle New Zealand with maximum damage in the Buller Gorge of the mountainous district of the north end of the South Island.

The shock was severe in Wellington, dismantling the Milne-Shaw seismographs. Aftershocks on these instruments indicated epicenters in the northern part of South Island. Murchison suffered the most damage. Landslips in precipitous country destroyed four homesteads and killed fourteen people. Numerous chimneys and two clock-towers were broken, many walls cracked, one badly built two-story house partially collapsed after the second severe quake; on these data the preliminary statement of the Geological Survey Office makes the intensity at Murchison R. F. VIII.

There was a severe aftershock June 23. This and the main earthquake appeared to center on the White Creek fault-plane that crosses the Buller River 7 miles west of Murchison. It was possibly a twin-earthquake with second centrum on the Kongahu fault-plane off NW coast of South Island. Many aftershocks occurred, some perhaps on other fault-planes. Differential movement of about 14 feet displacement was found at the White Creek fault. In 1928 this fault had been mapped for seven miles, but it is not known whether the displacement since was sudden or gradual, nor whether movement has yet ceased.

At Whitecliffs on the west coast a strip of sea-bottom was uplifted 100 feet, forming a ridge 180 feet wide by 4000 feet long, apparently the west side of a small fault-block tilted. Tilting of the land at Kelburn is suspected.

Dr. E. Marsden, Minister for Scientific and Industrial Research, called a conference of scientists June 26 on earthquake investigation, seismograms are being registered at Wellington and Christchurch, a seismograph and sound-ranging instruments were set up at Murchison, having in view study of focal depth of aftershocks, and the Milne seismograph was set up at Westport to locate aftershocks, and check time-curves of the permanent instruments. Questionnaires were broadcasted and geological investigations are in progress. The air Defense Service will photograph the faults from airplanes. Soundings were made off the west coast, and repeat observations in levelling and triangulation are in progress. Bench marks have been placed and occupied on each side of the active White Creek fault, which appears to have allowed movements of earth blocks to take place since the earthquake.

On request of Dr. Marsden drawings and specifications of the Jaggar shock-recorder were sent to Wellington from the Hawaiian Volcano Observatory June 29 and he writes that two of these have been constructed. It is planned to have some of these shock-recorders distributed about the country, and to have an additional major station with three-component seismograph in the middle of the North Island. A full report of the earthquake will be published later. (Circular of N. Z. Geol. Surv. "Murchison Earthquake Investigations" by H. T. Ferrar, Acting Director, 31 July, 1929 (mimeographed.)

New Zealand has an exceptionally good field for path-breaking in the study of the relation of local earthquakes to instrusive magma. There are cold springs, warm springs, hot springs and boiling springs; active volcanoes, inactive volcanoes and ancient volcanoes, mountain folds, live faults, dykes and batholiths. There is much Tertiary and Recent mountain uplift. There is an axis of gradation of these things from Samoa to the South Island, from Hawaiian type volcanism to Norwegian type fjords.

No one knows what causes an earthquake. No one ever will know until local observers with local instruments and controlled experiments investigate local earthquakes in a strategic field. The doctrines of emergence angle, epicenters, distance, depth, nature of source, as nowadays applied to distant earthquakes, (and that means big earthquakes,) are not doing clinical work on local patients. The earthquake problem needs a Pasteur. Omori and the Italians were the pioneers. T.A.J.

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No. 246 **RELEASED WITHOUT COPYRIGHT RESTRICTION** September 12, 1929

KILAUEA REPORT No. 920

WEEK ENDING SEPTEMBER 11, 1929
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The week at Halemaumau lava pit has produced nothing new. Occasional dust is seen from small slides, but these are often caused by visitors rolling stones. Two notches up the wall north and northwest are deepening by avalanche erosion, and the buttress between them is likely to fall in the future.

Near the 1919 desert chasm, a quarter mile southwest of the Kilauea rim, there are patches one or two feet long of Pele's hair and pumice droplets scattered about in the holes of the sand. These have accumulated to leeward from the February and July lava fountains of Halemaumau.

Only four very feeble local earthquakes are registered for the week at Kilauea. The day records of September 5 and September 10 were omitted, owing to repairs. Microseismic motion increased slightly September 6 to Septem- 9. Apparent tilt, imperfectly recorded, was moderate NE.

ALEUTIAN NOTES

Alaskan Volcanoes 1929.

Mr. Austin E. Jones, seismologist for the Section of Volcanology, has spent the summer at Dutch Harbor and Kodiak establishing seismograph stations. He reports that a party landed on Bogoslof Volcano July 27, 1929, and found it very quiet. This is in line with its behavior in 1928, when the heap of steaming lava, in the midst of the circular lagoon, which had been so active in 1926-27, was much cooler and showed less steam than in the previous year.

Akutan Volcano had been reported in strong activity in 1928, and this year on June 18 the lower slopes were lightly covered with ash. It was reported fuming again during July, 1929.

Mount Cleveland and a volcano to the west of it, in the region of the Islands of the Four Mountains, were smoking heavily in July. A mountain west of Kanatak on the Peninsula was reported fuming in March. In the Katmai group Mount Martin and Mageik have been seen steaming throughout the year. Shishaldin, the great volcano on Unimak Island, was "flaming high" on May 28, 1929, and glowing matter was overwelling the edge of the crater and rolling down the slopes. On June 17 Shishaldin was quiet though steam was visible when the crater was inspected with field glasses. It was fiery again June 23 and appeared to have opened three new craters low on the north side. On August 4 the summit steam was barely visible to the naked eye. In 1928 Shishaldin was smoking heavily in August.

The above note on the fuming of Mount Cleveland recalls the heavy earthquake just south of those islands at the edge of the Aleutian deep reported in the Volcano Letter No. 220. This occurred March 6, 1929.

Aleutian Seismograph Stations.

Mr. Jones started work in the middle of June, 1929, at Dutch Harbor digging a cellar and building a hut over it to house the seismograph in the reservation of the U. S. Naval Radio Station at Dutch Harbor, Unalaska Bay, on Amaknak Island, a mile to the north of Unalaska village. The instrument was making a test run on July 16 and thereafter. It is a pair of Hawaiian type horizontal pendulum recording E-W and N-S components on smoked paper. The magnification is X135 and the damping by vanes immersed in oil. The time control is a Howard master clock, and an electric connection makes it possible for the operator from the radio station to impress directly on the seismogram the time signal received daily from Mare Island, California. The location of the hut is lat. 53° 53′ 08″ N. and long. 166° 32′ 07″ W. The distance is about 400 feet SSE. from the radio station on the line of the hand railway leading to the station jetty. The excavation was carried to a depth of five and a half feet where rock was reached. The hut is a 10 by 10 foot shed projecting one and one-half-feet above ground at the back, with double sheathing and a double window, roofed with tar paper, and banked up with earth and sod.

The instrument pier is Y-shape so that the stem holds the drum and the two arms carry uprights at their ends, all of concrete, which support the pendulums. The concrete is reinforced with steel.

The station is operated by Mrs. McDonald, wife of the Chief Radioman, using 120th meridian time (Pacific Coast). Microseisms were very faint in July, and the instruments registered two small local shocks and an earthquake indicating epicenter about 90 miles distant, not felt.

Work was started on reestablishment of the Kodiak seismograph station, by Mr. Jones, early in August. The 1927-28 station has been in the basement of the dwelling house of the Agricultural Experiment Station on the hill back of Kodiak, now turned over to the Bureau of Fisheries. On August 10 the concrete dairy house of the station was turned over to the Geological Survey for use as a seismograph laboratory. This is sturdily built of concrete with walls in places 30 inches thick. The Bureau of Fisheries occupies the establishment only during the summer season, but a local operator has been secured for year-around recording with the two-component Hawaiian seismograph, identical in model with those at Dutch Harbor, Lassen Volcano Observatory, Kealakekua, and Hilo.

Mr. Jones is to be congratulated on his successful season in constructing these stations, much of which he did with his own hands, and the Section of Volcanology is grateful for the cordial assistance given by the officers and men of the Bering Sea Patrol. U. S. Coast Guard, and the Naval Radio Service, and by the officers of the Bureau of Fisheries at Kodiak. T.A.J.

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No. 247 RELEASED WITHOUT COPYRIGHT RESTRICTION September 19, 1929

KILAUEA REPORT NO. 921

WEEK ENDING SEPTEMBER 18, 1929
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The inner pit at Kilauea remains quiet. There is a little steam on the southern talus slopes. Dust from avalanches was seen at 3:10 p. m. September 11 and 2:55 p. m. and 3 p. m. September 12. The slides of September 12 made a dense gray dust cloud of moderate size which hung over the northeast rim for a few minutes, and after the second slide the air within the pit was full of dust for many minutes. At 9 a. m. September 14 there was fresh debris on the north talus; and September 16 there was no change.

The seismographs have registered one feeble earthquake at 7:31 p. m. September 16, indicating origin distance five miles from the Observatory, and eight other very feeble disturbances. A teleseism of moderate amplitude was registered for about 50 minutes beginning 9:04 a. m. September 17. The long waves developed soon after the start and no preliminary waves were detected. Microseismic motion was slight, and tilt was imperfectly recorded with moderate WSW. trend.

ROCK BENEATH THE DEEP SEA

What is called the deep ocean includes depths of two or more miles. Professor Twenhofel, a leader in sedimentation studies, has made an important contribution in answer to the question, "How thick are the deposits under the deep sea?" (Magnitude of the Sediments under the Deep Sea, by W. H. Twenhofel, Bull. Geol. Soc. Amer. Vol. XL, pp. 385-402, June 30, 1929.)

The text books have asserted that the deposits in the very deep oceans are trivial, and recent theories, such as that of July, would lead one to expect basalt only a short distance below the red clay at depths of 18,000 feet of water. "The rates of deposition in the deep sea are unknown, and no methods seem to have been devised by which they may be measured." Sediments from rivers have been thought to remain near the lands where they originate, and it was always believed impossible to transport considerable thicknesses of land sediments out to the deep oceans.

Twenhofel corrects all this, with evidence to indicate the deep sea sediments may even exceed those of the shallow water, that the quantity of lime in the earlier deep sea sediments was small in comparison with the lime in those of later geologic ages. On the basis of the deposition of 20 tons of mineral matter per annum over each square mile of an ocean basin averaging, since the beginning of Devonian time, an area of 115,000,000 square miles, and according to current estimates of geologic time, he finds there has been deposited in the deep sea approximately 80,000,000 cubic miles of inorganic sediments.

During the same time there was deposited an unknown volume of lime carbonate, silica, and other substances, the precipitating agencies being surface organisms which have increased in effectiveness in later geologic ages.

Underneath these deep sea sediments there is buried an unknown and possibly large volume of shallow water and continental slope sediments, the total thickness of which is dependent on what length of time in the pre-Paleozoic represented shallow water conditions, for the areas that subsided in the Devonian and later, on the basis of Walther's conclusions.

It is suggested that the deep sea sediments of the early ages contain more insoluble and undecomposed materials, in contrast to the ages since the late Mesozoic, during which the organisms of the surface waters have deposited much lime over the lesser depths, and this lime is permanently removed from the continental masses.

The major factors in the problem are the length of geologic time, the dimensions of the deep ocean basins, and the fact that few deep sea sediments have ever really been destroyed, whereas the shallow water sediments have been repeatedly uplifted and partially destroyed, and with each uplift have contributed their constituents to the deep abysses of the sea.

Calcareous organisms are deposited all over the sea bottom, but the shells pass into solution at depths beyond 16,000 feet. The siliceous shells go into solution around 18,000 feet. Over the entire area of the deep sea there is a shower of inorganic material such as clay, silica, iron oxide, small particles of resistant minerals, manganese oxides, phosphatic matter, minerals of igneous rocks whose direct origin is uncertain, matter which clearly is of volcanic origin, and rare particles believed to come from meteorites. There is also some lime of inorganic precipitation.

The atmosphere transports fine materials for long distances, as shown by the vast loess deposits of the continents. Europe has received 266 tons per square mile per annum during 3,000 years; 850,000,000 tons of dust are carried 1,440 miles in the air of the Mississippi Valley each year. This material falls over the sea as over the land.

Flocculated particles are carried by the currents of the sea, and the muds of the Amazon are visible 300 miles from its mouth. No one knows how much volcanic matter comes up through the sea bottom or falls from the air.

Sea water contains 1,500 tons of solid matter per cubic mile. This is precipitated more rapidly in warm tropical waters. As the waters of the deep sea cover 115,000,000 square miles with average depth of two miles, they contain 234,000,000,000 tons of sediment in suspension, or more than 21 times the amount carried to the sea by streams.

The length of geologic time since the beginning of the Paleozoic may be estimated to be at least 567,000,000 years, and since the beginning of large deep oceans 300,000,000 years. At the rate of only one foot of sediment in 87,100 years there would be deposited since the Devonian about 4,000 feet, or 0.7 mile, of mineral matter from all sources over the present deep sea bottom.

Twenhofel concludes that the sediments on the continent above sea level are little more than half the calculated volume of the inorganic sediments in the deep sea deposits, and only about 28 per cent of the total volume of all deep sea sediments including limestones. These astonishing conclusions add new zest to the project of boring beneath the mud of the deep sea bottom, the last stronghold of nature unexplored by man, and constituting more than 70 per cent of the earth's surface.—T.A.J.

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No. 248 **RELEASED WITHOUT COPYRIGHT RESTRICTION** September 26, 1929

KILAUEA REPORT No. 922
WEEK ENDING SEPTEMBER 25, 1929
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The week at Kilauea has been entirely lacking in visible volcanic activity. The lava pit Halemaumau has been quiet, and no changes have been noted. From time to time dust from avalanches has been observed, sometimes caused by earthquakes originating at distant points.

On September 19 at 11:50 a. m. a small cloud of dust rose NE. On September 21 at 2:30 p. m. a few stones were heard falling NE., and very slight smoke was noted at the north July grotto at intervals. On September 22 a new line of sulphur at the floor edge north of the grottoes was observed. Steam was slight on the west talus and normal on the south talus. At 6 p. m. dust from a slide was seen from the Volcano House.

On September 24 at 9 a. m. there was no change. New debris lay on the north talus. At 3 p. m. an avalanche occurred, sending up dust. At 4:15 p. m. and thereabouts there were other clouds from larger slides, the buff-colored dust probably originating on the red north wall of the pit. Today two new bright scars can be seen on the south wall from the Observatory.

An extraordinarily large number of seismic disturbances have occurred during the week, the total count being 221. This is an especially surprising number when contrasted with the total of nine shocks for the week preceding. The earthquakes appear to originate in North Kona District, on the west side of the island of Hawaii, but are felt all over the island, intensity decreasing with distance. Due to crowded and overlapping lines on the seismograms some shocks could not be counted.

The earthquakes appear to portend lava activity, but at the present time nothing has been observed to indicate flow. It may be significant that the shocks fall on the equinoxial period. Many of them are of the very feeble, or imperceptible, class; others are classed as feeble, slight. and moderate, and can usually be felt. Moderate shocks are generally strong enough to dismantle the seismograph pens.

The earthquake distances vary from 14 to 37 miles from the Observatory. Plotting these distances on a map of the island, in conjunction with distances shown by records of two other seismograph stations at Hilo and Kealakekua, the epicenters of the shocks appear to fall on points along lines extending both northwest and northeast of the summit of Mauna Loa. The apparent locations of a large number of the shocks are in the region lying between Mokuaweoweo and Hualalai.

Some of the shocks showed distances in miles as follows: 2, 14; 3, 17; 5, 18; 2, 20; 7, 23; 4, 25; 1, 26; 1, 28; 1, 30; 1, 32; 2, 37.

Frequently the distance phase of earthquakes is obliterated by long tremors obscuring the preliminary wave of the shocks. In such cases it is impossible to compute distance.

A few of the earthquakes of this series are tremors varying from two to 17 minutes in length, which occasionally wax in aplitude sufficient to become perceptible. Tilt for the week accumulated slight NNE.

SEISMIC CRISIS ON HAWAII

Numerous tremors beginning soon after noon September, 19, 1929, at Puu Waawaa Ranch, seven miles north of the summit of Hualalai Volcano, a mountain 8,269 feet high on the west side of the island of Hawaii, inaugurated a seismic crisis. This has gone on increasing to September 25, and implies new movement of the Hawaiian Lava column.

At Puu Waawaa there were more tremors September 20, becoming shock groups in continuing series on September 21. The spasms were at first separated by several hours, later they were lenghtened so that the intervals of quiet were only for an hour or two. Also the motion spread to the entire Kona District and perceptible earthquakes became numerous at equal distances from Hualalai to the north and northeast. The belt shaken most is about 35 miles from Hualalai as a center, and the region of the Kau, Puna and South Hilo districts has received the least shaking. The seismograps at Kilauea Volcano have shown increased disturbance both in intensity and frequency.

At Puu Waawaa on September 21 there were 13 shocks in 10 hours, on September 22 there were 79 seismic spells in 22 hours, and on September 23-24 there were 86 spells in 26 hours. This makes the number of disturbances per hour 1.3 for September 21, 3.6 for September 22, and 3.3 for September 23-24.

Huehue Ranch, eight miles northwest of the Hualalai summit, recorded 73 felt shocks in 34 hours, averaging 2.2 per hour. At the F. R. Greenwell residence, Honokahau, six miles WSW. from Hualalai summit, 444 shocks were felt in 73.5 hours, averaging 6.0 shocks per hour. Slight rumble through the ground seeming to come from the mountain was observed with some of the quakes at Huehue and and Honokahau. This was not heard at Puu Waawaa.

For intensity Honokahau registered 71 that were sharp, and Puu Waawaa about the same number, the intensity increasing between September 19 and September 25. As the number of sharp shocks increased, the perception of them over the island at great distances also increased. For frequency the Kealakekua seismograph gave a consistent record for five days beginning September 19-20 of 13, 21, 60, 92, and 280 disturbances per day. For distance of origin from the three seismograph stations Kilauea, Hilo, and Kealakekua, the records suggest the saddle between Hualalai and Mauna Loa volcanoes as an important epicenter, and other seismographs imply motion both northwest and northeast from the central crater of Mauna Loa. The local felt earthquakes all indicate motion on the northwest flank of Hualalai.

The writer examined the summit region of Hualalai September 22, found no fresh cracks, no signs of heat, and felt no earthquakes. The Hualalai and Mauna Loa profiles have been clear, and as yet have shown no fume.

Summarizing, the situation shows increasing tremor earthquakes of volcanic quality centering about the northwest region of Hualalai, accompanied by deeper earthquakes centering about the northern slopes of Mauna Loa and extending their perceptibility to the whole north half of Hawaii Island. Everything suggests that the Mauna Loa lava column, which has sent out its flows from the southwest rift of that mountain during the last 25 years, is now transferring its upward wedging in the direction of Hualalai. This is just what happened in 1801, ten years after the explosive eruption of Kilauea. The present time is five and a third years after the explosive eruption of 1924.

T.A.J.

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No. 249 **RELEASED WITHOUT COPYRIGHT RESTRICTION** October 3, 1929

KILAUEA REPORT No. 938

WEEK ENDING OCTOBER 2, 1929
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Halemaumau continues to be very quiet and without lava activity. Numerous earthquakes during the week have probably been the cause of several slides.

A total of 244 shocks were counted on the seismograms. In addition to these were several spells of spasmodic tremor. Some of the tremor occasionally waxes into wide amplitude and earthquakes. Earthquakes registered were as folows by days: September 25, 63; 26, 61; 27, 27; 28, 27; 29, 29; 30, 15; October 1, 19, October 2, 3. September 25 and October 2 are incomplete days coming at the beginning and at the end of the period covered by this report. It should be stated that many more shocks are felt in West Hawaii, the apparent center of the present seismic disturbance, than are recorded at Kilauea.

Thirteen shocks give distance 23 miles, 10 distance 28 miles, 6 distance 30 miles, 7 distance 32 miles; others distances varying from 14 to 46 miles from the Observatory.

Microseismic motion was slight throughout the week. Tilt was strong ENE.

CONTINUED HAWAIIAN SEISMIC CRISIS

The development of swarms of earthquakes, as reported last week, on the west side of the island of Hawaii, has continued throughout a second week without the appearance of lava activity to date (noon October 1). The concentration of local shaking in frequency and intensity has remained about Hualalai volcano. In general until September 26 the frequency mounted to a maximum, and thereafter it systematically declined. The intensity of individual shocks has occasionally been extremely strong between September 25 and September 30, but no shock has exceeded grade IX R. F.

The strongest shock of the series to date appears to have been at 6:20 p. m. September 25, felt generally throughout the inhabited Hawaiian Islands. This inaugurated groups of heavy shocks which have occurred in west Hawaii 6:20 to 11:00 p. m. September 25, 10:00 to 12:00 p. m. September 27, 3:18 to 5:18 September 28, 5:00 to 6:00 a. m. and 10:00 to 11:00 p. m. September 29. Extremely severe shocks have occurred (other than 6:20 p. m. September 25) at 10:50 a. m. September 27, 7:08 a. m. and 3:18 p. m. September 28, and 11:55 a. m. September 30. All of these have added greatly to damage of tanks, masonry, stone fences, chimneys, roadways and weak buildings on slopes. There have been numerous other wrenching shocks in the North Kona district which would rank as very strong.

The Count of Earthquakes

As before, the two places which have received larger numbers of groups of felt shocks were Honokahau and Puuwaawaa. Thus for the twenty-four hours midnight to midnight September 24, Puuwaawaa counted 144 earthquakes, Kealakekua only 40. For September 25 Puuwaawaa 171, Kealakekua 30. Kealakekua is twenty miles south of Puuwaawaa. These were felt spasms or groups of shocks. For a twenty four hour period, September 24-25, about 210 shocks were registered at Kealakekua by an 80-times magnifying seismograph.

A shock recorder of magnifying power 25 was set up on a verandah at Puuwaawaa Ranch and for each twenty-four period beginning midnight September 26 registered individual quakes, small and great, in the following numbers:

September	26	599 shocks	
"	27	541 "	
"	28	400 "	(about)
"	29	334 "	
"	30	221 "	

The Kealakekua seismograph was injured by the earthquake of 6:20 p. m. September 25, but thanks to the prompt action of Captain R. V. Woods, was re established September 26. It showed some decline in frequency and amplitude of earthqaukes September 25 to 27, the decline in frequency becoming pronounced on September 27, but with it there came seven shocks of much larger amplitude September 27 to 28. The seimogram of September 30 to October 1 shows an increase of frequency to about 100 shocks.

Comparison With 1868 Crisis

The summary of the situation on October 1. 1929. is that a period of tremor began at Hualalai volcano in west Hawaii at noon September 19, produced a damaging shock of grade IX, six and one half days later, then produced decline in frequency and some increase in intensity of shock groups for five days more. The populace nearest to the mountain is sleeping in the open air, stone walls have been thrown down with notable fracturing away from the mountain, and the stronger shocks have been of the quality to displace furniture, throw down and overturn loose objects, move buildings, crack masonry and produce slides on steep slopes.

In the quality of growing gradually to a maximum from tremor to bumping shocks, and from bumping shocks to oscillations of longer period, this seismic crisis in Hawaii is quite unlike such earthquakes as those of San Francisco and Tokyo. These latter are called tectonic, and begin with a terrific earthquake, thereafter declining with aftershocks. Therefore it seems probable that the present Hawaiian series is volcanic, and marks the shift of magma underground from the Mauna Loa center toward the Hualalai center. We have a close parallel to this in the shift of magma from the northeast rift of Mauna Loa, to a new series of eruptions in the southwest rift, in the year 1868. There were no southwestern Mauna Loa eruptions recorded prior to 1868. In that year on March 9 came a hard earthquake in Kona, on March 27 the beginning of continuous quaking at the south end of Hawaii, on March 28 a very severe damaging shock of the same quality as the one of September 25, 1929, and thereafter an increase of very hard shocks along with many small ones, so that just as in the present year the earthquakes were felt farther and father away. On April 2 came a terrific shock of grade X producing a landslide near Pahala, destroying wooden houses as well as masonry ones, and leading four days later to a rapid outflow of lava, from the south end of Mauna Loa, that endured less than a week. Earthquakes gradually ceased, though there were still two or three a day, five months later.

In 1868 the shift of lava was from northeast to southwest. Now apparently the shift of lava is from southwest to northwest, if rising lava is making the earthquakes. That it should do so a few years after the explosive eruption of Kilauea of 1924, agrees perfectly with 1801, when Hualalai erupted after the 1790 explosions of Kilauea.

T.A.J.

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No. 250 RELEASED WITHOUT COPYRIGHT RESTRICTION October 10, 1929

KILAUEA REPORT No. 924

WEEK ENDING OCTOBER 9, 1929
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

No lava has appeared on the island of Hawaii. Halemaumau showed thin dust clouds from slides the forenoons of October 3 and October 5, and there were big slides in the pit and from the walls of Kilauea Crater at the time of the strong earthquake 9:22 p. m. October 5. There were more slides at the pit the forenoon of October 6 and examination of Halemaumau October 7 and 8 showed that falls from the rim had left streaks, the new lava floor is staned with dust from a big slide at the northwest, and a long strip of rim has fallen at the southeast. At that rim also cracks had widened. Small new talus cones were piled at the base of the western wall.

The Observatory seismographs registered 129 earthquakes for the week, and in addition there were spells of spasmodic tremor October 2, 4, 5, 8, and 9. The numbers of earthquakes for complete days midnight to midnight beginning October 3 and ending October 8 were 15, 18, 30, 19, 10, and 16. This shows a distinct frequency maximum on October 5, the day of the very strong earthquake, and does not support the notion that a decrease of frequency precedes violent shocks. This big earthquake began at 9:22 p. m. October 5. No preliminary waves were present to indicate distance of origin. The long slow waves moved the pendulums for an hour.

Seismometric evidence of distance of origin indicated two principal groups of centers, one from 24 to 28 miles from the Observatory, the other from 34 to 37 miles away. There were eight shocks for the shorter distance and seven for the longer. Other shocks indicated distances varying from 18 to 40 miles.

Microseismic motion was slight and tilt for the week was strong WNW. It is of interest to note that for the three weeks of the seismic crisis the tilts at the Observatory have all been northerly with increase of strength first easterly and now westerly. This suggests a swelling pressure under Kilauea.

THREE WEEKS OF HAWAIIAN EARTHQUAKES

The earthquakes that began in West Hawaii September 19 reached maximum of frequency the last week of September and have declined irregularly since that time both in frequency and in intensity.

The outstanding event of the first week of October was a very strong earthquake at 9:22 p. m. October 5, 1929, which was more disastrous than the one of September 25. There is good reason for believing also that it was more intense, as its effects in cracking roadfills and overthrowing embankments at the road spurs in North Kona introduced new phenomena. For the rest, the effects on buildings extended the damage for masonry and water tanks to Waiki and Waimea, while in Kona the long siege of shaking had weakened foundation posts, walls, and tanks with some 200 shocks recorded as sharp prior to October 5. Many of these had been very hard jolts, usually with maximum fling down the mountain slopes as shown by the collapse of hundreds of stone walls in a seaward direction.

Thanks to the Naval Air Service the writer inspected the districts of South Hilo; Puna, Kau, Kona, and South Kohala from an airplane at elevation 10,000 to 12,000 feet in the early morning hours of October 3, traveling approximately 160 miles from Hilo over Kilauea, across the south flank of Mauna Loa, and across the divide between Mauna Loa and Hualalai. The visibility was good, and all the upland of the three active volcanoes was revealed as showing not a trace of new outbreak. Other flights have since been made by the airmen, and the mountains have been clearly seen repeatedly including this date, October 9. Moreover the seismographs show no trace of continuous harmonic tremor, which is characteristic of fountaining lava.

The big shock of October 5 was reported by an observer in Hilo as no more severe than one of an earlier date. It seemed to last fully a minute, nothing in that house was overturned, no water was spilled from a glass three-quarters filled, and the cement basement was not cracked. Cement is reported cracked in the Federal Building.

In the concrete basement of the Observatory the writer perceived a long, gentle, swaying motion which dismantled the seismographs and subjected them to much strain: there was no jerking. Rocks were heard falling from the Kilauea cliffs and several fresh scars were seen on the high northwestern walls and elsewhere. One or two small cracks in the soil were reported.

In Kealakekua the motion was a heavy jerk, somewhat prolonged, and applied very suddenly. Vertical retaining walls broke on the downhill side of roads and of filled land, stone houses were cracked, tanks burst or were thrown off their foundations, and some weak structures collapsed. Furniture was moved and loose objects were thrown about.

Puuwaawaa Ranch received the brunt of the disturbance as usual, unbraced foundation posts went over, the masonry of the basement of the main house was partly thrown down, new avalanches fell in the gulches of Puuwaawaa Hill, bowlder fences were generally prostrated, and a chimney stump was broken for the second time. The effects suggest Grade IX Rossi-Forel for a radius of nine miles around Puuwaawaa Hill, and Grade VIII for a radius of 20 miles around a point northeast of that hill. Grade VII appears to include the Kohala sugar district and the region of Kealakekua Bay.

The count of felt earthquakes from October 1 to October 6 was 5 to 14 shocks per day at Kealakekua, 17 to 83 shocks per day at Holualoa, and 89 to 241 shocks per day as registered on the shock-recorder at Puuwaawaa. In each case there was decline in numbers during the week, with some revival for the day of the big shock October 5. Prior to the big shock there was a marked lull in frequency during the daylight hours. The seismographic registration gives the following numbers of shocks October 1 to 4 for different places: Hilo 38, 26, 13, 74; Kealakekua 155, 110, 96, 138; Puuwaawaa 241, 117, 97, 114. Each of these thus shows a revival before the big shock of October 5. The intensity relations, obtained by counting the numbers of strongish shocks, indicate a general correspondence between the curve of intensity and the curve of frequency; that is, there were maxima in numbers of strong shocks about September 24-25 and about October 5.

T.A.J.

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No. 251 RELEASED WITHOUT COPYRIGHT RESTRICTION October 17, 1929

KILAUEA REPORT NO. 925

WEEK ENDING OCTOBER 16, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in charge

Halemaumau the inner pit of Kilauea remains quiet and as yet no lava activity has appeared elsewhere, although the felt earthquakes in West Hawaii continue. October 9 the four jets of steam on the northeast rift of Mauna Loa at about 12,000 feet elevation were conspicuous owing to still air, but they have been there for many years without change.

Halemaumau has developed nothing new. The morning of October 10 there were many vapor jets owing to a night of rain. An avalanche fell at the north wall 1.23 p. m. October 11. This left a fresh scar above the northwest talus.

In general Halemaumau shows wet patches on the west talus and the three lava niches of the July fountains at the edge of the black lava floor at the foot of this talus. The south talus has a line of wet fissures with steam up and down its upper portion. The floor extends over the whole bottom area with only a few stones from slides overlapping it. It has a large area of white and yellow stain at its south edge and many cracks. The recent dust stain over the northwest side of the floor has been washed away.

The seismographs at Kilauea registered 97 shocks and tremor spasms, a decrease of 32 from the previous week. The average indicated distance of 39 shocks by Omori's formula is 44.3 miles. This is exactly the distance from the Observatory to Hualalai summit. The number per day October 9-15 was 15, 14, 10, 9, 9, 14, 23, thus showing marked revival October 15.

Microseismic motion for the week was strong. Tilt was slight NNW. The intensity of the earthquakes increased October 14-15 as well as the frequency.

THE EARTHQUAKE CRISIS

Hawaii has now had four weeks of unusual earthquakes centering about Hualalai volcano. There is no question about this epicenter. The local damage shows it, the perceptibility records show it, the instrumental frequency registration shows it, and the instrumental measures of distance show it at three stations Hilo, Kilauea and Kealakekua.

The seismograms of 39 local earthquakes during the past week at Kilauea Observatory, critically measured, indicated 20-30 miles for three shocks, 30-40 miles for 11 shocks, 40-50 miles for 13 shocks, and 50-60 miles for 13 others. The average distance measured is 44.3 miles, exactly the distance of the center of Hualalai mountain. The shocks fall into three principal groups, of distances 34-37 miles, 42-46 miles, and 51-60 miles respectively. These distances correspond to the east, middle and west parts of Hualalai ridge.

The history of the week ending midnight October 15 reports earthquakes in the Kona district diminishing in frequency and strength from October 9 to October 13, and increasing strongly October 14-15. There was a strong shock in Kona 11:35 p. m. October 14, and four strongish ones occurred on October 15 at 9:59 a. m., 1:04 p. m., 5:41 p. m., and 10:05 p. m. At the same time small shakings increased greatly.

At Kilauea the strong shock of 11:35 p. m. was registered as moderate and barely felt, dismantling one seismograph pen. The others registered with 3 to 4 centimeters of amplitude on the seismograms of about 120 times magnification. They would rank as slight earthquakes.

Hilo reported two shocks felt October 8 and 9 each, one each day October 10 and 11, and none October 12 to 14. The Kealakekua observer in Kona reported five October 7, three October 8, two October 9, eight October 10, six October 11, three October 12, and two October 13.

The Kealakekua seismograph showed

59	shocks	and	tremors	October	7-8
94	"	"	"	"	8-9
61	"	"	"	"	9-10
42	"	"	"	"	10-11
41	"	"	"	"	11-12
43	weaker ones			"	12-13
25	very weak			"	13-14

It is of interest to review the whole crisis from September 19 to the present time. The Kilauea Observatory seismographs jumped in their registration from only 9 shocks the week ending September 18, to 221, 244, 129, and 97 the four following weeks. The climax in frequency of local earthquakes was thus the week ending October 2, and the strongest shock of the series came at 9:22 p. m. October 5.

The number of shocks registered at Kilauea, and those of intensity corresponding to Kona earthquakes moderate, strong and very strong, were for the week ending

Sept.	18	Total	9	All	Small					
"	25	"	221	12	Moderate	2	Strong			
Oct.	2	"	244	18	"	12	"	1	Very	Strong
"	9	"	129	9	"	3	"	1	"	"
"	16	"	97	6	"	1	"			

The agreement between frequency and intensity of shakings is good, and the decline in both frequency and intensity during the last fortnight is so pronounced as shown by these figures, that the prospect is reassuring. However there is always a possibility of a very big earthquake when the lava breaks forth in a new place.

The concentration of seismicity at the north side of Hualalai volcano; the waxing of earthquakes in both size and number to a maximum about October fifth; and the persitency of seismic action still, although it seems to be lessening, all imply preparation for a volcanic outbreak as result of the intrusion of basaltic magma underground near the surface. The splitting jerks are now less, perhaps because the mountain fissures are more open, and the earth crust is in tension. Lava outbreak is expectable.

—T.A.J.

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No. 252 RELEASED WITHOUT COPYRIGHT RESTRICTION October 24, 1929

KILAUEA REPORT NO. 926

WEEK ENDING OCTOBER 23, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in charge

There has been no lava activity on Hawaii. Halemaumau pit remains quiet. Wet streaks have been noticed on the wall above the south talus, and higher there is steam at ancient cracks. Small avalanches tumble occasionally.

The seismographs at Kilauea registered 3 feeble earthquakes of the faintly perceptible class, 9 very feeble ones, and 41 prolonged tremors, very feeble, which were small earthquakes at their origin in Kona; total number 53 seismic disturbances as compared with 97 for the previous week. Microseisms were strong and tilt was very slight WNW.

The average distance of nine shocks computed seismometrically was 41 miles, corresponding to Hualalai. An earthquake was strongly felt in Kona about noon October 21. The observer there October 16-19 counted small shakes per day three, four, four, one, as felt. The Hualalai seismic crisis has declined.

VOLCANIC TUFF AND SUGAR CANE ON HAWAII

Studies of volcanic ash and tuff on the Island of Hawaii during the past summer show that the sugar industry is dependent partly on products of explosive vulcanism for its annual $1,250,000 crop. These materials, together with the slightly coarser agglomerate, either aa lava or of explosive origin, form the surface mantle where sugar is grown, and their weathering has apparently been essential to the production of a sufficiently deep and fertile soil on this Island.

On other islands of the Hawaiian group sugar cane grows on soils derived by the weathering of lava rocks, old enough so that a deep soil cover has been developed in those areas which have a moderate to heavy rainfall. The island of Hawaii, is mostly of such recent origin that in few of the areas where aa or pahoehoe lava forms the surface has a soil cover of value for sugar cane culture been produced. In the Kohala district, the sugar growing areas are underlain by agglomerate, made up of small fragments, and much more readily weathered than pahoehoe flow lava. Here the presence of detrital volcanic materials produced by explosive eruptions may be partly responsible for the soil in which cane is grown.

Very little is known as to the actual rates at which either lava or ash might weather under the varied conditions found in Hawaii. The rate of decay on the moist windward slopes, possibly may be ten or twenty times that on drier, leeward slopes. A considerable growth of trees and ferns may develop on lava flows in so short a time as 20 or 30 years under favorable moisture conditions. But the soil condition which will support such vegetation is still far short of that required for the growth and especially for the proper tillage of sugar cane. It may be doubted whether a soil sufficiently deep for commercial sugar production would develop from lava in a period shorter than a thousand years under the most favorable conditions found anywhere in the group.

On the other hand, the fine grained, powdery ash which has been produced at many different times by explosive eruptions on Hawaii, Oahu and other islands of the group has formed a mantle several feet thick over large areas in which weathering must have proceeded much more rapidly. Such material has from the beginning a constitution permitting plowing and cultivating and it seems likely that the finer grained phases of it may become sufficiently leached and modified to permit the growth of sugar cane in a few decades.

The soils of the Hamakua coast and Hilo districts as well as those of the Pahala district have been developed in this way, and the sharp southward limit to sugar growth which follows closely the course of the Wailuku River is the line along which the comparatively young Mauna Loa flows have covered the older ash from the Mauna Kea summit cones. The soils of the Olaa district are mainly derived from agglomerate, partly decomposed aa lava, similar to that of the Kohala region.

It thus appears that if a volcano must erupt and by spreading its product over the land, temporarily interrupt the growth of crops and other human activities, an explosive eruption is much to be preferred to lava. This is apparent if we attempt to compare the value of an acre of land freshly ash-covered with the value of an acre freshly lava-covered. If we take $200 as an average value for good sugar land and from the discussion above assume that perhaps 100 years may elapse before ash-covered land can attain this value through weathering we can easily compute the initial value of the ash-covered land. If the rate of appreciation is fixed at 6% per annum the initial value at the beginning of the hundred year holding would be $0.632 per acre.

Similarly if we assume that lava under favorable rainfall might attain an equally fertile and arable soil in 1000 years its initial value would be a very small fraction of one cent, and even at the end of the first 500 years an area of the size of the state of Texas would be worth only a cent from the sugar viewpoint.

All this is equivalent to saying that, whereas a fresh lava flow is about as worthless agriculturally as any terrane could be, a fresh ash-fall, even of great thickness, has a moderate but tangible worth. The good fortune of the Island of Hawaii is that its legacy was left largely in the form of volcanic tuff which in the twentieth century has attained its financial maturity in a crop worth a million and a quarter dollars. —C. K. Wentworth.

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NO. 253 RELEASED WITHOUT COPYRIGHT RESTRICTION October 31, 1929

KILAUEA REPORT NO. 927

WEEK ENDING OCTOBER 30, 1929

Section of Volcanology, U. S. Geological Survey:
T. A. Jaggar, Volcanologist in Charge

The week has produced no lava activity and the Kona earthquake crisis has continued. Halemaumau pit at Kilauea showed a few new slide rocks on the crater floor west the morning of October 26, but there has been no evident motion there except what the usual small earthquakes will account for.

Seismographs at Kilauea have registered 86 local disturbances divided among 56 tremors, 39 very feeble quakes, and one feeble earthquake at 4:04 p. m., October 29. The average distance for thirteen of the shocks measures 51 miles from the observatory seismometrically, corresponding to the west end of Hualalai volcano. The frequency is higher than the previous week.

Holualoa in North Kona reports numbers of felt shocks for the days beginning October 20 as follows: 6, 69, 5, 2, 8, 2, 1. The seismograph at Kealakekua gave a similar record with about 30 per cent more shocks shown instrumentally. Evidently the volcanic agency that started this seismic crisis is still at work, with marked revivals on such days as October 21 and 23. On these two days there were 41 and 31 disturbances respectively at the Kilauea instruments.

Microseismic motion at Kilauea declined during the week to normal, and tilt was slight NNE. Hilo reports two tremors felt October 18 and three October 21.

VOLCANIC MUD-FLOW IN JAVA

Prefessor B. G. Escher (L'Eboulement Préhistorique de Tasikmalaja et le Volcan Galounggoung, Leidsche Geologische Mededeelingen, Deel I, Aflevering 1, XI 1925, Blz. 8—21) reports on a quantitative study of the missing sector of the cone of Galounggoung volcano in Java, and its relation to the "Ten Thousand Hills of Tasikmalaja" nearby. There have been mapped a total of 3,648 of these hills or hillocks. Escher groups these into categories according to heights (0 to 10, 10 to 20, 20 to 30, 30 to 40, 40 to 50, 50 to 60, and 60 to 70 meters) and computes their total aggregate volume as 142,000,000 cubic meters.

The hillocks are composed of very fine material enclosing large blocks. Various exposures were studied where recent cuts had been made to get out the andesitic blocks for road materials.

The cone of Galounggoung is young and still smooth and nearly perfect except for a wedge-shaped valley sector on the southeast slope. A first glance at the topographic map suggests that this trench is a radial down-sunken block, narrow above and widening down the slope. Escher restored the original contours across the trench and by comparison with the actual contours prepared a map which shows by 100 meter layers the thickness which has been removed. Multiplying by the areas, he gets the total volume of the missing part of the cone as about 2,866,000,000 cubic meters, or about 20 times the 140,000,000 cubic meters of the hillocks.

The aggregate volume of hillocks is far too small to correspond directly to the missing part of the cone. One agency, though a minor one, is erosion that has carried part of the hillocks into the ocean.

A second probability is that the hillocks are only projections from a broad layer of similar rock and mud material. The underlying mixture forms a layer which is at least 20 meters thick at the center though it thins toward the margins of the area it covers. Escher holds that the underlying material and that of the hillocks are due to a single tremendous landslide or mud flow. Where the hillocks are highest is where the moving mass had its greatest energy. Within historic times mudflows caused by rains have produced similar deposits at the other volcanoes in Java. The thickness is difficult to compute. It could only be done where a capping of lava had protected and preserved the whole thickness, and such a capping is unfortunately lacking. It is clear that the volume of the hillocks is not the total volume of the landslide material for the underlying part must be added.

A third point to be considered in connection with the origin of the debris is the nature of the fluid which on its release caused the landslide. The two hypotheses which suggest themselves are that the liquid was lava and that it was water. Escher excludes lava for no lava is found in any of the cuts. It must have been water, which implies that the crater must have had an impervious lining capable of making a crater lake. The barrier must have consisted of alternating beds of lava and explosion material which were held in place by their great weight. Some very unusual condition must have arisen to allow it to be broken. Taverne has shown that the first eruptions of Galounggoung were from a central crater, and that later a new vent opened a little to the southeast which gnawed into the southeast wall of the first crater. A third vent was a little farther southeast and gnawed still more into the southeast wall of the original crater and finally thinned it to the breaking point.

When the crater wall had thinned sufficiently the crater lake broke through and caused an extremely violent and watery landslide. The hillocks represent the fixation of the last materials of the slide, clots that remained standing higher, the principal mass having slowed down because of increasing bottom friction as it spread out fanwise and lowered, and as it lost part of its water. The surficial parts continued their movement for the friction against the air was small.

The air pressure of the resulting landslide wind must have been tremendous and would undoubtedly have annihilated such a town as Tasikmalaja had there been one there at the time. Therefore one can confidently speak of the landslide as prehistoric for such an event would surely have been recorded had there been any written records.

It is not specifically so stated by the author, but the reviewer concludes that the volume of the hillocks plus the volume of the underlying layer of similar material may well be equal to the volume of the missing sector of the cone.

HAROLD S. PALMER

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No. 254 RELEASED WITHOUT COPYRIGHT RESTRICTION November 7, 1929

KILAUEA REPORT NO. 928

WEEK ENDING NOVEMBER 6, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

All has remained quiet in the volcanic districts of Hawaii during the past week. Small earthquakes have continued in the North Kona District with some slight revival about November 4, the shocks as usual being feebly felt in Hilo.

On Thursday, October 31, about 1:30 p. m., a considerable avalanche fell from above the northeast talus in Halemaumau crater. The wall continued to work during the afternoon and two more slides were reported about 3 p. m. These breaks in the wall left a scar noticed on November 2, and there was new dust on the northeast edge of the July lava floor. This was whitish pink and similar fresh material was seen on the east talus slope. A lump had been left in relief protruding from the red boss in the middle of the eastern wall.

On the morning of November 4, at 9:30 a. m., there had been more than two inches of rain and all walls of the pit were dark red with moisture while many small steam jets arose from cracks of the crater floor. The steam was specially conspicuous at the several sulphurous spots of the floor. A few rocks were heard falling on the north talus. At 10:15 a. m., November 6, dust rose from a slight slide at the north side of the pit.

The seismographs at Kilauea registered 57 local disturbances, of which 35 were tremors and 21 very feeble earthquakes. One earthquake slightly more intense ranked as feeble at 3:03 a. m. November 5. This and a preceding shock 12 minutes earlier indicated distances from Kilauea seismometrically of only 18 and 12 miles. They were felt in Hilo, and suggest jarrings local to the east side of the island. The distances for nine other shocks registered indicate origins 50 to 60 miles away, corresponding as heretofore in the recent seismic crisis, with the western or northern parts of Hualalai. Microseismic motion was slight, and tilt was slight to the south.

The Kealakekua observer reports many slight tremors and only three earthquakes in the preceptible class. Hilo reports four felt shocks for the week.

LASSEN REPORT NO. 21

TEST FOR ARSENIC AT MORGAN SPRINGS

There are rather persistent rumors that one or more of the individual vents at Morgan Hot Springs, about six miles south of Lassen Peak, are poisonous, because of the fact that cattle have died in this vicinity. The deposits at Morgan Springs contain silica and various sulphates as well as common salt. Because of the latter, they are commonly frequented by live stock. To keep stock away from the heavier deposits of salts, most of the larger springs have been fenced in.

During the latter part of the summer of 1929, the flow from many of the smaller springs was very low and some had ceased entirely. The quantity and temperature of the discharge from the larger springs were about normal. The incrustation of common salt, alum, and other material around the springs was heavier than usual, as might be expected during an unusually dry season.

The presence of arsenic in the springs has been offered as a possible explanation of the death of cattle in this vicinity. The Marsh test for arsenic of a number of samples of suspiciously colored water and incrustations from the springs failed to show any trace of arsenic.

Near the springs there is at least one poisonous plant which might account for the known death of cattle. An overdose of alum, epsom salts, and other material mixed with the deposits of common salt might result in the death of stock that used the springs for their source of salt.

CHAS. A. HUFF.

VOLCANOES OF FLORES

An admirable monograph on this subject has been published by Kemmerling accompanied by excellent photographs and maps (Vulk. en Seismol. Meded. No. 10, Vulkanen von Flores, by G. L. L. Kemmerling, Bandoeng, 1929, pp. 138, photos 54, plates 10). There are from 100 to 200 eruption points on the island, the young volcanic mountains making about one half its surface. The cones are arranged in rows either parallel or at right angles to the fold structure of the Tertiary rocks. Volcanism is older at the west. In the east, lines of young volcanic cones trend either E-W or N-S.

There are 14 active volcanoes, the records are scanty, and it appears that lava effusion is still important in the Indian Archipelago. Lava streams and lava plugs are common. Table mountains of loose ejecta have sometimes funnel-shaped explosion craters, which change to kettles with wide bottoms ascribed to a hardening of the central region, and cylindrical pits are rare. Lava slag heaps are very rare.

The volcano regions are comparatively uninhabited. There is indirect danger, however, of collapse near the sea causing huge tidal waves. The lavas are basaltic andesites with feldspars high in anorthite. The recent ejecta are basaltic and underlying gabbro or granodiorite is indicated by fragments.

T. A. G.

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No. 255 RELEASED WITHOUT COPYRIGHT RESTRICTION November 14, 1929

KILAUEA REPORT No. 929

WEEK ENDING NOVEMBER 13, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Volcanic quiet continues in Hawaii. Seismic activity, however, is still going on in the region of Hualalai Volcano. The frequency of local earthquakes there has averaged about the same as the previous week.

At 9:15 a. m. November 9 a few new rocks lay on the northwest edge of the floor of Halemaumau, and a pink streak up the wall above, as well as fresh purple dust below, indicated a recent slide. The dust on the northeast floor had washed away. A circuit of the pit November 10 at 3:30 p. m. showed that much steam rises from the middle and the top of the large west talus cone as well as up the middle of the south talus. This last line of steam jets curves eastward into the wall above. About 4 p. m. there were two small falls of rock at the west and northwest walls.

The seismographs at Kilauea registered 62 local disturbances for the week. Of these 32 were tremors, 28 were very feeble earthquakes, and there were two feeble shocks.

These last were felt generally in Hawaii; one was at 8:19 p. m. November 10, indicating a distance of 34 miles, the other at 8:17 p. m. November 11, distance 30 miles from the Observatory. Fourteen records gave an average distance of 44 miles from the Observatory as measured seismometrically, and this corresponds with the location of Haulalai summit.

Tilt for the week was moderate NNE., and microseismic motion was slight.

A VERTICAL MOTION SEISMOGRAPH

For some weeks we have been experimenting in the shop of the Volcano Observatory on a companion instrument for the horizontal pendulums, to register vertical motion of local earthquakes. For seventeen years, with the aid of two Japanese instruments, and with experimental machines optical and mechanical, this problem of measuring vertical motion has been studied here, but without any success in solving it. It is a very old problem in seismology. The vertical motion of an earthquake is smaller than the horizontal motion. To measure it we must secure a mass acting as an up-and-down pendulum, with exactly the same properties as the horizontal pendulums otherwise, in weight, damping, magnification and friction. Then if they register E-W and N-S motion, the new pendulum will register up-down motion, and we can calculate something of the vertical angle by which the earthquake waves emerge from the ground. This in turn furnishes data as to the depth of the local bumping or grating that is the cause of the quake.

The angle of emergence is a very important element of earth motion. Mallet at the Neapolitan earthquake measured it by the vertical angles of cracks across the corners of broken buildings. Dutton at the Charleston earthquake found buildings at the seismic center with the second storey fireplaces telescoped into the first storey chimney-piece. The thrust there was upward. By Mallet's theory the buildings more distant from the seismic center would be more vertically cracked, those nearer to the center would show cracks more nearly horizontal. Angle of emergence was of great practical importance in the earth waves that destroyed stone fences to the value of many tens of thousands of dollars in Kona recently. The walls were flung over in the direction away from the mountain in many cases, which was also the direction away from the seismic center. There is needed an instrument less crude than the breaking of masonry, for measuring this angle, and for measuring it during all the different phases of the progress of the earthquake.

The obvious answer of all machinists has been a spiral or flat spring with a weight on the end. Many vertical motion seismographs have been made this way. But unfortunately springs are also thermometers, so much so that in the Wiechert vertical instrument a temperature change of one tenth degree moves the writing pen three centimeters. This is compensated by a lever holding the spring supported by iron and zinc rods which expand on warming. To get a slow natural period in a helical spring seismograph, where the spring is counteracting gravitation, the usual method is to attach a horizontal rod to the support at a hinge-line, weight the end of the rod remote from the hinge, attach a spiral spring vertically to a support above the rod, and then attach the lower end of the spring to the rod so that the angle ULH (upper support, lower attachment and hinge) is so much less than 45 degrees that instability begins to set in. The weighted rod sways up and down on the spring, and at the lower part of its journey it tends to flop. When this is the adjustment, the natural period may be slowed to six or seven seconds. Meanwhile the stiffness of the spring, the weight to be carried, the size of the spring, and the frictionless quality of the hinge all play their parts.

What we need in Hawaii is a vertical moving pendulum with a mass equilvalent to 225 pounds, eight inches from the hinge line, a natural period of six seconds, a magnification at the pen of 120 times, complete correction against temperature change, against horizontal motion, and against tilt of the ground, and with recording mechanism, damping and friction identical with the Hawaiian type horizontal instruments. The experiments have been made with a small model, and then with a full size model wherein a variety of spring arrangements have been installed having in view temperature correction. Further progress will be reported from time to time. T.A.J.

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No. 256 RELEASED WITHOUT COPYRIGHT RESTRICTION November 21, 1929

KILAUEA REPORT NO. 930

WEEK ENDING NOVEMBER 20, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

There are no changes in the dormancy of Hawaiian volcanoes. Kona continues to feel about one earthquake a day, but the seismic activity has greatly declined.

Halemaumau has shown no changes except increase of steam due to heavy rain. Mauna Loa at 7 a. m. November 20 showed two remarkable convection clouds, each with pine-tree shape, a narrow stem with widened tabular top. One of these was over the summit crater, and the other over the steam-jet region of the northeast rift. Both were mere rain clouds induced by peculiar still atmospheric conditions, and both disappeared in the course of 20 minutes.

The seismograph at the Observatory registered 28 local disturbances and one distant earthquake. There were 16 very feeble shocks of which 5 indicated origin distance averaging 46 miles from the Observatory. The other local movements were tremors. The distant earthquake began at 7:39 a. m., November 15, recorded about 36 minutes, and showed imperfect phases. Microseismic motion was slight, increasing to strong at the time of the easterly wind storm November 17-18, and diminishing thereafter. Tilt for the week was slight SE.

EARTHQUAKES DUE TO MINE COLLAPSE

Earthquakes became numerous on the Witwatersrand mining district after 1907. (The Rand's earthquakes, by A. G. Boyden, South African Mining Review, December, 1928, p. 328.) Loss of life underground is occasioned by these disturbances, falls of rock trapping and crushing the miners, the collapse being the effect of the earth movement. The Rand syncline is unstable owing to many dykes and dislocations, the mine excavations constitute a belt of weakness many miles long and nearly a mile deep, and earthquakes have increased as this belt settled.

On the surface the major tremors have been alarming, but damage to property above ground has been slight. The following is the record of underground accidents:

Year	Local Tremors	Accidents	Killed	Wounded
1923		71	44	83
1924		79	45	76
1925	484	168	28	160
1926	528	137	34	143
1927	666	143	32	161
1928 (10 months)	558	130	22	168

The quakes are believed due partly to slipping on faults and dykes making frictional vibration, and partly to the reaction of a hammer-like blow of a large mass of falling rock for which this slipping is responsible. The collapse is taking effect in many ancient workings, and the jarring results in "rock-bursts" at the live workings, the yielding of pillars of ore left to support stopes. There are also "rock punches," when hard columns break through softer rock below them.

Committees appointed at three different times have grappled with the situation. Seismographs have been set up. The ore pillars have been replaced by timber and stone packs, designed to let the stopes close gradually. Another device was to fill the worked-out cavities with sand sent down fluid through pipes or bore-holes. This must be done on a large scale to lessen the big falls of "hanging wall." It seems the best procedure for preventing loss of life. An instrument is needed, delicate enough to detect increasing strain in the rock. The miners themselves hear and feel dangerous ground. T. A. J.

EARTH TILTING IN TOKYO

An Omori tiltometer compared with the registration of an Ishimoto clinograph (On the Tilting of the Earth Observed at Tokyo, by S. Haeno, Proc. Imp. Acad. IV, 1928, No. 4, p. 151) gave a daily and annual variation in approximate agreement with the corresponding variations of the earth's temperature at a depth of 10 cm. No agreement was found between tilting and precipitation nor between tilting and barometric pressure.

The daily variation exhibits a plumb-line swing counterclockwise ESE in the morning, WNW. in the forenoon and afternoon, and ESE again from about 4 p. m. to midnight. The plumb-line swings in a flattened elliptic curve with major axis 0.57 second N. 80°W.

The annual variation of tilt causes the plumb line to describe a clockwise swing N. 50° E. from July to February of 10 seconds, and SW. from February to July, with marked departures from regularity. The minor axis of the ellipse described (annual NW.-SE. variation) is 3 seconds. The abnormal movements may be connected with seismic phenomena. Agreement is close in direction and amount of annual tilting between Tokyo and Kilauea (Bull. Haw'n. Volc. Obs. Dec. 1927, fig. 48). T. A. J.

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No. 257 RELEASED WITHOUT COPYRIGHT RESTRICTION November 28, 1929

KILAUEA REPORT NO. 931

WEEK ENDING NOVEMBER 27, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The week has been uneventful at the Hawaiian volcanoes and the seismic activity in North Kona has continued to decline, though the registered earthquakes continue to indicate a source near Hualalai Volcano.

Halemaumau showed no changes November 20 and the next day appeared unaffected by a small earthquake which occurred that evening. Rock falls were heard at the pit at 12:08 p. m. November 24 and 7:45 a. m. November 26. They were heard at the Observatory because of the southerly wind. A very heavy rainstorm from the southwest with repeated wind thunder, and lightning crises between November 23 and November 26 flooded the country and coated Mauna Loa and Mauna Kea with snow. Consequently much steam rose from Halemaumau November 25, and after more than seven inches of rain for the 24 hours preceding the forenoon of November 26, the road near Keanakakoi was washed out. The July floor of Halemaumau showed about 25 new vapor jets clustered in front of the cone made by the lava fountain at the west, there were many scattered steaming places on the floor, and the stained areas at the floor edge south and northwest were steaming conspicuously. The walls of the pit were also steaming. The rock falls made a fresh scar at the west.

The Observatory seismographs at Kilauea registered 32 local disturbances, of which two were feeble, 12 very feeble, and 18 tremors. The two feeble shocks were in the perceptible class, and one of these at 8:29 p. m. November 20 was strongly felt in Hilo and feebly felt near Kilauea. Its indicated distance to origin was 12 miles. The other shock at 6:59 a. m. November 24 was felt strongly in Kona and had indicated origin distance 40 miles. The average origin distance of five such Kona earthquakes for the week was 48 miles, corresponding as recently during other weeks, to Hualalai Volcano.

Tilt for the week was moderate ESE., and microseismic motion became strong November 22-25, declining thereafter.

THE TENGGER CALDERA

Many craters in different parts of the world have the character of a large cauldron miles across surrounded by cliff walls, floored with the products of several inner vents, and broken at one side by a radial valley leading down the mountain. The radical valley is not an essential, but is common. In Java and Bali there are four notable calderas of different sizes, Idjen of diameter 16 km., Batoer 14 km. (Volcano Letter No. 215), Tengger 8 km., and Roeang 2 km. Escher defines caldera as "A very large steep depression with a flat floor in the top of a volcano, the diameter of the upper rim being much larger than that of necks." by "necks" are meant the inner conduits up which lava rises, these being smaller units than the whole caldera.

The caldera conception may be very well illustrated by Mokuaweoweo and Kilauea in Hawaii, each over 5 km. across and containing inner pits or cones that lie over necks. The Kau Desert is somewhat like a radial valley leading from Kilauea Crater.

Calderas have been subjects of controversy in geology. The disputes concern the question whether the large orifice overlies a magma column of that large size, whether the large cauldron was produced gradually or by a single titanic eruption, whether it was made by the up-welling and sinking back of lava, whether it was made by a gigantic explosion, whether it could have been made by gradual down-faulting and this be related to a down-faulted sector that made the radial valley, or finally whether it was produced by a plexus of causes not always the same in different cases. The last seems most reasonable, and is the moderate viewpoint of Dr. Escher in discussing Tengger (Vesuvius, the Tengger Mountains, and the problem of Calderas, by B. G. Escher, Leidsche Geol. Meded. Deel. II, pp. 51-114, 1927, Royal Geological Museum of Leiden).

The Tengger is a large crater ring in eastern Java near the resort Tosari, and famous for the activity of the crater Bromo and the wonderful photographic views which have been made of the sand-sea, the great smoking volcano Smeroe, and the marvelous landscape of the huge caldera which surrounds Bromo.

Bromo is in the Tengger caldera along with four other smaller craters. Off to the northeast extends the Sapikerep Valley leading away from the caldera. The older explanation was that there was first a big double volcano which had an enormous eruption accompanied by engulfment and such lava flows out through the valley as to break down that side of the mountain. Then came deposits of loose materials and finally younger lava filling through small new vents inside the caldera.

Escher was greatly impressed by the scouring effect of the gas phase in the eruption of Vesuvius in 1906 which he calls an eruption of the Perret type. He draws analogy for explaining Tengger from the sequence of events in Vesuvius between 1906 and 1926. This sequence in Vesuvius was (1) a small high crater, (2) the big eruption and the large deep crater, (3) crumbling walls, (4) building up the inner floor, and (5) high crater floor, one principal inner cone, some smaller cones and some lava domes.

The history of Tengger was probably as follows: (1) a twin volcano 4,000 meters high with one strongly developed erosion valley, (2) a gas phase in the eastern of two craters scoured out a deep funnel, (3) a gas phase and collapse funnel in the western crater, (4) lava overflowed this western crater into the eastern one and later into the radial valley, (5) a repose period, valley erosion, and subsidence of the eastern crater lava, (6) minor activity in the five inner craters of which Bromo is the survivor.

Assisted by Kuenen the author carries out experiments in gas erosion of upright funnels through sand with a compressed-air blast to make cylindrical and other chimneys by gas erosion. The paper contains striking maps, photographs, and block diagrams showing stages in the crateral evolution T.A.J.

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No. 258 RELEASED WITHOUT COPYRIGHT RESTRICTION December 5, 1929

KILAUEA REPORT NO. 932

WEEK ENDING DECEMBER 4, 1929

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

Seismic conditions on the Island of Hawaii remain unchanged. Fewer earthquakes were recorded this week, but distances indicate sources in the North Kona District of west Hawaii.

Kilauea Volcano has had some increase of steam activity at the various vents in and about the outer crater and in Halemaumau pit, due to southerly rainstorms. Small rock falls from the walls occurred from time to time, but no large avalanches have been noted or reported. At 3:10 p. m., November 27, after heavy rain, there was only one spot with vigorous steam, the sulphur stain on the southeast floor of the pit. A fresh scar was noticed on the east wall, and a slide was heard in that region. On November 30 at 9:30 a. m. much steam was coming from cracks on the floor, thickest at the southwest stained area. On December 2, about 9:30 a. m., there was a small avalanche over the north talus, and steam was still noticeable at the southwest sulphur stain. At 11 a. m., December 4, more slides were heard from the north wall, one from the rim sliding down the niche at the north end of the big sill. This part of the pit shows by scars that it has more slides than other sections have. Little steam was to be seen. Cracks of the lava floor are stained brown, giving them clear outline.

Twenty-five seismic disturbances were counted on the seismograms of the Bosch-Omori instruments, classified as follows: 10 tremors, 13 very feeble earthquakes, and 2 feeble earthquakes. One of the feeble earthquakes, at 2:06 p. m., December 1, was reported felt in Kona; it had indicated distance to origin 42 miles. Seven earthquakes showing distance phases give an average distance of 46 miles from the Observatory, corresponding very closely to average distances of previous weeks.

Tilt for the week accumulated slightly to the southwest. Microseismic motion was slight.

THE MURCHISON EARTHQUAKE, NEW ZEALAND

On the 17th of June, 1929, the South Island, New Zealand, was shaken by an earthquake which had its center in the northern part of the island near Murchison. The intensity of the shock is reported as VIII on the Rossi-Forel scale, as chimneys were shaken down and masonry walls cracked through an area over a hundred miles in diameter (Geological Reconnaissance in the Murchison Earthquake Area, by H. T. Ferrar and L. I. Grange, New Zealand Journal of Science and Technology, Vol. XI, No. 3, 1929, pp. 185-191). After the initial shock which did the damage the "northwest corner of the South Island continued to creak like the deck of a ship for weeks" due to the gradual release of earth-stresses.

The authors review the New Zealand earthquakes of the past and point out that, in most cases, they were associated with movements on fault-planes which were known to geologists to be active faults. A reconnaissance of the area disturbed by the quake of June 17, however, showed that earth movement had occurred only along the White Creek and Kongahu fault-zones, both classed by geologists as dormant faults. Further, most New Zealand faults are concave toward the upthrow block, whereas the White Creek fault is convex toward its upthrow side.

Marked differences in the extent of damage in different localities within the disturbed area are cited and explained in general by the effect of geologic structure on the transmission of the earthquake waves. For instance, Blenheim seems to have been protected considerably by the Wairau fault-plane which passes between that town and the quake center on the White Creek fault.

The disturbance on the Kongahu fault upraised a considerable area of sea-floor in the vicinity of Whitecliffs. This area is to be studied in detail next summer. The movement on the White Creek fault has been studied by H. E. Fyfe and is reported in the same issue of the Journal (Movement on the White Creek Fault, New Zealand, pp. 192-197).

The White Creek fault is the eastern one of two almost parallel faults which bound a strip of Tertiary rocks, inset by the faults in granite country rock. The dip of the plane is nearly 90 degrees, and its trace is slightly concave to the west trending slightly east of north. It has been known as a dormant fault for several decades. The fault is located about seven and a half miles west of Murchison.

At its intersection with the fault-plane, the Murchison-West Coast road was offset vertically 14 feet 9 inches, the east side of the fault having risen relatively to the west side. There was no detectable horizontal movement. The trace of the fault was clearly marked by shattered ground and disturbed vegetation for a distance of at least three miles.

Data obtained by releveling part of the Nelson-West Coast railway show that the level of the country east of the fault-line has been changed for a distance of about nine miles from the fault. At the fault, the eastern block was found to have risen 14 feet 9 inches, the total throw of the fault. The maximum measured increase in elevation of the eastern surface was 16.08 feet, about 25 chains east of the fault.

A graph showing the nature of displacement along the White Creek fault is compared with the graph by Reid illustrating the displacement of the surface along the San Andreas fault after the 1906 earthquake. In the California quake, the movement was horizontal and the total displacement was divided between the two blocks so that each block moved relative to a fixed point in the fault-plane. The movement along the White Creek fault-plane was vertical and, according to the data at hand, the entire displacement is accounted for by the upthrow of the eastern block. The author postpones his discussion of the application of Reid's elastic-rebound theory until the whole White Creek area has been releveled and the absolute movement of both blocks determined. H. A. P.

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No. 259 **RELEASED WITHOUT COPYRIGHT RESTRICTION** December 12, 1929

KILAUEA REPORT No. 933

WEEK ENDING DECEMBER 11, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Everything remains quiet at the Hawaiian volcanoes. At Halemaumau pit a slide on the north side at 11:05 a. m., December 10 made a roaring noise and produced a small dust cloud. A bigger avalanche occurred at noon, December 11, making a loud roar and sending up dust which remained visible for 15 minutes.

Seventeen local earthquake disturbances were registered at the Observatory. Nine of these were tremors, 8 were very feeble earthquakes, and 5 of these indicated distances averaging 47 miles from Kilauea. The duration of the most prolonged of the tremor spasms was 2 minutes. Tilting of the ground accumulated moderately to the west, and microseismic motion was slight.

LASSEN REPORT No. 22

Lassen Volcano Observatory, Mineral, California

R. H. Finch, Associate Volcanologist

During the afternoon and evening of November 17, 1929, eleven earthquakes were registered on the seismographs at Mineral. Another shake occurred during the early morning of November 18. Two of the earthquakes were plainly perceptible. The one that occurred at 7 p. m., November 17 gave buildings a sharp jolt. The disturbances can undoubtedly be classed as Lassen shocks as the indicated distance to origin, 12 miles, is equal to the distance to Lassen Peak from Mineral.

NOTICE

Recipients of the Volcano Letter are requested to examine the address on the envelopes and to notify the Hawaiian Volcano Observatory of any changes desired.

MAYON VOLCANO

On July 1, 1928, Mayon, the "Fujiyama" of the Philippines, was in mild eruption, sending blocky incandescent lava flows from notches in the rim of the summit crater, and emitting dust laden steam. Chlorine and sulphuric acid were found in the dust. The climax was reached about July 20, and in August the volcano reurned to its normal state, emitting steam vapors (Mayon Volcano and its Eruptions, by Leopoldo A. Faustino,, Phil. Jour. Sci. Vol. 40, No. 1, Sept. 1929, pp. 47, 24 illustrations). The lavas are andesitic basalts, with plagioclase, augite, hypersthene, magnetite, and hematite.

Mayon is in southeastern Luzon, 23 hours by rail from Manila. It is 2,421 meters high, and has had 28 eruptions in 114 years since a destructive eruption in 1814. There were two long quiet periods, 1814-27 and 1900 28. The normal condition is continuous mild activity. The most violent eruptions are followed by the longest periods of rest. The beautiful cone has never been destroyed, and the conduit has always been in the center. The losses of life have been by asphyxiation, dust blasts, overpowering incandescent slides, flood, and earthquake. The last two are secondary. The incandescent slides appear to be thrusts clear to the sea of unbalanced slopes attacked by radial aa flows above and bombardment of falling material. The lava flows follow the steep gulches and rise above them, forming ridges where trenches were before.

There were disastrous outbreaks in 1814 and 1897. The greater damage was the overwhelming of shore villages by a torrent of "fire, lava, and large hot stones." Two great disasters by flood and typhoon, in 1766 and 1875, were occasioned by heavy rainfall causing the unstable volcanic slopes to wash down to the sea as mud flow, with high mobility and great rapidity. Thousands perished and much property was destroyed. The path of the waters was an expanse of bowlders and sand, with pieces of wood, to mark the place where was once a thriving community.

The events in 1928, after 28 years of quiet, began with rumblings in January. June 16 the steam jets increased in volume and crater glow was seen. Dust "cauliflowers" began June 24. Incandescent flows overlipped the crater June 27. Army fliers June 29 circled the crater at 2,500 meters, and photographed the cauldron at 200 meters distance. They felt the heat strongly, inhaled sulphur, and estimated the crater diameter at 500 meters. It was circular, with vertical inner walls, a deposit of cindery material on the sides, and a pool of bubbling hot lava in the center. The rim is notched with a main chute or horseshoe opening on the eastern side. Aluminum sulphate and sulphur are common in the crater during quiet times.

Fragments were shot into the air, reports were heard, lava poured out through the notches in the crater wall and followed the gullies, forming snakelike trickles radiating from the summit. The molten material crusted over and cracked, and the impact of falling glow-stones made fireworks.

At the end of June the lava streams lengthened, resembling red hot glaciers covered with moraines. Black clouds of dust-laden steam swept down the mountain. The explosions waxed and waned until July 20. Hollows filled with the molten material and the junction of two valleys assumed the appearance of a subordinate crater. July 16 volcanic materials were descending the northern slopes. There was periodicity of three to five hours in the spells of roaring, hissing, cracking, and tumbling noise. At the climax there was a spectacular evening display of bombs describing parabolic curves of fiery rocketing at the summit. A column of heavy dark clouds rose 8,000 meters above the summit, the top of the mountain was rose red, brilliant lightning flashed from dustcloud to dustcloud, and streams of lava flowed in all directions. Sometimes the column moved spirally. When the wind arose, "the volcano appeared like a gigantic locomotive puffing on a heavy grade." T. A. J.

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No. 260 RELEASED WITHOUT COPYRIGHT RESTRICTION December 19, 1929

KILAUEA REPORT NO. 934

WEEK ENDING DECEMBER 18, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

No lava activity has occurred, but stormy weather has produced much steam in Kilauea Crater. On December 12, at 1:19 p. m., a steady roar from Halemaumau pit was heard at the Observatory caused by an avalanche lasting several seconds, which finally sent up dust above the east rim which drifted toward the north. A prolonged very feeble earthquake movement registered on the seismographs coincided with the slide.

A southwest rainstorm December 16 flooded the country and condensed much vapor over Kilauea and Halemaumau. Violent wind wrecked the Observatory weather-vane at 10:05 a. m. At noon, December 18, the pit was quiet and in spite of rainy weather there was hardly any steam on the south talus. Fresh debris lay on the north and east talus cones.

The Observatory seismograph registered 13 local disturbances during the week, of which nine were very feeble earthquakes and four were tremors. Seismometric evidence for five shocks indicated an average distance of 48 miles for the location of the origin. This corresponds to North Kona as in other recent weeks, and earthquakes are still felt in that district.

Tilting of the ground at the Observatory was moderate SSW. Microseismic motion increased December 16, accompanied with wind tremor. With the change of wind to northeast December 17, the microseisms remained large and rythmical.

A large distant earthquake was registered December 17, beginning 12:37 a. m., the preliminary phase indicating distance of origin 4,300 km. (2,600 miles). This distance corresponds to the north end of the Tonga Deep, the west end of the Aleutian Deep, the cordilleran belt of the west coast of North America, or the west end of the Alaskan Peninsula. The Kodiak station reports fire and smoke from three volcanoes between Kodiak and Unalaska.

THE CENTER OF THE TOKYO EARTHQUAKE

Professor Imamura, Director of the Seismological Institute of Tokyo Imperial University, has just published a brief summary concerning the most recent information about the location of several centers for the great Kwanto earthquake of September 1, 1923 (On the multiple source of origin of the Great Kwanto Earthquake of 1923 and its relation to the fault system connected with the Earthquake, by A. Imamura, Proc. Imp. Acad., Oct. 1929, Vol. V, No. 8, p. 330).

It was found that the Tango earthquake of 1927 had a double source of origin. It may be that the Tokyo earthquake had a multiple series of epicenters. The seismic waves that caused such widespread destruction emerged from at least three different places, along a line NE-SW. beginning at the middle of Sagami Bay. Two of these points were in the bay and one in the mountains north of Fujiyama. The first break was from the middle of the bay, the second from the mountains three seconds later, and the third, 7.5 seconds still later, came from the head of the bay west of Kamakura. Everything that succeeded these early phases of the earth motion, if the process repeated itself, was masked by the exceptionally large earth movements that lasted for more than a minute.

The Seismological Institute at Tokyo stood broadside to the big NW-SE. trending faults, and so with several pairs of seismographs could interpret the direction of motion of the earliest phases.

Imamura has continued the work of the late Professor Yamasaki in mapping the fault systems surrounding the epicenters. These have been interpreted in connection with precise leveling and triangulation. There emerges from this mapping a series of east-west faults across the Bosyu Peninsula and the eastern part of Sagami Bay; a series of very big faults along the volcanic axis NW.-SE. extending from the bay to the mainland along the Oshima-Fujiyama belt; and a series of N.-S. faults tending to curve westward in the entrance to Tokyo Bay and in the region west of Yokohama. Fifteen faults and flexures have been worked out with lengths varying from 1 to 22 km. and vertical displacements varying from 0.3 meter to 20 meters. Some of these topographical changes accompanied the first earthquake and others were probably adjusted along with the big after-shocks.

The details of these movements are worked out in accordance with the strength of effects and sensations in different places, and with seismogram records in different places. A map is presented exhibiting the directions of initial motion as recorded on seismographs all over central Japan, and the facts seem accordant with two main epicenters, one in the bay and one on the mainland. The time-distance curves of the preliminary tremors also accord with the double origin.

Imamura concludes that shearing stresses tore asunder the bottom of the bay on a weak zone and then leapt to the Tanzawa Mountain to release a second violent rending of the earth's crust. This was succeeded by a still bigger collapse in the bottom of the bay, when the whole countryside was thrown into agitation. It will be seen that this analysis is totally different from Imamura's earlier theories which attributed the earthquake to tectonic movements under the Pacific off to the east. T. A. J.

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THE VOLCANO LETTER

A Weekly news leaflet of the Hawaiian Volcano Research Association

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No. 261 RELEASED WITHOUT COPYRIGHT RESTRICTION December 26, 1929

KILAUEA REPORT NO. 935

WEEK ENDING DECEMBER 25, 1929

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Kilauea remains quiet. There are no avalanches. A white stain has appeared in a niche of the wall at the top of the northwest talus. On wet days fog has condensed over the pit and in it, but the steam on the talus slopes has diminished.

The Kilauea seismographs have registered 10 tremors and 3 local earthquakes, making 13 disturbances. Two of the local shocks indicate distances of 34 and 51 miles. These were felt in North Kona. Microseisms were slight, and tilting of the ground was stationary.

The distant large earthquake of December 17 is located by "Science Service" at the west end of the Aleutian Deep, near Attu.

A BIG ATLANTIC EARTHQUAKE

A powerful movement of the earth crust under the Atlantic Ocean along the steamer track between New York and Liverpool is unusual. Such an earthquake recalls the Charleston disaster of 1886. This is not a place of deep holes under the ocean like the earthquake centers off Japan and Chile.

The shock occurred about 3:40 p. m., eastern standard time, November 18, 1929, 180 miles south of the Newfoundland coast, off the edge of the continental shelf, and probably moved a large area of sea bottom. The bottom is fairly steep, and possibly submarine landslip accounted for the breaking of Atlantic cables in several places. The location of center was about lat. 44° N., long. 58° W.

The first reports told of very heavy shocks in Nova Scotia lasting for many minutes. Halifax was severely shaken. In Windsor chimneys were knocked down and dishes were broken. In St. John's, Newfoundland, the shock was only "half a minute" long, and not so strong, but the Burin Peninsula in south Newfoundland received a violent shaking. From Boston to Maine in the United States the phenomenon was described as "sharp earthquake shocks."

The big steamship "Olympic" was 300 miles from the center, and the captain felt the vessel suddenly quiver, as though she had lost a propeller blade, and this was followed by vibrations for two minutes. The ship was found to be uninjured.

Sea waves piled into the Newfoundland inlets along the west shore of Placentia Bay two and a half hours after the earthquakes. Burin and La Maline bays were most damaged. At Burin whole families were trapped at their dinner tables as a wall of water 15 feet high swept inland Boats and schooners were lifted from their moorings and dashed against the waterfront buildings and wharves. A mother, who was with her two children alone in her home, rushed to the door to learn the cause of the roar of waters. When she ran back to rescue the children, the wave broke over the house, drowned them all, and washed the wreckage out to sea.

Women and children were the greatest sufferers, as the men were away with the fishing fleets. Nine lives were lost at Burin, and 17 others at Lord's Cove and La Maline. In Long Harbor, at the head of a narrowing inlet, fishing booms and weirs were damaged and 75 yards of roadway were destroyed.

Twelve out of 22 telegraph cables in the epicentral earthquake area were fractured, and 10 of these cross the ocean. Two Western Union cables were severed at 90 fathoms depth off Nova Scotia, and a third at a depth of 900 fathoms. Thus the dislocation of the sea bottom was distributed. Davison reports (Nature, Nov. 30, 1929, p. 859) that such an earthquake occurred in 1884, breaking three cables along a straight line on the southeastern slope of the Newfoundland Bank, and that probably the present earthquake had a multiple origin.

Boston was 700 miles from the supposed center, and the U. S. Coast Survey (Science News, Science, Nov. 29, 1929, page X) estimates perceptible shaking over a million and a half square miles, and strong shaking over 200,000 square miles. This is a very large disturbed area, and yet not the slightest trace of this earthquake appeared on the Bosch-Omori seismograph of magnification x120 at Kilauea Volcano in Hawaii This distance is only 5,800 miles, and yet the Porto Rico earthquake at similar distance recorded clearly on these instruments.

It is 43 years since the last great earthquake (1886) on the Atlantic seaboard of the United States. That one, the Charleston cataclysm, was preceded a year and a half before (1884) by a disturbance breaking cables along a straight line off the Newfoundland Bank. In 1929 there is a new disturbance breaking 12 cables off the Newfoundland Bank.

We do not know what cycle controls the marginal movement of the North Atlantic basin around Bermuda as a center, but these west Atlantic earthquakes are so rare that seismological measurement should be made practical in the eastern United States during the next few years, with special attention to local frequency of small movements.

T. A. J.

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No. 262 RELEASED WITHOUT COPYRIGHT RESTRICTION January 2, 1930

KILAUEA REPORT No. 936

WEEK ENDING JANUARY 1, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

There has been no visible change in volcanic conditions at Kilauea during the past week. Halemaumau pit remains quiet. No new scars are to be seen on the walls and no new slides have been reported.

On December 30 an observer noted that a section of the center of the July grotto had fallen. Steam was noticeably absent at the vents within the pit on this day and on January 1, although rainy weather has been prevalent during the week.

Nine seismic disturbances were recorded by the seismographs. Of these five shocks, of very feeble intensity, gave an average distance to origin of 44 miles. One feeble earthquake, at 11:52 p. m. December 29, indicated an origin 9 miles from the observatory.

Microseimic motion was slight. Tilt accumulated moderately strong ENE.

ACTIVITY OF PELEE, MARTINIQUE

Little has been heard from Martinique since the terrible destruction of St. Pierre in 1902 by volcanic blast from Pelée. This volcano is in the middle of the Caribbee Islands, which extend in a curve from Porto Rico to Trinidad.

September 16, 1929, ash eruptions began again from the crater of Mount Pelée. At 8:45 p. m. September 26 an earthquake lasted a minute and a half at Fort de France. October 14 Pelée burst into eruption more strongly than in September. This calmed down on the 18th, but October 19 the director of the volcano observatory reported for the early morning of that day an outbreak stronger than the two preceding. Gas and ashes were thrown up, and the flashes of light lasted for 10 minutes. Intermittent rumblings and bursts of white steam accompanied the eruption, the dust column rose nearly 4,000 feet, and cinders were showered over the country. The activity occurred at the head of the valley of the Riviere Blanche, just as in 1902, beside the ruins of the famous lava spine which rose in that year.

The complete evacuation of Prêcheur, Saint-Pierre, and Morne-Rouge has been ordered by the authorities. It appears that Saint-Pierre had risen from its ashes by 1923, and possessed 1,000 inhabitants, more than 100 houses, a club, shops, a restaurant, a market, and a custom house. There is a daily steamer from Fort de France, and the town has running water, a sewage system, and is presided over by a mayor. The 1929 activity appeared to have been kindled at about the September equinox, just as was the seismic shaking in Hawaii, but like the latter, it dwindled. New activity is reported in December. (Seismological Despatches, Georgetown University; London Times, Oct. 21; New York Times, Sept. 21 and Oct. 20, Nov. 4.) T. A. J.

REVIVAL OF SANTA-MARIA, GUATEMALA

It will be remembered that the Pelée eruptions of May, 1902, were followed in October of that year by disastrous ash falls and floods from Santa-Maria volcano in Guatemala. In like manner the Pelée outbreak in September, 1929, is followed by a disastrous explosive eruption at Santa-Maria. This volcano is 12,361 feet high.

The volcano dominates the coffee lands of western Guatemala. Between 1922 and 1925 (Volcano Letter No. 87, Aug. 26, 1926) new stiff lava rose in the vast crater which the 1902 eruption had left in the flank of the mountain. The new plug replaced the crater with a lava hill 1,600 feet high and 4,000 feet across. Its top was a cluster of smoking turrets.

We now have despatches of November 5 and 8 which are difficult to interpret because of the newspaper habit of calling everything "lava" that pours from a volcano (Chicago Tribune, Paris, Nov. 5, and New York Times, Nov. 8). The "lava" is presumably glowing ash and mud floods.

On November 4, 1929, after three days of increasing rumblings, hot ash was vomited up about the new plug, probably cauliflower clouds of ash and steam shot thousands of feet into the air, incandescent blasts of falling material were impelled downward, and torrents of rainfall mixed with the hot ash to swell all the streams. Probably there was engulfment of the lava plug and widening of the crater. Heavy showers of ash were still falling November 7. There were destroyed villages, coffee plantations, and farms. El Palmar suffered the most, 21 bodies being recovered there. El Palmar is six miles south of the crater.

In the zone between Mazatenango, 15 miles to the south, and the crater cavity half-way up the mountain, the country is completely covered with ashes, and the air smells of sulphur. The buildings of El Palmar and the farmhouses thereabout still stand. On November 7 there were people still to be seen in the streets. Forty-five deaths are reported as the total, and loss of farm property in the coffee district to the value of one million dollars. Eight coffee plantations were destroyed, and the losses of life appear to be due to suffocation with hot ash, to burns, and to bombardment from falling stones, just as in 1902. Some bodies were found of persons who had climbed trees. The green foliage was burned to a dirty brown.

T. A. J.

The Volcano Letter

Hawaiian Volcano Observatory, National Park, Hawaii

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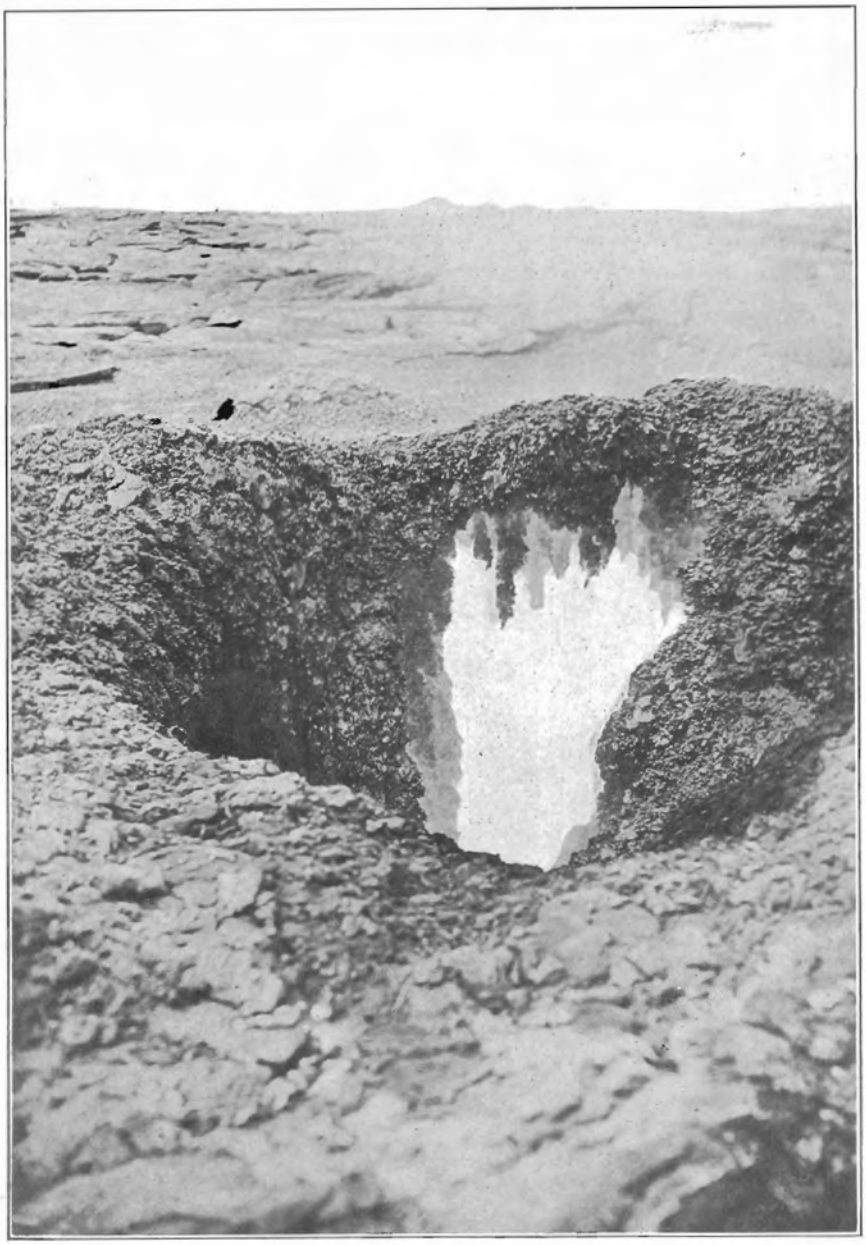
The Volcano Letter

No. 263—Weekly Hawaiian Volcano Observatory, National Park, Hawaii January 9, 1930



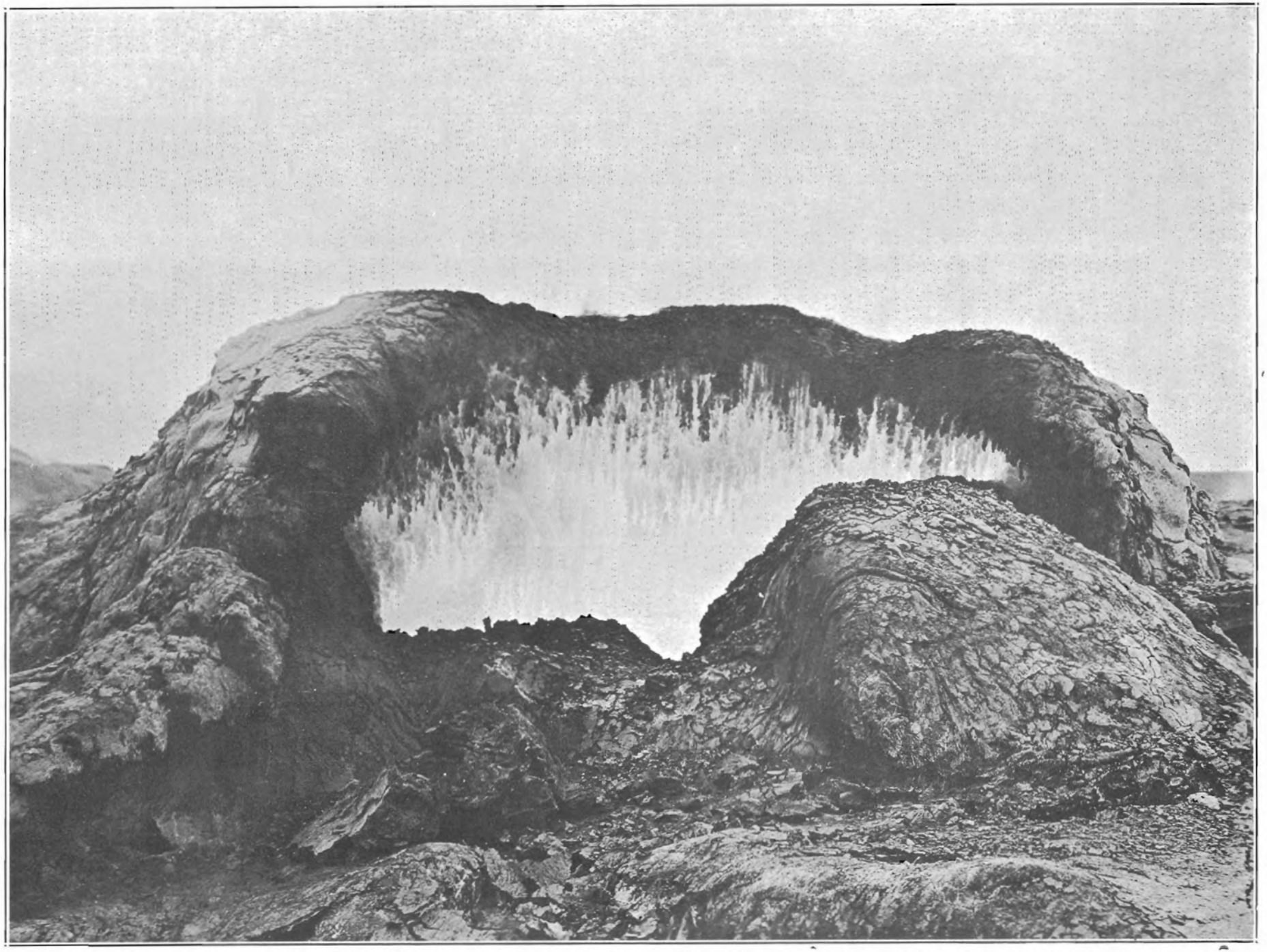
Looking into red hot tunnel hung with stalactites at orifice of eastern breathing cone, February 13, 1919, 11 a. m. This is inside Halemaumau pit on the inner floor when the lava lakes were level with rim of pit. The glowing tunnel connects through to the largest lake, and lava was splashing inside the tunnel. —Photo Jaggar.

BREATHING CONES

The extraordinary lava activity of the year 1919 at Halemaumau, the fire pit of Kilauea, marked the peak of the eleven-year cycle. To a tourist who sees the vast cauldron of today, a thousand feet deep and three thousand feet across, it is hard to realize that glowing molten slag was overflowing the edge of the pit a decade ago. The pit had its definite margin of cold rock, but within that margin and overlapping it there were lava lakes, pots, driblet spires, flow heaps, tunnels, stalactite grottoes, smoke holes, and breathing cones.

The East Cone of the spring of 1919 was a low hillock built up around a lava pot on the inner floor of Halemaumau. Visitors habitually walked over this floor, which extended from the lakes inside the pit area to merge with the overflows outside. This pot was supplied with glowing, gassy melt through a tunnel leading from the main lake. With the rise and fall of the liquid lava a cone was built around the pot, and the interior ceiling of the tunnel became hung with huge gas-glazed stalactites three or four feet long.

One could stand on the rim of this conelet, and gaze into the open pot where lava of bright yellow glow was splashing 15 feet below. Under the lip of the orifice the interior chamber was bright orange with incandescence, hung with the delicately sculptured fiery stalactites



Rift Oven of the Red Solfatara. This photograph was taken by evening light April 4, 1921, with panchromatic plate and deep red filter. The glowing oven, 9 feet high and 20 feet across, stood over the rift about 500 feet outside Halemau mau and remained like this throughout the spring. Photo Jaggar

shaped like long bunches of grapes. By night a banner was visible of blue-green flame fluttering above the orifice sending off pale blue transparent fumes acrid with sulphur.

As a whole during this period the lakes were rising, the inner floor was being overflowed in spasms, and the heaps, cones, and spiracles were building up. The East Cone hissed and breathed and roared at different times. Sometimes it would vomit up its molten stuff like an artesian well, and give vent to a glowing flow. At such times the pot and tunnel were obliterated, only to reappear with the stalactites reforming when the outflow ceased.

The grape-like droplets, and the gray, yellow, red, or brown glazes on the surface of these stalactites are not the result of direct spatter. There are other stalactites in curtains and frozen drip points which are formed by direct splash. The grape bunches, however, and the long worm-like stalactites are formed by the remelting of the roof of the cavern by slow action of the intensely hot burning gases. This burning is converted into a blow-torch effect when air has access to the tunnel so as to convert the combustible gases from the boiling lava into oxidation flames. When air reaches the volcanic gas pipe suddenly, the change in the iron oxides of the glaze may be equally sudden, and a whole cavern may be caused to glow by the access of air alone.

The illustration on the first page shows the East Cone here described at a time when the liquid lava was about 15 feet down. The second illustration shows a similar cone that developed over a crack about 500 feet away from Halemaumau in the direction of the desert to the southwest in the spring of 1921. This cone it was that displayed several times an extraordinary revival of glowing through access of air below while its walls were still hot.

This second cone was called the Rift Oven of the Red Solfatara. It was over the great deep crack that leads from Halemaumau radially down the mountain to the southwest. The two long, black gashes standing vertical in the present wall of Halemaumau as seen by tourists to the left of the visitors' station are where this rift emerges into the pit. It can be readily understood that if lava now rose into those tunnels by the filling up of the pit, and a vertical shaft outside of the pit led from the uppermost tunnel to a cone on the surface, that the gases from the boiling lava in the shaft would heat the cone. This was exactly the situation of 1921. The cone breathed and puffed, lava was visible far down the shaft, pale flame played around the orifice, and sulphurous gas was given off.

There was direct connection between the lava in this well and the lava lakes in the pit, but often the lava in the well by reason of gas frothing would stand much higher than the same liquid in the open pit. The gases kept the well at bright orange glow and maintained the stalactites, even when the heat from the open lakes and the glow above the pit decreased strongly. With the liquid lava 200 feet down the well in April, 1921, the glow was maintained up to the top, in a shaft 10 to 15 feet in diameter, by the action of burning gases. Finally there came a time, however, when the interior of the oven became dark red and even black and the stalactites were seen to be a silvery gray with the black oxide of iron. The hot gases continued to rise.

Now came the extraordinary and dramatic demonstration of what air could do in heating up a volcanic furnace. All this time the lava lakes in Halemaumau had been above the level of the wall tunnel. In July the lava lakes lowered below the tunnel so that a black cavern or arcade could be seen, just as at present, leading into the wall at the southwest. Immediately an air blast, smelling strongly of sulphuric acid came rushing with a roar up the outside well, where quiet gas had been rising before. The shaft, oven, stalactites, and the entire lining of an adjoining tunnel all began to glow again, the tunnel walls becoming red hot away out to its remoter entrance 150 feet away from the rift. Incandescent sparks were visible after nightfall in the blast. Then the furnace cooled off again and within four days the wells and the tunnel were dark, but the steel-gray glaze of magnetic needles of iron oxide, the common lining of such caves, had changed to brick red T. A. J.

KILAUEA REPORT No. 937

WEEK ENDING JANUARY 5, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The current report on volcanic conditions in Hawaii overlaps the preceding one by two days, as it introduces a new series of weekly reports ending at midnight Sundays. This is for convenience in the new series of the Volcano Letter, beginning 1930, prepared at the station on Mondays instead of Wednesdays.

For the week ending January 5, 1930, there is little change in Halemaumau pit. On December 30 part of the July fountain heap had slightly fallen in the middle. There is remarkably little steam emerging from the floor and talus slopes, in spite of recent rains. This is in contrast to the rim cracks outside of the pit, which on January 1 at 2 p. m. sent up much vapor. Much fine material was observed lying thickly on the talus at the north. January 3 much steam arose from the pit, in general blending with the clouds above, and from the cracks of the Kilauea floor. At 9:30 a. m. January 4 there was more vapor at the Halemaumau vents, particularly on the south wall.

Eight very feeble local earthquakes were recorded by the Observatory seismagraphs, and five of these indicated average distance of 44 miles, corresponding as heretofore since September to the distance of Hualalai from the station. One very feeble shock indicated distance of origin 19 miles.

Microseismic motion for the week was slight, and tilt accumulated strongly to the southwest. This tilt is characteristic of the seasonal curves for January.

HAWAIIAN VOLCANOES IN 1929

The end of 1929 finds the Hawaiian volcanoes quiet, but the year has produced three notable activities, two of them volcanic eruptions and one a seismic spasm of extraordinary quality. The first was the influx of new lava in the bottom of Halemaumau in February, following upon similar fillings of the bottom in July 1924 and 1927, and in January 1928. The second 1929 event was a similar influx in July and each of these eruptions of lava leaves a new floor higher than before so that the pit has decreased some 300 feet in depth since June of 1924.

A curve platted to follow the progress of these fillings of Halemaumau in relation to the lapse of time indicates decrease of interval between eruptions, so that the expectation was recorded that lava activity might return in the autumn of 1929 unless the magma were to rise in one of the other volcanoes. There are three of these which are potentially active, Mauna Loa, Hualalai, and Haleakala.

The seismic spasm which began in September and has continued, dwindling, ever since, appeared to confirm this expectation. The evidence of locality points to Hualalai. The shaking was violent in North Kona, reached its maximum October 5, and now has become very slight, but still shows signs of life. The indication is that the underground lava column at the Mauna Loa center, which for many years has vented itself to the southwest, is now pressing up along rifts extending toward the northwest and may eventually find release there.

Meanwhile nothing new has happened in the craters of Kilauea and Mauna Loa. The July lava in Halemaumau pit at Kilauea Volcano solidified with some shrinkage, leaving the scar of its big southwestern fountains in a built-up heap surrounded by pumice and shaped like an armchair, and leaving what was the lake area a lumpy floor surrounded by a rampart. The only changes have been falls of rock from the walls of the pit slightly overlapping the new lava floor with their debris.

Seismic phenomena local to Kilauea have not been remarkable during the last part of the year, and there is nothing in tilt, tremor, or earthquakes indicative of a change of magmatic action under Kilauea Volcano. The avalanching at Halemaumau in December has been remarkably slight. T. A. J.



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Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

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The Volcano Letter

No. 264—Weekly Hawaiian Volcano Observatory, National Park, Hawaii January 16, 1930



The southeastern rim of Halemaumau on February 22, 1918, the day before the pit overflowed the road terminus. The light ground at the right is the rim, the dark foreground is the overflow lava of the fountaining lakes, which are among the crags at the left. The rim rock shows no swelling.

THE SWELLING OF VOLCANOES

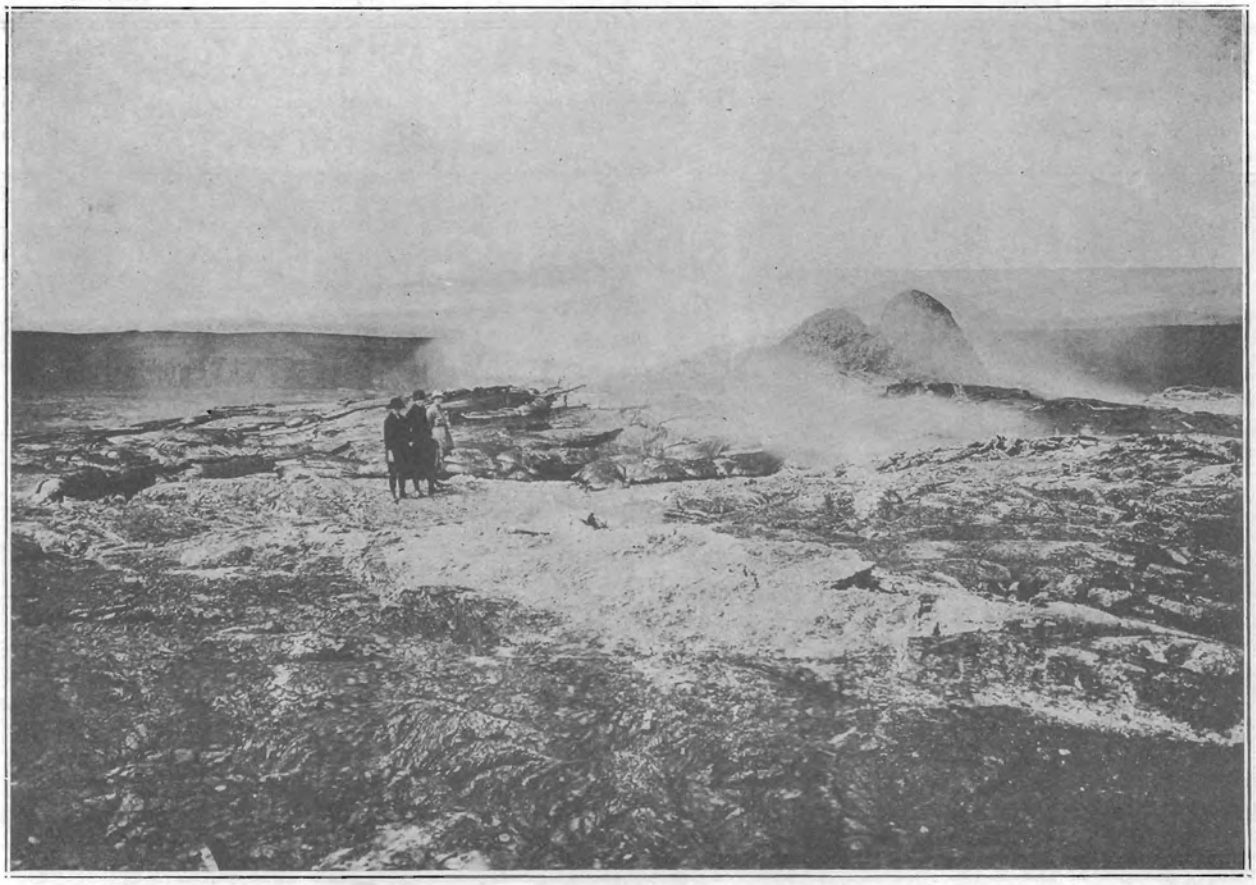
The edge of Kilauea Crater is a live place, no matter what the eruptions are doing. The ground under the Observatory and the hotel is always tipping away from the center of the crater, or else tipping back again. The ground at the edge of the firepit, always visited by the tourists, tips back and forth still more strongly than the rim of the greater crater. The ground between Volcano House and Hilo actually rose by amounts measurable in feet between 1912 and 1922 and sank by similar amounts at the time of the great engulfment eruption of 1924. This engulfment enlarged Halemaumau pit, by caving-in of the rim, some 700 feet outward on all sides. There is thus a cycle of swelling and shrinking in a volcano, and this note is to call attention to the gradations of swelling which have been studied by the Observatory.

Measured Tipping of the Ground.

Tipping of the ground is one of the subjects studied with pendulums at the Hawaiian Volcano Observatory. This means that the flat floor of the seismograph cellar tips a little each day back and forth. Accumulated tilting in a week becomes a real change in the plumb line. At the edge of a sink crater in the top of a lava dome over red-hot lava a little way down—such is the situation of the Observatory—it may be readily understood that when molten lava pours forth from the pit inside of the crater, an increased heat and pressure inside the mountain is developed. The effect of this should be a small swelling up of the mountain, measurable as tilt away from the center. Just such tilt was measured on the seismographs during the years leading to the great overflows which built up the Kilauea floor between 1918 and 1921. And the reverse of this, a strong, sudden and large inward tip toward the center happened in 1924 when the lava sank away. This was accompanied by collapse of the pit and the famous steam-blast eruption.

Visible Swelling at the Pit.

But this swelling of the volcano at the edge of the pit itself was so tremendous that it actually became visible. We are now speaking of Halemaumau, the inner pit of the Kilauea sink, more than two miles from the Observatory, and itself the crater of the domed-up inner floor of the large sink. The first illustration shows the southeastern rim of Halemaumau on February 22, 1918. The crowd of people is clustered on the rim, and a few of them have stepped down and are walking on the shells of new hardened lava which by rising has just reached the rim level.



At this time, December 28, 1920, great outflows poured from Halemaumau through the breathing rift cones just outside. This picture shows the Red Solfatara, with bright orange and yellow sulphur and selenium, in foreground, and flows around the cones.

It is as though the present floor which tourists see one thousand feet down were up to the level of the rim station.

This picture was taken the day before the inner lava overflowed the rim. The black crags on the left are adjacent to the lava lake, and represent blocks of the overflow benches of the lake which had been uplifted. There is a rectangular stone shelter on the rim of the pit in the background, and this was the principal tourist station of that time. The lake of slag was boiling and fountaining as a large puddle of molten stuff, generally in clover-leaf shape, off to the left of the picture, with risings and fallings from hour to hour which made the black fill in the foreground.

At this time the light-colored rim of the pit on the right was rising. The rise only showed as a faint tip away from the center. Then came the overflow which sent a torrent of candy-like lava a half mile away over the automobile road, and the inner floor of the pit swelled up into more crags. Within six days the old rock of the southwest rim of the pit had been pushed up nine feet in a ridge showing the profile of a half arch on the outer side, while the wall inside remained upright. This old, hard rock moved like broken wax. A year later came another spasm of swelling extending the pressure ridge for several hundred feet around to the tourist station. A six-foot leveled platform of concrete used as a surveying station was tipped back 45 degrees until it fell to pieces. By August of 1919 a similar leveled concrete platform 100 yards back from the rim of the pit on the north side was tilted away from the center 10 degrees or more. Meantime there had been numerous overflows, and gushings of lava up cracks back from the rim of the pit. It was clear that in fissures of unknown form the underpinning of the floor of the greater crater was surcharged with lava that caused it to swell.

This whole period of 1919-20 was a time of repeated risings and outflows about Kilauea Crater as a center. The pressure ridge around the south rim of Halemaumau became a great feature 15 or 20 feet high, and persisted until a deep collapse occurred in April, 1921. Our second picture shows the same rift cone that contained the glowing stalactites in the second illustration of Volcano Let-

ter No. 263, but at this earlier time the cone vent was vomiting out lava flows and burying brilliant colored deposits of alum, epsom salts, selenium and sulphur. This cone was over the deep crack leading from Halemaumau to the southwest, and about 500 feet from the edge of the firepit.

The illustration on the last page is a photograph of the first concrete monument above referred to. It shows the round surveying station on the old rim of the pit actually heaved up into the air and tipped back, so that all the ridge which extends across the picture had been the flat edge of the pit only two weeks before. The observer is looking toward the pit.

A Pendulum Set up at Halemaumau.

All this evidence of visible swelling when the lava was high made it interesting to place at the rim of the pit a machine to microscope such movements. A seismograph pendulum was set up in a stone hut a few hundred feet back from the tourist station at the southeast rim of the present big cauldron. A horizontal pendulum is somewhat like a barnyard gate. The boy sitting on the gate corresponds to the lead weight. If the gate post is tipped away from the pasture, and the gate is unlatched, the boy swings out toward the road. Just so it is with the pendulum at the crater, with a hinge at one side, attached to a concrete post, and the gate-like pendulum hung parallel to the edge of the pit. If lava comes into the bottom of the big pit so as to swell up the whole dome floor of the larger Kilauea Crater, the pendulum should swing away from the center of the pit. If the bottom of the pit collapses, the pendulum should swing toward it.

The pendulum at Halemaumau writes all day long on a sheet of paper which is pulled under its pen by a clockwork. If the pendulum swings away from the pit the written line shows it, and the amount of the swing may be measured for any hour of the day, and for any day of the year, by the position of the line on the paper. To revert to the boy on the gate, if an automobile were dragging a sheet of white canvas along the road, and the boy on the open gate dug his muddy heel into the canvas, the mark would show how much the gate was open. So it is with a seismogram.

The outbreak of lava far down in Halemaumau February 20, 1929, wrote a complete autograph on this instrument, 1,100 feet above it and at least half a mile from the center of fountaining. First there were little earthquakes written on the instrument and then a tipping of the ground away from the pit. The moment the lava fountaining began, the seismograph pen started writing a strong back-and-forth line like a tremulous invalid, and the tipping stopped. This tremor continued and became excessively strong toward the end of the two days' activity, and then the tipping began to go in the opposite direction, namely, toward the pit. This tipping and tremor continued up to the moment when the fountaining stopped, when the line became smooth and straight. These sheets of paper taking the pulse of an active crater for the three days, February 19, 20 and 21, 1929, are epoch-making in the history of science. They prove that a microscopic record of a lava outbreak may tell the story with perfect fidelity.

Swelling and Shrinking on a Large Scale.

We have seen that the visible gushing lava swells and shrinks its containing vessel, that the mountain top swelled and contracted during the cycle of activity from 1913 to 1924, and that these things were measured by instruments designed to show the trembling and tipping of the ground, and measured also by the careful methods of the surveyor. These last made use of the telescope, the level bubble, and the exact determination of mean sea level at Hilo with the aid of the tide gauge.

When the traveler gazes at the pure curve of the dome of Mauna Loa, he may well make inquiry, "How much of that is swelling?" This leads to the question, "How large a part do swelling and shrinking play in the mechanism of building active volcanoes?" And going still farther to such a region as eastern Japan or western California, where volcanic heat is still rampant and where great earthquakes occur, he may well ask, "Does not this mechanism of volcano swelling, deep under the earth's crust, play an important part in the uplift of the shore lines in both these uplifed lands?"

In Hawaii itself the question of large scale uplift and breakdown of the islands is of intense interest both geographically and with respect to the passage of time. The geographic evidence is the astonishingly regular gradation of height or uplift of the islands as we go from east to west; Hawaii is the highest and contains the active volcanoes; Midway Island, far away at the west, is a tiny coral reef. In between there are intermediate islands containing old volcanic rock. The time evidence shows that Kilauea at the east, among the active volcanoes, almost continuously ejects liquid lava, but is breaking down along its shore line. Mauna Loa, next to the west, is less continuously active, and Hualalai, farther west, has still greater intervals. Haleakala, the last of the four volcanoes with an active record, was probably last flowing very long ago, about 1750, and its crater is a more broken structure. In time and space the Hawaiian Islands are swelling and swollen at the east, and shrinking or shrunken at the west. T. A. J.

KILAUEA REPORT NO. 938

WEEK ENDING JANUARY 12, 1930

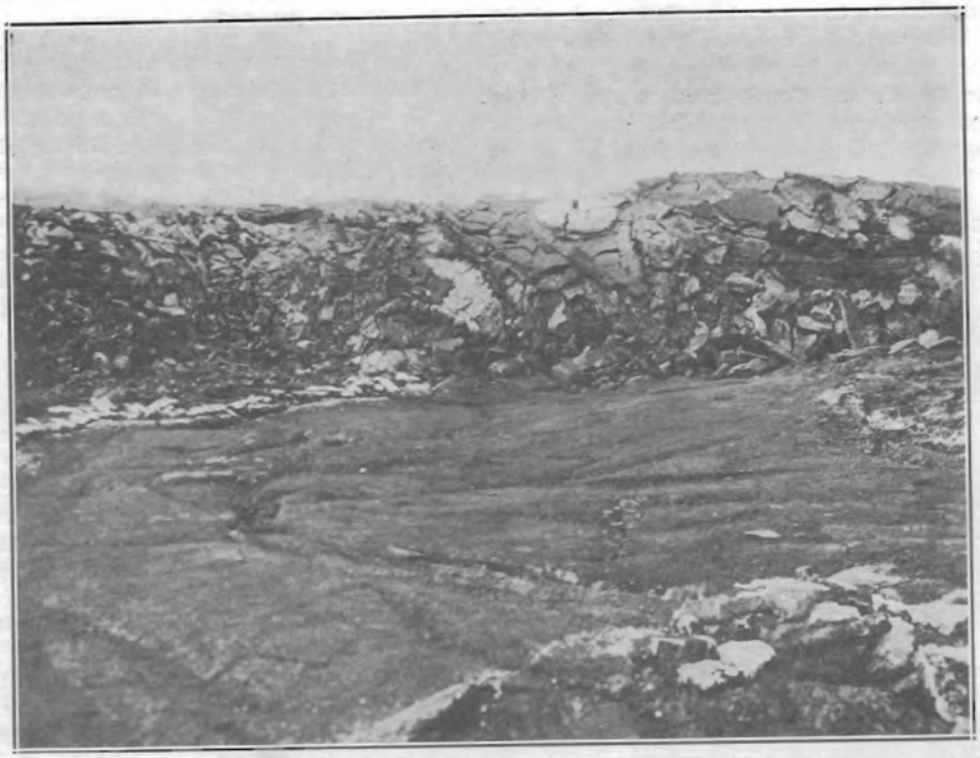
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The Hawaiian volcanoes remained quiet, fresh snow was observed on Mauna Kea and Mauna Loa when the mountains cleared January 8, and on Hualalai an odor of spicy sulphur was noticed by the foresters near the western summit January 7. A similar odor had been perceived there by the forest ranger December 31.

At Halemaumau dust from a slide at the north side of the pit was observed during the forenoon January 8, and the wall there was afterwards seen to be grooved from the loss of fresh debris, which lay on the talus below.

The seismographs at Kilauea Observatory registered 19 local disturbances for the week, of which 12 were tremors, lasting each from 15 to 45 seconds, and seven were very feeble earthquakes. One such earthquake indicated origin distance 52 miles, time 6:08 p. m., January 8. This probably centered in North Kona. Microseismic motion for the week was slight, and tilt was slight to the southeast.



The rim of Halemaumau, looking straight toward the pit. This photograph, March 6, 1919, shows southeast surveying station tipped up away from the pit on a pressure ridge 15 feet high. The swelling had begun suddenly February 25. Photos Jaggar.

THE VOLCANO LETTER

The Volcano Letter combines, after January 1, 1930, the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

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HAWAIIAN VOLCANO OBSERVATORY

Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

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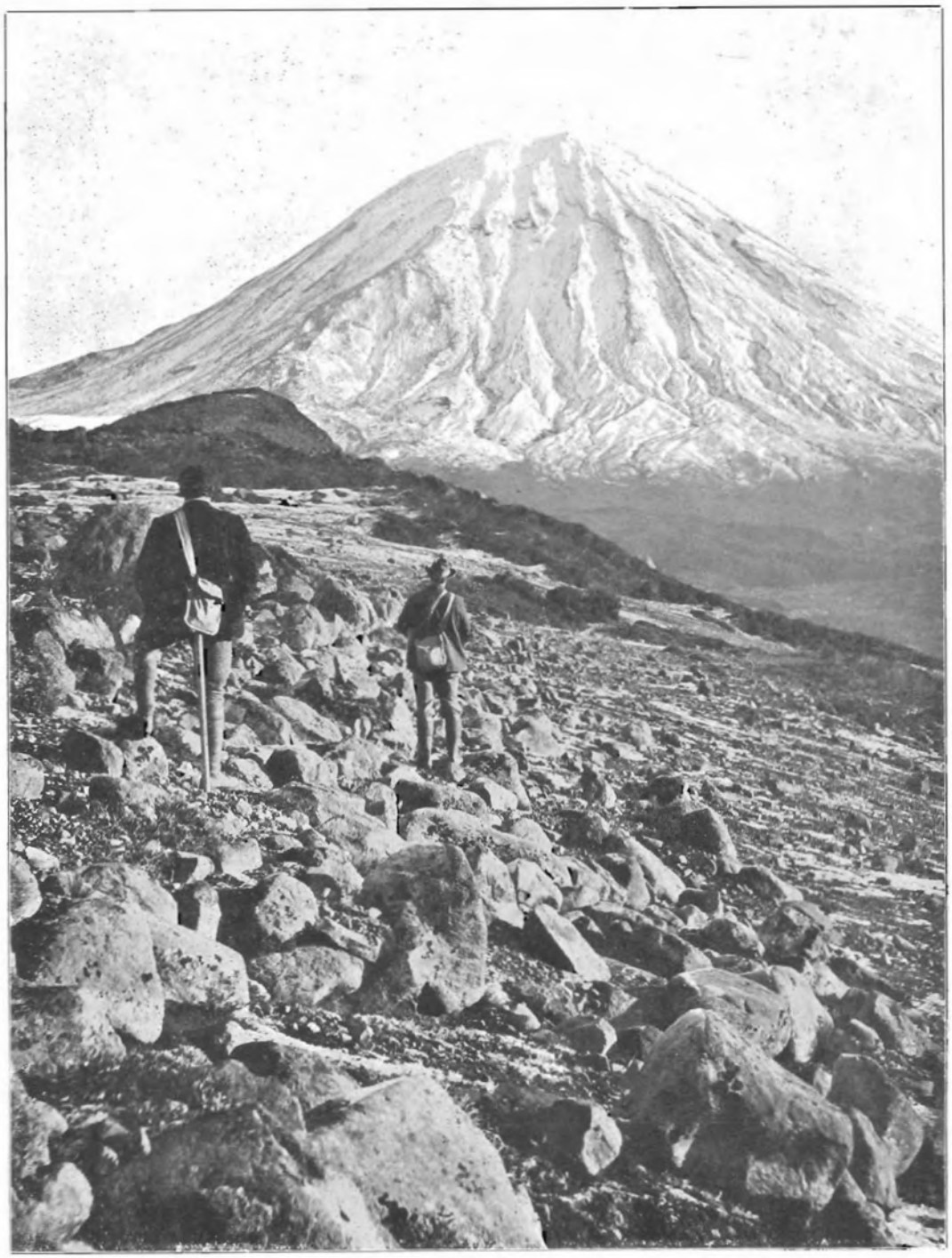
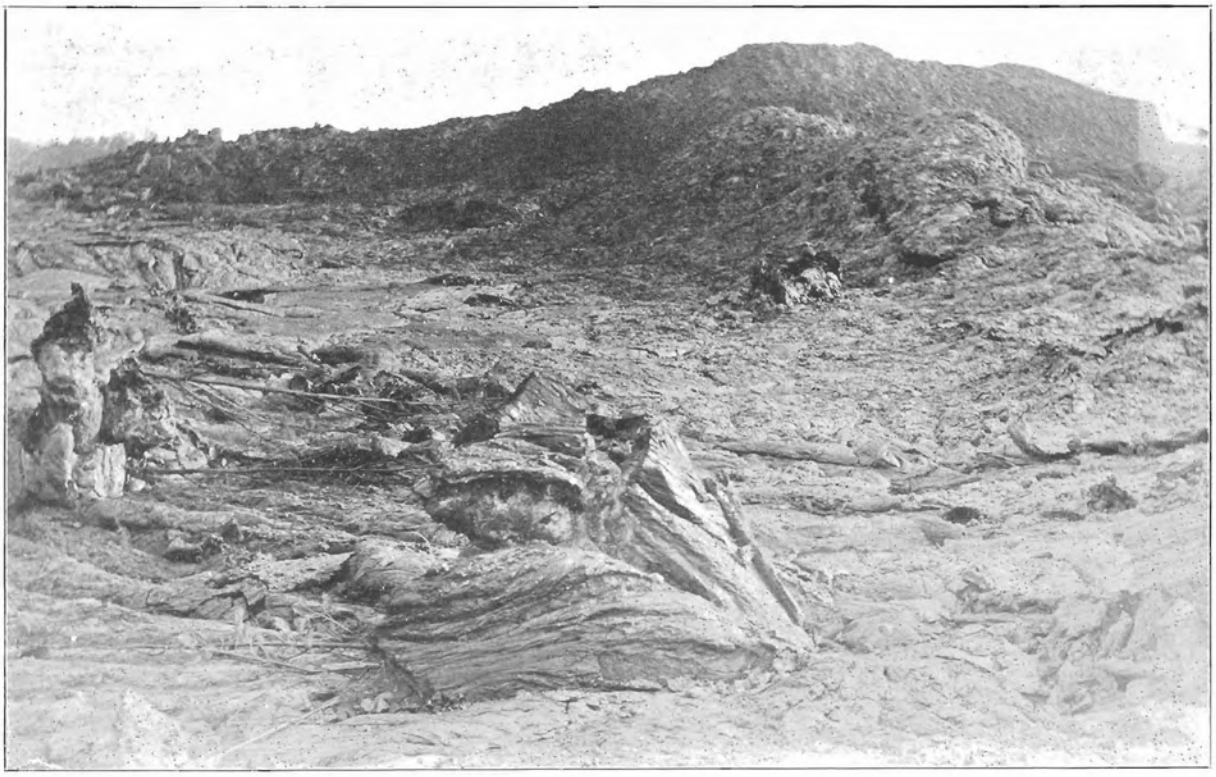
The Volcano Letter

No. 265—Weekly Hawaiian Volcano Observatory, National Park, Hawaii January 23, 1930



Ngauruhoe Volcano, New Zealand National Park, as seen in winter from the Eastern side. This is the most active of the splendid volcanic cones of New Zealand, and was throwing out rocks and had glowing lava within its crater in March, 1928. —Photo Malcolm Ross.



Fresh Pahoehoe Lava on Niuafou, 1913. There has been much controversy about whether historic lava flows have occurred in the Tonga Islands. This photograph, with fresh source cones and ropy basalt of 1912, when there was an eruption near Futu, settles the question in the affirmative. Photo from Captain Crawford, Canadian Australasian Steamship Company.

VOLCANOES OF NEW ZEALAND-TONGA BELT

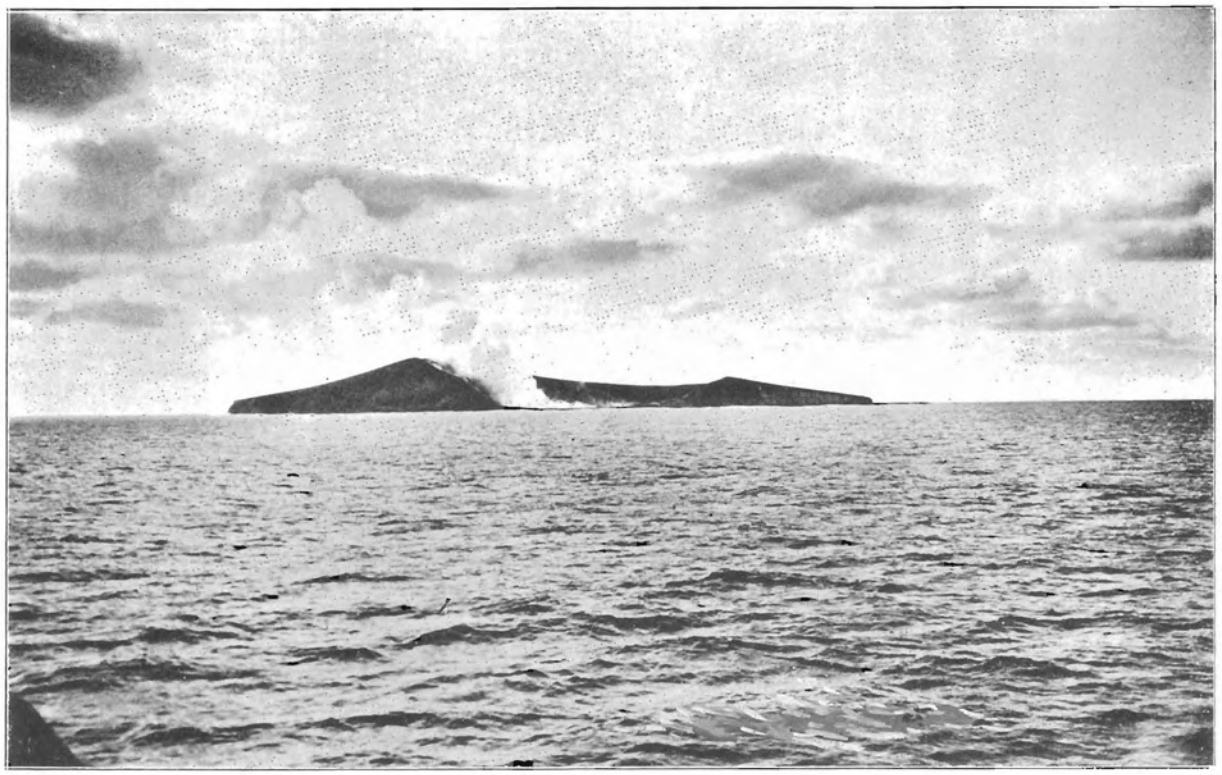
The recent disastrous earthquake in the mountains near Murchison, at the northern part of the South Island of New Zealand, makes the study of rift lines or faults carried out by the New Zealand Geological Survey of great importance in connection with the meaning of volcanoes. Mr L. I. Grange, of that Survey, has been making a detailed geological survey of the active volcanic zone of the North Island, and believes that the area of greatest interest for earthquakes and volcanoes is the 72 miles in a generally NNE direction between Lake Rotorua and Lake Taupo. An active fault, the Paeroa Rift, has been located through the volcanic district trending northeast in the direction of White Island from Lake Taupo, and if this fault were projected southward 200 miles it would go through well known earthquake centers in the western part of Cook Strait, and then pass through Nelson. If projected it would pass close to Murchison. The big displacement which has been studied at White Creek is eight miles farther west. The New Zealand geologists do not connect the fault movements of the South Island with anything but mountain-building forces. There are no volcanoes in the South Island. But large, active faults of both islands trend NE-SW, and the possibility should not be overlooked that deep volcanic faults with intrusive magma extend under the southern mountains.

This relationship makes the volcanoes of the New Zealand belt worthy of review. Along this great crack south of Lake Taupo lie the three big volcanoes Tongariro, Ngauruhoe, and Ruapehu, the last farthest south. These are in the National Park. Ngauruhoe is 7,515 feet high and has had eruptions 11 times since 1839. Its eruption of March, 1928, was reviewed in the Volcano Letter (No. 216, February 14, 1929).

The crater of Ngauruhoe has recently been described by F. W. G. White, and the inner crater has been continually changing. The walls of the outer crater are very precipitous, and in 1896 there was a hole on the southwest side of the level floor of the main crater. Earlier there had been an inner crater toward the northwest, and this all suggests what is so common in Hawaii, that the central level floor is the top of a lava plug, and that the gases of explosive eruptions churn out their vents around the wall crack at the borders of this plug. The southwest hole has become enlarged to be the principal center of activity.

In January, 1929, the activity was so slight that White went to the bottom of the innermost pit. The old northwest pit had become a rounded depression covered with ice. The walls of the southwest active pit were partly precipitous. In a conical hollow on the northeast side, Grange had seen lava in this pit in 1928. Its slopes were now steaming and there were two holes in the bottom from which hot air was issuing, each a foot and a half in diameter. The remainder of the bottom was covered with sandy material washed in among bowlders, and there was very little sulphur in the crater. The only other solfataric place that was steaming was well up on the edge at a rock projection east of the northern lip of the outer crater. The crater contained more ice and showed less activity than usual, at the time of White's visit (N. Z. Jour. Sci. and Tech. June, 1929, p. 48).

As has been pointed out in the review of J. Allan Thomson's admirable summary of the New Zealand volcanic belt (Volcano Letter No. 158), the question of lava flows from Ngauruhoe in 1869 and 1881 has been disputed. An aa flow now at the foot of the mountain is attributed to the 1869 eruption, and inside the conelet of March, 1928, wholly within the crater, Grange saw red-hot lava that appeared viscous, with blue smoke escaping through it with a tremendous roar, which flung up red-hot fragments 50 feet. The presence of lava in the center is thus unquestionable. The great explosive disaster at Tarawera Volcano in 1886, in the North Island, about midway between the active volcano White Island in the Bay of Plenty and the National Park group of volcanoes, has given New Zealand the reputation, like Java and Japan, of producing chiefly ash explosions. In all three of these lands we are learning more and more that andesitic and



Falcon Island, reported to have disappeared in 1913, reappeared with a violent series of explosions October 4, 1927, building up basaltic ash, scoria, pumice and lava blocks to make a cone and crater in the Tonga Islands. Photo from Andrew Thomson, Apia Observatory.

basaltic magma, or underground lava, which occasionally comes to the surface, is the prime mover of volcanism, but does not flow out so freely as in Samoa and Hawaii.

It seems likely that if we could know of all the submarine lava flows which come out through cracks in the bottom of the sea, between New Zealand and Samoa, we might discover that lava outflow is not so rare as has been imagined. The photograph reproduced on the second page is quite like the lava flows of western Samoa, and this unquestionably was pouring over the surface of the Island Niuafou in 1912. The description of the 1929 eruption of Niuafou, which follows this article, leaves no doubt that lava flow is characteristic of this island, and Niuafou is not more than 250 miles from Savaii where the great lava floods of western Samoa occurred in 1906-11.

The recent eruption of Falcon Island (Volcano Letter Nos. 151 and 210) has been newly reviewed by the investigators who studied it for the Bishop Museum (Amer. Journ. Sci. Dec. 1929, Falcon Island, by Hoffmeister, Ladd, and Alling. See photograph this page) to the effect that the great volcanic crack in the earth's crust which has piled up the line of Tonga-New Zealand volcanoes, starts at Savaii and extends across Cook Strait into the South Island of New Zealand. The formations along the line are said by Park to be "broken, sharply folded, faulted, sheared and up-tilted" Niuafou lies off the line to the west 150 miles, but it is doubtless part of the same system. These explorers of Falcon Island reach the conclusion that many of the atolls, or horseshoe-shaped coral reefs of the southwest Pacific, may have been started by corals and other organisms building on a circular bank built up by a temporary volcano such as Falcon and later cut down by the waves. It may be added that while such volcanoes exhibit chiefly fragmental material, it must be remembered that a pile of solid lava in the form of a dome probably exists beneath. How an outflow of liquid lava like one of the Mauna Loa flows, would behave under deep, cold water is a matter of theory, not of observation.

ERUPTION ON NIUAFOU, TONGA ISLANDS

Niuafou is a roughly circular wooded island about 20 miles in circumference in the middle of the triangle of ocean between Fiji, Tonga, and Samoa. It is about 600 feet high. There are many craters, including a large main lagoon near the center of the island, where there are hot springs. The shoreline is worn into lava cliffs.

There is difference of opinion as to whether lava flows have occurred; Sapper cites destruction of villages by lateral lava flow in 1853 and 1867 (Vulkankunde, p. 336) Thomson allows only explosive eruptions (N. Z. Jour. Sci. Tech. 1926, p. 369) as the 1886 outbreak destroyed the coconuts and covered the surface with 2 to 20 feet of ash.

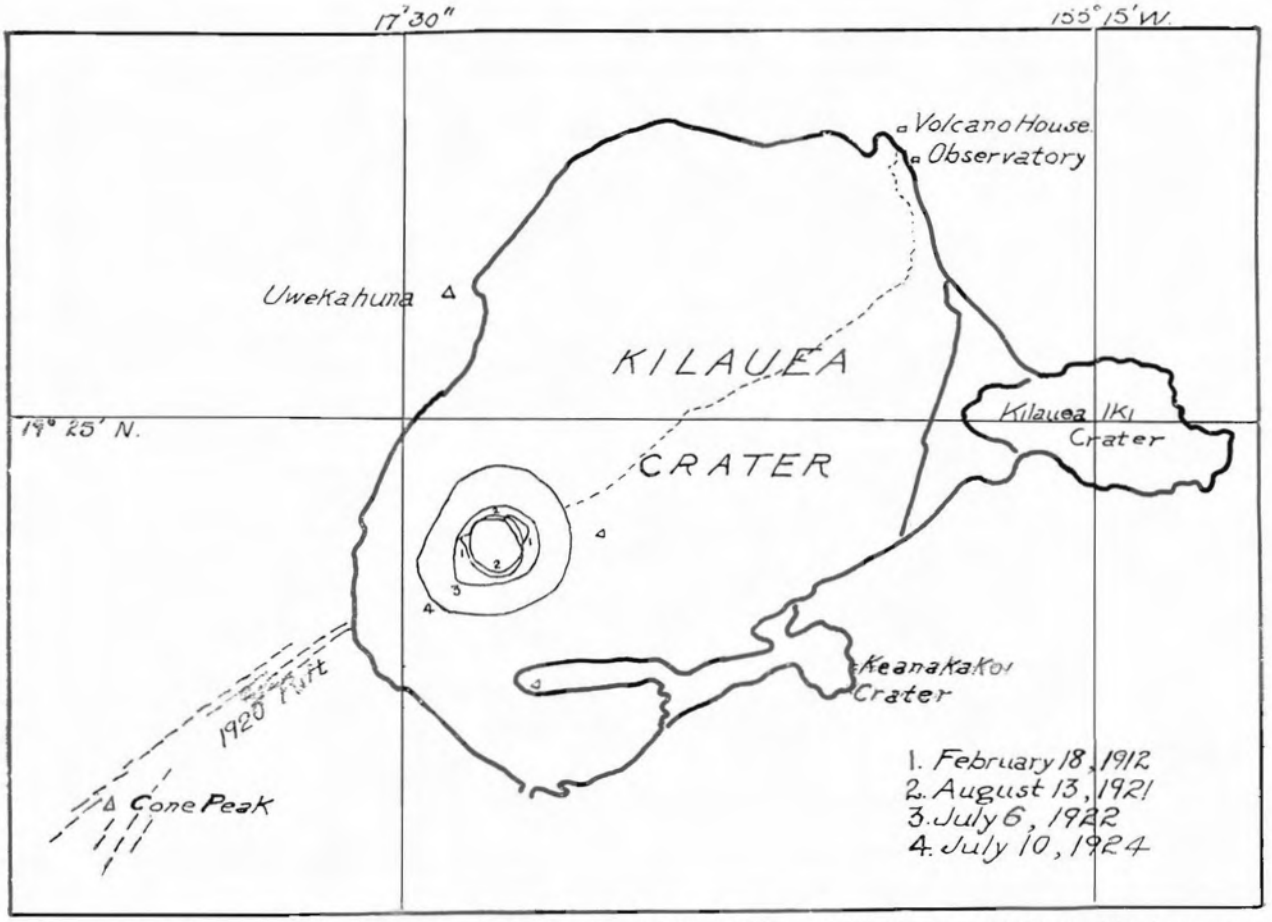
In spite of 5 eruptions in 115 years, Niuafou has nine seaboard villages with a population near 1,000, and belongs to the Tongan monarchy under British protectorate.

The last eruption was in 1912, when 30 craters were in action between the lagoon and the strandline near the village Futu, on the west side of the island. Pahoehoe lava flowed into the sea. Of this we possess a photograph taken in 1913, (see second page).

The new eruption July 25, 1929, was similar and wrecked Futu. It began at 4 a. m., overrunning a long strip of coast a mile wide. Copra crops, houses, horses and pigs were burned and buried.

Three craters burst open without warning to the south of Futu. The populace hurried to Agaha, the larger village at the northwest, and took refuge on the high ground back of it. Their discomfort was increased by rain and wind.

The correspondent (Auckland Star, Aug. 6, 1929) climbed on horseback to Hala-gutu, the high lip of the interior crater lake, and saw that a chain of craters was forming along the low coast land. Each vent belched out molten rock and deep red flames. "Among the clouds and swirls of smoke and fumes were to be seen streams of lava thrusting their way in tortuous twists and turns through the rich vegetation, scorching it to brown and black cinder."



The recent enlargement of Halemaumau Pit, the inner lava cauldron of Kilauea is here shown. The lava rose and overflowed, and the pit grew smaller, for outlines 1 and 2. The pit enlarged by collapse for 3 and 4.

The smoke cleared July 26. At the extremity of the flow 40 acres of new ground had formed, altering the contour of the coast line. Halfway between there and Futu, goats were marooned on a new islet. Sulphurous fumes were bad, but the explorer with his two native companions finally reached the ruins of Futu by boat. The village site was a field of smoking lava, only a third of the habitations escaping destruction. Native houses were found battered to the ground by the hot wind blasts. Numbers of animals, including horses which had broken tether, were found alive in the village remnant. The stone Roman Catholic church was burnt out, and the lava had flowed round a cemetery, leaving the stone cross intact in its center. The Wesleyan mission church escaped. No lives were lost.

The foregoing account is sufficiently definite and circumstantial to indicate that this eruption was a lava flow. There is no mention of darkness or ash fall. It seems likely that Niuafou is the crest of a volcano recently built above sea level, liable to both outflow and steam blast.

Niuafou is reported to have many earthquake shocks, "almost of daily occurrence" (Sydney Morning Herald, Aug. 2, 1929). These are attributed by the natives to their god Maui, rocking the island by his troubled subterranean sleep. It is hard to imagine a better place for the study of tilt and volcanic earthquakes, and this island is strategically placed for very interesting geophysical and oceanographic observations. There ought to be a seismograph station there with a permanent staff in close touch with the Observatory at Apia. T. A. J.

KILAUEA REPORT No. 939

WEEK ENDING JANUARY 19, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The week has produced no change in the Hawaiian volcanoes, new snow has fallen on the mountains, and in Halemaumau pit of Kilauea Crater all that is noticed is the presence of a few new scars due to slides along the north and northwest walls. On January 15 in the afternoon of a dry day there was almost no steam in the bottom of the pit, but in the forenoon of January 18, after heavy rain, much visible vapor rose from cracks. This is characteristic also of the outer floor of the greater crater.

The seismographs for the week ending midnight January 19 registered 10 local disturbances, of which five were tremors less than one minute long and five were very feeble local earthquakes, one of which indicated distance from Observatory 48 miles. A weakly recorded distant earthquake began 6:50 a. m., January 17 and registered for 4 m. 47 s. Microseismic motion was moderate for the week, and tilting of the ground was strong SW.

THE VOLCANO LETTER

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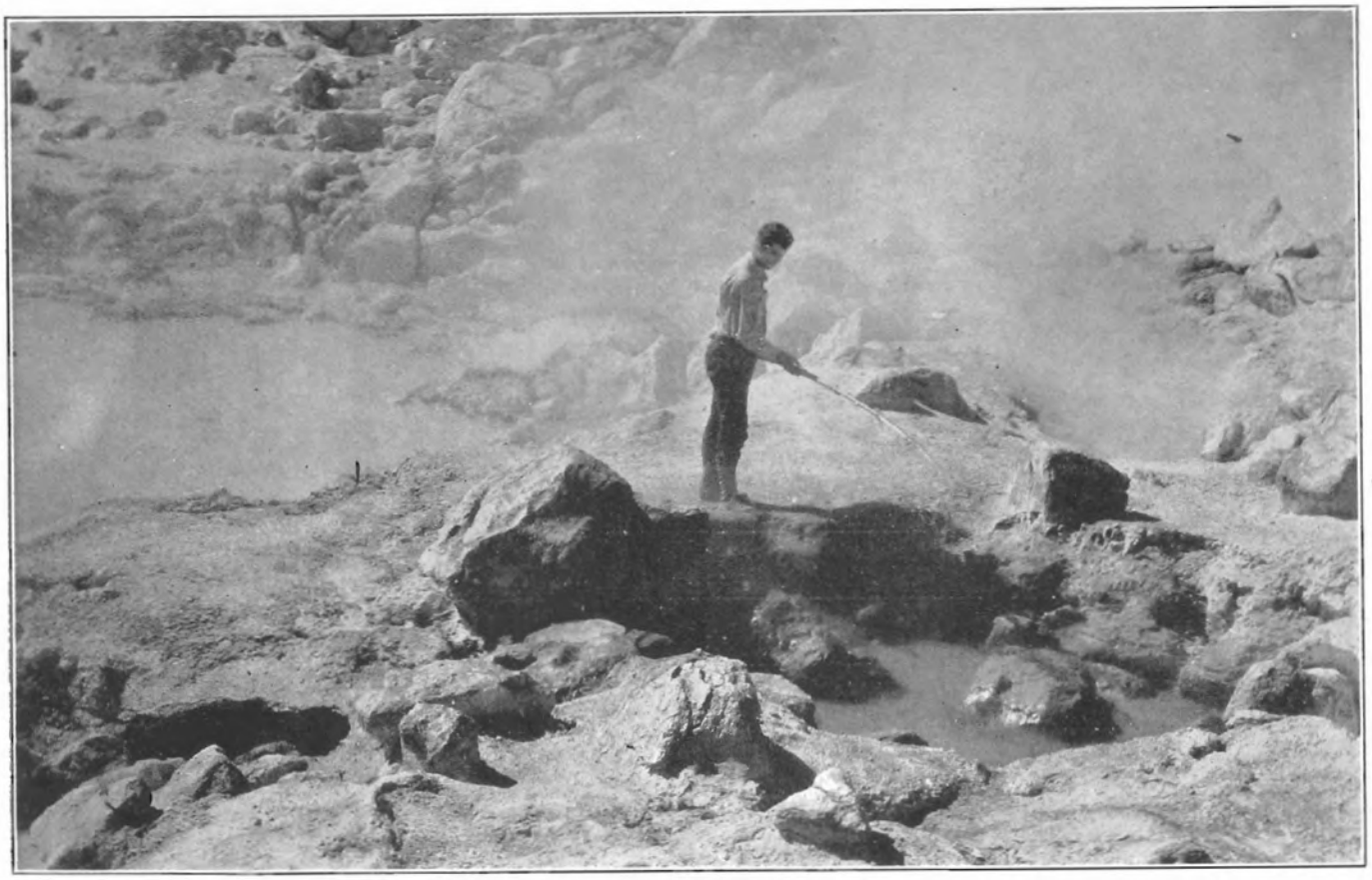
The Volcano Letter

NO. 266—Weekly Hawaiian Volcano Observatory, National Park, Hawaii Jan. 30, 1930



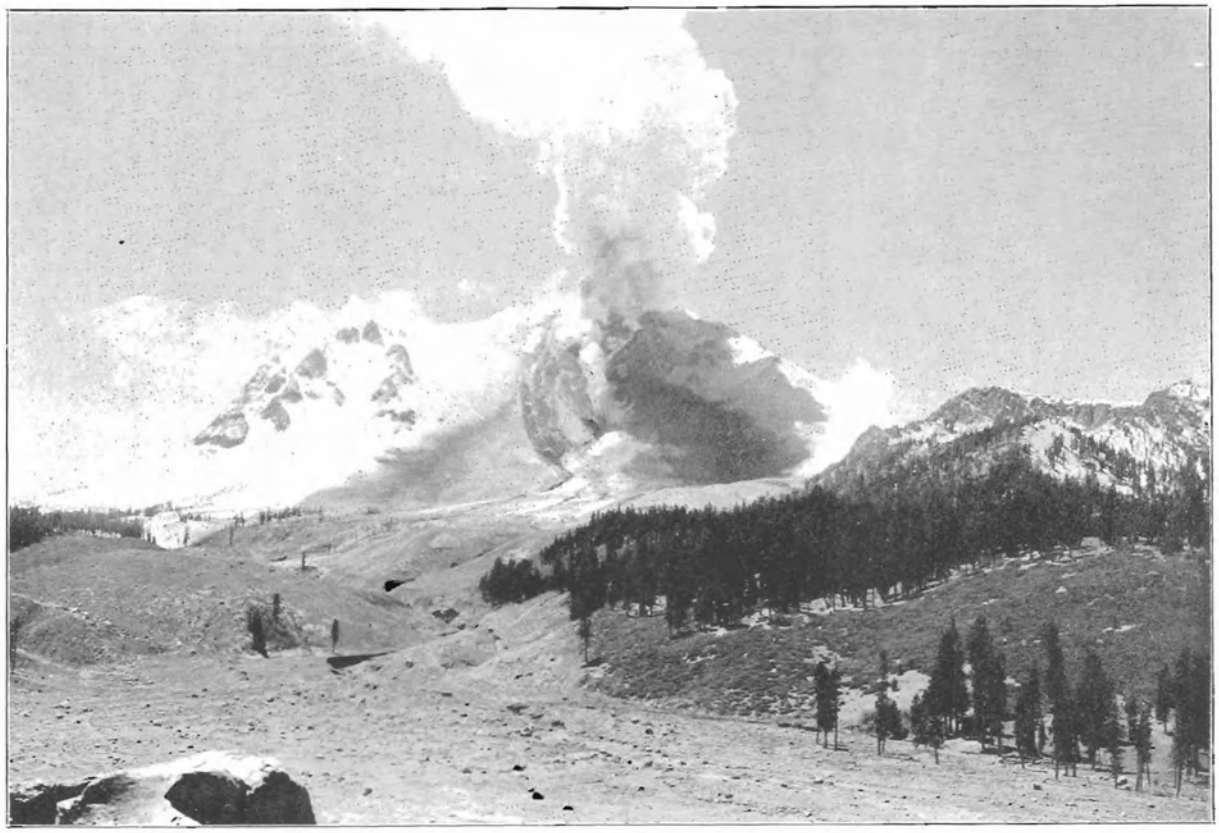
Bumpass Hell, one of the solfataras with boiling waters far up the slopes of Lassen Volcano in California The pool is black because of a scum which overs it consisting of minute particles of sulphide of iron, or pyrite. The observer from Lassen Volcano Observatory is at work immersing a thermometer in the scalding waters. Photo R. H. Finch, August 26, 1927

MUD FLOW ERUPTION OF LASSEN VOLCANO

On May 30. 1914. the old crater depression on top of Lassen Peak, a volcano in northern California, ejected dust and steam, the crater hole enlarged, explosions increased in number during the year, occurring every few days and rarely lasting more than 20 minutes. A big eruption occurred May 19, 1915, which devastated the creeks northeast of the volcano with a mud flood. Three days later, May 22, a much bigger explosion occurred, producing a down-rushing steam blast which overturned trees and cut a swath through the forest in the same direction as the preceding flood for at least four miles. The explanation of the mud flood has been problematical, as Lassen had no crater lake, as in the case of Mount Pelee in Martinique. Lassen was, however, covered with snow. The resident photographer and creator of the Lassen Museum, B. F. Loomis, believed that both Lassen eruptions gave vent to liquid water from within the mountain, a region of many hot springs, and that the water was followed by steam. (A Pictorial History of Lassen Volcano, Anderson, California, 1926.)

Dispute centers about this water question. Day and Allen (Volcanic Activity in Hot Springs of Lassen Peak, Carnegie Institution) attribute the flow to the melting of snow by the several agencies hot rain, hot volcanic ash, and a hot blast of gas. Day has shown that the mud flow started some distance below the crater rim. The flood originated in an embayment on the northeast slope of Lassen Peak that was uniformly covered by snow with a depth of several feet over most of the area. (See third picture on page 3).

It is hard to believe that hot water came out of the mountain in such volumes, but the writer agrees with Loomis that the evidence does not indicate the occurrence of a hot blast or any considerable explosion just prior to the mud flow of May 19, 1915 Except for a small flood below the western flow of aa lava that came out of a notch in the crater, the notheast flood was the only important one of this date. Even if there had been an explosion, any rain accompanying it would probably have been but little warmer than any other rain—certainly not hot. It is also doubtful under the conditions existing on Lassen Peak at



Lassen Volcano in eruption, photographed from the northeast by B. F. Loomis at 2:30 p. m., May 22, 1915, a few hours before the biggest eruption. Flood wash of May 19 in the foreground. Note the crateral gash, the cut in the snow, and the ash stain on the snow at the left. This is the critical picture. No sign of horizontal blast.

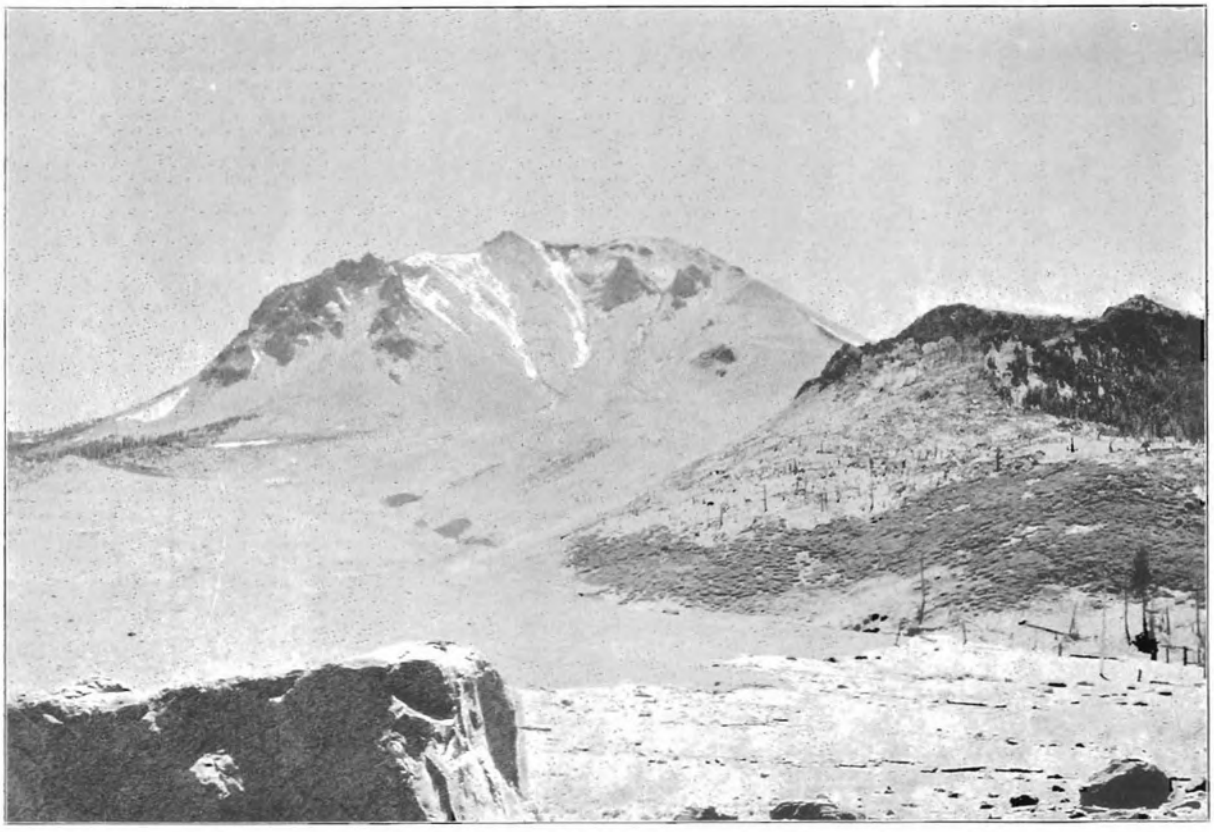
that time, whether a rainstorm unless of very unusual intensity, could cause a flood of the magnitude observed. If there were no explosion and no hot blast, then there would not have been any hot ash deposit nor warm rain.

It is true that the known explosions of May 22, 1915, three days later, produced several small mud flows. The behavior of rain on snow is worthy of some discussion. A few feet of snow of uniform covering can absorb several inches of rainfall so that the rain produces but little immediate run-off. If there had been bare spots in the snow field, water could have accumulated so as to run under the snow in considerable quantities in caverns and, in a place as steep as the Lassen slope, might have undermined so as to start avalnches. A hot blast, unless long continued, or a slight deposit of volcanic ash would produce much the same effect as a rain—a melting of superficial layers of snow and an absorption of the water by lower layers. A hot blast or a hot ashfall on a steep slope not uniformly covered with snow, could start streams under the snow as in the case of rain, and might thereby cause avalanches. It would seem that the Day and Allen theory of rain and ash may be questioned as a sufficient cause for the tremendous Lassen mud flow of May 19, 1915.

An examination of enlargement of the photograph (see illustration top of page) taken by Mr. Loomis immediately after the mud flow of May 19, 1915, and just before the maximum explosive eruption which occurred on the evening of May 22 (this photograph was taken at 2:30 p. m. that same day, May 22, and the great explosion occurred while the party was returning home), and of other photographs, and of the material transported by the mud flow, all indicates that a large volume of hot lava poured through this eastern notch of the crater where the V-shaped column of steam extends down the mountainside.

There is much new lava that was carried in fragments down the flood. The source of this at the flow in the notch was not only much more voluminous than the one through the western notch of the crater, but as would be expected it was probably as a whole more molten and less viscous. The lava flow could easily have melted the snow down to the ground and have sent a stream of warm water under the snow lower down the slope. An avalanche mixed with hot rock could have been started in this way and might have produced a flood of the magnitude observed, if great snowdrifts were present.

Minor mud flows did accompany the explosions on May 22, 1915. There was a horizontal component of this explosion that was parallel to the course of the upper part of the mud flow on May 19, 1915. The area affected by this blast was much wider than the area devastated by the mud flow of May 19, so that the blast encountered snow banks with exposed edges. The largest mud flow that accompanied this explosion followed the course



Lassen Volcano after it had quieted down, summer of 1924, showing linear remnant snowdrifts in summit gulches only. All the rest is the debris of May 22, 1915, and later, showing removal of the forest by the blast Photo Loomis.

of the one on May 19th. Much hot ash was thrown out by this eruption, and at places where there was still a uniform snow covering, the mud flows occasioned by hot ash and possibly by mud rain at this time for the most part remained on top of the snow R. H. F

THE LASSEN MYTH

In 1915 the Lassen eruption awakened the public to the knowledge that this volcano is active. It was immediately dubbed "the only active volcano on the mainland of the United States". Nothing could be more erroneous.

Geologists have long known that the volcanoes of the northwest are potentially active. Tradition has it that Mount Saint Helen's and Mount Baker have both had eruptions in historic time. The Cinder Cone east of Lassen was well known to the Indians and to geologists as the maker of a modern lava flow within a century. Eighteen volcanoes lie along the Cascade fault in Oregon, and many more extend north through Washington into British Columbia. At Geyserville just north of San Francisco there is rushing volcanic steam under high pressure. This was in the epicentral belt of the San Francisco earthquake.

Mount Shasta or any of the volcanoes exhibiting fresh lava flows in the northwestern United States might erupt at any time. Intervals between outbreaks are long in continental volcanoes of this class, and the white man's history is short. T. A. J.

KILAUEA REPORT NO. 946

WEEK ENDING JANUARY 26, 1930

Section of Volcanology, U. S. Geological Survey

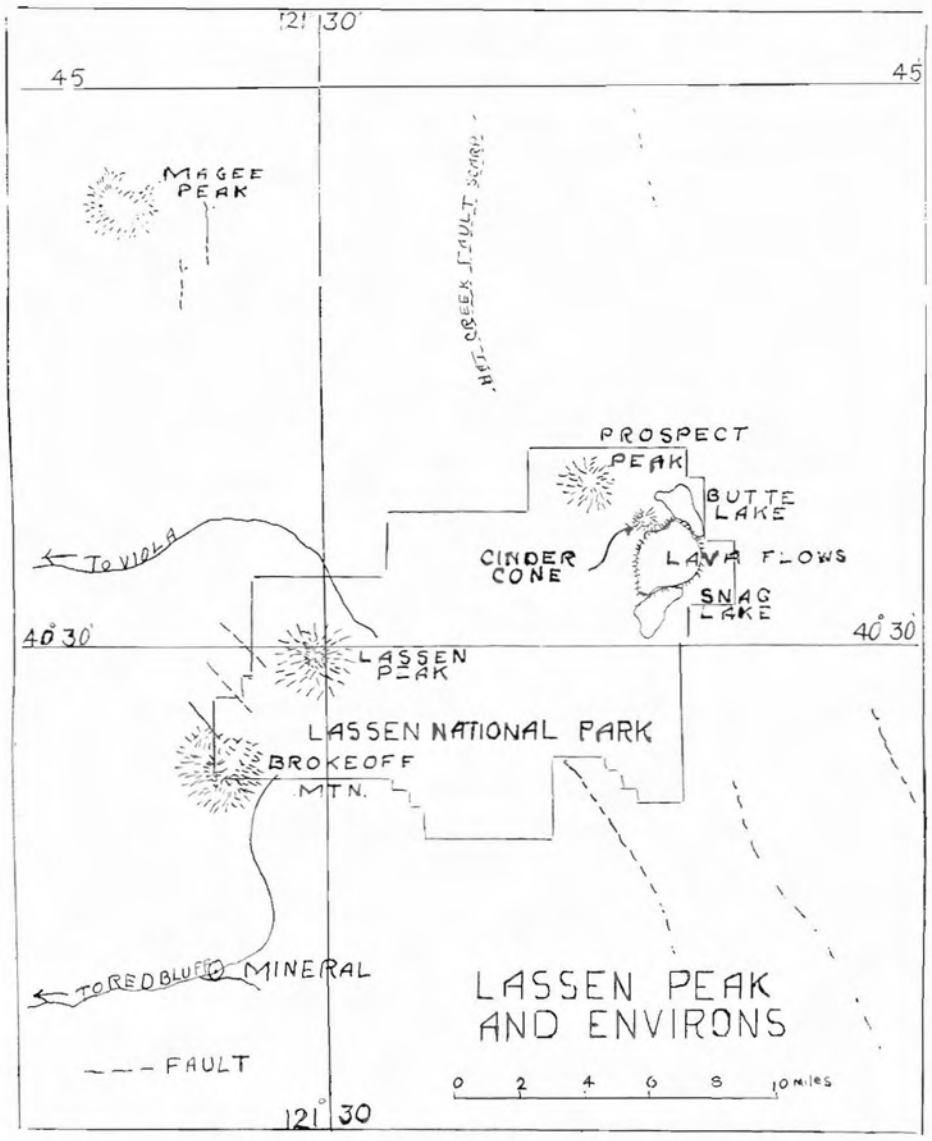
T. A. Jaggar, Volcanologist in Charge

There are still no changes in the appearance of the Kilauea fire pit to be construed as indicating lava activity. The volcano remains quiet.

On January 20 there was very little steaming. A new scar was seen on the northeast wall, caused by a slide. Early on the 22d considerable steam rose from the various Kilauea floor vapor vents and two large columns rose from the Halemaumau rims south and southwest. A new scar from a slide showed on the north wall. At 11:45 a. m., January 23, thin gray dust from an avalanche rose over the northeast corner of the pit At 4 p. m. dust rose on the north side. On the 24th, at 6:15 and 7:30 a. m. more dust from slides was seen.

The instruments at the Observatory recorded six tremors and three very feeble earthquakes. One of the latter, occurring at 2:09 a. m., January 23, indicated 34 miles as the distance to origin.

Tilting of the ground at the Observatory accumulated moderately to the NNE. Microseismic motion was slight.



Sketch map of Lassen National Park showing position of Lassen Peak. Observatory is at Mineral, R. H. Finch in charge. The eruption flood devastated a sector due northeast from the summit in the direction of the Hat Creek fault scarp, making flood damage down Lost Creek due north of the mountain.

THE VOLCANO LETTER

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The Volcano Letter

No. 267—Weekly Hawaiian Volcano Observatory, National Park, Hawaii February 6, 1930



New lava filling bottom of Halemaumau as seen from east side of pit, 5:30 p. m., July 9, 1927. Torrent pouring in from high cone on talus at the left. Three inflows have occurred, burying this floor, since 1927. Photo Tai Sing Loo, copyright.

KILAUEA'S LIGHTED FURNACE

Travelers do not realize, when they visit the silent, sleeping fire pit, that the live smelting furnace of Kilauea is ready for action at any moment. It is hard for them to imagine that it is possible for the liquid lava to spurt up through the rocks at the side of the black lava floor while they are watching, and without doing them any harm. The liquid lava of the inner pit never does anyone any harm. Pele comes back with the silent gleam of a beacon light at night, with only a wisp of vapor, and then the slag fountains wax in vigor and majesty All of this happened twice, with magnificent fireworks, during the past year

These demonstrations that the pilot light is always burning have occurred seven times since the summer of 1924 That summer the lava began to flow into the bottom of Halemaumau, two years later gigantic floods of lava streamed to the sea from Mauna Loa, and in midsummer of 1927 four beautiful fountains of fiery melt appeared in the bottom of the Kilauea fire pit. They came quietly in the midnight hours of July 6-7, sending up fume which reflected the glowing jets beneath. They covered up the earlier lava floor, and the liquid basalt spread out into a molten lake so as to drown the vents of two of the fountains. The vents lay in a line tending to be parallel to the great west cliff of Kilauea Crater And this bluff in turn is parallel to the cracks that lead out into the southwestern desert. These facts mean that under the round craters there are straight fissures going down deep, and it is up these fissures the lava comes.

The first picture is looking toward the west from the eastern rim of Halemaumau near where tourists stand at present. It shows on the left the two new source cones of 1927, and the top of the higher one stood 122 feet above the level of the liquid lake below. This vent had broken out through the slide-rock slope far above the bottom of the pit. The picture was taken two days after the beginning of the eruption when 30 acres of new lava had spread over the bottom. The jets on the first day had begun with blue flames and rushes of gas, followed by light basaltic pumice with the gas jets, and this in turn became more viscous although all such lava is more or less a froth. At the fountain jet it is bright yellow, but the blobs of freezing froth which drop back on the cones change color to orange, scarlet, crimson, maroon, purple and black. By "freezing" is meant consolidating from a molten condition. The material is a true glass containing



Halemaumau bottom from the east, 8:15 a. m., January 11, 1928, when the two black flows had squeezed up cracks in front of landslip shown in background. Foreground is floor of July, 1927. Photo Wilson.

much iron oxide which gives the thin edges a greenish brown translucent color. The ingredients are silica, alumina, iron, lime and the alkalies as in the slags of commerce. The temperature is around 2 000 degrees Fahrenheit. The gases which maintain this temperature and are actually burning in their upward rush are hydrogen, sulphur and the oxides of carbon.

After the first day only the large southernmost vent (the left-hand cone of the picture) was visibly working, and after 13 days the eruption of 1927 ceased It will be noticed from the picture how strikingly the process inside Halemaumau resembles a river and its delta. The molten streams meander and distribute on their flood plain and build lobes penetrating the hollows between the different talus slopes. Then the lower portion actually becoems a liquid lake, within ramparts of its own solidification, and when the eruption ends the slag pool loses gas and shrinks, leaving the ramparts standing up as a border, which shows in the picture. There is just such a border in the bottom of the present pit at the beginning of 1930, and this is remnant from the solidified pool of July, 1929. To return to 1927, the molten lake filled to a depth of about 80 feet, most of this pouring in during the first day, and the diameters were 1,760 by 1,420 feet.

The psychological effects on the community are characterized by intense enthusiasm, and a rush to see the fireworks, which is like the opening of a world's fair In the early morning of the first outbreak in 1927 there were 50 spectators at Halemaumau, during the first day there were 1,800 visitors, and on succeeding days the numbers diminished to just such extent as the spectacular quality of the performance decreased.

When the lava sinks away after such a release of gas pressure, and the eruption comes to an end, there is a tendency to collapse of the mountain blocks which were held apart before. The walls of the pit lean inward and large rock slides occur from time to time. the eruption of July, 1927, came to an end on the 20th of that month and on July 21 slides were incessant and the air above the pit was heavy with dust. Also the mountain blocks grate against each other and this makes perceptible earthquakes. These local seismic movements do no damage and are mostly known only by the records of the delicate instruments at the Observatory. There are tremors all the time everywhere in the world. The volcano observatory is feeling the pulse of the ground, and the lists in the weekly Kilauea Report are merely adding statistics, that point the way to the meaning of the next outbreak of fireworks. There are quick-period tremors and tippings of the ground, suddenly increasing at time of outbreak. Otherwise the tippings are seasonal as recorded for January, 1930, in this number of the Volcano Letter. (last page)

January of 1928 produced an upwelling of new lava shown by the small black flows that came up cracks in the lava floor left by the July eruption of 1927 (see second picture) The photograph is from about the same point of view as before. It will be observed that the July floor was squeezed down by an immense avalanche in the background, which had fallen from the wall at midnight January 10-11, 1928. Red glow immediately appeared, the outflow was sluggish with only a slight blue flame, and the measurable flowing lasted only an hour or two. The

effect was as though liquid lava were present as a remnant from July under the crust, but peculiar seismic disturbances in December, 1927, the month before the outbreak, makes it more probable that it was a half-hearted eruption brought into being by the shock of the avalanche.

The year 1929 was ushered in, by such a disturbance underneath the pit, that an immense avalanche carried away the tourist station in January, and this was followed February 20, 1929, by a new eruption of lava, in the bottom of Halemaumau, of short life and great intensity. The Volcano House watchman saw a black dust cloud rise from the pit, followed by white steam in the moonlight, at the usual hour near 1 o'clock at night. He notified the community by a bugle call. A bright glare developed over the pit At 2 a. m., a line of fountains lay across the bottom of the pit in a northeast-southwest direction as before but close under the west wall of the pit, and this time the biggest fountain was at the north end of the crack It shot out its jets diagonally eastward to a height of 225 feet and built up a big pumice cone. The line of fountains was about 1,000 feet long, spraying upward in a cluster of jets that soon became engulfed in the new lake under the west wall of Halemaumau but made a magnificent display, doming up the golden fluid with a boiling 50 feet high, and making concentric and radial cracks of incandescence in the dark crust of the pool, the blocks of which eternally streamed into the center of activity and sank. Meantime there developed an even pattern of bright lines streaming outward like a fan from the huge northern fountain. The rumbling thud of the fountains became deep and heavy with occasional detonations. The cone at the north changed to an armchair in shape, and on the second day the southern group of fountains (left-hand in third and fourth illustrations) went out of action in the forenoon, the lake subsided and left a border rampart, and at 1:10 p. m., February 21, 1929, the eruption came to an end. The two pictures show the new flood on the bottom of the pit from the same point of view as the earlier photographs, the first exhibiting the high activity at the beginning and at night, the second the dwindling activity of the second day after a lava shore line had solidified. The other activities of 1929 will be described in a later issue. T. A. J.

KILAUEA REPORT No. 941

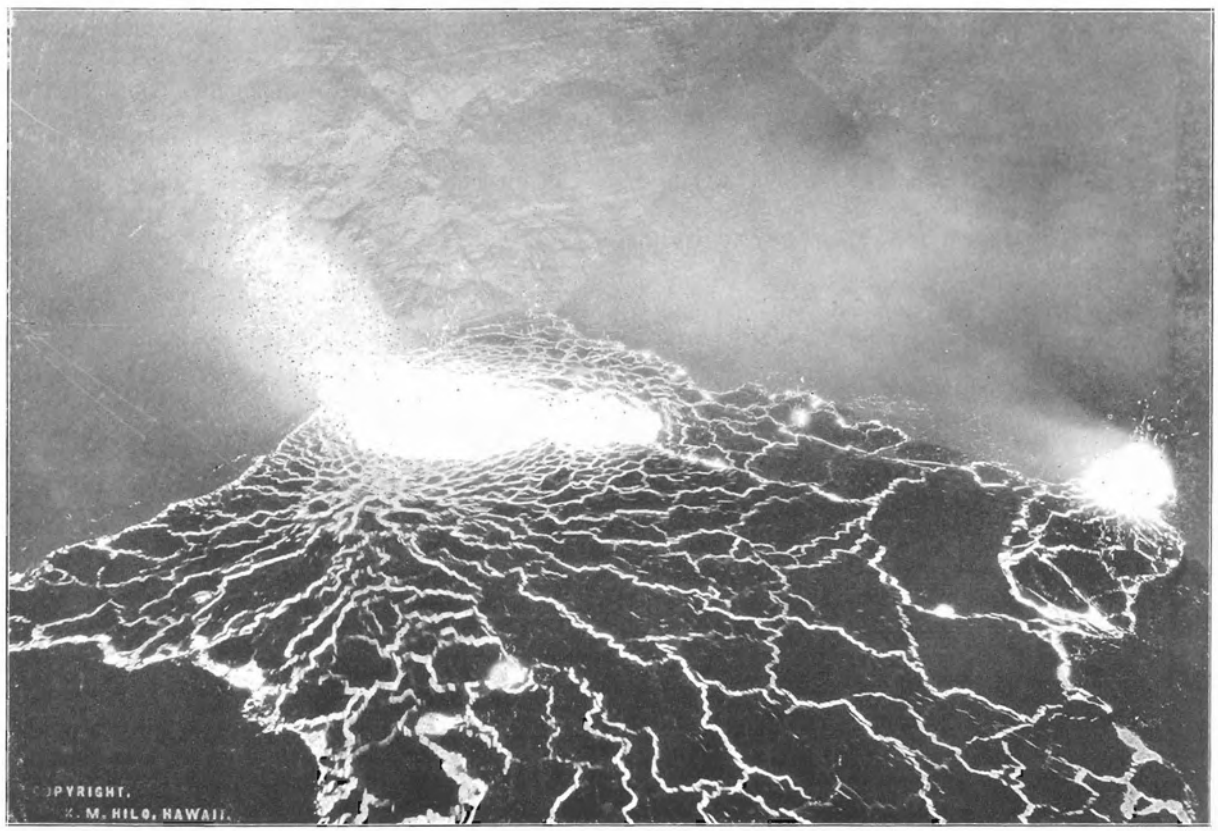
WEEK ENDING FEBRUARY 2, 1930

Section of Volcanology, U. S. Geological Survey

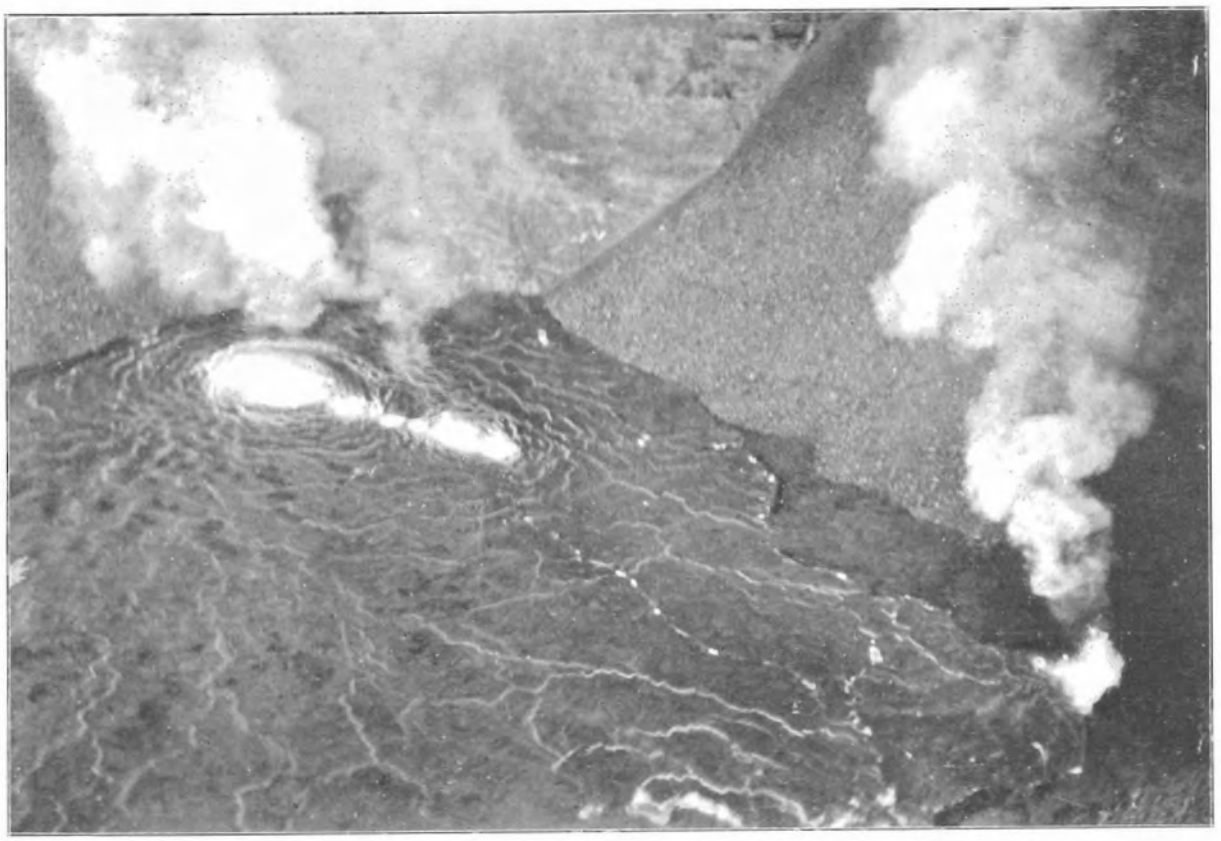
T. A. Jaggar, Volcanologist in Charge

On January 27 at 2 p. m., dust rose from a slide at the northern wall of Halemaumau, and at 3:30 p. m. more thin dust was seen over the pit. On January 29 at 1:30 p. m., the wind was blowing a heavy gale from the south, and the Halemaumau orifice was nearly hidden from view of the observatory by the dust. Great clouds of dust were blowing in the Kau Desert. The wind increased during the day so that wind tremor was strong on the seismograms. On January 31, after a rainstorm, the walls were dark red with wetting, there was the usual steam, and some fresh debris was observed on the northeast talus.

Fifteen seismic disturbances were registered at Kilauea. Seven were tremors and six were very feeble local seisms, three of which indicated average distance to origin 41 miles corresponding to the North Kona center One very feeble seism indicated origin 18 miles away, possibly corresponding in origin to another feeble shock, origin distance 23 miles, at 2:38 a. m., January 29. A slight shock



Glowing and fountaining liquid lava pool at dawn February 20, 1929. Interior of Halemaumau from the east, big north fountain on right. This buried the floor of July, 1927, to a depth of 64 feet. Photo Maehara, copyright.



This photograph is a daylight view, same scene as the last, at 6:30 a. m. of the second and last day of the eruption. February 21, 1929, when the fountains had dwindled. In the background is the northwest talus. Condensation of fume over the fountains and deep rumble had increased. Solidified rampart shore of lake is shown. On the right is the grotto which had been built high by the large fountain. The source crack lay along the line connecting this grotto with the line of fountains at the left, all of which at first had been a fissure following the edge of the plug left by the July eruption of 1927. The former plug lifts like a cork in a funnel, and the slag froth escapes between the cork and the wall. Photo Maehara.

was more strongly felt at 6:42 p. m., January 29, origin distance 48 miles, probably felt generally on the island of Hawaii. Very feeble, feeble and slight are technical terms of increasing intensities.

Microseismic motion for the week was moderate both E-W and S-W, and tilting of the ground was very strong SW.

JANUARY TILTING OF THE GROUND

At the Hawaiian Volcano Observatory, on the north-east edge of Kilauea Crater, just opposite the Volcano House, the tilting or tipping of the ground as measured with seismographs in a concrete basement was as follows for the five weeks following December 29, 1929. This is expressed as angular change and direction of motion of the plumb line.

December 30-January 5 . . .	3.21 seconds SW
January 6-12	1.33 seconds SSE
January 13-19	3.75 seconds NNE
January 20-26	2.06 seconds NNE
January 27-February 2	5.38 seconds SW

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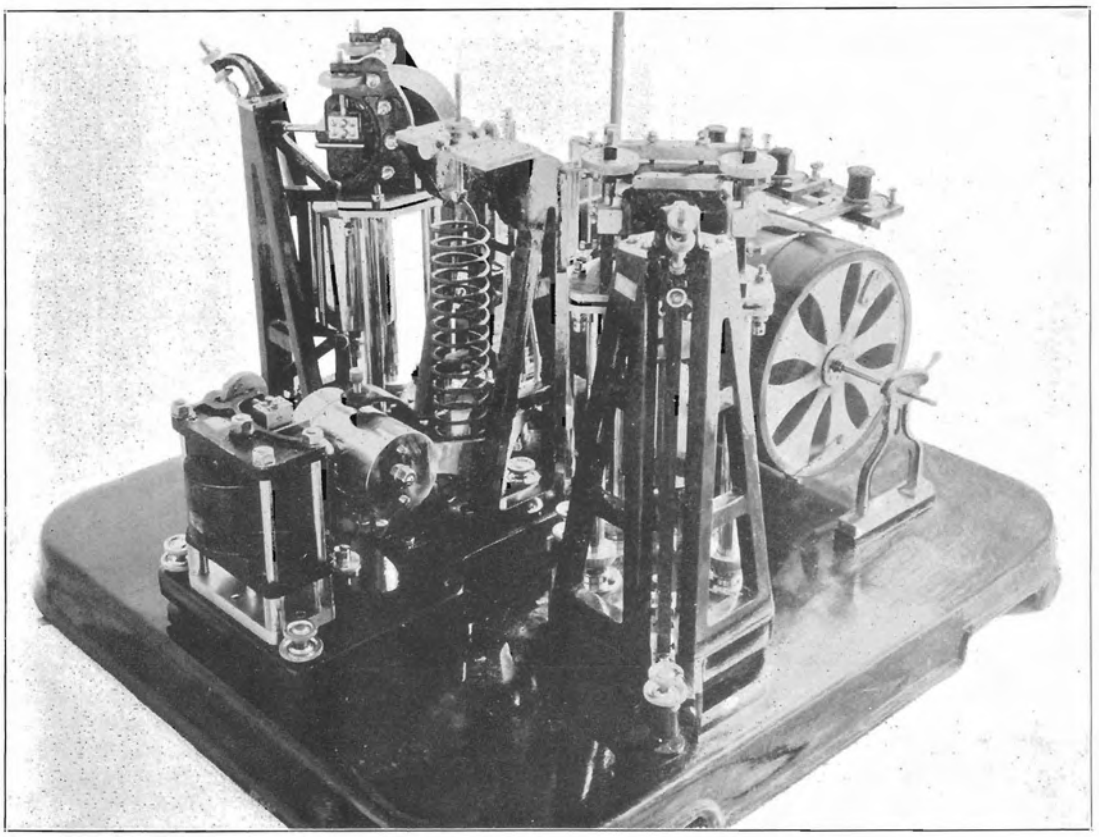
The Volcano Letter

Two dollars per year — Ten cents per copy

No. 268—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — February 13, 1930



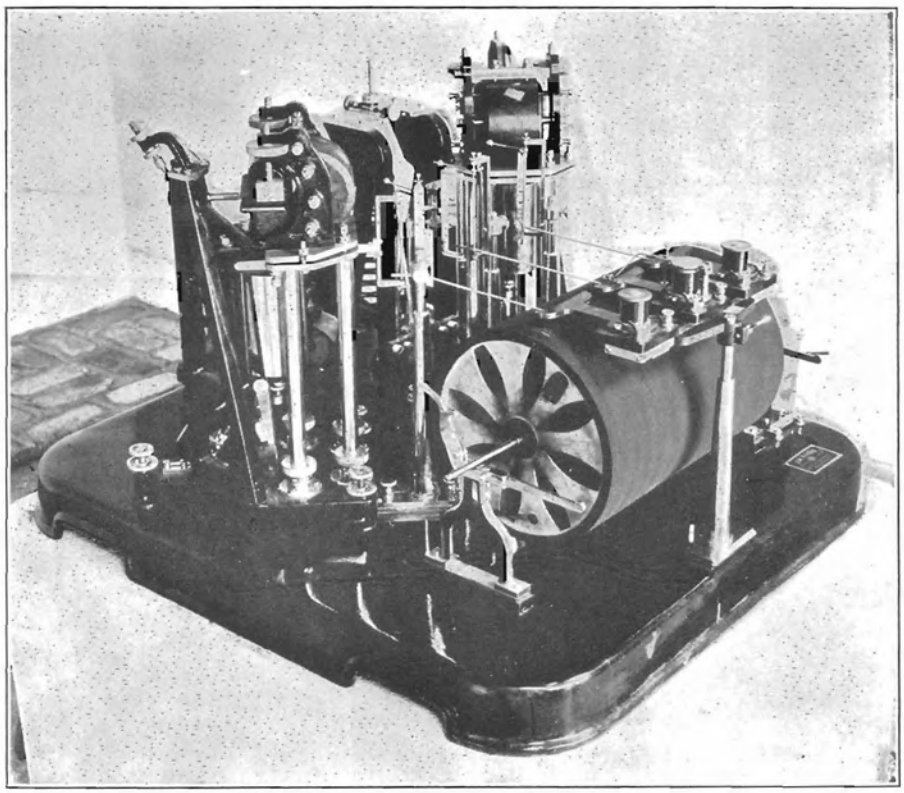
Back of Imamura seismograph as installed at Uwekahuna Observatory, Kilauea Crater. Vertical component pendulum on the left, recording drum on the right. Large gleaming cylinder in background is one of the horizontal pendulums under its damping magnet.

HOW THE SEISMOGRAPH WORKS

There is much misunderstanding about seismographs and earthquakes. One woman visited the seismograph cellar at the Hawaiian Volcano Observatory, and was observed to be looking around in all the corners of the room, seeking for something. When asked what she was looking for, she remarked that she was searching for the main wire. It later appeared that she thought the seismograph was connected in some mysterious electrical fashion with the inside of the volcano. Probably most travelers who see for the first time the excellent little seismograph, made in Japan, exhibited in the alcove of the Uwekahuna Observatory and Museum at Kilauea, as shown in the above picture, imagine it is far too complicated for them to understand. As a matter of fact the principles involved are extremely simple.

The reason the picture looks so jumbled is that this instrument attempts to combine six different things. These are respectively three different pendulums, a damping or clogging apparatus to keep the pendulums from swinging too much on their own account, a recording machine to compel all three pendulums to write their autographs on smoked paper all the time with high magnification of their relative movement, and a time-keeping device which also is compelled to mark the minutes on the paper. Each of these things by itself is very simple, but to make all work in harmony on one piece of paper is like asking a wrist watch to make a record of everything the wearer does.

There are three japanned openwork iron frames in a line across the baseplate, each holding a 13-pound cylindrical weight lightly hung on pivots. These are the pendulums and these are at the heart of the apparatus. Two of them are hung like doors at right angles to each other; their free motion is much like that of the needle holder of a gramophone. If with the sound box turned back, you hit with your fist the side of the gramophone cabinet, the sound box will jump towards your fist. If you hit the other side it will jump the other way. If you let the sound box hang down without any record under it, and imagine it immersed in a tumbler of oil, it will move through the oil by the amount that you have displaced the cabinet, but it will not waggle back and forth afterwards. That is what is meant by damping. It is an oil damper. The machine in the picture uses magnetism for damping, the rounded objects at the top and at the left being horseshoe magnets with a plate between the poles which is attached in each case to the cylindrical weight. The magnetic forces restrain the weight from waggling. The left-hand weight is hung on a spiral spring as shown, and differs from the other two in that its motion is up and down like the child's wooden ball hanging from an elastic band.



Imamura Seismograph, Uwekahuna Observatory, showing the pendulums at the back, the three slender pens, the clock-driven drum covered with smoked paper, and the three electro-magnets (spools) at the right. These lift the pen points once a minute.

This is called the vertical pendulum and registers up-down motion of the ground. The other two are horizontal pendulums and register east-west and north-south motion of the ground.

Now let us look at picture No. 2. This is the same instrument seen from the front. The heavy baseplate is set on concrete, this is on bedrock, and the alcove is protected from wind currents. Three very dainty slender levers protrude from a magnifying connection with the three pendulums. They are the three straight lines that look like strings protruding horizontally from the group of pendulums, and at their right-hand outer ends they hold tiny pivoted steel pens which rest on the smoked paper that covers the surface of the big cylindrical drum. If there is a north-south movement of the ground, the farther pen will move back and forth on the smoked paper 50 times farther than the ground itself moves; the middle pen similarly magnifies 50 times the up-and-down motion of the ground, and the near pen the east-west motion. Accordingly the single sheet of smoked paper will receive a back-and-forth white line for all three motions of the same earthquake, and we may compare side by side at that place on the paper, how much the motion was north-south, up-down, and east-west.

A digression is necessary here, because the reader thinks that the pendulum moves. It is perfectly true that if I move the pendulum with my finger, the pen will move 50 times as much. The seismograph, however, is not designed to ask the earthquake to move the pendulum. It rather asks the pendulum to stand still while the earth oscillates under it. This is what you ask the gramophone arm to do when you move the cabinet sidewise. If the iron door of a basement furnace is hanging open, and an earthquake moves the cellar sidewise, the door at first swings (apparently) in the opposite direction from the cellar. What it really does is to stand still by its inertia, while the furnace does the moving. So it is with the seismograph pendulums.

The time when the earthquake began at the instrument, the time when its vibrations changed from very short tremors to longer movements, the time occupied by each independent back-and-forth movement (known as the "period" of the earth wave), the time when the long movements slowed down to short movements again, and the time when the last trace of quaking stopped, are all important features of a seismogram. The seismogram is the paper record, the seismograph is the instrument itself. It will be seen above that if the paper stood still and an earthquake happened, we would get three short lines scratched on the smoke of the smudged white paper surface. This smoking, by the way, is obtained by merely twirling the paper-covered drum over a smoking kerosene lamp. The three short lines on stationary paper would tell us that there had been an earthquake, and how long its biggest oscillations were, respectively north-south, up-down, and east-west. But it would not tell us how long it lasted, nor at what o'clock it occurred. Here is where the drum comes in.

The surface of the drum is turning around all the time on a screw spindle that passes through the center of the drum, turned by a clockwork at the end of the drum. A fresh paper is wrapped around the drum and started every morning when the clockwork is wound. The three pens are thus writing lines round and round the drum, and the screw spindle pushes the drum along lengthwise, so that when a complete revolution is made each pen is

offset a little from its previous position. Thus each pen writes a band of lines, each line corresponding to an hour say, and the band of 24 lines corresponding to the pen's work for the 24 hours of the day. If the ground does not move, the lines are straight and smooth and owe their existence solely to the rotation of the drum. If, however, an earthquake occurs each pen departs from its straight line and writes a zigzag, lasting as long as the earthquake lasts, its back-and-forth scrapings being close together if the earthquake is of quick period, and being far apart if the earthquake motion is slow. This is best understood by reference to the print of an actual seismogram on Page Four. There is an upper and lower band of lines, the upper south-north, the lower east-west. Near the bottom of each band there are big back-and-forth scrapings of very slow earthquake waves that came from a center in southeastern Alaska October 24, 1927. Right in the middle of this there are quick back-and-forth scrapings, the record of a local earthquake here at Kilauea Volcano at 6:20 a. m., feebly felt, on the same day. Possibly the slow wave motion of the big distant earthquake, 2,700 miles away, released the accumulated friction of the local mountain block in Hawaii, which slipped and jarred the island.

In the middle of the close-set lines of the local earthquake will be seen a gap in the record. There are in fact gaps of this kind a little less than an inch and a half apart on all the lines, marking the minutes. These are marked in on the seismogram by the three electromagnets, which look like spools at the right of the drum in the pictures.

The electromagnets are connected by wires through a battery with a big pendulum clock that hangs on the wall of the seismograph alcove. This clock closes a contact once a minute with its second hand, and once an hour with its minute hand, and the electric impulse lifts the three little pen points off the drum for about a second, and thereby creates a minute mark in the form of a gap in the line. A longer gap is made on the hour. The operator, when he puts on the drum in the morning, writes on the smoke the time of starting, and the rest is easy. With these time marks we may measure all the facts of time and duration of the earthquakes, and their several phases.

The picture on the third page shows a simplified single-pendulum seismograph set on a concrete shaking table, which is attached to a lathe chuck, through which in the shop of the Observatory artificial earthquakes may be made. This is a horizontal pendulum, and the big black cylinder is its swinging weight. At the right-hand end, also on the concrete table, are the drum and driving clock with a single writing pen and electromagnet. The lever from the lathe has its motion reduced at the steel rollers underneath the concrete table, so that the very small motions of the ground, which are characteristic of a local earthquake, may be imitated. T. A. J.

KILAUEA REPORT No. 942
WEEK ENDING FEBRUARY 9, 1930

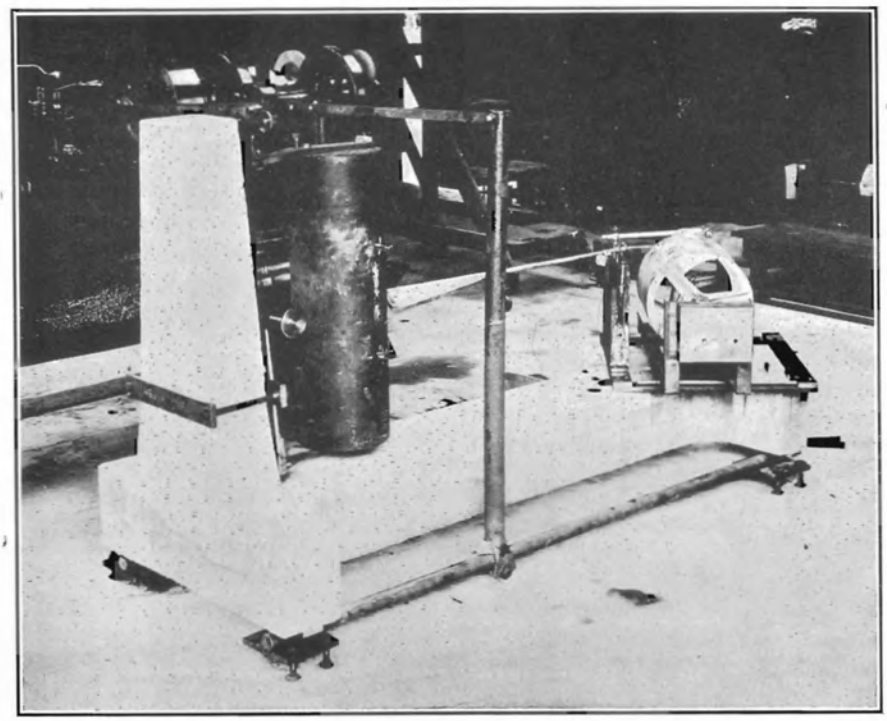
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Halemaumau pit continues quiet. On February 5 a few big bowlders from a recent avalanche lay on the southeast talus. A fresh streak of debris was also on the same talus heap. Steam was absent on the crater's floor. On February 8 no changes were observed, and there was very little steam.

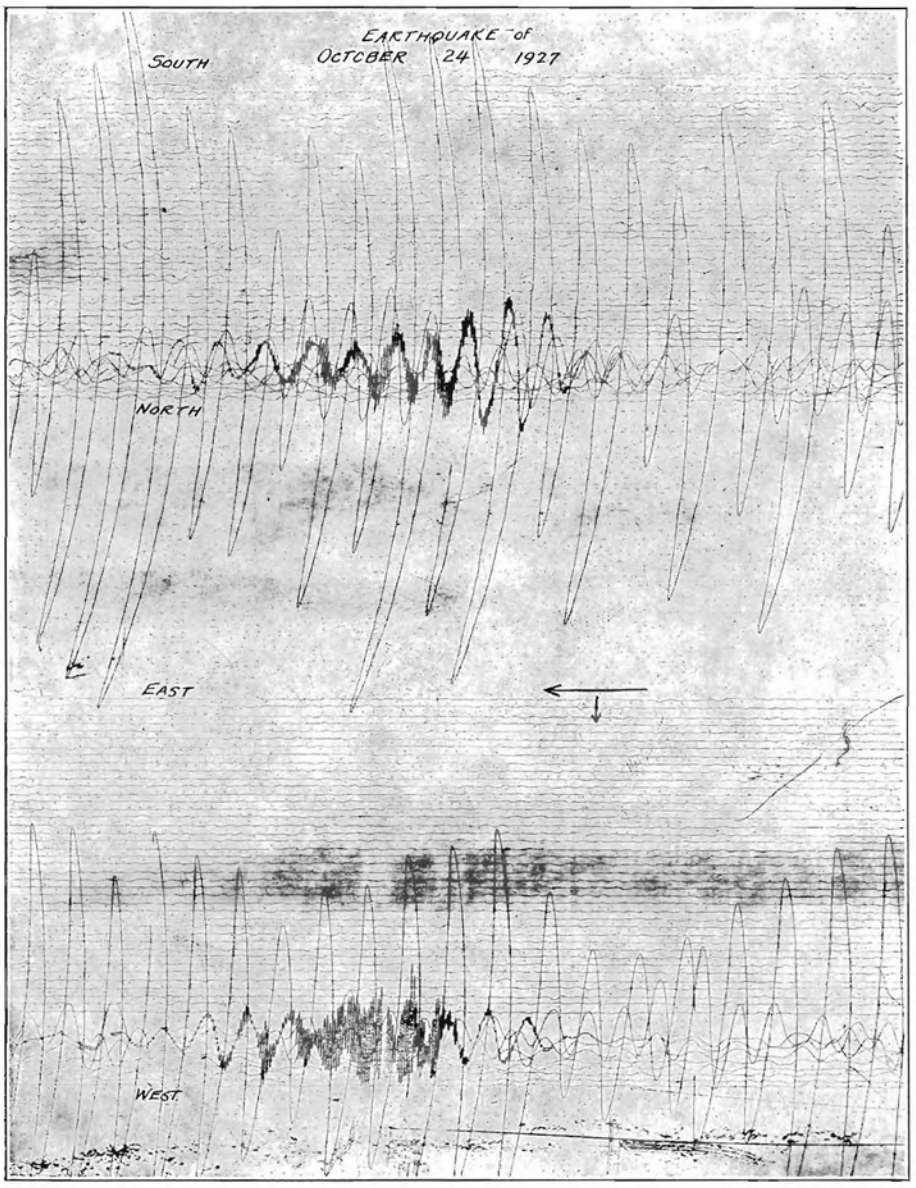
The seismographs at the Observatory recorded eight tremors, two very feeble and four feeble seisms. The feeble shocks were felt in some places on the island, and occurred as follows:

February 2, 6:02 p.m.,	indicated	distance 32 miles
February 8, 8:06 p.m.,	indicated	distance 32 miles
February 8, 8:13 p.m.,	indicated	distance 23 miles
February 9, 9:43 a.m.,	indicated	distance 40 miles

Microseismic motion was slightly stronger than normal early in the week, decreasing to normal on the 6th. Tilt accumulated moderately strong to the northeast, directly reverse to the direction of tilt during the previous week.



Concrete oscillating table operated by a lathe chuck. The complete single Hawaiian type pendulum is hung on the table, along with its recording drum, and subjected to artificial earthquakes. In Hawaiian Volcano Observatory shop.



Seismograms of the two earthquakes October 24, 1927 The upper and lower bands of lines register a night's work of the seismograph. The upper is north-south motion. The lower is east-west motion. The big oscillations shown are the faint slow waves of an Alaskan giant earthquake as registered in Hawaii. The close-set zigzags, like shading in the middle of the large motions are made by a local Hawaiian earthquake, which possibly was "touched off" by the big earth waves. Lines read from right to left, and begin at the top. The breaks in the lines are minute marks, or time signals.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Lorrin A. Thurston, President; Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

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The Volcano Letter

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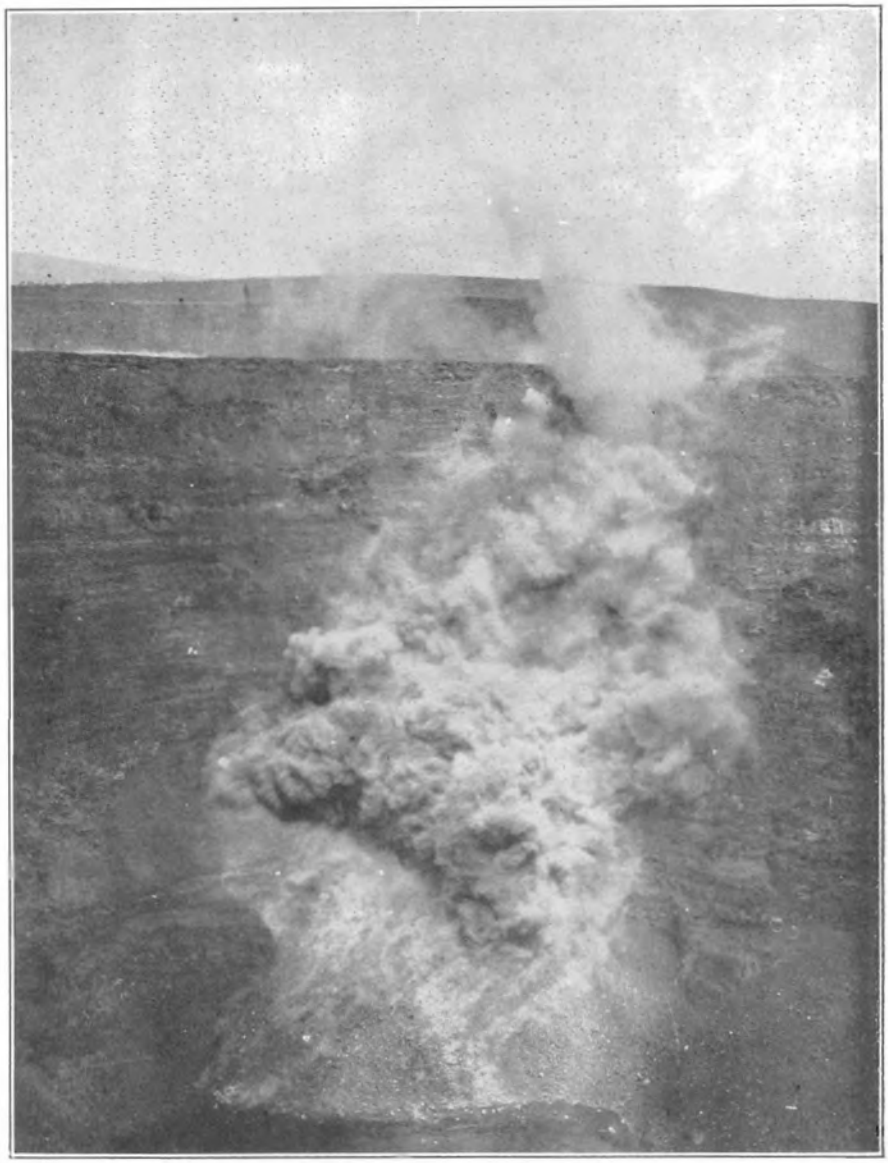
No 269—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — February 20, 1930



Avalanche falling on northwest talus of Halemaumau 10:27 a. m. October 5, 1927. This picture shows how cauliflower clouds of dust are easily generated by the grinding of falling rock. An exaggeration of this with all the walls falling at once, and steam rushing up, is what happens in an explosive volcanic eruption. Photo Evans.

MEANING OF CRATER AVALANCHES

Many visitors to the fire pit of Kilauea happen upon the adventure of seeing and hearing large or small slides of broken rock that fall from the walls of the pit. A splendid motion picture of such a slide is exhibited to tourists at the Uwekahuna Observatory. The lower portion of the rock wall begins to "work", and black cascades of gravel and dust are seen streaming down the notches to the talus. Then pieces of the wall flake off higher up. Finally a very large piece shows itself to be in process of separating from the face of the wall, with black cascades on each side, the moving portion being a flat cake of wide area often extending to the very top edge. All the rock matter breaks up on its impact below, and during the crushing and grinding of its separation from the wall, hundreds of tons being involved. The talus or slide rock slope below receives the impact, is built up at the top, and tends to become steeper than the angle of rest. This starts a sliding in the debris slope, and great clouds in "cauliflower" form carry the dust boiling above the edge of the pit. These slides have been renewed from time to time during the past six years, becoming very vigorous from no apparent cause.

The photograph on the first page and the map on Page Four show one of these avalanches and the contour plan of its results. The place where this avalanche occurred in 1927 is the wall in the upper left-hand rectangle of the map. The evenly spaced contour lines of the lighter portion of the map of the pit are mostly slide-rock slopes of about 30 degrees inclination. The flat of the bottom lava is out-

Two photographs of the north corner of Halemaumau pit showing the detail of the wall before and after avalanches of February 18 and 20, 1928. The first January 2, 1923, shows two talus cones, the prow of the big sill next above, and a light band above that which is a cross section of an old debris slope with lava flows on the right lapping against it. The second February 26, 1928, shows the same scene after the avalanches had scoured the talus cone and the wall above had flaked off all the way to the top. Photo Wilson.

lined in dots. The rock wall shows close-set and irregular contour lines. This wall exhibits a flat bench of light shading in the upper right-hand rectangles. This bench is the top of a thick sill or sheet of intrusive lava which was red hot but hard at the end of the explosive eruption of 1924, when that wall of the pit broke and started red hot avalanches from this sill. The sill is well shown in the first of the two pictures on Page Two as a rock ledge shaped like the prow of a boat next above the talus slopes and to the right of the sharp pointed talus cone.

When this map was made in July of 1928 the surveys showed that there had been four cavings-in from the rim during the preceding 12 months. Over this northwest talus a strip 700 feet long and containing nearly an acre of rock was missing. The picture on Page One shows how it happened, but a still bigger avalanche here January 11, 1928, had caused the debris slope below to break away as a landslip and flow out over the floor. Other portions of the rock wall, totally changed since the surveys of a year before, were at the southwest, at the north-northeast, and a long, narrow strip three-quarters of an acre in extent at the east-northeast. When we add to this the tremendous southeastern caving in of the rim of the pit which occurred in January of 1929, making it necessary to change the inspection station at the road terminus, it will be seen that two years of wall-breaking had pretty well encircled the pit.

This gradual encircling of the pit by slides was noticed during the early years of the work of the Observatory, when lava was almost continuously present, rising and falling in the pit. The times of maximum avalanching were also times of maximum subsidence of the lava, of maximum local earthquake frequency, and of maximum inward tipping of the ground toward the center of subsidence. The jarring of earthquakes doubtless loosens the wall material, but no conspicuous causal relation whereby earthquakes make avalanches has appeared. In some definite cases, on the other hand, avalanches conspicuously make earthquakes. The greatest of these was the grand avalanching that enlarged the pit during the explosive eruption of 1924. Since then there has been instituted measurement of the width of cracks close to the edge of Halemaumau. In January, 1928, when the big avalanching at the northwest was starting, crack measurement showed an opening of five inches in 11 days, and leveling revealed a lowering in eight months of nearly half a foot for the ground at the edge of the pit. The ground was tipping in toward the crater center during these weeks. During a time of similar opening of cracks in August, 1928, an avalanche of large size occurred which produced a tremor record much larger on a seismograph nearer to the pit than on the Observatory seismographs, and showing other evidence that the slide was the cause of the tremor.

Now if we examine the map on the last page, we shall see these border cracks as dotted lines just back from the edge of the pit, and parallel to the edge in many places. It also appears that the pit is a pentagon rather than a circle, the five angles being at the tops of the taluses southwest, northwest, north-northeast, east and south. Each of these angles has a reason for its existence, and the reasons are evident. The straight sides of the pit southeast and northwest roughly conform to the rift system that extends far out into the desert. The steep southwest wall is a cross fracture between these two more gently sloping rift walls. The northeast side is very steep and clearly determined by the two ends of the big sill which have been places of motion and weakness since 1924. The short north wall is a cross facture between the sill wall and the rift wall, a remnant, so to speak, adjusting the big hole, during its engulfment, to the controlling deep joints. This formation of a pentagon has repeatedly been observed in photographs of the craters on the moon, which are also engulfment pits. The fundamental cause, then, of straight sides to an otherwise circular pit, is a guidance by deep straight fissures or lines of weakness in a process of breaking which is controlled by a small center of engulfment.

The meaning of crater avalanches reverts to a center of engulfment. Why should there be a center of falling in? This takes us back to how a volcano begins. It begins by lava welling up a crack. If it kept on welling up the whole length of the crack it would make an even ridge. It does not do this. Cracks are not regular and the narrower places become clogged. Then the wider places become centers rather than linear fissures. They become centers because the upflow is through the soft material of their own overflow. The crack is buried far below and an oval or circular heap of new lava becomes the dominant structure up which the eruptions are building. If the eruptions were perfectly continuous, without alternations of gas and liquid, and without alternations of rising and falling, there would be no craters. There would be a lava lake eternally overflowing. There is no visible pit when Halemaumau fills to the brim. The pit is the product of a sinking back of the lava whereby the hardened walls fall in, and reveal something of the shape of the well. The volcanologist as a detective has to learn from what happens by cracking, shaking, steaming, and tipping of the outside ground, what is the probable shape of the bottom of the well when the lava retreats.

This is no simple matter, and the accumulated learning of the world from the mapping of cross sections of old volcanoes, from the study of volcanic earthquakes, from the reports of explosive eruptions, and from studies of physical geography of craters, needs study in order to make an accurate guess as to what the lava column would look like if we could cut a slice through the volcano straight down for seven miles. For there is seven miles of lava building if the Hawaiian ridge started in a deep part of the Pacific. Computations suggested that the lava column sank about a mile under Kilauea in 1924, and that previously it may have wedged out right and left several miles in some kind of underground reservoir. The pit was left a rather flat funnel, but some of the flatness is due to the debris plugging the bottom. Our work with instruments is like that of the surgeon with the X-ray and the stethoscope. We must learn the internal organs of a volcano, the chemistry of its digestion and excretion, the cycle of its breathing, and the shape of its alimentary canal.

The avalaches grow more or less frequent as the walls of the pit are more or less undermined. Under the debris is a rock wall of flat slope. Is this a wall, or is it a congestion of gigantic wall slabs? Have these slaps slipped down? And are they jammed about the center? Such a notion of the structure agrees with the fact that eruptions start through crevices high up around the border of the inner pit bottom. Are these slabs the top of a column of debris which fell in, in 1924? And is this whole column being infiltrated with lava? If so, does the column lower when the stiff lava lowers, and so start earth tremors and avalanches? And does it rise when the lava expands, and so stop all undermining?

This would cause the outside country to tip away. Such is the fact when lava rises. And also the avalanches cease when lava rises. Thus it appears that the rock slides are not only what creates these pits and keeps them circular. The slides are also indicative of what is going on far below. T.A.J.

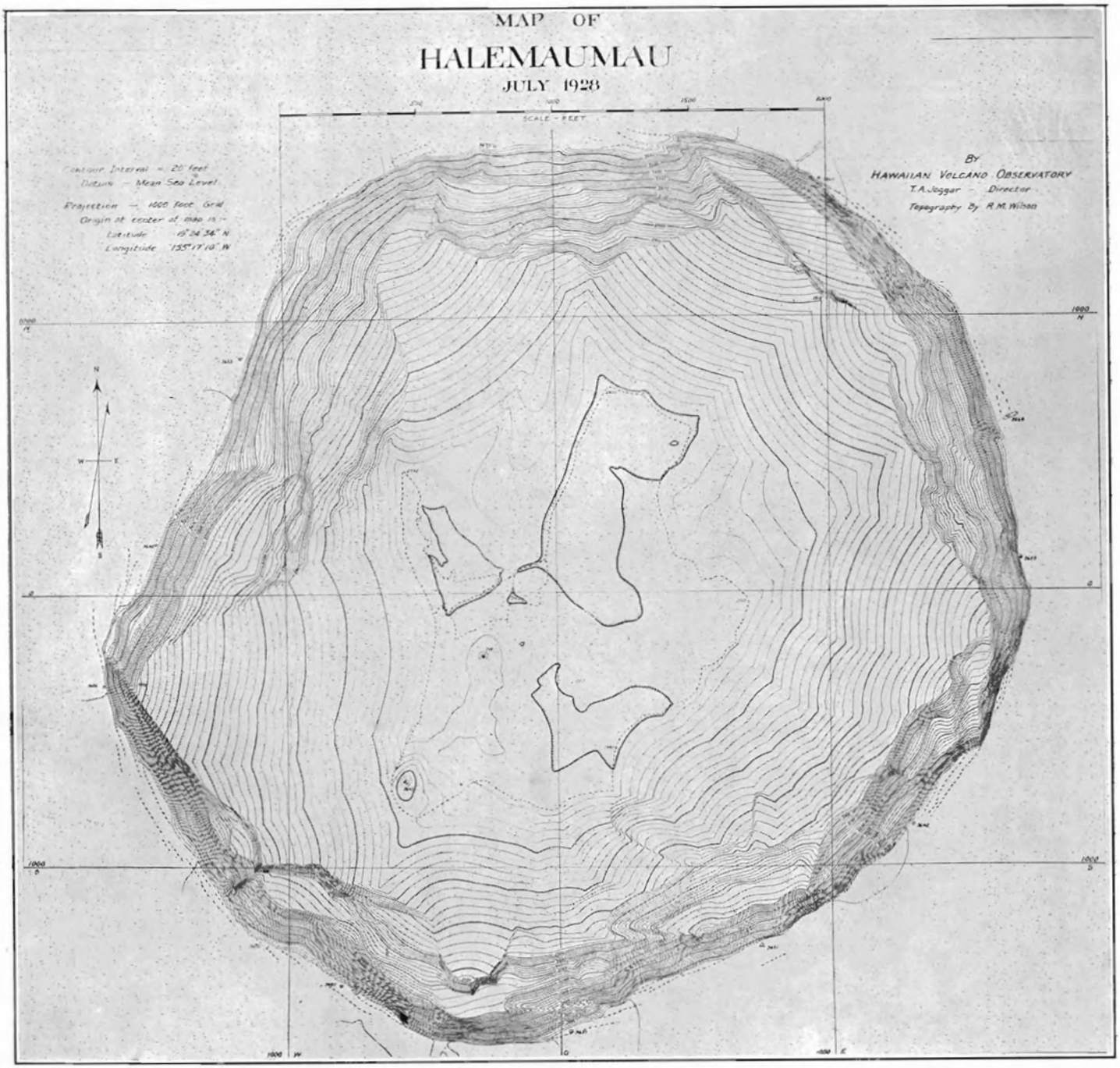
KILAUEA REPORT No. 943

WEEK ENDING FEBRUARY 16, 1930
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On February 11 at 1:30 p. m., gray dust rose from an avalanche within Halemaumau pit apparently from the west side. This lasted for several minutes. Another was reported at the north wall of the pit at 4:10 p. m. Inspection on February 12 indicated that the slides had been voluminous, leaving much dust. At 8 a. m. February 14 a convection cloud hung over the pit, and a similar condition at 9 a. m today, February 17, appeared as a high column of vapor from the northeast wall of the pit, occasioned by unusually calm conditions which had covered the whole floor of Kilauea Crater with a steam fog.

The seismographs at the Observatory registered 16 tremors and 7 very feeble local seisms during the week ended at midnight February 16, two of the shocks indicating origin distance 23 miles and one a distance of 43 miles. These distances correspond closely to Mauna Loa and Hualalai. The tremors did not exceed one minute in duration.

Microseismic motion for the week has been slight, and tilt accumulated strong SW, again reversing the direction of the previous week. Such strong pulsations of tilting sometimes indicate underground lava movement.



Map of Halemaumau Pit, contour interval 20 feet, surveyed July, 1928 by R. M. Wilson. Dotted outline is lava bottom of July 1927. Dotted lines at edge of pit are cracks. Talus slopes make the open contours of the lower area. The rectangular net marks 1000-foot intervals. Bottom is 2482 and top 3692 feet above sea-level. The rock wall extends clear to the bottom in funnel shape northwest and southeast, between the northwest and west taluses, and between the southeast and south taluses. The two black spots in the southwest wall are caverns on the Kau Rift, and the line of four cones across the bottom follows this fissure, which determines the longer axis of the pit.

ILLUSTRATED LECTURES IN HONOLULU

A course of five illustrated lectures by T. A. Jaggar on "How the Volcano works" is in progress in Honolulu, and the dates have been changed. The place is the ballroom of the Royal Hawaiian Hotel, the hour nine in the evenings of February 11 and 24, March 14 and 24, and April 14. These are open meetings of the Hawaiian Volcano Research Association during the tourist season.

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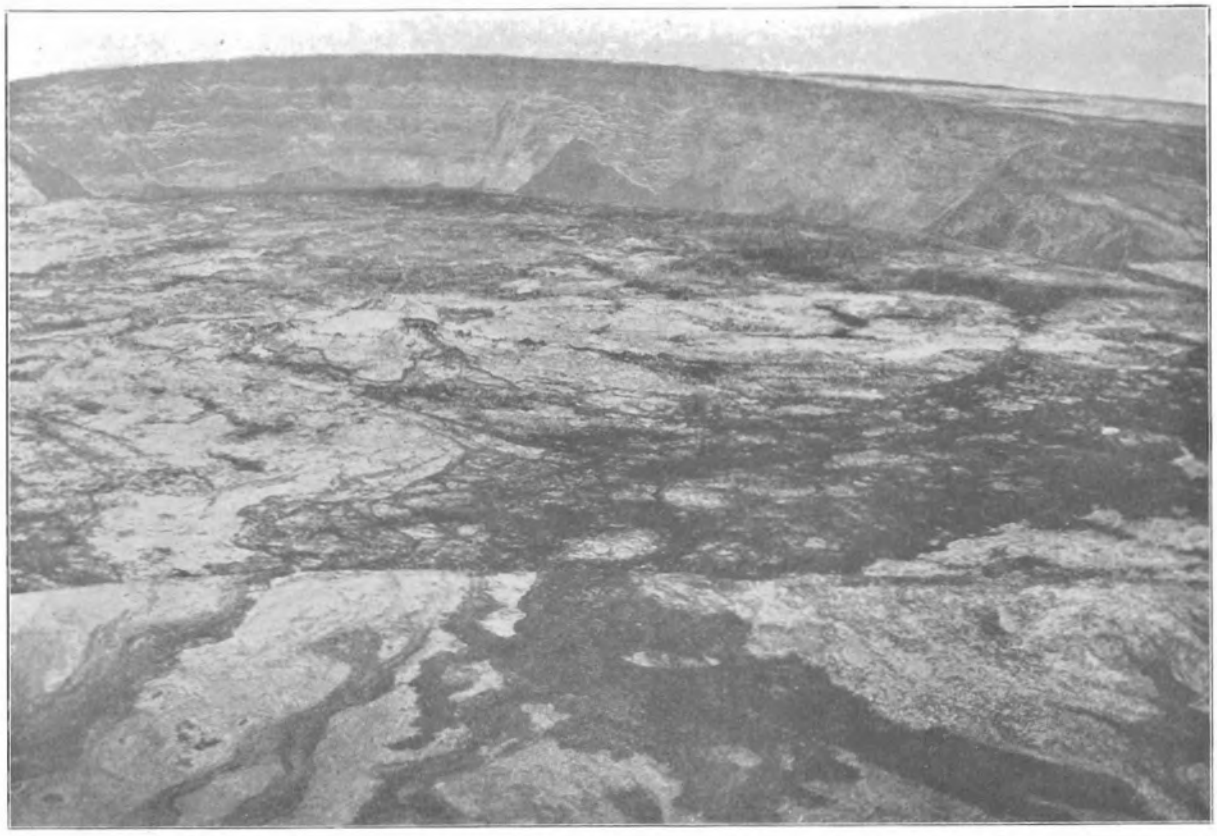
NO. 270—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — February 27, 1930



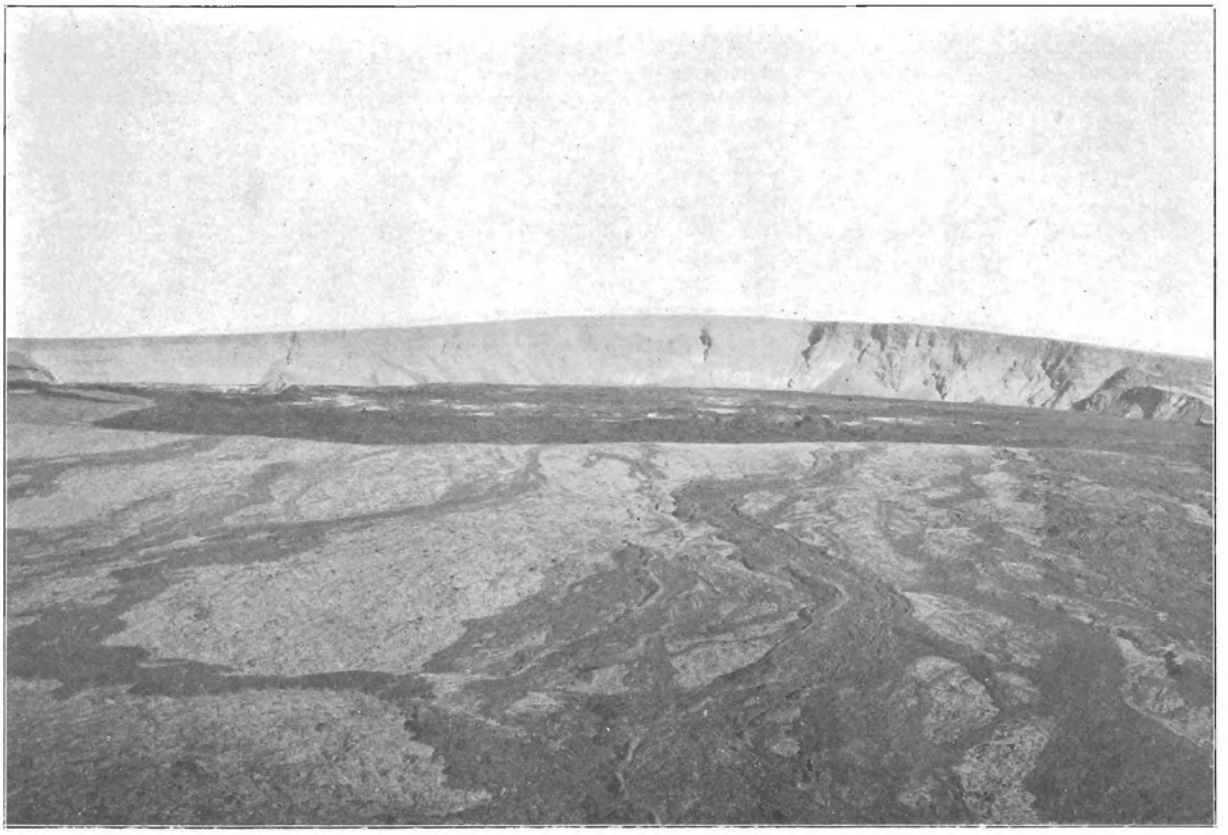
Mokuaweoweo, the summit crater of Mauna Loa, at 9:45 a. m. October 9, 1929, photographed from the east from an airplane at elevation 15,200 feet. This shows part of the northern half of the crater mantled with a light snowfall, the high western wall, and the cone of 1896 in the bottom, with the eruption crack of 1914 athwart it showing a line of spatter heaps of lava. In the foreground are clinker flows of the east edge of the cauldron. Photo Bureau of Aeronautics, U. S. Navy, by permission of Rear Admiral George F. Marvell, Commandant Pearl Harbor, Hawaii.

AIRPLANES FOR VOLCANOLOGY

The volcano Pelee in Martinique developed gas and ash eruption in the autumn of 1929 which was renewed in December (Volcano Letter No. 262, January 2, 1930). The following is a picturesque statement of our modern birds-eye viewpoint: "A student of the Imperial College of Tropical Agriculture, who returned to Trinidad January 12, 1930, from leave in the United States, in an airplane of the West Indies Airways, says that Martinique was hidden in a volcanic cloud through which could be caught glimpses of silent villages and deserted cocoa estates. The northern part of the island has been evacuated and public gatherings are prohibited." (London Times January 14, 1930.)

Thanks to the U. S. Army and Navy air services, planes and air photographers have been placed at the service of the U. S. Geological Survey so that mapping of the culture and the drainage of southeastern Alaska, the Mississippi Valley and the island of Oahu in Hawaii, as well as many other places, is more perfect and less expensive than ever before. Repeatedly airplanes with photographers have been supplied to the Hawaiian Volcano Observatory, in times of stress, on the island of Hawaii, and the results have revealed the meaning of lava outbreak on these vast flat volcanoes, in a way that could never be approached by land expeditions. Over Vesuvius both motion and still pictures have been taken of the crater activity. One of the most remarkable monographs on craters ever published is entitled, "Volcano Studies in Java," by N. J. M. Taverne of the Netherlands East Indies Volcano Service, issued in 1926, containing supurb photogravures of 24 craters pictured from the air over a wild mountainous country of savage jungles. The pictures reveal the cones in profile, the gullys on their flanks, extraordinary lava plugs standing in relief, the distribution of hot springs and solfataras in the jungle, double craters and inner benches, details of relief in adjacent peaks which it would take years to map, inner lava floors and domes, crater lakes, flank craters and sharp peaks with lava plugs, and all the manifold complexities of unsuspected pits in the jungle and erosion of ash covered surfaces that might be missed entirely by a land expendition.

During the recent seismic activity in September-October, 1929, on the western side of Hawaii, the writer was privileged to inspect the whole eastern, southern, and western flanks of the island mass in a Naval plane at elevations from 10,000 to 12,000 feet, traveling about 160 miles from Hilo over Kilauea Volcano, across the great rifts that extend down the southwestern flank of Mauna Loa, and then northward over Kona across the divide between Mauna Loa and Hualalai. The relief of the great Hawaiian turtleback mountains, with the straight fault cliffs and sink craters, the lines of circular pits on Kilauea, and the lines of pumice cones on Mauna Loa, all revealing meandering black aa flows like giant serpents leading to the



Mokuaweoweo from the southeast, photographed from an airplane, June 25, 1929, showing on the crater floor the cone of 1914 on the left and the cones of 1896 on the right, both amid patches of solfataric whitish stain. Photo by permission 11th Photo Section Air Corps, U. S. Army.

sea, is in marked contrast to the steep cones of Java. The visibility was excellent on this flight and no trace of new outbreak correlated with the earthquake spasm was found. It would have taken weeks to explore the same territory with pack train, and even then a small outbreak might have escaped notice.

Thanks to the courtesy of Rear Admiral George F. Marvell, Commandant of the Pearl Harbor Naval Station, U. S. Navy, we are permitted to exhibit on Page One a photograph of Mokuaweoweo, the summit crater of Mauna Loa, made by J. A. Pringle with a hand-held 4 by 5-inch camera and 10-inch lens at 8:45 a. m. October 9, 1929, from the east at elevation 15,200 feet. This was photographed from a small scout plane capable of flying at these high altitudes. The far rim of this sink crater is at elevation 13,653 feet above sea level, and the area is coated with a light fall of recent snow. This serves to exhibit on the floor of the crater the old cone of 1896, cut across from left to right with the gash and line of driblet cones that were formed in 1914. In the foreground is the east edge of the crater with aa flows, and the dark objects under the distant cliffs are talus slopes. If there had been new activity it would have appeared as spurting lava sending up clouds of blue sulphurous gas.

It is of interest to compare this same scene, photographed without snow from a greater distance by the Eleventh Photo Section of the Air Corps, U. S. Army, June 25, 1929 (Page Two). Here there is sulphurous stain on the black lava floor of the crater, and as this picture is taken from the southeast the 1896 cones appear on the right and the cone built by the large fountain of 1914 is shown at the left. The angle in the high cliffs at the back where the white expanse changes to shadowed bluff, is the angle in plan between the southwestern and northeastern rifts of the Mauna Loa dome. Extended down the mountain the northeastern rift is the seat of a line of cinder cones that poured flows toward Hilo in the nineteenth century. On the other side of the mountain the Kahuku rift gave vent to an increasing succession of flows from 1868 to 1926, the later ones devastating portions of South Kona.

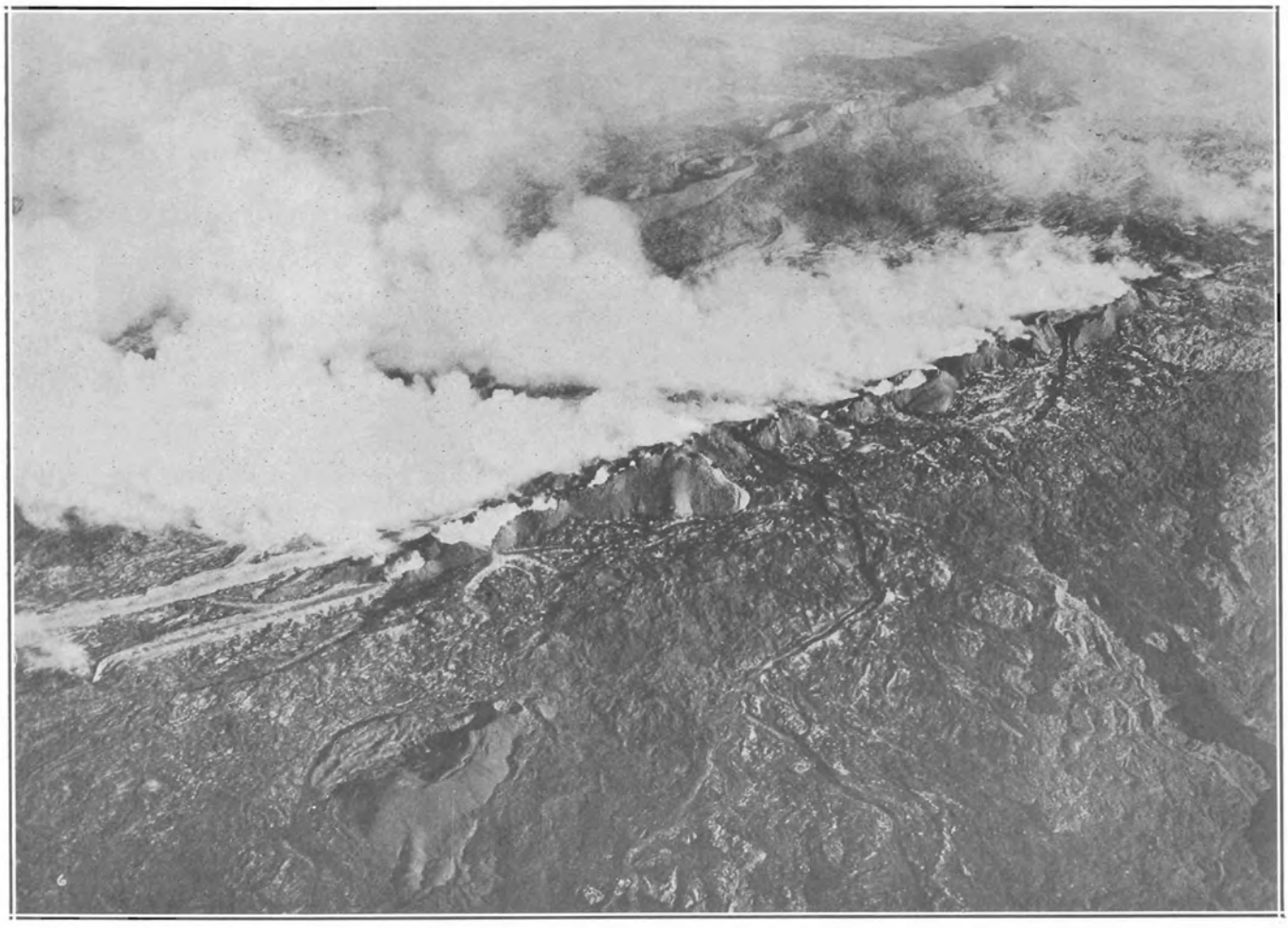
The photograph on Page Three follows the eruption of April, 1926, down the southwestern ridge of Mauna Loa and presents a most comprehensive picture from the air revealing how the mountain ruptures along a belt of parallel cracks. This place is the source, about 7,600 feet above sea level, of the actual flood of slag which swept down on the village of Hoopuloa at the sea shore, and destroyed it. The aviators were flying along the southeastern side of the rift belt and the wind was blowing from the eastward so that the fumes sweep off to the west in the picture. In the foreground is shown an old cone containing a large crater and two smaller ones over a crack in general parallel to the active fissure, and in the background the line of dead cup craters, also parallel to the 1926 rift, is the scene of the tremendous eruption of the Alika flow of 1919. Here then are several active cracks parallel to each other, all constituting a rift belt, or fractured zone of the mountain, several miles wide. The active crack of 1926 is very straight and had built up a dozen cones each 50 to 75 feet high along about two miles of length shown in the picture. The right-hand end is up the mountain and the left-hand end shows two white streams of lava flowing in very straight courses down the mountain. The nearer one is flowing along the fissure and has found an open vent on the fissure into which it cascades. There are other live streams behind the smoke, vented by the middle and lower cones shown. The upper cones on the right have gone out of action, and one of their dead river beds is shown in the lower right-hand part of the picture. All of the live streams were distributing over the flat upland, but they united in a single torrent when they passed over the shoulder of the mountain and went down the steep slope through the forest into South Kona. A characteristic detail of the actual lava river is the dark line of rafts and partly congealed crusts carried down the middle of the stream, while the border portion remains

bright and glowing with escaping gases along the belt of friction on the banks.

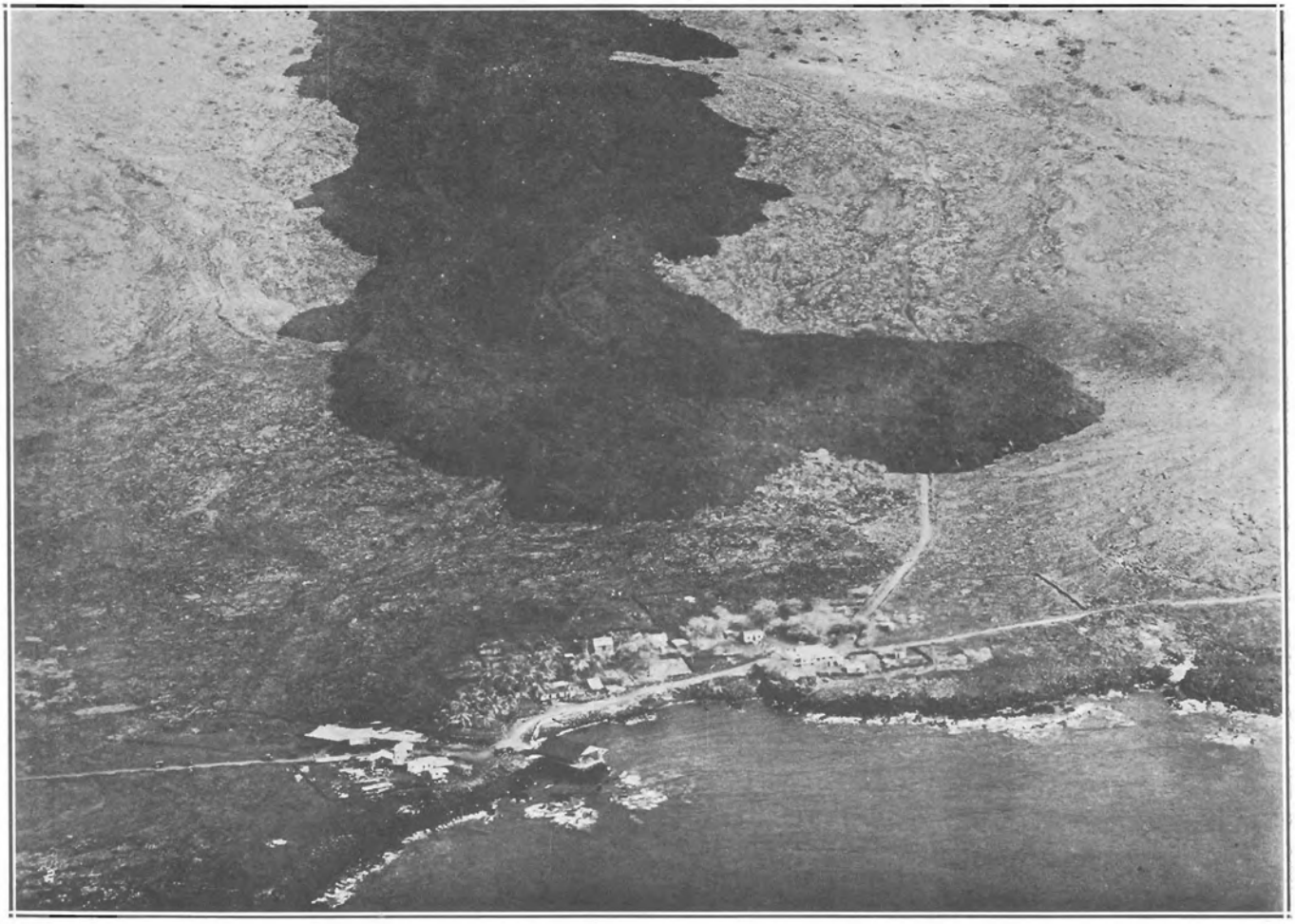
These pictures illustrate the alignment stage of volcanic outpouring, before the accumulations have built high enough to obscure the fissure and to produce a dome rather than a ridge. There are many heaps and pittings along fracture belts on the moon which are strikingly similar to the detail of this Mauna Loa fissure eruption. It is the occurrence of pits in direct relation to fracture lines around the edges of the big craters, and to straight fault fissures, on the moon, that effectively denies the validity of the impact theory of lunar craters. This theory imagines pits to have been made by the impact of meteorites. When the pits are definitely grouped along fractures, and smaller ones are structurally related to the lines of breakage around the edges of the bigger craters, it is incredible that meteorites should have sought out lines of cracking for their impacts. There is every reason for believing that the lunar craters resemble the Hawaiian pits in a sequence beginning with rampart rings of large diameter, and ending with small pits along curved fractures, the curves being guided by the older and larger domes and rings, which broke down when they became decadent.

The last air picture of the Army aviators gives a wonderful map of the western shore of Hawaii at Hoopuloa April 17, 1926, at 4 p. m., about 12 hours before the front of aa lava entered and burned the town, obliterated the harbor and the road, and crushed and buried the wharf. Here the winding stream through the flow is only faintly seen, and the main character of the advancing fronts, 20 to 40 feet high, is that of a caterpillar tractor. An upper layer of bowlders and gravel is rolled forward on a viscous red-hot paste inside, tumbles down at the front in a debris slope, and this is eternally overridden by the advancing mass for which it lays the track. The flow consists of four different mechanisms. There is the main river, the overflow fields of clinkery bowlders, the main front, and the subordinate fronts at the sides of the flow which build lobes and widen the slag flood as a whole at the expense of its height. It is interesting to observe in this picture the two ancient lava rivers right and left of the 1926 stream. It is the notch between their two deltas that had created Hoopuloa Harbor. It was the valley between their two heaps that guided the Hoopuloa flow straight down on the village which had unwittingly assembled its houses in this fatal lowland. Exactly the same lesson has been taught again and again by Vesuvius, and never has been learned. The lowlands and bays are attractive to the vine growers and the fishermen, but if they sought safety in a volcanic land they would be compelled to rebuild on the ridges and the points of land.

T. A. J.



Southwest slope of Mauna Loa giving vent to fissure eruption of lava April 18, 1926. This is the rift source of the lava flow that destroyed Hoopuloa fishing village. The line of cones is at elevation 7,600 feet, photographed from an airplane looking north showing lava source of 1919 in background, ancient cone in foreground, live lava streams on left, and dead flows of the new eruption on the right. Photo 11th Photo Section Air Corps U. S. Army.



Airplane photograph of Hoopuloa at 4 p. m. April 17, 1926, 12 hours before the village was buried. Aa lava flow with front 1,100 feet wide, 30 feet high, advancing 3 feet per minute. The tongues would push forward now here, now there. The two old lava stream beds on each side show how the new flow crept down the valley in between. Photo 11th Photo Section, U. S. Army Air Corps.

KILAUEA REPORT No. 944

WEEK ENDING FEBRUARY 23, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Many avalanches have occurred during the week at Halemaumau. The whole north wall has been working between the niches extending upward from the tops of the north and northwest taluses, rocks trickling almost continuously. Dust from the slides lay thickest on the west side of the floor. Avalanches were sometimes heard at the Uwekahuna Observatory, the rumbling of the sliding masses of debris preceding by several seconds the appearance of the dust clouds above the rim of the pit.

Cracks along the east rim show a slight widening, and one of the measured points, No. 14, widened nearly two feet since December 4, 1929. Here the ground shows much cracking and settling, as though this end of the big sill were working in sympathy with the north end. Few slides have been noted here, however

There was increase of copper salt southeast noticed February 17. With dry weather steaming has been very slight at Halemaumau.

There were 13 tremors, nine very feeble seisms, and one slight seism recorded by the seismographs. The slight shock occurred on February 19 at 5:42 p. m., with indicated distance to origin 27 miles. and was felt strongest in Kau District.

Microseismic motion was slight. Tilt accumulated moderately SSE.

THE VOLCANO LETTER

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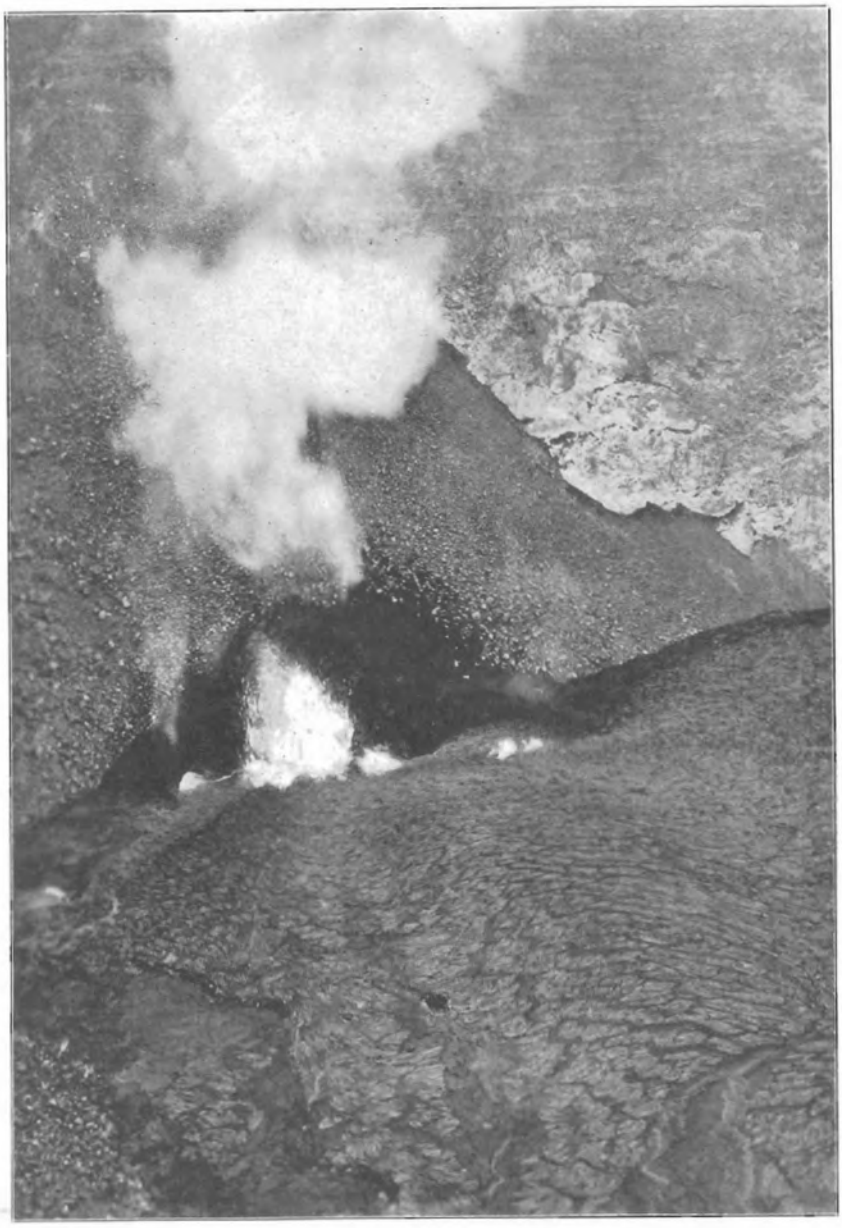
No. 271—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — March 6, 1930

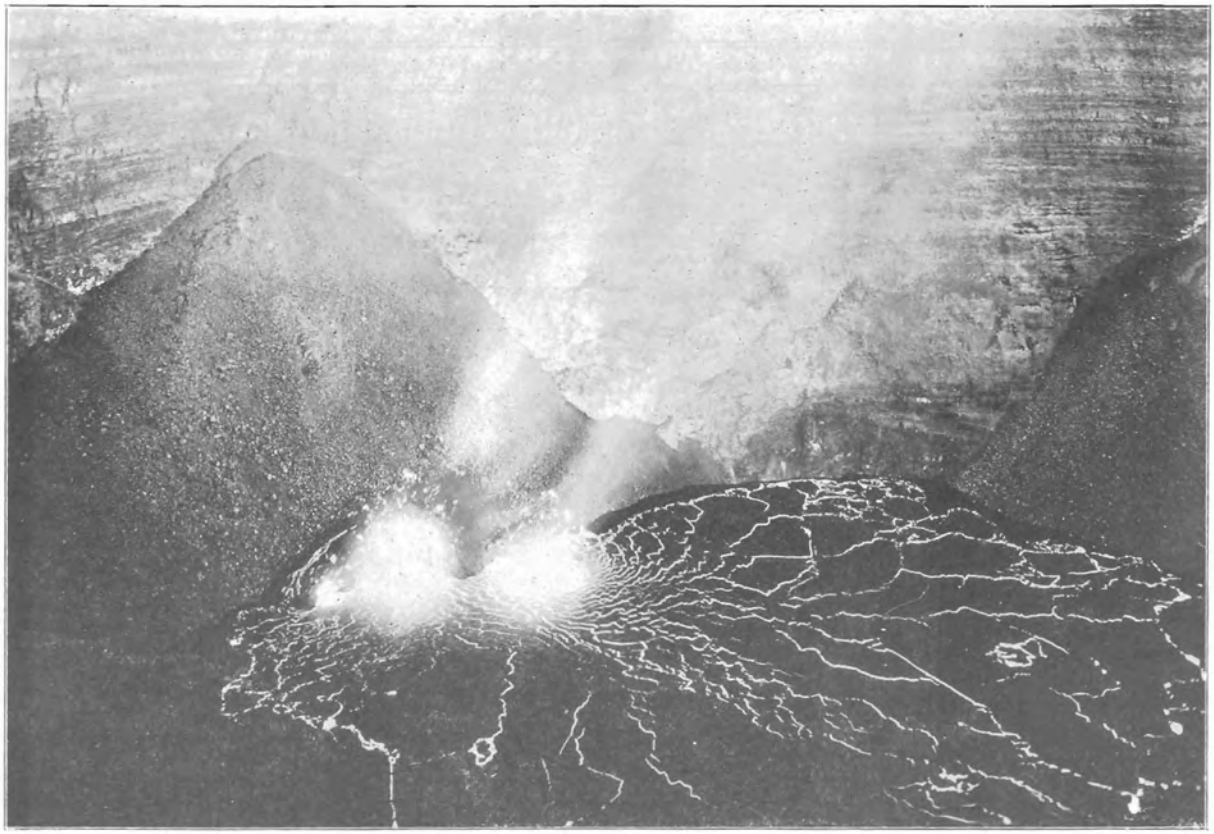


Interior of Halemaumou pit July 28, 1929, showing west wall, the great west talus slope the triple fountain niche with condensing fume, and the built up rampart around the borders of the new lake. Photo M. Furuya. Copyright.

KILAUEA ERUPTION IN JULY, 1929

The fiery activity of the bottom of Halemauman pit. the inner cup of Kilauea Crater, which was described in Volcano Letter No. 267 as being so brilliant in February of 1929, now seems to visitors to be a myth, particularly as recent avalanches coated the black lava floor with pinkish dust. But the inrush of lava in spectacular fountains was not limited to February of last year. The process was repeated during the last week of July, with a performance of magnificent fireworks that lasted four days, when thousands of automobiles brought a vast flock of visitors from near and far to stand spellbound night and day on the edge of the fire pit, like a congregation of worshippers. At such times the psychological effect on the community is one of the wonders. The Observatory workers surveying at the far edge of the cauldron, looking across at the tourist station, see a stationary line of human beings four deep in coats of many colors, fringing the top edge of the abyss. Behind them is a steady stream of newcomers, and still farther back the endless snaky line of motor cars winding up the cliff, like ants at the approaches to an ant-hill. And at night the ants are all aglow in their progress, and those clustered on the rim twinkle like fireflies with their flashlights, while the volcanic fires illumine the line of white faces stationed motionless above the cliff. And the cliff is flooded with glaring rosy light.

This July outbreak developed its maximum inflow of



Halemaumau at dawn July 28, 1929, showing the active grottoes and bright line pattern of new lava lake with the west and northwest taluses in the background. The active belt of February had been along the base of the right-hand talus shown (see photograph Page Three). The new active crack was along the base of the left-hand talus. Photo Hilo Photo Works.

lava at the western edge of the floor of February, and on a line of cracking intermediate between the February fissure and the crack straight across the middle of the pit which had been the source of the 1927 inflow. This can be understood by an examination of the picture on Page Two, where the line of the new July fountains is parallel to the base of the big left-hand talus cone. Comparing the picture on Page Three it will be seen that the February fountains extended from the extreme right, which is the north corner of the floor, to the big belt of boiling lava that lay under the wall between the two taluses. This last photograph shows the shape of the lava pool of February and the floor left behind when it cooled off. The new crack of July followed the upper left-hand shore line of the pool shown on Page Three, that is, the lava cracked its way up one margin of the February fill, doubtless lifting that fill as a wedge-shaped cork and tipping it a little away from the western talus slope. It may have been the same mass of lava, still liquid below, recharging itself with gas until it could lift the plug.

What happened in July to inaugurate the new eruption was, firstly, a series of very small earthquakes a few minutes apart about 4:35 a. m. July 25, 1929, registered on the seismographs but not felt at the Observatory on the edge of the greater crater next to the Volcano House. These little jarrings were each accompanied by a tilting of the ground to the east. Then spasmodic tremors developed in the lines written on the smoked paper of the instrument by the tiny steel pens, and after 6:30 a. m. this became a strong continuous tremor well known to the seismologist as the volcanic vibration which is a sure sign of lava fountains in Halemaumau pit, two miles away. At 6:10 a. m. a cloud of bluish smoke was rising from the pit.

The observers at once drove to Halemaumau and found inside the pit two fountains of lava spurting high from above the lower edge of the large western talus cone. The blue smoke that rose from them smelled strongly of sulphurous acid gas, and sometimes there were puffs of brown sulphur fume. Then the new heat made a billow of moisture cloud shape itself high above the pit. The fountains gained strength, always sending a cascade down to flood the February floor of the pit, and began to fling blobs of pumice-like lava 200 feet into the air, along with strings and shreds of brown spun glass. This material falling back built up a greenish brown mossy bank against the slide-rock slope. New lava vents opened between the two groups of fountains and the glowing melt oozed up through the crevices of the slide rock, trickled down to the floor below, crusted over, and left a glowing hole at the top and a bright cavern at the base. From this cavern a steady stream of golden fluid poured. Within an hour two-thirds of the February floor was covered.

The next event was a tunneling, under this floor, of the new lava, which ridged up the old slabs like a mole hill and sent a blast of gas out through a small orifice with a roar. Then sputtering lava fountains broke through the cracks along with flames and hot brown fume, and the roaring became spasmodic. By 8:30 a. m. the fragments of slag from the big fountains were falling forward on the new pool, the jets rising with a slow, majestic, steeply curved trajectory, of bright blood-red color, and made up of light weight material which fell lazily. By noon there were whirlwinds at the edge of the pit created by the tremendous updraft over the hot lake, and one could collect pellets of brown pumice, some of them two inches long, which were falling outside of the pit. There were also many glassy needles sometimes clustered together in straight sticks resembling golden straws. Tangles of Pele's hair were falling. This is made by the sputter and bluster of the gas rushing through the puddles of glass of which the fountains are composed, and so spinning siliceous cobwebs.

Quickly the older floor became covered ,and it was possible to estimate how deep was the new fill from the peak of the cone of 1927 which stands 2,643 feet above sea level near the south edge of the February floor, and from the February grotto of the north fountain which had

built up a high bank 2,635 feet above sea level. There was a terrace 30 feet high left by slumping in February, and this new fill of July had 30 feet of central saucer to fill up before it could surmount the terrace. On the second day, July 26, the new lake surrounded the remnant peak of the 1927 cone and about 10 a. m. it half encircled the north grotto heap of February, 1929. During the first 24 hours the lava rose 44 feet, at the end of 48 hours the depth had increased to 77 feet, and on the morning of the fourth day, July 28, the pit had been filled 88 feet. After 85 hours of inpouring, the afternoon of July 28, and just before the eruption stopped, the maximum elevation of the new lake surface was 2,640 feet above sea level, or 94 feet above the floor it had flooded. This entirely drowned the grotto heap of February, and left the 1927 cone protruding only three feet above the new fill. Then there was a sinking back, leaving a border terrace as before and lowering the central floor about 40 feet.

The eruption remained very brilliant at night during the three evenings of activity. Glowing cascades poured over ramparts along the edges of the new fill. The source fountains built up grotto niches like armchairs as shown on Page One. The surface crusts of the lake cracked up and foundered, and as in the February eruption there was a streaming-out of the surface skin on the slag pool making radial bright lines incessantly in motion away from the source region of the fountaining jets. The built-up spatter walls at these fountains would cave in and leave red-hot walls. A tropic bird flying around the interior of the pit was overcome by the gases, fell into the lava lake, and it was a pitiful sight to see it burst into flame. Broad spatter banks were built back of the large fountain group. Once or twice a fall of rocks occurred at the north wall of the pit. The source fountains finally developed three niches as shown in the pictures. The lava would slop down, making a glistening bank in daylight against the talus slope. This bank was eternally breaking down in red-hot landslides. Finally irregular clotted crust islands were left over the surface of the floor. The bottom had increased in length from 1,500 feet to 2,100 feet, and in width from 1,000 feet to 1,700 feet. Its area is about 50 acres, the volume of frothy lava that poured in, in three and a half days, was 127 million cubic feet, and the new rock that remained after shrinkage was 98 million cubic feet, equalling about 8 million tons of new matter The pit before had been 1,105 feet deep, afterwards it was 1,050 feet deep. T A.J

KILAUEA REPORT No. 945

WEEK ENDING MARCH 2, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

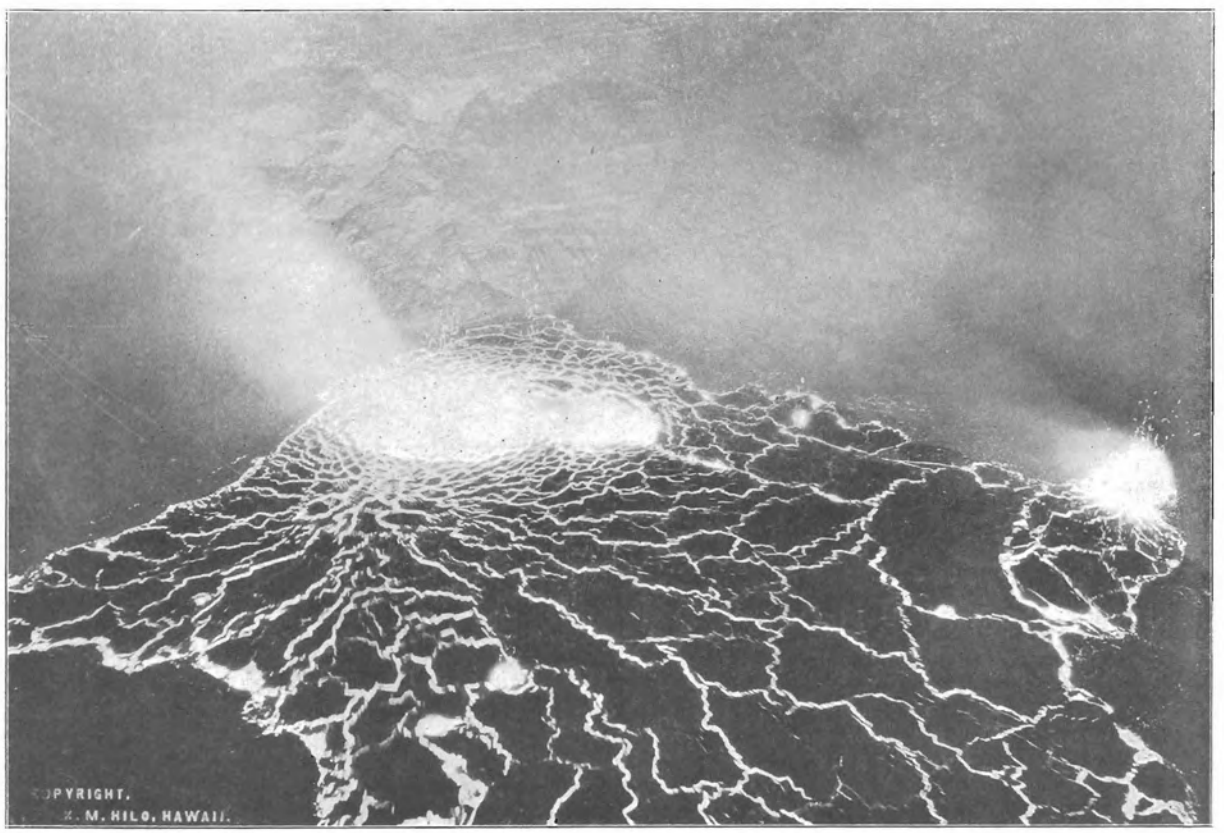
Little of importance has happened at Halemaumau pit during the past week. On February 25 the dust on the crater floor had been washed away by heavy rains. Dust from slides was seen occasionally during the week, notably at 12:30 p. m. and 1:08 p. m. February 26. Vapor was notably absent from the usual places March 1.

The seismographs registered three very feeble local seisms indicating distances of origin 34, 44, and 51 miles; and 8 spells of tremor. Microseismic motion increased February 27-28 along with strong northeast wind, and has otherwise been moderate. Tilting of the ground was strong NE.

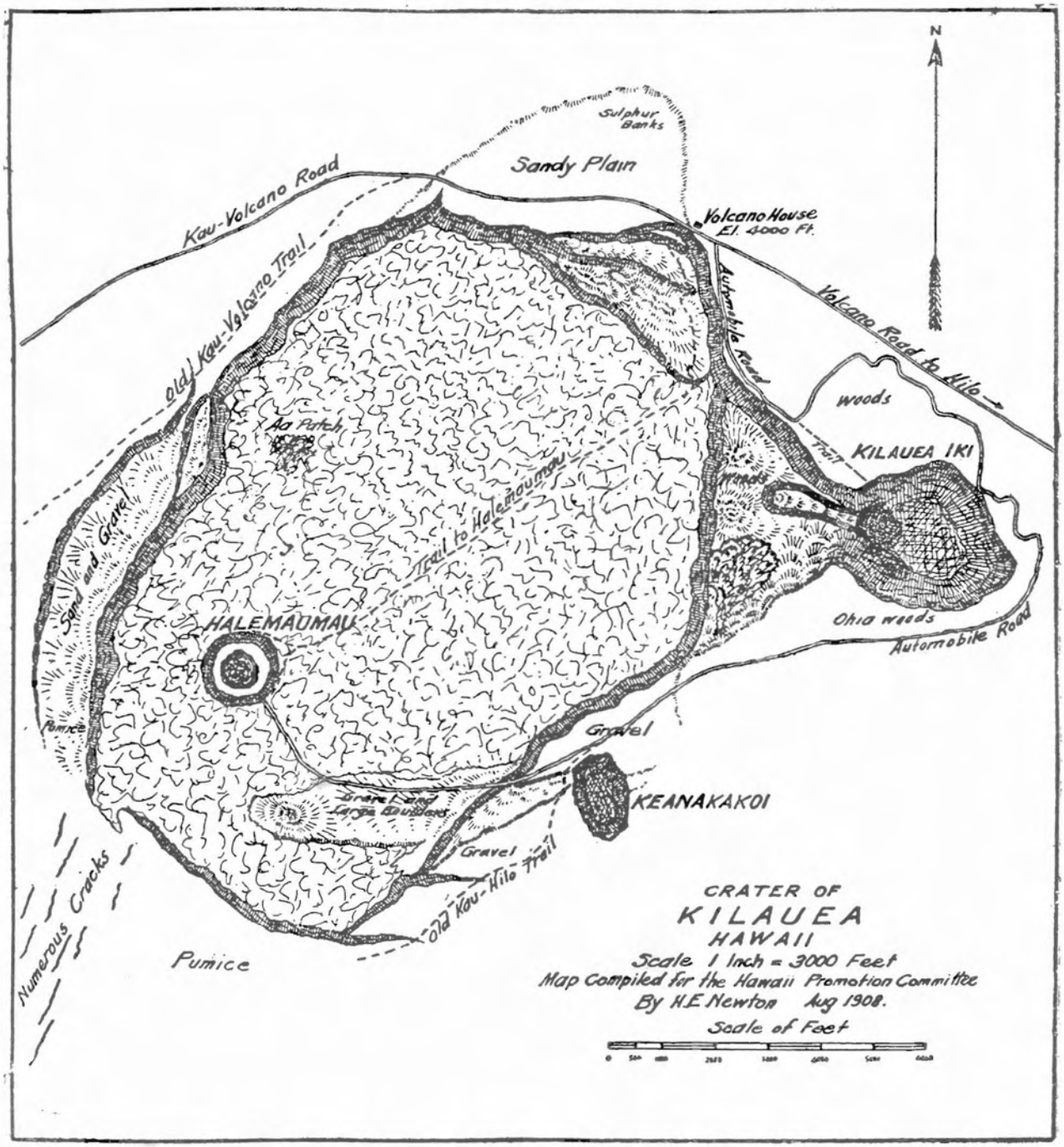
FEBRUARY TILTING OF THE GROUND

At the Hawaiian Volcano Observatory, on the northeast edge of Kilauea Crater, just opposite the Volcano House, the tilting or tipping of the ground as measured with seismographs in a concrete basement was as follows, expressed as angular change and direction of motion of the plumb line:

January 27—February 2	5.38 seconds SW
February 3—9	3.03 seconds NE
February 10—16	2.66 seconds SW
February 17—23	1.39 seconds SSE
February 24—March 2	5.26 seconds NE



The eruption of February 20, 1929, for comparison, showing approximate outline of the floor over which the new eruption poured its lava. The new eruption source was at the extreme left, and all the area here shown had become cold and solid when the July flood began. Photo Maehara. Copyright.



Old map of Kilauea, showing general relation of Halemaumau to Kilauea Crater. Present inner pit is much larger, and the new Chain of Craters Road now extends off to the southeast.

THE VOLCANO LETTER

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The Volcano Letter

Two dollars per year — Ten cents per copy

No. 272—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — March 13, 1930



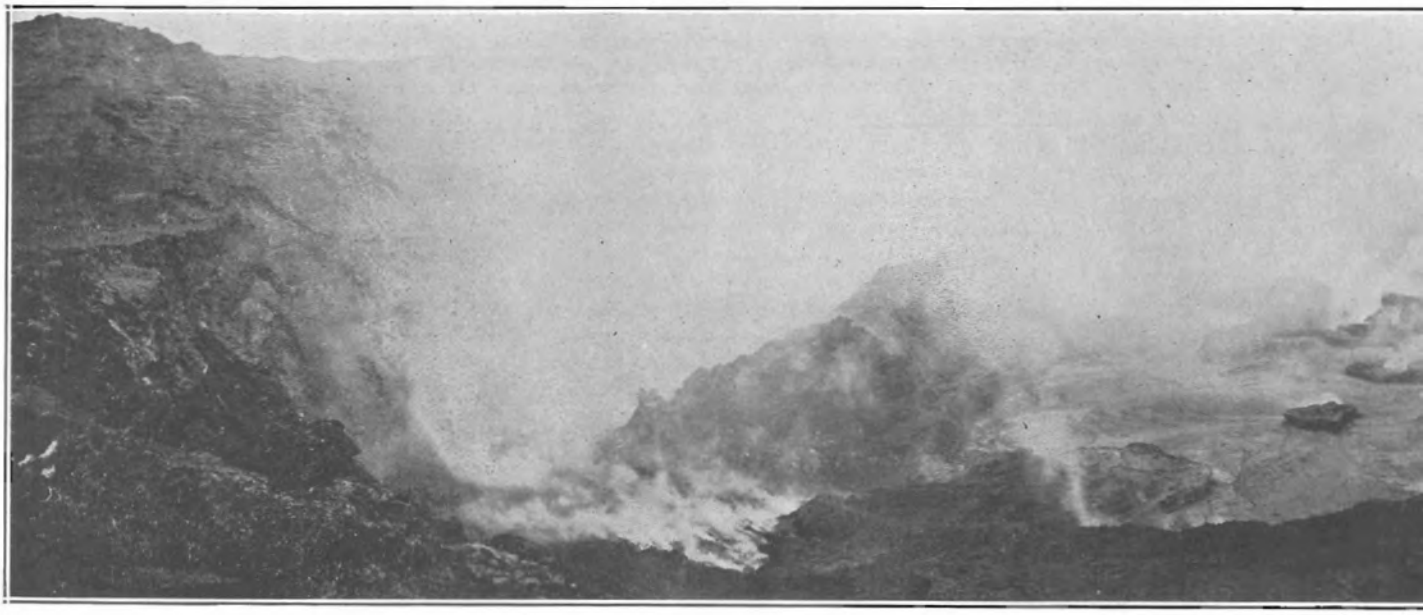
Interior of Halemaumau pit September 20, 1921. Crust of the north pool of the main lake in the foreground is being overflowed with liquid lava by the cracking up and sinking of the surface blocks. The crags are old overflow platforms, inside the pit, swollen up and tilted. Photo Jaggar.

LAVA FROTH AND LAVA PASTE

One of the most far-reaching discoveries made by continuous observation of the liquid lavas in the fire pit at Kilauea is that the lava in motion divides itself into two substances. This fact has been misapprehended in the past, owing to the supposition that the one substance is the liquid or molten material, and the other substance is the portion which has solidified. What are here referred to are two substances, both of which are liquid. Generally their viscosity differs, so that the one substance is highly fluid, and the other substance, forming the bottoms of the lava lakes, the side walls of the lava lakes, and forming the beds and marginal fields of the lava rivers, is semi-solid or pasty but mobile and red-hot. And this mobility shows itself in that the bottoms and side walls of the lava lakes, and the overflow fields of the lava flows all move with the liquid torrents, but with a more uniform pasty flow.

In the photograph on Page One the observer is looking toward the middle of Halemaumau pit from the north rim in September, 1921, when the lava column as a whole was rising. The black cliff in the background is the rim of the pit. There had been a strong lowering of the entire circle of crags and lava lakes during the preceding six months, and now the lava was rising again. The lowering in question had followed the tremendous overflowing of the pit rim in March, 1921. So the two equinoxes had produced risings. When the picture was taken, the very day of the equinox, there was a flood of glowing liquid lava welling over the border of the liquid lake and up through the crusts of the north pool in the foreground. A lake of liquid lava is often crusted over like a frozen pond in winter. The crusts burst apart if the pond below rises, and as the hardened crusts are heavier than the gassy froth beneath, they tip up and sink. That is what is happening in this picture and the jumble of peaks is a part of the paste on top of which the liquid lake maintained an irregular shallow saucer of its own. The platform in the foreground was a part of the rim of this saucer. The flat crusts being flooded on the left were the frozen surface of the main lake. The high peak on the right stood 105 feet above the lake which was boiling and liquid in the central region among the crags. The lake surface stood 75 feet below the pit rim.

The reader may well ask, "How can a jumble of peaks be a paste? Surely these are floating islands in the lava?" This conception of floating islands is a time-honored fallacy. Solidified basalt has a higher specific gravity, therefore is heavier, than liquid basaltic melt. Much more is it heavier than gas-foamed liquid basaltic melt of the fountaining and flaming lava lakes. Therefore solidified crusts sink, and solid crags and peaks certainly do not float on liquid lava. These solid crags grade downward into a red-hot, dense, heavy substance which from time to time has revealed itself as continuous with the rock of the crags, extending under the liquid lakes as submerged

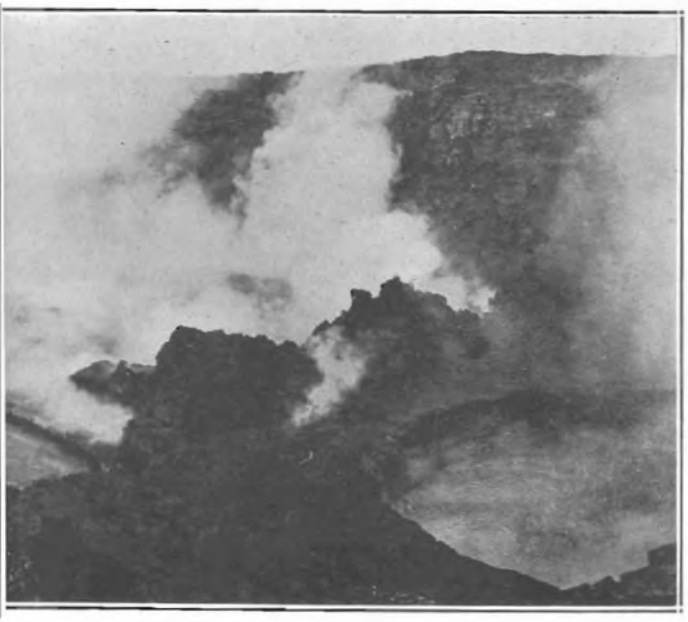


Halemaumau from the north September 14, 1920, after many months of low and smoky lava. The small island in lava lake is the same as the one suddenly uplifted in the picture below. Photo Hilo Photo Works.

incandescent cliff or bank or shoal. The nature of the revelation has been by sudden uplift, forty feet in a few hours, of the shoreline of a lava lake, or by sudden downward drainage of the lake itself. These processes have revealed smooth glazed surfaces under the lake, and comparatively small wells or tunnels feeding the liquid slag into the shallow lake basin. The half-hardened paste of the inner crag matter is the substance from which these basins are sculptured. All the lake basins are shallow, because the lakes are puddles of rapidly cooling melt maintained liquid by the hot gases which are rapidly escaping. The lakes cool and partially solidify on the bottom and



Island in the central lava lake of Halemaumau which was lifted suddenly March 15-16, 1921, by the swelling up of the lake bottom, revealing a mushroom stem and a broad base. This heaving of the lava paste preceded the gushing of the liquid lava March 18. Photo Jaggar



at the sides. The side solidification forms a rampart over which the rising lake floods in short-lived fills which stratify. The feeding well, up which the hot lava froth rises through a deep accumulation of this lava paste, has its walls continually congealing inward in proportion to the volume and heat of the oncoming new lava from the depths.

The two pictures on Page Two exhibit a small flat lava islet which lifted itself suddenly just before the intense overflowing of March, 1921. This performance was one of the revelations above referred to. The first picture, in September, 1920, was taken when the lava lake had reached a low position of 280 feet below the rim of Halemaumau, and the jumble of crags and lakes was very smoky. The whole lava column had been lowering during 1920. About the September equinox of that year it started to rise just after this picture was taken. The flat triangular islet represented the top of a shoal in the lake, and appeared or disappeared according as the lake lowered or rose more than the pasty lava column of the crags. The islet was a part of this stiff lava column through which a honeycomb of wells fed the lake. When measurements were made with transit from the edge of the pit during the next six months, both the crags and the liquid rose together, the liquid greatly gaining on the crags and partially drowning them about January 1, 1921. Then there was a temporary lowering when the crags emerged again, but the crags also lowered more slowly than the lake. This kind of alternation is the rule in measurements of the rise and fall of the lava column, and these measurements are part of the proof that we have to deal with two substances in the pit, a slow and steady larger mass of paste, and a more tumultuous and erratic smaller body of froth.

The lower picture, and the map on Page Four show what happened just before the intense effervescence and overflow of Halemaumau of March 18, 1921. The islet had reappeared and is shown on the map just under the words "Cent Lake". This central lake was 110 feet below the rim March 14. Then crags and lakes began to rise. This inconspicuous little island, a few feet across, between March 15 and 16 suddenly lifted from beneath the lake, and became a huge ungainly gray monster with rounded back, flat topped head, and slender neck. This great bulk of lake bottom substance, which was pushed up faster than the liquid in the center of the pit, demonstrated a swelling in the under paste that was exceptional.

During the next 24 hours the crags rose 10 feet, and then came the intense fountaining up of the liquid in artesian fashion so as to fill the whole vast cylinder of Halemaumau to overflowing in six hours. Approximately 283,000 cubic feet of liquid entered the pit in that time, allowing 50 per cent of the space to the hard paste. This would imply an inflow of more than 47,000 cubic feet per hour.

The lifted islet in the third picture stood like a thin-stemmed wine glass on top of the newly uplifted hill of lava dross. The summit stood 40 feet above the lake like a tilted toadstool threatening to fall at any moment. A portion of it broke away the next day. The lower hill was a rounded black elephant's back with a smooth surface and some shore marks steeply upturned. Evidently the stem of the islet had narrowed just below lake level in the days before the uplift and during the uplift the whole mass was toppled over towards the west.

In the cross-section under the map (Page Four), a feeding well is indicated at the southeast, and one of the connecting tunnels following the wall crack, or edge region, of the fill, at the northwest. These tunnels have the same kind of history as the wells. They represent a solidifying inward of the walls of a surface stream of slag, until the stream is flowing in a sewer pipe of its own making. The cross-section shows how much bulkier is the paste or craggy matter, as compared with the liquid. There is good reason, based on experiment, for thinking that the rising liquid gets hotter upward, being heated by reactions between the gases that are escaping from solution to the bubble form, and are increasingly mixing with oxygen. Technically we speak of the paste as the "bench magma," the word "magma" meaning dough, and the liquid lakes or flows as "lake magma." This dual quality of basaltic lava we shall have to consider further in treating of smooth-lava and clinker-lava flows. T.A.J.

KILAUEA REPORT No. 946

WEEK ENDING MARCH 9, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On March 5 it was evident at the north wall of Halemaumau that sliding had been resumed leaving fresh breaks in the wall. About six slides were noted by workmen during the day. The roar of a slide was heard at 2:34 p. m., and another was seen a few minutes later, both causing dust to rise. The pit seismograph indicated 12 avalanche tremors during the preceding day. At 3:15 p. m. there was another dust cloud. Two dust clouds at 11:15 a. m. and 11:40 a. m. March 6 indicated fairly large avalanches. On March 8 there were slides at the north and northwest walls, and on March 9 slides were numerous during the forenoon, one making a large dust cloud at 10:50 a. m. About 4 p. m. a very large cauliflower cloud rose over the whole pit from an unusual avalanche.

The seismographs at Kilauea registered during the week 5 tremors, 7 very feeble local seisms, and one recorded as feeble indicating origin distance 9 miles 10:56 p. m. March 8, and reported as felt in Hilo. Three other distances indicated for very feeble shocks were 31, 38, and 46 miles. Kapapala reports numerous recent shocks. The tremors lasted from one-quarter to three-quarters minute. Microseismic motion was slight, and tilting of the ground was slight to the north.



Halemaumau from the north September 14, 1920, after many months of low and smoky lava. The small island in lava lake is the same as the one suddenly uplifted in the picture below. Photo Hilo Photo Works.

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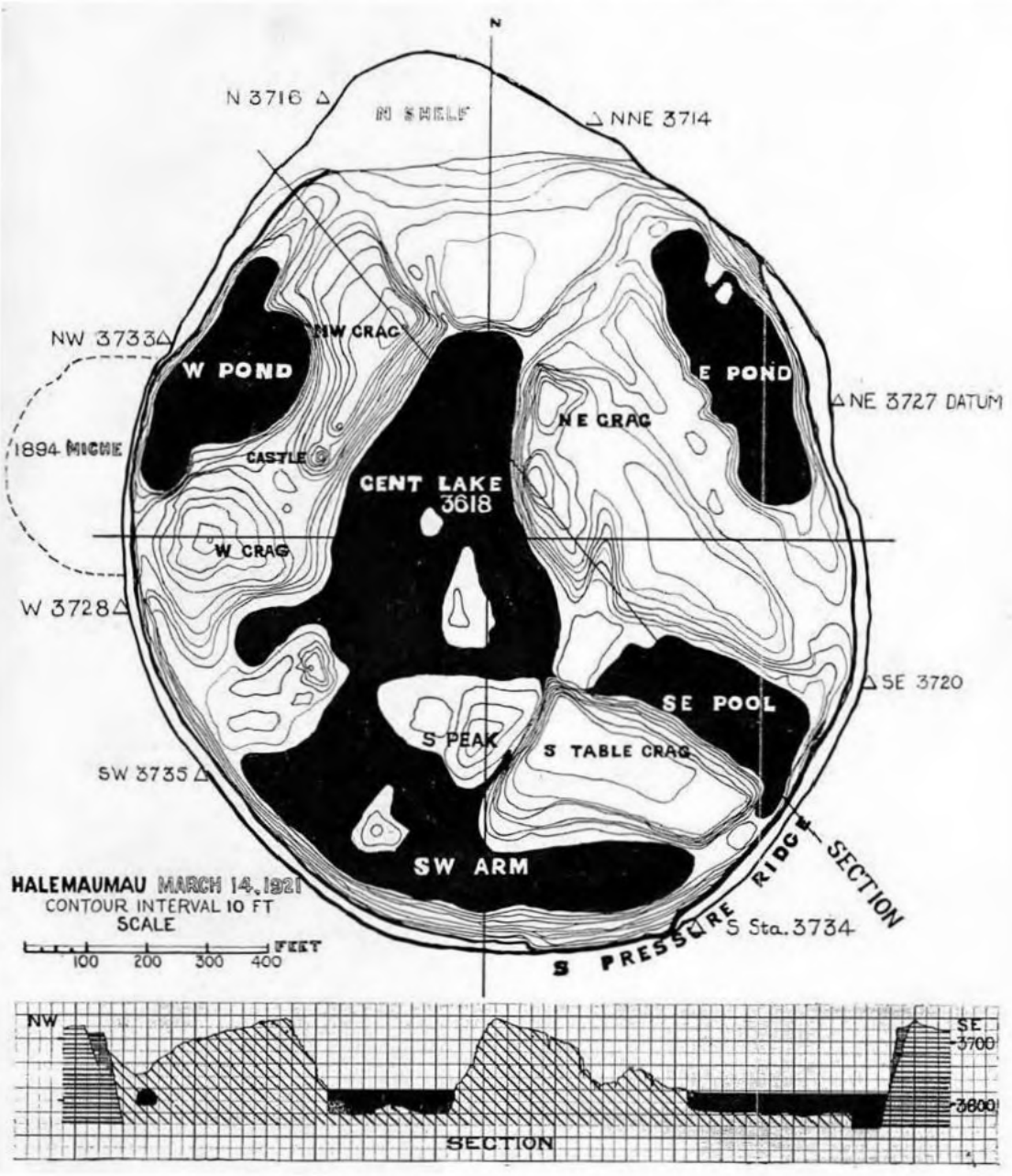

Map and profile section of Halemaumau, surveyed March 14, 1921. Shows the very small central islet before its upheaval March 16. Elevations in feet, bench lava in 10-foot contours referred to lake level, liquid lava black. Surveying stations indicated by triangles. Survey by Jaggar.

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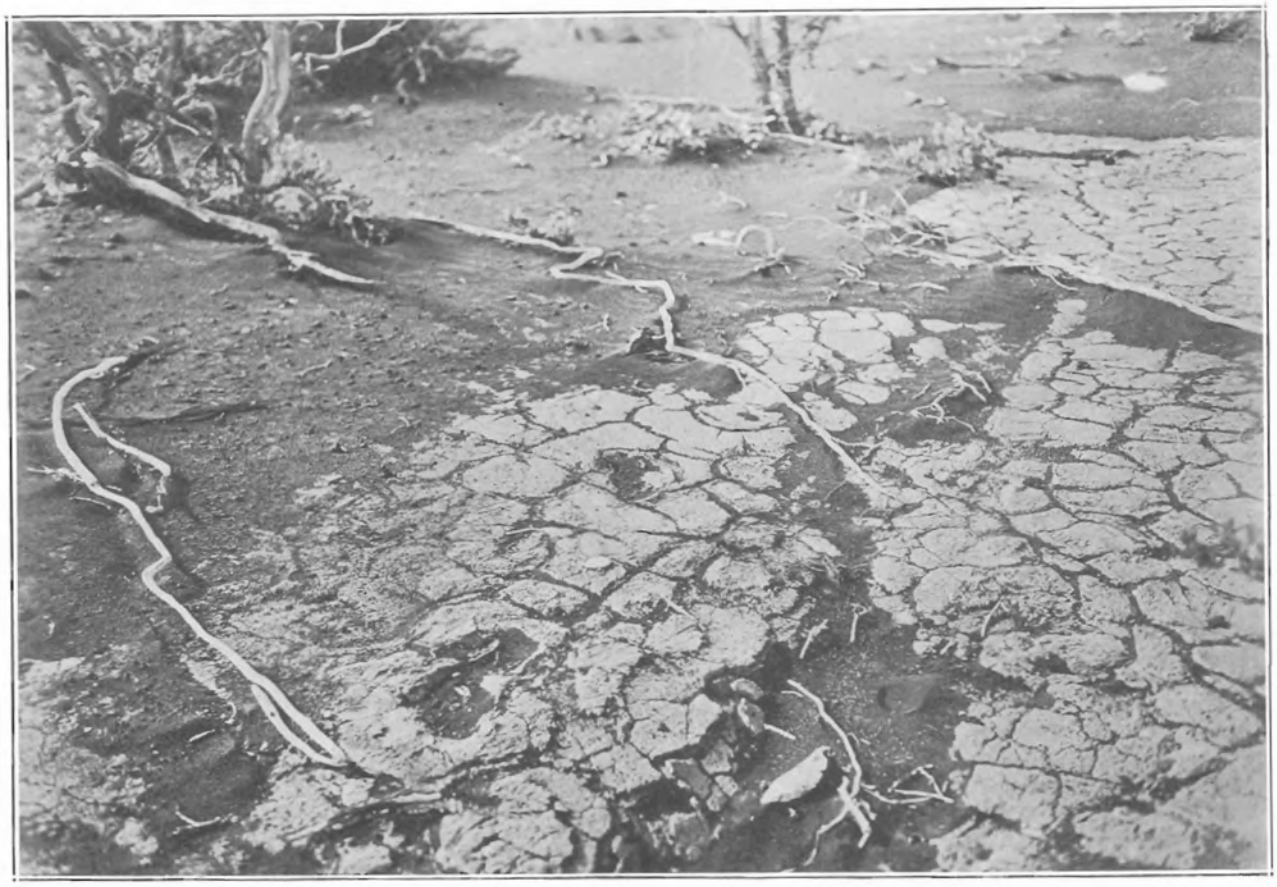


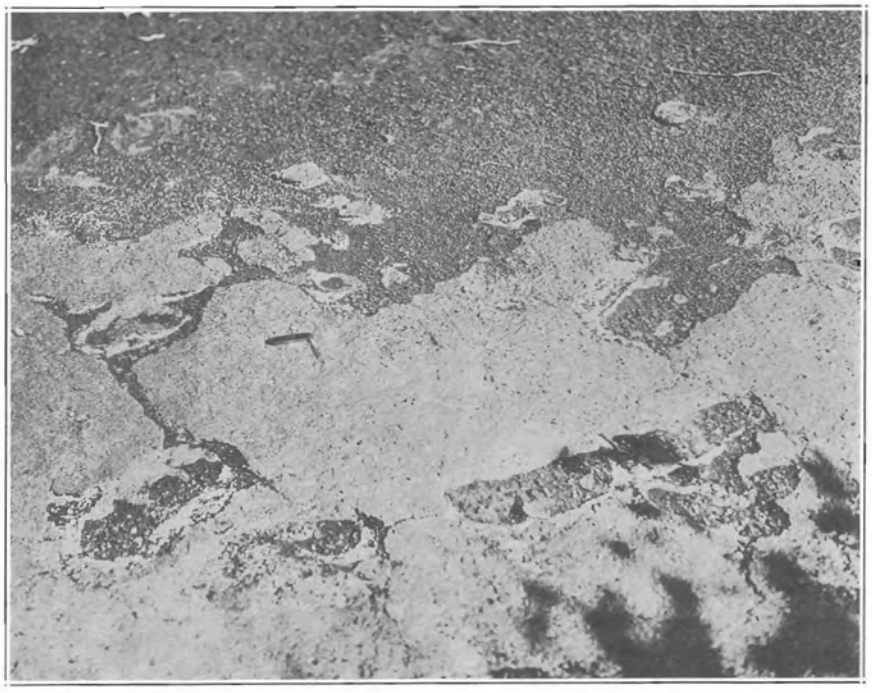
Photograph of fossil human footprints in the lower of two layers of Kilauea ash mud of 1790. The upper layer is here eroded away. There was black sand and cinder between the two layers. The ash is a hardened natural cement. As these footprints are in the ash of the first ash eruption, and are elsewhere buried under the second ash layer, they must date from the eruptive period. Photo Jaggar.

THE HUMAN FOOTPRINTS IN KILAUEA'S ASH BED

Two archeological discoveries of interest as bearing upon the human side of the ancient eruptions of Kilauea were made in 1919 and 1920 as incidents of the work of the Hawaiian Volcano Observatory. One of these was the finding by R. H. Finch of well preserved hardened footprints in what had been the ash-mud of heavy rainfalls in the Kau Desert southwest of Kilauea Crater, dating from the explosive eruption of that crater about 1790. The other was the unearthing of a skeleton on the second shelf of Uwekahuna bluff by the late Joseph Hedemann. This discovery was made February 21, 1919, among the big bowlders a little way below the Uwekahuna Museum, and the remains appeared to represent a very ancient burial of a woman in reclining posture, half covered with ash and washed soil, and walled in between two large rocks. The evidence indicated a time of burial not far removed from 1790. The locations of these two finds may be identified on the accompanying map of Hawaii as just to the west of the head of the flow of 1920 at the edge of the National Park, for the footprints, and the west cliff of Kilauea Crater, for the skeleton.

The photograph shown on Page One exhibits a surface of ancient, sun-cracked mud which consists of what geologists call pisolitic ash. Pisolites are little pea-shaped balls occurring all through a layer of the ancient rock dust that fell over the country during an explosive eruption. This dust was hurled upward in the midst of clouds of steam, and fell round about like snow. It is characteristic of such times that the atmospheric moisture condenses as heavy rainfall ,usually with thunder and lightning. When the dust is caught in the raindrops, the rain falls as mud. If such mud drops fall along with dry ash, or into beds of dry ash, they will form a layer of pellets. These pellet layers were common in the explosive eruption of Kilauea in 1924, and at Vesuvius in 1906. If the rain is abundant the ground may be muddy while still preserving the identity of the pellets. If this muddy ground is afterwards heated by the sun, it will shrink and crack in irregular blocks as shown in the picture. The volcanic dust had been greatly roasted by the combined fire and steam activities of the eruption of 1790, and this made it into a weak Portland cement. On drying it would harden and resist erosion for many years.

Between the two white sticks in the foreground of the picture may be seen two footprints which are the impressions in this muddy cement of large, naked, human feet advancing toward the observer, the left foot at the back with its ball joint and big toe clearly seen on the left-hand side of the impression, and the right foot in front showing complete heel and toes, the print being filled with drifted black sand. The stride was long and in a direction down the mountain with the ball of the foot digging in as though the man were hurrying. It will be observed that the drifted dune sand and cinder lie over



Footprints of adult, probably the mother, in hardened ash of foreground, and of child in background. They show the impress of separate toes. These were progressing to the right, or down the mountain. Penknife shows scale. This is the upper ash layer, without sun cracks, and the little white pellets are fossil mud raindrops. Photos Jaggar

this layer of sun-cracked mud. This fact is of importance, for in the second photograph on Page Two, footprints are shown in another and higher layer of the same kind of ash filled with fossil raindrop pellets, having the dark cinder underneath the ash layer. This upper layer is also cemented, but it is everywhere lacking in the sun cracks, which are characteristic of the lower layer. The upper layer has pebbles which fell during the eruption, the lower layer has none. Everywhere the two layers may be found in this same relation, with the dark sand and cinder in between, and the whole thickness from two to six feet of beds in different places. What they mean is that there was a first eruption that deposited the lower ash and pellet layer without any pebbles; then there was a more violent eruption which buried this layer under sand and cinder; finally came more fine ash, mud pellets, and a little cinder to pepper this last layer with pebbles. These several eruptions may have been hours or days apart.

Now we have shown in photograph No. 1 that after the first layer was formed and before the sun had come out and dried it, a big native strode down the mountain and left his footprints, before the violent flurry of ash and cinders buried them up. The surface that we see in this photograph has been washed clean by more recent rains, for nine-tenths of the ash of this period has been eroded away. It is only in a few fortunate hollows that this footprint record is preserved. A few other footprints have been discovered in the lower sun-cracked layer, and they usually show that the makers were running and going down hill. On the other hand, the footprints in the upper layer are more leisurely, are crowded in large numbers and represent men, women, and children, and are progressing both up and down the mountain. In other words, the persons present at the time of the lower layer were there in the midst of the dangerous period, with more eruptions yet to come. This succession proves conclusively that the footprint-making was contemporaneous with those explosive eruptions.

Who made the footprints? Why were natives in considerable numbers crossing the mountain just at the time of this dangerous eruption? The missionary Ellis tells us (Narrative of Tour Through Hawaii, by William Ellis, Hawaiian Gazette Company Ltd., Honolulu, 1917) that Keoua considered himself the legitimate heir to the throne of the island of Hawaii and in the year 1789 marched from Hilo with all his forces to attack the warriors of Kamehameha in Kau and Kona. He crossed Kilauea Volcano, and "an eruption took place that very night, and destroyed the warriors of two small villages, in all about 80 men." The Hawaiians told Ellis that Pele favored Kamehameha, and aided his cause by destroying Keoua's soldiers. Keoua had broken the tabu of Kilauea, Pele was exceedingly angry "and soon after sunset repeatedly shook the earth with the most violent heaving motion, sent up a column of dense black smoke, followed by the most brilliant flames."

"A violent percussion was afterwards felt, streams of bright red lava were spouted up, and immense rocks in a state of ignition were thrown to a great height in the air. A volley of smaller stones, thrown with much greater velocity and force, instantly followed the larger ones, and striking them caused the larger stones to burst frequently with a report like thunder, accompanied by the most vivid flashes of lightning."

"Many of Keoua's people were killed by the falling fragments of rocks, and many were actually buried beneath the overwhelming mass of ashes and lava." Not intimidated by this event, Keoua continued his march, and the volcano continued its action, confining its operation within the boundaries of Kilauea. Ellis states that he heard this account several times from natives with some little variation as to the numbers killed, and a variant of the story said that Pele appeared to Keoua, in the column of smoke as it rose from the crater. The main facts about the natural history of the eruption he believed to be true.

Other accounts of this eruption indicated that Keoua camped three nights at the volcano while eruptions were in progress, especially at night. On the fourth day he divided his people into three companies, with the chief's division in front, and they had not proceeded far before the ground shook violently, and then an immense black cloud rose out of the crater and produced darkness. Black sand, stones, and dust came down in a destructive shower, some of the first party were killed, and all of the second division were asphyxiated with the hot dust and their corpses were discovered by the third division, some lying down, others sitting up and clasped in farewell embrace. The warriors had their families and livestock with them, and the only living being discovered was a solitary hog.

It is probable that the fossil footprints were made by Keoua's people. The second picture shows the footprints of an adult in front and a child in the background headed down the mountain at the locality west of Mauna Iki where probably the natives were beyond immediate danger, trudging through rain-soaked puddles of muddy ash. This material now is hard enough for a man to walk over it with heavy boots without breaking the shell. Some broken crusts may be seen in the foreground on Page One. This trail of fossil footprints has been followed uphill from the southwest for seven miles in the direction of the west side of Kilauea Crater to a point a mile and three quarters southwest of Uwekahuna bluff. Here the material of the upper layers is coarse and pebbly, but a lower layer of fine ash, corresponding to the mud-cracked stratum of Photograph One, reveals footprints at the margins of erosion patches where the bottom layers protrude. The track of a barefoot adult was found headed south, with stride 24 inches long and foot 10½ inches long, and some of the ash surfaces showed raindrop imprints as well as the pellets. Other tracks were headed north, made by a smaller person, with long strides as though running. There are several places along the trail where the walkers converged to narrow passes so that the ash was beaten down by many feet. (For discussion see Bull. Hawn. Volc. Obsy., July and October, 1921.)

The burial represented by the skeleton (now in the Bishop Museum) lay just on the line of this trail where it would have passed Kilauea. The ash there is too pebbly to preserve any footprints. The skeleton may have been one of the priestesses of Pele. There was formerly a heiau or Hawaiian temple to Pele somewhere in this vicinity. It is also possible that this was one of the victims of the eruption among Keoua's people. T.A.J.

KILAUEA REPORT No. 947

WEEK ENDING MARCH 16, 1930

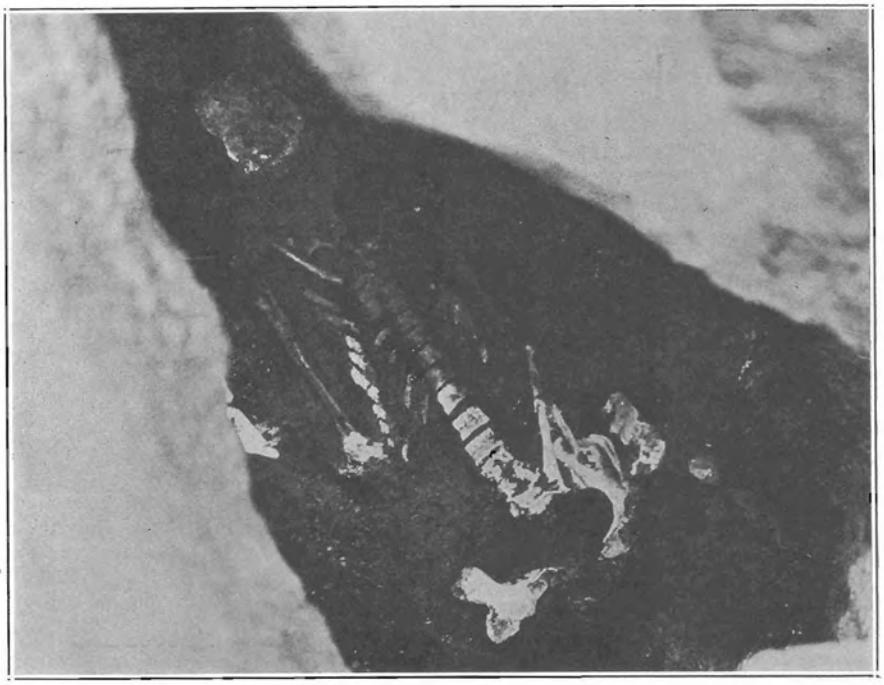
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Numerous slides occurred at Halemaumau March 10 to 14. These were mostly from the north rim and wall, as during previous weeks. The seismograph near Halemaumau recorded many avalanche tremors not strong enough to be registered on the Observatory instruments farther away. Probably the largest slide during the week was at 8:35 p. m. March 12. Sliding was nearly continuous between 6:30 and 7 a. m. March 14, and a few light falls of rocks were heard later in the day.

Heavy rains fell, causing much steam at times. Steam was as usual on the south talus and wall.

A total of 15 seismic disturbances were recorded by the instruments at Kilauea, divided as follows: nine tremors, five very feeble seisms, and one feeble seism felt locally and in Kau at 6:01 a. m. March 13. Its indicated distance to origin was 10 miles.

Tilt at the Observatory was moderate to the southwest. Microseismic motion was slightly stronger than normal.



Skeleton burial found lying in niche between bowlders on high east face of Uwekahuna bluff, the west cliff of Kilauea Crater. The skeleton was in a half-seated position, facing toward Halemaumau, walled in in front. Length from skull to end of spine 27.5 inches. Photographed February 25, 1919.



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The Volcano Letter

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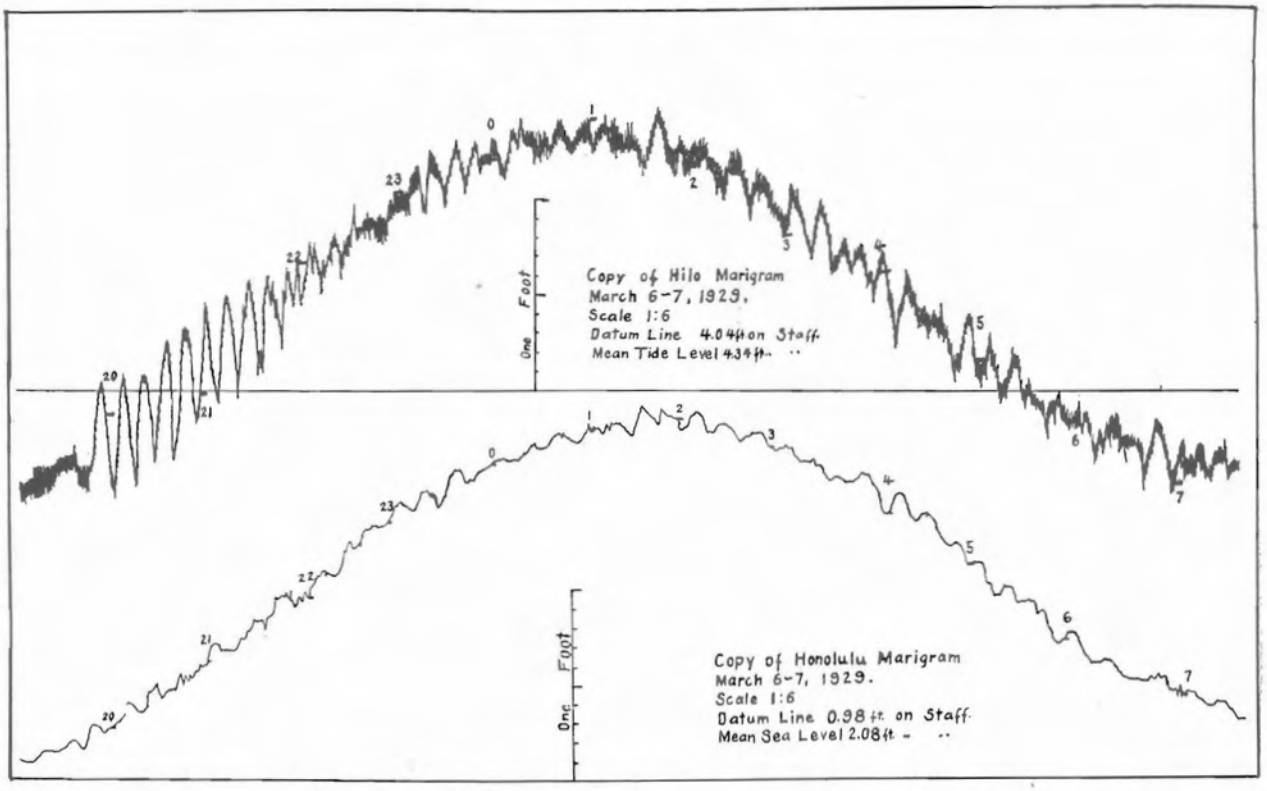
No. 274—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — March 27, 1930



Tide gauge writings at Hilo and Honolulu showing on the left of the Hilo marigram the pronounced waves of the ocean from a distant submarine earthquake off the Aleutian Islands March 6, 1929. The Honolulu record shows only a faint trace. The datum line for each marigram is at the base of the one-foot scale.

OCEAN WAVES FROM SUBMARINE EARTHQUAKES

In the Volcano Letter of February 13, 1930, a seismogram is shown, the autograph written by a pendulum at Kilauea Volcano recording slow waves through the mountain from a gigantic earthquake in southeastern Alaska. The earthquake originated in the mountains 2,700 miles away, and a few minutes later the magnifying apparatus attached to the pendulum in Hawaii indicated swayings with a period of 10 seconds, elastic wave movements swinging the rock of the Hawaiian ridge back and forth about one thirtieth of an inch. At the source the jolts may have shaken the mountains back and forth several inches in a period of a second or so. The waves slow down and widen out as they progress rapidly through the substance of the globe.

This earthquake was in the mountains and so did not affect the sea bottom. But there are many such earthquakes off the coast of Alaska and the Aleutian Islands which jolt the deep valleys under the sea, and probably drop the bottoms of those valleys, sometimes by several feet. On the coast there was a measured lift of over 40 feet during an earthquake spasm in 1899 at Yakutat Bay. These lifts of the continent are believed compensated by drops of the sea bottom. Such movements may be more than 100 miles long, and a large block of water of the ocean is instantly and violently disturbed. This water is thrown into what is called a tidal wave, or tsunami, having its own period and rate of propagation across the ocean dependent on reflection from the shores, on resonance with or opposition to the normal tide waves of that ocean, on the depth of the ocean both at the place of disturbance and along the route of travel, and finally, for any place where the tidal wave is received, on the shelving quality of the shore and the local complication with waves due to the wind.

There is popular misunderstanding about what a tidal wave can do when it arrives. Hundreds of sea waves due to earthquakes arrive at San Francisco, Los Angeles, Callao, Queensland, Japan and Hawaii which are recorded only by the tide gauges. The public does not know of their existence. When a very exceptional one piles up the waters in a confined bay back of a shelving bottom there may be a disaster, but these are rare. Much the same kind of a disastrous shore flood may be produced by persistent hurricane winds as in the Galveston, Mobile and Florida disasters. In all cases the piling of the waters goes into unfortunate rythmic harmony with the local waves and tides, for every bay has its own normal swing of several minutes duration, like a big pendulum.

The two tracings of tide gauge curves on Page One represent the swing of the same tide for 12 hours beginning at 7 p. m. (19 o'clock) March 6, 1929, the range be-



Wreckage in Wailoa River February 3, 1923, at Hilo, Hawaii, due to the piling up of the waters from a distant Aleutian earthquake under the Gulf of Alaska seven hours earlier. Sampans were thrown over the railway bridge which was destroyed, at Waiakea station. Photo Morihiro.

ing about two feet up to 2 a. m. March 7, and back again by the same amount around 8 a. m. of that date. The upper curve was written by a float under the wharf at the head of Hilo Harbor back of the breakwater, and the lower curve was similarly written for Honolulu Harbor. It will be observed that both curves in the right-hand halves exhibit three or four swings to the hour each 20 or 15 minutes long. These are the normal seiches or water basin swayings dependent on the sizes and shapes of the Hilo and Honolulu basins respectively. When the earthquake wave comes in, as strongly shown in the 15-minute pulsations at 20 o'clock on the left-hand side of the Hilo marigram, and hardly shown at all on the Honolulu marigram, this normal pulse of the bay is exaggerated into a pronounced oscillation which dwindles and dies in three hours.

This tidal wave movement of Hilo Bay was forecast on the seismographs in Hilo, at Kilauea, at Kona, and in Honolulu about 3:11 p. m. by the outbreak, so to speak, on the writing pens, of the record of a tremendous submarine Aleutian earthquake. The imperceptible underground waves caused the wirting pens on the Hilo seismograph to swing back and forth 10 inches and to write for more than three hours; and even to write the record of the earth wave that went around the other side of the globe remote from us so as to arrive here at the end of about four hours. This means a very big earthquake; the origin was indicated by the seismogram to be 2,200 statute miles away and that distance could not mean a mainland earthquake, therefore a submarine disturbance was a certainty. The evidence favored an origin either north-northwest or south-southeast of Hilo, which would be either near the Aleutian Islands, or else near the Marquesas Islands. If it were north, the expectable ocean wave would reach the north side of Oahu and the east shores of Maui and Hawaii; if it were south, the stronger movement of the waters might have been recorded at Honolulu, but past experience did not make a southern origin probable.

The nature of the seismogram resembled that of an Alaskan earthquake of February 3, 1923, which had made a destructive tidal wave at Kahului in Maui and at Hilo in Hawaii about seven hours after the earthquake happened in the north Pacific. The record had come to our seismographs about seven minutes after the jolt at the origin. There was thus plenty of time to notify Hilo of the possibilities in the case, and this notification was given, but was not on that occasion taken seriously. The indicated distance to origin in 1923 was 2,500 statute miles, and the origin proved to be under the ocean about 250 miles ESE of Unimak Pass in the Gulf of Alaska. There was probably a sudden inrush of ocean waters over a lowered sea bottom, and then a wave spread out across the Pacific with a speed proportionate to its size. It is this great speed which makes these waves comparable to tides, and the free wave of the daily tide lifted by sun and moon in the north Atlantic Ocean, a basin 3,000 miles wide, travels some 500 miles an hour. Either a tide or an earthquake wave may become dangerous if forced on a shelving shore. The Galveston flood was a wind-forced tide. The wave of 1923 at Hilo began about 12:30 p. m. and smashed sampans over the Hilo railroad bridge across the Wailoa River (see photographs Pages Two and Three). This wave reached Haleiwa in northern Oahu at 12:02 p. m., and it traveled thence to Hilo at about 518 statute miles per minute. At Waikiki in Honolulu the first movement was a long recession of the waters revealing new reefs during about 20 minutes. Then there were in-and-out surges at intervals of 15 to 20 minutes. This

earthquake was strongly felt in Alaska, was registered on seismographs all over the world, and the sea wave was registered on tide gauges in San Francisco, South America, and at Adelaide, Australia.

Returning to the seismogram of March 6, 1929, although the origin was even nearer than the center of February 3, 1923, and the amplitude of the motion in Hawaii was greater, and although Unalaska reported a severe shock on land and telegrams from steamers confirmed the location as south of the middle Aleutian Islands, where the crews on the vessels felt the bump; yet the amplitude of the sea wave, as shown on Page One, was only about seven inches at Hilo and two inches in Honolulu, and the surge in the sampan basin of the Wailoa River, lasting from 7:45 p. m. until 10 p. m. at intervals of 15 minutes, was something over a foot. Even this movement at its maximum between 8 and 9 p. m. was sufficient to break the stern lines of a steamer at one of the wharves back of the Hilo breakwater. The sampan fleet anchored out in the bay until the disturbance was over. The harbor authorities are always notified of the facts by the Hawaiian Volcano Obesrvatory and take proper precautions, just as any sailor would do at the possible approach of a storm. There is usually much less danger than in the case of a storm, but it would be folly to be unprepared.

Of 11 sea waves due to earthquakes on the sea floor which have been discussed at the Hawaiian station, the rate of propagation has varied from 284 to 481 statute miles per hour. An earthquake 3,915 statute miles from Kilauea in the Acapulco deep, jolted coast towns of Mexico at 4:49 p. m. June 16, 1928, and the sea wave arrived at Hilo 1:18 a. m. June 17, traveling 7.7 miles per minute. The waters at Hilo rose and fell 1.32 feet, the periodic oscillations were 15 to 22 minutes, and the water disturbance was indicated for more than 24 hours. The record was very feeble on the Honolulu tide gauge. On the other hand, an earthquake near Kamchatka December 28, 1927, 3,310 miles away made a tide record as well marked in Honolulu as in Hilo, the sea wave traveling 7.3 miles per minute. (See Page Four.) T. A. J.

KILAUEA REPORT No. 948

WEEK ENDING MARCH 23, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

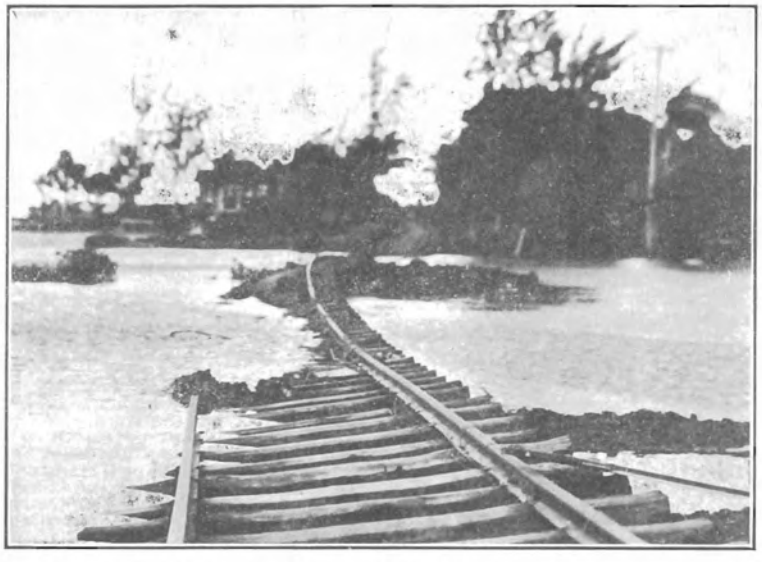
There were fewer slides at Halemaumau than during the previous week, though avalanche dust was observed on the 17th, 18th, and 19th. On March 22 a big scar was noticed above the northwest talus. There was little change in steaming.

Seven seisms, the smallest number since early September, 1929, were recorded by the Kilauea instruments. Two were tremors and five were very feeble seisms.

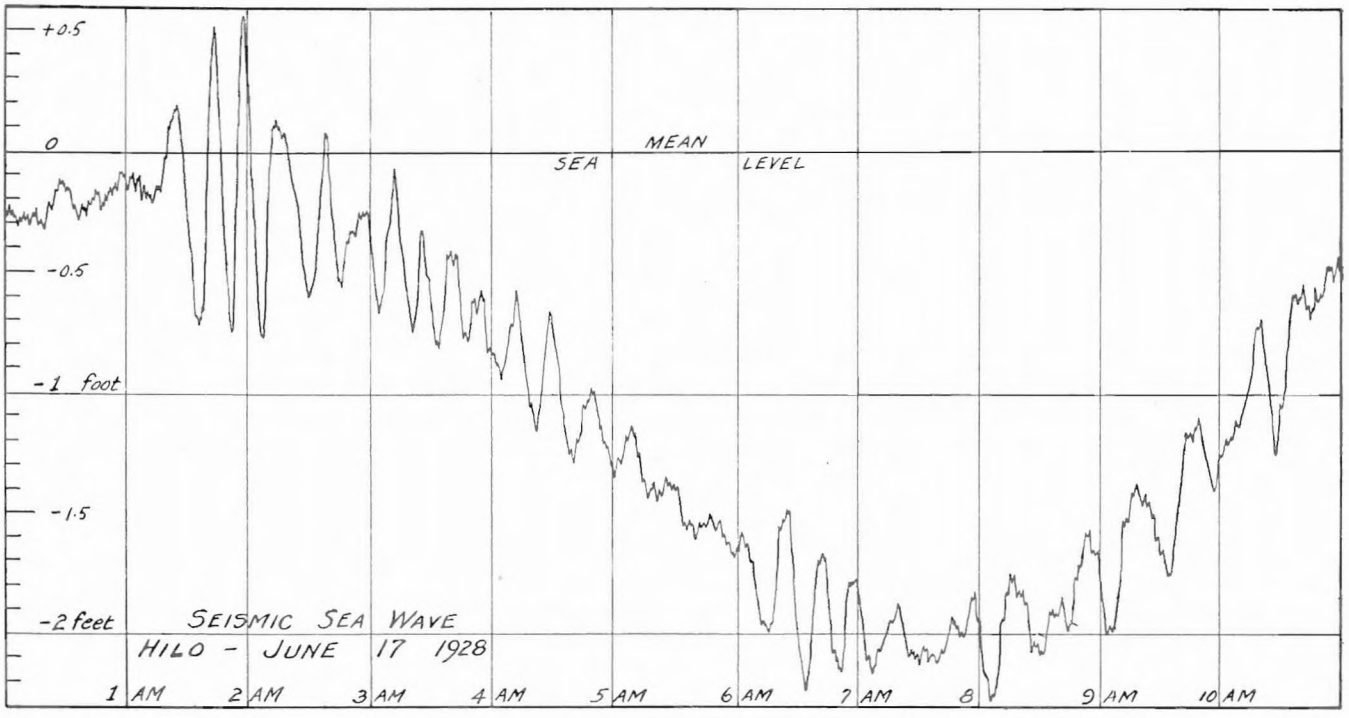
Tilting of the ground was slight southwest. Microseismic motion was normal.

NOTICE

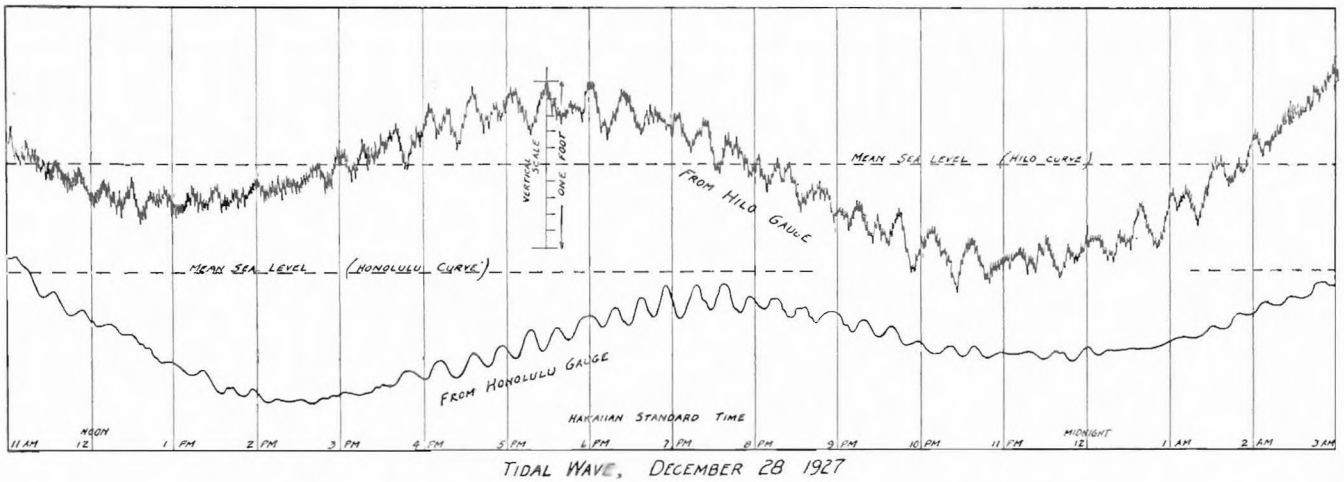
Copies of the Title Page and Index for 1929 have recently been mailed to all persons on the Volcano Letter mailing list during that year. A copy will be sent to any person sending application to the Hawaiian Volcano Observatory, National Park, Hawaii.



Railroad embankment washed down by tidal wave between Hilo and Kuhio Wharf February 3, 1923. The major wave at Hilo was the third noticed visually, and the waters rose over 20 feet in places damaging wooden houses and wharves. Damage was done also at Kahului in Maui. Photo Morihiro.



Tide gauge record of seismic sea wave, Hilo, Hawaii, June 17, 1928 This was made by an earthquake off Mexico.



TIDAL WAVE, DECEMBER 28 1927

Tide gauge records for Hilo and Honolulu compared. These were written December 28, 1927, by a seismic sea wave from an earthquake off Kamtchatka in a direction N 22 W. from Hawaii, and so registering more strongly in Honolulu than in the figure on Page One.

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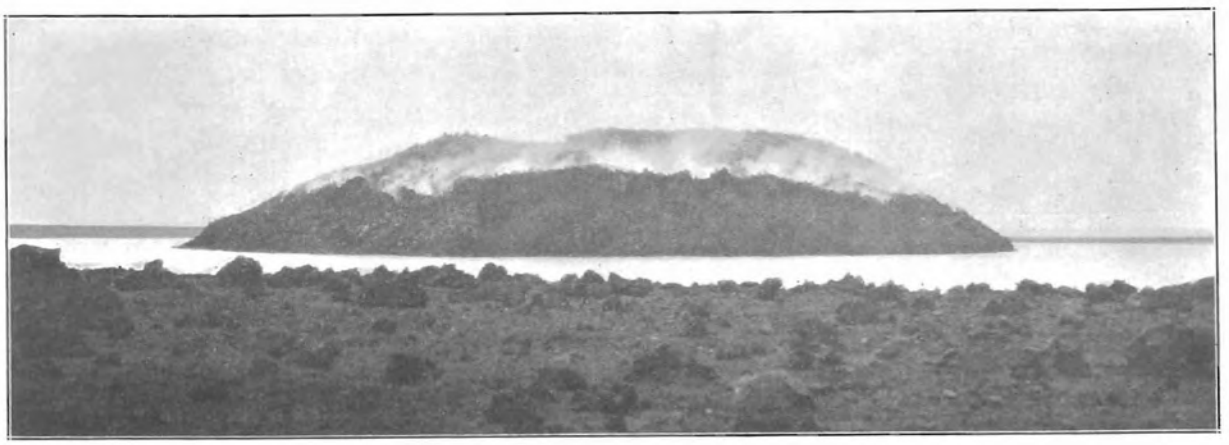
No. 275—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — April 3, 1930



Bogoslof Volcano in the Aleutian Islands, belonging to the United States. New lava heap in warm salt lagoon, surrounded by a ring of explosion debris, about June 28, 1928. The two older peaks are right and left outside the picture. Photo looking southwest, by Captain Roy A. Wheeler, Alaska Game Commission.

RECENT ACTIVITY OF BOGOSLOF VOLCANO

If the reader studies the map on the back hereof, he will find that nearly all of the steamship courses radiating from Honolulu either reach or pass by lands of active volcanoes. The northern course reaching Unalaska in a distance of 2,016 nautical miles, touches the middle of the Aleutian chain containing forty cones which have had historical eruptions. To the east this curve extends up the Alaskan Peninsula, to the west it goes through the Aleutian Islands to Attu, the whole length being some 1,500 statute miles. On the globe this is nearly a circular arc about the inner bight of the gulf of Anadyr as a center. None of these island volcanic arcs is truly circular; they are always somewhat straight at one end and hooked at the other. So in this case the curvature is greater at the western end. As in most of the island arcs, the active volcanoes tend to line the inner side of the curvature, toward the shallower ocean, in this case the Bering Sea .The same thing is true of the Caribbee Islands confining the eastern of the Caribbean Sea; and Martinique with its destructive volcano Pelee ,is the gem in the midddle of that volcanic necklace.

When the real meaning for this hook and curve alignment of volcanic islands has been discovered, we shall know much more about the globe than we know now. Underneath the volcanoes in the Aleutian Islands there are old granites and sedimentary rocks, exposed especially on the Pacific side, which protrude from the Alaskan continent, folded and pinched along axes parallel with the island line, and falling off to a profoundly deep trench to the south. This trench is also straight on the east and hooked northward at the west. This trench is over 20,000 feet deep. A basin more than 10,000 feet deep extends into the southwestern half of Bering Sea, but the rest of this inland sea is very shallow. The Aleutian Islands are really a submerged peninsula extending westward from Unalaska with the mountain peaks rising above the waves. Just in the eastern corner of the deeper basin of Bering Sea, and 40 miles north of Umnak, the large island next west of Unalaska, some rocky pinnacles stand in the ocean where on either side the water is 6,000 feet deep. These rocks are sometimes connected into a single island called Bogoslof, and at other times a channel between two of them has been washed clear by the sea. They are of enormous interest, for they consist of nothing other than the peak of a 6,000-foot volcano which during the last two centuries has been squeezing up stiff lava like paste from a paste tube, to add to the volume of its apex.

The rise of the first rocky spine above the water at Bogoslof was reported by early navigators about 1768 and was called Ship Rock. Another stiff aa crag of andesite, Castle Rock, rose to the southeast of Ship Rock with much explosion and oceanic disturbance in 1796, alarming the natives of Unalaska. According to Krusenstern, who made



Sea lion herd at east end of Bogoslof, June 1928. Photo Wheeler

a map in 1826, Castle Rock was then two nautical miles long, 4,000 feet wide, and 350 feet high, without summit crater, and with pinnacles on top. Castle Rock was extensively washed away and made smaller during the nineteenth century. In 1883 a new eruption began and a huge tabular crag of lava rose precipitously from the sea more than a mile to the northwest of Castle Rock and enclosed Ship Rock in its debris in the space between, the bombs and gravel and sand beaches joining the two peaks to form an elongate island. For more than a decade the boiling continued at Grewingk, as the table rock was called, but the erosion of the arctic storms, and explosive outbreaks, destroyed Ship Rock, and opened a channel between Castle Rock and Grewingk, which were apparently dead at the beginning of the twentieth century.

In 1906 new lava monsters began to rear their heads from the squirming lava tangle inside the undersea volcanic mountain, and these first appeared as a steaming new heap about midway between the two older islands, connected with the northwest table Grewingk by a low flat ridge of debris but separated from Castle Rock by a channel seven fathoms deep. The new mound was conical in appearance, with sulphurous eruptive rocks emitting large volumes of steam, and showing at the summit a broken horn bending to the northeast like the famous Pelee spine in Martinique, and consisting of a mass which had been forced up through an aperture while in a plastic condition, with smooth and scored sides. The new hill was named Metcalf Cone. The heat of the steam jets varied from 94° to 224° F., and cracks in the rock were hot enough to light paper. Metcalf Cone measured 2,000 feet across the base and 400 feet high. There were the usual alternations of explosive eruption with rising stiff lava, and at the beginning of 1907 Metcalf Cone was broken in two, while the channel between it and Castle Rock had filled itself with a new steaming heap of lava, McCulloch Peak.

At this time the writer visited Bogoslof, and on August 7, 1907, landed in a dory in the midst of a herd of roaring sea lions. The precipitous cliffs were covered with millions of murres and herring-gulls, and the air was darkened by myriads of them in rapid flight. Bogoslof was now a continuous island two miles long, the two active cones were 400 and 500 feet high, McCulloch Peak was three-quarters surrounded by steaming salt water at 90° F., and it looked like a huge lumpy potato with the bulbous lumps split apart, and the whole jagged mass encircled by debris slopes that led down into the orange-colored warm water of the lagoon. Immediately adjacent to it was the Metcalf half-dome, with the central spine wonderfully revealed in cross section. The spire appeared in the cliff like an inverted fish horn, its base 360 feet across and its top rounded both in plan and profile like a beak. There were regular markings on the rounded surface horizontally, as though the horn has been shoved up at intervals. It was like a great worm rising from its burrow with its head turned toward the east. It was 400 feet high and at the top it was broken away through lack of support into a ragged 40-foot precipice, overhanging the back slope.

Bogoslof in 1907 was at its maximum of volume above the waves, for the period since the big island of 1796 had been eroded away. It was now four rocky hills, Castle Rock at the southeast, then McCulloch Peak fuming and tumbling and encircled by sand bars and lagoons, then the half-dome of Metcalf Cone with its spine, bordered by a dry lagoon on the north, and at the northwest the tabular rock Grewingk with gravel banks piled against it. Our party discovered elevated rock platforms backed by sea caves which had been at sea level a year before, so that everything indicated that the huge pressure inside the submerged volcano, which was pushing up McCulloch Peak, was also lifting the volcano on its back and carrying the chain of islets with it. This heaving of the older land was

particularly interesting, because the main island of Unalaska showed elevated sea benches, and now we know that at Kilauea, during the rising lava period of 1913-1922, the mountain top surrounding Kilauea Crater was lifted more than two feet, and carried the Volcano House up with it. In other words, the turtle-back of a volcano swells when the lava rises and flows out, and shrinks when the lava sinks back.

September 1, 1907, a dense black cloud rose from Bogoslof, ash and sand fell at Unalaska mantling everything with a snowstorm of rock powder a quarter inch deep, and there were rain and lightning and distant rumbling. McCulloch Peak had blown itself up. A steaming lagoon was left in its place, the rest of the island was piled high with fallen debris, and the backslope of Metcalf Cone had the smooth concave cone profile of a Vesuvius. There appeared to be a rythmic sequence to the events whereby Metcalf Cone built itself up 400 feet high and 2,000 feet across, lived 10 months and exploded, then McCulloch Cone was built up 450 feet high and 2,000 feet across, lived 10 months, and was destroyed. It is probable that this means a pulsation of rise and fall of lava, and when the lowering comes, the sea water penetrates the hot voids below, under great pressure and by many inlets, generates steam, and the path of least resistance for the exit of the steam is through the crannies of the wall crack, around the crater edges of the risen lava column.

In July, 1908, the remains of Metcalf Peak had subsided and there had probably been another explosion the previous winter. There was renewed activity in the bay surrounded by beaches that lay between Castle Rock and Grewingk, in September, 1909. A new lagoon was formed shut off from the sea, and two small lava islands arose which in June, 1910, had united and reached a height 178 feet above the water. A survey September 10, 1910, made the island one and a half statute miles long and three-quarters of a mile wide. The old rocks were becoming smaller. A new explosion September 18-19 1910, sent up immense clouds of vapor, smoke, and ashes, flames were reported, and a true crater was opened in the top of the central peak. This was the first time that a real crater within one of the lava domes was ever seen and photographed by the Coast Guard officers who have done so much valuable work in making these reports on Bogoslof. In July, 1913, this crater had steam and smoke slowly issuing from it, but the following year all smoking had ceased. During the next eight years Tahoma Peak, as the new hill of 1910 was called, was eroded away, and a channel was again opened between Castle Rock and Grewingk so that a boat could sail between the two older islands. Grewingk had greatly diminished in size, and Castle Rock was now two rocky horns with a big accumulation of sand and gravel heaps piled against them, especially on the northern and eastern sides, these trailing off into a long sand spit at the north, and the whole of this larger island was surrounded by sand beaches.

The writer visited Bogoslof for the second time July 6, 1927, and found a new period of moderate lava activity inaugurated, with a pile of steaming lava rising from a warm lagoon in the midst of sand banks, and again these banks joined all of Bogoslof into one island with a complete ring-shaped salt water lagoon, surrounded in turn by a complete ring of sand permitting no connection with the sea except by seepage. The lagoon was at 70° F., there were the usual herds of sea lions and myriads of birds, the bottom sand and pebbles of the lagoon were all coated with orange colored ochre, the lagoon was everywhere only two or three feet deep, there were numerous skeletons of dead birds on the beach, and in the sand were impact craters made by newly fallen bombs having rough aa surfaces. There were blocks of pumice one to two feet in diameter. The central lava heap (see Page One) was about 200 feet high and 1,000 feet wide. Its crest consisted of uniform aa clinker, steaming much more heavily than in this picture of a year later. It made no noise, and it is characteristic of Bogoslof that during most of the visits reported noise has been absent. In September of 1910, however, a week before the explosive eruption, roaring steam jets were found. in 1927 the annular ridge of gravel, sand, and explosion products stood about 10 feet above tide.

The new activity had started in July of 1926 when there was open water between the two older rocks. An explosive eruption was then seen by a whaler, and the natives reported explosions July 17 as seen from nearby islands. The water was greatly muddied and the whaler on August 12 saw black smoke with darkness accompanied by thunder and lightning, ending with a cloud of white steam and "fire" about 2 p. m. There was also an explosion in December, 1926, and it is probable that the lava dome of 1927 emerged thereafter. Probably the eruption began with a series of lava pulsations, alternating with explosion. In 1928 the activity was mild as shown in our pictures. A landing party on Bogoslof July 27, 1929 reported all quiet.

T. A. J.

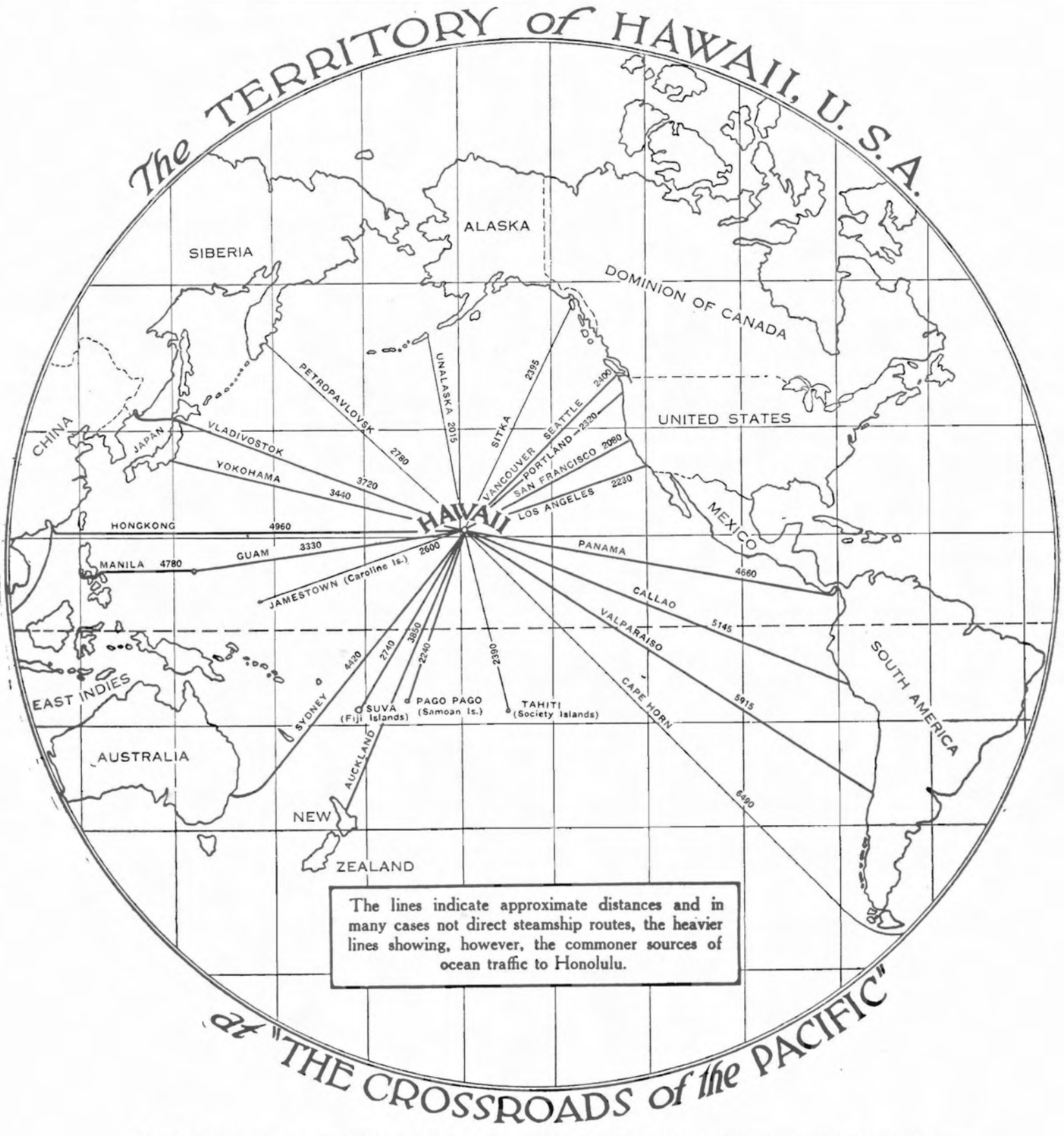
KILAUEA REPORT No. 949

WEEK ENDING MARCH 30, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Kilauea remains quiet. Halemaumau on March 26 exhibited a few fallen rocks at the north, and the pit seismograph showed some avalanche tremors. At 10:30 a. m. March 28 a little dust arose from the northeast wall, and such dust was seen occasionally March 30. At 3 p. m. March 30 there was fresh dust on the northwest wall and a triangle on the floor below was stained with dust. Otherwise the floor was mostly washed bare. A wide area of greenish-white solfataric stain has developed at the south edge of the floor. New bowlders extend out on the eastern floor. The talus NNW has increased in height, and a deep notch in the wall above the north talus has been extended upward.

Four very feeble local seisms have occurred during the week showing tendency to east tilt accompanying the shocks. Nine tremors are recorded each lasting less than a minute. Microseismic motion has been very slight, and tilt was moderate NNE.



Pacific Ocean, showing distances in nautical miles from Honolulu to the surrounding girdle of volcanic lands. Seismographs of the Section of Volcanology, U. S. Geological Survey are at Hawaii, California, Kodiak on W. side of Gulf of Alaska ,and Unalaska.

THE VOLCANO LETTER

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The Volcano Letter

Two dollars per year — Ten cents per copy

No. 276—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — April 10, 1930



Tarumai Volcano in Hokkaido, North Japan, from an airplane looking northwest, photographed by the Otaru Shimbun 1:45 p. m. October 19, 1926. New activity of gas eruption through the summit lava dome of 1909, and through cracks south of the dome. Lake Shikots in the background. Photo from H. Tanakadate

ERUPTIONS OF TARUMAI VOLCANO

Tarumai is in the forested mountains of southern Hokkaido, the north island of Japan. It is one of several volcanoes in that vicinity which have had many eruptions, of steam, sulphurous gases, and stiff andesite lavas. Tarumai is a cone of ash and pumice 3,300 feet high which renewed its activity after a long repose in the spring of 1909. It had been quiet since 1894.

From January to April of 1909 there were numerous explosive "cauliflower clouds" that went up from the cup in the summit cone. April 19th revealed a new lava dome on top of the crater. A very stiff aa flow upward had taken place, lifting the crater floor, opening outward like a flower in its calyx, and finally filling the former crater and rising above it 440 feet. The dome was all covered with jagged lumps and had a diameter of 1,400 feet. The rock was hypersthene andesite. The mountain was now 130 feet higher than it had been by reason of this addition to its summit. (See photograph Page One).

The lava dome of Tarumai was much like the several domes of Bogoslof in the Aleutian Islands, and made of similar rock. On May 9, 1909, the writer visited Tarumai and with a thermo-element thrust into a crack a foot deep in the tumble of crags at the side of the lava heap determined a maximum temperature of 855° F. (457° C.). This was more than hot enough to burn wood. The dome was steaming, particularly around the edges. This new lump remained on top of the mountain.

In 1917 the gas activity through a fissure in the lava dome started new eruption sending up fire, sulphurous smoke and ash, with much trembling. Such activity continued in 1918, 1919, 1920, 1921, and 1923, forming craterlets in the dome precipitating ash and lapilli over the surrounding country. Small stones fell on a village Tomakomai in 1919, eleven miles to the southeast of the mountain. In 1923 ash fell on the city of Sapporo, the capital of Hokkaido, 25 miles to the north of Tarumai.

The photograph on Page One was kindly furnished by Professor H. Tanakadate and was taken from the airplane of the Otaru Shimbun at 1:45 p. m. October 19, 1926. At this time a new series of gas-made ruptures broke athwart the lava mound as well as across the mountain summit to the south of it. Stones fell about the mountain, the usual cauliflower clouds shot into the air, and ash fell 220 miles to the east. The picture was taken from the southeast, and shows both the lava heap of 1909 and the ground to the south of it smoking, while off to the north two and a half miles away stands Tarumai's twin volcano Fuupushinupuri, and behind it in the distance stands lake Shikots.



Halemaumau January 14, 1918, showing the hard top of the lava column swolle ing from the outside edge inward. The steaming cliff on the left, and the dista lava lake is in the fume amid the central crags. Photo Jaggar.

Tanakadate has classified the volcanoes of Japan, (Proc. Fourth Pac. Sci. Cong., Java 1929 pp. 621-631) as ranging from abortive eruptions with no explosions or outflow, to liquid lava lakes in a crater. The abortive eruptions have many earthquakes localized about a dormant volcano. This is the same kind of activity as was localized in Hawaii in October, 1929, about the volcano Hualalai. Hakone is a district adjunct to Fujiyama which has frequently shown swarms of earthquakes, and in the Izu Peninsula south from there such earthquakes are producing damage and alarm at this moment.

At Oshima Island out in Sagami Bay opposite the Izu Peninsula is a fuming volcano, seen by tourists arriving at Yokohama, which is characterized by liquid lava, of rather stiff aa type usually, that rises and falls in its crater. This is Mihara Volcano, and comes nearer to the Kilauea type than anything else in Japan. Sakurajima produced a stiff lava flow, Tarumai dome was still stiffer, Usu, a few miles to the south of Tarumai, produced earthquakes and a lifted block of the mountain flank in 1910, with no lava except what was thrown up as bombs. Bandaisan in 1888, in central Japan, disrupted a mountainside with steam explosion, and other volcanoes throw out crater lakes and make mud floods, with no apparent lava. Many of these produce elevation of the country.

GROUND MOVEMENT IN A VOLCANO

The Volcano Letter has called attention (No. 264) to the swelling of volcanoes and in describing Bogoslof last week we pointed out that the eruptions of 1907 indicated uplift of sea shore in a year. A publication entitled "Topographical Changes accompanying Earthquakes or Volcanic Eruptions," by A. Imamura (Publ. Earthq. Invest. Comm. Japan No. 25, 1930), makes the following statement: "The character of the acute earth tiltings which accompany an earthquake is inferable from the chronic tiltings that precede the earthquake, and vice versa. And topographical changes which take place prior to volcanic eruptions have characteristics in common with those that take place prior to earthquakes."

These statements may be paraphrased by saying that either a great earthquake or a volcanic eruption indicate that acute earth tilting or tipping of the surrounding country is taking place. This tilting may accompany either a lift of the country or a dropping of the country. Experience shows that the center of the rising or the lowering of the country during the crisis may involve a mosaic of crustal blocks in case of an earthquake, but is apt to involve the crater itself in case of an eruption. And finally this accute uplift or lowering of country indicates that chronic tiltings of the region may be inferred as preceding the crisis, and these chronic tiltings are now being measured. This measurement is of the utmost importance for the future of seismology and volcanology. The reason for this importance is that probably prediction of cycles and crises may be based on knowledge of chronic movements. Chronic tippings have been measured for years in Hawaii and Japan, and their relations to small local earthquakes are like the relations of strain in a timber to its creakings. It seems probable that there is here open to view a new vista in volcano-earthquake science.

The review of Tarumai eruptions in the preceding article exhibits a pair of volcanic mountains close by a de-



the crust on a pudding as an incipient dome with stages of higher and higher swell-h cliff with stone shelter on top at the extreme right, are the edges of the pit. The

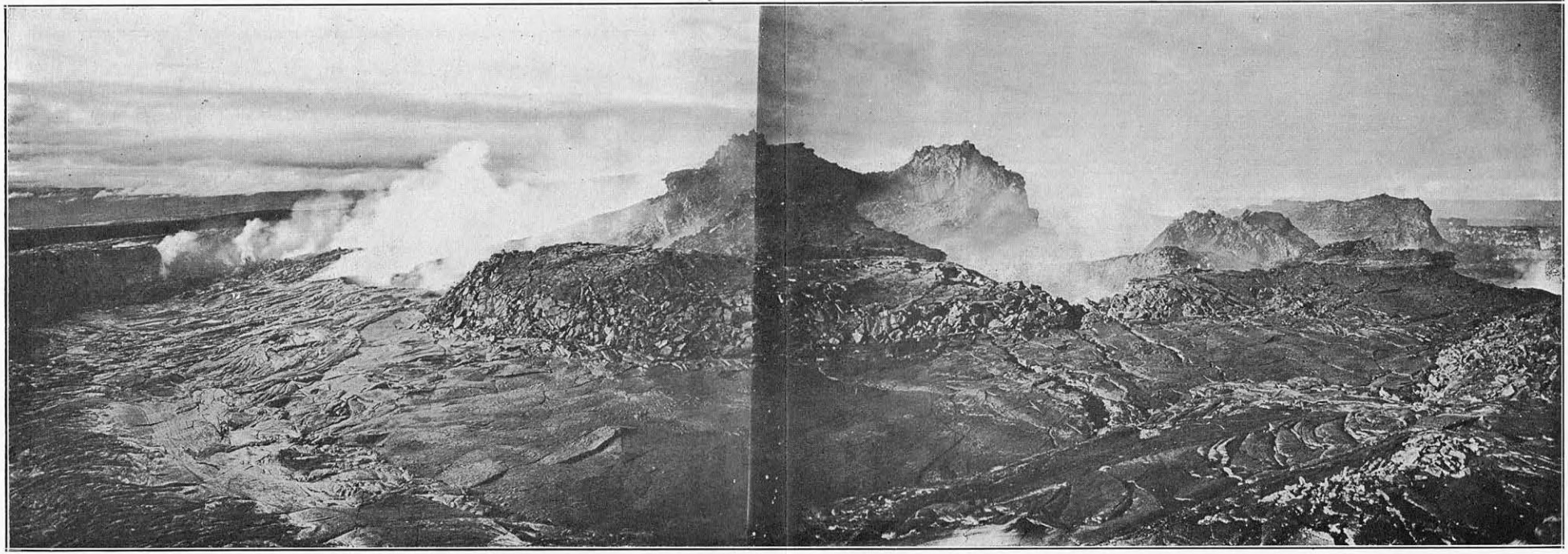
pressed lake basin. This relationship in Japanese volcanoes is very common. It appears to mean fault blocks which are tipped or warped down in the mosaic of the earth's crust under the lake basin, and swollen up under the volcano. The pairing of the two follows some definite and important law in the mechanism of the earth's crust. The lake basin lowers through the ages and the volcano dome swells up.

The picture (Pages Two-Three) of the inner floor of Haleamumau pit at the active center of Kilauea Volcano in a time of great activity of rising lava, and just before the first overflows within Kilauea Crater during the last eleven-year cycle, as shown above, is comparable to Tarumai. If the reader will examine carefully the left-hand side of this picture, he will see that within the low cliff the curve of a swollen dome, like the crust of a pudding, circles into the foreground of the picture and passes on around to the right of the big cluster of crags in the middle. If he will look still farther inside the curve, he will see a swollen inner dome in a half circle between him and the central crag. And beyond this is the group of central crags pushed up still higher as irregular blocks, and amid these blocks lay the liquid lava lakes fountaining and streaming among the wells that led up from the lava column below to the apertures amid the crags. This is all just as true a lava dome as the one on Tarumai.

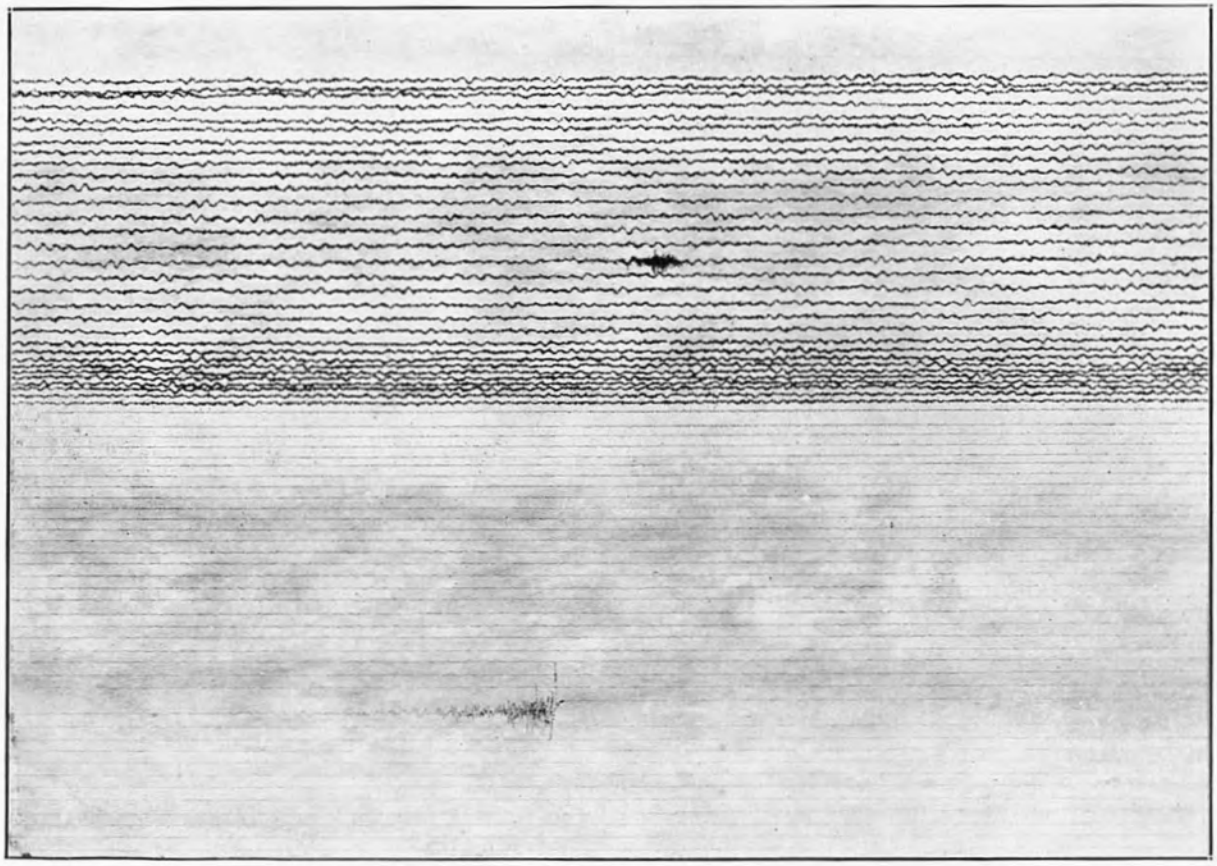
Now this deep lava in its rising at Kilauea was lifting the surrounding outer country. This was proved by leveling in 1912 and again in 1922. The edge of the pit was lifted from five to fifteen feet, and the edge of the outer crater was lifted over two feet. The seismographs there showed a strong and progressive tilting away of the ground.

The illustration on Page Four is a part of the wonderful seismogram described in Volcano Letter No. 264 as the autograph written by a pendulum hung like a door parallel to the edge of Halemaumau with a pen attached to it that wrote the lines round and round a drum turned by clockwork. The drum moved on a screw during the day toward the pit so that the pen would normally have written lines one-twentieth of an inch apart. This normal writing is shown by the light lines in the lower half of the picture. The autograph of the earth here shown is a record of the activity of big fountains of lava in Halemaumau pit half a mile away. The top line was the beginning of the autograph of the ground the morning of February 21, and this was the day when the fountaining stopped. Each successive line from the top downward is part of a half hour following the preceding line. The dark lines of the upper half of the seismogram are full of tremor from the lava fountaining. They open apart at first because the gas pressure was high, the crater was lifting, the seismograph cellar floor was tilting away from the center of the pit, and the writing pen moved away from the lines it had previously written. In the midst of this came a little earthquake showing black on the diagram.

Then at noon the gas pressure gave out, the lava began to go down, the ground tilted back toward the pit, and the lines became crowded, though the fountaining and the tremor still continued. Just before the fountaining stopped between 1 and 2 p. m., the record of tremor also stopped, everything became stationary, the tipping of the ground toward the pit ceased, and the lines on the seismogram recorded the event perfectly by no longer exhibiting tremor and by becoming normally spaced without any crowd-



Halemaumau January 14, 1918, showing the hard top of the lava column swollen up like the crust on a pudding as an incipient dome with stages of higher and higher swelling from the outside edge inward. The steaming cliff on the left, and the distant whitish cliff with stone shelter on top at the extreme right, are the edges of the pit. The lava lake is in the fume amid the central crags. Photo Jaggar.



Seismogram of February 21, 1929, written at the edge of Halemaumau pit in a closed hut by a horiontal pendulum with the writing boom hung tangential to the curvature of the pit. Tremor due to lava activity at the top, inward tilting due to sinking lava shown by crowded lines in the middle, cessation of activity and a local earthquake shown by normal lines at the bottom.

ing. About midnight February 21-22, as shown in the lower part of the seismogram, a normal local earthquake was felt and this as shown was accompanied by a widening apart of the line as though upward pressure were restored and the earthquake were a creaking of a block tending to tilt suddenly. This is what is meant by tilt accompanying local earthquakes. It is hard to imagine a more fascinating earth autograph than this one showing the tremor and centrifugal tilt above, the centripetal tilt in the crowded middle lines, and the sudden resumption of normal conditions at the bottom, all corresponding to observed volcanic activity.

T. A. J.

KILAUEA REPORT No. 950

WEEK ENDING APRIL 6, 1930
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Dust from slides has been seen at Halemaumau at 2:35 p. m., 3 p. m., and 4:15 p. m. March 31, and at 4 p. m. April 2. These slides produced much fresh material on the eastern talus heaps. On April 3 steaming on the south talus was very slight. A big slide occurred NE at 2:45 p. m. April 4 producing important changes in the region of the 14-ton bowlder northeast of the tourist station. The next day a number of large stones lay on the lava floor at the east side and steam was noticeably absent. At 10:25 a. m. dust again rose at the NE.

The Observatory seismographs have recorded 5 very feeble local seisms and 12 tremors during the week. Microseismic motion has been slight, and tilting of the ground slight NE.

THE VOLCANO LETTER

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

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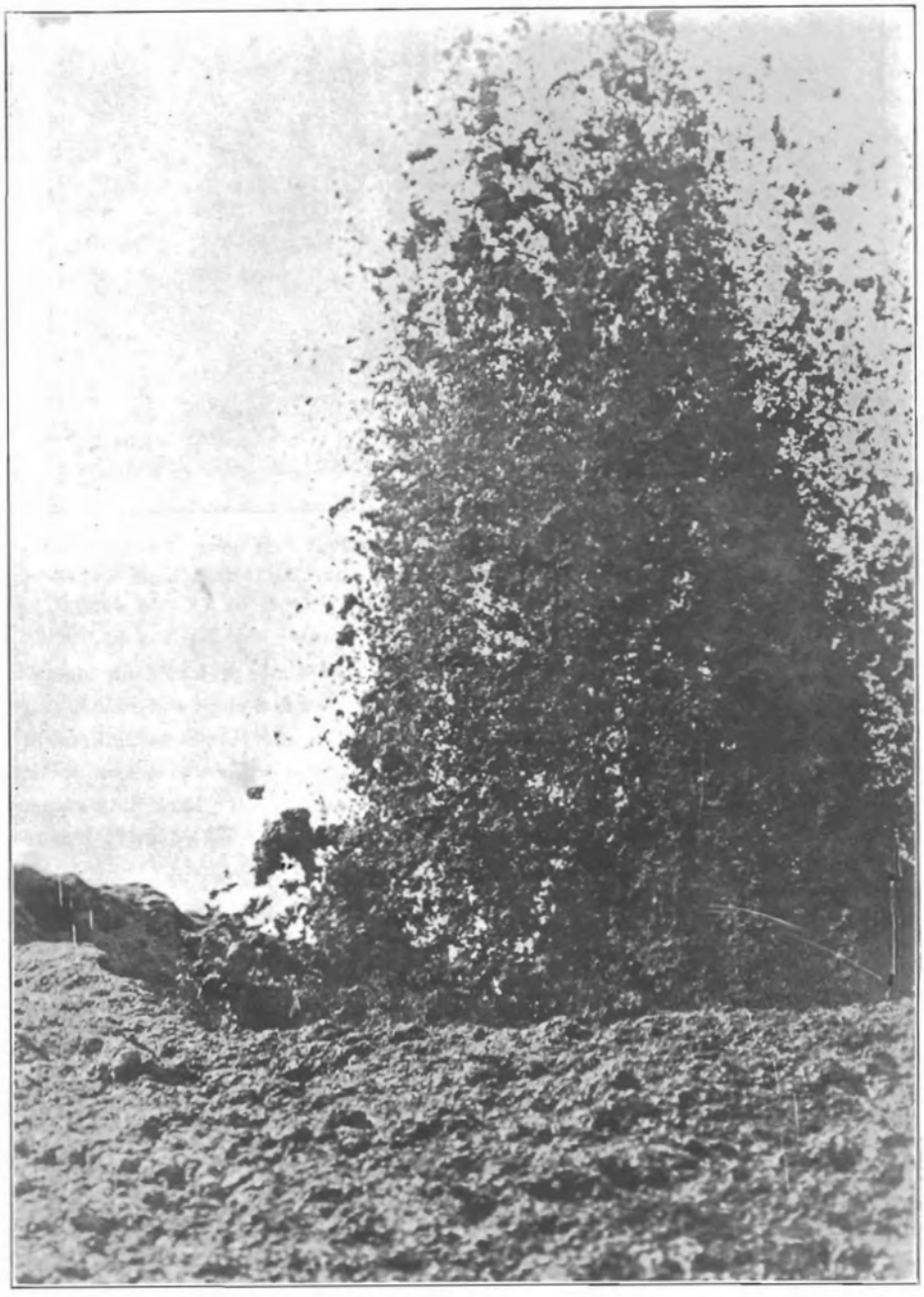
The Volcano Letter

Two dollars per year — Ten cents per copy

No. 277—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — April 17, 1939

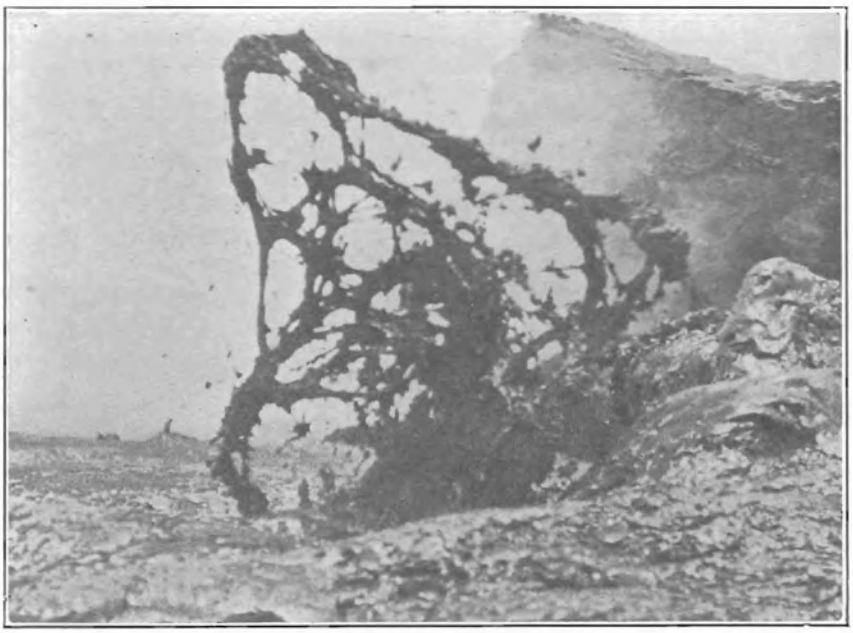


Gigantic incandescent lava froth fountain at north crater of Alika flow source, eruption of Mauna Loa October 25, 1919. Fountaining 50 feet away and 200 feet high, looking west from edge of new cone 200 feet above surrounding country. Southwest rift of Mauna Loa 7,834 feet above sea level. Photo Jaggar.

THE BUBBLING AND GUSHING OF LAVA

If a volcano enthusiast among Hawaii residents had written the title of this article, he would have called it "lava fountains."

Such is the common term used in Hawaii for the uprush of liquid lava at one place. This upward rushing of slag makes in the liquid lava lakes of Halemaumau the clustered burst of big bubbles through the slaggy skin in the middle, called "central fountains." The agent that lifts the central fountains is gas, but W. L. Green in the nineteenth century thought it was air. When these bursting bubbles recur about once a minute at Kilauea, they have often been called "Old Faithful," and for many months about 1910-12 Old Faithful stayed in nearly the same place. In 1913 there came a time when there were two pools, and the new pool had a "New Faithful." Then in 1916 and



Eorder fountain of heavy lava spinning Pele's hair at east cove of main lake May 23, 1917, interior of Halemaumau pit. Lava spurt is 15 feet high. Exposure 1/100 second. Photo Jaggar.

thereafter when experiments were conducted at the edge of the lava lakes, many fountains were studied which had a tendency to migrate along the surfaces of the streaming pools with repeated bursts of gas, the gas sometimes flaming, at other times making puffs of unburned, brown, sulphur fume. These migrations commonly ended at a "border grotto," a place of continuous marginal fountaining or bubble bursting, where the black vitreous melt was flung over the bank and built up an oven. The continuity of the effervescence here indicated some localized disturbance such as a subsurface streaming against the bank to determine a continued release of gas bubbles. And sometimes these continuous fountains formed in the middle of the lake indicating a subsurface pouring of lava down a well, and thereby a stirring out of the bubbles, which rose and burst eternally.

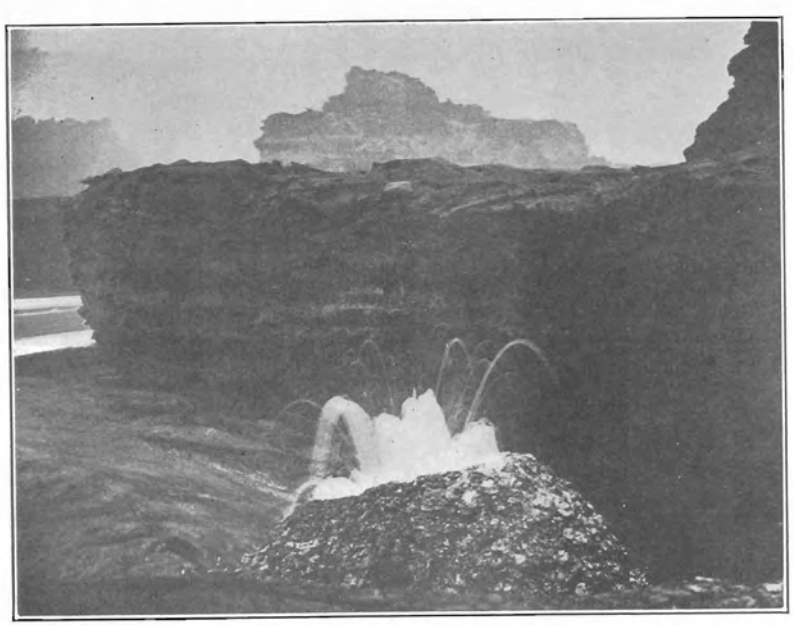
When a pot of porridge boils, it is not customary to call the bubbling places "fountains." "Fountain" is a misnomer for the golden slaggy dome bursts of incandescence in a liquid lava pond. The layman conjures up a picture of a spouting jet over an artesian well or an oil gusher when he hears the word "fountain." Just such fountains occur in lava. The picture on Page One, a very lucky snap shot, shows a true lava fountain 200 feet high. This was made at the time when in 1919 Mauna Loa had opened a crack in its flank releasing gas-charged lava from the depths to spout up like an oil gusher. After a month this had built up a cone 200 feet high with a marvelous cauldron of violently seething golden glassy froth boiling inside, and from the tube below a jet of this molten basaltic pumice was shooting into the air through the pool without interruption. Sometimes it would go higher, sometimes lower. For weeks it was going continuously. The material separated into lumps and shreds as millions of bubbles expanded in the pool, some of it was drawn out into hairs and membranes, and the larger hardening skeins and slops of this molten rock matter were four to five feet long.

In order to take the photograph, it was necessary to clamber up through hot pumice of buff color on the outside of the cone to windward, where over the summit edge lay the fountaining basin with its gigantic waves surging forward to a cascading outlet at the right. From under the back wall of this cup rose a geyser of fiery fragments, the pieces bright red-hot and very porous, and at the edge there were occasional fragments still glowing, showing that from moment to moment the jet was turned, like a lawn sprinkler, first in one direction and then in another. This made it necessary to take some chances in running in to within 50 feet of the nearest falling jets, on the summit edge, point and snap the camera, and get away without being bombarded. The sensation of looking up at that towering curve of rising and falling bombs, the highest pieces shooting from 200 to 300 feet above the summit and the lighter ones seeming to float like burning paper, all with intolerable heat and a complex of rumbling, whirring, and pounding noises as the larger lumps flopped down on the ground close at hand and stuck there, viscid and glistening, was an adventure to be remembered. More than a second or two of that heat would have ruined the camera. The crater was like a titanic open chalice of fiery liquor foaming in scarlet surges, these being impelled continuously forward by the geyser jets behind, the flood lift-

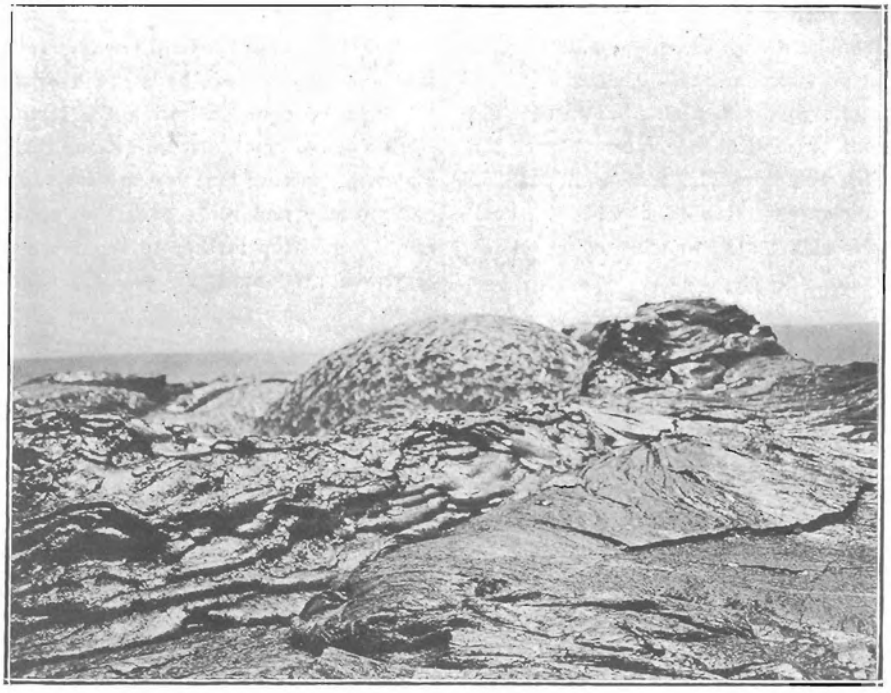
ed by the jets losing its liquid aspect almost instantly, and the expanding gas within giving it the appearance of very loosely knitted worsted. The beaten foam quickly quieted down to form black curds where the pond cascaded through the sluiceway leading to outflow. The color of the molten stuff is bright yellow at night, but in daylight is a reddish transparent tone with a luster like jelly, brightly glistening in the sunlight, and with purplish shadows, the jet distinctly changing color with the cooling from orange on the rising side to wine color on the falling slope of the arch.

Such is the most magnificent of the true lava fountains and it may well be compared to the prominences on the sun, but the latter are wholly of gas. Probably in both cases hydrogen is the dominant gas. A tremendous banner of burning gas stands above the Mauna Loa fountain at night, salmon and rose with bands of green. The motive power is gas expansion, just as it is in the bubble bursts of Kilauea. In the picture on Page Two the camera is 25 feet from a border fountain in Halemaumau, the lava lake being beyond and to the left, and the foreground is the lake margin. This shows the process of spinning Pele's hair. Gas is rushing up through a stiff, viscous lava, and carrying the lava with it, drawing it out into shreds, and the bank reflects it back into the lake like a surf repelled from a rocky shore. The tangle of fine glassy cobwebs, puffed and blistered by the endlessly bursting glass blisters on the melt, is caught up by rising heat currents of air and carried away by the wind.

This same corner two months before was building a border cone through the closing in of a marginal grotto so that the oven became entirely enclosed except for a crater through the top (see Page Three). Here we have a beehive cone with a lava fountain inside, connected by a tunnel with the lake, only a few feet away. Such cones are generally formed by a crack opening in one bank of the lava lake, and allowing the lava to penetrate it and start convectional streaming with release of gas. This makes a spurting fountain in the crack which opens a circular crater and roofs over its cupola and its tunnel. It is only one step farther to the place where such gushing of gas-charged molten glass, escaping from Halemaumau through a large radial crack at a place 500 feet from the pit (Page Four) wells up in a dome through a shell or half-cone of its own spatter and marginal congealing and keeps on welling up like an artesian gusher with its surface eternally coated with a net of bubble membranes, as shown in the picture, and so forming a "standing fountain," the source of a flow which was pouring off to the south on the Kilauea floor during the great crisis of overflow at Halemaumau in March, 1921. Thus we see that there is a transition from the central to the border fountains, and from the border fountains to outflow fountains. The explanation of the rhythmic fountains such as Old Faithful appears to be that they are always over a small well under the shallow lake, where the convectional circulation is draining the gas-charged liquid downward, and stirring out an accumulation of bubbles which cluster together and escape at regular intervals through the viscous lava of the lake surface. Whether there shall be rhythmic release or continuous escape probably depends on the depth and viscosity. T.A.J.



Same east cove of Halemaumau as Page Two, on March 30, 1917, in the evening. Flaming and spurting cone, exposed for 30 seconds, and exhibiting a succession of jets. Photo Jaggar.



Smooth dome fountain at source of flow outside of Halemaumau 500 feet to the southwest, March 20, 1921. The liquid part stood nine feet high, of orange incandescence, rising from under the knob on the right and pouring away into the background. Photo Jaggar.

KILAUEA REPORT No. 951

WEEK ENDING APRIL 13, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On April 9 a big scar on the east wall under the 14-ton bowlder showed as the location origin of the avalanche of April 4, which threw immense rocks far out on the lava floor of Halemaumau. The 14-ton bowlder is doomed to fall into the pit with the ledge which helps to support it on the east rim. This was the largest rock blown out during the explosive eruption of May, 1924.

The sulphur stain on the south bottom of the pit has become whitish in color. Steaming is as usual, and no other changes are to be reported.

The seismographs at the Volcano Observatory registered 12 tremors, the longest having a duration of three-quarters minute; and one very feeble seism. The net accumulation of tilt for the week was slight south. Microseismic motion was normal.

MARCH TILTING OF THE GROUND

At the Hawaiian Volcano Observatory the tilting or tipping of the ground in the seismograph cellar, expressed as angular change and direction of motion of the plumb line, was as follows:

March 3—9	1.03 seconds	NNE
March 10—16	2.32 seconds	WSW
March 17—23	1.06 seconds	SSW
March 24—30	2.05 seconds	NNE

This computation is by overlapping seven-day means. January and February were by direct reading (Volcano Letter No. 267 and No. 271).

THE VOLCANO LETTER

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The Volcano Letter

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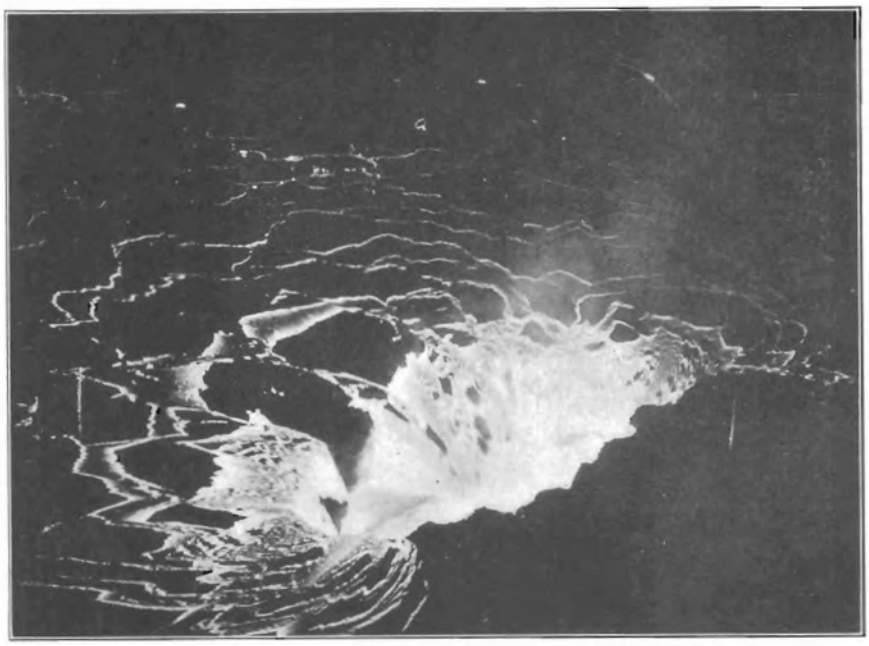
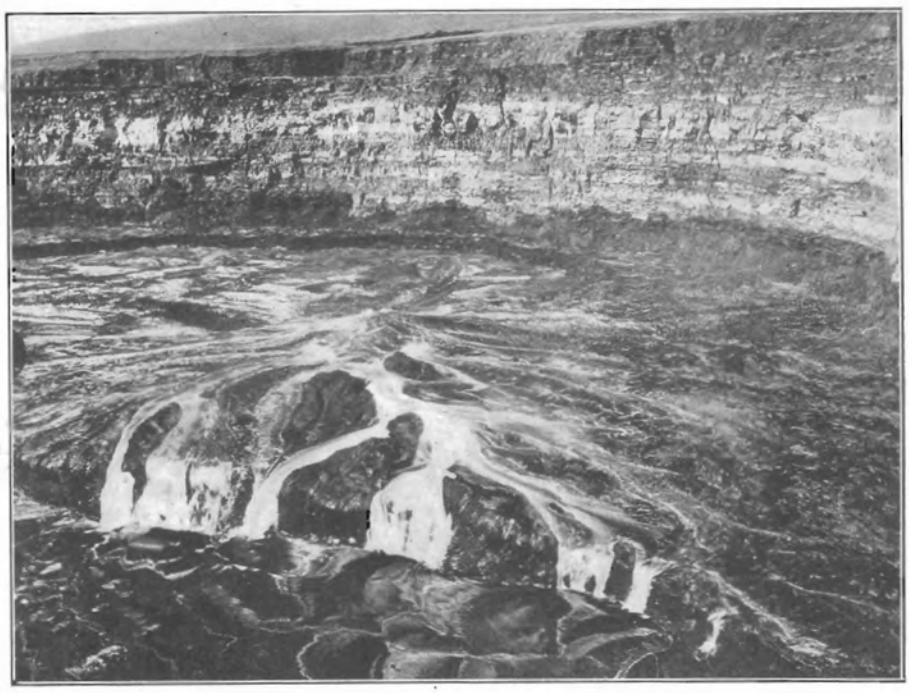
No. 278—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — April 24, 1930



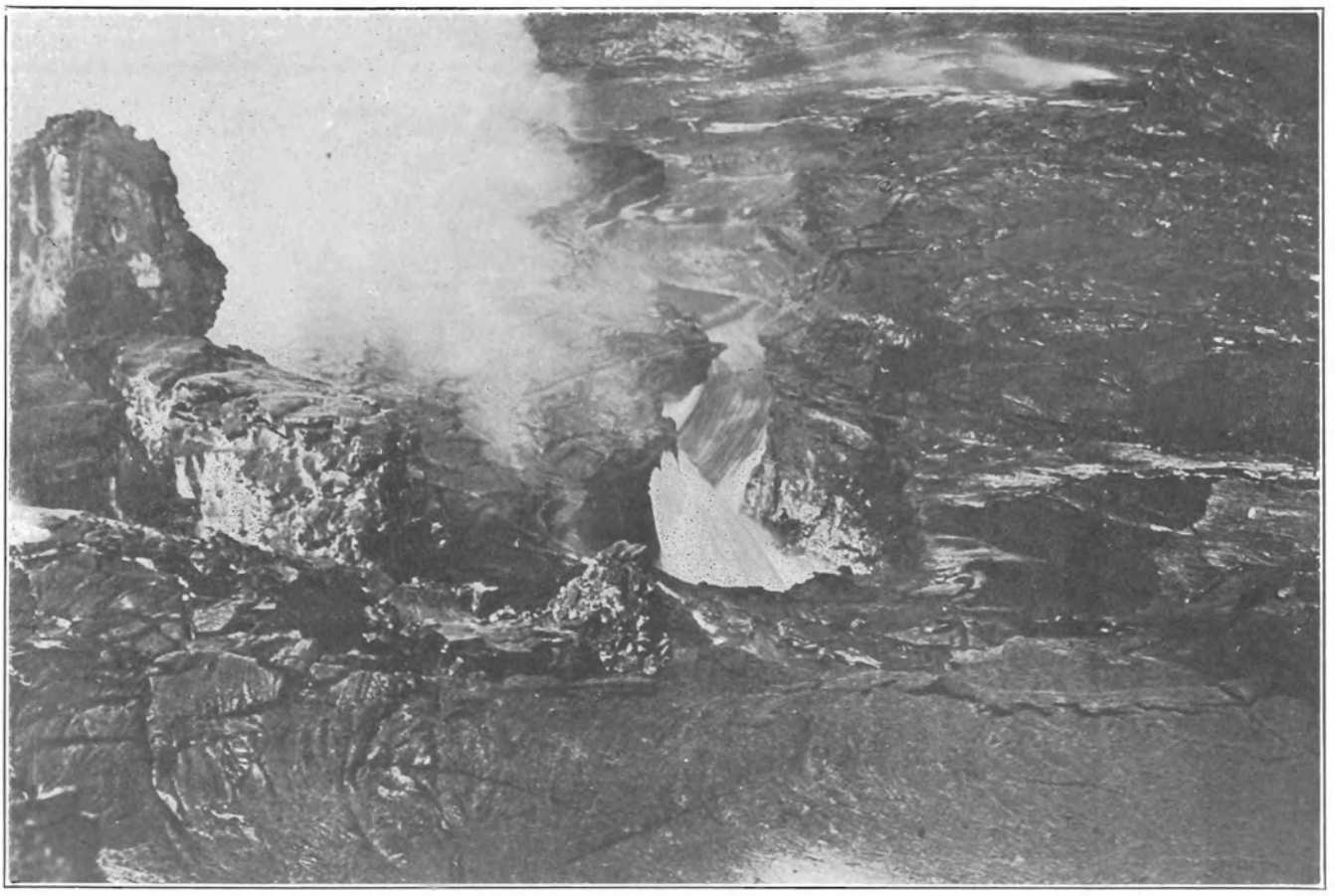
Lava cascade into North Pool of Halemaumau, 7 p. m. December 21, 1923, showing the concentric breaking of crusts as the incandescent fluid was sucked down a well which had temporarily become a sinkhole. Photo Finch.



Overflow flood of lava from North Pool of Halemaumau January 8, 1924, the North Pool lying in the middle of the radial flows. These cascade into the main lake in eight fiery ribbons shown in the foreground. Photo Emerson.

LAVA CASCADES IN HALEMAUMAU

To understand the distinction between lava paste and lava froth in Halemaumau pit of Kilauea Volcano, the observer should compare the happenings of different periods, when in the one case the froth (liquid lava) fountains up in artesian fashion through one of the wells or shafts that leads down through the paste (bench lava); and in



Cascade from remnant lake after a subsidence, into a sinkhole in what had been lake bottom in January,1917. Photograph was taken February 14, 1917, revealing the former bottom of the lake as a shallow affair about 40 feet below the former lake level. This bottom is the lava paste or bench lava. Photo Jaggar.

the other case the froth lowers in its well so that the remaining liquid lava rising through other wells streams across the lake area and cascades down into the evacuated shaft. Lava pulsations up and down for periods of a week or more are characteristic of a time of high activity, and the feeding well, which this week is overflowing on one side of the pit, may next week be receiving a cataract of golden incandescent fluid from its neighbors.

The general arrangement at a time of high rising, when the lava was actually level with the rim of Halemaumau, and had just been overflowing on the northeast, is shown in the map on the last page. This was in January, 1921, when there had been a big December rise, and the lava paste, shown by the shaded block in the cross-section, had been lifted bodily within the funnel, so that wells for the liquid lava were developed at the two wall cracks right and left (shown in black). The section goes from southwest to northeast, and the northeast margin of the pit is shown freshly overflowed in plan and section. This of course was a cascade into the open country. Now if we suppose the well, shown at the left in the section, to lose its supply of feeding lava in the depths and reverse its flow from up to down, while the right-hand well, connected by tunnels with all the lakes, keeps on bubbling up strongly, there will be developed a cascade into the left-hand well. Whatever may be the cause, it is a fact that the wells maintain different levels in the circulation, from time to time. (See Volcano Letter No. 272.)

The most intense fluctuation between different wells in the paste, with domings up and outflow over one well one week, and siskings down with inward cascades in the same well the next week, occurred during the last great rise of Halemaumau lava that preceded the explosive eruption of 1924. There had been a big subsidence in the pit of 400 feet in August, 1923, accompanied by the outflow in the forest near Makaopuhi on the Chain of Craters road. There was immediate rapid recovery in Halemaumau throughout the autumn of 1923, developing an enormous lava fill, from wall to wall, only 114 feet down January 21, 1924. At times this was a sea of liquid lava when all the bench lava was flooded, at other times it was a large shallow heart-shaped pool surrounded by a flat platform, with four low islands, and at the north an isolated pond of liquid lava in the platform between the two lobes of the heart. This was called the North Pool.

It is of interest to note that the lava paste, represented by the islands and platforms, was doing some horizontal moving which the islands exhibited. Thus in November, when at the beginning of the month the lava was 320 feet down and by fairly uniform rising stood only 260 feet below the rim November 30th, an island in the main pool, which had been there for several weeks, moved nearly to the southeast bank during November 24-25. A second island had appeared in the main pool November 10, disappeared on the 12th, reappeared on the 13th, and soon thereafter became joined to the larger island. In December the lava showed numerous oscillations in level, making a net gain of 39 feet.

These oscillations of December, 1923, are what produced the spectacular cascades. The dominant rising was at the south, and on December 7 there was a very strong spurt with downrushing cascade into the North Pool. These performances were repeated about once a week so that on the 14th and 21st December (see first photograph) similar torrential cataracts into this pool reached still greater size. On the 27th the influx was repeated

with very rapid fluctuations, so that during a half hour more than ten million cubic feet of lava was poured out, and over 40 acres were covered with the molten flood that drowned all islands and individual lakes. Then tumultuous fountains would break out at various places, some of the source wells would become sinkholes, and in all five wells were located.

In January, 1924, the weekly periodic flooding continued, but the North Pool sometimes became a source, and on January 8 (see second photograph) this pool was sending out extremely liquid radial torrents which cascaded into the main lake, as shown in the picture. The heat was almost unbearable at many places on the rim of the pit. A cone at one side discharged gas through a crack near its base. Several islands were drowned. On January 18 the liquid rose 65 feet in less than 16 hours so that on January 21 the lake was 45 acres in extent with no islands or separate pools visible, and the tumultuous fountains often hurled up spray 100 feet into the air. These violent fluctuations continued in February, but after February 12 the whole lava column including the paste lowered gradually until by February 21 the floor was 380 feet below the rim, the cascades into the North Pool being repeated February 15, 17 and 18, sometimes with a drop of 40 feet, while the main source was a south feeding well from which bright lines radiated. The topography of the paste lava reappeared and then collapsed around the northern pool along with the development of fume. Glow was last seen at the southeast, where there had been a conelet. In April came the subsidence and earthquakes in Puna, and in May the gigantic collapse at Halemaumau, accompanied by steam-blast eruption.

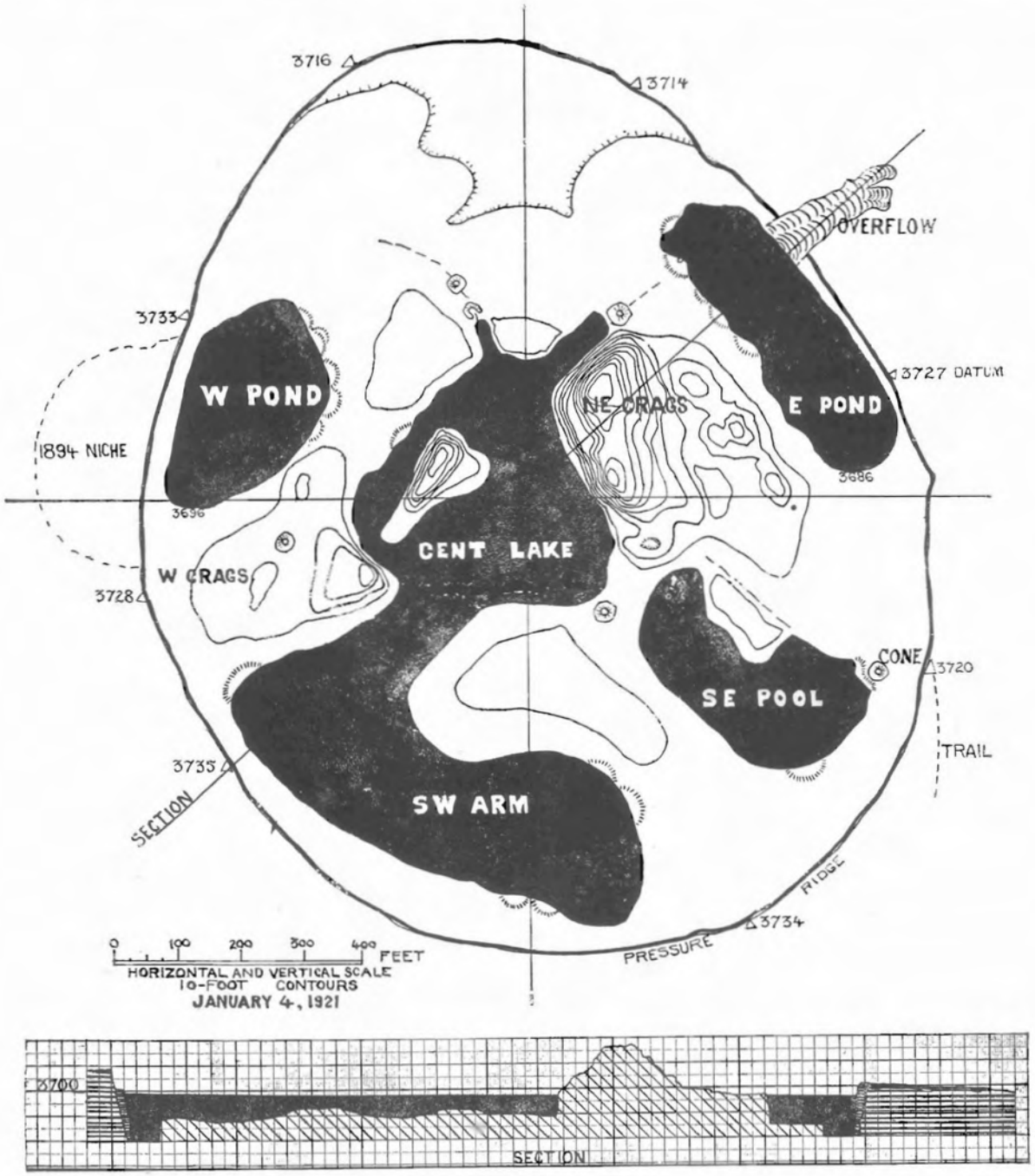
What process causes a well to be a feeder one day and a sinkhole the next is a matter of speculation, but there are many measurements on hand at the Hawaiian Volcano Observatory, the study of which may help to solve this problem. If the map and cross-section on Page Four are compared with those of Page Four of Volcano Letter No. 272, it will be seen that January 4 differs from March 14 of 1921 in that the paste lava block had been lifted clear of the two walls so that there were cracks filled with liquid lava on each side, whereas in March the level was lower and the cake of paste, which must be shaped like an inverted cone to fit the funnel of the pit, was settled differently within the tapering shaft. The lift of the paste as a whole is somehow connected with the gas expansion of the deep magma, from solution in which the gases escape and unite with increased heat and consequent liquefaction of the melt in which they formed bubbles, and it is highly probable that the few wells of the upper part of the combined lava column fork out into a network of wells down below. This network expands and lifts the whole sponge. If this is what happens, probably the upper harder part of the paste, with its crags and floors and overflows, is always breaking into blocks with doming and splitting of the crust, and this motion changes the relation of the different wells to each other. There is a circulation of the liquid froth with a maximum of rising where it is lightest and hottest, and of sinking where it has lost its gas and become heaviest. It is also eternally solidifying here and liquifying there, the partial solidification adding to the material of the paste. Thus the source wells and sinkholes shift in accordance with the equilibria of all these processes.

The photograph on Page Two shows the southern part of what had been the lava lake of Halemaumau a few days before, in February, 1917, when a sinking spell had revealed a well under the lake where the fountains had been. Into this well now there was a mighty cataract of molten lava with hot flame of pale bluish aspect rising from the sinkhole, and fume condensing above and to the left. This was the first great topographic demonstration of the shallowness of the lava lakes. The picture on Page Three, shows a marginal cataract of 1919 of the same character, with the whole lake pouring continuously into a void, tearing great skins on its surface, all of this ac-



Main lake in Halemaumau cascading into a well at the Northeast cove June 9, 1919, a process that kept on for 11days without altering the relative level of the lake, though the entire lava column was sinking at this time.

Photo Jaggar.



Map of Halemaumau and profile section January 4, 1921. Elevations above sea level in feet. Liquid lava black, diagonal shading bench lava, broken lines are cracks. This situation followed a marked rise in December when the liquid lava had gained at the expense of the crags and islands, and had overflowed the rim of the pit from the East Pond.

companying subsidence of the lava column and disturbance of the bench lava, but all a part of normal circulation phenomena, and not an outflow, for the level of the lake remained relatively constant for 11 days while the cascade persistently poured into the gulf. The lava lake even rose at times, relative to its own banks, while this was going on. T.A.J.

KILAUEA REPORT No. 952
WEEK ENDING APRIL 20, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

No changes in Halemaumau have been noted except additional rocks on the bottom below the 14-ton bowlder. The bowlder has not changed its position. Crack measurements show no changes near the tourist observation station.

Dense steam was rising from Halemaumau on the afternoon of April 18 and the morning of the 19th due to light rains.

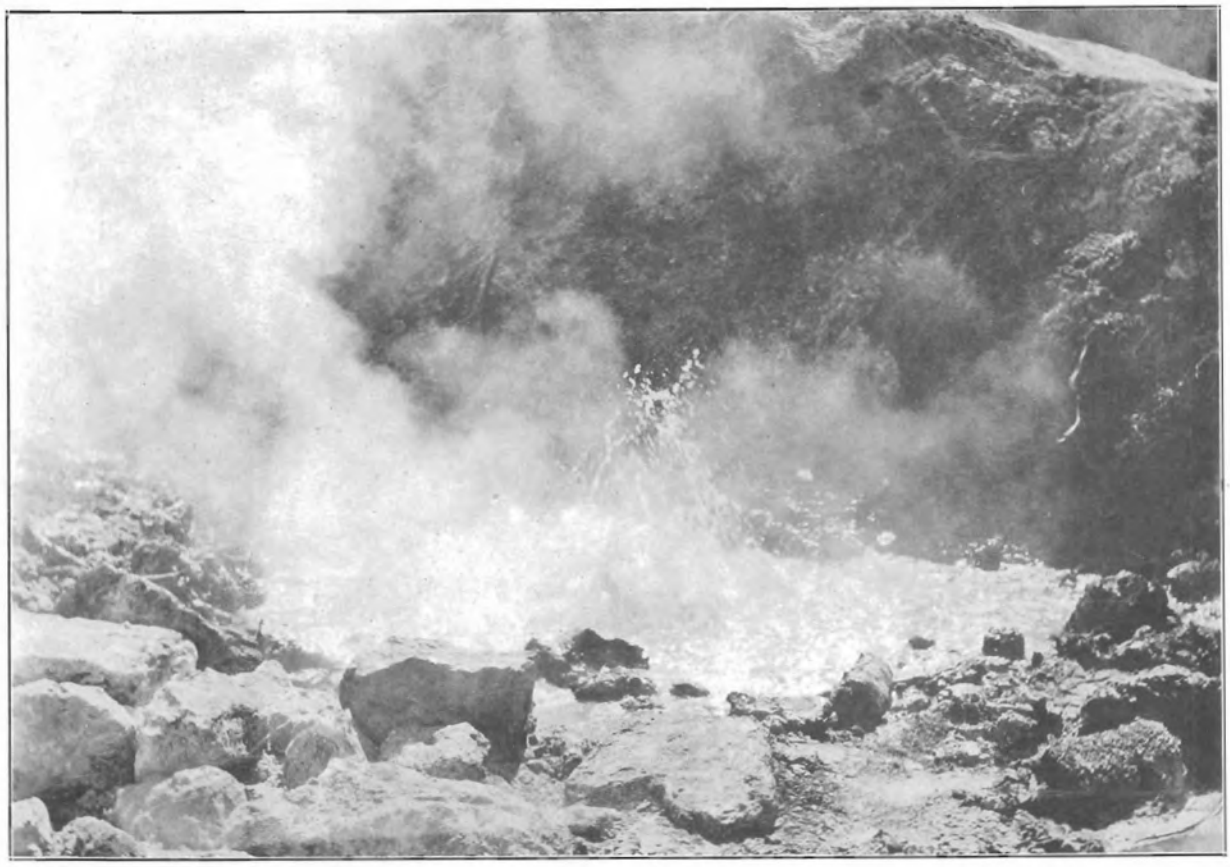
Ten seismic disturbances were registered by the instruments at the Observatory during the week, classified as follows: Six tremors, the longest with three-fourths minute duration; three very feeble seisms, one showing an origin 18 miles away; one distant earthquake, the long wave recording feebly at 9:09 p. m. April 15.

Tilt accumulated moderately SW. Microseismic motion was slight.

The Volcano Letter

Two dollars per year — Ten cents per copy

No. 279—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — May 1, 1930



Boiling pool of solfataric water in Devil's Kitchen, five miles southeast of Lassen Peak, August 17, 1929. Photo C. A. Huff.

LASSEN REPORT No. 25

LASSEN VOLCANO OBSERVATORY
R. H. Finch, Associate Volcanologist

SEASONAL VARIATIONS IN HOT SPRINGS

During the summer of 1928 the most active vent in the Supan soltatara, Lassen National Park, showed the following temperatures:

Early Summer	194° Fahr.
July 28	240° Fahr.
Sept.	235° Fahr

Similar variations of this vent have been noted in other years.

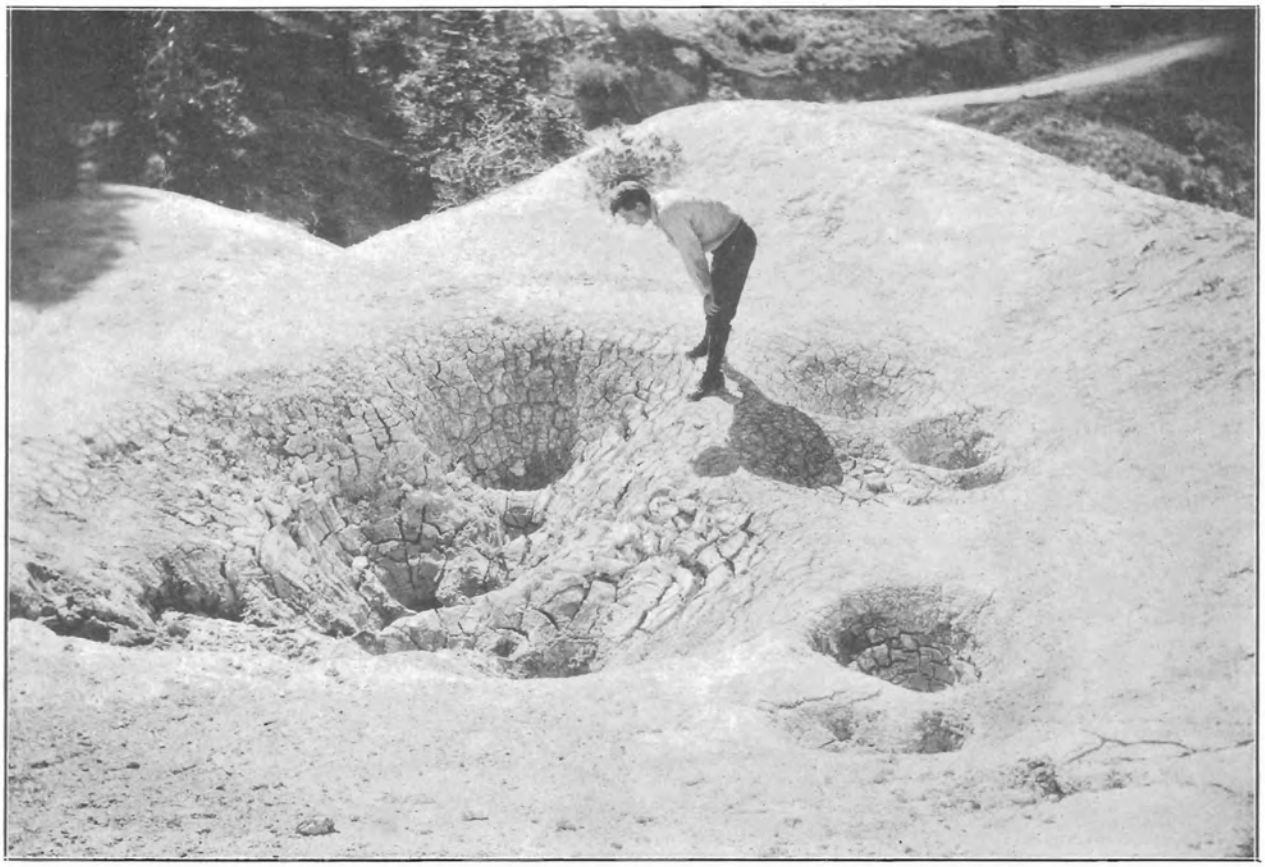
Whatever the ultimate source of the heat of hot springs a decrease in the amount of discharge should allow the smaller volume to be more highly heated. As is to be expected, there is a seasonal variation in the temperature of many hot springs, the highest temperatures occurring in the dry season and the lowest temperatures in the wet season. Why, then, should the hot spring under discussion show a maximum temperature in July instead of in September. There was no rain between July 28 and September 5.

Now it is commonly noted that with the shorter days and increasingly cooler nights that are reached in September and October, there is a tendency for many springs to show an increase in discharge. Some that ceased to discharge in July or August or earlier will start flowing in September or October without any rain having fallen to furnish additional moisture. This phenomenon is especially striking in California where in many places there is commonly no rain between June and September. It is also noticeable at many other places with less seasonal contrast in precipitation. The increased discharge in the autumn is undoubtedly due to a decrease in evaporation.

The mud pots shown on page two, which are near the active hot spring under discussion, showed no water on August 27, 1929, and on September 30th there was over one foot of water in the largest hole with no rain having occurred between the two dates. The unexpected decrease in temperature of the hot spring noted must have been due to a slight increase in discharge.

SLIPPING AT SUPAN SLOPE

At Supan Solfatara a line of stakes placed 50 feet apart in November, 1927, parallel with the valley, and across a belt of fissures where slipping is in progress in the highly solfataric soil, has been remeasured from time to time with both tape and transit. Some of the stakes were disturbed, and in general the region of stake No. 0, one thous-



Mud pots in the Supan Solfatara, three miles south of Lassen summit, showing no water August 27, 1929. A month later water had risen in the large hole without any rain in the intervening period. Photo Finch.

and feet up the slope from stake No. 20, moved downhill 3 inches toward No. 20 as shown by transit measurements. Some of the intervening cracks diminished in width, the upper land overriding the lower land, so that some of the 50-foot intervals between stakes show a minus change. The following are the changes:

Stake Interval	Nov. 1927 to July 1928	July 1928 to Aug. 1929
No. 0-1	+0.1 foot	+0.3 foot
No. 2-3	+1.4	—0.4
No. 3-4	+1.3	0.0
No 4-5	0 0	+0.2
No. 5-6	—0 6	—0.2
No. 6-7	—0.4	0.0
No. 7-8	—0 2	0.0
No. 8-9	—0.2	0.0
No. 10-11	—0.1	0.0
No. 11-12	+0.2	0.0
No 12-13	—0.4	0.1
No. 13-14	—0.1	0 0
No. 14-15	—0.1	—0.1
No. 15-16	—0.2	0.0
No. 18-19	0.0	+0.2

EARTHQUAKES AT LASSEN VOLCANO OBSERVATORY

The number of earthquakes of local origin recorded at the seismograph in the Lassen Volcano Observatory at Mineral, California, during the calendar year 1929 was 96. The indicated distance to origin for the local shocks ranges from 8 to 12 miles, which is about the distance of the Lassen Volcano mass. The numbers of shocks recorded during the three complete years since the establishment of the observatory are:

Year	Number of Quakes
1927	266
1928	37
1929	96

Tilting in 1929 was much the same as during the preceding two years, and frequent adjustments of the instruments were necessary. The accumulated tilting of the ground appears to be greater than what can be accounted for by the changes of atmospheric temperature. In the winter season of 1928-29 there was a pronounced accumulation of southwest tilt, possibly due to a doming of the Lassen volcanic mass.

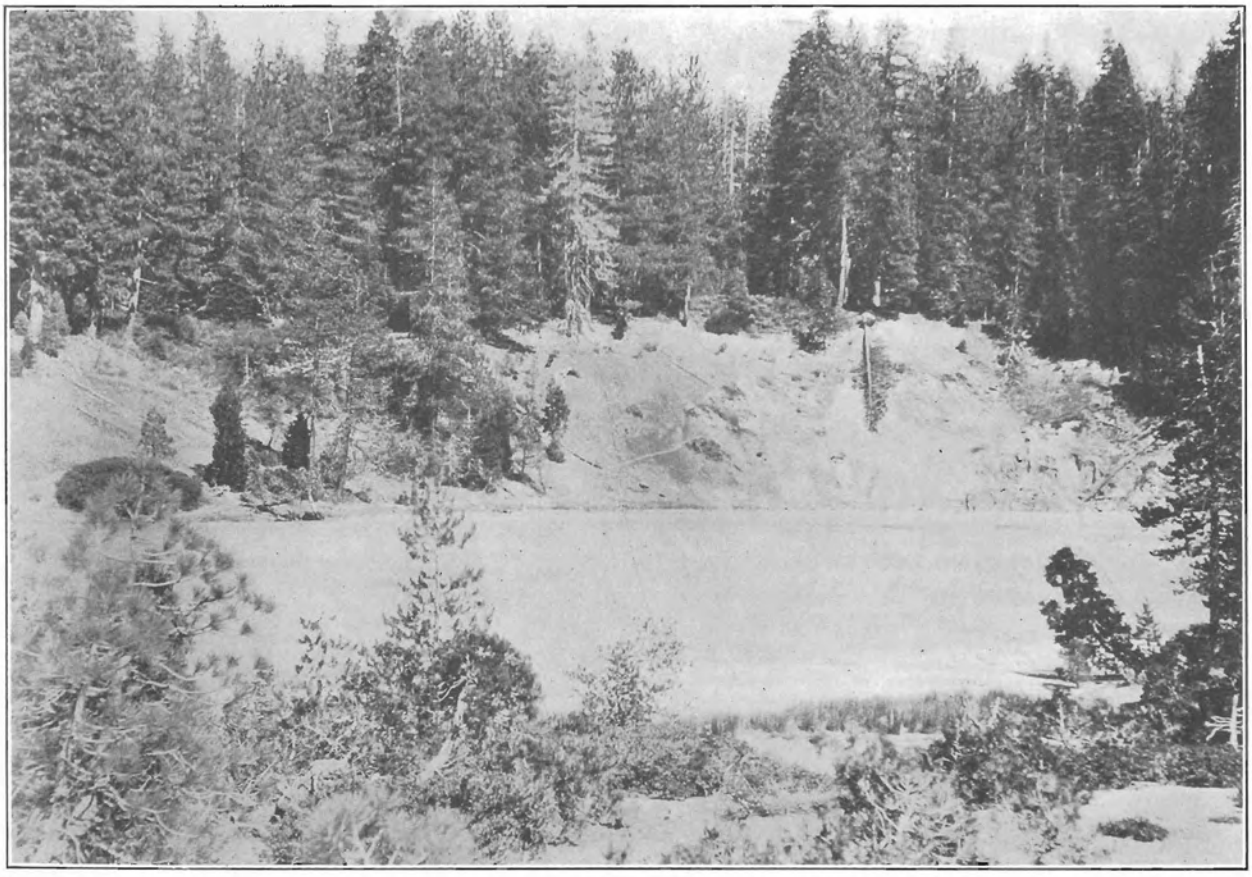
TEMPERATURE CHANGES LASSEN HOT SPRINGS

The following are a few of the measurements made at the different hot springs in Lassen Volcanic National Park, to show comparative data for different years. The later measurements made by Lassen Volcano Observatory are compared with each other and also with the records of Day, Allen and Diller between 1915 and 1923 (See Volcano Letter No. 238).

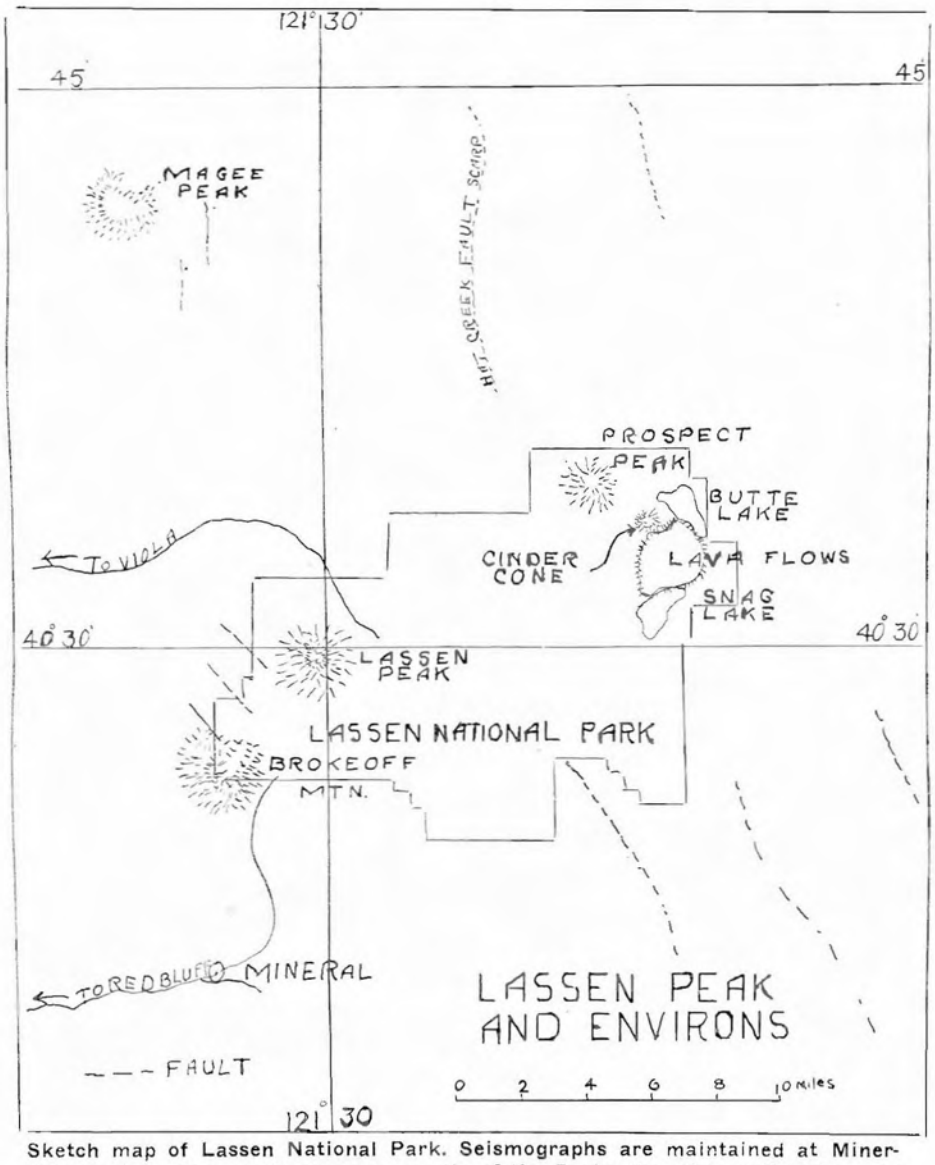
Location	Day-Allen	OBSERVATORY 1927	1928	1929
Supan's Solfatara				
Big Steamer, Aug. 11, 1923	185°F	Jan. 13 .... 194°F. July 6 .... 174 Sept. 23 240	July 28 .... 240°F. Sept. 5 235	Aug 27 .... 197°F.
Bumpass Hell				
Large steam vent west of northwest pool, July 3, 1922	196	July 6 183	Sept. 5 192	Aug. 26 176
Spring No. 8, June 5, 1916	242	Aug. 26 194	Sept. 5 194	Aug. 26 198
Spring No. 10, Aug. 10, 1923	198	Aug. 26 194	Sept. 5 174	Aug. 26 198
Spring No. 14, Aug. 11, 1923	201	Aug. 26 217	Sept. 5 190	Aug. 26 197
Boiling Lake				
Steam vent south end, June 30, 1922 (The ground here subsided several feet 1927-28)	201	July 8 212	Aug. 11 204	Aug. 17 200
Boiling pool south, July 3, 1922	201	July 8 200	Aug. 11 192	Aug. 17 198
Devil's Kitchen				
Northwest boiling pot, June, 1922	196	July 8 198	Aug. 11 189	Aug. 17 195
Southern pool, June, 1922	201	July 8 199	Aug. 11 198	Aug. 17 199
South pot, July, 1915	201	July 8 198	Aug. 11 199	Aug. 17 197
Morgan Springs				
The Growler, (Diller) 1921	204	Aug. 24 200		
Spring No. 1		Aug. 24 175	Aug. 7 177	Aug. 22 168
Steam pool No. 17		Aug. 24 201	Aug. 7 201	Aug. 22 201
Spring No. 6, NE		Aug. 24 146	Aug. 7 176	Aug. 22 195
Spring No. 23		Aug. 24 183	Aug. 7 192	(Many of the spgs. were dry)

The above are not necessarily entirely identical places as the springs shift and vary and the thermometer exposure differs. In 1929 the Morgan Springs showed increase in incrustations and the volume was diminished.

R. H. F



Boiling lake near Drakesbad, Lassen Volcanic National Park, July 8, 1927. This is six miles southeast of Lassen Peak. Photo Finch.



Sketch map of Lassen National Park. Seismographs are maintained at Mineral and Viola. Morgan Springs are south of the Park; the other solfataric areas are close to Lassen Peak.

KILAUEA REPORT No. 953
WEEK ENDING APRIL 27, 1930
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Halemaumau pit remains very quiet, only slight rock slides being noticed April 21 and 26.

Seven local seismic movements were registered by the Observatory seismographs during the week, of which four were tremors, each lasting from a half minute to a minute, and three were very feeble seisms. Microseismic motion was normal or slight, and tilting of the ground was strong NNE.

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No. 280—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — May 8, 1930



Distant photograph of Halemaumau pit March 25, 1921, from the summit of Uwekahuna Bluff, near where the museum now stands. Shows the entire circle of the pit filled with overflowing liquid lava that was rushing around the islands to the south cauldron in the background.—Photo Jaggar.

WHEN KILAUEA FIRE-PIT OVERFLOWED

To the visiting traveler it seems quite incredible that the vast yawning cauldron of Halemaumau, the lava pit of the inner floor of Kilauea Crater, was overflowing its lips in five directions at the March equinox of 1921, only nine years ago. The following is condensed from the Journal of the first three weeks of March, 1921:

"At the beginning of March the continued subsidence of the lava in the pit made the scene surpassingly impressive owing to the great inner crags towering above the five lava lakes. The walls around the several lakes were sheer precipices, 70 feet high in places, and the rim of the pit stood 90 feet above the liquid lava. Some of the crags on March 6 were still subsiding steadily. The second week in March produced slow subsidence, both lakes and crags lowering a foot or two per day. The glow from the pit at night was dark red.

"The third week produced a spectacular rise, after beginning with dull, crusted, stationary lakes." March 15 inaugurated the rising by a swelling up of the lake bottom and heaving into the air the elephantine island exhibited in cut three of Volcano Letter No. 272. "Suddenly March 18 the crusts broke up, violent fountaining began, the lakes rose 40 feet in a few hours and united into one around the crags as islands, and the overflows escaped from the rim of the pit on three different sides. The overflow northeast swept down for a mile in the Volcano House direction, crossed the trail, and made aa lava at its front." This is what tourists see when they walk out to the pit from the Volcano House.

"The gas release which followed the overflowing produced three sinkhole cauldrons inside the pit which developed enormous clusters of roaring fountains, inrushing cascades (see Volcano Letter No. 278) and upthrown slaggy flings that formed ramparts. (Volcano Letter No. 277). Showers of grit and spun glass fell to leeward. The eruption continued steadfastly, with pit in adjustment to overflow, and the crag islands, which had risen less than the liquid, began to disappear. The longest flow was pouring all over the southern end of Kilauea Crater and out through a gap in the wall of Kilauea Crater, where it advanced a third of a mile into the desert and stopped."

"This activity was accompanied by whirlwinds generated by uprush of hot gas carrying shells and fragments of glowing basalt hundreds of feet into the air and lifting the fountains and burning gases into streamers of fire. These whirls made loud roaring noise, and the larger fragments fell several hundreds yards from the pit. At night the illumination was so great that print could be easily read at the Observatory two miles away.



Halemaumau pit brimming full, with its hot lake and crag in the foreground. In the background stands Mauna Loa with a remarkable convection cloud over it, probably due to a gas eruption at its summit crater. Photograph by Jaggar, March 19, 1921.

"The end of the month started a rapid sinking of the lava column, crags and lake lowered 10 feet or more per day, whirlpools and shifting sinkholes formed, the crags increasingly emerged from the liquid, fume became thicker the outflows of course ceased, and glowing wells were left over underground chambers at the source cones of the flows."

The first picture the visitor may compare with what he sees today when standing at the Uwekahuna Observatory, where the motion pictures are shown. This is a view taken March 25, 1921, looking down at what had been Halemaumau pit. Except that the pit at that time was somewhat smaller than at present, the effect is exactly as though one looked down at the present cauldron filled brimming full of liquid molten lava which was overflowing off to the right. At the far side of the white lake of molten stuff is seen at the left the pressure ridge of the southeast rim, which was near the road terminus. When the picture was taken, there was a great sinkhole cauldron at the pressure ridge, and most of the surface streaming of the lava through channels amid the crags was toward this sinkhole. The dark foreground is the terrace of Uwekahuna Bluff making this somewhat of a birdseye view, with the observer looking down at a landscape 500 feet below him.

A group of earthquakes immediately before and during the first days of this March rising of 1921 was felt in the southern and western parts of Hawaii, showing that the lava under Mauna Loa took part in the movement that was vented at Kilauea. There was almost certainly some gas effect of outrush at the summit crater of Mauna Loa, for at 3 p. m. March 19, 1921, a remarkable mushroom cumulus of what appeared to be a steam cloud with a stem, developed over the summit of Mauna Loa, its substance an ordinary cloud, but its persistency and situation suggesting a heating effect, in or near the summit crater of Mauna Loa. There was no activity of Mauna Loa otherwise reported. The large picture on Page Two shows this mushroom over Mauna Loa, taken from the east side of the boiling, rushing, lava lake of Halemaumau, and showing what was left of the great northwest crag of the fire-pit with the streaming and fountaining melt all around it. In the foreground is shown the glistening spatter lava and the general shimmer is due to the intensely hot gas rising from a million bubblings.

This overflowing of 1921 was the last of a series of such floods from Halemaumau which had been building up the Kilauea Crater floor at different times during the years 1918, 1919, 1920, and 1921. The last picture on Page Four shows the detail of a portion of the actual southwestern rim of Halemaumau in process of overflowing in 1919, and this was a third time within a twelemonth that this had happened. The light-colored surface at the left in the photograph is the Kilauea Crater floor with the western bluff behind it and the northeastern slope of Mauna Loa still farther in the background. All the dark lava on the right is the Halemaumau interior brimming full of lava, and in the foreground streams of this lava are seen flooding over the broken rocks of the rim in pahoehoe festoons like treacle or candy. These flows are pouring away to the left. The white post on a small bluff near the middle of the picture was the southwestern trig station of the Halemaumau rim. Here again the observer of the present day sees what it would be like to have the lava of the floor of the pit up to his level and trickling over a low part of the present rim, while he stood beside it, and watched it flow. It is extremely difficult for most travelers to visualize this, or to imagine that that still black floor of the pit as he sees it today is capable of breaking out in a moment and making lava floods, tending in the course of years to fill up the cauldron. T.A.J.

KILAUEA REPORT No. 954

WEEK ENDING MAY 4, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

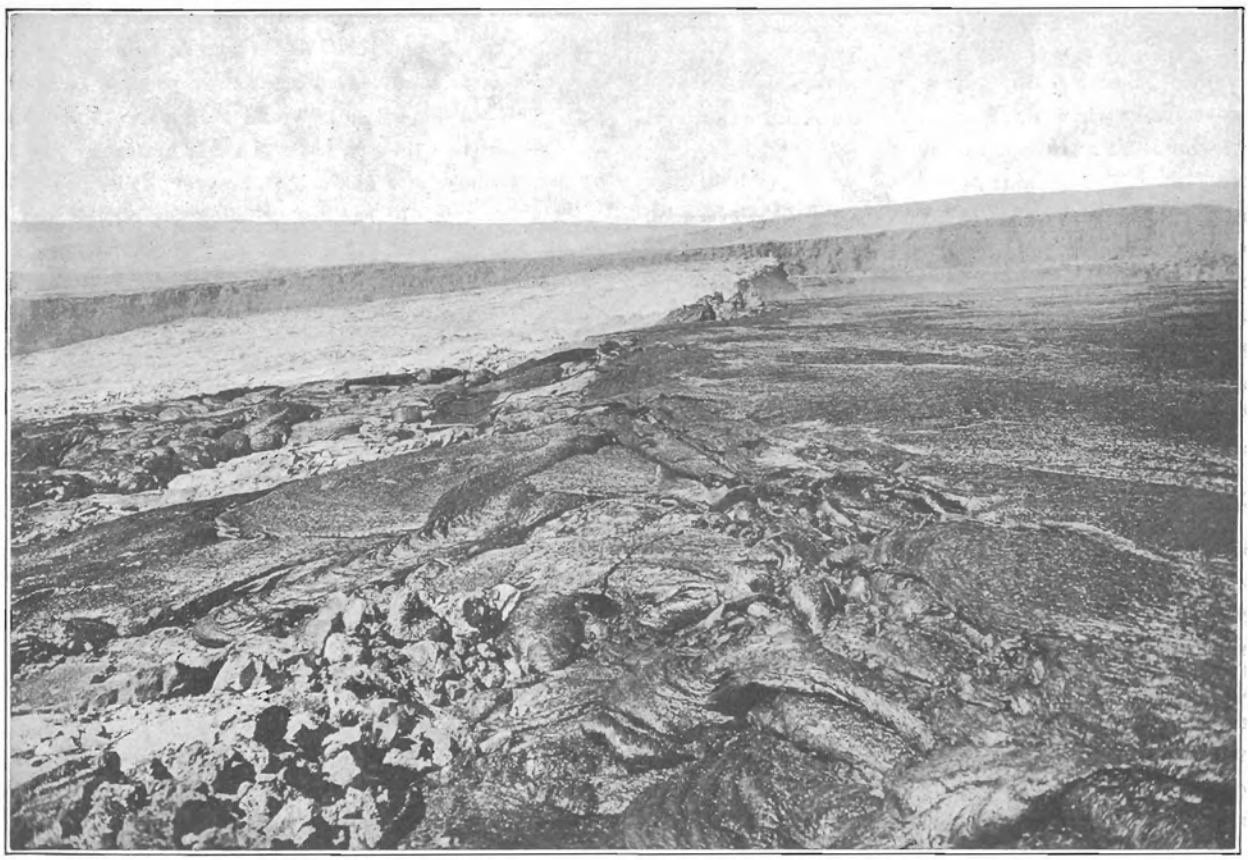
Halemaumau remains quiet, but a few rocks were heard falling from the north rim at 10 a. m. April 28. A white sulphurous spot was noted in the southwestern wall, and with very rainy weather steaming is seen at the south talus.

Eleven seismic disturbances of local origin were registered during the week, of which five were very feeble seisms. One of these indicated origin distance nine miles and was accompanied by tilt east, and another origin distance 16 miles and was accompanied by tilt south. There were six tremor spasms lasting each from one-quarter minute to one minute. Microseismic motion for the week was slight, and tilting of the ground was slight NW.

APRIL TILTING OF THE GROUND

At the Hawaiian Volcano Observatory the tilting or tipping of the ground in the seismograph cellar, expressed by overlapping seven-day means, in terms of angular change and direction of motion of the plumb line, was as follows:

March 31-April 6	1.11 seconds NE.
April 7-13	0.79 seconds SW.
April 14-20	1.03 seconds SW.
April 21-27	2.42 seconds NE.



Looking along the south margin of Halemaumau January 19, 1919, Uwekahuna Bluff in the background. In foreground lava of Halemaumau overflowing the rim in trickling streams.—Photo Jaggar.

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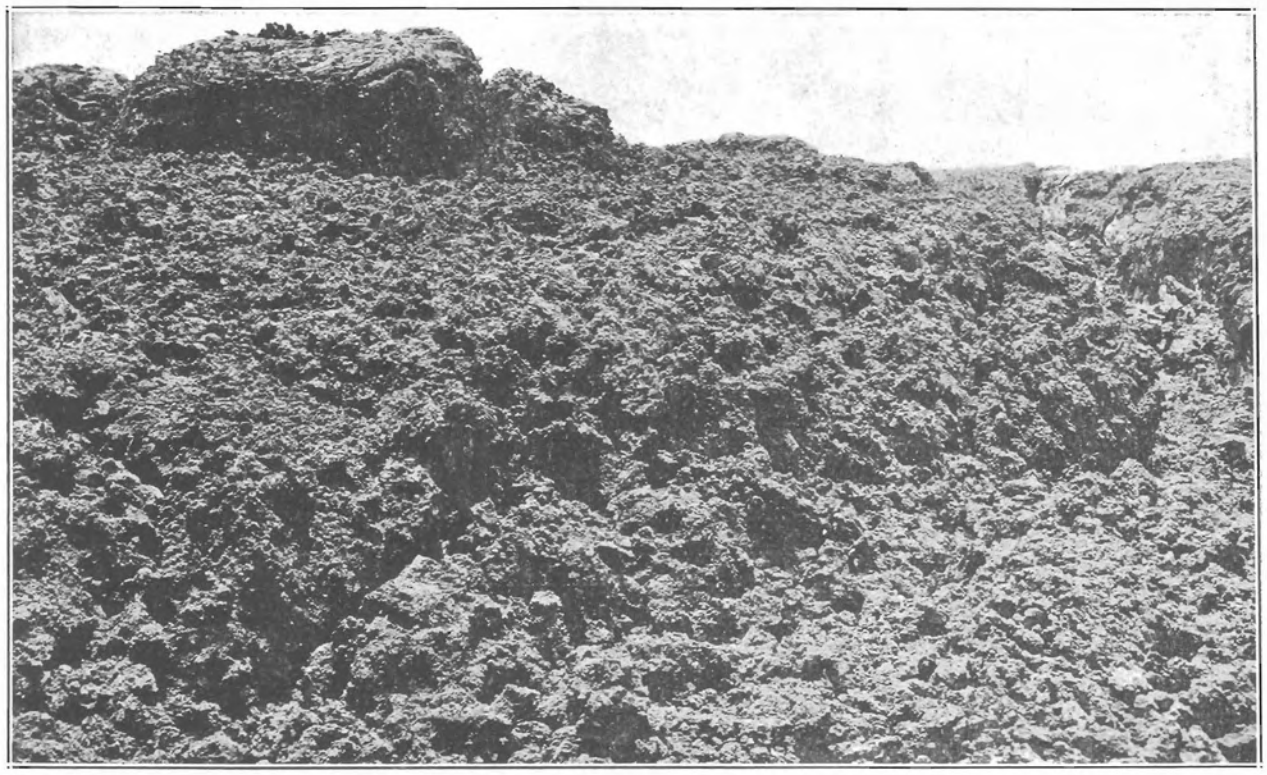
No. 281 Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — May 15, 1930



Aa lava and channel of Alika flow in South Kona on the slope of Mauna Loa, 1919. This shows typical aa texture on the bank that congealed after the glowing stream ceased flowing. This stream, 40 feet wide, swept through the channel for days at eleven miles per hour.—Photo Kanemori.

DISTINCTION BETWEEN PAHOEHOE AND AA OR BLOCK LAVA

The picture shown above represents a characteristic surface of what the Hawaiians call aa lava (pronounced ah-ah), in contrast to the smooth candy-like surfaces (pahoehoe) of basalt shown on Page Two. In the experience of the Hawaiian Volcano Observatory four eruptions of Mauna Loa have been studied, many years of lava activity in Halemaumau pit at Kilauea have been occupied with photographing and note-taking amid spouting and streaming basaltic melt, and three times the flanks of Kilauea Mountain have given vent to flowing lava, with both the aa and pahoehoe types represented. It is generally agreed by investigators that there is no essential difference chemically between aa and pahoehoe, and it is well known on Mauna Loa and Kilauea that the fountaining pahoehoe at the source of a flow may turn into aa clinkers within a half mile of the vent, and remain aa for the rest of its course down the mountain into the sea. It must not be inferred from appearances that pahoehoe is more liquid and rapid flowing. Some aa flows have rushed down Mauna Loa very rapidly, the source region making a glassy and frothy pahoehoe which quickly transformed itself to clinker a short distance away from the source. Some pahoehoe flows at the end of an eruptive period have found their way down the mountain very slowly as the end-stage of the outflow, the progress being through tunnels and crusts of their own making. When an observer stands on the bank of a golden, liquid torrent of lava flowing so rapidly as to make no crusts or skins, he can not tell from the appearance of the liquid whether it will solidify as pahoehoe or aa.

It thus appears that both pahoehoe and aa may occur on the same flow, that they both have the same chemical composition, that they both flow rapidly at times and slowly at other times, that they both may be very sluggish and viscous or swift and liquid, and that in general pahoehoe is conspicuous around the summit craters and near the vents of outflow, and aa is characteristic of the long flows far down the mountain slopes. Two notable exceptions to this last generalization were the last stages of the eruptive period of the 1881 flow from Mauna Loa to Hilo, which was pahoehoe, and the last stages of the



Rift floods of pahoehoe in the timber of the Mauna Iki region, December 24, 1919, six miles southwest of Kilauea. These flows came up a crack in the mountain, drained down the level of Halemaumau, poured out for seven months, and built up a hill.—Photo Finch.

eruptive period of the 1920 flow from Mauna Iki on Kilauea, which also was pahoehoe. The former flowed 30 miles from the vent as smooth lava in tunnels, and the latter five miles from the vent. In both these eruptions the early stages of the eruptive period produced aa flows whenever the scurce heap (pahoehoe) gave vent to a long flood down the mountain slopes. There is a suggestion here that crystallization is stimulated by free flowing of highly liquid frothy melt, that more crystallization or "sugaring" due to stirring may be the characteristic of the clinkering that is distinctive of aa lava, and that such internal stirring is stimulated by the greater gas-bubble content of the lava at the beginning of an eruptive period.

The photograph on Page One shows on the right the channel which had been occupied by a torrent of brilliant yellow molten slag for many days in September-October, 1919, where the Alika flow in South Kona crossed the road about 1,400 feet above sea level. On either side for a width of 2,000 feet this torrent had created a clinker field by backing up and overflowing from time to time during the eruption. The progress downhill through the forest was first a tongue of aa lava that pushed over the brow of the mountain into the steeper country and marched forward like a caterpillar tractor dumping talus over its front and then overriding the fragments beneath. This advance was about one mile per hour. After it reached the sea the congealed sides of the flow became the clinker field, and the stream inside rapidly narrowed and started its pulsations of backing up and making lateral tongues of overflow, now here, now there. Wherever any of the lava congealed, except within a half-mile of the source crack at 8,000 feet elevation, it solidified as clinker or aa as shown on Page One. The narrowed torrent was very brilliant, flowing perhaps eleven miles per hour, bringing large rafts or blocks of material broken away from the banks, and occasionally dumping these on one side or the other during a spell of overflow. Such a raft is shown in the stranded lump on the left of the picture. The process of solidifying, when one watched a tongue of overflow cooling, proceeded without any skins forming, and with the development of small black dots on the surface of the incandescent liquid, these becoming centers of congelation accompanied by a sprouting or crumpling action which made the whole hardening area appear like a bed of coals, with cherry red glow in the cracks. Flames are often seen among the cracks, but they are deceptive in a flow of this kind, because it contains so much burning vegetable matter that it is impossible to distinguish true volcanic flames. The surface of a cooling aa flow is excessively hot, with intense radiation like a bed of coals. In contrast to this, the surface of a pahoehoe flow starts to skin over with a membrane of glass the moment it begins to cool, this membrane draws out millions of oval bubbles so that the appearance is like layers of netting one above the other, and the result is a thickening, glassy skin which wrinkles into ropes and folds the size of which is dependent on the thickness of the flexible crust available. This vesicular crust is an excellent heat insulator, so that one may approach close to the front of the bellying toes of a pahoehoe flow before he perceives that the sluggish monster is hot and creeping forward. There is no suggestion of cracks or flames, unless a heavy hardened crust breaks open and gives vent to a new tongue, which emerges as a rounded bulb encased in a newly formed skin.

It will be seen from this description that the surface

of pahoehoe lava is characteristically glassy. The surface of the lumps and sprouts of aa lava is an endlessly broken jumble of partially crystalline rock, bounded by broken gas vesicles. After both kinds of flows are cold and solidified, the rock of the interior is a continuous sheet of largely crystalline basalt with many gas blebs or vesicles, and such interior rock is just the same for both kinds of flows. The broken bowldery appearance of the surface of an aa flow is largely an illusion, as many of the bowlders are not loose at all, but are sprouts and crags connected with the continuous ledge beneath. There are, however, many flows which break up these crags into bowlders which are rolled along on the surface of the paste and become plastered like snowballs into rounded spheres coated on the outside with lava layers.

Dr. O. H. Emerson made experiments in 1926 (American Journal of Science August, 1926, page 109) by melting Hawaiian lava in crucibles and stirring the melt. It was found that the tendency to crystallize was greatly enhanced by the stirring, the material along the walls of the crucible being glassy with some crystal nuclei, while the stirred parts consisted of a mass of small crystals with some glass in the interstices. Both aa and pahoehoe lava from Hawaiian flows were ground to powder and melted, and both when stirred produced typical aa clinker or arborescence. The mass was at a yellowish white heat and had the consistency of honey; it was allowed to cool in the dying fire, being at the same time constantly stirred with an iron rod. When the ball of slag was broken open the interior was aa and the outside was pahoehoe. It thus appears that higher crystallinity favors congealing as aa if the material is stirred in the open, and from this it might be argued that the more crystallized material under a pahoehoe skin should flow out as aa if it were allowed to escape. Exactly this has happened at Kilauea. Repeatedly lava domes of pahoehoe have formed, like the one at Mauna Iki which invaded the forest six miles southwest of Kilauea in December, 1919 (see photograph Page Two). When this dome reached a certain height, it burst open and gave vent to aa lava rivers repeatedly (see Page Three). On Page Four is shown the lower slope of aa beneath an island in Halemaumau which was suddenly lifted 40 feet in a night in 1917. This indicated that a sudden disturbance of the equilibrium of the pahoehoe crusts in the Kilauea fire-pit so as to cause a sudden congealing of the lava paste, may reveal crystallinity in that paste quite capable of making aa. By thrusting steel pipes into the lava lakes, the stirred melt which crystallized on the outside of the pipes in clots was drawn out as typical aa lumps, although the lakes themselves maintained an equilibrium which made only pahoehoe skins and crusts on their surfaces and at their shores. T.A.J.

KILAUEA REPORT No. 955

WEEK ENDING MAY 11, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

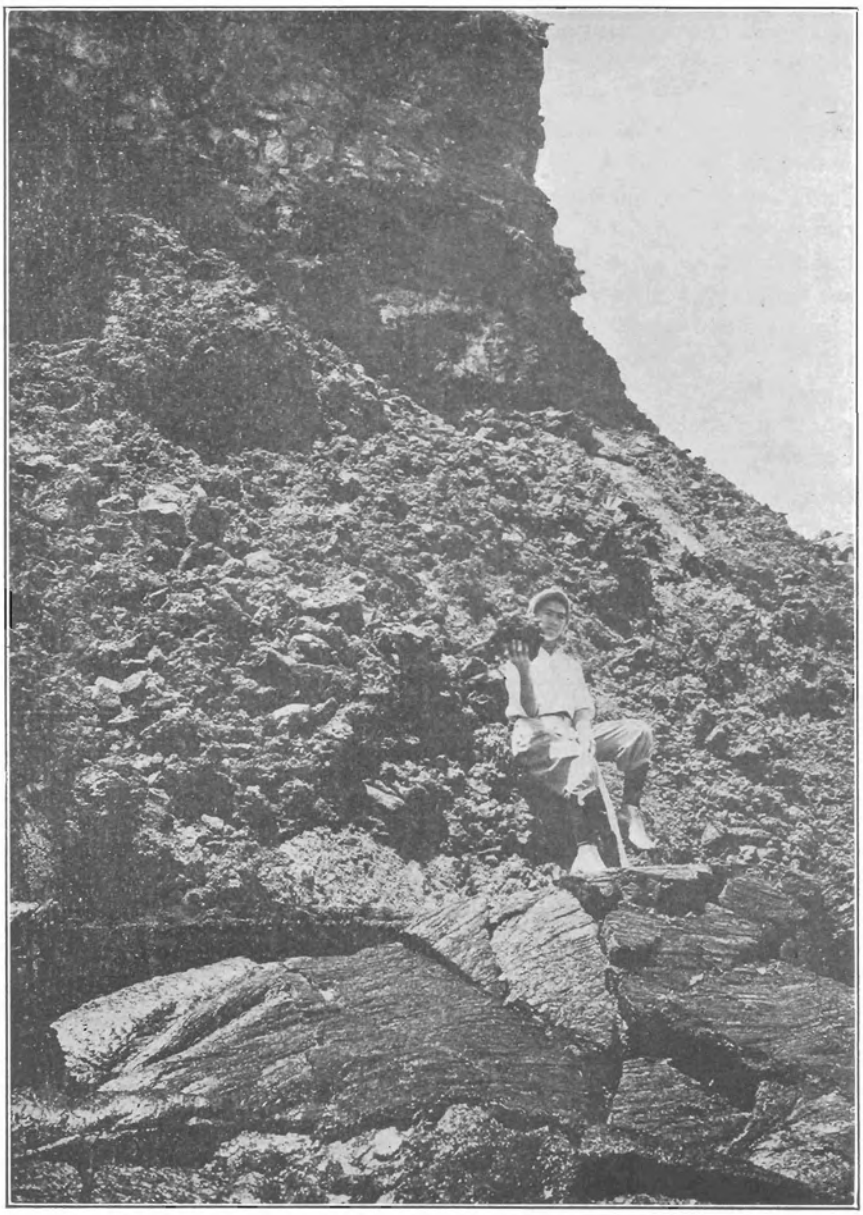
No changes have been observed at Halemaumau during the past week. Steaming is slight at all vents, and working of the walls has been negligible. Small slides on the north wall were noticed on May 10 and 11.

The Observatory instruments have recorded seismic disturbances as follows: 11 temors, the longest with duration 1.5 minutes; 3 very feeble seisms; 1 distant earthquake very feebly recorded on the north-south component at 3:54 a. m. May 9.

Microseismic motion was slight; tilt accumulated slight SSW.



An aa lava river which flowed five miles down the mountain from Mauna Iki, and was pahoehoe lava at the source. It turned into aa a few hundred yards away from the source and was first observed December 31, 1919. This shows the characteristic dark stream with clinkery surface, so different from the glistening folds and festoons of pahoehoe.—Photo Finch.



Aa pedestal of island in Halemaumau April 5, 1917. Two weeks earlier this island had been pushed up suddenly while an adjacent larger crag subsided and the underpinning of the island was revealed as a raw reddish wall of aa lava, in contrast to the slabs of pahoehoe in the foreground.—Photo Jaggar.

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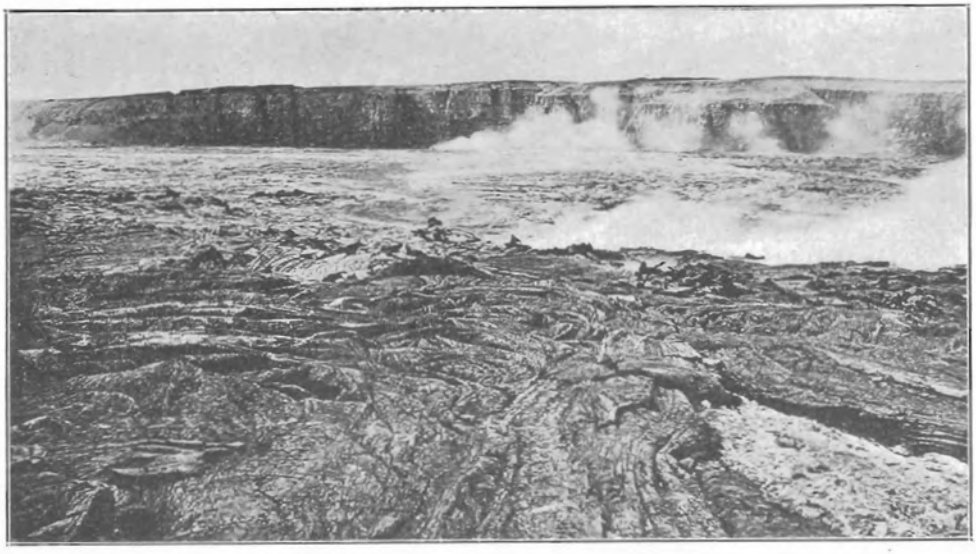
No. 282—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — May 22, 1930



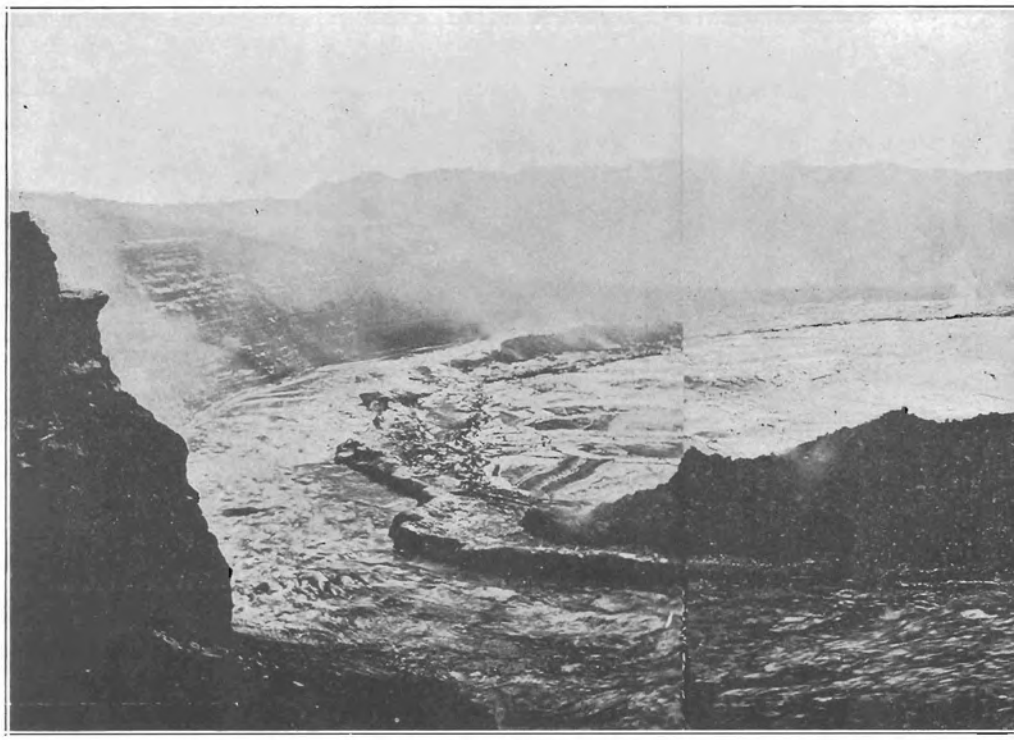
The steam belts border a flood of liquid lava, fed by about 50 fountains spurting from a radial crack, extending from Halemaumau to the southwest wall of Kilauea. December 15, 1919, 11:30 a. m..



The Kau Desert rift, opening and showing black pahoehoe lava rising up the crack, here about four feet wide. The western of two fissures about five miles southwest of Halemaumau, December 22, 1919.

WHEN KILAUEA MOUNTAIN BROKE OPEN 1920

Flank outbreaks down the sides of the mountain at Kilauea Volcano, by the splitting open of the ground and letting out the lava from Halemaumau through underground fractures extending all the way from the crater to the place of outbreak, are rare on Kilauea, though similar fissure eruptions have been common on Mauna Loa since the first white explorers came here. The map on the last page indicates the main Kilauea outflow fissures along the chain of craters to the east extending all the way to Ka-



Ring-island of bench magma in Halemaumau looking SSW with outer ring-pool fountaining lifted rapidly so as to part from its containing funnel and let the liquid fill the wall-crac

poho, and along a similar chain of craters to the southwest marked by the flows of 1920 and 1823. There is another small flow area of 1868 between the last two. These eastern and southern belts mark definite rift zones of very ancient origin extending from Kilauea Crater as vertical cracks, somewhat curved in plan, down the slopes below sea level. They mean that a slice of the mountain southeast of the crater is broken and tending to fall away toward the ocean, and the fault cliffs back of Keauhou are parallel slices already slipping into the sea.

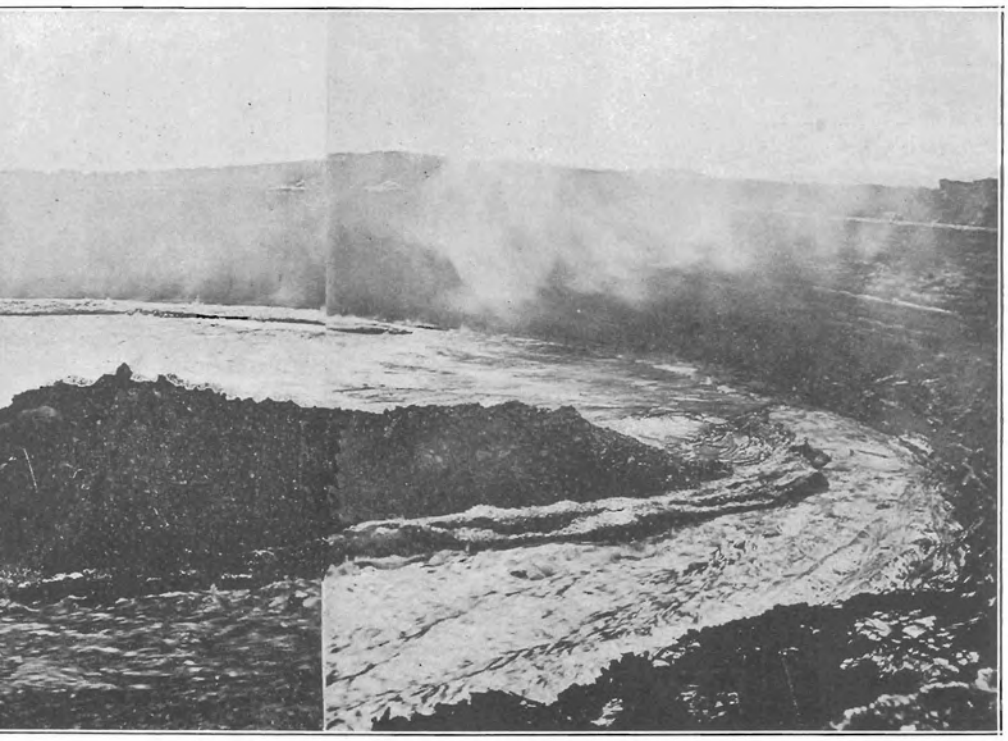
Some visitors to Hawaii National Park take the trail to Mauna Iki in the Kau Desert. Mauna Iki is a fresh lava hill so hot through cracks on its top that sticks burst into flame when thrust inside. Mauna Iki was completely built by lava welling up the southwest rift beginning December 15, 1919, and continuing action until the autumn of 1920. The breaking open of the mountain began by a radial split across the floor of Kilauea Crater southwest from Halemaumau December 15, 1919, at 11 a. m. whereby floods of lava formed steaming lakes along the foot of the southwestern walls of Kilauea. (See first photograph Page One.)

The next thing that happened was the rising of steam along the southwestern Kau Desert cracks outside of Kilauea Crater, and when these old cracks were examined, a freshly opened zone was found of many parallel cracks showing new breaks in the dirt, extending for a mile and a half away from the edge of Kilauea Crater. This zone was a quarter mile wide. The larger chasms had yawned open and engulfed their dirt fills. Creaking and tumbling could be heard within them. One of them, on this day of the outbreak across the Kilauea floor, was found in the afternoon to be 80 feet deep and five feet wide, away down to a narrower space that led below to black depths. Acid sulphurous steam arose with a temperature above 100° F., and along the line of the principal crack five steam columns had appeared, four of these being in a group near to Kilauea.

This gushing of the first day on the Kilauea floor pulled the level of the lava lake in Halemaumau down from 35 feet below the rim, to 148 feet on December 16, but the outflow in the south part of the greater crater stopped within an hour of its first eruption. In the afternoon of December 15 a swarm of earthquakes recorded on the instruments indicated that a sharp readjustment was going on along the rift belt, and doubtless lava was pouring from Halemaumau into underground cracks that were opening in that direction within the larger mountain edifice. When the first outflow on the Kilauea floor was seen, the cliff bounding the big crater, along the line of the gushing crack in the floor, was seen to make little avalanches, indicating that the crack in motion extended beyond the mere crater fill. After December 16 the lava in Halemaumau rose again until the liquid was even five feet higher in the pit (30 feet below rim) on December 22, than it had been on December 15. This created a new tension in the mountain and the flank rifts which had been opening in the Kau Desert started flowing so that the level of Halemaumau lowered again. Outflow on the southwestern Kilauea floor was resumed December 19 as soon as the liquid in the pit reached the level of the outflow vents.

The splitting open of the outside mountain was dramatic in its quietness. It seems quite incredible that a vast rocky dome made of heavy black basalt can split asunder along nine miles down its slope and give vent to increasing lava flows without any big earthquakes or explosions. But this is just what happened.

The writer followed these events day after day and watched the splitting of the ground farther and farther away from Kilauea Crater. December 21, starting at the southwest edge of Kilauea Crater, he found an open network of gaping fissures, and the five-foot crack of December 15 was now a chasm 15 feet wide, broken through rock below and volcanic ash above, the sand continuously slipping on the inner slopes and thereby giving evidence of motion in progress. Farther away down a crack four feet wide sluggish pahoehoe lava could be seen 50 feet below the surface, welling up in heavy snake-like folds, throwing out incandescent toes, and making a crackling noise by reason of the heating and snapping of the adjacent rock.



trongly, and inner lagoon quiet. The island is the top of a lily-shaped cake of lava paste
Photos Jaggar.

No vapor arose here, the steam columns always coming from small cracks of presumably wet ground adjacent to the lava fillings.

Beyond Cone Peak, which lies on the rift zone a mile and three quarters from Halemaumau, the ground was freshly broken along an active zone a quarter mile wide with two main cracks, and these two cracks in the region west of Puu Koae showed live lava inside which reached the surface level of the mountain along a half mile of the surface about five miles from Halemaumau. As one walked down the mountain live lava was seen in the western crack at considerable depths, and a half mile farther this lava rose to the surface level, filling the crack with heavy black pahoehoe through which hissing gas vents were flaming and either building small spiracles or heaving the skin on roundish puddles. An occasional deep detonation suggested that the crack was being heaved open in the depths by the expanding lava. Ot one place the crack overflowed in two small pools 30 to 50 feet in diameter. The pools were crusted over and glowing toes oozed out from under their marginal skirts. A line of 15 spitting and spurting driblet cones followed the crack through the pools, and farther downhill this crack narrowed and was marked only by vapor jets. Thereafter the activity was transferred to the eastern crack which extended farther down the mountain and emitted bluish-brown fume and was full of hardened lava apparently stagnating level with the surface of the country. The gas hissed through spatter cones and the adjacent ground was splashed with spatter lumps from a previous spurting action which had ceased. The character of these cracks with their black fills is well shown by the second photograph, Page One.

After this about Christmas time of 1919 the fissures in the desert split their way day after day to a point nine miles from Halemaumau where the live crack opened beneath deep banks of dune sand, and the lava built up a hill 80 feet high in the forest. The outflowing pahoehoe made tree moulds, and when it penetrated old caverns in the forest the mixture of carbon gas and air made explosions that ruptured the cavern roofs and flung rock fragments away from the holes. Then the activity of outflow centered about floods of pahoehoe lava two miles long and three quarters of a mile wide with liquid lakes and pits on top. This was Mauna Iki, the new "baby Mauna Loa" in shape, and so named "little mountain."

The remarkable ring-shaped island in Halemaumau exhibited on Page Two-Three was the conspicuous feature of the interior of the pit at the time of these ups and downs that accompanied the Mauna Iki flowing. This ring-crag of bench magma was surrounded by an outer ring-pool fountaining violently, and contained an inner circular pond of quiet lava. The ring-island was the top of a lily-shaped column of the stiff lava paste moulded to the funnel shape of the containing pit, and lifted very rapidly so as to part from the walls between November 28 and December 15, 1919. Up the space between it and the walls boiled the foamy or liquid lava following as usual the wall-crack, or marginal fissure between wall and plug. This was the very peak or climax of the 1913-1924 cycle, when Mauna Loa had just been flowing, and Kilauea was about to flow.

T.A.J.

KILAUEA REPORT No. 956

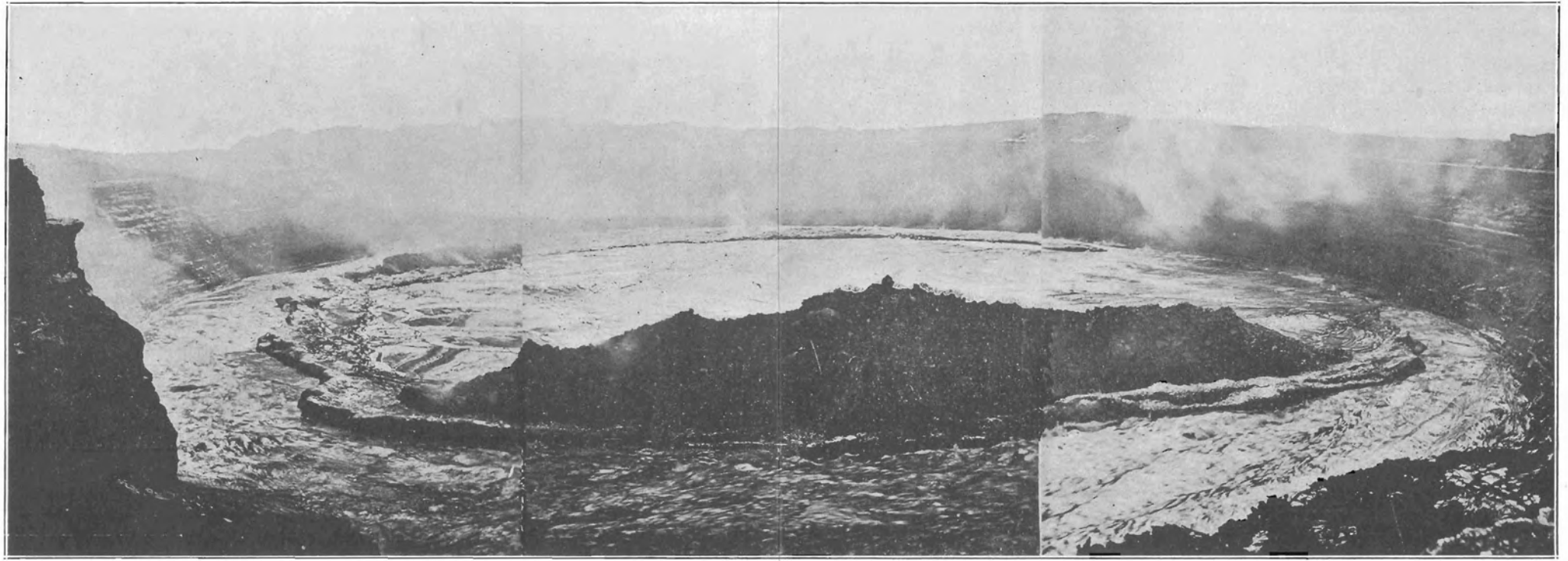
WEEK ENDING MAY 18, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

At Halemaumau pit in Kilauea Volcano the steam on the south talus disappears entirely on dry days and rock slides are infrequent and very small. The pit is unusually quiet.

At the Kilauea Volcano Observatory eight very feeble local seisms have been registered during the week, three of them idicating respective distances of origin 15, 16, and 23 miles. Eleven spasms of tremor have been recorded, mostly from one-half to three minutes long, but two unusual periods of tremor lasted 10 and 12 minutes. Microseismic motion was normal, and tilting of the ground was slight SW.



Ring-island of bench magma in Halemaumau looking SSW with outer ring-pool fountaining strongly, and inner lagoon quiet. The island is the top of a lily-shaped cake of lava paste lifted rapidly so as to part from its containing funnel and let the liquid fill the wall-crack. Photos Jaggar.



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The Volcano Letter

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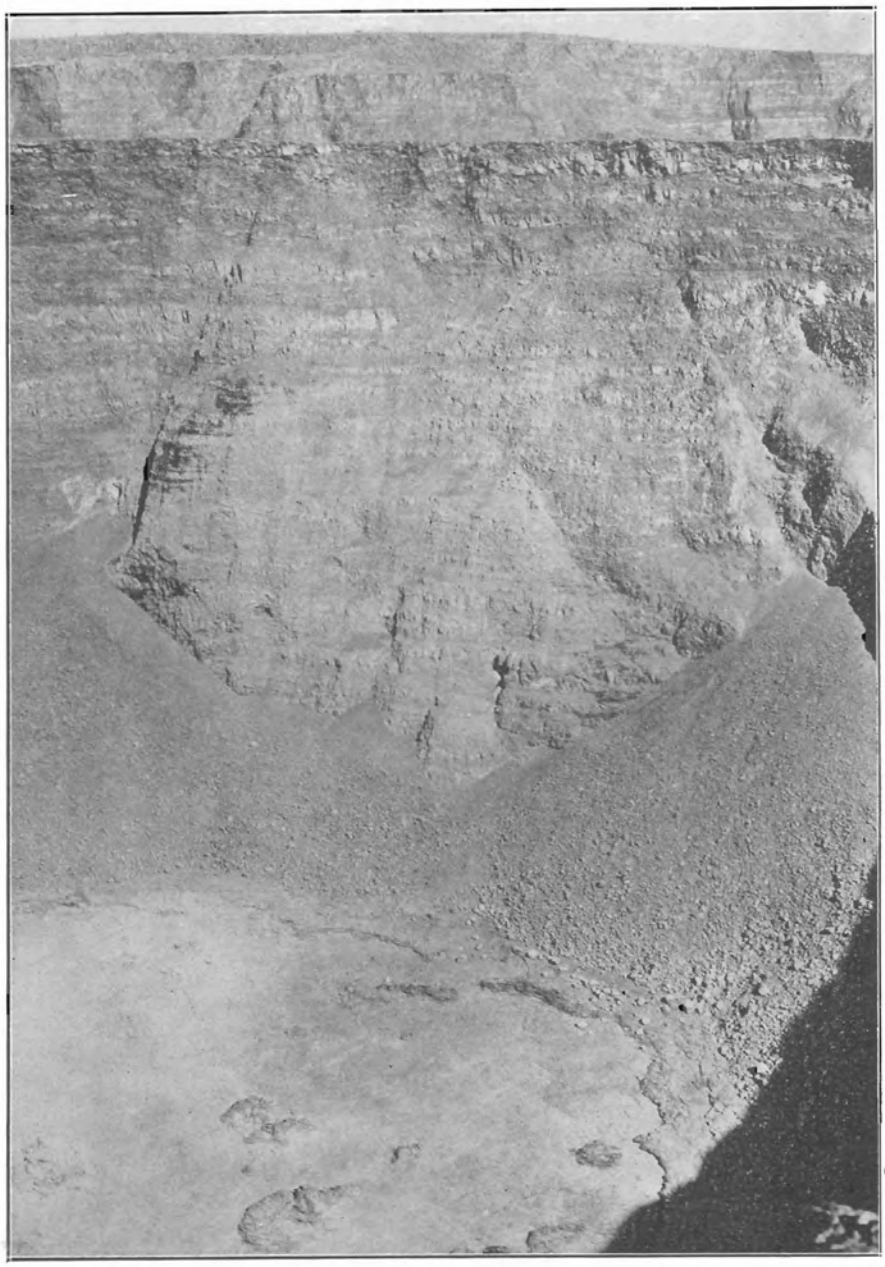
No. 283—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — May 29, 1930



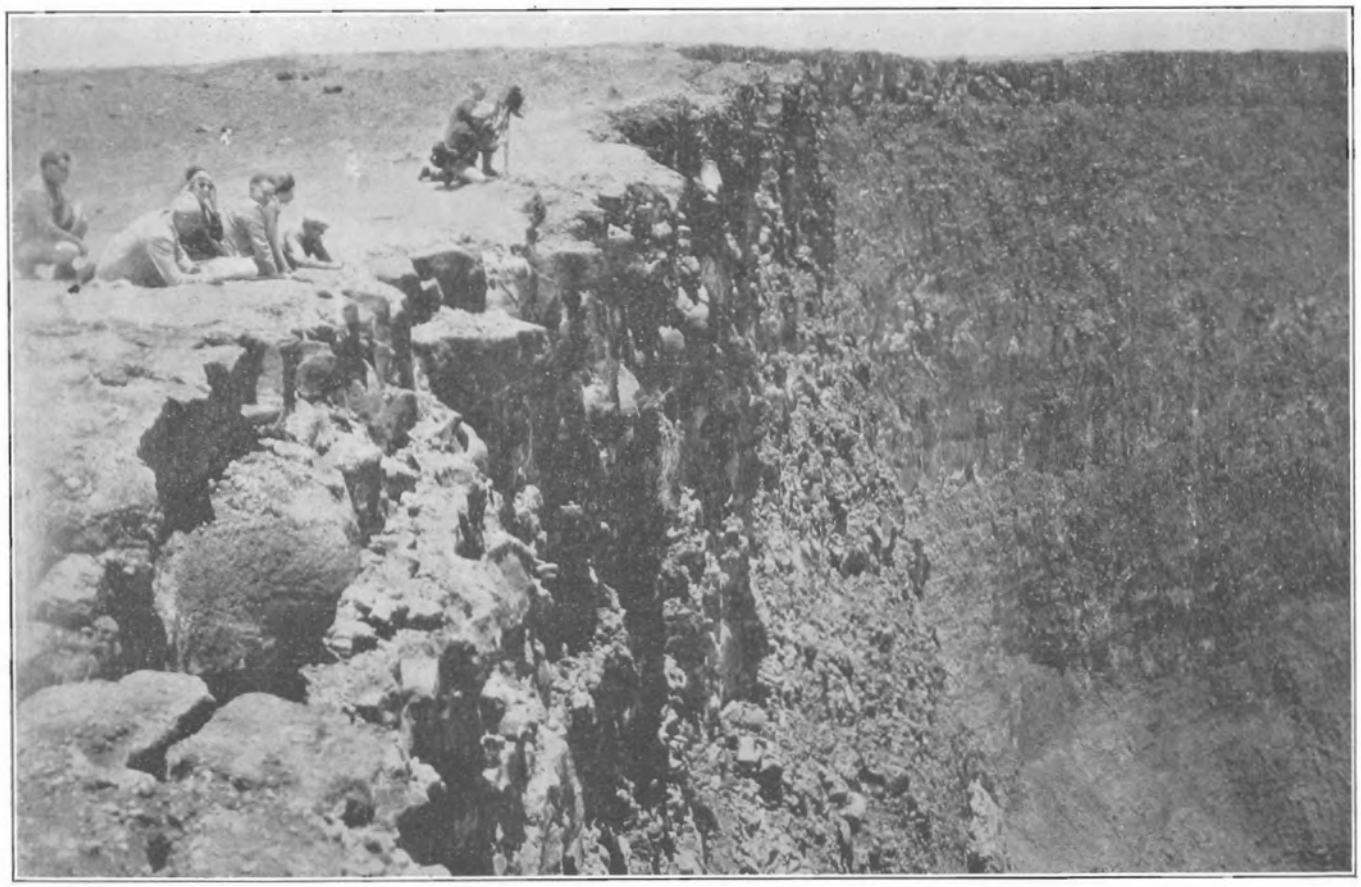
North rim of Halemaumau February 20, 1930, showing wall newly stripped off to build a new small talus between the two large taluses, thus coating the lava floor with dust. Avalanching has developed cracks into gulches up the wall right and left. Photo Jaggar.

RIM CRACKS AND CRATER SLIDES

The tourist visiting Halemaumau pit at Kilauea Volcano is now barred from the immediate edge of the pit by a rope fence which guides him to a station off to the east, which is safer than that part of the rim of the pit which is immediately opposite the automobile terminus. This breakage of the upper rim of Halemaumau so as to destroy the usefulness of the National Park station at the southeast, which had hitherto been considered very safe, occurred unexpectedly early in January, 1929, when big avalanches occurred at the south corner of the pit.

Referring to the map on Page Four, it will be seen that there are numerous cracks indicated as more or less parallel to the pit rim, but lying outside the edge of the pit and expressed as dotted lines. These indicate that the rock of the steep upper wall surrounding the pit is everywhere weak and tending to split off through the undermining action of the movement of the lava under the central part of the bottom of the pit. This was explained in Volcano Letter No 269.

It is of interest to note that big spells of avalanching occurred in January, 1928, at the northwest; in January, 1929, at the south, and in February, 1930, at the north and northwest again. The photograph on Page One was taken on February 20, 1930, from the eastern rim of the pit, and shows the lava floor which had been left by the July eruption, 1929, completely coated with new pinkish dust from slides



Southeast rim of Halemaumau looking south during activity of July, 1927. There are other cracks back of the observers. Photo Tai Sing Loo.

which had been falling from the eastern, northern, and western walls throughout January and February, becoming strongest during the week ending February 23, 1930. These avalanches send a cloud of dust downward and forward when the falling rock matter strikes the floor, the dust cloud boils vortically, and as it loses velocity it dumps its dust on the ground beneath. In the picture it is evident that dust from the slides lay thickest on the west side of the floor, and the wall above was seen to be scarred and streaked from repeated falls. It will be seen that the north-northeast talus, on the right of the picture, and the northwest talus on the left, are both surmounted by gulches which extend up the wall above, and these gulches terminate at the upper rim in cracks which are shown at the top of the map. The rock wall between these gulches constitutes a buttress or slab backed by these cracks, the slides are eating away the cracks and weakening the buttress, and so the buttress is breaking up, making the small middle talus, and getting ready for a big slide from the top.

Now it is a remarkable thing that when these spells of general sliding occur, the rim cracks tend to widen, even on sides of the pit remote from the avalanches of that particular time. Thus we find the statement in the Kilauea Report for February 23, 1930, that crack No. 14 (easternmost of the cracks just below right side of the map) widened nearly two feet since December 4, 1929. These cracks along the southeastern side of the pit have been marked with paint at a number of points, and the places have been numbered.

This work was started by R. M. Wilson on July 6, 1927, after observation of the Halemaumau rim during the previous month had shown that cracks were widening and slides were occurring simultaneusly, with increasing effect to the date mentioned. This action at that time was chiefly at the east. Mr. R. B. Hodges was detailed to conduct the measurements of the cracks from time to time and has done so since 1927. It happened that this month of working of the Halemaumau wall slabs immediately preceded the outbreak of July 7, 1927, and this made the measurement of the cracks doubly interesting. There was every suggestion that the widening of the cracks, the working of the walls, and the consequent avalanches accompanied tumescence or uplift of the rock structure surrounding the lava column just prior to its outbreak.

The procedure of crack measurement is very simple. The photograph on Page Two shows a characteristic small crack in the foreground at the left, this being that portion of the rim of Halemaumau looking south where excessive opening of cracks occurred in January, 1919, back of where the group of people is shown. This photograph shows the change of angle on the right from steep cliff above to funnel slope below. The photograph on Page Three shows the caliper used as adjusted to two paint marks on opposite sides of a crack at a numbered location. The caliper is adjusted to the crack, and the departure of its two points is measured with steel tape. Fifteen points along cracks were so marked and measured along the southeastern rim of the pit. These fifteen locations had dwindled to five remaining unbroken and accessible on April 14, 1930. The others had either caved in over the rim of the pit, or had become dangerously inaccessible as wide chasms, or had broken down at their marked points. The striking obvious feature of the motion of the cracks was that they had been opening and collapsing, and the pit rim had been enlarging, during these two and three-quarters years.

Measurement on six selected crack locations progressively northeastward back from the southeastern rim of the pit, the last No. 14 being in the vacinity of the fourteen-ton bowlder of 1924, is shown in the table for 15 of the 34 dates of measurement since 1927. This table shows the actual widths of cracks as they changed from date to date, reading downward. Reading from left to right for the same date cracks 10, 13 and 14 are on the same fissure growing wider as it approaches the place where it emerges on the edge of the pit. Cracks 3 and 4 are a little farther west. (These cracks extend from trig station 3641 to 3646 on the southeast side of the map Page Four)

OPENING OF RIM CRACKS SOUTHEAST OF HALEMAUMAU

Caliper Measurements in Feet, of Distances Apart of Paint Marks on Opposite Sides of Each Crack, from 1927 to 1930

Date	Crack 3	Crack 4	Crack 5	Crack 10	Crack 13	Crack 14
July 6, 1927	2.14	1.17	0.42	0.77	1.54	1.63
July 24, 1927	2.17	1.25		0.77	1.61	1.65
Sept. 3, 1927	Gone in	1.65	0.44	0.79	1 61	
Oct. 1, 1927		1.83	0.45	0.80	1.67	1.82
Dec. 6, 1927		1.83	0 44	0 81	1.77	1 96
Feb. 13, 1928		1.83	0.50	0.84	2.35	2.75
April 21, 1928		1.83	0.51	0.87	2.41	2.90
June 18, 1928		1.83	0.57	0.84	2.46	3.00
Sept. 10, 1928		1.83	0.54	0.88	2.47	3.17
Dec. 4, 1928		1.83	0.56	0.89	2.50	3.24
Mar. 29, 1929		1.91	0.70	0.90	2 52	3.36
July 7, 1929		1.96	0.72	0.91	2.57	3.60
Dec. 4, 1929		2.20	0.73	0.95	Broken	3.96
Feb. 19, 1930		2.22	0.74	0.96		5.71
April 14, 1930		2 25	0.73	0.98		Inaccessible



Marked crack where it emerges southeast rim of Halemaumau, showing method of measurement with wooden calipers at painted spots.

The table shows that all the cracks have tended to open gradually, and that the same crack has widened the more the nearer it approached the pit rim as an open chasm. The cases of a crack becoming narrower are only three, and of a few hundredths of a foot. As the cracks fill below with fallen debris it is natural that they should fail to close. The two remarkable features of the table are the steadiness of the process of yawning open in all the cracks, and the greater opening the wider the crack. It is evident that this belt of cracks at the southeast has been steadily yawning open and that it was stimulated in its opening along with eastern avalanches of June, 1927, preceding the eruption of the following month, and that it was stimulated extensively along with southern avalanches of January, 1929, preceding the eruption of the following month. That eruption of February, 1929, produced five seconds of accumulated tilt away from the pit (see Volcano Letter No. 264). This confirms the notion that the yawning open of the cracks is an upward swelling of the inner dome of Kilauea. The first large change in the crack of Nos. 10 to 14 followed the eruption of January 11, 1928, and there were considerable changes after the eruption of July 25, 1929. The big avalanching spells circled the pit as follows: E, June, 1927; SSW, September, 1927; NW, January, 1928 S, January, 1929; NNW, February, 1920. The study of cracks coupled with study of tilt and avalanches is evidently a profitable activity for volcanology at craters.

T.A.J.

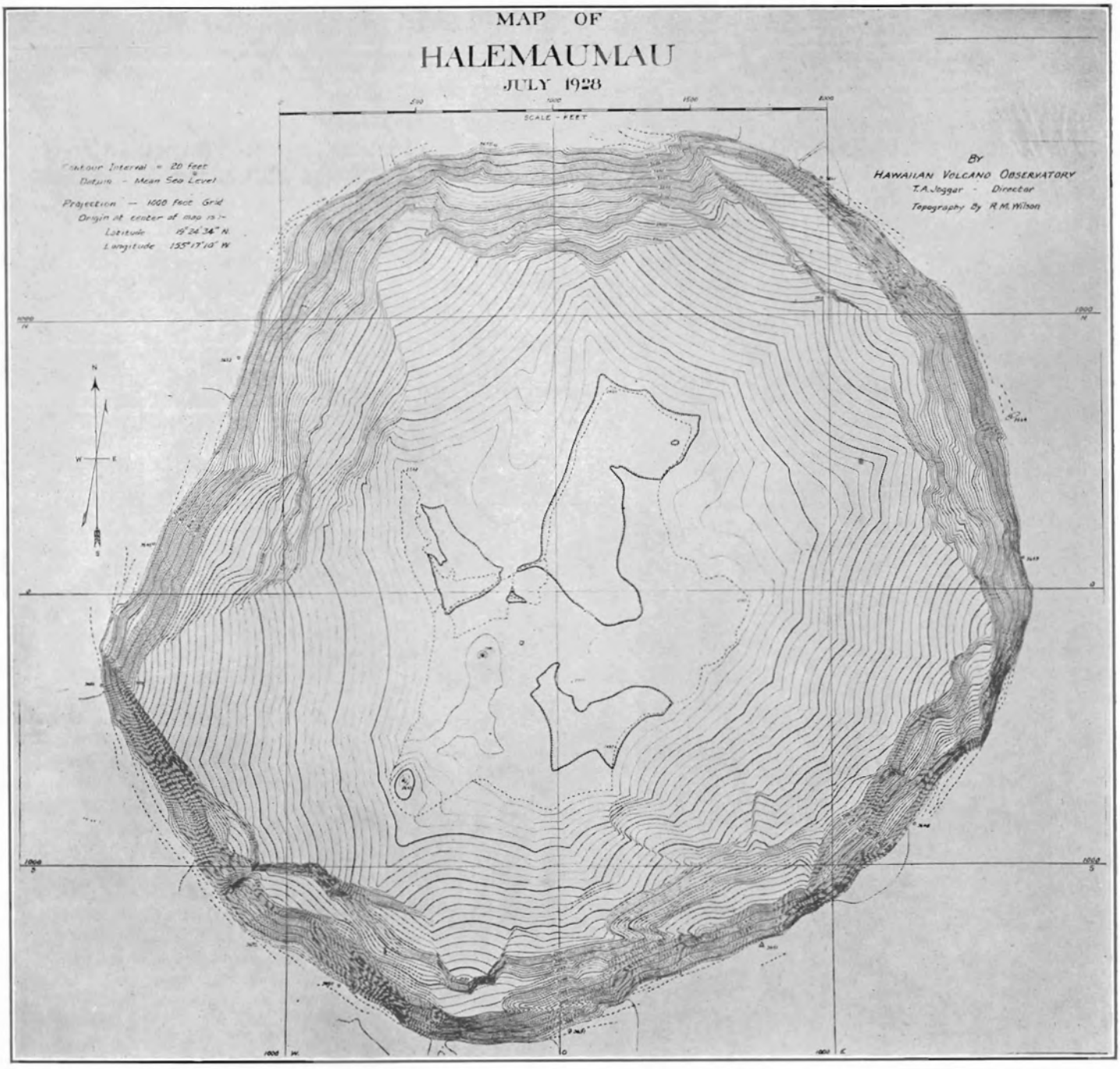
KILAUEA REPORT No. 957

WEEK ENDING MAY 25, 1930

Section of Volcanology, U. S. Geological Survey; T. A. Jaggar, Volcanologist in Charge

The inner pit of Kilauea Crater has shown nothing of interest during the week. Some fresh debris lay on the east talus May 23 and a few rocks were heard falling on the north wall.

The seismographs at Kilauea Volcano, at Hilo, and at Kealakekua have registered some unusually intense local disturbances. The Kilauea instruments recorded 11 local



Map of Halemaumau pit, contour interval 20 feet, showing cracks by dotted lines at edge of pit. The long, straight sides of the pit are SE and WNW, and these are backed by curved cracks completing the northeastern circular curve of the pit. Pit axis follows rift NE-SW.

seisms, of which five were tremors, three very feeble, two feeble, and one a moderate earthquake. The tremors lasted from one-quarter to one minute, and one of these was accompanied by tilt to the east. One of the very feeble shocks indicated origin distance 16 miles, and another showed tilt to the east. The two feeble shocks indicated origin distances 106 and 61 miles, respectively, were felt locally, and the times of beginning were 2:47 a. m. and 6:52 p. m. May 20. The perceptible periods of vibration were rather slow on the east side of the island, and quicker in North Kona, suggesting an origin in the Hualalai direction. Like the Hualalai shocks of October, 1929, the perceptibility was more pronounced in North Hilo than at Kilauea.

The moderate shock occurred at 8:17 p. m. May 25, was strongly felt all over the island, no overturning of objects has been reported, and the accounts indicate stronger motion in Kau and Puna than in Kohala and Kona. At the Kilauea Obseravtory all the seismographs were dismantled, but the Uwekahuna instrument restored its pens and recorded the declining vibrations. The vertical component instrument showed a heavy downward fling as though the earthquake were epicentral at Kilauea. The first movement flung off all the pens instantly at Kilauea, but is reported to have written a short preliminary on the seismograph at Kealakekua in Kona. The first fling of the ground at Kilauea was downward to the south and east, and the restoration of the pens indicated tilt to the south and west. Keaau Beach in Puna, where the Hualalai shocks of 1929 were barely felt, perceived this shock strongly. At a Hilo theater the motion began with a swaying, followed by strong jerks that quickly ended, first to the northeast then to the southwest. The motion was not prolonged like the Hualalai shock of October 5, 1929. Puwaawaa reports a long vibration not particularly strong, Honokahau a moderate shock accompanied with thunderous noise, Kealakekua an alarmingly sudden quake, but without the overturning power of the Hualalai shocks. All of these facts suggest a deep movement somewhere under Kilauea and Mauna Loa.

Microseismic motion for the week was slight, and tilt at Kilauea was slight to the west.

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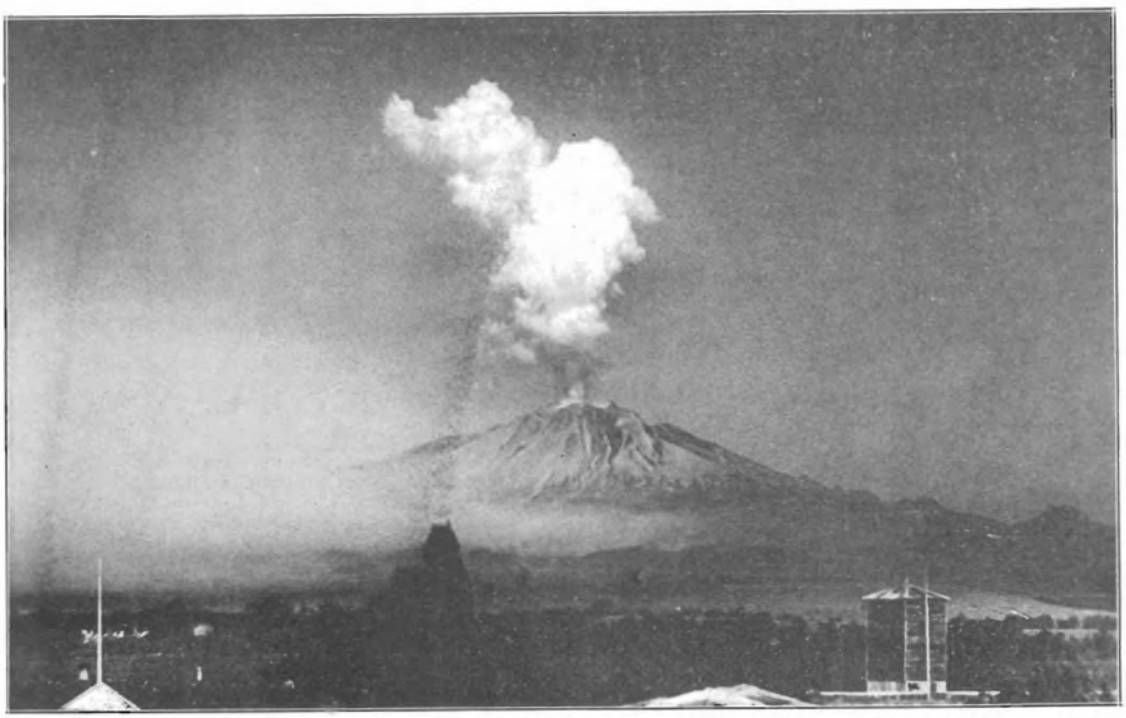
No. 284—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — June 5, 1930



Eruption of Calbuco Volcano, Chile, January 6, 1929, photograph taken from Puerto Varas probably in early forenoon. Photo Karl. Steam apparently issuing with force. Pall of ash to the left.

EDITORIAL NOTE

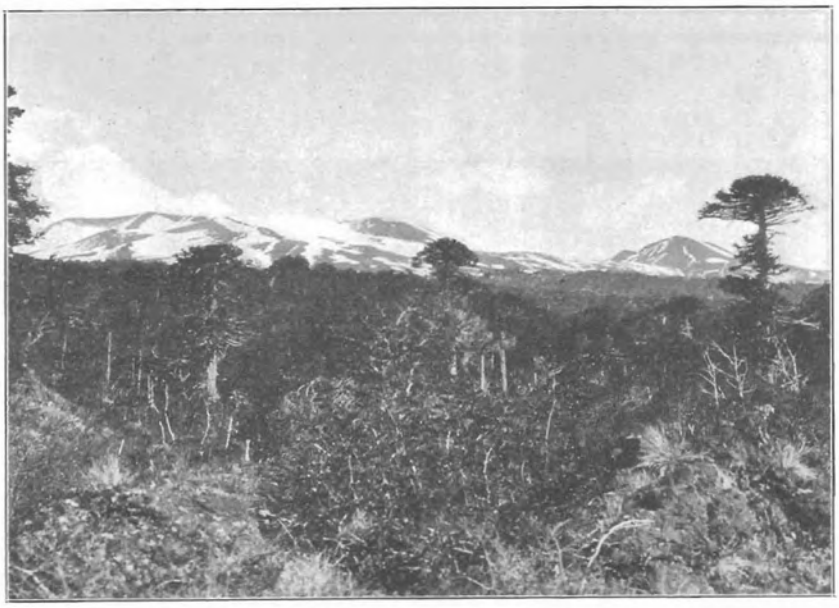
As reported in Volcano Letter No. 235, Dr. John B. Stone during the winter 1929-30 completed on February 12, 1930, at Valparaiso an exploration of some volcanoes in south-central Chile occupying three months and six days. This was done under his appointment as Research Fellow of the Hawaiian Volcano Research Association. Starting from the scene of the recent disastrous earthquake at the city of Talca, Dr. Stone passed by the active volcano Quizapu near Cerro Azul, and then visited in turn the volcanoes Chillan, Antuco, Llaima, Villarica, Osorno, and Calbuco, climbing several of these. He observed from a little distance the volcanoes Trolguaca, Lonquimai, Quetrupillan, Shoshuenco, and Puyehue. All of these are potentially active and all lie between the latitudes 35° and 42° S. This region offers a great field of volcano research in the midst of a land of serious earthquakes, and it is to be hoped that Dr. Stone's investigations will stimulate public and private endeavor to create volcano observatories in Chile. The following is a first note on Chilean volcanoes.

TWO ACTIVE VOLCANOES OF CHILE

By JOHN B. STONE

The Chilean volcanoes east of the capital city, Santiago, lie near the crest of that portion of the Andes chain that includes the highest summits of the western hemisphere, but farther south the volcanoes are lower down on the west flank of the cordillera. In the region between the cities of Temuco and Puerto Montt, or roughly between the latitudes of 38° 30′ and 41° 30′ south, they lie along the line where the farms of the central longitudinal valley give way to the forests and mountains of the high Andes, and their summits reach only 6,000 to 10,000 feet above sea level. The two most active volcanoes of this region are Llaima and Calbuco. Both lie in a rainy belt and as a consequence their lower slopes are heavily wooded and their summits are capped by snow and glacial ice.

As seen from the southwest Llaima is an elongated cone with one principal summit and another slightly smaller and lower one off to the southeast. In December



Llaima Volcano, Chile, from the west. Araucanian pines and old aa lava in foreground. Photo Stone.

1929, the mountain was still covered far down its slopes by the snows of the preceding southern winter, and both the summit craters were emitting streamers of dense white fume.

The journey to Llaima is best begun from the provincial capital Temuco. A branch off the main north-and-south railroad extends for nearly 35 miles across partly cleared and cultivated lands and past several large, prosperous farms to the little village of Cherquenco. Beyond Cherquenco the forest is less broken by farms but is dotted with little sawmills producing rough lumber, which is hauled to the railroad on clumsy two-wheeled ox-carts. One of the sources of good lumber is the sharply defined belt of Araucanian pines that girdles the upper slopes of the volcano. The Araucanian pine or "monkey-puzzle" tree is similar to its close relative the Norfolk Island pine, familiar in the Hawaiian Islands (see Page Two). A sawmill high up in the pine forest on the northwest slope of Llaima was a convenient base of operations for the writer during the bad weather that prevailed at the time of his visit.

The double cone of Llaima stands on a broad base or platform built by earlier volcanic activity. Part of this platform and of the cone also are covered by basaltic aa flows, but the northwest summit cone and the southern slope of the mountain are largely concealed from observation by glaciers. Shiny black scoriae are common on the surface, and a layer two or three inches thick covers the glacial ice on the south side. Llaima was active from October 5 to 8 and again from November 27 to December 5, 1927, and at that time a "river of fire" is said to have been seen on the south slope. No recent flow could be distinguished by the writer beneath the winter snow, but a line of cones was seen far around to the southeast. These cones may mark the source of a flow as well as the site of the fountains which produced the fresh scoriae. Unfortunately it was impossible to reach them. Another possibility is that the scoriae were produced by fountaining in the summit craters and that the "river of fire" consisted only of the freshly fallen and still glowing cinders.

Calbuco is the farthest south of the volcanoes in the continuous mainland part of Chile, although others are known in the region of fiords and glaciers extending from Puerto Montt to the Straits of Magellan. Calbuco was observed in activity by Darwin in 1835, but had long been inactive before 1893 and had accumulated a thick cap of ice and snow. In the latter year the volcano returned to life. The heat of the eruption melted the ice and snow and caused floods that swept down the mountain leaving paths which can still be seen. Fortunately the country affected is very sparsely settled even now so that little damage was done, but the occurrence illustrates the most serious danger in this land of intermittent volcanic activity and heavy snowfall. An even greater flood occurred at Villarica volcano in 1910.

The last eruption of Calbuco was on January 6, 1929 (see Page One), and lasted only a few hours. Dull underground noises in the night of January 5 had warned the few people living on the north side of the volcano and they had fled from their little farms taking with them what livestock they could collect. At about 2 a. m. on the 6th a great flash shot from the top of the mountain

and was followed by an enormous cloud of ash accompanied by much lightning. The ash eruption continued until the early hours of daylight. Only coarse sand reached the highest house on the mountain, but before the west wind the fine ash drifted far off to the east so that a layer a few millimeters thick was formed at Peulla 35 miles away, and light dust reached the end of the State Railway in Argentina more than 100 miles away. A terrific blast blew down the valleys on the north slope killing and leveling the brush and small trees growing there (see Page Three). Floods from the melted snow and ice rushed down the stream channels killing the trees along their margins and dumping volcanic sand on a few cultivated fields near the lake. For two weeks after the eruption no rain fell to wash the covering of ash from the grass and leaves so that cattle had to pick a meager nourishment from the tips of the highest bunch grass which had shed some of the dust.

On January 19, 1930, the writer and a Chilean helper made the first ascent to the crater of Calbuco since the eruption of the previous year. The route from Ensenada on Lake Llanquihue leads up a valley swept by the floods of 1893 and 1929. Exposures in the steep walls of the stream channel show a history of past explosive eruptions. Lava flows reaching the lower slopes are rare and none is seen on the surface, but everywhere there is a deep cover of broken rock and sand like that thrown out by Kilauea in 1924. The new crater of Calbuco is a straight-sided hole perhaps 500 feet across (see Page Four). The rim, especially around the northeast edge is deeply covered by gravel and ejected blocks. Thick white fume escapes in several places from the talus slopes inside the pit. The crater plainly owes its present shape in part to collapse after the explosions.

KILAUEA REPORT No. 958

WEEK ENDING JUNE 1, 1930

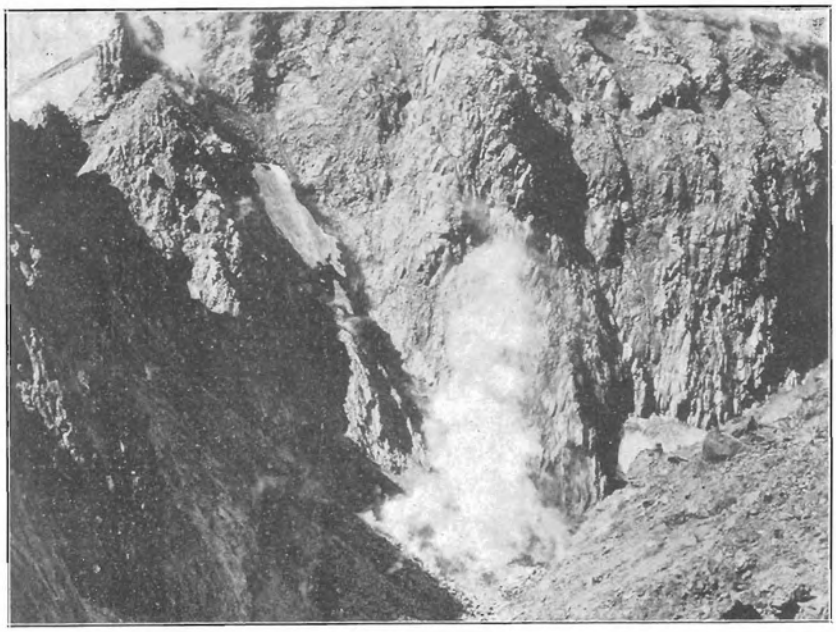
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Kilauea Volcano continues to be quiet and without visible signs of magmatic change. Early in the week numerous small rock falls occurred from the north wall of Halemaumau, the slides at times accumulating sufficient material to make dust clouds. Much fine debris has piled up against the foot of the wall between the two large north talus heaps. The fire pit was without sounds and with very little steam at the end of the week.

The seismographs registered nine tremors, two of which lasted one minute each; one very feeble seism, with origin distance 28 miles; and one distant earthquake recording feebly at 12:08 a. m. May 31. Microseismic motion was slight throughout the week. Tilt accumulated very slight WSW.



Brush in valley of Rio Caliente killed and bent over by eruption of Calbuco Volcano in Chile in 1929. Photo Stone.



Looking into the new crater of Calbuco Volcano, Chile, from the north. Photo January 19, 1930, by Stone. Thick white fume issuing from talus.

THE VOLCANO LETTER

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Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins

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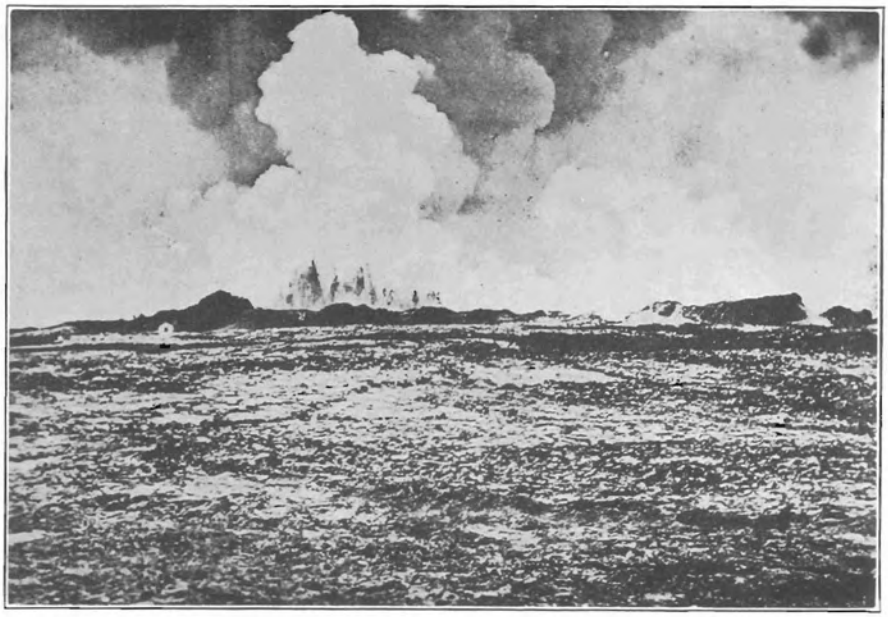


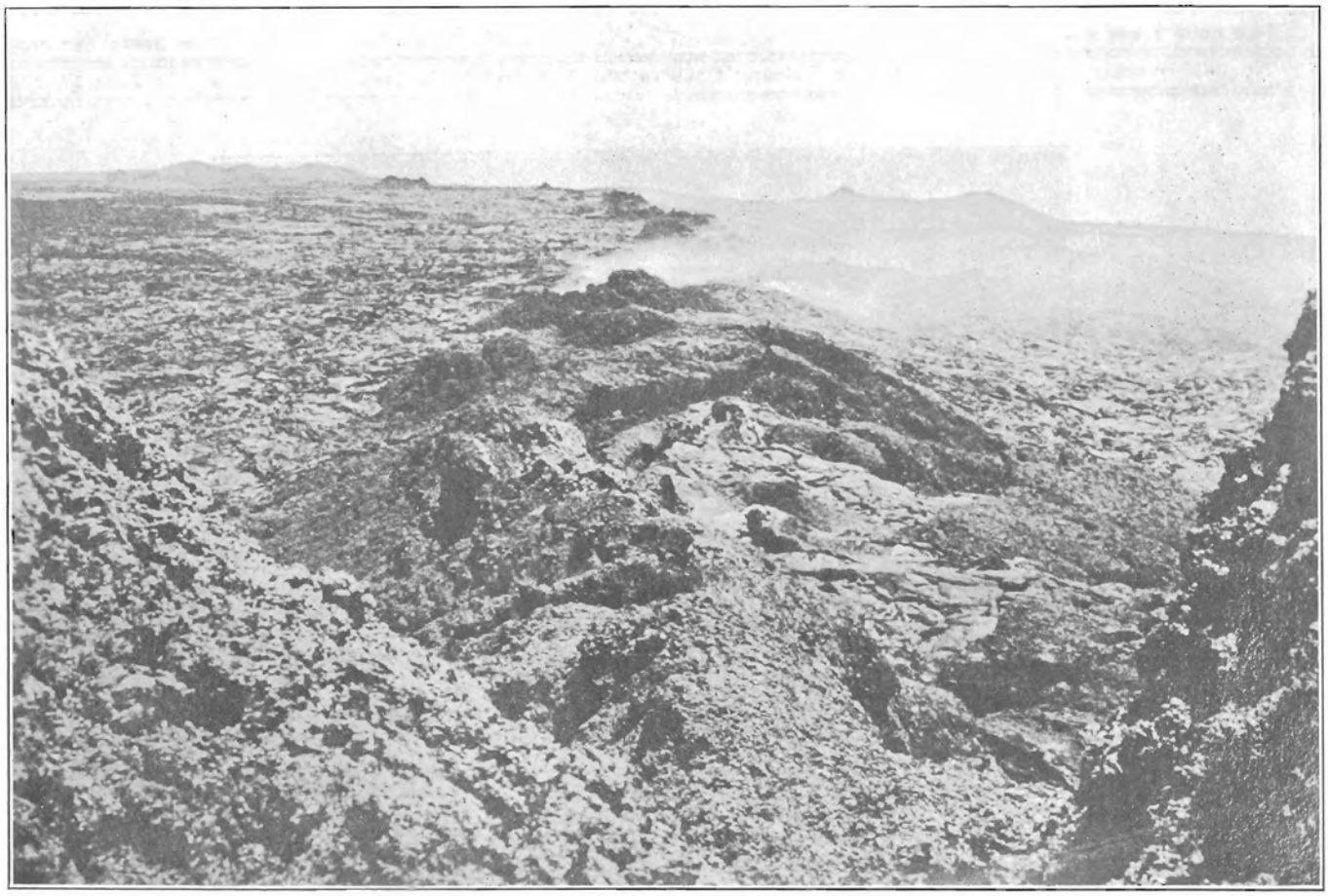
Mauna Loa rift source from the east, October 1, 1919, showing lava fountains, steam, and fume spouting up within ramparts of pumice. The new cones extend right and left outside the picture. Photo Jaggar.

SOURCE VENTS FOR MAUNA LOA FLOWS

There is apt to be much confusion in the mind of a visiting traveler when he hears talk of a lava flow. Careless writers are apt to speak of a lava flow in Halemaumau pit. An eruption of lava in the bottom of this great pit depressed below the southern floor of the larger crater of Kilauea is not a lava flow in the Hawaiian sense. A lava flow means to the residents of these islands an outbreak on one of the volcanic mountains which courses down the flank and is prone to enter the ocean if it lasts long enough. While it is possible for such a flow to arise by lava overwelling the brim of a summit crater, and although there have been short historical flows which originated in or near the summit craters of Kilauea, Mauna Loa, and Hualalai, none of these has ever traveled far. Usually such flows are confined within the compass of the large summit sink-craters by the overflow of the inner pit or the development up a crack of a new cone by rupture of the crater floor. The great lava flows of history, in the Hawaiian sense (see map last page), have emerged from the mountain flank along well known rifts that have been the sites of many outbreaks. The places of outflow have been from one to twenty miles away from the large summit craters, but there is generally a preliminary gush of some sort at the summit region.

Several pictures of Mauna Loa rift sources have recently been printed in the Volcano Letter (Nos. 270, 277). The well known rifts on Mauna Loa extend southwest and east-northeast from the summit. Indeed there is a strong suggestion that about the Rest House at the north at elevation 10,060 a new hump or dome is building up about the eastern rift, and that similarly a separate volcano is building about Puu o Keokeo as a center at elevation 6,870 to the south. An understanding of these rift belts as zones of potential weakness on volcanoes is essential to the understanding of lava flows. These radial fractures in a volcanic edifice may be curved or straight, several or few, but they stand for a deep-seated breakage in the dome, and along these broken belts there is underground connection along upright fractures with the central pipe, and this in turn is nothing more than the upright line of meeting of the rifts. Observation of the miniature slag lakes and overflow floors of the inner pit of Kilauea has shown how this fracturing of a dome happens. The overflow about a vent forms a slag heap. The slag heap becomes hard inside while remaining red hot. Renewed overflow at the central vent is accompanied by swelling gas pressures which rupture the heap. The lines of rupture are apt to be along the boundaries of three or more sectors. These sectoral cracks open widest along the contour of the heap which is lengthened the most by the swelling action. This is where the summit plateau changes its grade to a steeper marginal slope. There is probably a systematic geometry of building up domes and breaking them which has produced the strikingly uniform distances and triangular arrangement of crater summits on Hawaii.

The picture on Page One was made on October 1, 1919, when the writer was approaching the spouting source crack of the Alika flow from the east and looking from an old red cone at the new constructions of the active belt at a place about five miles north of Puu o Keokeo. After tethering the riding animals and walking across some ten alternations of rough aa and smooth pahoehoe, the aa making the most terrible footing on earth, there could be seen the line of rift cones, some 40 of them visible at one time, extending from near Puu o Keokeo northward. The source of the outbreak was revealed in panorama, consisting of a line of new gushing hillocks of slag, a true fissure eruption. Here great fountains were spouting continuously for a thousand feet like a wall of red flame, and in detail they were seen to be made of incandescent, light, crumbly material, yellow when it shot up, and red when it came down. Gas was rushing through a lava pool filling the rift, churning it to a foam with a noise like surf, and flinging up the foamy matter to solidify as it fell. Northward the smoking patches and driblet heaps became progressively smaller. This activity had all started by a simple splitting



Mauna Loa eruption of 1926, line of cones formed along rift, dying crater of main flow in foreground. Looking down mountain toward distant Puu o Keokeo on left. The flows poured off to the right. Taken May 4, 1926. Photo Jaggar.

open of the mountain flank along a new line within the belt of fracture generally known as the rift, and the splitting had progressed from the summit crater region downhill. The process had begun by strong earthquakes September 14 and 18, followed September 26 by a gush of smoky cauliflower clouds with chocolate-colored edges from the region immediately southwest of the summit crater of Mauna Loa. Two distinct columns of smoke developed side by side and a mile or so apart. The top of the jet reached 7,000 feet above its base, and with nightfall the cloud was illumined a bright orange-red. These gas jets waned so that by 10 p. m. only one fume jet could be seen, and by 3 a. m. the preliminary eruption was over.

The glow illumining the summit smoke in the first eruption was undoubtedly caused by a gush of frothy lava. There was then a lull from early morning of September 27 to 1:45 a. m. September 29, when moderate red glow and fume appeared over the southwest rift of Mauna Loa about the 8,000-foot level and both spread southward. This was the activity which quickly built up the line of pumice cones shown in the picture on Page One. There had evidently been a first release of gas from the expanding lava column up the central pipe, this in turn produced an expansive swelling that took two days to open the southwest rift, and thereafter the path of least resistance lay at the 8,000-foot locality and the outflow gathered volume there and maintained the release for several weeks The eruption gradually dwindled in November. No sudden event was observed to mark its termination on Mauna Loa, but on Kilauea, where there had been continuous outflow in the big crater for many months, the lava suddenly subsided in Halemaumau on November 28.

An earlier published airplane picture (Volcano Letter No. 270, Page Three) showed well the straight lines of cones built up from 50 to 100 feet on the southwest rift of Mauna Loa in April, 1926, when there was another lava flow of the same quality as the one just described for 1919. In fact the photograph in question shows the line of cups within cones that had been built in 1919 about a half mile to the west of the new fissure that was opened in 1926. The same picture also shows in the foreground a short line of still older cones with their interior cup-craters lying to the east of the 1926 crack. The characteristic initial structure is an elliptical cone at each of the many openings along the crack, with an egg-shaped cup inside, and in many cases as the eruption dwindles there will be two cups where a revival of activity has made an inner cone at some larger spindle-shaped crater whence the activity had shifted elsewhere and returned during the progress of the eruption from many vents.

The photographs on Pages Two and Three show the line of cones made at the source of the 1926 eruption looking towards Puu o Keokeo and the older cones of that district, and an excellent airplane picture of the western flank of Mauna Loa above the forest line and below the rift belt exhibits the torrent of molten lava in the midst of a band of solidified aa. The source vent picture was taken May 4, 1926, just as the eruption ceased and shows the place where the final source fountain had been in the foreground, still fumy with sulphurous acid, with very hot air rushing up the cracks, a depression 5 to 10 feet deep floored with a swirl of lava. The flow picture was taken on the same day (April 18) that saw the destruction of the fishing village of Hoopuloa by the front of the flow at the sea shore 10 miles farther down the mountain (Page Four Volcano Letter 270). The surface of the golden torrent shows a dark line of crusts and rafts down the middle

and a tendency to form distributaries around islands, the rapid stream maintaining in general a middle position along the band of semicongealed black clinker produced by earlier overflows of its banks. At the top of the picture this band is seen to change to lighter colored lava under the fume and cloud of the source vent region, and this lightness is due to the presence of pahoehoe or smooth lava, with glistening surfaces on all the upper heaps within a half mile of the rift. This transition from pahoehoe to aa a short distance from the Mauna Loa source cracks is characteristic, and shows the results of stirring on a steeper slope as described in Volcano Letter No. 281.

We see then that the source vents for Mauna Loa flows create true fissure eruptions, with many cones and cups along miles of cracked mountain flank, and that a new eruption tends to start at the top of the rift belt and to split its way down the mountain to that place on the flank where the lava finds a path of least resistance for continuous flowing. Quite commonly the splitting of the crack extends below the place selected for final adjustment to outflow: this happened in 1919 and 1926 on Mauna Loa, and in 1920 on Kilauea. Thus the lowest opening on the crack is not the vent selected for most voluminous flowing, showing that the outpouring is not strictly hydrostatic, but is rather selective of that portion of the rift which may be opened widest by the swelling of the mountain.

T.A.J.

KILAUEA REPORT No. 959

WEEK ENDING JUNE 8, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

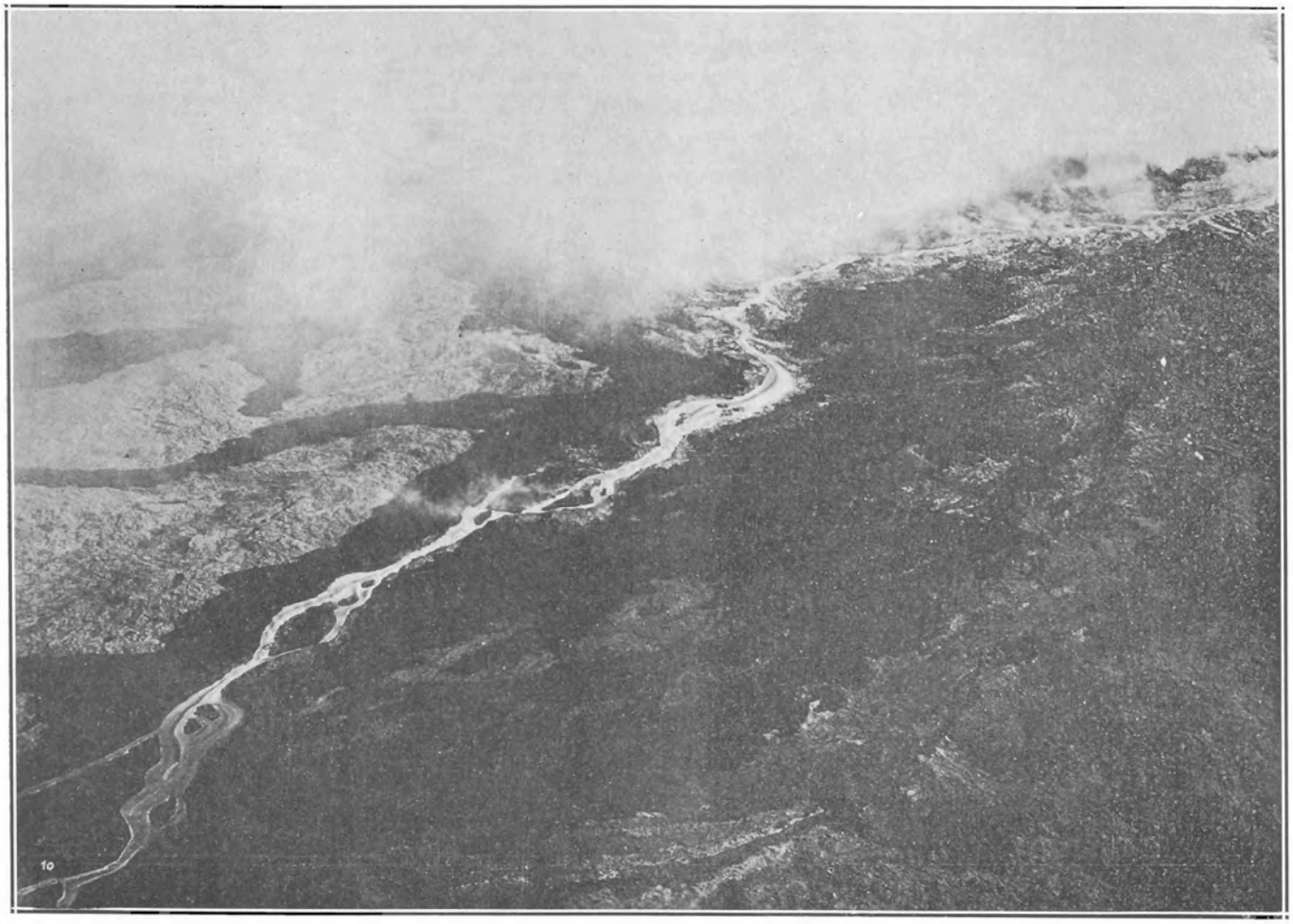
Halemaumau pit in Kilauea Crater remains quiet. At 11 a. m. June 5 no steam could be detected at any of the interior vents of the pit, though the vapor rising from cracks back of the west rim was as usual. On the morning of June 7 a little vapor could be detected at the south talus.

Ten local seismic disturbances were registered, of which six were short tremors lasting less than one minute, one was a very feeble seism, and three were feeble quakes. Two of these were felt on both east and west sides of the island, the times being 4:54 a. m. June 3, indicated distance from Kilauea 67 miles along with southeast tilt at the Observatory, and 6:32 p. m. June 4, probable distance 14 miles. The other was at 3:39 a. m. June 5, distance 28 miles. Tilt for the week was slight NE, and microseismic motion was slight.

MAY TILTING OF THE GROUND

At the Hawaiian Volcano Observatory on the northeast rim of Kilauea Crater, the tilting or tipping of the ground in the seismograph cellar, expressed by overlapping seven-day means, in terms of angular change and direction of motion of the plumb line, was as follows:

April 28-May 4	1.03 seconds	WSW
May 5-11	1.33 seconds	WSW
May 12-18	0.48 second	ENE
May 19-25	0.85 second	WNW
May 26-June 1	0.85 second	WSW



Airplane view of Hoopuloa lava flow of April 18, 1926, showing incandescent stream within aa fields at about 5,000-foot contour of mountain. Mauna Loa eruption of 1926 from southwest rift pouring westward above Puu o Keokeo. Transition pahoehoe to aa upper right. Photo Eleventh Photo Section, U. S. Army Air Service.



THE VOLCANO LETTER

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Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Lorrin A. Thurston, President; Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

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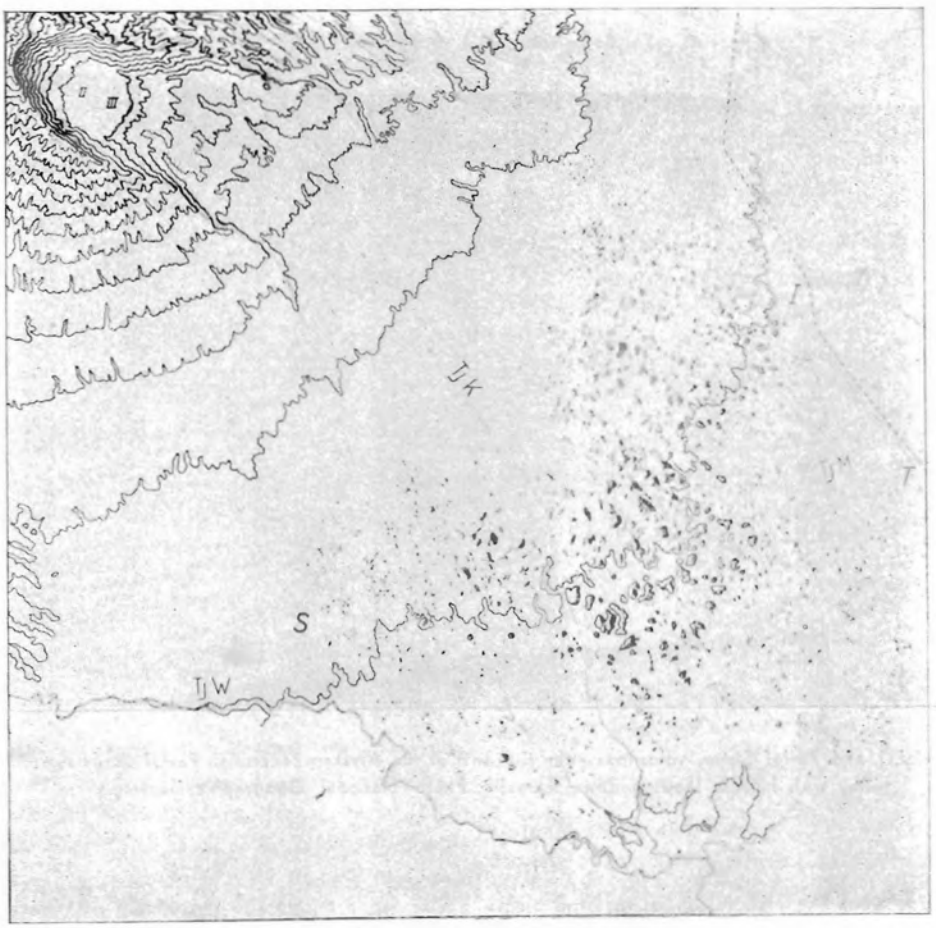
The Volcano Letter

Two dollars per year — Ten cents per copy

No. 286—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — June 19, 1930



Map of southeast slope of Galounggoung Volcano in Java. The many hills indicated by mottling southeast. Crater valley at northwest is four miles long. Tj=streams, S=Singaparma, T=Tasik Malaja, I=Indihiang. May by Escher.

THE CRATER OF GALOUNGGOUNG

In west central Java the active volcano Galounggoung is a big cone 2,168 meters high with an amphitheater hollowed out of its eastern side, and from this amphitheater three streams drain off to the south in a flat country where many villages were devastated in a terrific eruption accompanied by mud floods in 1822. This flat country is covered by many hundreds of prehistoric small hills from 10 to 250 feet high. The map above shows the crater trenching the east-southeast flank of the cone, and the roman numerals I, II, and III at the head of the crater valley mark eruption centers. The principal historic eruptions were in 1822, 1894, and 1918, the last developing a lava dome below point III on the map. The first two eruptions were explosive and produced great floods in the rivers. In addition there was a landslip in 1868, just as there was in the same year on the southeastern flank of Mauna Loa in Hawaii Indeed this amphitheater crater of Galounggoung is strongly suggestive of the gaps of Haleakala Crater, which open into valleys toward the sea, and of the Waipio, Mohakea, and Wood Valley embayments on the island of Hawaii. The hundreds of preristoric hillocks of Tasik Malaja bear some resemblance to some of the moraine-like hills on the north and west sides of Mauna Kea near the base of the mountain, these hills consisting of a jumble of mud and bowlders, possessing very irregular forms, and exhibiting no craters such as are characteristic of true cinder cones.

The places on the map of the Tasik Malaja hills marked Tj are streams. the hills are indicated by the mottling, and their disposition with the largest ones out in front of the crater valley certainly suggests a relationship between their origin and some ancient discharge from the valley. As Professor Palmer pointed out in his review of Escher's paper (Volcano Letter No. 253), 3,648 hills have been mapped, and the map here reproduced is taken from that paper, published by the Geological Society of Leiden in 1925.



Pavlof Volcano (right) and Pavlof Sister, volcanoes near the end of the Alaskan Peninsula. Pavlof shows summit crater and open valley with hillocks leading down from it. Photo National Geographic Society.

Each hill is composed of very fine material enclosing large blocks of andesite rock. The cubic content of all the hillocks taken together is about one twentieth of the material missing from the cone of Galounggoung at the great amphitheater. Underneath the hills, however, there is an underlying mixture of bowlders, gravel, and mud some 70 feet thick in the middle and thinning out toward the margin of the hilly area. If we add this under layer to the volume of the hills, we still fall far short of the volume lost from the big crater.

According to Escher the material of the hills had slid down from the crater in the condition of mud, probably from a crater lake. As a succession of eruptions had migrated from a summit crater to the southeast, it is probable that the crater lake broke through and caused a violent and watery landslide. "The hillocks represent the fixation of the last material of the slide, clots that remained standing higher, the principal mass having slowed down because of increasing bottom friction as it spread out fanwise and lowered, and as it lost part of its water." The finer mud and surface material flowed on down the slope, leaving the clots in relief where irregular clusters of bowlders clothed with mud made the remnant hills. The largest of these were in the middle of the landslide fan and opposite the middle of the crater valley. Taverne (Vulk. Med. No. 6, Mining Bureau of the Netherlands East Indies, Galounggoung and Telaga Bodas, Weltevreden 1924, page 29, and plate III) has reproduced an old map of Galounggoung after the eruption of October, 1822, and the area devastated and buried by this eruption corresponds closely with the area of the hills.

The following second review kindly sent us by Professor Palmer presents another explanation for the hills of Tasik Malaja. T.A.J.

THE BOWLDERY HILLS OF GALOUNGGOUNG

A paper by the eminent Dutch geologist, B. G. Escher, relating to the "Ten Thousand Hills of Tasik Malaja," was reviewed in the Volcano Letter for October 31, 1929 (No. 253). Escher considers these hillocks to be stranded masses of landslide material, the rest having swept on down the slope.

A short paper by Dr. F. X. Schaffer, head of the Division of Geology of the Naturhistorisches Museum in Vienna, has been received and suggests another origin for these hills ("Die Zehntausend Hugel von Tasikmalaja," Centralblatt f. Min. etc., 1926, pp. 207-209). Dr. Schaffer visited the region a year before read-

ing Escher's paper. At that time he was of the opinion, which he still holds, that the hillocks are man made. Most or many of the hillocks bear houses and friut trees. As dwelling sites they offer some protection from the numerous mosquitoes and rats which infest the rice fields at the bases of the hillocks. They offer some immunity from attack by hostile persons, and they insure dryness for the dwellings. They also offer places of refuge from the volcanic mud-flows that from time to time rush down the depressed sector of the volcano where they are to be found. The gently sloping, fan-shaped region built up by the mud-flows is very favorable for rice cultivation, which has undoubtedly been practiced from time immemorial. However, the preparation of the rice fields has involved the movement of great volumes of rock and earth in order to bring them to grade. In the process of clearing the land it would be probable that the people would make dumps of the bowlders and cobbles from the mud-flow material. Thus the dumps have become hillocks, and it was a simple matter to take advantage of the favorable characteristics of the hillocks that are favorable for house sites. The objection might be raised that the volume of man beings. This might be true of occidentals, but is not beyond the powers of the numerous and ant-like industrious Malays.
material moved is too great to be conceivable as the work of hu-

The reviewer has attempted to give Dr. Schaffer's views and nothing else on this occasion, which is what he attempted on the previous occasion for Professor Escher's paper. Schaffer concedes that the cores of the larger hillocks are not man-made. It is to be regretted that we have no information as to native legends of the origin of the hillocks. H.S.P.

SOME ANALOGOUS BOWLDER HILLOCKS

The foregoing discussions of bowldery hills in fan-like grouping in front of a crater valley in Java are too important to pass without some comment. This question of crater sinks merging into collapsed valleys has been splendidly reviewed and illustrated by Friedlaender, (Volcanological Review, Berlin, Vol. II, page 186, 1916, "On volcano fault-valleys," with maps of Bandaisan in Japan, of Hawaii, of Brava, San Thiago, and Fogo in the Cape Verdes, of Palma in the Canaries, of Stromboli in Italy, of Savaii and Tau in Samoa, and of Crater Lake in Oregon.) As mentioned in the last Volcano Letter, the Hawaiian volcanoes are breaking down by faulted sectors. When such downbreak is accompanied by explosion at the volcanic center, big downblasts, floods and land-slips are common. The accompanying photograph of the north face of Pavlof (Page two) cones shows down-broken sectors, the right-hand peak, Pavlof proper, exhibiting an open A-shaped gash, clotted rocky hillocks of debris below it and under the crater, and a vast jumble of bowlders and wash spread out in a fan farther down the slope. This jumble contains hundreds of mounds like those described under Galounggoung. (See Nat. Geog. Mag. January 1929, pp. 130 and 134).

The most perfect parallel to the Galounggoung cluster of hills is to be found on the north slope of Bandaisan volcano in Japan, and these mounds were created by the explosion and landslip of the great eruption of July 15, 1888. They were described as follows (The Eruption of Bandai-san, by Sekiya and Kikuchi, Jour. Sci. Coll. Imp. Univ. Tokyo, Vol. III, Pt. 2, 1889, page 110, plates xv, xviii, xxi, xxii): Large and small conical mounds stand out from the surface of the debris in immense number. There are big bowlders, measuring from five to ten meters, carried along as part of the mud current, and thousands of mounds, large and small, have been formed on the vast sea of mud, standing out of the debris like so many miniature Fujiyamas. They consist of disintegrated crumbling rocks, and the refuse falling around their bases has assumed a conical shape by forming taluses around them.

The writer examined this field of landslip of Bandaisan in 1914, where a huge amphitheater was quarried out of the flank of the mountain by the eruption, making just such a map as that of Galounggoung on Page one. The hillocks are clustered fan-like amid the tumble of rubbish in front of the crater niche. There were scars on the sides of the valley devastated, 75 to 100 feet above the debris, showing how the mud and earth had sunk away from its highest level. This high level corresponded with the tops of the mounds. The mounds had mostly a hard bowldery core, and many of them stood as islands in the lake which the eruption had produced by damming. One hill sketched was a pyramid with four surfaces fallen away, its summit sharp, made of earth and stones. The explanation adopted by the writer was that the first rush of the landslide was a thick fan while the huge rocks were grinding up, then the vast amount of water acquired by the finer material made this finer stuff rush much farther as a mud flood, carrying smaller bowlders and bowlder clots, and spreading as a thinner layer. This outspreading of the lower fan drained down the deposit from the scar level to the final level, and the larger rock fragments in units and groups remained in relief, as mounds which resisted farther progress. This would leave the larger clots nearer the crater, the smaller ones farther away, and precisely that effect is shown by plate XV of Sekiya and Kikuchi, and by Escher's map on our Page one. There is every reason to suppose that Galounggoung has had the same type of eruptions as those of Bandai. In both cases the same expression is used by scientific observers, "thousands of conical mounds." Escher's explanation appears to the writer to be correct, and to account for the gradation in size, and the distribution relative to the crater, and the rocky cores, while Schaffer's observation concerns human selection after a cataclysm had created the hills. T.A.J.

KILAUEA REPORT No. 960

WEEK ENDING JUNE 15, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

There are no changes in the crater of Kilauea, and only once during the week was a little sliding observed at the pit walls.

The seismographs at the Observatory have registered one slight earthquake, three very feeble local seisms, two of them accompanied by easterly tilt, and four tremors lasting each from one-half minute to one and one-quarter minutes. The slight earthquake was generally felt on the east side of the island at 12:25 a. m. June 14, the seismogram indicating distance of origin about 12 miles from Kilauea Observatory. The felt movement was prolonged and moderate at Kilauea, shorter and ending in a sharp jerk at Hilo. The vertical component was very pronounced on the Kilauea seismogram.

Tilt for the week was stationary, and microseismic motion was very slight.



Note on this map the horseshoe valley west of Pahala and the depressions northeast of Kohala summit, as well as Kilauea Crater, all amphitheaters similar to Galounggoung Crater.

THE VOLCANO LETTER

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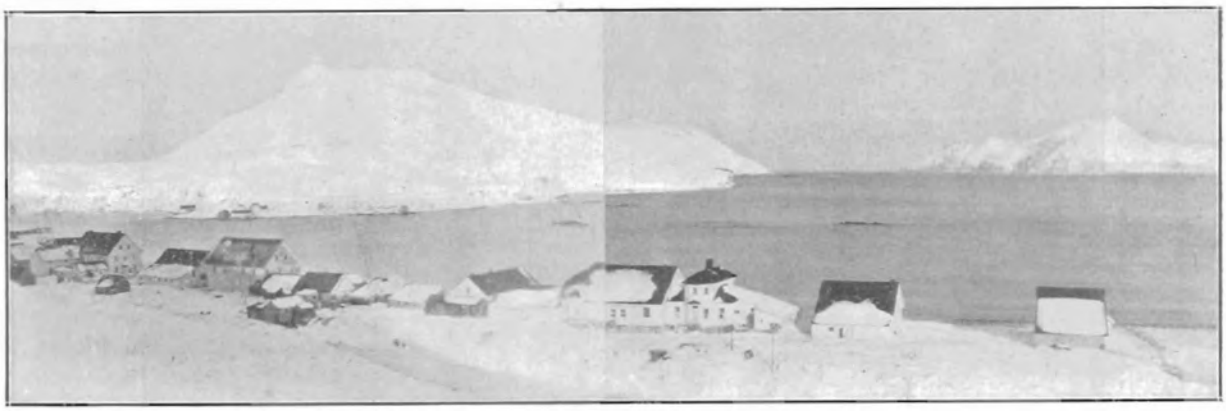
The Volcano Letter

Two dollars per year — Ten cents per copy

No. 287—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — June 26, 1930



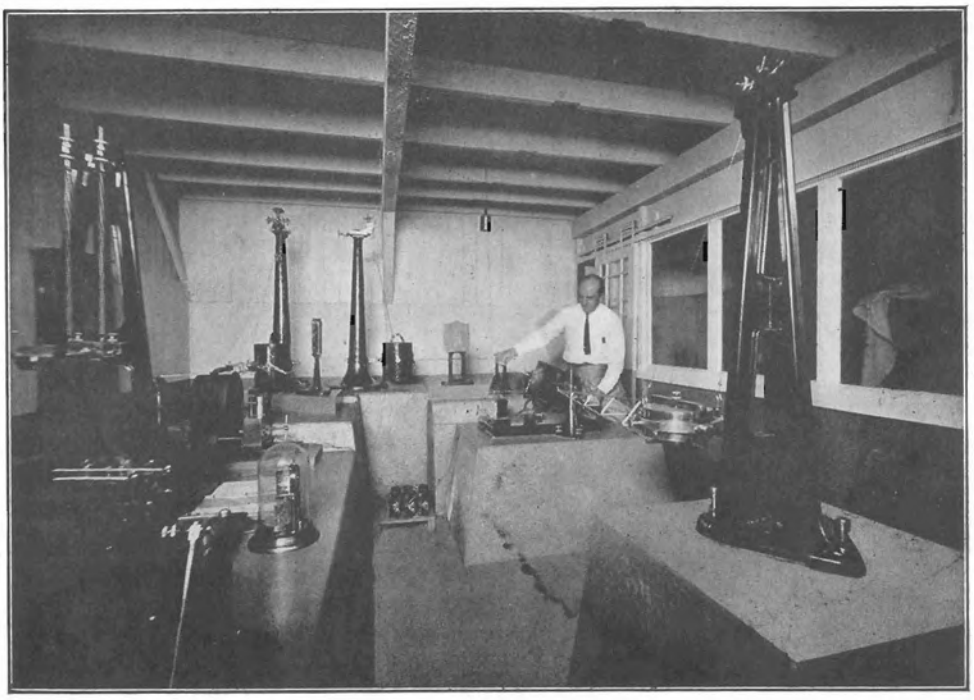
Unalaska harbor, in the Aleutian Islands, looking north in winter time, showing the village in foreground and on the left Amakmak Island, where are Dutch Harbor and the Naval Radio Station that houses the seismograph of the Volcanology Section, U. S. Geological Survey. Photograph by Yatchmeneff.

THE PULSE OF THE PACIFIC

How the seismograph works has been the subject of another number of the Volcano Letter (No. 268), and one of the first objects of investigation when the Hawaiian Volcano Observatory was started in 1912 was the pulse of the ground at an active volcano. For fifty years the Japanese have been taking the pulse beats of the earth crust in Japan, led first by John Milne, second by Professor Omori, and third by Dr. Imamura. All of these were stimulated by their researches to give attention to the active volcanoes of Japan, and recently the work has been narrowing down to what Imamura calls chronic earth tilting. The San Francisco earthquake of 1906 revealed a great rift extending for hundreds of miles, and the Coast Survey determined horizontal movement whereby the two sides of the rift shifted in opposite directions during the earthquake. Monuments have been set up to learn how much of such movement is chronic and continuous. The Carnegie Institution of Washington has set up sensitive instruments in southern California to learn how many small jarrings are associated with such faults. The Section of Volcanology of the Geological Survey has extended the Hawaiian work to Lassen Volcanic National Park in California and to Kodiak and Unalaska (see photographs Pages One and Three) in Alaska in order to take the pulse of new places. New Zealand and the Dutch East Indies are at work on the same problem.

All of this may be regarded as a big experiment requiring both time and space, the half century of time and for space the whole fiery circle of the Pacific, in order to find out, for local seismology, what movements of the ground are sufficiently continuous, chronic, or frequently repeated. One subject of local seismology at the volcano belts is to determine important cycles leading to recurrence of eruptions. For the geography or space side of the argument, the object is to determine what volcano or vent will erupt. For the places where volcanoes are not active, like Wellington or San Francisco, the object is to determine the earthquake danger, and what are the cycles in time for big earthquakes at the same place, and what are the places where the snapping of the earth's crust may progress through the ages from point to point, not accidentally, but because of some deep-seated law of which hitherto man was ignorant.

Thus in Hawaii the volcano observatory is seated on a comparatively simple structure, an island with three active volcanoes and two old ones. We have five active seismograph stations where pendulums register the tremblings, jolts, and tiltings of the ground and the lists exhibit thousands of earthquakes where in the year 1800 the only lists were in the memories of the natives or the log books of explorers. In 1800 there was an eruption with lava flows down the west side of Hualalai Volcano, and we know nothing of what spasms of earthquaking then preceded the bursting open of that dormant mountain. Ten years before Kilauea on the other side of the island had a bad explosive eruption with much shaking



An early photograph of seismograph cellar, Hawaiian Volcano Observatory, which is dug down to bedrock. The concrete tables hold the rigid posts on which pendulums are swung equipped with chronographs that register movements on the rock on smoked paper. Station near Volcano House, Kilauea Crater.

and an enormous sinking of the bottom of its crater. Here were two events in a decade and two volcanoes somehow related. Compare with this the decade 1924-1934. Kilauea in 1924 had an explosive eruption with much shaking and sinking of its crater. Hualalai in 1929 had two months of shaking in excess of anything experienced there for a centry. Here were the same two volcanoes somehow related, but this time harnessed with seismographs. The transference within six years of the underground activity from Kilauea to Hualalai hints at a repetition of 1790-1800. The seismographs and tilt machines and leveling instruments, as well as continuous notes on Mauna Loa and Kilauea, had proved a rise and fall of the east side of the island, accompanied by rise and fall of lava in both Mauna Loa and Kilauea, for the eleven years preceding 1924. We see from all these facts that the observatory notes of only 20 years of work have enabled the scientists to sketch out an important eleven-year cycle, and the adjustment of this cycle to past history enables them to sketch out an important forecast relating to the geography of adjacent volcanic craters. Underlying these researches is the pulse of the crust of the earth measured by recording pendulums, and these have been writing the autograph of the bedrock since the summer of 1912.

The cut on Page Two shows the seismograph cellar built on the bedrock under the Hawaiian Volcano Observatory back from the edge of Kilauea Crater on its northeast side. A number of iron posts are seen, bolted into the concrete. Heavy beams support the floor above, so that the building rests on the outer margins of the cellar, and the walking of people on the upper floor does not press down the floor of the cellar locally. This is important, for every time an observer enters the cellar to change the chronograph drums as shown in the picture, his weight in walking by a post is sufficient to swing the magnifying pens a half inch across the smoked paper. The instruments are very sensitive, and are designed to record on different chronographs strong motions and weak motions, up-and-down motions, east-west and north-south motions, and to distinguish between tiltings, tremblings, local earthquakes, and distant earthquakes. A local earthquake makes a quick motion, a distant earthquake makes a slow motion. With all of this goes continuous registration of time from a clock, and correction of the clock by wireless. With 15 or 20 local earthquakes

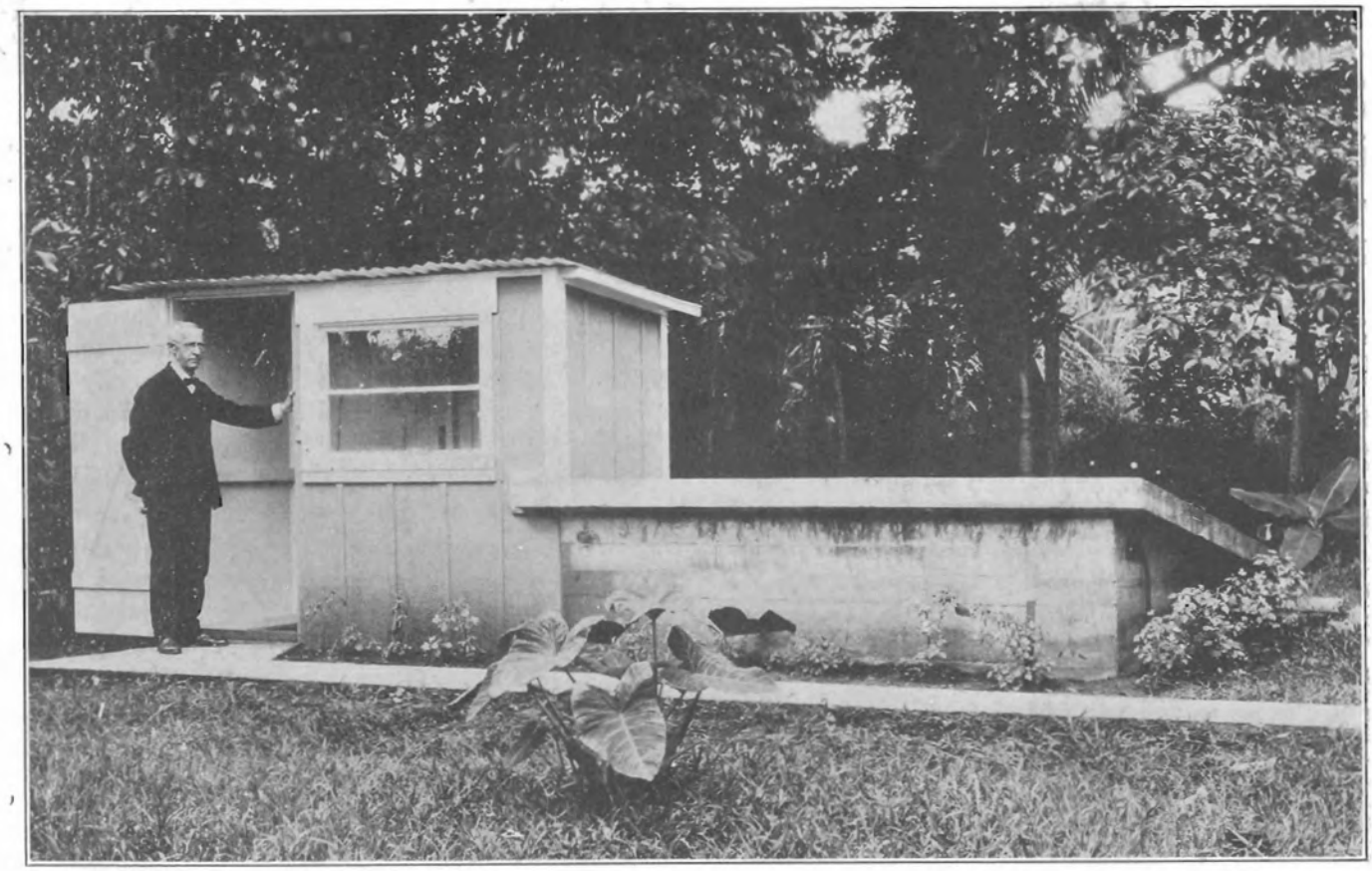
a week, numerous distant earthquakes throughout the year, small wave movements in the ground due to lava in the pit, the action of a storm, the pounding of a distant surf, or the passage of a steam roller: with hundreds of earthquakes when an eruption begins: with tilting and certain kinds of tremor always in progress; it will be seen that it requires experience to decide what seismograms to study, and where to place seismographs in order to cover geographical questions. As a matter of fact, the published seismograph records from volcano stations are unsatisfactory, because the volcano seismologists have too much to study.

It is popularly supposed that we look at a seismogram and predict an eruption. But neither eruptions nor big earthquakes herald themselves in this manner. The science of local seismometry is steadily working to narrow down all these many movements so as to reject the unimportant ones, and then to measure intensively, with distributed instruments, those chronic movements that are directly related to the lava underground. Japan and Hawaii have both concluded that chronic tilting or tipping of the ground goes with chronic rise and fall of the land. In Volcano Letters 264 and 283 we have shown how gradually Kilauea swells and how gradually the rim cracks of the pit spread open. From week to week we publish changes of tilt at the seismograph cellar, because big changes accompanied big risings and fallings of the lava. Imamura has shown that in Japan both volcanic eruptions and earthquakes are preceded by years of important tilting. Large earthquakes near volcanoes are proving themselves to be in a different class, involving deeper movements, than the small surface jarrings of an active lava period. Here there is a gradation that can only be explained by placing many seismographs in geometric relation to a single volcanic mountain. There is undoubtedly some relationship between numbers and intensity of earthquakes on the one hand, and the magnitude and direction of tilting on the other, but to discover this relationship a limited piece of ground must be studied.

The Hawaiian station is now at work on its records of 18 years with a view to narrowing down the problem of earth motion in relation to underground lava as applied to Kilauea Crater alone. The most hopeful line of attack appears to be the measurement of tilt at a number of stations all equipped with the same instrument, and a determination of policy and of instrument construction that will permit the operation of the system so as to eliminate earthquakes, tremors, temperatures,



Lassen Volcano Observatory at Mineral, California. This simple house in the forest is over a concrete cellar containing the seismographs of the Section of Volcanology, U. S. Geological Survey. R. H. Finch is in charge of the station, designed to study the seismic movements of Lassen Volcano.



Special seismograph cellar at St. Mary's School, Hilo, Hawaii, operated by Brother J. B. Albert for the Hawaiian Volcano Research Association. This houses a pair of Hawaiian-type seismographs made in the shop of the Kilauea Volcano Observatory. The records are compared with those of the crater, 30 miles away.

storms, and artificial disturbances, and a routine sufficiently simplified as to make possible the measurement for a term of years at reasonable expense. T.A.J.

KILAUEA REPORT No. 961
WEEK ENDING JUNE 22, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The Hawaiian volcanoes continue without action, and nothing has been observed in motion at Halemaumau pit of Kilauea Volcano except the sliding of a few rocks at 2:20 p. m. June 18 and at 10:25 a. m. June 20.

The seismographs at Kilauea recorded six very feeble local seisms, two of these indicating distances of origin 18 and 23 miles. Seven tremors were registered lasting from one-quarter to three-quarters minute each, and easterly tilt accompanied one of these and one of the above mentioned local seisms.

General tilt for the week was slight NNE, and microseismic motion was slight.

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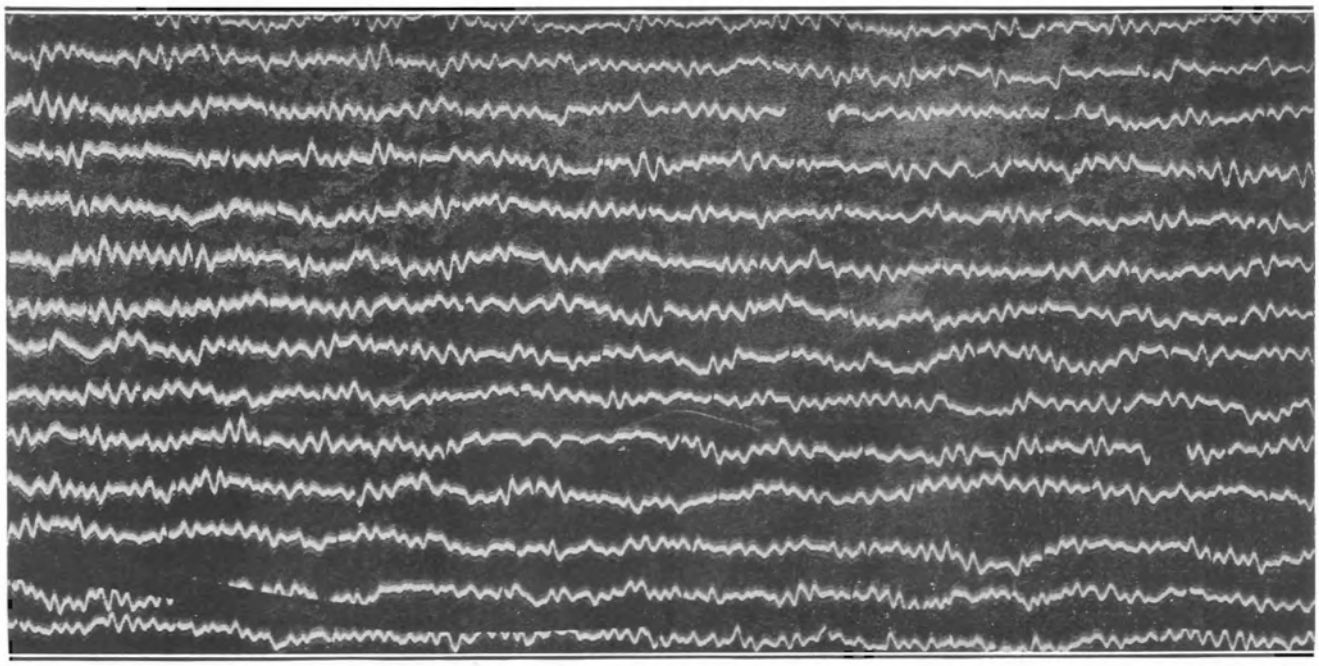
No. 288—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — July 3, 1930



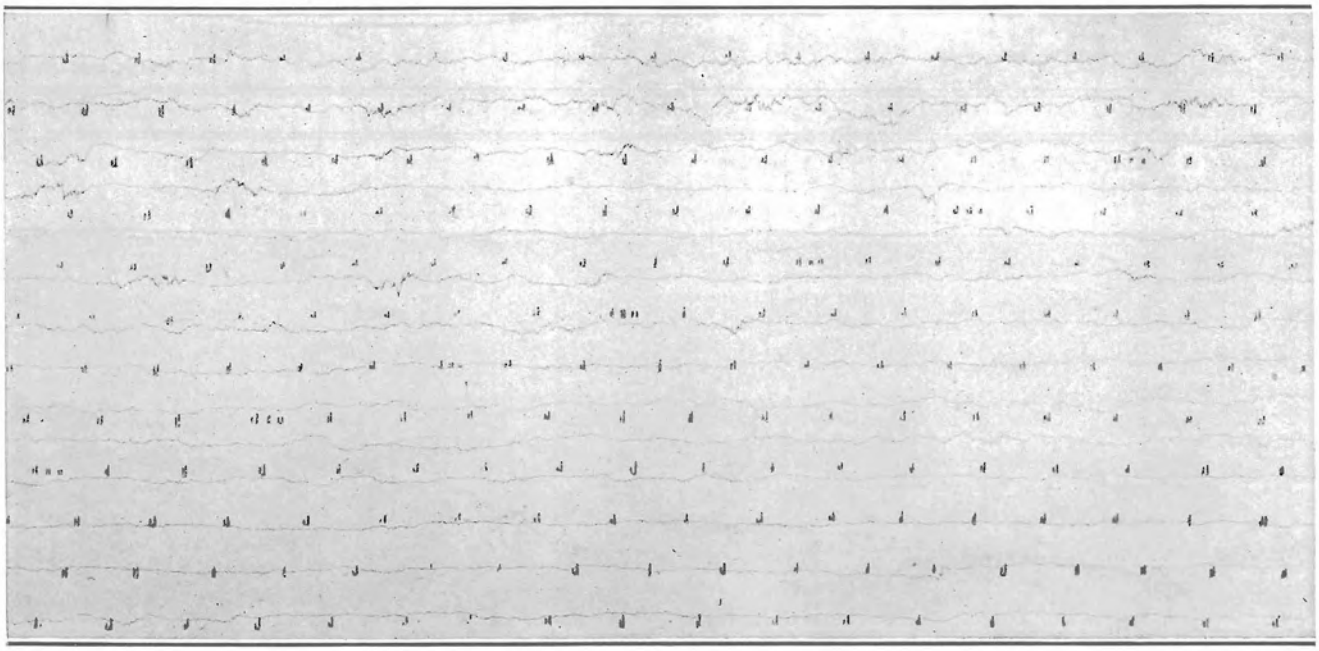
Seismogram, showing the lines written with a beam of light on a Kodak film in June, 1918, exhibiting microseisms as the principal wave movements. Minute marks are exhibited as gaps in the line. Registration of experimental seismograph pendulum of high magnification, Hawaiian Volcano Observatory.

SOME TECHNICALITIES OF VOLCANO STUDY

The reader of the bulletins and reports of the Hawaiian Volcano Observatory will be helped to understand the descriptions of the seismic movements at Kilauea, and of the rising and falling lava in the inner pit Halemaumau, and of the flowing of lava down slopes, if the observers at the stations of the Geological Survey will turn aside occasionally from technical description in order to explain the meaning of terms. Harmonic tremor, local seisms, avalanche vibrations, microseisms, streaming, fountaining, the wall crack and rim cracks are everyday structures, processes, and events at a volcano station equipped with seismographs. But the visiting traveler finds even such a simple word as "tilt" incomprehensible. He is not accustomed to a land which is tilting, and even if the house he lives in tilts back and forth between noon and midnight under the stress of the neighboring ocean tide and the weight of the changing water on the shore, he probably does not know it.

It has been the purpose of some recent numbers of the Volcano Letter to explain lava flows, rim cracks and crater slides, pahoehoe and aa, the bubbling, gushing, and cascading of lava, the swelling of the mountain, the seismogram of a distant earthquake as foretelling a tidal wave, the distinction between lava froth and lava paste, the working of a seismograph, and the heating of lava tunnels and wells by gas. Tilting or tipping of the ground was described last week in Volcano Letter No. 287 as an interesting chronic motion whereby a volcano is breathing through the weeks and months and its breast is accordingly rising and falling (Volcano Letter No. 264).

The present article is designed to show some seismograms and a diagram exhibiting movement of the ground in the shell of a mountain which is over a hot lava column. By lava column is meant an upright body of natural slag charged with gas in solution and occupying a natural shaft or well which goes down many miles and widens out in subterranean forms which it is the object of Volcanology to discover. Just as General Gorgas and Walter Reed discovered by experiment in Cuba that the mosquito carried yellow fever, so by experiment is it possible to show eventually that the lava under these great volcanic mountains swells out into a bulb, or a dome, or a lens, or a net of upright cracks. Experiment at the Kilauea Observatory has already shown that the mountain swells with rising lava and that the local ground always swells at the crack where rising lava is coming out. Leveling has shown that this swell extends down Kilauea Mountain to within 14 miles of Hilo, and that after the great collapse at the crater in 1924 there was subsidence of a foot or more at two stations in the National Park near Volcano House, and farther down the road very little effect. During the gradual rising of lava in Halemaumau from 1912 to 1921, the marked stations along the road



Seismogram printed directly from smoked paper, the quick tremors shown here and there being spasmodic volcanic vibrations. The slower waves are microseisms. Minute marks are dots. Hawaiian Volcano Observatory.

from Hilo to Kilauea showed in tenths of feet a rising approximately as follows:

Distance from Hilo Wharf	Change Between Levelings of 1912 and 1921
10.9 Miles	+ 0.0 tenths feet
14.1 "	+ 1.3 " "
17.2 "	+ 2.4 " "
20.4 "	+ 4.1 " "
31.3 " (Park entrance)	+ 8.1 " "
32.5 " (Volcano House)	+10.1 " "

The graded increase of change in these figures as the crater is approached leaves little doubt of actual rising of the ground that has been discovered to a still greater degree close around and within the crater of Kilauea (Monthly Bull. Hawn. Volc. Obsy. Vol. XV No. 6, p. 40). The tilt measurements of a single year at the Observatory are shown in the diagram on Page Four as though the trace of a hanging fountain pen were enormously magnified. The bend July 8 coincided with an eruption.

There is suggestion that the underground lava rising in Kilauea Crater between 1912 and 1921 was spreading out underground as a wedge for 16 miles in the direction of Hilo. The implication is that the tipping up of the country over this wedge grows less and less so that 21 miles away it is zero. There is a quantity of other information derived from running levels in the direction of Pahala and across the Kau Desert. The placing of instruments in small chambers in the solid rock in many places that would measure this tipping from year to year would furnish evidence of the rate at which the changes in level take place and the times of sudden changes if any.

As explained in Volcano Letter No. 268, the seismograph may be made to measure several things. Here are some of the terms used: A microseism is a slow, wavy movement in the ground consuming about four seconds to each wave as shown in the optical seismogram on Page One. Each line there represents a part of a different hour, the minutes are marked by gaps in the lines, and the lines were written by a tiny spot of light on a moving Kodak film, the light beam being reflected from a little mirror oscillated by a pendulum, and the pendulum registered the movement of the ground. It will be seen that the wavy movement comes in spells which wax and wane every minute or two. Microseismic movement is common everywhere and is variously explained.

Volcanic tremor is shown in the seismogram on Page Two, where the lines were written by a scratching pen on smoked paper and the time marks for minutes are closer together and are made by little double dots from a mechanical marker. Many spasmodic groups of tremors are shown, much quicker than microseisms, and these are common at Kilauea when there is active lava in Halemaumau. Such was the case when this seismogram was made by a pendulum set up two miles away from the pit. A complete wave motion for this tremor occupies two tenths of a second. Sometimes the tremor becomes continuous and even, when it is spoken of as "harmonic," and this has been found to agree with times of fountaining lava in the pit.

Local seisms are merely local earthquakes and the ordinary ones registered on instruments at Kilauea are technically defined as very feeble (of which we have thousands), feeble, slight, and moderate. The first two are totally unfelt, but when an instrumental earthquake gets so big as to be "slight" it is usually felt by everybody. To those who do not understand technical grades of intensity, it is hard to understand how seismologists can say to each other, "Do you mean to say that earthquake was slight at Hilo? At Kilauea it was only feeble." In other words, slightness is stronger than feebleness. In the same way "moderateness" is quite big, dismantles the high magnification instruments by throwing the pens clear of the drum (see seismogram Page Three), and the shock is referred to by inexperienced people as "terrible" or "strong." It is not "strong" technically, because it does

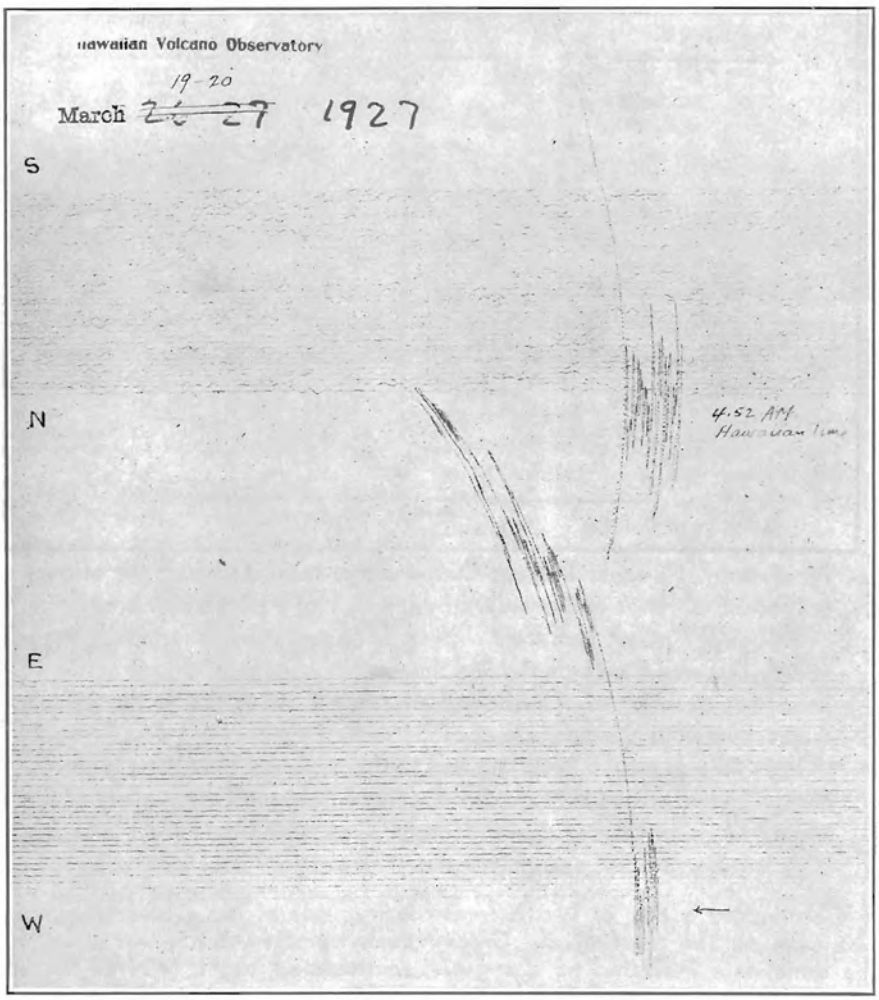
not knock over anything, and we have to reserve some words like strong, very strong, and disastrous for the grades of very big earthquakes.

The "indicated distance" for the moderate earthquake shown on Page Three is indicated by the duration in seconds of the preliminary motion. In the upper south-north band of lines, just to the left of "4:52 a. m.," there is registered a group of vibrations about an inch wide up and down and occupying a quarter inch in the direction of the lines. Then there comes a big sweeping movement where the pen goes off the paper. In the lower band of lines (east-west) the pen starts to go off sooner. The quarter inch corresponds to so many seconds of time of preliminary motion, or the first phase of the earthquake, and by Omori's formula for local earthquakes four seconds means 18 miles, eight seconds 37 miles, 12 seconds 55 miles, etc., of distance horizontally to the place on the earth (or on the map) which lies over the place underground which bumped or scraped or snapped. The place underground is called the center or origin, and the place above it the epicenter. Sometimes the ground at the instrument tips suddenly at the time of the earthquake and this widens or narrows the space between the lines on the seismogram, while gradual tilt of the ground widens or narrows the lines gradually (see seismogram Page Four, Volcano Letter No. 276). Avalanche vibrations are occasioned by the falling of great masses of rock from the crater walls (see Volcano Letter No. 269), and these write their records on the seismogram as quick waves gradually increasing to a maximum and then dying away. An earthquake is different, with a small preliminary, and then the sudden wide movement of the long waves, followed by gradual decline. T.A.J.

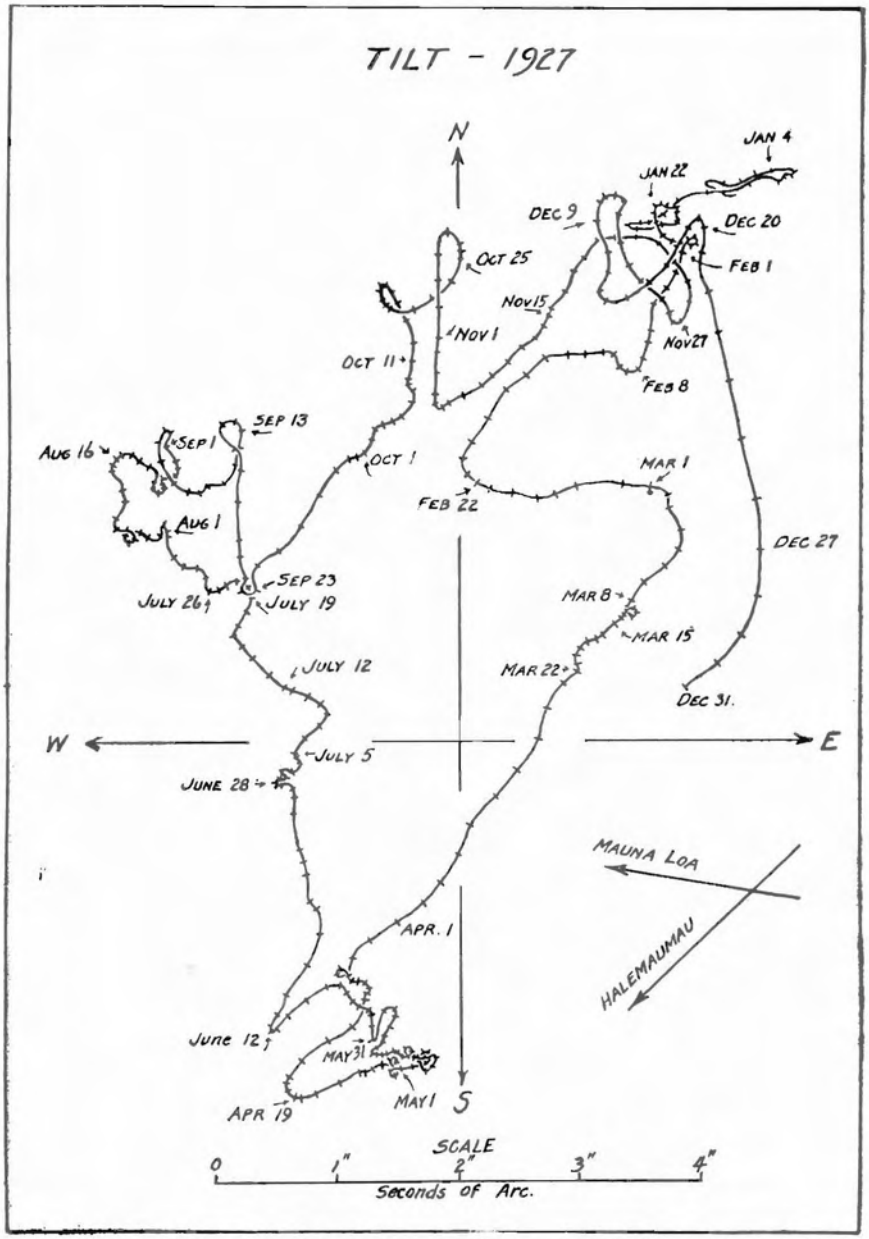
KILAUEA REPORT No. 962
WEEK ENDING JUNE 29, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Kilauea Volcano remains quiet and without visible changes. On June 28 a small scar at the top of the west Halemaumau wall appeared to mark the location of a



Seismogram showing two bands of lines registering horizontal motion, the upper south-north, the lower east-west, made on smoked paper originally, and showing a local earthquake 4:52 a. m. March 20, 1927, of moderate intensity. Shows preliminary tremor, and then the pens are flung off. Magnification about 100 times.



Tilt diagram, Hawaiian Volcano Observatory, calculated from the seismographs for direction and amount of departure of a plumb bob in seconds, as though the plumb bob were writing its record in ink, enormously magnified. Linear distance on the line shows daily change of tilt, direction of line shows direction of change, and a marked bend to the northwest July 8 corresponds to the outbreak of Halemaumau the previous day. Seasonal tilting to the southwest in spring, and to the northeast in autumn is normal here. The two arrows indicate the directions from the Observatory of the Mauna Loa and Kilauea crater centers. Comparing January 1 and December 31, net change for the year was four seconds south.

slide seen from the Observatory a day or two before. No steam was to be seen on the pit bottom. Crack measurements on the same date indicated no changes.

Only six seismic disturbances were recorded by the instruments at the Observatory, of which five were volcanic tremors and one was a very feeble local seism. Tilt accumulated slight WNW. Microseismic motion was slight.

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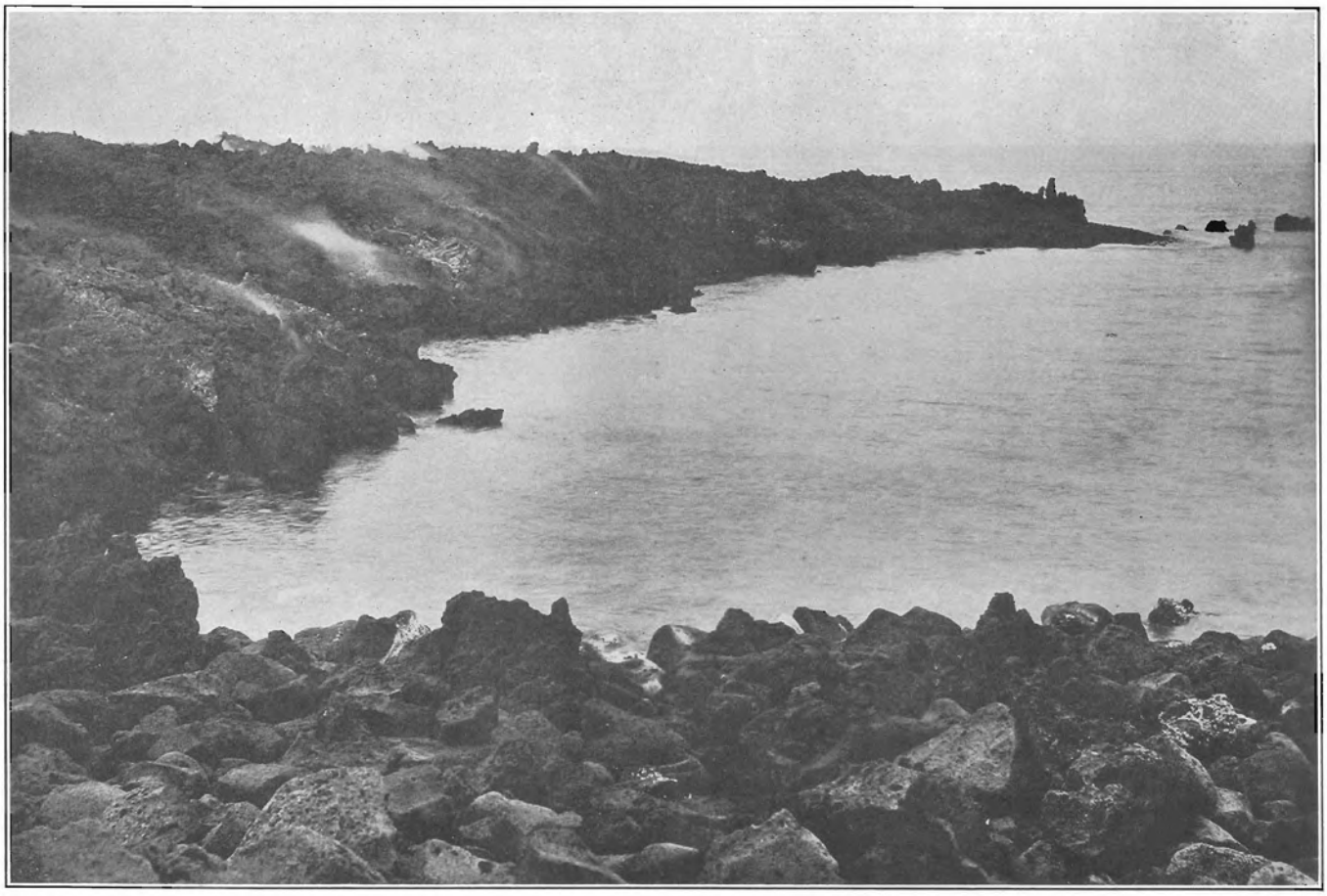
No. 289—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — July 10, 1930



Hoopuloa when the first buildings were burning and the lava front had just reached the sea, at 6:21 a. m. April 18, 1926, looking south. Photo Tai Sing Loo.

MARINE EROSION AT HOOPULOA FLOW

In 1926 during the month of May Mauna Loa produced one of its periodic displays with outpouring of molten lava, first from near the summit, then spreading down the southwest rift, and finally settling down to a steady flood of basalt from a vent at about the 8,000-foot level. This puddled on the flattish upland as usual for this district, the edge of the pool spilling in several directions before settling down to a final flow. The progressive feeling for an outlet in such a flow is partly conditioned by the tendency of the source crack or rift to open its way down the mountain. A vent is formed at a certain place on the crack, builds up a cone, overflows to the east, the cone-building clogs the hole, the crack opens a new vent farther down the mountain, and the escape of lava there is easier than at the first hole. The new cone overflows to the west, where the country is flatter, the slagheap backs up, the source is impeded, and a new place on the crack still farther down makes a freer outlet. In this way vent after vent is opened down the rift line. Finally a lower series of vents clog themselves and force the oncoming fluid from the depths to adopt one of its first openings a little farther uphill. The spouting melt is now dammed above and dammed below, and keeps flowing at one place. The flood



The site of Hoopuloa April 26, 1926. The foreground is old rock. Notice beginning of sand spit at point. The lava is still steaming. This is the cove which was later shut off. Photo Jaggar.

accordingly feels its way to the nearest declivity where finally it crushes a path for itself down a steeper grade through the forest, and this flow forms an adjusted canal through its own clinker fields to the ocean.

The flow of 1926 adopted this program, and the canal selected was a slight sag in the steep mountain slope of South Kona. This sag or valley, between old lava flows (see airplane pictures Volcano Letter No. 270, Page Four, and No. 285, Page Three) ended as is natural, in a shoreline indentation. This bay was where the fishermen naturally had chosen a landing for their canoes, here in some shelter had been built a wharf for the steamer landing, a beach had accumulated at the head of the bay, and dwellings had followed the demands of fishing and transportation. So this was the ancient fishing village of Hoopuloa, built to be sure on old and desolate rough lava flows, and only a short distance away from where in 1919 the Alika flow cascaded over the shore platform into the ocean, and made some short-lived tidal waves which wrought havoc at the Hoopuloa wharf. There was threat of danger, but why worry? There are lava flows everywhere.

The choice of a bay of the coast by men is also the choice of the fire goddess for good sledding on her lava. The aa flow of 1926 pushed right through the village ruthlessly, spared neither wharf nor dwellings, and nearly filled up the bay. There was left only a small cove at the northern quarter of the indentation where the wharf had been. Our pictures show the sequence of events.

At 6:21 a. m. April 18, 1926, we would have looked southward across Hoopuloa Bay (Page One), as the spectators and photographers in the foreground of the picture are doing, and we would have seen the crumbly incandescent front of the lava enveloping the village houses with flames, and just touching the water to start columns of white steam. The palms and the dock in the foreground are soon to be swallowed in molten rock. Jets of gravel will shoot up in zigzag trajactories, and the great steam-cloud will be blackened with exploded sand, while the heated

and poisoned sea-water will kill small fish by thousands.

Within twenty-four hours, by 9 a. m. of April 19, all motion in the flow at the sea front had stopped, and the new point of lava, thirty to forty feet high, extended out 300 feet. The photograph on Page Two, taken a week later, shows the old sea worn rocks in the foreground, and the new lava promontory still steaming. Not a single building was left of Hoopuloa village. The destruction could not have been more complete if it had been a deliberate engineering enterprise. Of the original harbor there was now only a small cove shown in the picture. A canoe reposed in this cove. A large beach had been formed by the sea on the flow itself. Some of this is shown at the tip of the cape. These new beaches were evidently growing very rapidly in several places.

The hot gas rising, smelling strongly of ammonia and carbonaceous products, appeared to indicate that buried wood of the forest and the habitations was still smoldering under the flow. These smells were common at places remote from former habitations. When the large number of heavy sap-filled trees which the flow overwhelmed are taken into account, and when it is realized that they had no time to burn when they were smothered in the lava, it appears reasonable to suppose that all this carbonaceous matter may continue to burn slowly, with what oxygen it can get from the lava vesicles, for many months. This process will supply heat as well as gas, and the many explosions which are heard at old caverns when a flow is progressing through vegetation are occasioned by mixture of carbon monoxide, from the burnt wood, with air. Such explosions do not occur at the lava front when it advances over bare rock, where it has not travelled through vegetation.

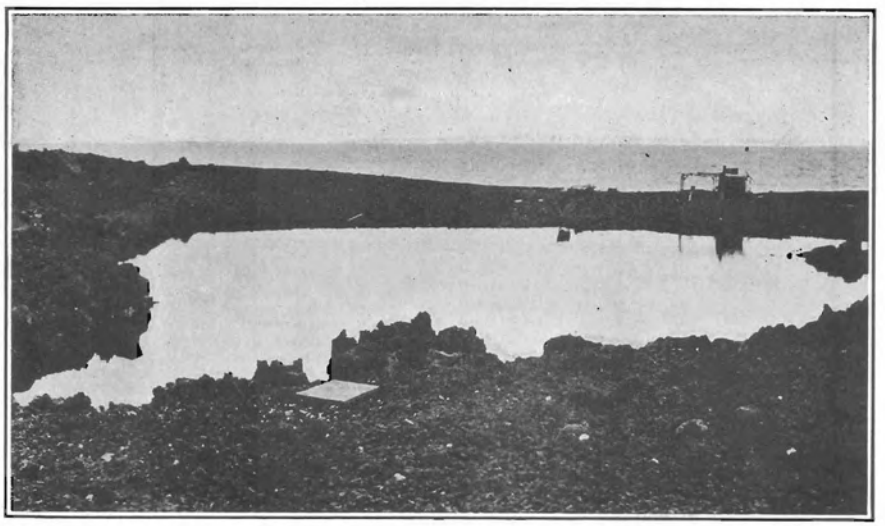
Less than a year after this destruction of Hoopuloa even their little cove was denied the fishermen. The abundant loose material of triturated and tortured clinker that forms the upper surface of an aa flow, furnished a rich harvest to the mowing machine and reaper of the winter storms from the south in 1926-27. This building of beaches, so rapid within a month, created big sea-walls within the year and a barrier beach was thrown straight across the entrance to the cove, straightening up the entire shore-line. The cove became an enclosed fish-pond of the type prized for mullet storing by the Hawaiians, but all trace of a harbor was lost. The new beaches are of gravel and sand with steep fronts sloping rapidly into comparatively deep water (Pages Three and Four). The observation of this rapid shore process of erosion and filling acting on a fresh lava flow, suggests the possibility of interpreting the age of a past lava flow by the amount of wear of the stones and the arrangement of the beach fills.

T.A.J.

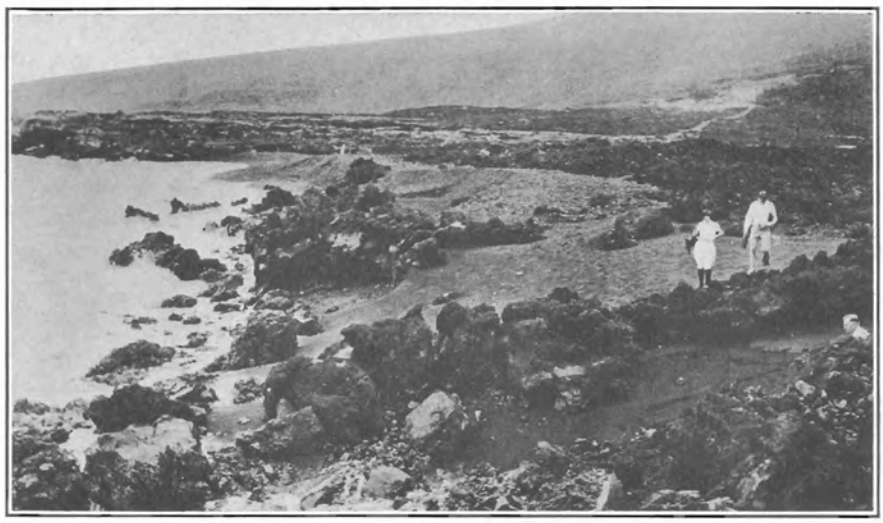
JUNE TILTING OF THE GROUND

At the Hawaiian Volcano Observatory on the northeast rim of Kilauea Crater, the tilting or tipping of the ground in the seismograph cellar, expressed by overlapping seven-day means, in terms of angular change and direction of motion of the plumb line, was as follows:

June	2- 8	1.08 seconds NE.
"	9-15	0.48 second NW.
"	16-22	0.97 second NNW.
"	23-29	0.48 second N.



Looking west at Hoopuloa Cove converted by barrier into a fish pond. Hut is on the new beach ridge. Compare Page Two. Photo Godfrey.



May 29, 1927, shore wash of the new flow at Hoopuloa thirteen months after. Sea wall beaches built up from winter storms. Looking north, showing barrier beach that cut off Hoopuloa. Photo Godfrey.

KILAUEA REPORT No. 963

WEEK ENDING JULY 6, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Very few slides have occurred at Halemaumau during the week. White dust was twice seen rising on July 4. A little steam was observed on the south talus early in the week. The south sulphur area had a little whitish color.

The instruments remained very quiet seismically. The only disturbances were three volcanic tremors, each of one-half minute duration. Tilt accumulated slight WSW. Microseismic motion was slight.

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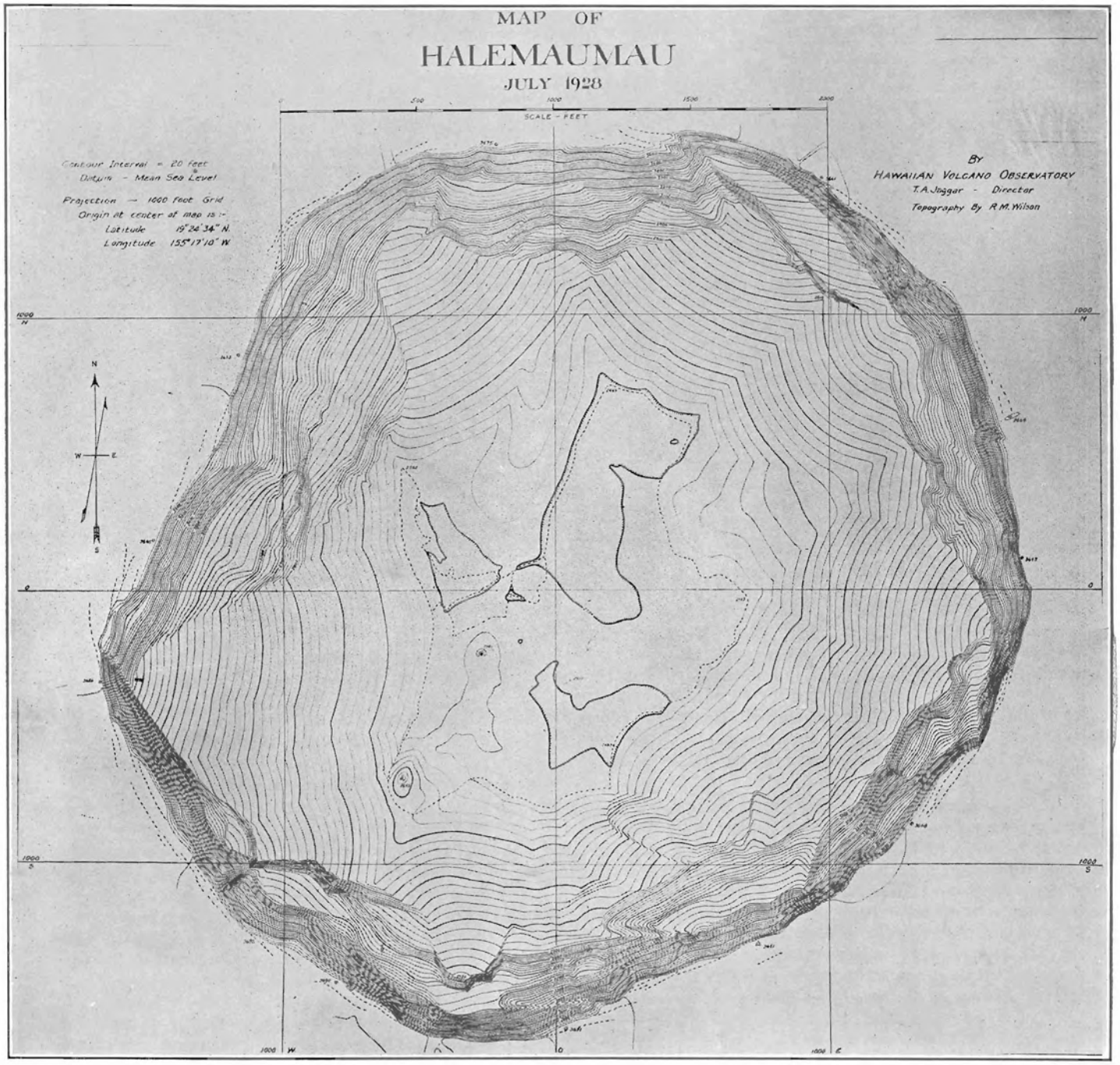
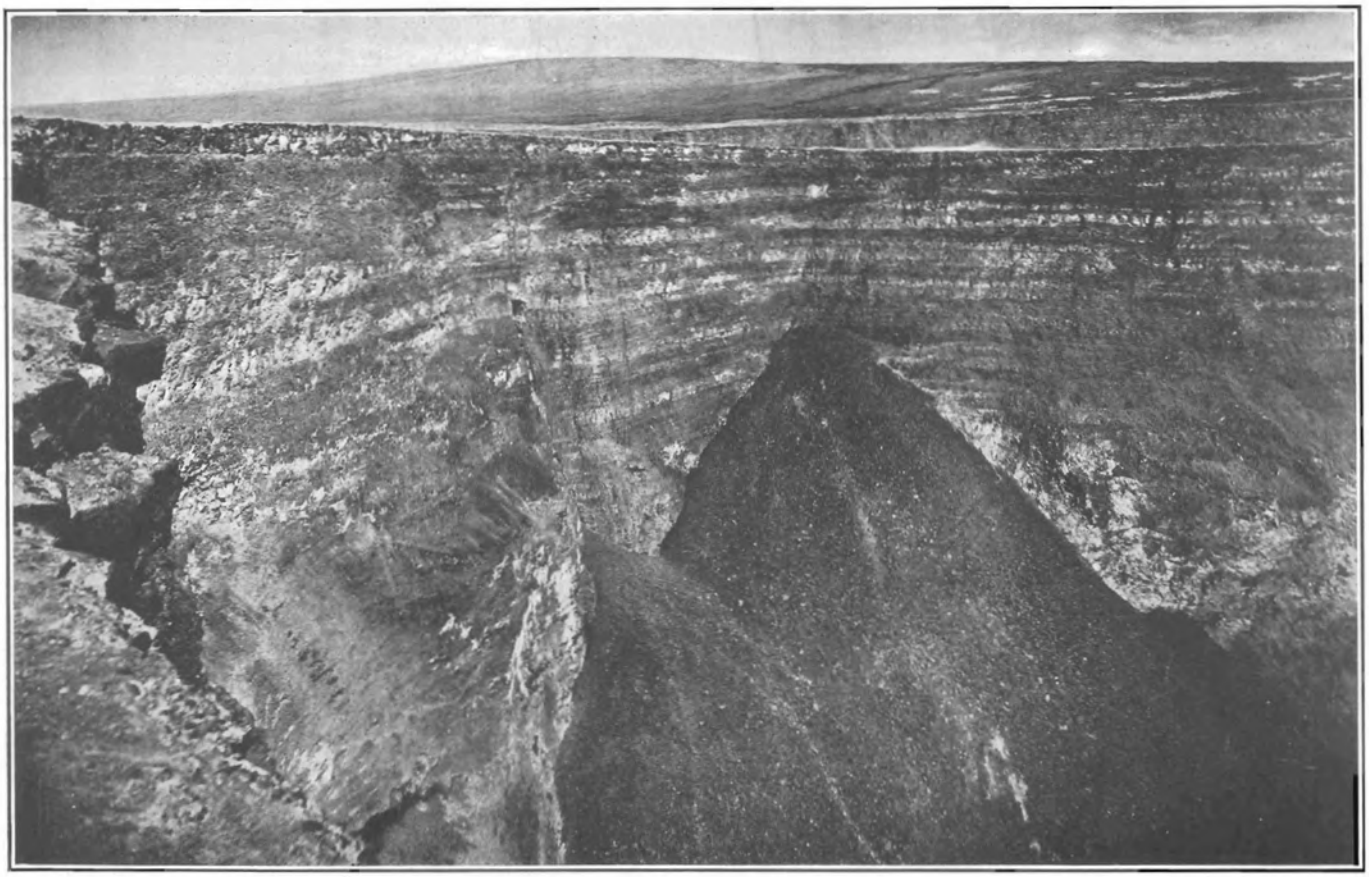


Map of Halemaumau, with twenty-foot contours, showing pentagonal form and star-shaped peaks of the big talus conoids at the five angles of the pentagon.

THE WALL PLANES OF HALEMAUMAU

There is much evidence in the manner of eruption of the lava pits of Hawaii to prove that these pits, although apparently circular, are really guided by definite upright planes. This applies equally to the large sink craters, like Kilauea and Mokuaweoweo, and to the small pits, such as Halemaumau or Makaopuhi. It is clear enough, from an inspection of the map, that the Chain of Craters extending to the southeast from Kilauea, is on a curved line, and this curved line must be guided by some geometrical echelon of cracks, if not a single crack. The outstanding event of the last twenty years at Halemaumau, which



Angle between southwest and south walls of Halemaumau showing the big west talus and Mauna Loa in the distance. Photo Wilson.

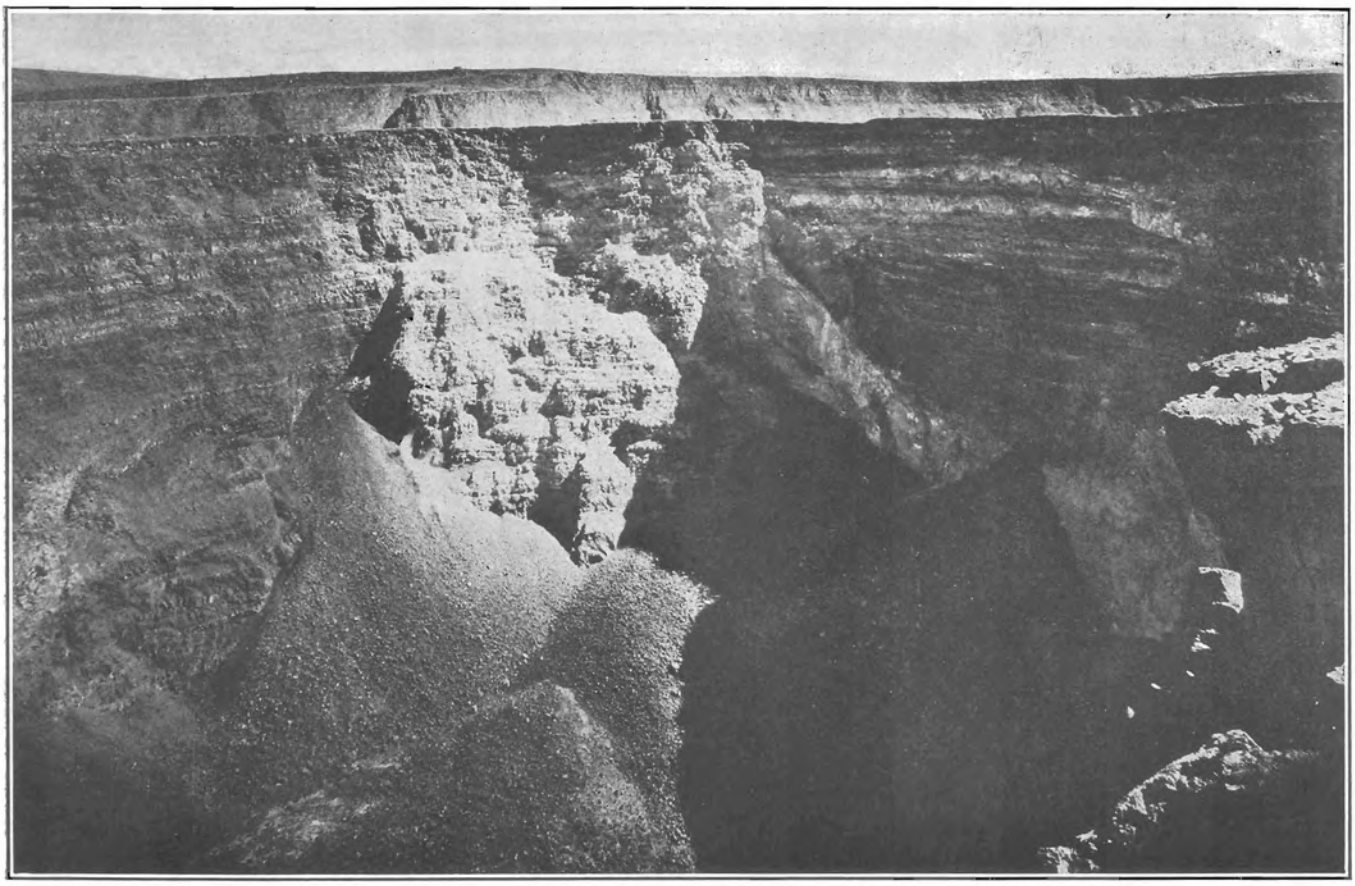
proved connection between a deep crack in the mountain and the opening of the pit, was the cracking open of the southwestern desert flank of Kilauea in 1919 to make a flow, and the visible drainage of Halemaumau at the same time through an upright crack in the wall of the pit (see the two black caverns in southwest wall, map on Page One above).

This map was made in July, 1928, with much care, and reveals a five-sided cauldron, with well marked angles between the five sides, and the light shade of open contours rising into a point at each of these angles indicate the peaks of conical talus slopes. In between these taluses there are rock walls. Four of these walls are fundamentally important planes in the mechanism which has generated the pit. These are the ones northeast, northwest, southeast and southwest. The fifth side is the north wall (Page Three), a remnant buttress between two gulches which are tending to join behind it at the extreme north corner of the map. That buttress has been undermined by avalanches right and left for years past, and threatens some day to fall into the pit and make a big avalanche, which would leave the pit four-sided.

If the reader will consult the outline map on Page Four, and there study the shape of Kilauea Crater, within the floor of which Halemaumau is an inner pit, he will find that the larger sink is also five-sided, with the two longer dominant walls northwest and southeast, and two shorter end walls northeast and southwest. Here also at the north there is a cross wall between the Volcano House and the Military Camp which is backed by the Sulphur Banks platform, an ancient remnant of a former crater floor, which if removed, along with the downfaulted Byron's Ledge, would leave the crater four-sided. Byron's Ledge is the triangular piece separating Kilauea from Kilauea Iki. It is thus clear that the outline of Halemaumau is a miniature of the outline of Kilauea, and both have their longer axes in a northeast-southwest direction on an extension of the 1920 rift. This rift is a deep fracture in the mountain, which has given vent to many lava flows off to the southwest.

The appearance of the Halemaumau walls is clearly shown by the photographs on Pages Two and Three. The picture on Page Two shows the great western talus with the western angle of the pit above it, a small talus cone adjoining it on the left, and this immediately below the rift caverns of 1919, and on the extreme left the south angle of the pit. Here are shown three of the wall planes, the ragged edge of the left hand foreground being part of the southeastern wall.

The picture on Page Three exhibits the north wall of the pit in bright sunlight, with a talus on each side of it, and this shows what is meant by referring to that wall as a lumpy buttress likely to fall away and leave a single angle behind it where the northeast and northwest walls meet. These two wall planes are shown right and left, the right hand one exhibiting the great white sill with a talus athwart it in the shadow, while in the foreground on the right is seen a craggy bit of the southeastern wall.



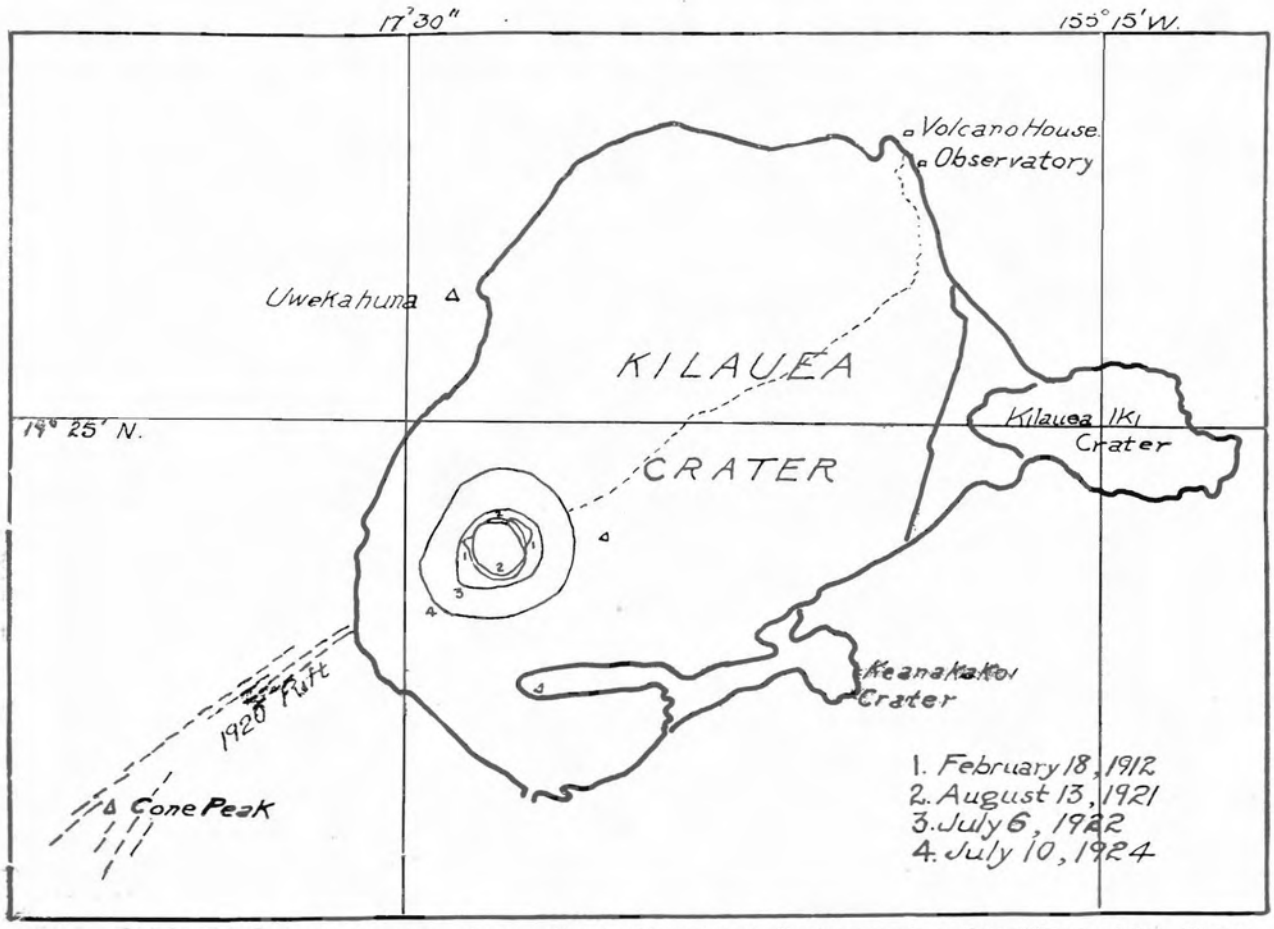
North wall of Halemaumau showing north and northwest taluses and protuberant buttress at north corner of the pit. Uwekahuna bluff in background. Photo Wilson.

Now if we go back to the map of Halemaumau, there will be seen across the bottom of the pit four small circles in a NE-SW line, which line if extended coincides with the rift tunnels at the southwest, and with a dyke or fissure filling which extends up and down the northeast wall (see upright line athwart the great sill on the right of the talus in the shadow in cut on Page Three). These bottom vents lay along the crack which opened in the bottom of Halemaumau July 7, 1927, the southern one building up into a big cone. A huge landslip from the north fell on the floor which was left January 11, 1928, and apparently cracked the floor in a semicircle around the lobate front of the landslip so as to let fresh lava ooze up and well out in a short-lived eruption. The fundamental crack of 1927 was approximately parallel to the northwest wall of the pit, and also to the northwest wall of Kilauea Crater. We may conclude from this that when Halemaumau revived after three years of repose, the deep rift which guided the revival was the great southwestern crack. And this great crack, in the original downbreak that formed Kilauea Crater, guided the production of the northwest and southeast walls of that crater.

The map on Page One shows that the northwest and southeast walls of Halemaumau have comparatively gentle slopes toward the center, and in plan they tend to converge toward the southwest. The northwest and southeast walls of Kilauea Crater (Page Four) also converge in plan toward the southwest. Apparently the great southwestern rift tends to have its cracks fan out or diverge in the direction of the rounded dome of the summit of the mountain and this is what has shaped the breaks which have determined the longer axis of both inner and outer craters.

All of the activities of rising lava in the pit since 1924 appear to have been controlled largely by the southwest rift. The big lava cone of July, 1924, was at the base of the western talus. The line of active vents of February, 1929, was at the base of the northwestern talus. The line of activity of July, 1929, was again at the base of the western talus. The surface fractures in each of these cases were doubtless determined by the breaking of the cake of lava left in each case at the bottom of the pit by the next preceding eruption. But there is no evidence in any of these outbreaks of lava that the northeast and southwest walls lay parallel to the crack which ruptured under the pit in order to permit the extrusion of lava.

The northeastern and southwestern wall planes of Halemaumau have very different quality from the walls of the pit which lead to the southwestern rift. They lie right athwart this rift and they are almost vertical down to the places where they join the talus. (See left wall, Page Two and right wall, Page Three). In plan these two steep walls also tend to converge, and this time it is to the southeast that the convergence points, which would take us to the Chain of Craters in Puna District off beyond Keanakakoi and Kilauea Iki. This is the second great flow rift of Kilauea mountain, and the two walls northeast and southwest of Kilauea Crater also trend in that direc-



Outline of Kilauea Crater and the stages in growth of Halemaumau pit as mapped on four different dates. Shows control of longer axis by southwest rift.

tion, as though the Chain of Craters rift tended to fan open into several major cracks as it approached Uwekahuna, the summit of the Kilauea dome (see Page Four).

If now we imagine the primitive Kilauea dome covered with lava flows from a summit well at the height of the top of Uwekahuna bluff and over the middle of Kilauea Crater, it appears likely that the flank of the mountain fractured and let out floods of lava southeast and southwest. When this period of big flooding ceased in prehistoric times, the top of the mountain tended to cave in about the meeting points of these two sets of rifts, each of which tended to finger apart and to cross each other at the summit region. This crossing of convergent southeast and southwest cracks determined the polygonal outline of Kilauea Crater as a sink, and it in turn determined the polygonal outline of its inner pit as a secondary sink.

T.A.J.

KILAUEA REPORT No. 964

WEEK ENDING JULY 13, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

There are very few changes to be reported at Kilauea Volcano. The sulphur area on the south floor of Halemaumau remains whitish and appears to be spreading slightly. Steam vents within the pit remain inactive. On July 10 thin, light dust rose at 2:50 p. m. and at 3:25 p. m. Small rock slides at the north corner were observed July 11 and 12. The west wall has had additional dusting from small slides.

The seismographs recorded eight disturbances on the 7th, 8th, and 9th. Of these four were tremors of less than one minute each, and four were very feeble local seisms. Two of the latter showed distance phases of 14 and 18 miles from the Observatory. One was accompanied by tilt to the east. No disturbances were recorded after the 9th.

Tilt accumulated moderately NNE, with movement strongest to the north. Microseismic motion was slight.

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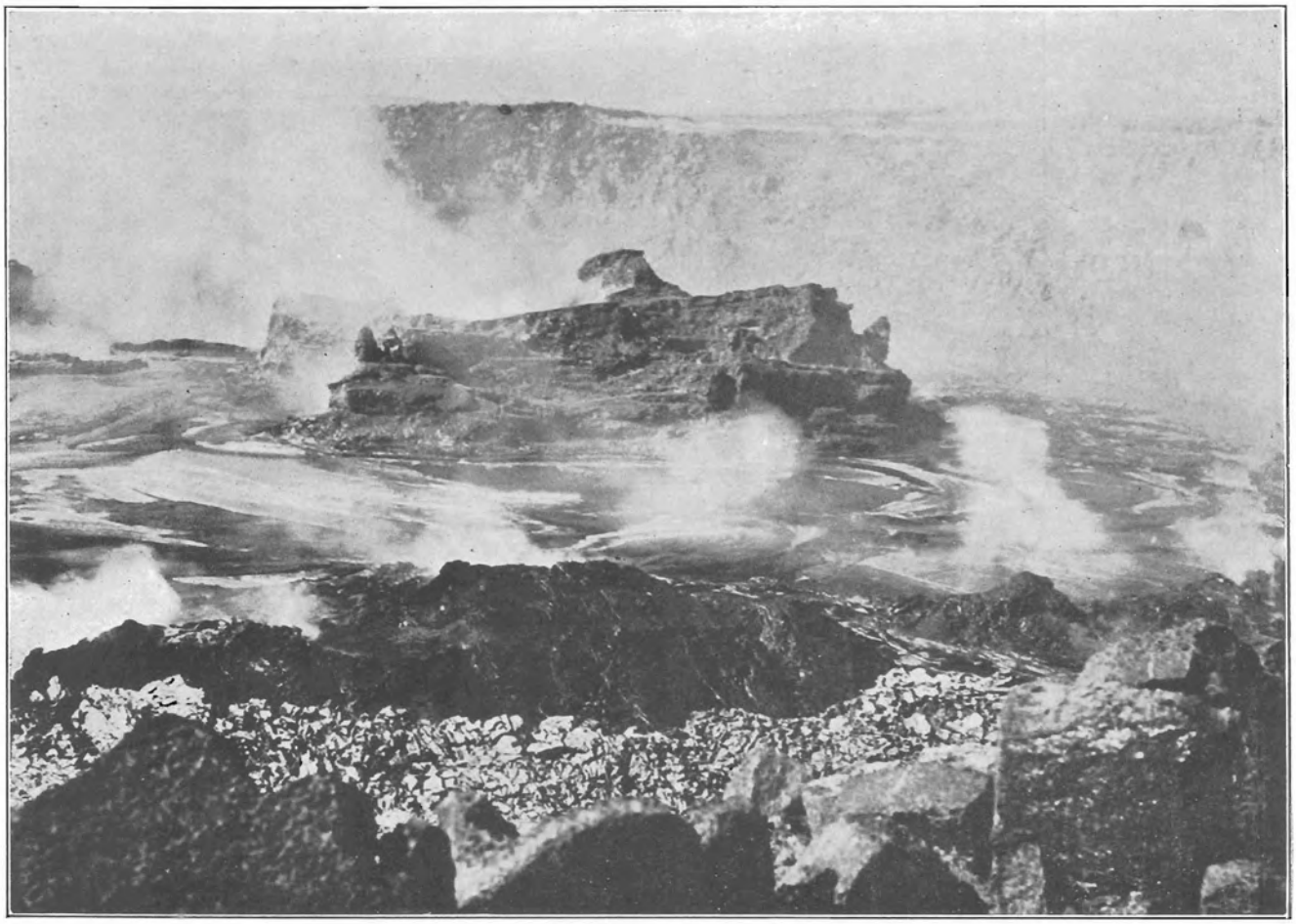
The Volcano Letter

Two dollars per year — Ten cents per copy

No 291—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — July 24, 1930



Rising lava lake and crag mass December 15, 1916, from northeast rim of Halemaumau. The several terraces on the crag mass are overflow benches which have slowly tipped up. A time of strong rising. Photo Jaggar.

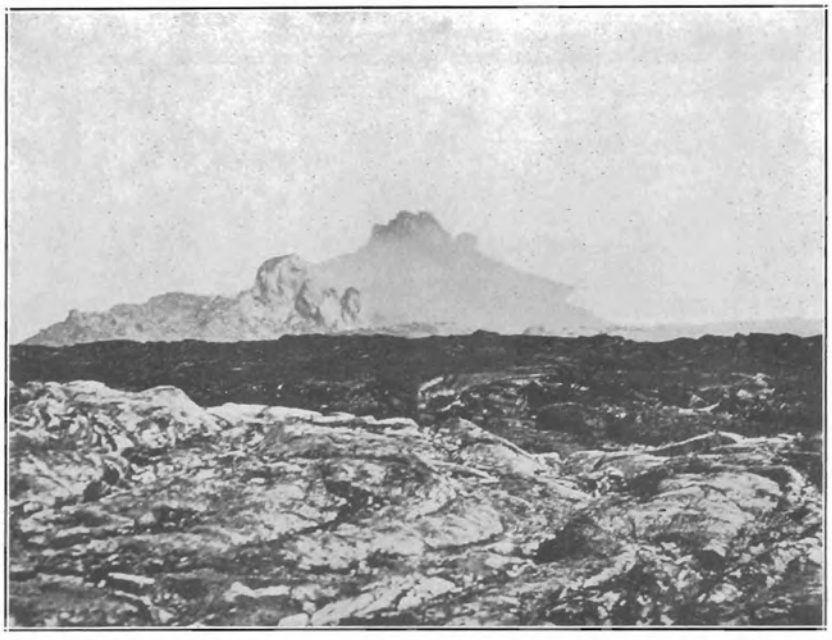
WHEN THE PIT LAVA RISES

To the observer on the brink of Halemaumau, that vast cauldron of the present day some 3,400 feet in diameter and 1,000 feet deep, the rising of the lava in the bottom is a very slow process. At present the bottom has shallowed more than 300 feet since June of 1924, but this has proceeded entirely by the building of layers in several eruptions in 1924, 1927, etc. The rising of the lava column in the bottom of Halemaumau becomes a continuous process very different from this piecemeal building of layers when the inpouring of the slag behaves as it did between 1914 and 1924. This was a real rise of the lava column, and the phenomena distinctive of rising lava are worth examining.

During the six years beginning with 1914 the top of the live lava in the bottom of Halemaumau pit rose gradually from a position 600 feet below the rim of the pit to the top, so that the rim was building up, lava flows occasionally poured over the rim, and other lava flows in great volume poured for months at a time up cracks a little way back of the rim. These last were just as much "overflows" as the spillings which crossed the actual rim of the pit. They equally were draining the pit lava, but by mechanism of internal expansion of lava gas which permits the fluid to well up small outlying cracks to higher levels than are occupied by the broad open effervescing lakes. The mechanism of lava overflow as contrasted with flank outflow has been reviewed in Volcano Letters Nos. 280 and 282.

The rate of rising during a big rising spell was thus approximately 100 feet per year, but this is merely the statistical result, for the actual risings were often much quicker, and the prolonged rising spell was interrupted by many sinkings of hundreds of feet, each occupying either a few days, a few weeks, or several months. Sudden subsidences of from 50 feet to 400 feet occurred repeatedly, and rapid risings averaging about 30 feet per month were common.

These risings of 30 feet per month were themselves



Halemaumau full of lava in September, 1918, showing lifted crags from the west. Observer is at level of pit rim. Looking across fresh flows dating from March, 1918. Photo Jaggar.

punctuated by risings and fallings of 10 or 15 feet from week to week, this being particularly noticeable at times when the curve of major rising tended to flatten out to a spell of relatively stationary lava preparatory for a temporary decline. The same thing was true of a stationary period at the end of a temporary decline, when the lava would fluctuate more from week to week than during a term of steady strong rising. There were times during the early years of work at the Observatory (and something of the same sort has been noticed for earthquake frequency during recent years) when the observers thought they detected a periodicity of three weeks in the fluctuations.

The most rapid rise ever recorded at the Observatory was during the month following November 28, 1919, when both liquid lava and crag lava rose 30 feet a day, making the crag lava into a ring-island as recorded in Volcano Letter No. 282. Excessively rapid rising of this sort is accompanied by unusually strong effervescence of gas, implying an exceptional release of pressure on the underlying magma. In this particular case, Mauna Loa had just finished an eruption, its underground lava had presumably sunk back into the depths, and this in connection with the Kilauea lava had released pressure by causing an enormously rapid subsidence of the Kilauea lava column of some 400 feet in two hours, which was immediately followed by the rapid rising above referred to. Such happenings as this lead to the inquiry, "What makes the lava column rise at all?" This in turn leads to a second query, "Is the sinking of lava an exact reversal of the process that makes it rise?"

These are very pregnant questions. What Dana called the "ascensive force" in lava has been a subject of much controversy and much doubt. This was because the early observers of the Mauna Loa lava fountains describe them as glistening jets like molten metal ejected hundreds of feet into the air, and these observers did not perceive that they were impelled by gases. They were looking for steam, the traditional gas of the Italian volcanoes, and when they saw no steam condense, they inferred that the spouting must be hydrostatic. To get hydrostatic spouting in a molten slag free from gas, on the top of Mauna Loa 13,000 feet above sea level, it was necessary to imagine expanding forces within the liquid itself, or else to imagine a pressure on the reservoir deep under the mountain such as might be produced if blocks of the earth's crust were settling on top of the liquid.

All of this presumed liquidity for the underground lava as a matter of course, and such an assumption created great difficulty if one attempted to connect Mauna Loa with Kilauea hydrostatically. If Kilauea were open at 3,500 feet elevation, necessarily it ought to drain Mauna Loa if the two were connected. Both were open at times and erupting together, yet Kilauea did no draining. Therefore, so ran the argument, the two are totaly unconnected. William Lowthian Green combated this, and insisted that the two show a sympathy of alternation of eruptions.

These difficulties disappear when lava is understood to be a dense glass at high temperature, with many times its volume of hydrogen, sulphur and carbon gases dissolved within it. Deep in the cracks under the mountains this glowing gas-charged glass is so compressed as to be almost a solid. In such condition it may be thought of as an enormously expansible and combustible paste. If Nature pulls apart the crack which it occupies, the gases puff it

up like beaten foam. If the gases thus by release of pressure unite in bubbles, they mix with air and burn. If they burn they heat the foam more than before and make the mass more liquid. Greater liquidity means more mobility and a foam pressure capable of opening cracks and doing work like a steam engine. But here we have rather a chemical engine, a multiple expansion engine and a heat engine all combined in one. This engine is dependent on Nature for cranking it, and for supplying the gas-charged glass, or "magma." Given an age-long supply of magma up the cracks, and a systematic self-starter which will pull the cracks apart once in so often, and volcanic eruptions will result.

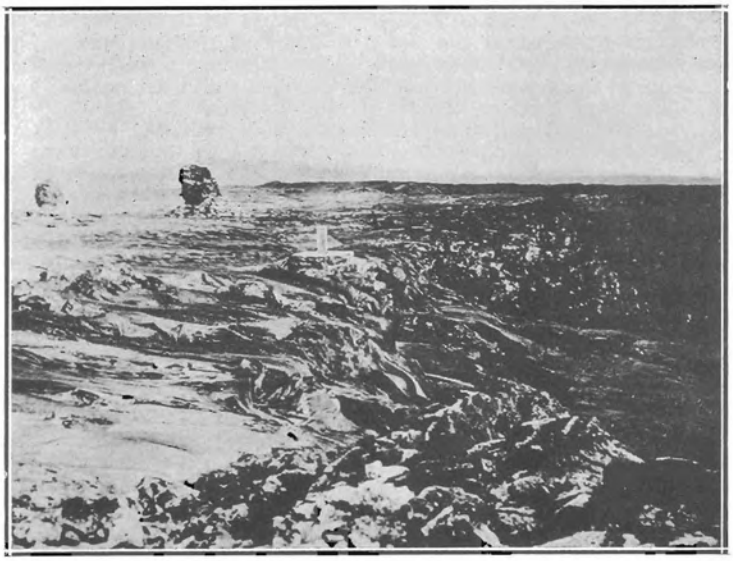
The supply of magma in Hawaii and similar basaltic volcanoes is unquestionable; it builds new layers of land and new promontories in the sea, and swells up the islands by intrusion. It makes the island ridge bulker than it was before. Probably this is at the expense of the sea bottom round about, which may sink proportionately lower than it was before. If so, the magma is the matter of the primitive substratum of rock-forming glassy paste under the crust 30 miles down. It is eternally rising until the ridge of its own building becomes so massive that its weight balances the downsinking blocks of sea floor. Then and then only will volcanic eruption become "extinct."

After outpouring of lava ceases, intrusive irruption of lava in cracks and among strata may continue and swell the country and heat the springs, long after the volcanoes have ceased to give vent to lava. This continuity of internal activity ought to be measurable on the surface of the country, if we study changes of the plumb line, changes of elevation, relation of these to earthquakes, and changes of temperature and composition of hot springs. There is little sense in laboriously studying things like earthquakes and hot springs unless we study them IN RELATION to something. These time and change relations are worth while. There is no fixed observatory in the hot spring belt north of San Francisco to tell us how the ground changed its tilt, and how the ground-water changed its salt content, its temperatures, and its flow after the great earthquake of 1906.

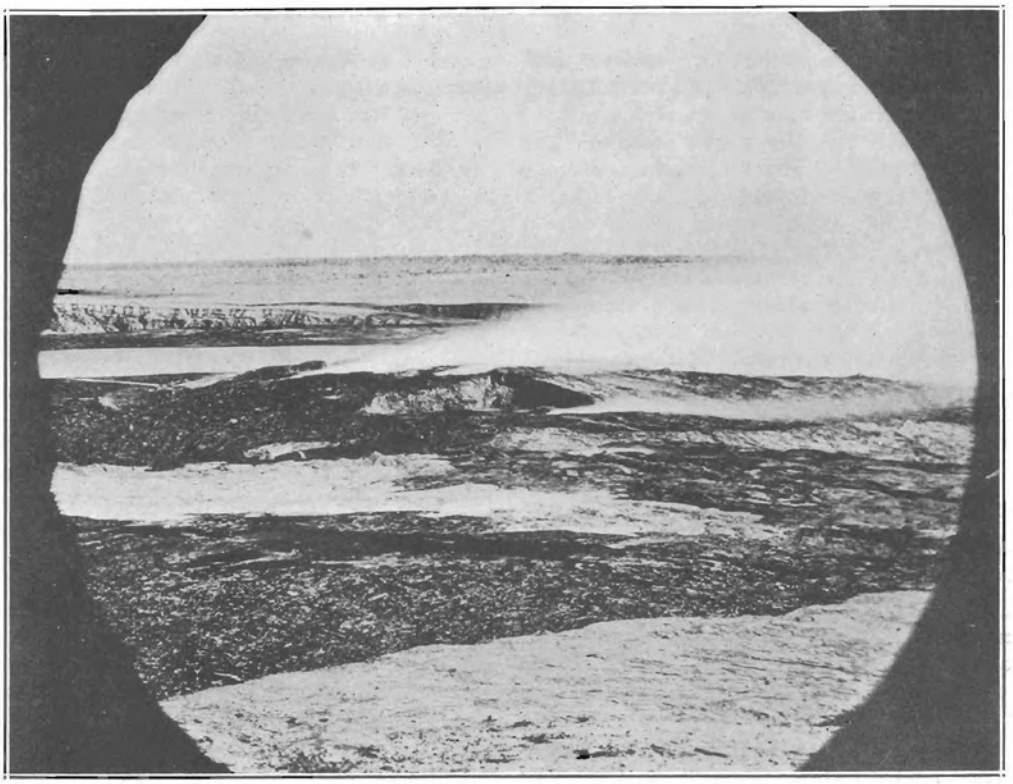
But what is the systematic self-starter that makes lava rise? In 1924 in Hawaii the "eruption" came to an end. Lava immediately reappeared in the bottom of the pit. It froze there. In 1926 it reappeared in great force on the top of Mauna Loa. In 1927, 1928, and 1929 it reappeared mildly in Halemaumau. In the autumn of 1929 its intrusion shook up Hualalai. Perhaps after all nothing came to an "end." Perhaps after all the engine is always running and Nature puts her foot on the accelerator rather than on the self-starter. Her accelerator is any force that will pull the trigger to ease the pressure on the gas-charged paste.

There are the crust blocks of the sea bottom acted on by centrifugal force as the globe whirls. There are the changes in that force as the sun and moon make tides in the earth itself. There is the greater diameter of the equatorial protuberance of the globe, acted on angularly by these forces. There is the cracking down of the great Hawaiian ridge along its old fault or rift planes as the lava flows drain its reservoirs, or fracture it with steam blasts, or upset its water drainage, or settle its crater wedges, or weight down its flanks. The "yielding of the edifice," as an engineer would say, is probably the most potent control of the accelerator, and a cone would not build itself in a circle without a geometrical law of control of the vent by the arrangement of the structure. It is the final task of volcanology through the ages of man to discover this law.

T.A.J.



North rim of Halemaumau November 2, 1918, with floods of fresh lava pouring from an outside crack at a level higher than the lava lakes in the pit. These flows as shown were cascading inward to the pit on the right. Photo Jaggar.



Telephoto of Halemaumau May 9, 1919, from west bluff of Kilauea. Fresh overflows in foreground. The lava column was now topped with a swollen dome above rim of pit, punctured with lava lakes. Photo Jaggar.

KILAUEA REPORT No. 965

WEEK ENDING JULY 20, 1930
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Steam continues to be absent from the vents in Halemaumau pit. This may mean that the top of the Kilauea lava column lies close to the surface of the volcano edifice and thus dries up moisture seepage. Dry weather has been prevalent, however.

A large section of the east rim fell on July 15 at 10 a. m. This leaves the 14-ton bowlder of 1924 nearer the edge of the pit. Small rock falls on the north wall were noticed from time to time. Some slides southeast on July 19 were caused by visitors dropping rocks.

Thirteen seismic disturbances were recorded by the seismographs during the week, classified as follows: Six tremors, the longest having duration two and one-quarter minutes; six very feeble local seisms, two showing origin distance 23 miles from the Observatory and one showing 14 miles; and one teleseism which registered faintly at 12:41 p. m. July 14. No disturbance was perceptible.

The net accumulation of tilt was very slight SW. Microseismic motion was slight.

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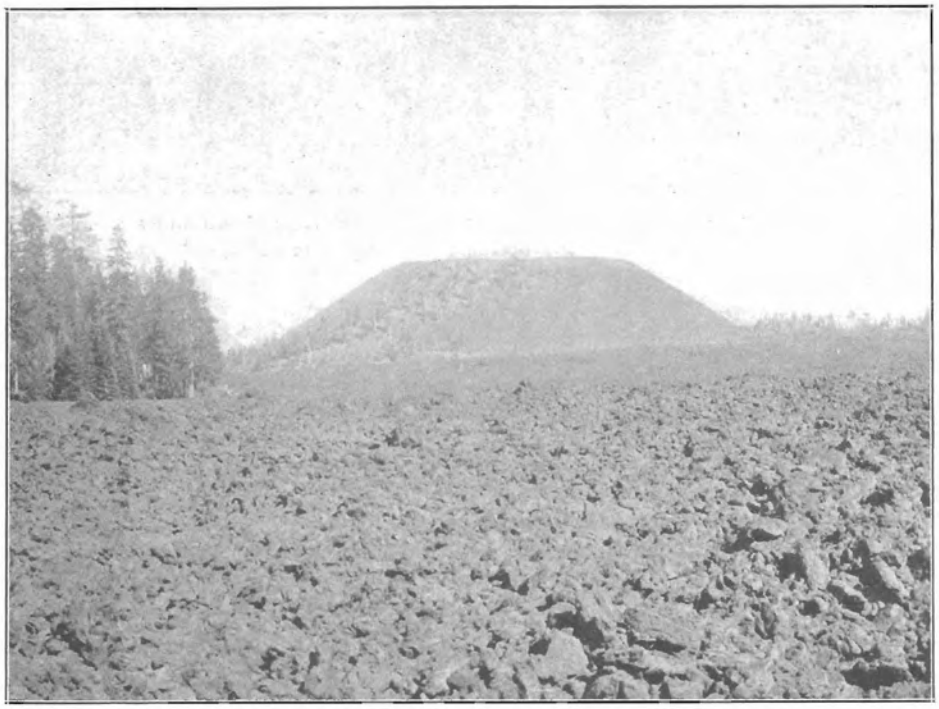
No. 292—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | July 31, 1930



An aa flow of basaltic lava and the cinder cone associated with it called Burnt Lava Flow. Photo Powers.

THE GLASS MOUNTAINS OF NORTHERN CALIFORNIA

Among the legends of the Modoc Indians of northern California are stories of an ancient time when their hunting grounds trembled beneath their feet, when the silence of the forest was broken by strange thunder, and the mountains around their Medicine Lake were lighted up by unearthly fires. Today, the presence of a number of flows of fresh looking lava and mountains of pumice in this area suggests that the Indian legends describe the last activity of a small volcano. Medicine Lake, in the heart of this region of recent volcanic activity, is located north of Lassen Peak and about 30 miles east of Mount Shasta in northern California.

This interesting volcanic region may be easily reached by automobile from Shasta City, California. Since it lies within the boundaries of the National Forest Reserve, one must first obtain permission to build fires in the forest from the Forest Supervisor at Shasta City, who also makes sure that every automobile in the party is equipped with a shovel and an ax as a rough and ready fire control. This is a regulation passed for the protection of public property and is very rigidly enforced. On one occasion two prominent government officials were ordered out of the National Forest because they had failed to equip their car with an ax and shovel.

Leaving the Pacific Highway near the city, one passes over a long ridge built up by lava flows from Mount Shasta. The flows are of great age and their surface is mantled with a rich soil which supports a luxuriant growth of pine and fir. The road soon drops down into the valley of the McCloud River and passes through the flourishing little lumber town of McCloud.

A few miles beyond, the road becomes extremely dusty and many dead and dying trees are noticed in the forest. This is the country which was buried by a so-called mud flow from Mount Shasta in 1925. This mud flow was not of volcanic origin; in fact, quite in contrast, it was caused by a glacier on the high slope of the mountain. As the river of ice moved slowly down its valley, it ground up quantities of rock into a very fine powder called rock flour. At the lower end of the glacier, this rock flour piled up with unpowdered rocks and other debris to form a sort of dam called a terminal moraine. During a period of very hot weather in 1925, a great deal of the ice of



A flow of rhyolitic lava north of Medicine Lake, with a flat but rugged top and a nearly vertical flow front over 100 feet high. Photo Peacock.

the glacier was melted and this terminal moraine became so saturated with the water from the melting glacier that it became a huge pile of very slippery mud. It immediately began to slide and the slope of the valley was so steep that it became a veritable river of mud which flowed for several miles, burying the underbrush and piling up around the trunks of the forest trees in its path.

Soon after leaving the mud flow, the road begins a long, gradual climb up the gentle slopes of an old volcanic dome. This was built up by lava flows from a little satellitic vent on the eastern slope of the mighty volcano which formed Mount Shasta. After the lava stopped flowing from this little volcano, the top of the dome began to settle and a circle of cracks was formed around the summit. If this settling and cracking had continued it would have yielded a large crater in the top of the dome very comparable to the large crater on the top of Kilauea. However, the sinking of the top was interrupted by another outburst of lava which issued from a number of places along the circle of cracks around the top of the dome. These numerous small eruptions built up a circle of cinder and lava cones which formed a crown upon the top of the older volcano. Futhermore, the crown of small volcanoes formed the rim of a large basin-like depression, which was filled with water to form a large lake. The water for the lake was supplied by the melting of many small glaciers at the end of the Ice Age. Since that time, the supply of water by ordinary rain and snow fall has not been great enough to keep pace with the evaporation from the lake, and the original large lake gradually decreased in size until it became the present Medicine Lake. Thus it is that Medicine Lake is located on top of a volcano and yet is not a simple crater lake.

Long after the end of the Ice Age, the old volcano took a new lease on life and broke out with many small eruptions on its flanks and its top. Those from its top emitted lava and pumice of rhyolitic composition. They are very rich in silica and low in iron and magnesia, contrasted to a basalt which is low in silica and high in iron and magnesia. While all of these summit eruptions happened much more recently than did the main eruptions of the volcano, they did not all take place at the same time.

The earliest of the late flows came out of a crack in the top of the volcano just north of Medicine Lake and spread out over a square mile of the old lake bed. The lava was extremely viscous and spread somewhat after the fashion of very cold tar. As a consequence the outer edges of the flow were maintained as nearly vertical walls over 100 feet high. Since the lava cooled, the rock has been broken a good deal by freezing and thawing and by the prying action of the roots of trees which grew on the flow. These broken blocks have fallen to the foot of the flow front and form talus piles which hide much of the original steep wall of the flow. However, the slopes are much too steep for safe climbing, especially in view of the fact that the lava is almost like a glass and breaks into knife-edged fragments. The photograph on Page Two shows the edge of this flow. It also brings out the fact that the top of the flow is very rugged. Broadly viewed, the surface of the flow is quite as flat as the surface upon which it spread, but in detail it is made up of a maze of crags and depressions. During the movement of the lava, the upper parts of the flow cooled quickly into a thick crust, but the lava beneath was so viscous that it could not flow quietly beneath this crust as does the Hawaiian basalt in a pahoehoe flow. Therefore,the movement of the flowing lava continually shattered the frozen crust and carried the blocks along on the surface of the lava stream. These blocks were titled and jumbled together, and when the flow ceased its movement and all of the lava consolidated, the blocks were frozen in the top of the flow in every conceivable position. It is this haphazard chaos of broken blocks which makes the top of the flow so rugged.

In the last phase of the summit eruptions, which is probably the one described in the Indian legends, there were both flows of lava and ejections of pumice. At one locality west of Medicine Lake and just outside of the cones which form the crown of the mountain, the explosions were so violent that they built up a mountain of pumice about 800 feet high. This huge pumice cone is the white knoll in the right background of the picture on Page Three. It is formed entirely of white and grey pumice in pieces ranging in size from that of small peas to that of a man's head. All of it consists of volcanic glass blown so full of volcanic gas bubbles that even the largest pieces will float on water.

Two of the lava flows of this last eruption are of

enormous size and thickness and form what are called Big and Little Glass Mountains. Both mountains are almost entirely devoid of vegetation. Big Glass Mountain lies to the east of Medicine Lake and its lavas cover more than nine square miles and are piled up in the center to a height of about 1,000 feet. It is not easily accessible, but it is actually only a larger model of Little Glass Mountain which is passed by the road into the lake. Little Glass Mountain is made up entirely of volcanic glass with the chemical composition of a rhyolite. The outer edges of the flows are very similar in structure to the edge of the older flow shown in the photograph on Page Two. The broken edges of the glass from this flow are even sharper than those described before. The lava of the Little Glass Mountain flow has frozen in a great many different forms. Much of the top of the flow is really a froth of volcanic glass and looks very much like a rubber bath sponge except that it is made of glass. At the other extreme, much of it is a dense, black glass which is called obsidian. This is the material from which the Indians made many of their arrowheads and cutting implements. Then between the two extremes can be found all intermediate stages, from obsidian with a few large bubble holes to bath sponge stuff with streaks of solid obsidian drawn through it.

The frothy top of the flows have been thrown into waves and troughs by the movement of the flows so that the surface of the mountain when viewed from the forest lookout on Little Mount Hoffmann presents somewhat the appearance of a lake of froth with ripples roughly concentric about the center from which the flow issued. This phenomenon is poorly apparent in the photograph of Little Glass Mountain on Page Three.

The many small eruptions from the flanks of the old volcano yielded lava and cinders of basaltic composition, very similar to the lavas of Kilauea. Most of the flows are small and incline more to the aa than to the pahoehoe surface texture. Over each small vent from which a lava flow issued was built a cone of cinders and slag. The small vents were so numerous and so close together that large areas of the mountain flanks are covered with rough basaltic lava and dotted with cinder cones. This broad waste land on the north flank is called the Modoc Lava Beds and formed excellent hiding ground for the small band of Indians which resisted a large force of American troops in the Modoc Indian War.

One of the youngest flows of this basaltic lava with its associated cinder cone is called Burnt Lava Flow and is located on the southeast flank of the mountain. It is so young that it supports almost no vegetation as can be seen from the photograph on Page One. Mr. Finch and a party from the Lassen Volcano Observatory are planning to determine if possible the exact age of this flow. Its eruption probably occurred within the last 500 years, though it is actually older than the pumice eruptions from the top of the volcano near Medicine Lake since little pockets of the pumic can be found on the surface of Burnt Lava Flow. H.A.P.

KILAUEA REPORT No. 966
WEEK ENDING JULY 27, 1930

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On July 21, after week end rains, steam reappeared on the south talus in Halemaumau. Still more steam was noticeable in the pit during rain on July 26. A few wall slides occurred during the week, notably one at 5:50 p. m. July 25. There was no change at the 14-ton bowlder.

An earthquake at 1:53 p. m. July 22 was felt generally all over the island, especially in North Kona. Workmen at the halfway house on the Mauna Loa trail were severely jolted. No damage was reported, but the shock was alleged to have been the strongest since the Hualalai series of the previous autumn.

The instruments recorded a total of 10 seismic disturbances for the week. Four of these were short tremors, five were very feeble seisms, and one was a moderate shock felt as described above. Its epicenter appears to have been in the saddle between Hualalai, Mauna Kea, and Mauna Loa. Two of the very feeble seisms were also perceptible; one at 3:10 p. m. July 22 at Paauilo, and one at 3:54 p. m. July 27 at Kapapala Ranch, Kau.

Tilt for the week was slight ENE. Microseismic motion was slight.



A birdseye view of Little Glass Mountain, built up of flows of rhyolitic lava. A mountain of pumice appears in the right background. Photo Powers.


NORTH KOHALA
SOUTH KOHALA
NORTH HAMAKUA
NORTH HILO
SOUTH HILO
HILO
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SOUTH KONA
NORTH KONA
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KAU
HAWAII NATIONAL PARK
KAU DESERT
MAUNA KEA 13,825
MAUNA LOA 13,675
SUMMIT 5505
HONOKAA
PAAUILO
OOKALA
LAUPAHOEHOE
HONOMU
PEPEEKEO
PAPAIKOU
HILO
HAENA
KAILUA
KEAUHOU
KEALAKEKUA BAY
HOOKENA
KAOHE
HOOPULOA
PUNALUU
KAALUALU
KA LAE
South Point
WAIPIO VALLEY
WAIMANU
KUKUIHAILE
KAWAIHAE
PUAKO
KIHOLO
West Point
Old Royal Fort
Rock Pictures
Cook's Monument
City of Refuge
Napoopoo
Honaunau
Pahoehoe
Kapopala
Ranch
Kaiholena
Halehaku Ranch
Rest House 10,060
Military Camp
Volcano House
Kilauea Crater
Bird Park
Tree Jungle
Lava Trees
Crater of Craters
Cave of Refuge
Kaimu
Kalapana Cocoanut Grove
Glenwood
Mountain View
Tropical Jungle
Hot Spring
East Point
Green Lake
Pohoiki
Heiau
Opihikao
Kamaili
Kehena
Wahaula
Heiau
Rock Pictures
Half Way House
Kamakaia
Keauhou
Pahala
Honuapo
Kaiohina
Pololu
Niulii
Kohala
Mahukona
Honoipu
Upolu Point
North Point
Meiau
Kawaihae
Puukohola
Ruins of Ancient Hawaiian Settlement
Kamuela
Parker Ranch
Puu Waawaa
Fantastic Lava Formation
Hualalai 8,269
Lanihaiea Cave
Old Mission
Waiuluulu Cave
Anaa Umi
Holualoa
Kainaliu
Keauhou
Kealakekua
Napoopoo
Heiau
Honaunau
Puu o Keokeo
Kiikiepepe
Hoopuloa
Kaiholena
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The Volcano Letter

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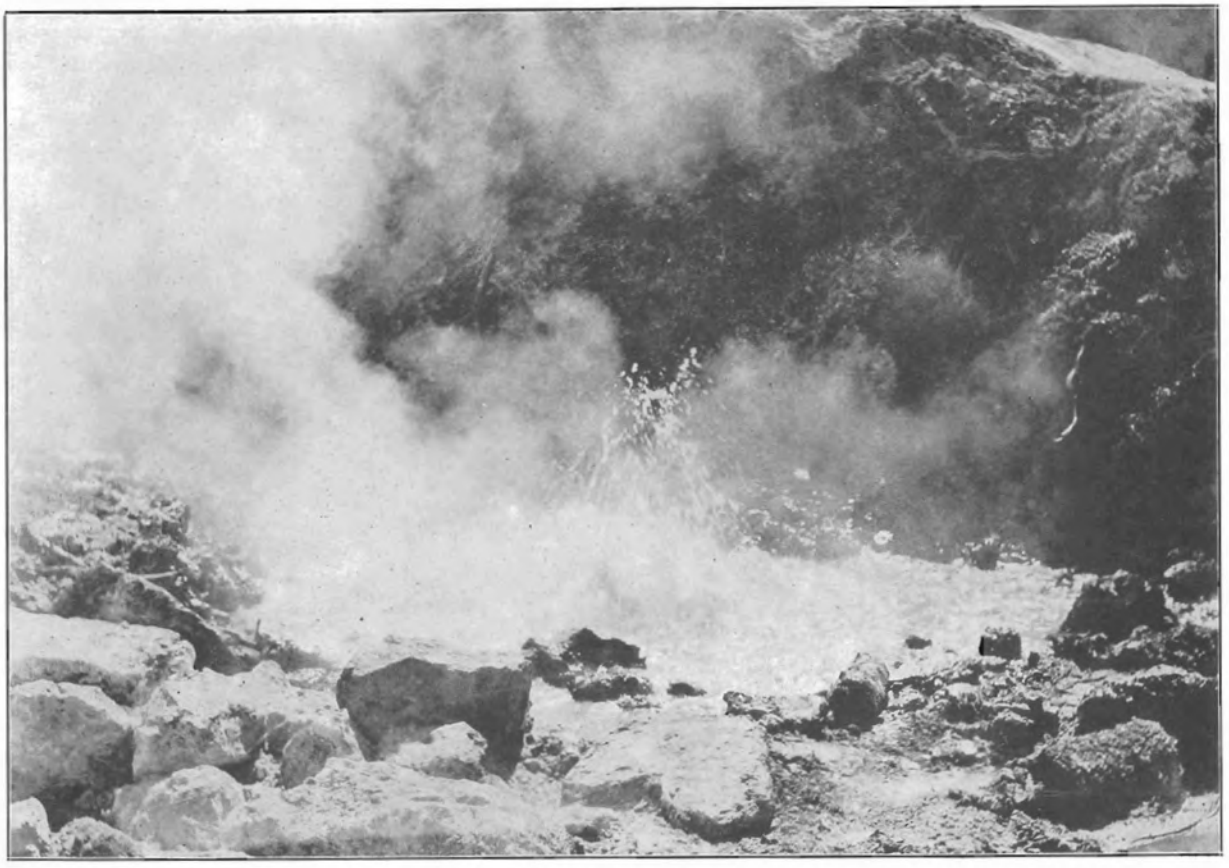
No. 293—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — August 7, 1930



A pool of boiling, solfataric water in Devil's Kitchen, Lassen Volcanic National Park, California. Photo Huff.

HOT SPRING PHENOMENA OF LASSEN VOLCANIC NATIONAL PARK

(From "Volcanic Activity and Hot Springs of Lassen Peak," by Arthur Day and E. J. Allen.)

Location

The springs are located mostly in Lassen National Park in northeastern California. Geologically, they are found in a region of thick lava flows, composed mainly of andesite and dacite, with a little basalt on the edges. The springs themselves are all found in the dacite areas. They occur on the line of faults between the Sierra Nevadas and the Klamath mountains. For the most part they are found on normal faults.

Number

There are about eight groups at intervals of a few miles, their allignment suggesting that they follow two intersecting fissures. A. and B.

Fissure A.

1. Geyser springs.
2. Boiling Lake.
3. Drake Springs.
4. Devil's Kitchen.
5. Bumpass Hell

Fissure B:

1. Mill Creek Springs
2. Supan's Springs.
3. Morgan's Springs.

Most of the work here discussed was done upon the Boiling Lake, Devil's Kitchen and Bumpass Hell, but the springs all seem to have similar characteristics.

Description

1. The Geyser: This is the principal spring of a group of three connecting pools, about 25 feet in diameter, the Geyser being the first. The temperature ranges from 20° C. to the boiling point, which is 94° C. Sometimes it spouts as high as eight feet, though it is often without action.

2. Boiling Lake: It has an oval basin of hot water. Its greatest diameter is 200 yards. The banks are steep for the most part, and it suggests its origin as the basin of an ancient crater. There is a small inlet of cold water at the south end, and a larger outlet of warm water at the north. Both of these become entirely dry in summer. Gas bubbles rise over the surface of the lake. The temperature is about 50° C. Much muddy sediment makes it appear shallow. Algae may be present. It is almost encircled by

a chain of small springs and mud spots, most of which are near the boiling point in temperature. Most of them are near the lake shore, but a few are farther up the slopes. The northern shore is red in color and composed of decomposed lava which has been dyed by iron oxides.

3. Drake's Springs: These are three-fourths of a mile north of the Boiling Lake. They differ in appearance from all of the others. They have a much lower temperature, the highest noted being 62°C. They are, probably because of this lower temperature, choked with bright green vegetation. They are all small, and the individual ones are not well marked. Their mineral content is similar to that in the other springs. but they contain no free acid, or H_2S.

4. Devil's Kitchen: Its site is a deep narrow valley, with a swift, cold stream, called Warner's Creek. The Kitchen, which is rather a flat area, is surrounded on nearly all sides by high steep walls. There is almost no sign of activity on these slopes, but there are many mud pots and hot springs upon the floor. There is no vegetation near them, but the area is forested elswhere. The temperature is about that of Boiling Lake, but the amount of the hot water indicates much greater thermal activity. The Devil's Kitchen also shows an area of precipitated sulphur, while there is almost no free sulphur at Boiling Lake. The Kitchen has many pools which are covered with pyrite as a thin scum, of dark material. The ground near Warner Creek is reduced by decomposition to a dangerous thin crust of earth over hot, sticky mud.

5. Bumpass Hell: This has a crater-shaped basin which is 500 by 1,400 feet in area. It is located high in the mountains, and has almost no vegetation. The thermal action is more concentrated, and the spectacle much more striking in appearance than the others. It contains many boiling fountains, sulphur springs, etc. The rocks are much decomposed at the surface, and the ground is undermined, and easily broken through. The pools are large in size and few in number. There is much free sulphur as a precipitate in some of the pools, and it is also found in needle crystals in many small fumaroles in the west. There are fewer mud pots here than in the Devil's Kitchen. The temperature is usually just below the boiling point, but one fumarole in 1916 gave a temperature of 117.5° C.

6. Supan's Springs: These cover a small area, and most closely resemble the Devil's Kitchen, but they are much smaller. The temperature range is like that of Bumpass Hell. There are many sulphates present, and previous to man's entrance much free sulphur, but this has much of it been removed, though there is apparently not enough present to pay the expenses of a real mine.

7. Morgan's Springs: These were not studied by this party, but the description of them has been taken from Waring. They occupy an area in a meadow, and are composed of quiet pools with a small flow, which are quite shallow and contain some algae, native sulphur, and deposits of calcium and silicon. There are also many chlorides present. The highest temperature is 95.6° C., thus showing the boiling point of springs at this altitude to be lower than that of the others.

Types of Springs

1. Hot Springs. The Lassen hot springs are of the solfataric type.

2. Mud pots. The characteristics of these are a limited water supply, large amount of heat, and no visible outlet. The mud itself may be the result of local chemical action, or may be transported.

3. Mud Volcano. This is caused by drying of mud pot to allow escaping steam to force out clods of mud which build up the cone.

Field Work

1. Maps were made.

2. Temperatures were measured by means of a thermometer in a brass cage. There was no great attempt at accuracy. Their findings showed that the variations in temperature were too great to be accounted for on the basis of change in barometric pressure.

3. Tests for H_2S with $Pb(C_2H_3O_2)_2$ paper showed that though H_2S was widely distributed, only small quantities were escaping from the springs. Also the rise of the gas was not uniform over the entire surface of a pool.

4. Rough litmus paper tests, later borne out by titrations in the laboratory, proved most of the springs to be either neutral, or slightly acid, only a very few being slightly alkaline.

5. Ferrous iron was also tested for at camp, and conclusions were that practically all the iron was in the ferrous form.

6. The amount of free acid was also determined in camp.

7. The water was then carefully bottled and sent to the laboratory.

Laboratory Conclusions

The water was found to consist of sulphates almost entirely, and to be practically free of Cl and Al. The Al present seemed to depend upon the acidity of the water, the greater the acidity the more Al. The springs had no ferric iron present at all, while Boiling Lake had no ferrous, being entirely ferric iron.

The volume of gases given off was found to be very small. The analysis showed the presence of CO_2, H_2S, CH_4, H_2, N_2, A, O_2, and the order of these as given indicates roughly the order of the amounts found.

Deposits of soluble salts are to be found about the springs at various times, though no one has been able to determine as yet just what causes them to appear and disappear when they do. These salts upon analysis gave tests for Al, Fe^{++}, Mg, Na, K. and So_4 in all cases, and for these additional ones in some cases: Fe^{+++}, Ti, Mn, Ca, Li, NH_4 H, S_3O_6. One case showed Cl. S was also usually present. (It is rather surprising that, if the statement that these springs showed the presence of NH_4 as salts is true, the gas analysis showed no NH_3 present in the water.)

Pyrites were found at Geyser, Boiling Lake, Devil's Kitchen, and Bumpass Hell. They were not looked for elsewhere.

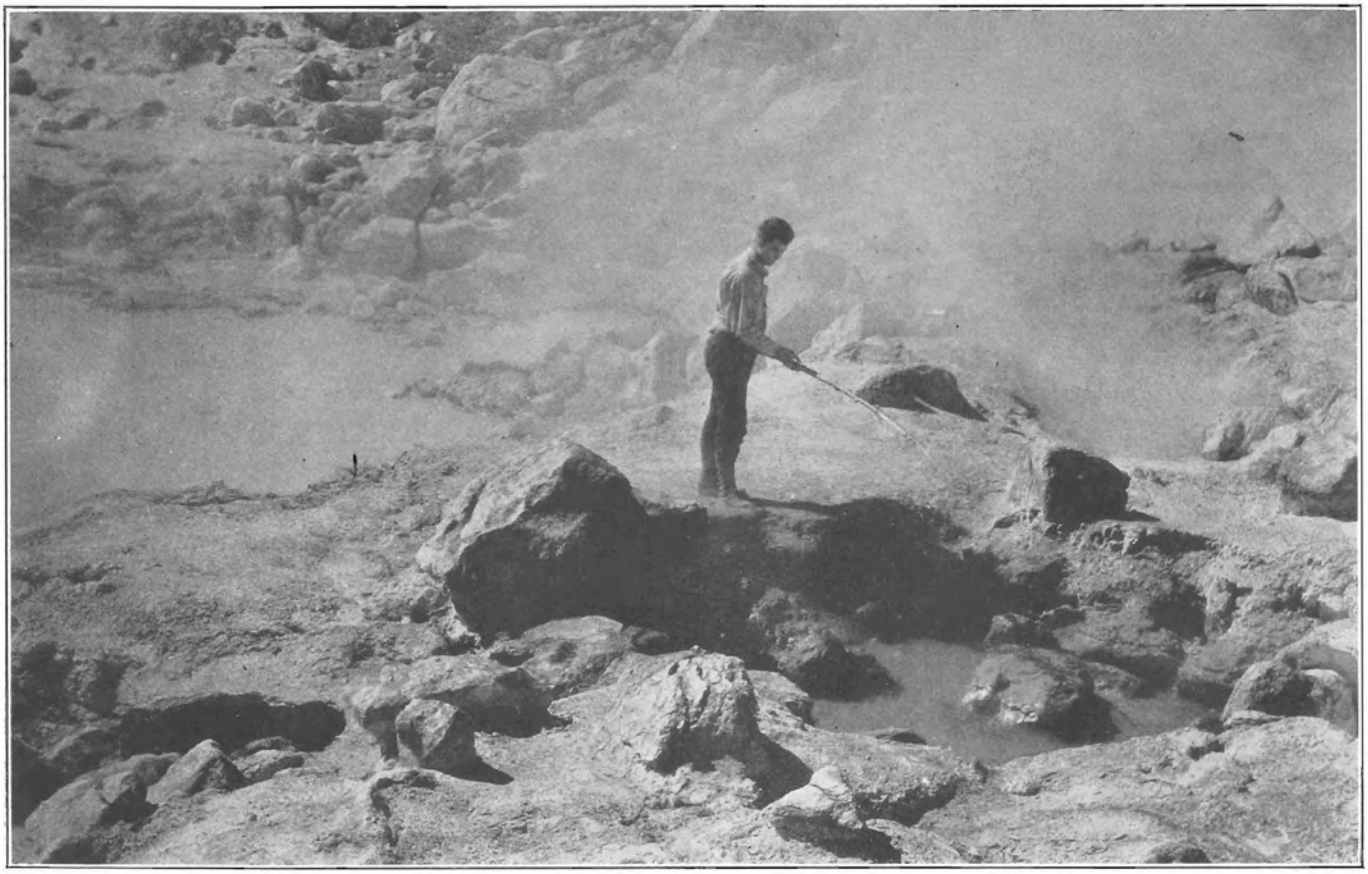
Chemical Effects

1. The formation of pyrite. Problematic, possibly from $FeSO_4$.

2. The formation of H_2SO_4. From S by oxidation. (Park—possibly from oxidation of pyrite.) (Bunsen—by oxidation of SO_2 and combination with water.) But this last would also produce H_2SO_3 and there is none at all present. There is evidence, however, that H_2S is directly changed to H_2SO_4.

Chemical Decomposition of Lavas

Silica is always the final residue. There are two types of reaction: (1) Those which produce kaolin and no $Al_2(SO_4)_3$; (2) those which produce silica and $Al_2(SO_4)_3$.



Method of taking pool temperatures by immersing thermometer in the scalding water. Pool at Bumpass Hell. Photo Finch, Lassen Volcano Observatory.

Pentathionate is probably the decomposition product of lava due to the action of SiO_2 and H_2S.

Original of Hot Springs and Their Relation to Igneous Activity

The heat supply must be great. Possible sources are

1. Radioactivity. This has absolutely nothing to do with it since it was shown that the cold water in the Yellowstone was slightly more radioactive than the warm.

2. Chemical Processes. This is a minor factor, and the reactions are not rapid enough or extensive enough to yield either a heavily mineralized water or much heat.

3. Volcanic. Therefore since the other possibilities have been proved false, the only possible explanation is that of heating by means of magma. That this is the fact may be proved by the location of these springs along cracks or fissures, and the fact that gases are emitted.

Conclusion

The conclusions reached are that the springs are fed chiefly by surface water, derived from precipitation, and that another portion of the water rises in the form of very hot water or steam, from an underlying batholith, which mingles with the other and thus heats it. This shows the close relation of the hot springs to fumaroles, and explains both the variations in temperature of the water and in size, and appearance on the basis of the amount of precipitation.

Hazel G. Robinson.

JULY TILTING OF THE GROUND

At the Hawaiian Volcano Observatory on the northeast rim of Kilauea Crater, the tilting or tipping of the ground in the seismograph cellar, expressed by overlapping seven-day means, in terms of angular change and direction of motion of the plumb line, was as follows:

June 30-July 6	0.60 second	SW.
July 7-13	1.09 seconds	S.
July 14-20	0.36 second	NW.
July 21-27	0.48 second	NE.

KILAUEA REPORT No. 967

WEEK ENDING AUGUST 3, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

No changes were observed at Kilauea Volcano throughout the week. Steam was absent from the interior of Halemaumau except a little seen on the south talus at 2 p. m. August 1.

In addition to three very feeble seisms recorded by the seismographs were 10 minute volcanic tremors, three showing tilt to the east during registration.

Tilt for the week accumulated moderately NNE. Microseismic motion continues to be light.



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The Volcano Letter

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No. 294—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — August 14, 1930



Front of the 1926 flow of aa lava from Mauna Loa as it crossed the government road above Hoopuloa. The resemblance to a pile of huge cinders is shown well in this picture. Photo Boles.

A REVIEW OF THE AA-PAHOEHOE QUESTION

(By G. L. CHANG)

Most of the lava flows at the basaltic vents of Kilauea and Mauna Loa in Hawaii assume surface forms known commonly to us as "aa" or "block" lava and "pahoehoe" or "ropy" lava.

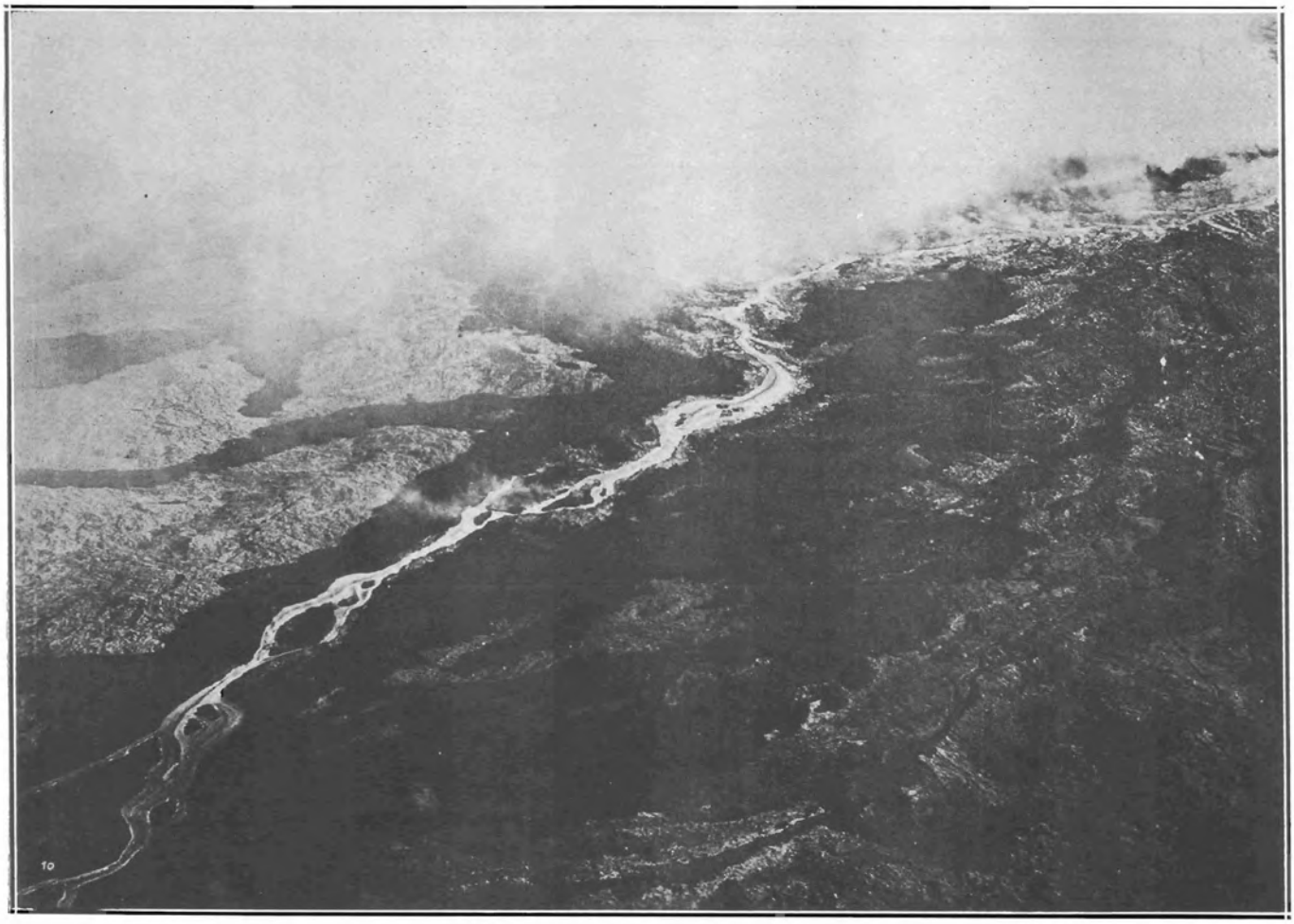
The rough aa surfaces are formed by material which is essentially crystalline, while the smoother pahoehoe surface is formed by a definite layer of glass. This glassy skin varies greatly in thickness; also in vesicularity it varies from a froth to an almost continuous solid. A surface that is not glassy is commonly more or less rough and aa-like, and not infrequently such surfaces are found in pahoehoe flows where cracking of the surface crusts has exposed crystallizing lava.

That there is no noteworthy difference chemically between aa and pahoehoe is generally accepted. The crystalline parts of a lava mass generally have a higher proportion of ferric oxide than the glassy ones, and the cause of the difference may be complex. A flow frequently starts as pahoehoe and changes to aa, but the reverse apparently never occurs, although in a great eruptive period like that of Mauna Loa in 1880 and 1881 the earlier discharges are dominantly aa and the later ones pahoehoe. In the transition zones the two forms are often intimately mixed, and, further more, hand specimens can be found having the glassy pahoehoe skin on one side and the rough features of aa on the other.

By several experiments it has been proven that the formation of aa is due to crystallization while the flow is in motion. When a given mass of lava has crystallized to the extent that it ceases to flow readily, and the forces acting on it are sufficient, it crumbles into loose blocks, some of which subsequently stick together giving the fantastic shapes so characteristic of aa. In the field, crystallization must frequently take place rapidly as the transition from a liquid stream to blocks of solid aa is often very short both in time and distance. However, if the flow is slower, allowing skins of chilled glass to form over the surface and if the force of the flowing lava is insufficient to break them, pahoehoe is formed.

The flank eruptions of Mauna Loa start with giant fountains which pour out enormous and rapid streams of lava. They may flow a short distance as pahoehoe, but usually soon change to aa. The Alika flow of 1919, which broke out from the southwestern flank of Mauna Loa at an elevation of about 8,000 feet, was fed by a series of fountains some 200 feet high, and the lava which cooled near the source was a glassy and frothy pahoehoe. Farther down, the lava flowed in a definite channel at a rapid rate, and where it crossed the government road in Kona 10 miles from the source it was still intensely hot and liquid. At times the stream rose and overflowed its banks and the resulting flood cooled as aa. Dr. Jaggar, who observed all this, said that at no time was there any tendency to form glassy pahoehoe skins. A thin section of some of the lava, collected where the main Kona road now crosses the flow, contains about 10 per cent of phenocrysts (large crystals), chiefly feldspar, enclosed in a matrix made up largely of glass (lava which has frozen too rapidly to crystallize). This composition indicates that comparatively little crystallization had actually taken place before the overflow.

It is in the declining phases of the Mauna Loa activity that most of the pahoehoe is formed. Crusts form over the lava until the stream of liquid lava flows continuously in tunnels and so may flow for long distances without los-



Airplane view of Hoopuloa flow of April 18, 1926, showing the incandescent lava stream flowing through a field of aa already frozen from the same flow. Transition from pahoehoe to aa lava is shown in the upper right. Photo Eleventh Photo Section, U. S. Army Air Service.

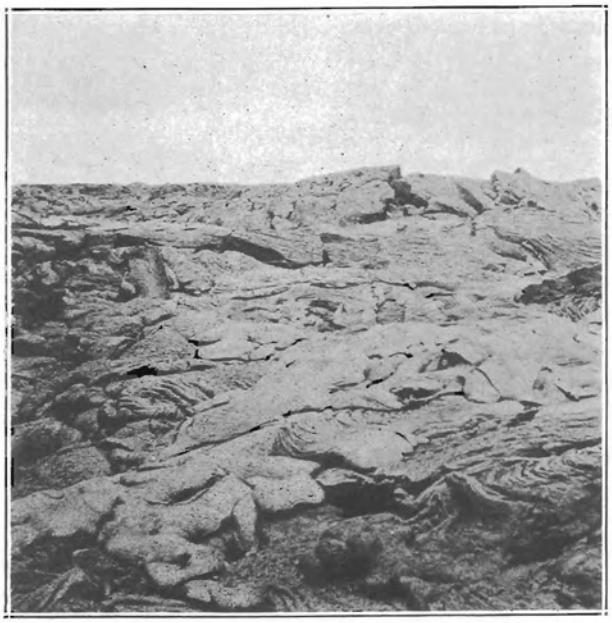
ing much heat. The flow advances by pushing out bright toes along the edges, which flow gently compared with a raging torrent like the Alika lava river.

In Kilauea crater there is little aa. Most of the overflows of Halemaumau have spread out over the gentle slope in large sluggish sheets or have been the thin shelly variety without any body. However Dr. Jaggar has observed several times that when the lakes in Halemaumau are drained, the bottom is covered with aa.

The eruptions from the flank of Kilauea in 1823 and 1840 appear to have been similar to the Mauna Loa outbreaks and much aa was produced. A significant feature of the 1823 flow is that the change from pahoehoe to aa took place just as the lava reached the edge of the gentle slope upon which it was discharged and started down a much steeper incline. An excellent record was kept of the 1920 flow which was probably the greatest discharge from Kilauea during historic time. The main activity took place some six miles southwest of Halemaumau where there was a rapid and voluminous flow which in a very few days travelled six miles. The extreme upper part of this was pahoehoe, but farther down it quickly changed to aa. Subsequently this vent poured out a series of short pahoehoe flows which built up a broad low dome. The summit crater behaved very much like Halemaumau with its bubbling and fountaining, and all of the flows from it were pahoehoe. Occasionally the flank of the slag heap was ruptured, discharging a mass of aa which resembled a landslide more than a flow.

An attempt was made to see what differences there are in the crystallinity of pahoehoe interiors and aa. Accordingly thin sections were made of representative types of lavas from the flows of 1868, 1887, 1880, 1881, 1907, 1919, and 1920. There was also a sample of aa from the bottom of Halemaumau which was exposed in May, 1917. This brief study indicated little tangible difference between the two.

It has been suggested that gases dissolved in the melt, of which water is the most abundant, are important agents in controlling crystallization and the formation of aa and pahoehoe, the theory being that aa is formed from lava containing and releasing the greater quantity of gas. Concerning this view, Dr. Jaggar said, "I know of no quantitative proof. Flames about aa are very apt to be due to



Toes of pahoehoe lava advancing slowly in the Mauna Iki flow of July 23, 1920. Kau Desert, near Kamakaia. Photo Jaggar.

burning vegetation. Pahoehoe crusts over so much that it confines its gas rather than gives it off. Pahoehoe pools remote from the source region often form blowing cones with flames at the orifices. Live streams of both pahoehoe and aa show bubbling, the former making blisters or small fountains, and the latter, occasional heavy, viscous bursts." In vesicularity, both aa and pahoehoe vary within wide limits, but the total volume of vesicles in aa is inclined to be less in a unit volume of rock than in pahoehoe, and the individual aa vesicles are inclined to be more irregular in both size and shape.

References

O. H. Emerson, The Formation of Aa and Pahoehoe, Am. Jour. Sci. 12, 1926, pp. 109-114.

H. S. Washington, The Formation of Aa and Pahoehoe, Am. Jour. Sci. 6, 1923, pp. 416.

T. A. Jaggar, Aphrolith and Dermolith, Jour. Wash. Acad. Sci. 7, 1917, pp. 277-281.

R. A. Daly, Igneous Rocks and their Origin, 1914, p. 290.

Monthly Bulletin of the Hawaiian Volcano Observatory, Oct. and Nov., 1919.

KILAUEA REPORT No. 968

WEEK ENDING AUGUST 10, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

To the casual observer, there have been no important changes in the appearance of Halemaumau during the week August 3 to August 10. Some new scars left by small rock slides were noticed on the north and east walls on August 5, and the steaming from the wall and talus cracks was slight during the early part of the week. During the heavy rain of the week-end intense steam clouds rose continually from the pit and from the cracks of the Kilauea floor.

However, the instrumental records show a number of interesting features. Two feeble earthquakes, one at 8:52 a. m. August 5 and one at 11:14 a. m. August 8, were felt in the National Park area. The center of the first was located 9 miles from the Observatory and that of the second was located at Kilauea. There were three very feeble shocks which were not felt in the Park timed as follows: 10:03 a. m. August 4 distance 14 miles, 3:09 p. m. August 8 distance not known, and 5:50 p. m. August 9 distance not known. There were several small tremors recorded (each lasting a fraction of a minute), with more of them showing on the two instruments close to Halemaumau than on the instrument at the Observatory which is nearly two miles from the pit. This would seem to mean that the feeble tremors had their origin in or under Halemaumau. They were recorded as follows:

Date	Observatory	Uwekahuna	Pit
August 4	1	2	2
August 5	0	7	5
August 6	2	2	2
August 7	0	1	0
August 8	0	5	2
August 9	2	4	3
August 10	0	0	1

Measurements of the tilting of the ground under the Observatory show that the average accumulation for the past week has been a slight tilt to the northeast. In other words, the rim of Kilauea crater under the Observatory has been tilted up and away from the pit, possibly by an increase of lava pressure under Halemaumau. Heretofore, the weekly tilt report has been taken from the difference in tilt between the last day of the current week and the last day of the preceeding week. From now on, the tilt report will express the difference in average accumulation of tilt between the current week and the preceeding week.

The small seismograph on the edge of Halemaumau indicates that the rim at that place has been tilted up and away from the pit. If one imagines a vertical wand standing on the edge of the pit, the tilting of the ground under it during the past week would have inclined the wand over 10 seconds of arc from the vertical position away from the pit. This is an extremely strong tilt and is much more than the Kilauea rim under the Observatory has been tilted during the same time.

Microseismic motion was strong from August 7 to August 10 accompanying the high wind and the heavy surf. This microseismic motion is a very slight vibration of the earth which causes the seismograph pens to write a wavy line, but is probably not caused by any volcanic forces.

The conclusion drawn from all this evidence is that lava pressure is increasing under Halemaumau. **It is impossible to say whether or not this will result in an eruption,** but it can be said confidently that conditions look more favorable now than at any time in the past several months.



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No. 295—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — August 21, 1930



Dr. E. S. Shepherd and Alec Lancanster collecting gases with vacuum tubes from the edge of a lava lake in Halemaumau. From Journal of Geology, April-May, 1925.

COMPOSITION OF GASES OF KILAUEA

(A review by A. N. LIKE)

The search for the sources of energy back of volcanic phenomena requires not only a continuous observation of the physical activities of the volcano but also an examination of the material thrown out from the crater, i. e., lava in all its forms and gases. It is the latter with which we are concerned in this review. The gaseous emanations have necessarily attracted much attention.

The chief gas collections made at Kilauea in 1912 were from a flaming cone on the floor by Day and Shepherd. The somewhat crude apparatus used in this collection was a train of collecting tubes and pumps. On account of the condensation of water in the tubes, quantitative results could not be reported on the gas as a whole. In 1917, Shepherd endeavored to collect gases by thrusting vacuum tubes into flaming holes in the crust of the lava lake. The difficult part of such collecting is to get the gas in the tube sealed off without having the tube filled with air during the process. During 1918 and 1919, Dr. Jaggar made a number of gas collections from various sources at Kilauea with intent to discover not only the nature of the gases evolved but also the most favorable sources.

In 1912, the gases collected at Kilauea by Day and Shepherd had the following approximate average composition by volume for one thousand liters of gas:

H_2O	CO_2	SO_2	CO	H_2	S_2	N_2
.04	.25	.50	.02	.03	.02	.14

This collection by Day and Shepherd demonstrated the presence of the three combustible gases, CO, H_2, and S_2, and of the products of combustion, CO_2, and H_2S. There was an abundance of nitrogen in these collections.

The samples collected in 1917 gave the following analyses:

Table I, volume per cent at 1200° C.

Tube	CO_2	CO	H_2	N_2	A	SO_2	S_2	CL_2	H_2O
1	2.65	1.04	4.22	23.22	n.d.	0.16	0.70	n.d.	67.99
2	17.95	0.36	1.35	37.84	n.d.	3.51	5.49	n.d.	38.48
3	33.48	1.42	1.56	12.88	0.45	29.83	1.79	0.17	17.97
4	11.12	3.92	1.42	.....	0.51	.....	8.61	0.02	77.50
5	9.54	1.12	1.53	10.47	.....	9.90	2.72	.....	64.71
6	1.97	0.82	0.21	3.50	0.07	0.95	2.70	.....	89.77
7	17.25.	0.62	0.76	5.88	0.18	9.75	1.07	0.25	64.18
8	15.27	0.45	0.70	0.87	0.14	6.98	0.49	.....	75.08
9	8.32	0.82	1.82	8.92	0.29	16.80	2.49	1.01	59.97
10	1.54	0.43	0.37	2.44	0.39	.....	3.56	1.34	89.93
17 (°)	11.61	0.37	0.58	1.29	0.04	6.48	0.24	0.05	79.31

(°) Collected by T. A. Jaggar, March 17, 1919.

These analyses bring out certain relations. CO is usually present in less quantity than H_2. Next to H_2O, CO_2 is the chief constituent and often the rare gases (computed as argon) are no more than would be required on the assumption that the nitrogen came in as air. The chlorine content is surprisingly low. On the other hand, tube 4 shows over 7 per cent of sulphur which agrees with the observation that at times fountains break which set free violent brown fumes which look like sulphur vapor. The water is surprisingly high in all the samples and it is always present. Either we must allow some validity to the thesis that salt water diffuses through the earth's crust and reappears in the volcanoes, or admit a thesis by Dr. T. A. Jaggar that the combustible gases are burned at and below the lake surfaces by air carried down by sinking crusts, air sucked by fountaining, and oxygen diffusing into the lava as it rises in the conduit. These analyses



Direct photograph with a Wratten Panchromatic Plate of pale yellow-green flames about five inches long from a distance of five feet, August 23, 1918. Photo Jaggar.

indicate perhaps that all three of the processes postulated by Dr. Jaggar are active. Trapped air would call for a great deal more of nitrogen, but this does not apply to oxidation along the conduits or at the lake surface. Dr. Shepherd tends to accept the surface combustion as an important factor in the maintenance of the lake's heat supply. On the other hand, the great variations in composition of all samples collected lends support to Day's thesis that a part of the energy may be derived from the shifting of gas equilibria due to a lack of equilibrium among the gases rising in the magma.

Tube	CO_2	CO	H_2	N_2	A	SO_2	S_2	SO_3	CL_2	H_2O	A/AN
2	5.97	0.00	0.00	7.92	nd	4.76	0.00	2.41	4.08	75.03	0
3	6.63	0.22	0.15	2.37	0.56	3.23	0.00	5.51	1.11	80.31	0.191
4	6.79	0.14	0.17	2.33	0.00	1.38	0.15	3.43	0.62	84.98	0.000
6	0.87	0.16	0.07	20.01	0.00	0.01	0.00	0.13	0.03	78.71	0.000
8	47.68	1.46	0.48	2.41	0.14	11.15	0.04	0.42	0.04	36.18	0.054
10	16.41	0.11	0.10	15.03	0.21	13.57	0.05	3.56	0.03	50.88	0.013
11	20.93	0.59	0.32	4.13	0.31	11.42	0.25	0.55	0.00	61.56	0.069
12	1.42	0.05	0.08	0.68	0.05	0.51	0.07	0.00	0.03	97.09	0.068
13	16.96	0.58	0.96	3.35	0.66	7.91	0.09	2.46	0.10	67.52	0.139
14	14.81	0.47	0.17	2.91	0.00	3.65	0.10	1.03	0.00	76.84	0.000
15	11.53	0.13	0.10	6.20	0.16	6.14	0.03	1.70	0.10	73.89	0.025
16	18.03	0.56	0.67	3.11	0.08	8.53	0.15	2.53	0.08	66.25	0.025
17	11.61	0.37	0.58	1.29	0.04	6.48	0.24	0.00	0.05	79.31	0.030
18	17.55	0.74	0.83	4.50	0.12	10.81	0.22	3.22	0.13	61.88	0.026

Table II. Gases collected from Kilauea, 1919. Volume per cent at 1200° C.

A comparison of these figures with the Shepherd collection of 1917 and with the two gases from Mauna Loa shows a general agreement in major constituents, a general agreement in the degree of oxidation, and a lack of any uniformity in the quantities of the minor constituents. One can definitely say that there is no evidence of equilibrium obtained from among the various sources.

Summary

The analysis of some 25 samples of gas taken at Kilauea between 1912 and 1919 shows that:

1. The major emanation from this volcano is water (H_2O), the average of water in all analyses being about 70 per cent of the gas evolved.

2. Second in order of magnitude comes carbon dioxide (CO_2) with sulphur dioxide (SO_2) following in the third place.

3. Sulphur trioxide (SO_3) occurs in variable amounts, in one instance rising to five per cent, whereas, in the two samples from Mauna Loa, it reached the high value of near eight per cent

4. Sulphur, while usually small in quantity, sometimes makes up as much as eight per cent.

5. In general, the 1917 collection, obtained from passing crusts at the lake edge, contains higher amount of hydrogen and carbon monoxide than that of 1918-1919. The general inference is, however, that, quite regardless of the

source from which the gas is obtained. it reaches the surface almost completely burned or else is actively burning in the upper layer of the lake.

6. In general the ratio of argon to nitrogen is about three times as great as in atmospheric nitrogen.

7. Chlorine occurs in relatively small amount The presence of fluorine could not be tested satisfactorily in the volumes of gas which were analysed. In the 1912 collection there was evidence that fluorine was present in about twice the volume or amount of chlorine.

8. Hydrocarbons are apparently absent or else present in inappreciable amounts.

9. The water present may well be partly due to oxidation of evolved hydrogen, but such oxidation must occur in the body of the lake presumably near the surface. It does not seem probable that this combination could occur at the actual surface since any such quantities of hydrogen as would be implied by the great amount of water would certainly show marked explosion phenomena. Certainly the highly oxidized condition of these gases taken as they are from all sorts of promising sources argues strongly for the hypothesis that combustible gases are burned at and below the lake surface.

The outstanding fact about the samples of gases from Mauna Loa is the high degree of oxidation. Hydrogen is practically absent and carbon monoxide is nearly as minute in quantity. Certain unexplained eccentricities in the analytical data might indicate very small amounts of hydrocarbons but with such minute quantities, a definite decision is impossible In any case, everything that could oxidize has done so yet the amount of nitrogen is not excessive. Here, as in Kilauea gases, the amount of nitrogen is insufficient to account for the water present. Perhaps the next important fact is that SO_3 is present in relatively large amount and this accounts for difficulties both in breathing and smelling. It is common experience that SO_3 particles or even sulphuric acid particles are not easily removed from the air. Rare gases computed as argon are relatively high, and chlorine is notably lacking. On the whole the Mauna Loa gases seem to be like those from Kilauea.

References

T. A. Jaggar, Gases of Kilauea, Am. Jour .Sci. 44, 1917, pp. 161-168

E. S. Shepherd, Composition of Gases of Kilauea, Haw. Volc. Obs. Bull., vol. 7, No. 7, pp. 94-97.

E. S. Shepherd, Two Collections from Mauna Loa, Haw. Volc. Obs. Bull., vol. 8, No. 5, May 1920, pp. 65.

E. S. Shepherd, Kilauea Gases, 1910, Haw. Volc. Obs. Bull., vol. 9, No. 5, May 1921, pp. 83-88.

KILAUEA REPORT No. 969

WEEK ENDING AUGUST 17, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

On Monday and Tuesday of last week, during and immediately following the heavy rains, huge clouds of steam were rising from Halemaumau. They were so unusual in appearance that they formed the basis of a rumor circulated in Hilo to the effect that the pit was active again. By Wednesday, the steaming of the Halemaumau floor-cracks had ceased except in the small sulphur-stained area in the southwest part of the pit. Even these had stopped their steaming by Sunday. There has been no avalanching from the walls, and the weekly measurement of the cracks around the 14-ton bowlder showed that no movement has occurred at that point.

The average accumulation of tilt at the Observatory for the week was moderate to the S-SE, which would indicate a depression of the Kilauea wall toward the south.



Northwest cone from which gas was escaping under high pressure and burning as soon as it reached the air. The photograph on page two was taken on the side of this cone at 11 p. m. Photo Jaggar.

It was interesting to note that much southerly tilt was recorded on August 10, 11, and 12, during the heavy rain, but slight recovery to the north began on the 13th after the rain had stopped. Two very feeble quakes which seemed to center on Mauna Loa were accompanied by tilt to the east as if the ground at the Observatory had moved a little up and away from the center of the quakes. The ground under the instrument at Halemaumau sagged slightly toward the pit on Wednesday after the rain ceased, and has remained almost stationary for the rest of the week.

Three very feeble earthquakes, not felt in the National Park, were recorded as follows: August 14, 12:12 a. m. distance not known; August 16, 3:46 a. m. distance doubtfully 23 miles; and August 17, 7:30 p. m. distance doubtfully 55 miles. Small tremors lasting less than a minute have not been as numerous as during last week, but more of them still are recorded on the Pit and Uwekahuna instruments than on the one at the Observatory. Between 9:16 and 9:45 p. m., August 15, all three instruments recorded about twenty minutes of slight but continuous tremor. Microseisms, caused by the constant vibration of the earth, have been slight since August 11, which date seemed to mark the end of the heavy storm of last week-end.

It would seem from this information that the pressure under Halemaumau has moderated during this past week. The coincidence of the abrupt tilting to the south with the heavy rainfall suggests that the weight of the water added to the surface of the mountain may have caused the tilting, but this cannot be proved without a number of parallel cases to support it.

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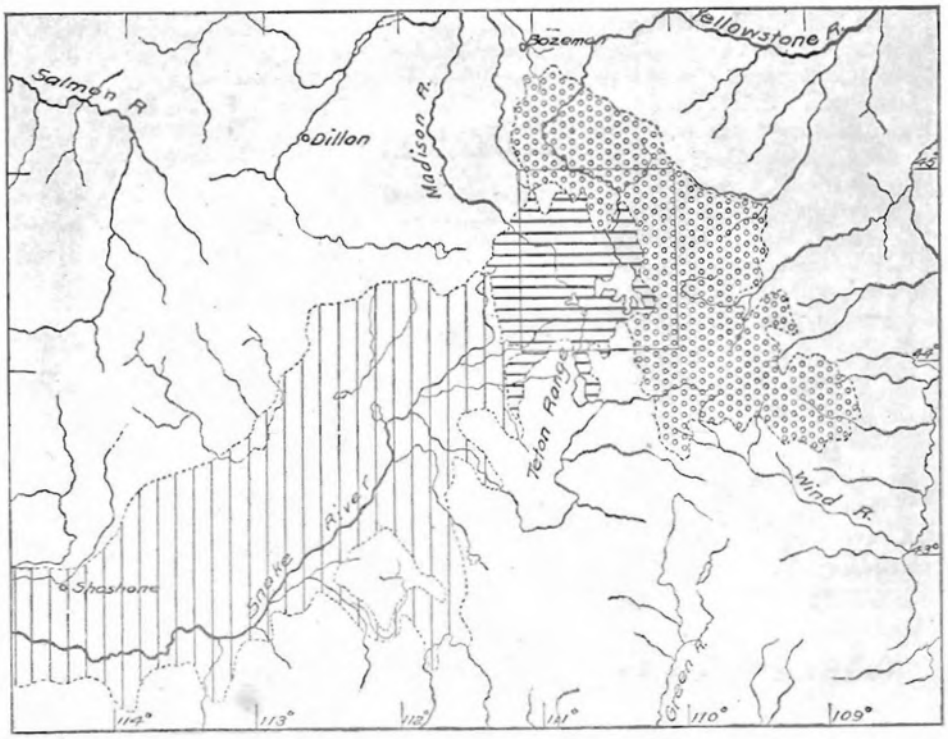
The Volcano Letter

Two dollars per year — Ten cents per copy

No. 296—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — August 28, 1930



Region of Shoshone and the Snake River Basalt (vertical lines) in relation to (Pliocene) Yellowstone Rhyolite (horizontal lines), and andesites of the early Tertiary (circles). Proc. Amer. Acad. Arts and Sci., June, 1911, p. 64

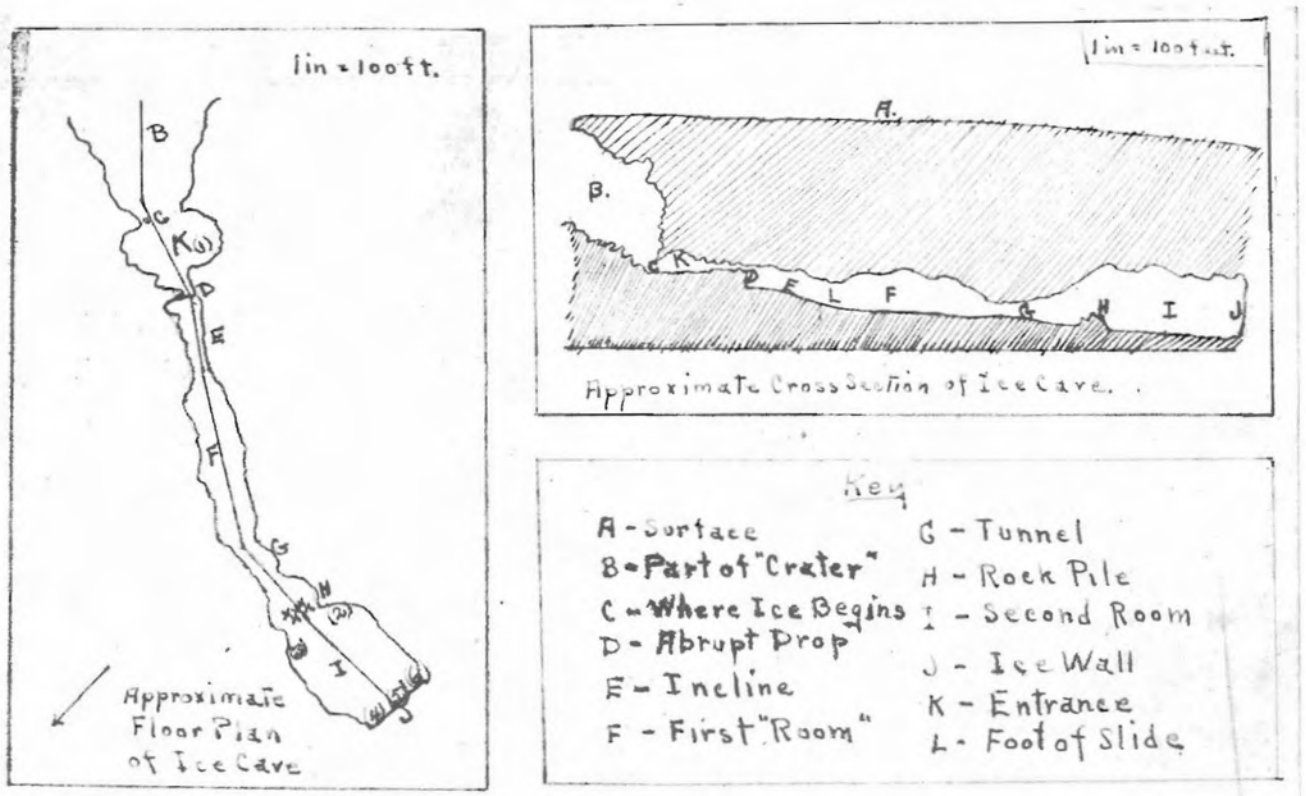
THE SHOSHONE ICE CAVE, IDAHO

(By H. G. ROBINSON)

This ice cave is located in south central Idaho about thirty miles north of Shoshone, just off the state highway leading to Hailey. The entire region is underlain by Pleistocene lava, but in several places there are Recent lava flows. The most famous of these are the Craters of the Moon, which are located about eighty miles north of the Shoshone Cave. The cave is situated in another small Recent flow, the surface of which has been undermined by huge gas bubbles, which have subsequently caved in, leaving the otherwise fairly smooth surface of the flow broken by many crater-like depressions from one to two hundred feet in diameter. Several caves, or apparent remnants of the old tubes, lead off from these "craters," and one other of these besides the Ice Cave has ice in it near its entrance at certain times of the year, thus obtaining the name of Little Ice Cave.

The Shoshone Ice Cave opens at the bottom of the western end of one of these craters, and extends back in a southwesterly direction for four hundred feet, where it is abruptly terminated by a solid wall of ice. A study of the cave was made during the first part of 1930 in an attempt to determine the causes of the phenomenon.

The first visit was made Saturday, January 4. The weather was clear and cold. The temperature outside the cave was -7 degrees Centigrade (seven degrees below freezing). There was a fall of several inches of snow upon the ground. The party set iron stakes in the ice at various points, measuring the amount which protruded, in the hope of obtaining some idea of the amount of melting or freezing during the succeeding months. Measurements of the length and breadth of the cave were also made and heights were estimated. The party took several flashlight pictures also. There was much hoar frost on the ceilings and walls, and many ice stalactites and stalagmites might be observed. There was no water to be found upon the floor of the cave, but instead a sheet of solid ice, several inches thick, covered the entire floor between two points marked "C" and "J" on the diagram. This fact was noticed with great interest, since the local tradition is to the effect that "the ice melts in winter, and freezes in summer." This was proved untrue by the absence of water on the floor during this visit in the dead of winter—one of the very few, if not the only one, that has been made at that time of year. There were, however, two places near the rock pile marked "H" where a slight dripping from the ceiling was noticed, sufficient to make the ice somewhat slippery under foot.



	Temperatures in Degrees Farenheit.							Amount of Stake Protruding in Inches.					
Date	Outside	Entrance K	Foot of Ladder D	Foot of Slide L	Tunnel G	Rock Pile H	Ice Wall J	Entrance (1)	Left Floor (2)	Right Floor (3)	Right Wall (4)	Center (5)	Left Wall (6)
Jan. 4	13°	32°	35°	39°	34°	34°	34°	Flush	1¼"	1"	4⅞"	3¾"	1¾"
Feb. 15	50°	28°	30½°	33°	31½°	33¾°	31°	¼"	1¾"	⅞"	2¼"	3¼"	1⅛"
Apr 6	78°	32⅛°	35°	—	—	34°	33½°	½"	1¾"	1½"	2¾"	Removed	2⅛"
May 18	80°	34°	35°	—	—	—	37°	⅜"	1⅜"	1¼"	Removed	"	2⅜"

A plan and section of the Shoshone Ice Cave (above) and the table of measurements showing changes of temperature and amount of melting ice. H. G. Robinson.

The second visit was made on Saturday, February 15, 1930. There was still much snow on the ground. The members of the party had to wade through knee-deep drifts in the "crater." The weather was clear but not as cold as on the last visit, the thermometer registering about 50 degrees Farenheit in the sunlight. Conditions at the entrance seemed much the same as on the last trip, despite the much warmer weather outside. But we had not gone far into the cave before we heard the sound of dripping water. Hurrying through the first cave, at the end of the tunnel which leads into the larger room we found several ice stalagmites from six inches to a foot in height on the floor of the tunnel. A little farther, at the rock pile "H," water was dripping steadily from above. and there was enough water on the floor to wet the feet and splash a little as we went through it. This was the same point at which the moisture was noticed on the last visit, but at this time it was much more abundant. At all other

parts of the cave the floor was solid ice as on the first visit.

More pictures were taken of the ice wall at the rear, and some excellent views of the stalagmites were obtained. On throwing the beams from our flashlights upon the roof we noticed much more crystallization there than on the first visit. In fact both the walls and roof were covered with the most glorious and fantastically shaped ice crystals. Several flashlight pictures were attempted but proved to be disappointments. It was not until a few months later when we got a portrait attachment for the camera that we were able to get anything like satisfactory pictures of these crystals, and even they do not do justice to the original.

The third visit was made on Sunday, April 6, 1930. The thermometer registered about 78 degrees F. The day was clear and hot. No icicles were seen on this trip. Stalagmites were still present and much crystallization on the roof. A new feature of this visit was the presence of great quantities of ice on the rocks outside the entrance between "C" and "B." This was not present on any of the previous visits, and is hard to explain since the ice-covered rocks were under the overhang of the "crater" wall where the drip from the melting snow could not have easily reached them. Patches of snow were seen occasionally. The dripping at the rock pile "H" had almost entirely ceased, the floor being only a little slippery from the presence of a thin film of water on the surface. The ice was everywhere as thick as usual, in fact, we have reason to believe that it was thicker than on our first visit. A newspaper brought in with the flashlight powder on the first trip had been left on the rock pile. This paper was now covered with ice to a depth of at least four inches, the ice undoubtedly having come from the freezing of the water which dripped in above the rock pile.

The fourth visit was made on Sunday, May 18, 1930. The weather was clear and quite warm. Upon this, the last visit, several more pictures were taken, in particular several of the crystals, with the portrait attachment, and one of a huge stalagmite at the top of the rock pile. There was still ice to be seen at the entrance outside, though it seemed to be melting rapidly. The crystals were not as perfect as on the previous visit, but some very fair pictures were obtained. There was no water at all in the bottom of the cave, though the ice was very slippery for an extensive area about the rock pile, and the rock pile itself was so slippery, being practically covered with ice, that it was almost impossible to climb it. Since there was no drip from above, this seemed to indicate a true thaw.

The accompanying table gives the temperatures of the cave as recorded on the several visits, and also the readings of the lengths of iron stakes projecting beyond the surface of the ice. It can be seen that no appreciable melting took place during the season observed. Also, though the temperatue of the cave varies, it is invariably colder right at the entrance than at any other point, even when thawing is apparently taking place as on May 18.

As a result of this study it is easy to understand the method by which the ice on the floor and sides of the cave is renewed. The water from the melting snow upon the surface of the ground seeps down into the cave, where the low temperature maintained by the wall of ice in the end causes it to freeze in the winter and spring. People who have been there in the early summer state that the floor of the cave is then covered with water, and that this water disappears later in the summer leaving the floor entirely dry during the late summer and early fall. This may be explained by the fact that early in the summer the level of the water table is high enough to prevent the water escaping, and as the water table lowers during the dry summer, the cave floor becomes dry. However, it is easy to see how this condition has led to the local tradition that "it melts in the winter and freezes in summer," since the first people to go there in the spring often find it full of water, which indicates thawing to them, and later the dryness makes them think it is freezing again. Though this study has outlined the cycle of the yearly accumulations, it has given us no clue to the method by which the great ice wall itself was formed, and that remains, at least for the present, a mystery and a matter for speculation.

KILAUEA REPORT No. 970
WEEK ENDING AUGUST 24, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

There have been no visible changes in the condition of Halemaumau during the week ending August 24. No avalanching from the walls of a magnitude sufficient to cause dust clouds has been noticed, though isolated rocks are still dropping from the rim almost continually. Steaming from the wall cracks and talus piles has been much less than usual, in fact, during two visits to the pit, no steam could be seen issuing from the cracks within the pit.

The number of earthquakes recorded is very small. One feeble shock which was felt only by a few parties in the National Park was registered at 10:43 a. m. August 21. The distance to its origin was measured as 8 miles. Three very feeble shocks which were not perceptible were registered at 7:47 p. m. August 21, 11:39 p. m., August 23, and 5:52 a. m. August 24. It was not possible to measure the distances from these records, but two of them were accompanied by tilt to the east. There were 25 records of small tremor of volcanic origin during the week. Most of these tremors lasted for less than a minute. but at 11:00 p. m. on August 22 a vibration started which continued for 18 minutes. The non-volcanic continuous vibration of the island has been slight during the entire week.

There was no significant tilting of the crater rim under the Observatory during the week. The tilt reading varied slightly from day to day and the average of the week compared to that of last week showed a slight accumulation to the southeast. The instrument at the pit recorded no conspicuous movement of the walls of Halemaumau.

The number of small tremors recorded is somewhat greater than the usual number for the past few months. The tilt record suggests that there has been no notable swelling or settling of the crater walls. It must be concluded from this that lava is neither rising nor falling at present.



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No. 297—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — September 4, 1930



View of the great aa lava flow of 1783 on the north side of Asama Volcano, Central Japan. Photo Omori, 1911, Bull. E. I. C., VI, No. 1, 1912.

ERUPTIONS OF ASAMA-YAMA, JAPAN IN 1873

(A Review by I. Toyama of part of "The Eruptions and Earthquakes of Asama-yama" by F. Omori, Bull. Imp. Earthquake Investigation Comm., 6, 1912.)

Date of Occurrence. The series of explosions of Asama-yama, in third year of Temmei (1783) ended in a tremendous catastrophe of August 5. It is a memorable circumstance that the great Calabrian earthquakes were recorded in the same year on February 5.

The frequency of the eruptions of Asama-yama is subject to an annual variation which indicates two maxima occurring respectively in April and August.

Weather at the time of Eruptions. It rained slightly in Yedo, the present Tokyo, on the 28th of July; in the province of Kotsuke which lies east of Asama, the weather was clear on July 31 and August 1, and fair on August 2 and 3. Considering all reports, the weather was dry and fair in the central part of Japan during the one week period before the main eruptive period, while on the 3rd, 4th, and 5th of August the weather was calm in the vicinity of the volcano. This shows that an area of high barometric pressure existed over Asama and the central part of Japan during the later part of the eruption. Immediately after the catastrophe, a strong cyclone swept across the country.

Course of the Eruptions. The eruptions which lasted for 88 days, began on May 9. On June 24 detonations like distant thunders began to occur at about 7:00 a. m. On the 25th, between 10 and noon, loud detonations were heard, accompanied by a strong explosion. The sounds also occurred the next day, June 26. between 4 and 6 p. m. The mountain then remained quiet for twenty days until July 16, when loud detonations occurred during that night and the night of the next day. After eight days, on the 25th, detonations continued from 8 a. m. to noon, although smoke emission was slight during the day. This marked the beginning of the last stage of the great eruption.

On the 26th of July, at 4 p. m., there were detonations accompanied by an explosion which threw out smoke toward the east. The detonation lasted until evening. On the 27th, when it rained heavily, there were detonations and emission of smoke toward the southeast at 4 p.m. Volcanic manifestations became greatly intensified in force on the 28th when, in fair weather, there occurred at noon a powerful explosion which was stronger than that of June 25th, and which threw out smoke toward the east. From this time, the effects of the eruptions could be felt in such distant places as Yedo, where ashes fell on July 28. The people of this region wondered why the houses and doors were shaken, although the ground and the water remained undisturbed.

On July 29th, burning began at 3 p. m. which continued until 5 p. m. On the 30th, the explosion which began at noon became excessively great between 2 and 8 p. m. and came to a temporary end at 4 a. m. July 31. The eruptive activity continued to increase during that day and on the following day.

On August 2, the weather was fair and clear. The eruption reached its maximum violence and the volcano emitted fire from 6 p. m. until midnight. A large quantity of stones and sand were thrown out and Maikake-yama, which was near by, was converted into a litteral sheet of fire. The eruption ceased for a short while in the morning of the 3rd of August and resumed its violence on the same day from 2 to 10 p. m., covering Kiba-yama, another nearby mountain, with red hot stones of different sizes.



Map of Central Japan, showing Asama Volcano in the shaded ellipse, which is the area of strong sound during the eruption of April 3, 1911. Wind direction is shown by arrows, and black dots indicate spots where detonations were heard. There was a zone of silence or sound shadow between the two shaded areas. From F. Omori, Bull. E. I. C. VI, No. 1, 1912.

On the 4th, explosions began with detonations at 8 a. m. and caused such an excessive fall of ashes between 1 and 4 p. m. that people as far distant as Fukaya in the province of Musashi had to use lanterns during the day to see their way through the darkness caused by the falling ashes and sand. On the 5th the weather was fair. Outbursts which began at 4 a. m. became extremely violent from 8 to 11 a. m. A little after 10 a. m. a huge mass of burnt rocks, lava and hot mud descended with deafening detonations from the crater and swept down the northern side of the mountain, rushing into the valley of Azuma-gawa.

The Course of the Eruptions in Four Stages.

First stage, commencement, May 9.
Second stage, outbursts, June 24 to 26.
Third stage, outbursts, July 16 to 17.
Fourth stage, outbursts, July 25 to August 5.

The Lava. The great lava flow of 1783 which forms an imposing spectacle on the northern flank of Asama-yama, descended into the Rokuriga-hara plain. The lava mass terminated in an abrupt manner, forming a slope of about 40 degrees which runs for a considerable distance. Its height varies from 30 to 50 meters. The area covered is somewhat of the shape of a triangle, 6 kilometers along the base of the flow.

The Great Volcanic Avalanche. The great torrent of volcanic material, which swept down the slope with a very high initial velocity, caused much damage and devastation in all the villages along the northern slopes and base of the Asama-yama and those along the Azuma-gawa. The principal course of the flow was along the deeply cut ravines that run from the foot of the mountain toward the north.

The volcanic avalanche blocked the flow of the Azuma-gawa for a while, producing a temporary decrease of water in the lower course of the river. At about 11 a. m. August 5th, the water broke forth through this newly formed dam of debris, and together with the steaming volcanic material, rushed down sweeping and carrying with it houses, furniture, and everything that blocked its way.

Ash and Smoke. Ash fell at Yedo, Choshi, Maebashi, and the surrounding regions during the morning of August 6. Mud rain fell in Karuizawa, Sakamoto, and Isobe on the fifth of August. In the city of Takasaki, 44 kilometers away from Asama-yama, ash accumulated to a thickness of 6 inches. The old and weakly built houses were crushed, and endangered the lives of the occupants.

The area covered by the fallen ash and stones measured about 220 kilometers long and 100 kilometers wide, or about 11,000 square kilometers. The thickness ranged from one to six inches, and taking the mean thickness as 2 inches, the quantity of fallen volcanic material will be about 0.9 cubic kilometer.

Conclusion. This great eruption of Asama-yama was not the beginning but the result of the outburst of the volcanic energy accumulated during the course of many years. The eruptions were caused by powerful underground explosive forces, that were suppressed until the last stage.

The shallowness of the crater caused the immensely large mass of molten and burning rocks and lava and mud to overflow and cause the dreadful volcanic avalanche. Had the crater been deeper and larger, the catastrophe and disaster caused by the eruption would not have been as severe nor as terrible.

KILAUEA REPORT No. 971

WEEK ENDING AUGUST 31, 1930

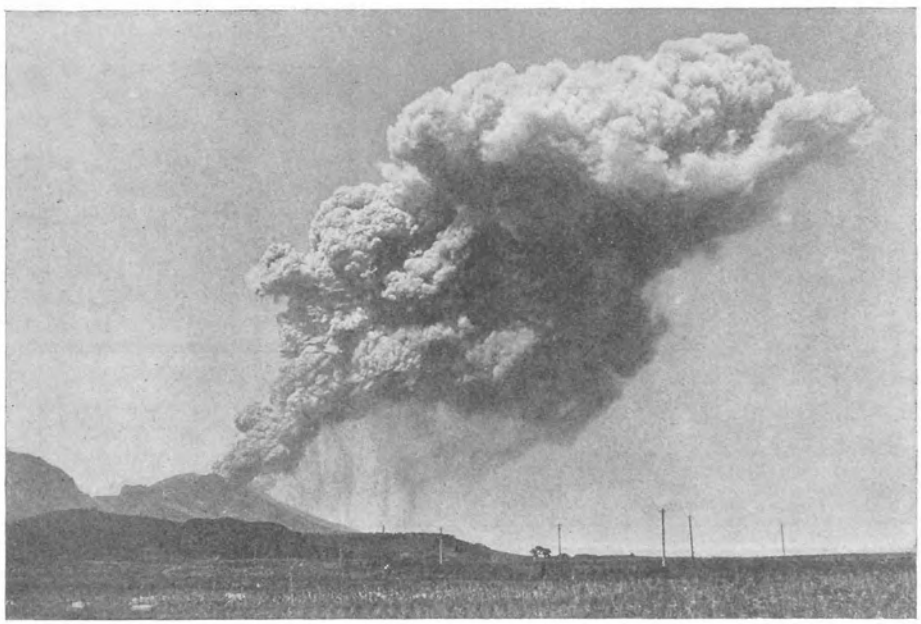
Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

But one thing of interest has happened at Halemaumau during the week from August 24 to 31. On Saturday, August 30, about 3:30 p. m., a large slab of the wall between the 14 Ton Bowlder and the pit loosened itself and made an avalanche which was heard at the Military Camp over a mile from the pit. Other than this, the fire pit has been exceedingly quiet. The amount of steam from the wall and floor cracks has been variable but has averaged even less than usual. A number of small quakes were felt in Pahala and other nearby towns of the Kau district.

The seismographs at the Observatory registered five very feeble shocks as follows: August 26, 4:19 a. m., 5:01 a. m., 10:26 a. m., and 2:38 a. m.; and August 30, 8:54 a. m. distance 32 miles. Judging from all the available information, these quakes probably had their centers somewhere in the region of Puu o Keokeo. The instruments also recorded 31 very small tremors of less than a minute duration. Of these, 17 occurred on August 30 during the time that several avalanches were observed in the pit. Some of the tremors may have been caused by these rock slides. The continuous trembling of the earth (microseisms) which is probably not of volcanic origin has been very slight during the week.

Measurement of the tilting of the ground under the Observatory show that there has been a slight accumulation of tilt to the southwest. In other words, if one imagines a vertical wand placed on the ground at the Observatory, the tilt during the week would have inclined this wand a little bit toward the southwest. The ground at the edge of Halemaumau has shown a similar movement, which suggests that this tilting has not been caused by any changes of pressure under the fire pit.

It may be concluded that there has been no measureable change in the volcanic conditions at Halemaumau. However, slight movements of the flanks of Mauna Loa similar to a series which occurred last spring have been resumed.



A modern strong eruption of the Asama-yama, May 8, 1911, seen from Komoro looking northeast. Photo Uozu, from Bull. E. I. C. VI, No. 1, 1912.



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No. 298—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — September 11, 1930



Eruption of the north flank of Usu Volcano in Hokkaido, north island of Japan, August 2, 1910. West Maruyama is the forested hill on the left. From Omori, Bull. E. I. C. vol. I, 1911.

ERUPTION OF USU VOLCANO IN 1910

(From Oinouye, "1910 Eruption of Mt. Usu," J. G, 25, 1917, pp. 258-88. Reviewed by K. Onishi.)

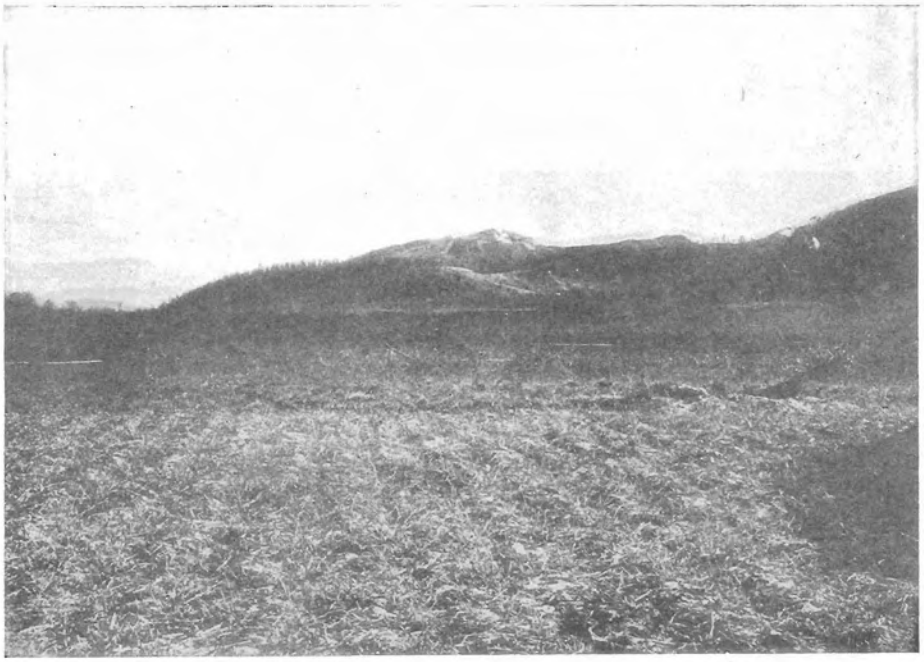
Mt. Usu, a volcano located in northern Japan on the island of Hokkaido, rises 736 meters above sea level and is approximately two kilometers in diameter. Two domes crown the top of the volcano, their names and elevations being O-usu and Ko-usu and 736 meters and 609 meters respectively. Since the craters resemble in shape the "usu," a Japanese mortar used in making "mochi" a kind of pounded rice cake for festivals, the people have named the two craters "usu" with the prefixes "O" and "Ko" to indicate the sizes, the former signifying big and the latter small. Hence O-usu is the larger of the two craters.

The clear and able report by Oinouye deals particularly with the interesting phases of the eruption. The author narrates in detail the following observations of the outbreak: earthquakes, mud cones, explosions and their processes, explosion craters, the changes in topography of the land, and the damage done by the overflow of mud and the scattering of ash and other material from the pits.

Prior to the eruption, four days to be exact, frequent earthquakes had disturbed the people. The occurrence of these undulations of the earth's crust grew more numerous as the days passed after the first shock. On July 23, 1910, 110 shocks were recorded, about 350 on the following day, and 163 on July 25, the day of the first outbreak. Two violent shocks, one on July 24 at 4:30 p. m. and the other on the following day at 5:00 p. m., thoroughly alarmed the people. The results of the quakes were some fissures made on the west side of the volcano almost parallel to the coast line. These varied in width from 3 cm. to 40cm. There also resulted two faults going in an east and west direction on the western foot of the mountain.

Another result of the quakes was the formation of mud cones on the flat land north of the volcano. The first resulted from the severe shock of July 24. The cones were formed of mud and sand, well stratified and flat and conical in shape and ranging from 6cm. to 3 meters in diameter and from 3cm. to 60 cm. in height. The water level in the neighboring wells rose and the volume of the water was doubled. Several new springs were formed but the water everywhere was turbid and dirty.

The first explosion took place on July 25 at ten o'clock in the evening from the northwest slope of the main volcano. Red hot bombs were thrown into the air. July 26



View from the same point as Figure 1 taken on November 9, 1910. The "New Mountain" is shown elevated back of the right shoulder of West Maruyama. From Omori, Bull. E. I. C. vol. I, 1911.

witnessed the explosion accompanied by black and white smoke that rose to a height of 700 meters. July 28 was a dreary day with two explosions, rain, thunder, intense lightning, huge columns of dense smoke, and low roaring noises contributing to the general atmosphere of gloom.

The explosions were quite remarkable. A cannon-like sound announced the arrival, a "V" shaped vent opened the path, and a procession headed by black smoke, sand, and ashes came into view. This material helped to form the cones, each requiring a day or a week to complete one, the time depending on the amount of matter ejected and the size of the vent.

During the period of greatest activity, from July 25 to August 2, fifteen new craters were formed, the number increasing to 45 for the ten weeks of the eruption. These craters were grouped into two groups of 16 and 29 lying in two parallel lines. The distance between the two lines of vents was about 800 meters. All of these craters emitted quantities of black smoke, ash, sand, and bombs. Five of them spit mud and hot water as well. The greatest distance to which the ash was carried was 44 km. In places the land was covered to a depth of 30 cm. A mud flow to the lake at the foot of the mountain measured 200 meters in width, 500 meters in length and 1.5 meters in thickness.

The chemical composition of the mud flows, the sand of the seashore, and the substance in the mud cones was practically identical, showing evidence that all the material came from the same source, a brown pumice at the base of Mt. Usu.

Bombs hurled into the air produced a sound like a firecracker when they were struck in midair by other ascending bombs. They were basaltic in composition, dark grey, porous, somewhat round, and not more than 25 cm. in diameter. An abundance of pores filled with ash and sand on the exterior of the bombs was contrasted with a scarcity of pores in the interior.

The topography of the land was changed materially. The water in Lake Toya rose 30 cm. on the north margin of the lake and the slope of the south shore tilted to 30 degrees from the original 5 degrees. Before the eruption, Nishimaruyama could be seen from the village of Nishikohan, but after the activity of the volcano, the view was obstructed by the so-called "New Mountain." The maximum height of this newly constructed ground is 120 meters.

Professor Omori is of the opinion that an intrusion of lava in the form of a dome or spine caused the elevation of this new mountain. Sato believes the intrusion to be a laccolith. Oinouye, the author of this article, thinks that the uplifting of the new land was caused by a plug which was intruded in the midst of the activity, the intrusion being materially helped by the faulting of the land.

The damages incurred included the destruction of a fine forest on the slope of the mountain, and the burial of houses and farm lands within a radius of two kilometers.

Many houses suffered cracks in the walls and a number were completely destroyed.

TILTING OF THE GROUND IN AUGUST

A graph showing the tilting of the ground from day to day is plotted at the end of each month. The position of the tilt recorder with respect to an assumed fixed point in space is read each day. However, these daily tilt readings are affected to a certain extent by causes other than true volcanic tilt such as rapid temperature changes, heavy rainfall, and slight instrumental errors. To eliminate as many as possible of these outside influences, the curve showing the daily tilting is "smoothed" by computing "overlapping seven day means." This means that the tilt reading plotted on the graph for each day is actually the average of seven days, ie. the three days preceeding and the three days following the day in question. This smoothed curve thus shows a truer picture of the tilting of the ground as caused by volcanic forces of comparatively long duration. The curve obtained by this method of plotting may be figuratively described as being the curve traced by a wand placed rigidly in a vertical position in the earth at the observatory, with the upper tip of the wand writing the curve on a piece of paper held above it in a fixed position in space. As the earth tilts, the wand is tipped from its vertical position and the tip of the wand writes a curved line on the paper. The net change in position of the top of this wand for each week in August is expressed in a compass direction and angular degrees of arc in the following table. For example, from July 28 to August 3 the wand had tipped through 0.96 seconds of arc in a northeasterly direction.

July 28-Aug. 3	N.E.	0.96	sec. of arc.
Aug. 4-Aug. 10	S.S.E.	0.87	" "
Aug. 11-Aug. 17	S.E.	1.45	" "
Aug. 18-Aug. 24	S.E.	0.72	" "
Aug. 25-Aug. 31	S.W.	1.45	" "

KILAUEA REPORT No. 972
WEEK ENDING SEPTEMBER 7, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

The famed 14 Ton Bowlder has advanced one more step on its journey back into Halemaumau. The sliver of th rim which supports the bowlder has slipped downward until the top of the bowlder is several feet below the level of the solid rim behind it. This slipping occurred during a spell of almost continuous avalanching which began about noon on Thursday, September 4, and stopped sometime Saturday evening, September 6. Most of the larger avalanches, however, fell from the northeast part of the rim a considerable distance from the 14 Ton rock. Aside from this, at the risk of being very monotonous, it must be reported that little excitement has happened at Halemaumau.

National Park Rangers have reported that two avalanches have fallen from the walls of Kilauea Iki during the past ten days. It is entirely possible that these resulted from blasting which has been done in the course of the construction of a new trail into this crater.

Six very feeble quakes, probably originating in the Puu o Keokeo area, have been recorded during the week as follows: Sept. 1, 7:41 a. m.; Sept. 3, 6:45 a. m.; Sept. 4, 8:34 p. m.; Sept. 5, 3:17 a. m.; Sept. 6, 6:28 a. m., distance questionably 20 miles; and Sept. 6, 6:51 a. m. Twenty-six small tremors were recorded on the Observatory instrument. The larger number of these occurred during the spell of avalanching and probably are records of these rock falls. Microseismic motion was slight during the entire week.

Tilting, both of the Kilauea rim and of the Halemaumau rim, was slight to the southwest.

It must be concluded that pressure under Halemaumau is decreasing from the maximum attained during the second week in August. There is no evidence as yet that lava pressure is building up under Puu o Keokeo even though there have been a number of recent quakes which seemed to center in that region.





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No. 299—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — September 18, 1930



Mihara Crater in the summer of 1907. Diameter 825 meters E-W. (Nakamura)

The same crater, January 1, 1913. (Okamura)

The same, 1916, showing block lava, terraces, spatter cones, ditches, pits, and fuming holes. (Tsuboi)

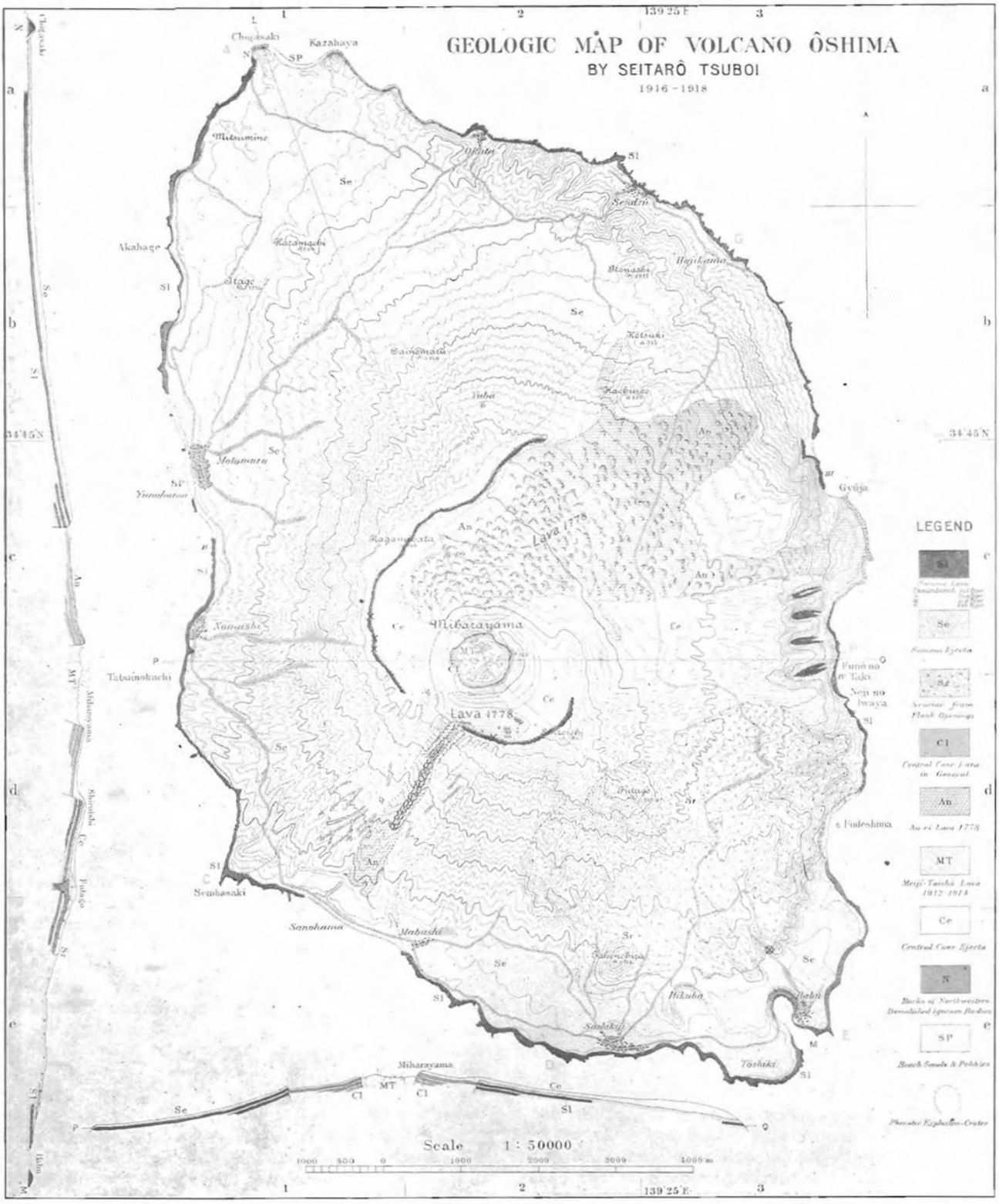
STRUCTURE AND ACTIVITY OF OSHIMA VOLCANO

(Review by Y. Yamamoto of "Volcano Oshima, Idzu," Seitaro Tsuboi, J. C. S., Imperial Univ. of Tokyo, Vol. 43, 1920.)

Geographic Sketch. Oshima is the largest number of a group of volcanic islands off the Idzu peninsula, and lies in the sea of Sagami about 110 km. southwest of Tokyo. The island itself is a gigantic lava and ash volcano with an elevation of 755 m. above sea level. It consists of a central cone called Miharayama, with an active crater at its summit. The outer slopes of the insular volcano vary greatly in different directions. On the western side the slope is regular and makes a fine concave curve. On the eastern side it is abnormal, varying from 15 to less than 5 degrees, and continuing from the summit half way down, until on approaching the shore, it becomes suddenly as steep as 40 degrees. The relief of the cone surface is further diversified by a number of parasitic knobs on its flanks, but as a whole, the shape of the island is that of a cone, and its outline viewed from a distance conveys a strong impression of the volcanic origin of the island.

Structural Outline. The volcano is a composite stratified one consisting of double cones—a somma and a central one—and is built up of numerous layers alternately accumulated of lava and fragments of basaltic nature. The somma has several satellitic bodies. On the flanks of the main body of the somma there are eight parasitic knobs. The top of the somma is truncated with a ring-wall that surrounds a huge oval caldera. The wall is not completely closed but there are two gaps, a greater one on the northeastern and a smaller one on the southwestern side. The active central cone, Miharayama, stands in the caldera, and its volcanic products not only cover the ground within the encircling wall but have also spread down to the sea shore through the gaps in the wall.

The Central Cone. The central cone, Miharayama, which is a perfectly preserved undissected heap, stands somewhat to the south of the center of the caldera. The cone is very simple in its structure, being composed of superfluent lavas and ejecta, the alternately accumulated layers of which may be well observed on the inner wall of the summit. The volcanic products of the central cone, both lavas and ejecta, not only fill the caldera but are also spread down to the sea shore through the northeastern and southwestern gaps of the ring-wall of the somma. Especially on the



Geologic map of Oshima Volcano in Sagami Bay near Yokohama, with profiles N-S and E-W. After Tsuboi, Jour. Col. Sci. Tok. 43, 1920.

eastern part of the island, the products of the central cone are so distributed over the surface of the somma body as to conceal its original slope. The present crater seems to have attained its size in 1684 according to historic records. The features of the inside of the crater are always changing. It is habitual that when the volcanism displays its full energy, lava fills the crater, and on declining, the layer of lava depresses more and more due to its own weight, leaving the peripheral parts in the form of terraces.

The Meiji-Taisho eruption (1912-14) began with the outpouring of lava from the vent. During this interval, the extrusion of lava took place intermittently, five times, of which the second and fourth can be considered as the after effects of the first and third respectively. In the first period during March-June 1912, the lava reached a level of 62 meters below Kawajiri, burying half of Naumann's cone and forming a new Nakamura's cone. The second eruption in July was the squeezing out of a new molten lava due to the depression of the lava layer at the crater bottom and resulted in the breaking up of Nakamura's cone. In the third activity, September-October 1912, the extrusion of the lava took place from a new vent at the western part of the crater bottom and was accompanied by the formation of a new spatter cone, Omori's cone, around the vent.

The whole crater is at present in a state of deep tranquility. No motion is seen and no sound is heard to cause any uneasiness. Activity is only indicated by fumes with a faint peculiar choking odour of sulphur dioxide. The fumes rise calmly at varying places from pits and clefts of the elevations on the crater bottom and from cracks and fissures traversing the lava which fills the crater floor, depositing sulphur in a yellow crust on any objects.

Volcanic Activity in Historic Times. The first eruption ever recorded in Japanese chronology took place on November 29, 684 A. D. Several authors are of the opinion that the area now occupied by the villages of Motomura and Nomashi was formed by this eruption. During the period from the eighth to the eleventh century there was no eruption at all. In the twelfth century, on November 18, 1112, there was one eruption. Two eruptions took place during the fifteenth century. In the seventeenth century there were four eruptions. There was one eruption in the eighteenth century in the years 1777-78. This eruption of the An-ei era was the most violent one ever recorded in the history of the volcanic activity of Oshima. Five eruptions were recorded in the nineteenth century. The last one of this period which occurred in 1876-77, was a rather violent eruption. The activity lasted forty days. Lava was poured out in the crater of Miharayama but it did not run over the brim of the crater. The eruption of 1912-14 lasted for two years and three months. During this eruption, lavas were extruded in five periods with short intervals of quiet between spasms of activity. They did not run over the brim of the Miharayama crater, but they changed the state of the inside of the crater. The activity in the month of October in 1915 continued about twenty days but ceased without having poured out any lava.

KILEAUEA REPORT NO. 973

WEEK ENDING SEPTEMBER 14, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

The 14 Ton Bowlder fell to the bottom of Halemaumau during the evening of September 10. No one was present to watch the manner of its going, but a little news was yielded by the seismogram from the pit instrument. About 9:30 p. m. a landslide initiated a series of fourteen different slides large enough to record on the instrument. Two of the largest occurred at 10:30 p. m. It is probable that the 14 Ton Bowlder was carried in by one of these two. A section of the rim over fifty feet long and thirty feet wide dropped in during these avalanches. As a rough estimate, over 65,000 tons of rock fell from the wall of the pit.

Aside from the series just mentioned, there has been little avalanching during the week, and the steaming from the cracks in the pit has been slight except during one half day of rain.

Only one very feeble earthquake was recorded on the instrument at the Observatory on September 11 at 11:39 p. m. A total of 46 small tremors were registered during the week, of which a small number are probably avalanche records. Microseisms have been slight during the entire week.

The average tilt for the week showed a slight gain to the north at the Observatory. A careful analysis of the records suggests that the tilting is being influenced more by Mauna Loa than by Halemaumau. The tilt seems to be a series of small movements to and from Mauna Loa, and gives no evidence of increasing pressure under that mountain.

Again it must be concluded that things are very quiet at Halemaumau ,and that nothing of obvious consequence is happening at Mauna Loa.





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No. 300—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — September 25, 1930



Tower of the stone church of Sataputu, Savaii, all that remains to mark the site of a village buried under thirty feet of lava. There is subsidence around the tower, probably due to fluid lava entering the building below. After Tempest Anderson, Q.J.G.S. London, 1910.

ERUPTION OF MATAVANU, SAMOAN ISLANDS, 1905-10.

(Review by L. Smith. Reference: The Volcano of Matavanu in Savaii, Tempest Anderson, Quart. Jour. Geol. Soc., 66, 1910, pp. 621-639.)

Before the eruption of 1905, a sort of elevated plain surrounded by mountains stood where the crater of Matavanu is now. A deep valley extended from near this place down to the sea. On the western side of its coast were the villages of Saleaula, Salago, and Toapaipai. Farther to the east of Toapaipai was a stretch of "iron-bound" coast, or a coast made of old lava not protected by an encircling coral reef. Still farther east were the villages of Malaeola and Sataputu. These were on a part of the coast protected by coral reefs.

The eruption began August 4, 1905 with an explosive phase, sending forth mostly solid ejecta which did not cover an extensive space.

September 2 to September 4 saw molten lava pouring out and extending for a distance of two miles.

October 28 found the lava at Saleaula, and on November 3, this lava-stream was a quarter of a mile across. The side of the crater fell out and from the collapsed part a flood of lava issued.

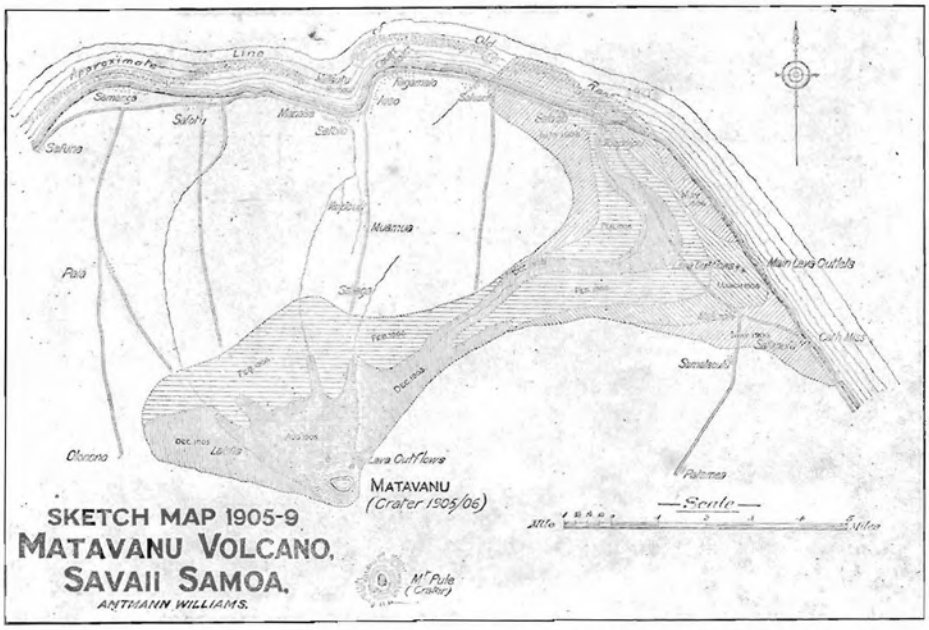
The lava reached the sea at Toapaipai on December 7, filling up the lagoon between the shore and the coral reef, then taking a westward turn along the reef, leaving untouched a part of the lagoon which was not filled up until later.

From January 28, 1906 to the middle of February, there was a great increase of activity. The lava extended along the coast from Salago to Saleaula, filling the space between the shore and the reef. Farther east, half the town of Malaeola was destroyed.

The lava ceased running in the swamp behind Saleaula on March 3, 1906. Near the coast about half the town of Saleaula had been destroyed. The lava filled up the space between the shore and the reef at Saleaula and extended westward, blocking up one of the entrances to the lagoon. The lagoon between the shore and the reef was not filled up until later.

On March 6, 1906, the lava extended eastward along the coast to two hundred yards from Sataputu which was destroyed somewhat later. Where the coast was "iron-bound" its formation was little changed for the lava flowed directly over the sea cliff into deep water.

Around the first of September, 1906, the lava-flows near



Map of the northeast side of Savaii Island showing the region of the crater and lava flows (shaded) of 1905-9 of Matavanu Volcano. After Tempest Anderson.

the sea coast extended eastwards, overwhelming the village of Sataputu, filling up the lagoon which was thirty feet deep in places, and pushing the coast-line seawards about 3000 feet. The total length of sea-front covered at different times by the lava was nearly nine miles.

It was noted on August 7, 1908, that the lava continued to run strongly into the sea, making its course mainly in the direction of that district where Toapaipai formerly stood.

A visitor to Savaii in the year 1910 or thereabouts would have seen a crater, 2000 feet high, surmounted by a canopy of white steam shaped a little like a pine tree, often breaking into cauliflower lobes, rising to a height of 8000 to 10,000 feet. Great fields of black lava, whose rough and irregular surface had large areas of both the aa and pahoehoe variety, comprised a considerable area around the cone, but on its southern and eastern sides their journey has been checked by hills. They are greater toward the west and north where they have filled the upper parts of several valleys. In the northeast, toward the sea, is the most extensive field of the fresh lava.

Of course, all vegetation overwhelmed by the lava was killed, but much more damage was done by the "Ua Sami," or poisonous gases, discharged from the crater or formed by the action of the hot lava on the sea water. Descending the crater from the west, the destruction of trees was complete, and for a distance of nearly two and a half miles, their bleached skeletons alone were left. It was only in a few sheltered places that the low undergrowth was beginning to return from the old roots. The towers and other parts of two churches are nearly all that remains of the villages of Saleaula and Sataputu.

The bottom of the crater is oval, entirely occupied by a lake of liquid lava, all in rapid motion and of such fluidity that it continually beats in surging waves against the wall. The lava is at a brilliant white heat with a darker scum continually forming on the surface, especially when the trade wind blows strongly on it. These pieces of scum break up and flow down to the north-eastern end of the crater where they disappear along with the liquid lava down a tunnel about 30 feet at the foot of the cliff. The surface of the cone is composed mostly of a series of flows of basaltic lava, and a number of bombs or ejected blocks of lava of similar character are scattered over the surface.

KILAUEA REPORT NO. 974

WEEK ENDING SEPTEMBER 21, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

A large part of the badly cracked section of the southeast rim, near the old site of the 14 Ton Bowlder, has fallen into the pit. Starting last Sunday, September 14, the

avalanching was almost continuous until daylight the morning of Thursday, September 18. Between midnight and 4:30 a. m. of the 18th, a number of very heavy slides formed the climax to the series and produced the most visible changes in the rim. The edge of Halemaumau moved back about fifty feet through a distance of more than one hundred feet as a result of the avalanching.

Other than this sliding from the wall, there have been no events of interest at the fire-pit. Steaming has been very light and none of the earthquakes of the week has had its origin under Halemaumau.

The seismograph at the Observatory registered five very feeble earthquakes during the week, one of them on September 20 being felt in Kau. The times of the shocks were: September 15, 7:27 a. m.; September 18, 2:50 a. m. and 4:14 a. m.; September 20, 5:24 a. m.; and September 21, 6:08 p. m., distance 28 miles. During the spell of avalanching, 36 small tremors were recorded at the Observatory, while the pit instrument showed a total of 90 small shocks caused by the rock slides. During the last three days of the week, 13 tremors registered on the Observatory instrument of which none seems to be due to avalanching. The ordinary microseismic trembling of the ground which is thought to be of non-volcanic origin was slight for the week.

The tilt of the Kilauea rim under the Observatory gained slightly to the southeast, and the rim of Halemaumau showed the same amount and direction of movement. The daily tilt diagram shows continued small movement back and forth from the south ridge of Mauna Loa, but no gain of pressure under that mountain is indicated. Kilauea does not seem to be affecting the tilt to any appreciable extent at this time.

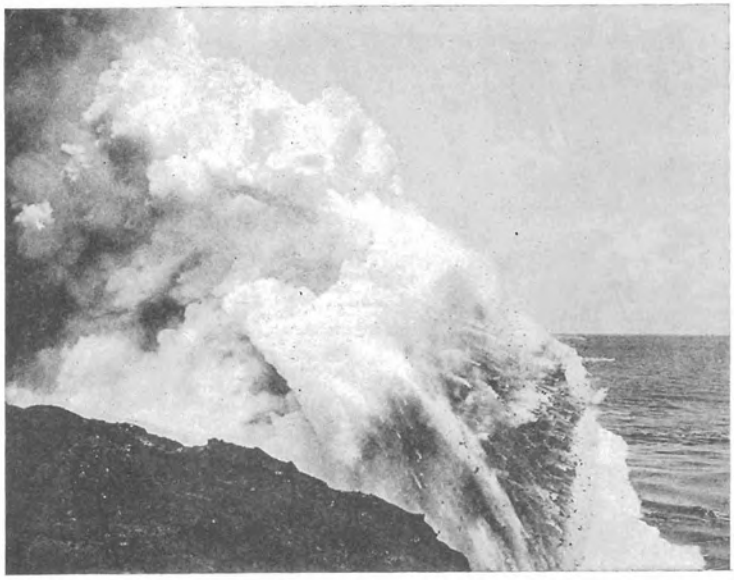
LAVA "SQUEEZE-UPS"

The Sunset Crater Lava flow, northeast of Flagstaff, Arizona, not only presents the most recent evidence of volcanic action in the San Francisco Mountain area but also contains a curious phenomena on the surface of the flow. These are fissures filled with basalt which have been given the name of "anosma," or "squeeze-ups." Through the middle of the main flow from Sunset Crater is a fissure, varying in width from a few feet to seventy feet, and a mile and a quarter in length. Through this fissure, basalt, apparently in a plastic condition, has been squeezed, under pressure, several feet into the air. The sides of the protruding basalt tongue are grooved conforming to the walls of the fissure, and slickenside surfaces are usually present. In the wider fissures, the more plastic inner layers of the mass have slid over the outer less plastic plates so that we get a condition of a series of vertical layers pushed into the air.

That the mass was plastic like stiff clay is evident from the rough surface of the sides of the mass that have been in contact with the walls, a condition often seen in the moulding of bricks. Further, the plates of basalt, as they have been thrust into the air, have bent under their own weight to form graceful arches in some places.

Besides the long squeeze-up, others are known of which many are less than 100 feet long. Most of these squeeze-ups are found on or near the edge of the main lava flow and form the source of smaller secondary flows. These secondary flows must have been more or less contemporaneous for in many cases they have coalesced.

It is thought that the formation of the squeeze-ups is related to the fact that the lava is contained in an intercone basin, a basin with no outlet surrounded by cinder cones. Into this basin, lava has poured from a vent near the high side of the basin. The remains of numerous fumeroles and the altered condition of much of the surface of the primary flow indicate that the main flow was deep and long in cooling. The squeeze-ups, in some way, seem to be associated with this condition.—HAROLD S. COLTON.



Lava of Matavanu entering the sea through a tunnel near Toapaipai. Fragments are being thrown up, each with a trail of steam, by the force of the explosions which occur when the lava enters the water. Photo Allen, after Tempest Anderson.



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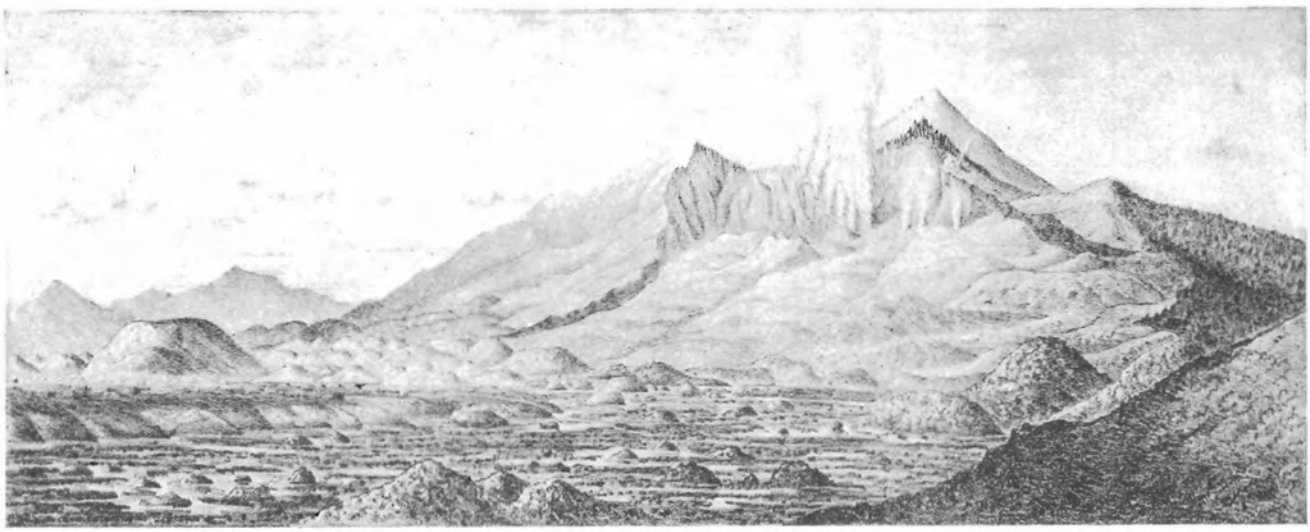
The Volcano Letter

Two dollars per year — Ten cents per copy

No. 301—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — October 2, 1930.



Crater of Bandai-san three weeks after eruption, looking south, showing the many conical mounds, similar to Galoung-gung (Vol. Letter No. 286). Bare hillsides on the right were scored by the mud torrent. After Sekiya and Kikuchi.

THE ERUPTION OF BANDAI-SAN, CENTRAL JAPAN, 1888.

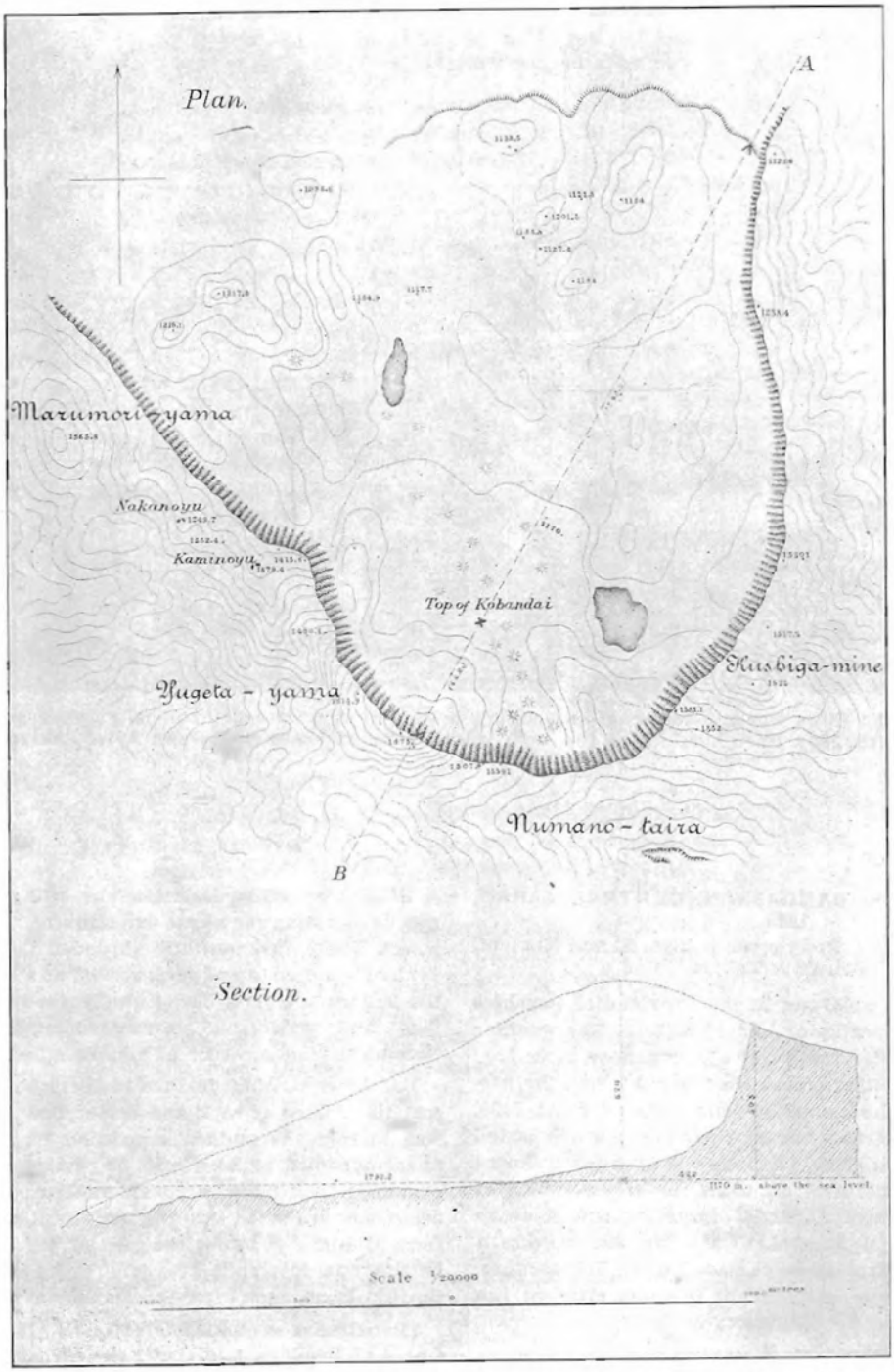
(Reviewed by L. K. Fo. Reference: Sekiya, S. and Kikuchi, Y., Jour. Sci. Coll. Tokyo, Vol. 3.)

The eruption of Bandai-san in the Province of Iwashiro took place on the morning of July 15th, 1888. The weather was clear and a gentle breeze was blowing. Soon after 7:00 o'clock, curious rumbling noises were heard which the people thought to be the sound of distant thunder. At 7:30, there occurred a tolerably severe earthquake which lasted more than 20 seconds. This was followed by a most violent shaking of the ground. At 7:45, while the ground was still heaving, the eruption of Kobandai-san took place. A dense column of steam and dust shot into the air, making a tremendous noise. Explosions followed one after another, the steam on each occasion except the last attained the height of 1280 metres or 4200 feet.

The last explosion, however, is said to have projected its discharge almost horizontally towards the valley on the north. It is probable, from the topography and form of the crater, that previous discharges were also more or less inclined to the vertical in a northerly direction. The main eruptions lasted for a minute or more and were accompanied by thundering sounds which continued for nearly two hours. Meanwhile the dust and steam rapidly ascended and spread into a great cloud like an open umbrella in shape. At the immediate foot of the mountain there was a rain of hot scalding ashes, accompanied by pitchy darkness. A little later while darkness was still great, a shower of rain fell, lasting for about five minutes. The rain was quite warm. While darkness still shrouded the region, a mighty avalanche of earth and rock rushed at a terrific speed down the mountain slopes, buried the Nagase Valley with its villages and people, and devastated an area of more than 70 square kilometres or 27 square miles.

The most striking feature in the whole of this eruption was the deluge of rock and earth. The destructive agency was merely the sudden expansion of imprisoned steam, unaccompanied by lava flows or pumice ejection. When the explosion took place, a considerable amount of rocks and earth was projected into the air, and a part diffused in the form of dust, but by far the greater part of the bulk of Kobandai was just split into mighty fragments which were thrown down much after the manner of a land-slip.

The stream of materials of July 15th, ran down the slopes of Bandai-san, dividing as it went into two principal branches. The main branch flowed northward. Kobandai sloped on the north towards Nagase Valley in an unbroken descent, and as the mountain burst on this side, the debris dashed with great violence down this northern slope in the direction of Hibara, 9 km. away. One part of the rock torrent actually ran up the valley, toward the source of the River Nagase, burying on its way the three hamlets of Akimoto, Hosono, and Osuzawa. A part, however, ran down the valley reaching Kawakami spa and submerging it to a depth of probably more than 40 metres. The other and



Plan and profile of Bandai-san as destroy ed by the steam blast eruption of July 15 1888. Heights given in meters, dotted lin e shows former profile. After Sekiya and Kikuchi.

much smaller branch took quite a different route making an angle of 120 degrees with the main stream.

The combined volume of these two great streams entirely covered an area of 27 square miles with a solid sea of mud and rock, beneath which were buried all features of the landscape together with cattle, people, and all other living things.

The mud current also carried along numerous big boulders, some of them measuring from 5 metres to 10 metres each way.

The explosions were accompanied by terrible wind blasts. In some exposed parts, houses were levelled to the ground and trees torn up by their roots. Marumori-yama, situated near the mouth of the crater, and fully exposed, received the most severe damage. This hill was formerly covered with a thick forest, but now presents a melancholy appearance, the few trees which were left standing being as naked as telegraph poles.

This eruption of Bandai-san was more destructive than constructive. The materials which had accumulated in past ages gave way and were thrown down from a higher to a lower level in less than an hour in a gigantic landslide. The loss of property is said to have been immensely great. There is absolutely no hope of recovering or reclaiming the buried land.

Formation of new lakes due to the damming up of the river Nagase by the shattered mountain was also a striking effect of the eruption. There were four lakes formed in this manner, called Osuzawa, Hibara, Onogawa, and Nakatsu. Fifteen days after the eruption, the village of Onogawa was covered with water from the gradual accumulations in these lakes.

Out of the total of 461 dead, only 116 bodies were recovered, the rest remaining buried under the mud from the avalanche. Seventy individuals were injured by the hurricane of hot ashes and falling stones.

TEMPERATURE OF STEAMING CRACKS

The steaming cracks on the rim and floor of Kilauea Crater are, at present, the most visible indications of the presence of latent volcanic forces. They inspire numerous questions and are worthy of considerable study. Where does the steam come from? Are all of the cracks of the same temperature? Does the weather have any effect on the amount and temperature of the steam? These and many other questions of a like nature easily come to mind.

Since the beginning of the constant observation of the volcano, some notice has been taken of the steaming cracks. Measurements of temperature both at the surface and in holes bored beneath the surface have been made at a number of different times since 1912. At the present time, a daily record is being kept of the temperature and behavior of three accessible steaming cracks.

In February and March, 1912, a comprehensive survey was made of the temperature of steaming cracks in the entire crater area. The results of this survey are reproduced here in the following table:

Locality	No. of Cracks	Maxima	Minima.
Sulphur Banks	6	95.5 C. (204 F.)	66.0 C. (151 F.)
North edge Kilauea	2	70.0 C. (158 F.)	55.0 C. (131 F.)
Steaming Cliff	13	80.5 C. (177 F.)	47.8 C. (118 F.)
Observatory	2	59.0 C. (138 F.)	25.5 C. (78 F.)
North floor Kilauea	11	89.0 C. (192 F.)	36.7 C. (98 F.)
Northeast floor Kilauea	5	81.7 C. (179 F.)	57.8 C. (136 F.)
East floor Kilauea	7	84.0 C. (183 F.)	39.0 C. (102 F.)
Southeast floor Kilauea	7	94.5 C. (202 F.)	43.4 C. (110 F.)
South floor Kilauea	2	73.3 C. (164 F.)	66.6 C. (152 F.)
Around Halemaumau	6	145.5 C. (294 F.)	64.0 C. (147 F.)

The table does not include the Postal Rift which maintained temperatures varying around 320 C. (608 F.) for a number of years before it was buried beneath a flow of lava in 1919.

In June 1922, a hole was bored in the Sulphur Bank to a depth of 50 feet, and the temperature was found to be consistently about 96.0 C. at the bottom of the hole. A surface reading in one of the steaming cracks was made at the same time which showed a temperature of 95.5 C., identical with the maximum temperature of these cracks in 1912.

At the same time, temperatures of about 65.0 C. (149 F.) were measured at the bottom of an eighty-foot hole drilled in the south floor of Kilauea Crater. A surface crack gave off steam at a temperature of 55 C. Two cracks measured in this area in 1912 had temperatures of 73.3 C. and 66.6 C.

In January 1925, temperatures were recorded from cracks on the rim of Halemaumau as follows: west rim, 75 C. (167 F.); southwest rim, 86 C. (187 F.); south rim, 72 C. (162 F.); and southeast rim, 76 C. (169 F.). These temperatures taken when there was no lava in the pit contrast with those of 1912, taken when lava was present, which showed a maximum of 145.5 C. and a minimum of 64.0 C. Two cracks on the south floor of Kilauea showed temperatures, in 1925, of 87 C. (189 F.) and 90 C. (194 F.).

A reading of 66.4 C. was obtained from the bottom of the eighty-foot hole in January 1926, and the steaming crack near the hole showed 57 C. These compare with 65.0 C. and 55.0 C. for the two localities in 1922.

Three generalizations are obvious from these earlier records. First, the temperature of the steaming cracks in the vicinity of Kilauea varies over a wide range. Second, three individual "hot spots" show very little change over a period of several years. Third, the temperature shows no definite relation to the presence of lava.

Since May 1930, a continuous record has been kept of the temperature of a narrow steam crack about one hundred yards south of Halemaumau. During May the temperature averaged about 71 C. (160 F.); during June, 70.5 C; during July, 70.0 C.; and during August, 69.5 C. (157 F.). For comparison with the curve of variation of the temperature of the steam crack, records have been kept of the daily rainfall, daily average air temperature, daily range of air temperature, daily barometric pressure, daily wind condition, and air temperature at time of reading the steam temperature. The results obtained so far seem to indicate that the temperature of the steam from the crack does not depend on any one of these outside influences.

In an effort to test this information more fully, daily records have been started on two more steaming cracks, one about 100 feet south of Halemaumau, and one on the Steaming Cliff on the northeast Kilauea rim. It is hoped that comparison of all of these records will permit some definite conclusions as to the origin and control of the temperatures of the steaming cracks.—H.A.P.

KILAUEA REPORT No. 975

WEEK ENDING SEPTEMBER 28, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

There have been very few avalanches, and steaming from the cracks in the crater has been very light during the past week. Sunday evening, September 28, at 8:35, a few people in the National Park felt an earthquake which was also reported as felt in Kona.

Between September 22 and September 27, four very feeble quakes were recorded on the Observatory seismographs as follows: September 23, 5:09 p. m. distance 37 miles; September 24, 4:16 a. m. and 9:03 a. m.; September 25, 7:55 a. m. None of these was felt in the Park. At 8:35 p. m., September 28, a quake of moderate intensity dismantled (this means that a small safety device is disconnected which prevents serious damage to the writing pens) all of the instruments at the Observatory and was followed by a number of feeble and very feeble shocks as follows: 8:59 p. m. very feeble, 9:05 p. m. feeble, 9:08 p. m. very feeble, 9:13 p. m. very feeble, and 10:56 p. m. feeble.

The moderate shock at 8:35 gave some interesting but puzzling records. On several of the instruments, the distance to its center was measured as 12 miles, while on the others its distance was 20 miles. It had a strong vertical movement, yet it was felt as a very gentle rocking motion by a very few people. The best guess which can be made from the conflicting records is that the quake had its origin at great depth under the island and cannot be assigned definitely to either volcano.

Twenty-three short tremors, probably of volcanic origin were recorded during the week, and the non-volcanic microseismic trembling was somewhat stronger in the middle of the week.

The tilt for the week still seems to be controlled more by the southern part of the main Mauna Loa rift than by Kilauea. The ground at the Observatory was tilted moderately to the northeast.

The deep seated earthquake probably indicates deep movement of lava, but it is too soon to tell whether the lava is rising into one of the volcanoes.

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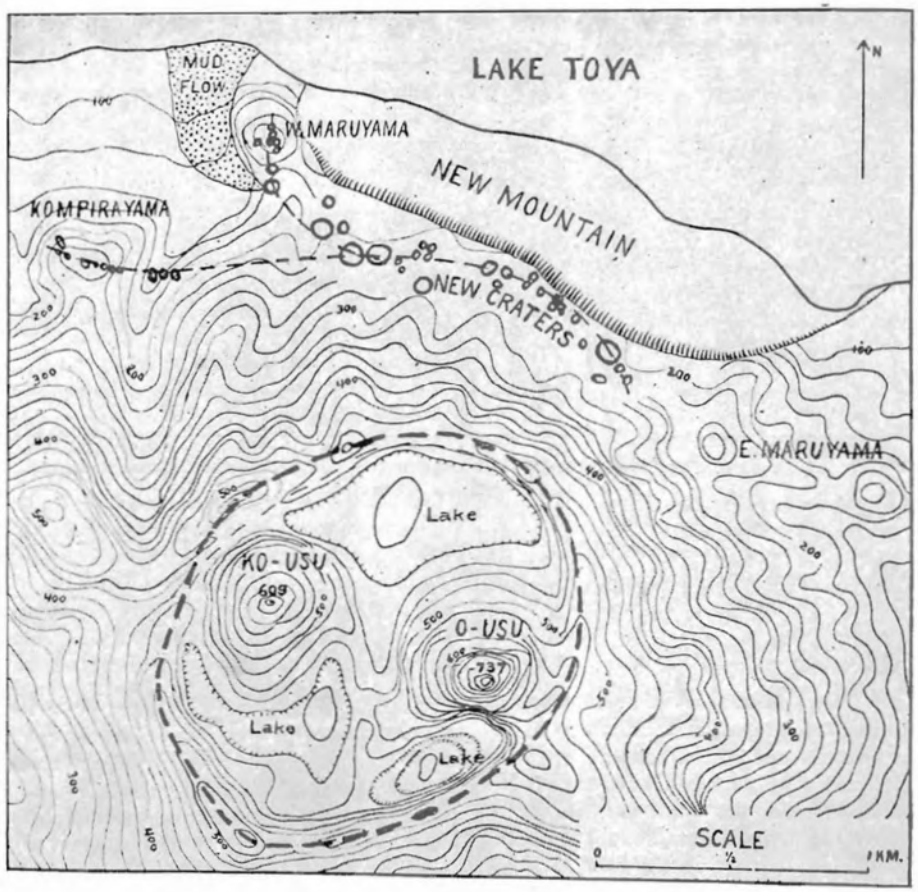
No. 302—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — October 9, 1930.



Map showing old somma ring and domes of Usu, the line of active craters of 1910, and the uplifted segment which makes the "New Mountain" escarpment. After Daly.

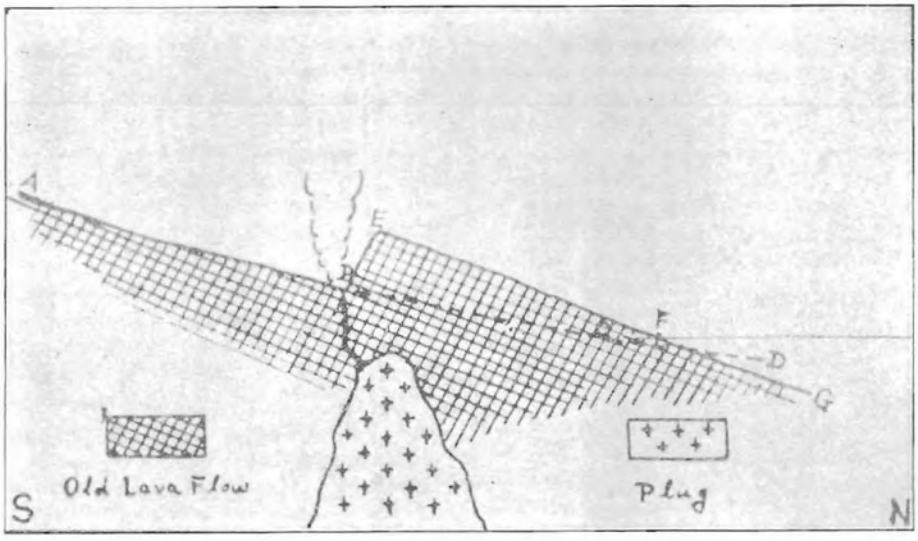
CHANGES OF ELEVATION AT USU VOLCANO, JAPAN

(Review by D. Malone of the paper by F. Omori, Bull. I. E. I. C., 5, 1913)

The volcanic outbursts in 1910 of the Usu-san volcano were followed by the formation of the "New Mountain." The elevation phenomenon was not confined to Usu-san but in November, 1910, in the town of Auta on the southwest base of Usu-san, a fence surrounding a field which had been level was at the time invisible from one side to the other. The Military Survey Department, in 1911 and 1912 undertook the determination of the heights of the first order benchmarks on the lines of precise-levelling running along the northeast coast of Volcano Bay and along the western foot of Usu-san.

In the summer of 1911, the height was examined along the Volcano Bay coast from the vicinity of the town of Benbe southeast to Abuta-Tokatan, then along the southwestern base of Usu-san to Tokotan on the Toya Lake and then to Muko-Toya along the western coast of Toya Lake. The total distance was about 25 km. In the summer of 1912, the measurement was repeated, being further extended 12 km. southeast along the coast of the bay to the town of Nishi-Monbets which is about 8 km. southeast of the central crater of Usu-san.

As may be expected from the proximity to the site of the "New Mountain," the benchmark at Tokatan was elevated 2.4244 meters, while benchmark Number 6596, situated midway between Toya Lake and Volcano Bay, was elevated 1.1601 m. At Abuta-Tokotan, on the coast of Volcano Bay, the elevation was 0.358 m., although the distance from New Mountain is 6 km. On the other hand, the benchmark No. 6597, not far from 6598 (at Tokatan), suffered a depression of 0.0739 m. while Nos. 7192 and 6599, at the distance of 2 km. to the northwest of Abuta-Tokotan and



Profile of uplift of the "New Mountain" segment at Usu Volcano in north Japan, as conceived by Ouinoue.

Tokotan respectively, were each depressed about 0.022 m. It will be seen that marked elevation took place at all benchmarks between Tokotan and Abuta-Tokotan, with the exception of No. 6597, and also at those between Abuta-Tokotan and Nishi-Monbets. As the southeast corner of the lake shore in front of the West Kohan School indicated an upheaval of some 1.333 m., it may be assumed that the whole mountain mass of the Usu-san and its base suffered an elevation, doubtlessly extending some distance beneath Toya Lake.

A comparison of the heights of the different benchmarks determined in 1911 with those again determined in 1912 shows that a sort of a level adjustment was going on both in the upheaval and the depression regions to no small degree. It may be seen that the three benchmarks Nos. 6596, 6598, and 6597 (the first two of which had been elevated by the greatest amount of 1.16 and 2.4244 m.) now indicated depressions of 18.4 to 29.2 millimeters. On the contrary, the three others, Nos. 7192, 6599, and 6600, which had been depressed by the maximum amount of 22 mm. were now raised to the amount of 2.0 to 3.1 mm. The ratios of the downward and the upward restitutions were thus greater than the former. It is likely that the process of the level fluctuatio ncontinues for many a year to come or at least as land as the volcano is in more or less active condition.

The problem of level change in volcanic districts forms an exceedingly interesting branch of geophysical research. Seismologically it is exceedingly desireable to investigate the changes in level which may take place in districts belonging to active earth-quake zones, previous to the occurence of destructive disturbances.

CYCLES OF VOLCANIC ACTIVITY

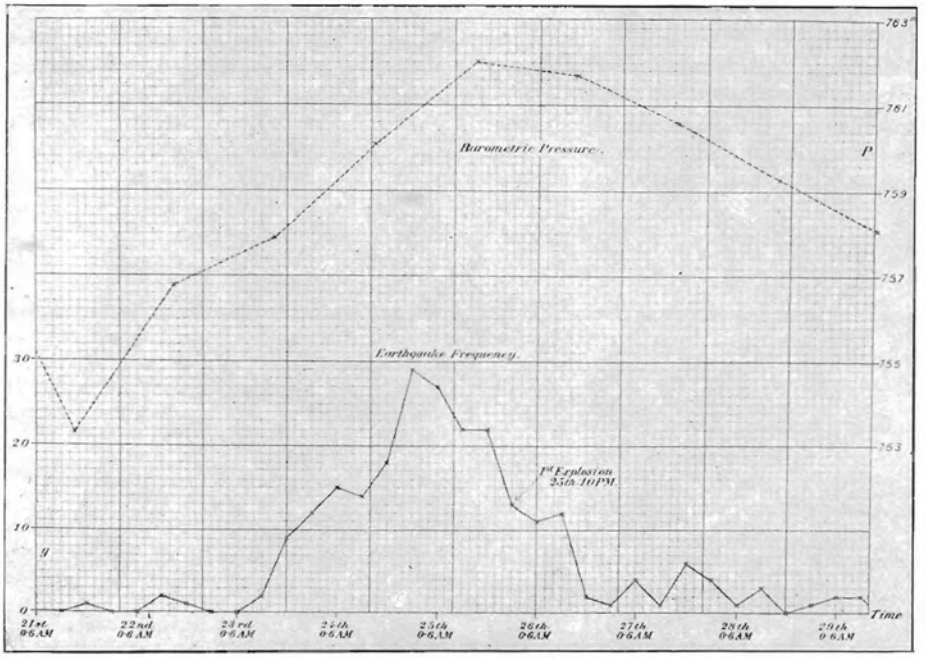
K. von Sapper, pp. 270-74. Translated from the German by H. C. Flattery.

The cycles of volcanic outbreaks and their possible connections with cosmic or terrestrial occurences are a subject that has been brought nearer to a solution by the keeping of statistics. Above all, a connection with sunspots has been accepted. J. Jensen finally came to the conclusion, through various experiments, that the greater frequency of outbreaks occurred simultaneously with the maxima and minima of sunspot coverage. Later W. Koppen, who has gone over this field again, found by studying the outbreak statistics of E. Kluge and de Marchi that the outbreaks were most frequent at the time of sunspot minima and most rare at the time of maxima. However, the record of outbreaks of K. Schneider gave a greater number of outbreaks for the time of maxima than for the time of minima. On account of these contradictory results, I have tried to examine my material with this in view: are the periods noticeable for the whole earth, or does an increase in certain districts equalize to some extent the decrease in others? For this purpose I have determined year by year the number of known activity units, and for the smoothing of the curve, I have, in each instance, considered the preceeding and the following figure at its weighted value—b equal ¼ (a plus 2b plus c). I ignored the continuously active volcanoes as they do not influence the curve. The southern hemisphere, on account of the greater number of continuously active volcanoes, is ahead of the northern hemisphere in general frequency of activity. But it shows a lower frequency figure, if one disregards the continuously active volcanoes, which is in keeping with its smaller

land surface. Only seldom does the southern hemisphere gain a preponderance. The beginning of the list is in the year 1749 as only from this time on is the sunspot curve known through observation. The absolute number of outbreak units is continually getting higher, the nearer we approach the present time. This can be explained through better reporting and the addition of new volcanic districts. The frequency curve plainly shows a number of periods. They are not of equal duration, but vary from six to twelve years. Very often they approach the duration of sunspot periods, so it is not remarkable that several times a high frequency of outbreaks coincided with sunspot minima and at other times with maxima. According to my figures there were seventeen frequency periods from 1749 to 1914. During the same time there were only fifteen sunspot periods. This shows that a fundamental connection cannot be established between the two. Nevertheless. a certain relation is not out of the question for it is noticeable that during a time of the pronounced flattening of the sunspot curve (1798-1825) the frequency curve too is less sharply defined. Gigantic outbreaks sometimes correspond with a high, and sometimes with a low point of the curve, or even in between, so that no particular regularity can be read from this material for the occurence of great volcanic catastrophes.

Even though the sunspot theory may fail to be proved, positive causes of terrestrial or astronomic nature may yet be found in the course of time for the periodical volcanic outbreaks. Perrey and Falb (during the second half of the 19th century) believed to be able to predict the earthquakes and volcanic outbreaks under the supposition that there was a flow of the molten liquid of the earth's core. This theory has now been abandoned, but there is still much speculation as to the influence of the constellations of sun, moon, and planets on these phenomena.

F. A. Perrett came to the conviction, after careful observation of the activity of various Italian craters, that the position of the moon and also the sun to each other and to the earth has a decided influence on volcanic activity. Perret took into consideration the distance of the moon from the earth, the quadratures and syzygien, and the changes of the declination of sun and moon. He found fortnightly and half yearly maxima. The first show a stronger swing. H. O. Wood, who was at the Kilauea Volcano Observatory from 1912-1917, criticised Perrett's curve, because it showed the fortnightly amplitude as greater than the half yearly one. He emphasized the great value of declination. The observations at Kilauea showed that high lava levels and strong surface activity occurred at solstice, low lava level and little activity at equinox. T. A. Jaggar, who has had charge of the Kilauea Observatory since 1917, calls attention to the fact that from 1911-1913 the lava measurements may have corresponded with these data, but not so from 1914-1918. He shows that occassionally solstice and equinox have high lava levels, but at other times they may be accompanied by low lava levels. He found that on the average the lava in Kilauea had a tendency to rise in April-May and October-November, and to fall in July-August and January-February. From these various views one might well draw the conclusion that the observations have not been recorded for a sufficient length of time to show reliable results. H. O. Woods pointed out that in a cycle of 18.6 years the moon exerts an increased influence on the earth. This is caused by the regression of the occuring moon (nutation) while the change of breadth of the same is completed in



Curve showing the rise of barometric pressure and of earthquake frequency just before the first explosion at Usu eruption. After Omori.

a seven year cycle. It is remarkable that the multiplication of these two periods is about 130 years. Half of this is 65 years. Woods notes that Omori, in examining the eruption history of Asama-yama, finds the mean interval to be 63.5 years and in doubling it, 127 years. Dr. Jaggar prophesied in 1918 that in 1920 (the 130th year after the great eruption of Kilauea) another such eruption would take place. In fact, great lava flows occurred in this year and the explosive outbreak repeated itself in 1924. As such successes lead us to hope that through the careful collection of observations of all kinds and through the consideration of the outbreak history of the various volcanoes it may yet be possible to shed light on the causes and the origin of these eruptions.

For a long time one has tried to connect eruptions not only with astronomic events but one has also thought of the possibility that atmospheric influences, above all heavy rainfall, at least in case of explosively active volcanoes, might be the cause of eruptions.

Systematic observations were first made by G. de Lorenzo at Mt. Vesuvius. He found that heavy precipitations increased the activity of this fire mountain. F. Stell-Starrabba extended the observations to Etna and later on to Japanese volcanoes on information furnished by H. Tanakadate's paper "On the Activity of Japanese Volcanoes from January 1914 to August 1924." Lately the work referring to Japanese volcanoes was continued, using Karl Sapper's catalogue of the historical volcanic eruptions. This gave information on volcanic outbreaks since earliest times. Both sources showed the coinciding of rainy and eruption times. In looking over the entire eruption activity, the maximum seems to be delayed several months, during the short period from 1914 to 1924. This retardation is explained, according to Starrabba, by the fact that the general eruption list shows only major eruptions while in Tanakadate's compilation, even less important manifestations of activity are recorded.

KILAUEA REPORT NO. 976

WEED ENDING OCTOBER 5, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

On Monday and Tuesday a few dust clouds were caused by small avalanches from the walls of the pit. Since then it has been so rainy that any slides which might have occurred did not raise clouds of dust. The heavy rains which began on Wednesday, October 1, and have continued all week have caused an excessive amount of steaming from Halemaumau. A number of times, large cauliflower steam clouds have given a perfect imitation of eruption clouds.

One feeble earthquake was recorded on October 1 at 7:14 a. m. with a distance to its origin of 28 miles, and three very feeble shocks were recorded as follows: September 29, 12:31 a. m.; October 1, 1:05 p. m.; and October 5, 10:51 a. m. Twenty-five small tremors registered on the Observatory instrument during the first four days of the week, and three were recorded on October 5, the last day of the week. On two days there were neither tremors nor quakes. The microseisms, which indicate the non-volcanic trembling of the ground, were slight during the early part of the week but increased to moderate intensity over the week-end.

The Kona and Hilo records of the earthquake of September 28 give additional evidence which shows that the quake had its origin at great depth under the crater, Mokuaweoweo, on the main Mauna Loa rift line. Late reports also show that the quake was felt by some people in all parts of the island.

During the past week the ground under the Observatory has titled moderately in a south south-west direction. Unfortunately, the heavy rainfall of the latter part of the week has caused some tipping to the south, which tends to obscure the significance of the tilt record so far as volcanic pressure is concerned. Only one thing is certain, that is, if any excessive change of pressure had followed the deep seated quake of September 28, it would surely have made itself evident in the tilt record in spite of the obscuring outside influences

TILTING OF THE GROUND FOR SEPTEMBER

The general movement of the ground under the Observatory during the month of September was a slight tilting back and forth along a northeast-southwest direction. The net amount of tilting for each week, taken from the curve which is smoothed by calculating progressive seven-day means, is given in the following table:

September	1— 7	N. E.	.97	seconds	of	arc
"	8—14	N. E.	1.20	"	"	"
"	15—21	S. S. W.	.90	"	"	"
"	22—28	N. N. E.	1.33	"	"	"

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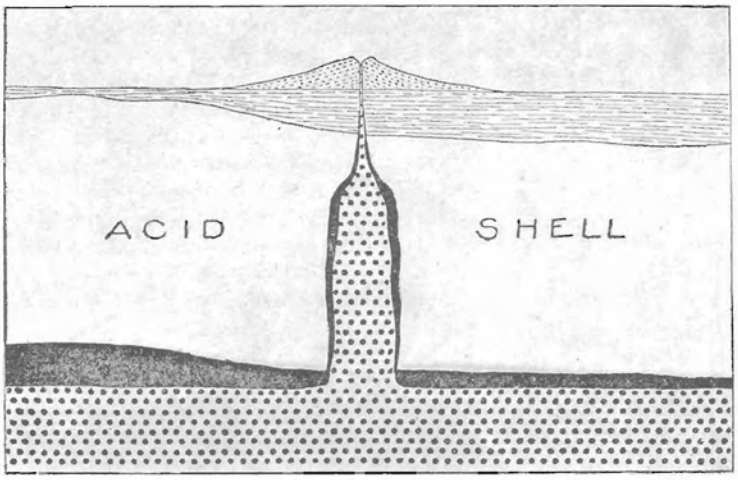
The Volcano Letter

Two dollars per year — Ten cents per copy

No. 303—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — October 16, 1930



Diagramatic section through the earth's crust showing sediments under a volcano, siliceous (acid) shell, black solidified layer of basalt, dotted liquid basalt of the substratum partly crystallized on the walls of the fissure leading to the volcano. The volcanic cone is represented as 5 km. in height. After Daly.

JOLY'S THEORY OF SURFACE CHANGES OF THE EARTH

(Reviewed by M. Gauntlett. The appendix of "Surface History of the Earth" by John B. Joly.)

After a sinking of the earth's crust with inflowing of the seas over the land masses, sedimentation takes place and then a gradual rising of the continental blocks again. Before the final climax of the renewed rising, floods of basalt arise and flow out through the cracks in the earth's surface. The geosynclines, or places which have received the most sedimentation, are lifted up to form mountain ranges. These periods of great crustal movement, or Revolutions, have occurred about four times, the last ushering in the present geologic age with the rising of the Eurasian chains.

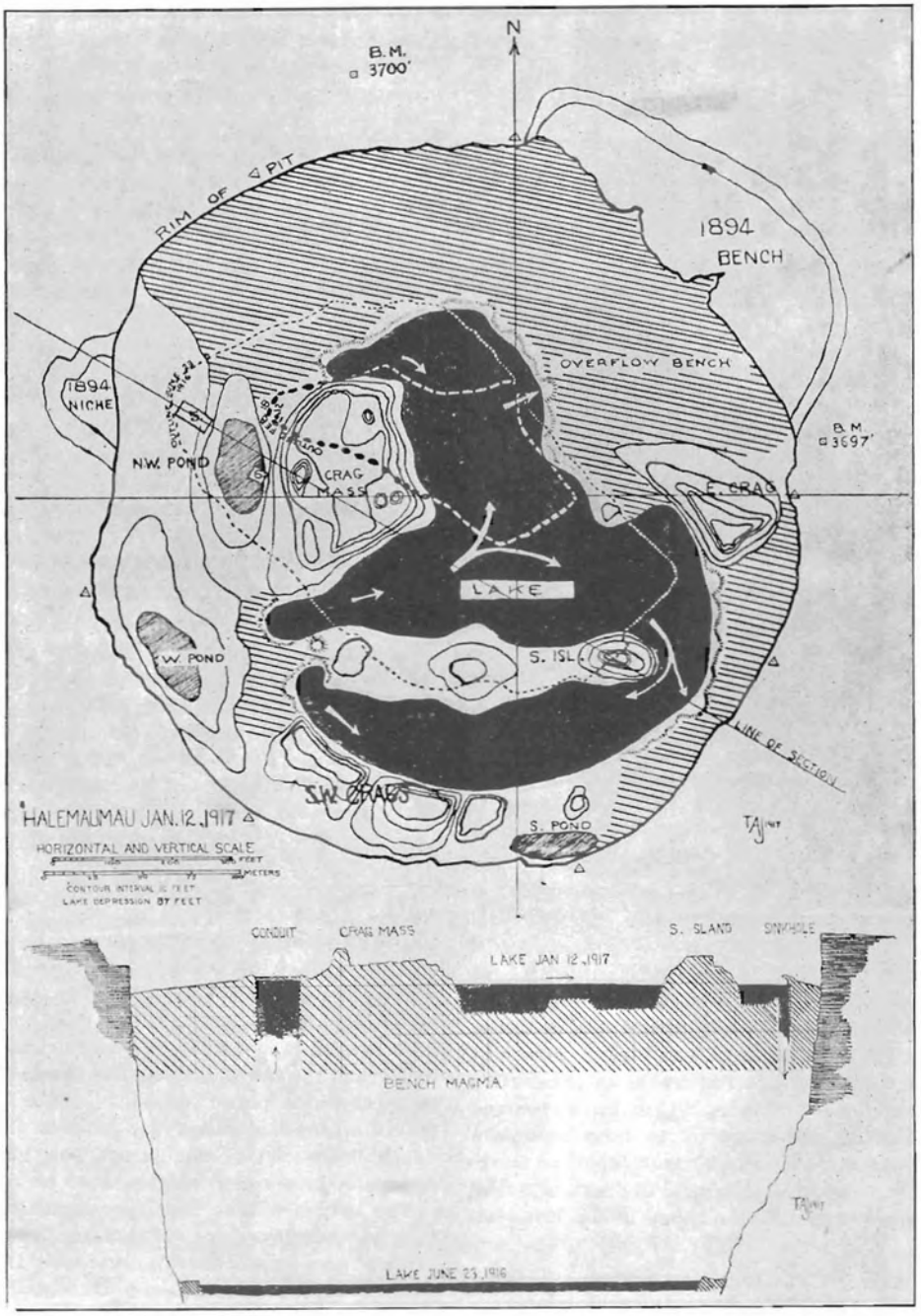
In the article, the origin and interrelations of these events, the sinking and rising of continental blocks, is traced in reference to: (1) the existence of a general basaltic magma-ocean or isostatic layer in which the continents float and upon which the oceans rest; (2) the presence of a certain amount of radioactive materials throughout this magma-ocean; (3) the maintainence both in past and present of isostatic equilibrium of the land masses; (4) certain forces acting on the earth's surface crust.

The general distribution in the rocks of energy-producing or radioactive elements was demonstrated by Lord Rayleigh about twenty-two years ago. This shows that there is everywhere in the rocks a perpetual source of heat which is unfailing whether the heat is accumulating or escaping. More thermal energy was evolved in past ages. Joly feels that this accumulated energy has been a dominating factor in the history of the changes of the earth's surface for all time.

The question of isostacy connoted the existence near the earth's surface of a layer of dense, plastic material in which the continental masses of lighter rock float and upon which the oceans rest. The law of compensation works here to a marked degree, the continental masses displacing more than the lower oceans. The greater mass of the mountain ranges is permitted because the lighter rock which makes up the mountains also extends downward to a great depth beneath the mountains. The Himalaya mountains are about 80 per cent compensated by this method.

The evidence that basalt or basaltic magma composes this isostatic layer are very strong. It is found that during disturbances on the earth's crust vast amounts of intensely heated, fluid basalt come up through the fissures. Basalt has a very high density. It is the most prevalent effusive rock on the globe. The oceanic islands are predominantly basaltic. Experimentally it has been found that basalt directly underlies the oceans. Joly designates the continents as a granitic scum which has separated out. The continents float in this underlying magma layer and the oceans rest upon it as oil on water.

From astronomical study and seismology it is found that at present this substratum must be solid and behave as an elastic solid towards rapidly changing physical forces. However, it is in the solid state very near its melting point, and in the past it has been in the fluid state just above its melting point. Now heat is being generated by



Pit plan and profile of Halemaumau. Shows in profile the bench magma shaded) as a narrow rim in June, 1916, and as the principal fill of the pit in January, 1917. Map shows lake, crags and western source wells. After Jaggar, A. J. S., Sept. 17, 1917, p. 168.

radioactive elements, and heat from a solid is given off only by slow conductivity, so heat is accumulating since it has no rapid means of escaping. It will take some 30 million years for enough heat to accumulate to change the basaltic magma back into the liquid state.

When this takes place there will be an uprising of the entire earth's crust due to the expansion of the basalt during melting which is 11 to 12 per cent, but there will be a sinking of the continental blocks because of the decrease of density of the basalt during melting. After liquifaction is complete, the rate of loss of heat is enormous due to the convection currents in the liquid mass. The heat will be lost mostly through the ocean floor. The loss of heat causes the magma to solidify again and the entire sur-

face of the earth sinks again with the continents rising due to the change in density of the supporting magma-layer. This is a cycle which occupies from forty to sixty-five million years as well as may be judged with the scarcity of known facts.

It is quite probable that, during this time of liquifaction, there are great tides in the magma and the continents shift with the ocean in respect to the deep lava.

In the formation of mountain ranges, Joly holds to the theory that the folding and over-thrusting of the layers of sediments are done long before the mountains are elevated. The sedimentation in large geosynclines, or troughs, forces these areas to bear down much more heavily into the superheated isostatic layer beneath, and later, when the horizontal mountain-making forces come into action, they do not push the mountains up but rather further down. The mountains do not rise until solidification of the underlying magma increases its density and the forces tending toward compensation become great enough to force the whole crushed mass of sediments upward as elevated mountain ranges. This elevation is due to vertical forces and not horizontal as has been stressed in earlier theories of mountain building. The energy comes from the expanded magma and is traceable to the accumulated radioactive heat.

According to astronomers this liquid layer of basalt has tides and the tidal movements greatly exceed in energy those of an ocean of water. There arises a west-to-east pressure transmitted from the rotating earth in opposition to the lunar and solar gravitational forces. This acts on the submerged westerly coasts of the continents. It is a fact that all of the great lava flows have occurred on the western sides of the mountain ranges and continents. The magma expanding about ten per cent would increase the equatorial width of the Pacific about thirty miles and that of the Atlantic eleven miles. The approximated thickness of the ocean floor would be twenty miles in twenty-five million years, and the thickness in inter-revolutionary times would be fifteen miles. During the period of thermal dissipation it will be attacked by super-heated currents and greatly reduced in thickness by melting of the bottom. It will rupture along the coasts of the continents, and the fractures will be filled rapidly by congealing basalt, forced in under pressure. During this time the heat is being dissipated and the ocean floor again thickens and strengthens. Then, when this thickened and enlarged oceanic crust sinks due to the cooling of the underlying magma layer it pushes against the coasts of the continents and causes buckling.

Earth movements and volcanism must result from this breaking down of solid to liquid. Also it is difficult to separate horizontal and vertical movements because of the tensional properties of the rocks and the fact that molten lava fills all cracks preventing return to the original dimensions. The vertical oscillatory movements become a source of ever-extending lateral pressures.

The relative amounts of land and water are explained by thermal equilibrium. If the temperature becomes too great, the continental rocks liquify and either rise vertically in great intrusive bodies called batholiths or expand laterally until the thermal equilibrium is reached again.

By the theory as represented many great facts of earthly tectonics are explained. Such cyclic changes not only arise consistently and naturally, but it may be said inevitably from the conditions present. "The events of the past cease to be mysterious, but become the natural outcome of the physical structure of the earth's surface."

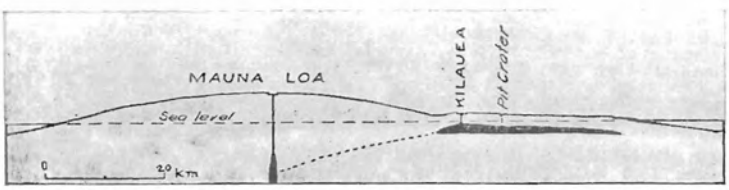
TILT AND RAINFALL

In Kilauea Report No. 969, August 17, the remark was made that abrupt tilting of the ground to the south was coincident with a period of heavy rains in the region around Kilauea crater. Additional data have thrown more light on this occurrence.

On several different occasions during the past few months, rainfall has been so heavy that streams of water have formed numerous short-lived water falls over the walls of the crater, and the crater floor has been dotted with countless pools of standing water which last for several hours after the rain ceases. One of these water-catching basins is located about 30 feet south of the building which houses the Halemaumau seismograph, and during the heavy rains it holds a pool of water perhaps 20 feet in diameter and one foot deep on the average. Thus approximately 4000 pounds of load are added to the surface of the ground just south of the seismograph.

The observer at the pit has noticed that this small basin has been filled on five different occasions, and, at each time, the seismograph has registered abnormal tilt to the south.

Date	Amount of tilt	Duration of abnormal tilting
Aug. 10, 1930	S—1.2 sec. of arc	4 hours
Aug. 11,	S—1.1 " " "	3 "
Sept. 10,	S—3.1 " " "	5 "
Sept. 19,	S—0.3 " " "	2 "
Oct. 8,	S—3.0 " " "	5 "



Profile of Mauna Loa and Kilauea after Daly, imagining Kilauea fed from a remnant lenticular intrusion. Daly, Proc. Am. Acad., June, 1911.

The exact amount and duration of these rains is unknown, so that a quantitative correlation between rainfall and tilt of this instrument cannot be made. However, observations have been sufficient to make certain that these short periods of abnormal southern tilting of the Halemaumau seismograph are coincident with the heavy rains which form the pool of water just south of the instrument pier.

The heavy rains at the pit on August 10 and 11 were a phase of a very heavy general rain which affected the whole area. During the three days, August 10, 11, and 12 about 12.5 inches of rain were recorded at the Observatory. On these same three days, the Observatory seismograph showed an abrupt tilt to the south which amounted to 3.5 seconds of arc. The other three instances of sharp tilt at the Halemaumau instrument were not coincident with any unusual rainfall or tilt at the Observatory. However, during the three days, October 3, 4, and 5, about 6.8 inches of rain fell at the Observatory, and a rather abrupt tilt to the south of 1.2 seconds of arc was recorded. These two instances from the Observatory are not sufficient basis for any generalizations on the correlation of rainfall with the general tilting of the Kilauea rim. It is evident, however, that abnormal tilt may be shown on the Observatory instruments which does not affect the Halemaumau station, and vice versa.

In an article appearing in the Bulletin of the Seismological Society of America in March, 1929, T. A. Jaggar and R. H. Finch discuss the relation of regional tilting to regional rainfall distribution. They point out that the northeast slopes of Kilauea receive many times as much load from rainfall as do the southwest slopes of the mountain. They conclude that "such a loading might be expected to give a northeasterly tilt at the Observatory. There is, (judging from their study of a three-year record) however, practically no correlation between tilt and rainfall, either daily or seasonal.—If the winter irregularities (in the tilt curve) were due to rainfall, we would expect that in 1918, the wettest year, the winter curves would be more irregular than for 1919, the driest year, but such is not the case."

The local instances cited in the present article do not affect, in any way, this conclusion on regional rainfall and tilting. They indicate simply that local loading of the surface may cause a temporary local bending of the lava structure of sufficient magnitude to show up as abnormal tilting on the seismograph records.

KILAUEA REPORT No. 977
WEEK ENDING OCTOBER 12, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

There have been no conspicuous avalanches from the walls of Halemaumau during the week. Large steam clouds have accompanied or followed several heavy showers, and on the evenings of Oct. 8 and 9 very striking cauliflower clouds rose over the pit. The wind was light enough so that they were not blown away immediately upon their formation.

At 12:04 a. m., Hawaiian Standard time, October 8, the instruments recorded a very small disturbance which was caused by a distant earthquake. The record is so poor that it is impossible to estimate either the distance or probable direction to the source of this teleseism.

Three very feeble earthquakes of local origin were recorded as follows: October 8, 8:16 p. m., and 10:30 p. m., no distance determined; and October 9, 7:46 a. m., distance to origin 35 miles. A total of 17 small tremors occurred during the week. This is the smallest number of these tremors recorded since the week ending August 17, 1930. The microseismic, or non-volcanic trembling decreased the early part of the week and has remained slight to the present.

The week's average of the tilt record shows that the ground under the Observatory has been tilted slightly to the northeast. The southwest rift of Mauna Loa still seems to be controlling the tilt movements, but there has been no notable increase or decrease of pressure to suggest movement of lava on a large scale since the deep earthquake of September 28.

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No. 304—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — October 23, 1930



One of the explosive eruptions of Mt. Lassen as seen from the northeast. The explosion is from the newly formed gash crater. The snow to the left of the crater is grey from the falling ash. Photo by B. F. Loomis.

ACTIVITY OF LASSEN PEAK, CALIFORNIA, UP TO 1915

By H. C. HANNA

References: Popular Science Monthly, March 1915, Professor Holway. Lassen Peak Folio, U. S. Geologic Atlas, Folio 15. U. S. Dept. of Interior Bulletin, June 1 to Sept. 15.

It is almost certain that no white man had ever witnessed an eruption of a volcano in the State of California until May 30, 1914. On that date Lassen Peak, a well known volcanic cone about seventy-five miles southeast of Mt. Shasta, suddenly burst into explosive action. During the six months that had elapsed when Professor Holway presented his article there had been an average of one eruption every three days, and no indication at that time that the activity had ceased.

A natural curiosity exists concerning the event that took place in view of probable developments of the future. Was this activity a sign of rejuvenation of a long quiescent volcano? Will this volcano again erupt lava?

Lassen Peak is located in the extreme southeastern corner of Shasta County, nearly two hundred miles from San Francisco. It lies on the southern tip of the great Tertiary lava field, some 250,000 square miles in extent, which covers not only northeastern California, but parts of Oregon, Washington, Idaho, and Nevada as well. Lassen marks the southern end of the Cascade Range and is the last of a series of volcanoes of which Rainier, Adams, Hood, Three Sisters, Pit, Mazama, and Shasta are familiar examples. South of this mountain range are the Sierra Nevada Mountains which were caused more by great faulting and uplift than by volcanic accumulation.

Until this recent outbreak (1914), Lassen Peak belonged to the class of doubtfully extinct volcanoes. As shown by the following statement, Diller did not consider the volcano extinct: "That volcanic activity is not yet extinct in Lassen Peak is shown by the presence of numerous solfataras and hot springs. At Bumpass' Hell, near the southern base of the peak, there are boiling mud pools and vigorous solfataric action."

Previous to the eruption of 1914, there have been several accounts of eruptions reported by the Indians who claim to have witnessed them shortly before the coming of the white settlers. Following is a report of Dr. J. W. Hudson of Akiak, California.

"I was in that region in 1904 collecting for the Field Museum of Natural History, Chicago, and heard much of



Lassen volcano in the summer of 1924 after all eruptions had ceased. Most of the light colored material on the flanks of the volcano and in the foreground is powered rock which was erupted during the activity of 1914 and 1915. Photo by B. F. Loomis.

Lassen Butte. An old Indian told me that when a child, an earthquake occurred at Lassen one summer day. The sun rose, but finally faded to the darkest night——. In many localities along the Pit River watershed, I heard similar reports amongst the aged Indians. The name of this volcano in Palinikau tongue is "Am bliikai," ie. "Mountain-ripped-apart."

Prompt investigation of the first eruption is due to the fortunate fact that the mountain is included in Lassen Peak National Forest, and that the U. S. Forest Service had built a fire look-out station on the topmost crag of Lassen Peak itself. When the eruption began in 1914, the lookout stations had not yet been occupied for the summer season. It can be seen that the interests of the forestry service made the activity on Lassen almost immediately investigatable.

The following is a report made by W. J. Rushing of the Forestry Service:

"Such wild stories are being circulated concerning Mt. Lassen that I am sending you the results of our observations to date. Saturday, May 30, the first outbreak occurred at 5 p. m. This was witnessed by Bert McKenzie of Chester who was looking directly at it when it occurred. Ranger Abbey investigated it on Sunday, May 31, finding a hole 25 by 40 feet in size and of unknown depth. Sand, rocks as large as a sack of flour, and mud were ejected. The heavier material was thrown over an area 300 feet across, while the ash was scattered over an area a quarter of a mile across. No molten material was thrown out. At 8:05 a. m., June 1, a second outburst occurred, throwing out large quantities of the same sort of material. Boulders weighing a ton were ejected. The vent was enlarged to 60 by 275 feet. On June 8, heavier volumes of steam were noted, and at night, another eruption took place, throwing out more ashes and fine material.

"Heavy volumes of steam are coming out of the vent today. We have watched it carefully, and at no time have we been able to see any flame or indication of fire. The vent is about one quarter of a mile from the fire look-out house, and if it continues eastward, as it has so far, it will finally break out on the east side."

Mr. Macomber, a member of the Forest Service spent the night of June 4 at the fire lookout house and reports: "The crater measured 275 feet long. It was then in a pause between explosions. Cracks appeared in the ground and sulphur smoke was rising from them. The walls of the crater were perpendicular and about 60 or 70 feet in height. In the center of the crater floor there appeared a pile of rocks."

On June 14, there occurred the heaviest eruption up to this time, and it was from this explosion that the only injuries during the whole six months period were incurred.

Mr. B. F. Loomis gives a brief summary of the experiences of the party that was caught by this eruption:

"Mr. Phelps party reached the rim of the old crater and sat down to rest a short time, watching the smoke from the crater, when the eruption began. Without any warning or explosion that could be heard, a huge column of black

smoke shot upward with a roar, such as would be caused by a rushing mighty wind, and in an instant the air was filled with smoke, ashes and flying rocks from the crater. They all ran for their lives. Mr. Phelps hid under an overhanging rock, which sheltered him from the rocks which brushed past him as they fell. Lance Graham was a few feet away and was struck by a flying rock, which cut a great gash in his shoulder, piercing the thoracic cavity, and broke his collar bone. He was left on the mountain as dead for a time, but was then removed with great difficulty. He is now recovered. Another of their party ran down the mountain and coming to a snow drift, slid down the mountain like a shot. The cloud of smoke kept pace with him and when he reached the bottom of the snow drift, he found a clump of bushes and diving into it, buried his face in the snow to keep out the blinding smoke and ashes. The smoke is described as causing the blackest darkness, black as the darkest night."

Volcanic dust or ash from the different eruptions has been reported as falling from ten to twenty miles from the peak, the amount and direction varying with the wind. The limits of the heavier falls of ash were within a circle of less than a mile. The direction of the dust outbursts varied, irregular streaks of ash such as that of June 26 showing minor outshoots of dust in various directions. Exaggerated reports of the distance to which stones were thrown were based on the distance they were found on the outer slopes of the old crater. To avoid mistaking such stones for those thrown out by the eruptions, careful search was made on level patches of the old snow so located that it was impossible for stones to roll down on to them. Wherever such places were found, there was no evidence that ejected stones fell at a much greater distance than to the lookout house, and certainly no further than one-half mile from the crater.

The winter's snow had largely disappeared and near the top of the mountain snow was to be found only in patches and beneath a covering of ashes. These areas appeared black in contrast with the light grey of the greater part of the mountain crest due to the presence of dust. This dust was so fine that it was easily moved by the wind and at times a strong gust would send immense clouds into the air, thus giving the appearance of an eruption which would fool observers at a distance and to these probably were due the many false reports about new eruptions that never existed.

During the month of August there were eight eruptions, fewer than either of the preceeding months. Seven out of eight of these threw dust as high as 10,000 feet and were considered quite severe. The record for September showed 17 eruptions, the largest number for any of the six months covered in this report. During this month there was an enlargement of the crater and new vents were opened.

The most remarkable change in the crater (new on the northeast side) occurred in September. The inner vent was 900 feet in length. The severity of these September eruptions is confirmed more or less by the fact that the lookout house there was completely demolished on the 29th of September. The forest lookout on Turner Mountain reported having seen red hot stones ejected. This was confirmed by other observers who claim to have seen flames. This, therefore, is the only observation during these eruptions that indicates such temperatures as molen lava.

The records of October and November are incomplete due to the severe storms in the vicinity which prevented observations. However, these two months are credited with 16 eruptions which shows that the volcano was by no means becoming quiet. Later in January 1915, the San Francisco Chronicle reported an eruption from a new crater on the east as equal to any that had gone on before. The article also stated that no one had visited the volcano for a period of three months.

Mr. Rushing in a letter to the author made some observations during November and states that the eruptions could be classed as medium. He gives a suggestion that this fact may be explained by the fact that a new vent had been opened at a lower level. A comparison of distant observations from the north and from the south would be necessary to test the correctness of Rushing's supposition.

The action of the "smoke" from Lassen is well described by Prof. C. F. Shaw who says:

"The smoke rolled up until practically the entire height of 12,000 feet was reached before any change in its form occurred, when just below the top of the column there was a tendency to stratification and a layer extended out toward the south and toward the north. When this appeared, the smoke column began to lean toward the north and, from our point of vision apparently toward the northeast, distortion took place with the inclination of the column, the upper part spreading out into streamers. As soon as the inclination of the smoke column became very plain, we could readily distinguish indications of falling material. The lower two-thirds of the column seemed to be dropping some material that was falling in a slightly oblique line, the obliqueness pointing back toward the mountain peak. As the eruption continued and the smoke column blew out more toward the north, the streaked condition indicating falling material become more and more apparent, but as the light was failing it became rather hard to distinguish the exact outlines of the lower portion of the column." c

The falling matter must have been the stones and coarser material in distinction to fine ash forming the top of the column of "smoke." Professor Shaw's observation is the only one received by the author that indicates the height to which the heavier fragments were thrown. His statement indicated a total height for coarser material of 8,000 feet.

All of the observers agree that there was no molten lava ejected. Samples of the ash were submitted to Professor A. S. Eakle of the University of California and his report states that the ejected material was composed entirely of fragments and dust particles formed by the shattering of the old volcanic rock which makes up Lassen Peak. The activity, accordingly, must have been all steam explosion, with no eruption of new lava to the end of 1914. (A plug of new lava did make its appearance in the crater of Lassen at a later date).

KILAUEA REPORT No. 978

WEEK ENDING OCTOBER 19, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

The early part of the week passed with no happenings of interest at the Volcano. About noon on Saturday, October 18, several medium-sized avalanches fell from the north wall of the pit, and small slides were noticed occasionally on Sunday. Steaming from the wall and floor cracks was very light during the entire week.

At 8:25 a. m., October 20, a moderate earthquake dismantled all of the instruments at the Observatory. The quake was felt over the entire island, with localities on the slopes of Kilauea receiving the strongest shock. This evidence corroborated the data from the seismograms which indicated that the center of the quake was under Kilauea crater. It is not yet possible to form an intelligent opinion as to whether or not this shock is the forerunner of an appearance of lava in Halemaumau.

There were two quakes of very feeble intensity during the week, recorded as follows: October 13, 4:12 a. m., and October 17, 7:31 p. m. Neither of them has been reported as felt anywhere on the island. Seventeen tiny tremors which may have been of volcanic origin registered on the seismograph at the Observatory. The non-volcanic trembling of the island which is reported as microseismic motion was slight throughout the week.

The average of the week's tilt recorded shows that the northeast rim of Kilauea has been tipped moderately (about 1.5 seconds of arc) in a north-northeast direction, ie. away from the pit. Tilting in this azimuth has usually been associated with changes of pressure under Kilauea crater, and the tipping away from the pit is considered as an indication of increase of volcanic pressure. The earthquake of Monday morning was accompanied by a sudden tilt of nearly 1.5 sec. of arc in the same direction, suggesting that the quake was associated with upward pressure under Kilauea.

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The Volcano Letter

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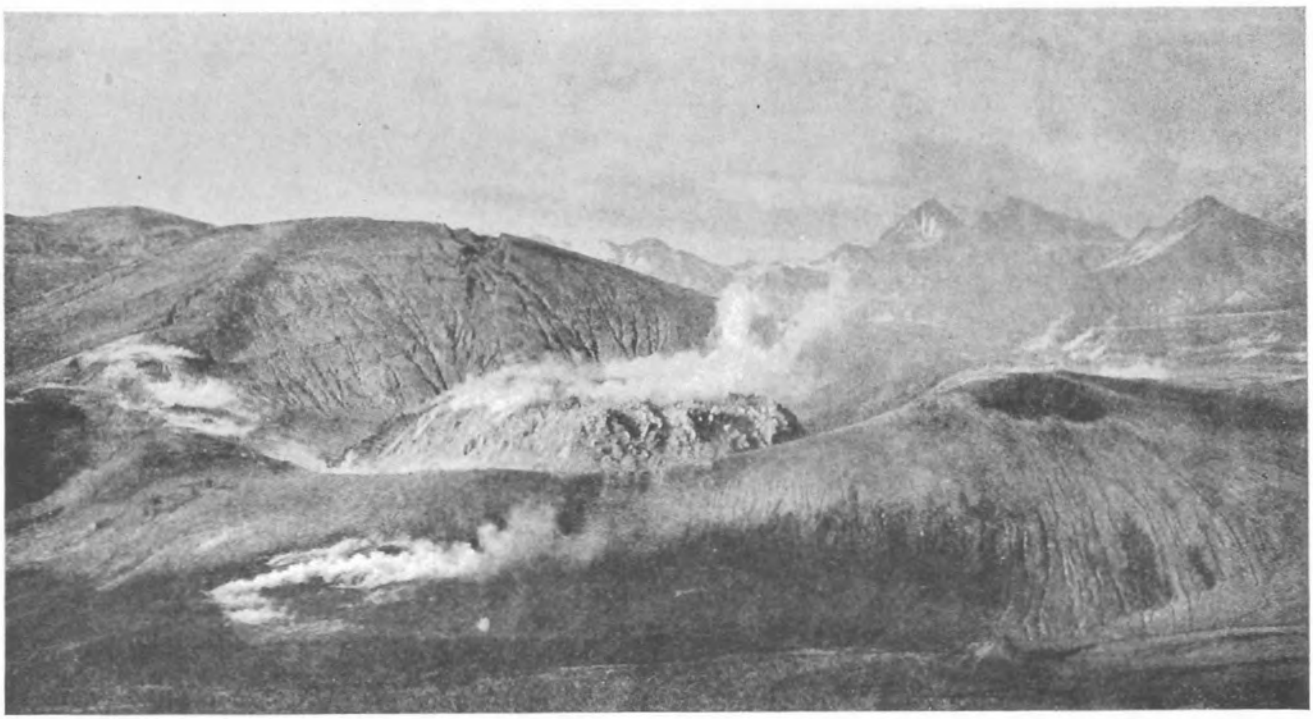
No. 305—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — October 30, 1930



Novarupta Dome, of siliceous lava, from the southwest, showing parts of the Valley of Ten Thousand Smokes beyond. Photo, National Geographic Society, 1919, from Katmai Series, No. 1.

THE ERUPTION OF KATMAI, ALASKA, 1912

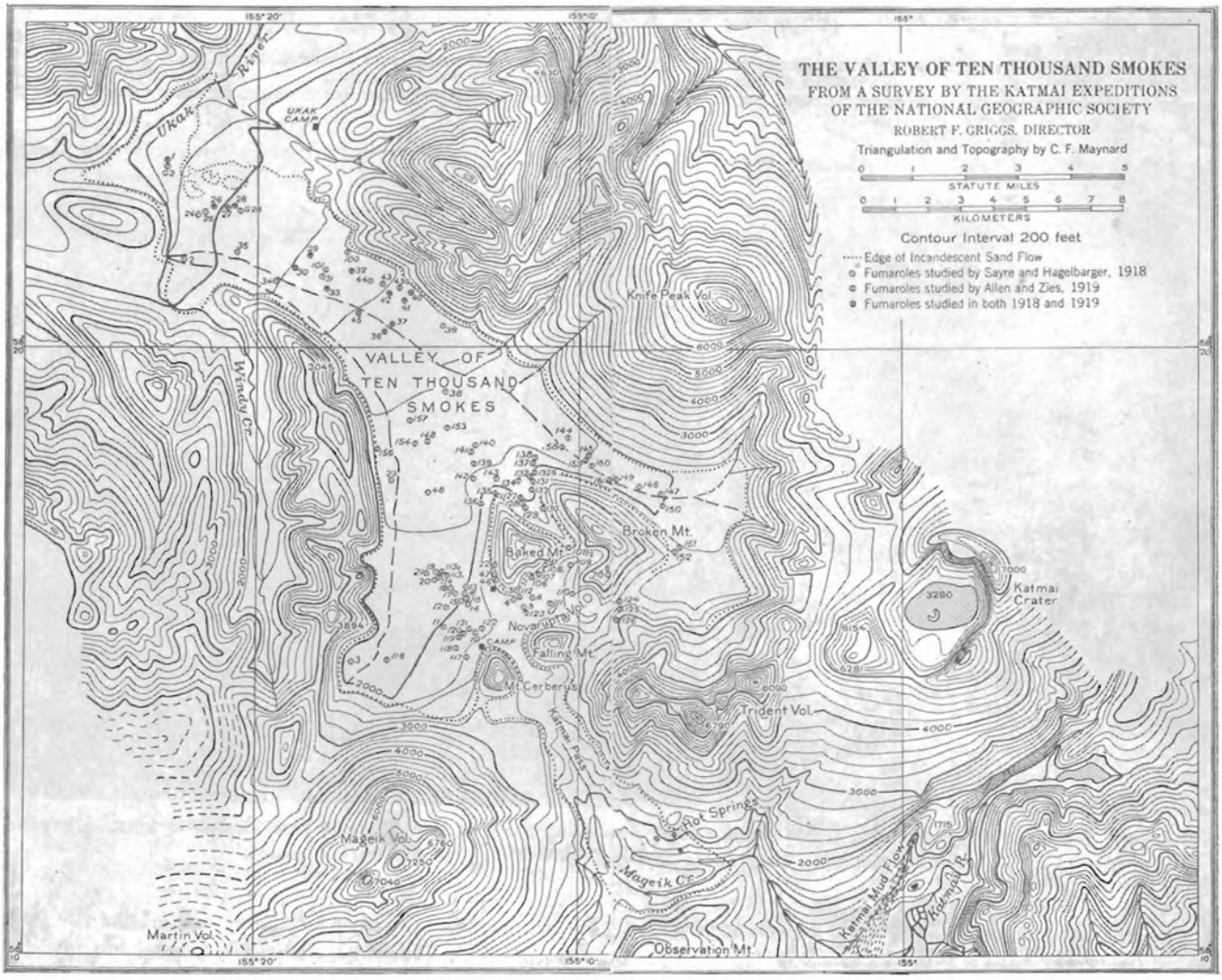
By H. Okimura. Reference: Robert F. Griggs, National Geographic, September 1921, pp. 219-292.

The explosion of Katmai Volcano in Alaska in June 1912 is ranked among the twelve greatest historic eruptions of the world. It is easy to see the justification of giving this rank when it is shown that as a result of this eruption, a town a hundred miles away was buried under a foot of ashes; that so loud were the concussions that the comments of people at a distance of 750 miles were excited; and that the quantity of dust thrown into the upper atmosphere was such that the intensity of the sunlight was diminished for many months throughout the northern hemisphere. The eruption giving rise to the Valley of Ten Thousand Smokes was a sequel to eruptions from the floor of valleys at a considerable distance from Katmai as shown by the fact that the stratified ashes from Katmai everywhere lie on top of the deposits of this earlier phase of eruption.

Lack of any eye-witnesses and any recorded happening resembling this sort of eruption made difficult the interpretation of the events of this great explosion. True, there was one, "American Pete" as he was called, who had witnessed the occurrence but aside from stating that it was dark and hot ashes fell, the only eye-witness could not much enlighten the explorers. The host of small volcanoes or vents which burst forth destroying the once beautiful green valley, presented a feature unusual in volcanic phenomena, for here no dormant vents had awakenend, but volcanoes had been formed in areas where none had existed. The new volcanoes, made simply of holes blown through the floor of the valley, began to thrown out ash and pumice in enormous quantities soon after their formation.

It is believed that in addition to myriads of fumaroles, hundreds of vents must have been belching forth incandescent material in veritable torrents of fire. Quantities of red-hot solids and liquids, sands and stones, masses of fluid or semi-fluid lava rushed out of the vents and poured out on the ground to roll down the slope and consume everything along its path. It is also believed that had one been able to witness the scene, there would have been seen many separate volcanoes each pouring forth its own mass and giving rise to great black clouds to a considerable height in ever-expanding convolutions. The smoke, instead of deriving its source from the mass of incandescent material around the vent, originated from the gases that boiled out of the semi-molten lava. The quantity of gas given off was so great as to be able to puff up the lava into pumice and entirely disrupt it by the expansive force of escaping gas.

The valley was overgrown to an altitude of 1500 feet by a dense forest and except for the ancient lava flow the rocks of the valley are not volcanic, consisting of sand and shale full of fossils of marine shell-fish of Jurassic age. Long before fires that consumed the surrounding vegetation had time to run their course, the mass of incandescent fragments accumulating round the separate vents coalesced until they covered the whole area of the valley,



Map showing Katmai crater on the east, Novarupta Dome in the middle, and the pumice-filled Valley at the left. From National Geographic Society, Katmai Series, No 1.

converting it into a single fiery torrent of red-hot sand and rock which began to roll down the valley under gravity for seventeen miles and even at that distance the heat was so intense as to reduce every stick it touched to charcoal. This fiery mass is not comparable to ordinary lava, although undoubtedly a liquid in the beginning, it did not remain so, for the escaping gas converted it to solid fragments suspended by the enormous quantities of gas given off.

The main arm is toward Naknek Lake for seventeen miles while another completely encircles Broken Mountains. The greatest length is twenty miles while the greatest breadth is nine miles, the total area covered being 53 square miles. The magnitude of the operation by which it was produced could be conceived if it is said that the sand flow is equivalent to the output of all the stone crushers in the United States for a period of 100 years.

The highest temperature was 645 degrees Centigrade and a stick thrust into the hole was changed to glowing coal within a few seconds. Big fumaroles furnished any degree of heat that might be needed for cooking, while snowdrifts behind the tents gave water and provided refrigeration. The steam from the fumaroles was highly charged with either hydrochloric or hydrofluoric acid which ate the rope to pieces and made holes in aluminum pots. Bacon was fried in no time, while corn bread was baked satisfactorily in Nature's oven.

In some places, columns of very hot steam came out under considerable pressure. The emerging gas came with such a rush that when a cup of water was poured over it, the water was vaporized before it had a chance to touch the bottom and a hat thrown in was tossed up thirty inches in the air.

Although the explorers had been able to get a fair idea of the "Smokes" themselves, they had no adequate conception of the marvelous coloration of the valley. One of the men who had lived on the brink of the Grand Canyon was impressed with the striking colors which were altogether different from those of the Canyon. The colors of the Canyon being remarkable at a distance, the coloration is produced entirely by the wonderful atmosphere and brilliant light which floods its recess. The colors of the valley are more brilliant when seen at close range, but at a distance they are grayish or brownish due to the fact that all the colors of the spectrum, being present close together, blend into a neutral color. In some places con-

siderable areas are leached out to a gleaming white by the acid fumes, while in some places pure yellow sulphur overlies other colors, and in still other spots where the ground is not too hot a bright green color is produced by the growing algae.

body of water to a height of four or five feet and occasional jets reach a height of 10 feet.

The Boiling Lake was the lowest during the summer of 1930 that it has been for several years.—R.H.F.

LASSEN REPORT No. 26

Lassen Volcano Observatory.
R. H. Finch, Associate Volcanologist.

During the summer of 1930 the National Park Service built a modern fire lookout building on the summit of Mt. Harkness, 8,039 feet above sea level. The United States Geological Survey installed seismographs in the basement of the building on August 21, 1930.

Eighty-eight tremors were recorded during the month that the seismographs were in operation. In addition to these tremors, there were, on many days, more or less slight continuous vibrations with a period of two seconds. This continuous shaking was stronger in the north-south direction than in the east-west. This type of vibration appears to be peculiar to the mountain top.

The entire mountain top is shaken by strong winds and the seismographs show a very irregular record on windy days. Puffs and gusts of wind produce records of tremor with considerable amplitude.

Good records were written of the southern California earthquake of August 30, 1930. The record of the Eureka, Cal., shake of August 23, 1930 was larger than that written by the instruments at Mineral. Several of the shakes that were recorded at Harkness were not recorded at Mineral.

Some time during July, the "Big Steamer" or uppermost large vent in the Supan Solfatara increased in activity and scattered mud for a distance of forty feet around the vent.

What was hitherto a large steam vent in the southeastern end of the Devil's Kitchen is now a boiling pool about 10 feet across. It boils constantly raising the main

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KILAUEA REPORT No. 979

WEEK ENDING OCTOBER 26, 1930
Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

A few avalanches in Halemaumau occurred simultaneously with the earthquake on Monday morning, October 20, which are thought to have been started by the quake. Since that time, no rock falls of noticeable size have been seen. The steaming of the wall and floor cracks has been very light except for short periods during rains.

The seismographs at the Observatory registered very slight traces of a distant earthquake on October 24. The record started at 9:55 a. m., Hawaiian Standard time. Only two local shocks were recorded during the week, the one moderate earthquake at 8:25 a. m. October 20, and one very feeble shock at 6:27 p. m. October 24. Fifty-seven very small tremors registered on the seismographs during the week, and the microseismic trembling of the island increased a moderate amount the later part of the week accompanying the few days of high wind and heavy surf.

During the earthquake of Monday morning, the ground under the Observatory was tilted to the north-northwest (errouneously stated last week as north-northeast). But since the quake, there has been practically no tilting of the ground as registered by the instruments. It would appear that the increasing pressure which caused the northeasterly tilting last week had culminated in the big quake. It will be interesting to see whether the first major change of pressure after this temporary standstill will be a decrease or a further increase.





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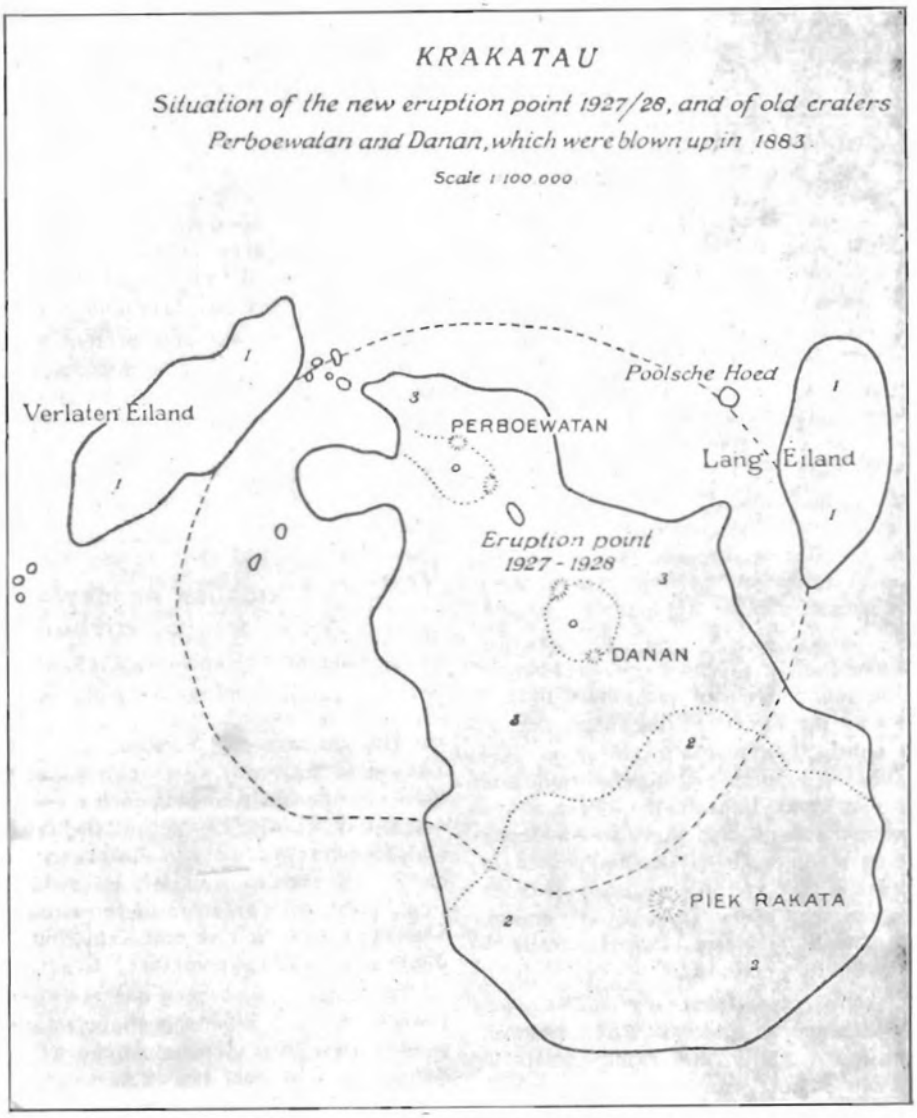
No. 306—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | November 6, 1930



Arrangement of the three craters Perboewatan, Danan, and Rakata of Krakatoa in 1883. The area enclosed within the heavy broken line is that region which was engulfed in the 1883 eruption. The location of the 1927-28 activity also shown. After Stehn.

THE ERUPTION OF KRAKATOA, 1883

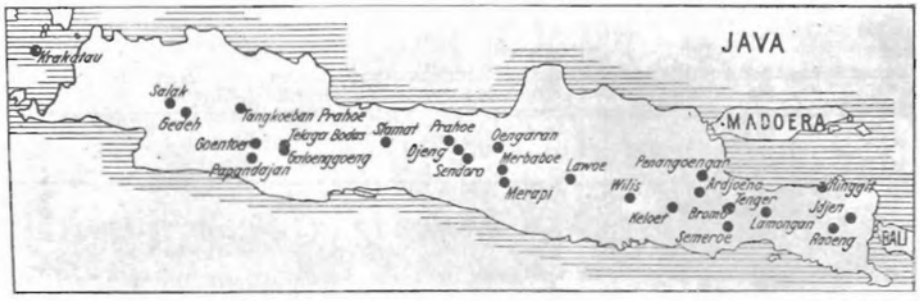
Review by R. A. Miyake of the Report of the Krakatoa Committee of the Royal Society.

Krakatoa is only a fragment of a great crater-ring rising out of the Sunda Strait, which separates Java from Sumatra. Along the line of this Strait we have evidence of a transverse fissure crossing the main fissure nearly at right angles. Upon this transverse fissure, a number of volcanoes have been built, namely: Pajung, in Java, with a height of 1,500 feet; the cone of Princes Island, 1,450 feet; Krakatoa, 2,623 feet; Sebesi, 2,285 feet; and Rajah Basai, in Sumatra, 4,308 feet.

In spite of the significance of its position at the point of intersection of these two great lines of volcanic fissure, Krakatoa had, until the year 1883, attracted but little attention.

On the afternoon of the 26th of August, and through the succeeding night and day till the early morning of the 28th of August, it was evident that the long-continued moderate eruptions (Strombolian stage) which had for some months been growing in intensity, had passed into the paroxysmal (Vesuvian) stage.

About 1:00 p. m. on August 26, the detonations caused by the explosions attained such violence as to be heard at Batavia and Brutenzorg, about 100 English miles away.



Distribution of active volcanoes in Java from Bali to Krakatoa. After Stehn.

One hour later, Captain Thomson of the Medea, then sailing at a point 76 miles east-northeast of Krakatoa, saw "a black mass rising up like a smoke in clouds" to an altitude which has been estimated as being no less than 17 miles. The great detonations at this time were said to be taking place at intervals of about ten minutes.

By 3:00 p. m. the explosions had so increased that their sound was heard at Bandong and other places 150 miles distant, and by 5:00 p. m. they had become so tremendous that they were heard all over the island of Java. The noise is described as being like the discharge of artillery close at hand, causing rattling of the windows and shaking of pictures and other objects hanging on the walls. Nearly all observers agree that there was nothing in the nature of earth-quake shocks, but only strong air-vibrations.

At 7:00 p. m., when the dense vapor and dust-clouds brought on early darkness, the whole scene was lighted up from time to time by the electrical discharge, and at one time the cloud above the mountain presented "the appearance of an immense pine tree, with the stem and branches formed with volcanic lightning." The air was loaded with excessively fine ashes, and there was a strong sulphurous smell. The steamer G. G. Loudon passed to the northwest and west of the volcano within a distance of 20 or 30 miles. It was seen to be "casting forth enormous columns of smoke" and the vessel passed through "a rain of ashes and small bits of stone."

The explosive bursts of vapor beginning on the afternoon of Sunday and continuing at intervals of ten minutes, increased in violence and rapidity, and from sunset till midnight there was an almost continuous roar which moderated somewhat towards early morning.

The constant augmentation of tension beneath Krakatoa in the end gave rise to a series of tremendous explosions on a far grander scale than those resulting directly from the influx of the sea-water into the vent; the four principal of these occurred at 5:30, 6:44, 10:20 and 10:52 Krakatoa time on the morning of August 27. Of these, the third occurring shortly after ten was by far the most violent, and was productive of the most wide-spread results.

After the great outbursts of the early morning of the 27th, it appears that there was a lull for a time inasmuch as no explosions were heard at Brutenzorg during the afternoon. At 7:00 p. m. the explosions began again, increasing in violence until 10:00 or 11:00 p. m., when they again declined and finally ceased to be heard at 2:30 a. m. on Tuesday, the 28th of August.

The soundings of the ocean bottom around the volcano after the eruption showed that a great depression or fissure had been formed, which extended eastward from Krakatoa for a distance of seven or eight miles, and extended nearly in the direction of the great line of volcanic activity which crosses Java and Sumatra.

The greatest outburst of Krakatoa in 1883 was the excessively violent though short paroxysm with which it terminated. The phenomena displayed during this eruption are to be accounted for, according to Judd, by the situation of the volcano and its liability to great inrushes of water from the sea.

KILAUEA REPORT No. 980

WEEK ENDING NOVEMBER 2, 1930

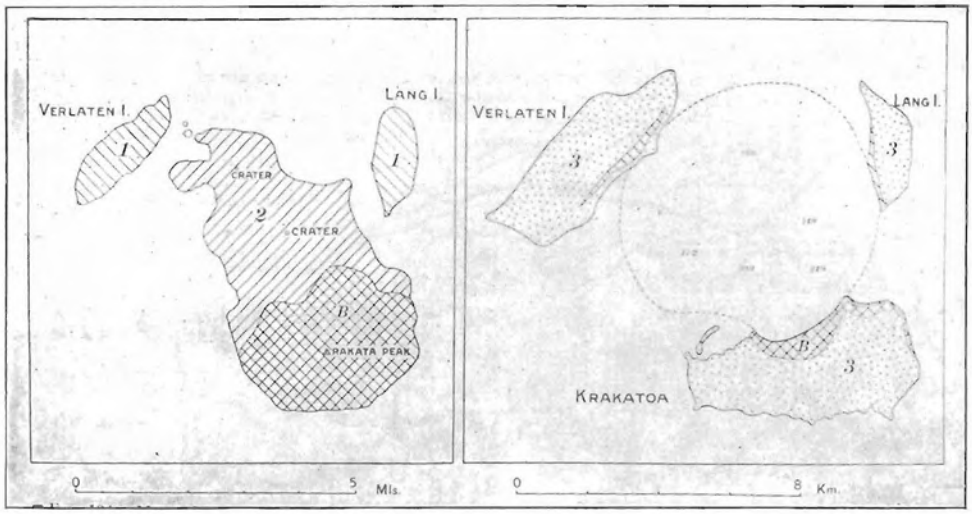
Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge.

Halemaumau still persists in showing no signs of reawakening activity. Even avalanching from the walls has been conspicuously absent during the past week, and the dry, sunny weather has permitted the steam from the wall and floor cracks almost to disappear. A slight earthquake on Friday evening was felt by many people in the National Park, and by some of the residents of Hilo. Probably it was felt in Kau and Kona, but was not sufficiently disturbing to cause comment.

The instruments recorded this quake at 6:23 p. m., October 31, as a shock of slight intensity. The distance to its origin was determined as 32 miles, which would place it as a Mauna Loa disturbance. Three very feeble quakes were also recorded by the Observatory seismograph as follows: October 28, 4:19 a. m.; October 29, 1:35 p. m.; and October 31, 7:41 p. m. None of these has been reported as felt, and the records were not clear enough to establish the distance to any of their origins. Small tremors which may have been of volcanic origin were more numerous this week, the instrument having recorded 42 of them in the seven days. Non-volcanic trembling of the island was slight during much of the week, but increased slightly with the strong winds of the week-end.

The average of the tilt readings for the week shows a very slight increase in a north-northwest direction. However, an analysis of the daily readings of tilt shows that there has been no consistent directional movement which would be the case if there had been a definite change in pressure conditions under either volcano. This makes the second week of apparent stagnation since the Kilauea earthquake of October 20. Some change, either an increase or a relaxation of pressure, may be expected during the coming week.



Plan of Krakatoa volcano before and after the great explosive eruption of 1883. After Daly.

THE ERUPTIONS OF CINDER CONE, LASSEN VOLCANIC NATIONAL PARK, CALIFORNIA

The existing knowledge of the eruptions of Cinder Cone, a small basaltic volcano near Lassen Peak, and descriptions and theories as to the origin of its rather remarkable lava are very well summarized in a recent paper by R. H. Finch and C. A. Anderson, "The quartz basalt eruptions of Cinder Cone, Lassen Volcanic National Park, California," University of California Publications in Geology, Vol. 19, No. 10, 1930, pp 245-273. The general descriptions of the eruptions is of considerable general interest inasmuch as the last lava flow from this vent is found to be one of the most recent flows in North America.

The first account of activity of Cinder Cone is a paper, published in 1874, by H. A. Harkness, "A recent volcano in Plumas County." He quoted statements from a number of independent observers which establish the fact that lights were seen in the Cinder Cone area on many different nights during the winter of 1850-51. Also two prospectors reported passing by an active volcano and hot rock in that region in the summer of 1851. On the strength of these reports and his own observation a little later, Harkness attributed all of the cinders and lava of Cinder Cone to activity in the winter of 1850-51.

J. S. Diller of the United States Geological Survey described a detailed investigation of Cinder Cone in several papers which appeared between 1890 and 1900. Diller showed that the volcanic features of this area are the product of two main periods of activity with a considerable time interval between. He showed that trees about 200 years old were growing near the old cinder cone, but that the more recent second period of activity might have occurred at some late date, though prior to 1840. He dismissed the Harkness evidence as in adequate proof of an eruption in 1850-51.

A. L. Day and E. T. Allen of the Geophysical Laboratory at Washington studied Cinder Cone in connection with their work on the Lassen Peak eruptions, and published their findings in 1925. They accepted Diller's idea of two periods of activity, but showed that a tree over 200 years old was growing at the edge of the younger flow. This new evidence was advanced against both Harkness' and Diller's dating of the late activity.

In 1927, R. H. Finch issued a preliminary statement to the effect that the later "flow" actually was made up of two or three flows of different age and that the youngest of these might be of very recent date.

In the same summer, A. E. Jones made a reconnaissance study of the magnetic properties of the flows at Cinder Cone. He found lava flows of at least five different ages; the three oldest belong to Diller's early activity, and the two youngest flows, to the late activity. The youngest flow was given an approximate date of 1846, and the oldest flow was dated about 500 A. D.

Finch and Anderson add a number of facts to this previously existing information. They show that the main cinder cone is the product of several different eruptions of pyroclastic material, probably separated by considerable intervals of time. Further several small cinder cones are found in different parts of the lava field, indicating that a number of vents were involved in the eruptive activity of the region.

They give a detailed discussion of the latest flow of black lava which is easily distinguished from the older flows by its fresh black color and its unweathered surface. This latest flow lies entirely on top of the older flows from Cinder Cone so that its hot margins never had an opportunity to destroy the vegetation which grows at the edges of the whole lava field. In view of this fact, the evidence offered by Day and Allen and by Diller to prove that the lava must be over 200 years old is not applicable to the youngest flow. Therefore Finch and Anderson conclude that this flow was formed by activity in the winter of 1850-51.—H. A. P.

TILTING OF THE GROUND DURING OCTOBER

A review of the tilt record for the month of October shows several features of interest. During the first few days of the month there was an extremely heavy rainfall at the Volcano. Accompanying this heavy rain, and perhaps caused by it, the ground tilted considerably to the south. Beginning about October 7, the ground tilted steadily and strongly in a north-northeast direction, which is up and away from the active center of Kilauea. Tilting in this direction has been found usually to accompany an increase of lava pressure in this volcano. This phase of the tilting was culminated by the earthquake of October 20 which produced a sudden tilt to the northwest. Since that date, there has been no consistent tilting of the ground, but only a very small amount of apparently aimless wandering. A tabulation of the amount and direction of tilt by weeks is as follows:

Sept. 20—Oct.	5	1.7	sec.	of	arc—S.
Oct. 6—Oct.	12	1.3	"	"	" —N.N.E.
Oct. 13—Oct.	19	3.1	"	"	" —N.N.E.
Oct. 20—Oct.	26	1.1	"	"	" —N.



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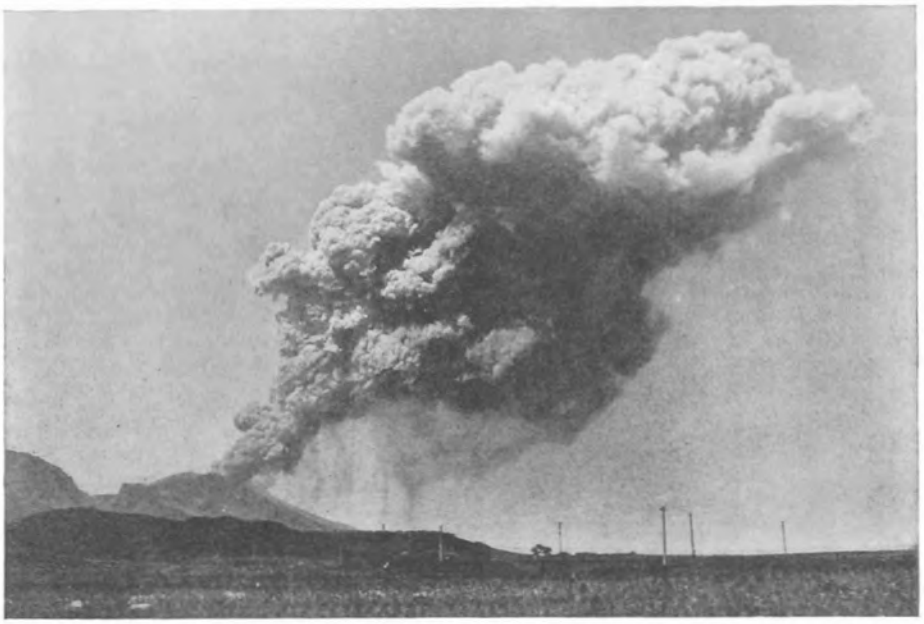
No. 307—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — November 13, 1930



An explosive eruption from Asama-yama in 1911. Much greater eruptions of this type from this volcano, Bandai-san, Krakatoa, Katmai, and others have thrown huge quantities of fine dust into the upper layers of the earth's atmosphere, creating a universal haze which affects the temperatures of the surface of the earth. Photo Uozo.

EFFECT OF VOLCANIC DUST ON EARTH TEMPERATURES

By H. C. HANNA

In June 1912, C. O. Abbot of the U. S. Geological Survey was in Algeria making measurements on the quantity of heat coming to the earth from the sun. At the same time, F. E. Fowle of the Geological Survey was engaged in making similar measurements at Mount Wilson in California.

At Bassou, Algeria, during Abbot's observations of June 19, 1912, he noticed streaks of dust lying along the horizon. These were joined by others and in a few days the sky appeared "mackereled" although no clouds were present. Finally the phenomenon became so marked that any observations were discontinued. On June 29, the whole sky was filled with haze which continually became worse until the expedition departed on September 10.

Thinking that this was merely a local condition, Abbot returned to the United States to learn of the eruption of Mt. Katmai in Alaska. He also found from reports of the Weather Bureau and European journals that these same atmospheric conditions had been noticed elsewhere.

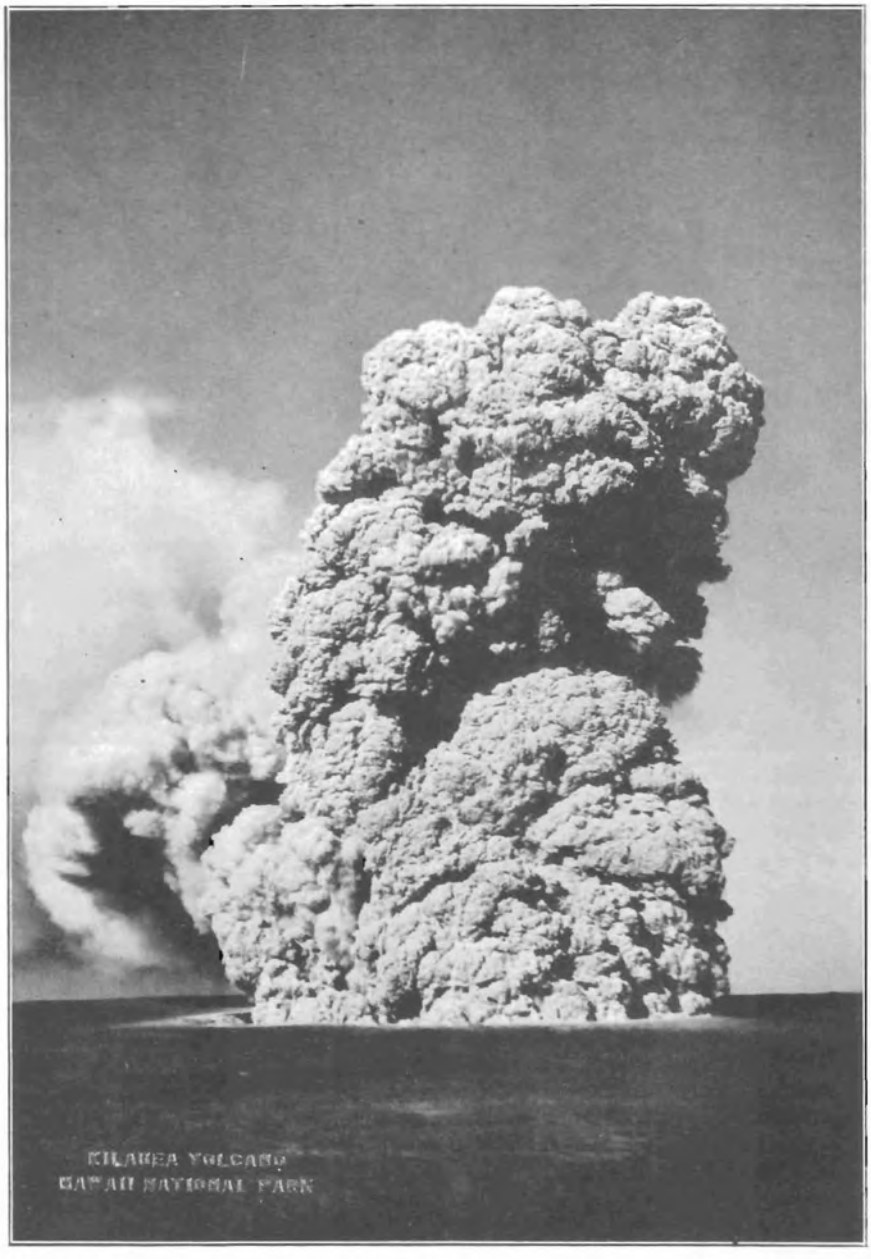
This effect was naturally assumed to have been caused by the Katmai eruption, and immediately estimates were made to discover the speed with which the dust reached certain distant points. Roughly the dust had moved at a rate of 40 miles per hour toward Washington; 25 miles per hour toward Basson; and 3 miles per hour toward Mt. Wilson. The small average speed toward Mt. Wilson probably is to be accounted for by the fact that it is more nearly south of Katmai and the high velocity winds follow a general course from east to west.

The nature of the observations made and the apparatus used should be considered; first, the pyrheliometer was used to measure the heating effect of the sun at the earth's surface; and second, the spectro bolometer, a device of Langley, was used to observe the excessively minute heating effects of the rays of different color in the solar spectrum. Using a thin, blackened thermometer, the heat produced by each ray of the spectrum from the ultraviolet to far beyond the red was measured.

Measurements were made at intervals of several hours. Then knowing the angular distance of the sun from the horizon at each time of observation, the thickness of the layer of atmosphere traversed by the solar beam was computed. After this it was possible to determine how much greater the heat intensity of the rays would have been had the observations been made outside of the earth's atmosphere—"for instance on the moon." Then it was possible to determine how much the ray of each part of the spectrum had been diminished by passing through the dust-laden atmosphere on its way to the earth's surface.

From these measurements it is shown that the haziness of the atmosphere during the summer of 1912 produced a very marked decrease in the direct solar radiation for all parts of the spectrum which reached nearly 20 per cent of the total heat at high sun.

There was naturally an increased brightness of the sky for this loss of heat in 1912. This was due to the



One of the explosions from Halemaumau in 1924. The Hawaiian volcanoes are not in the habit of erupting with a violence sufficient to throw dust into the uuper atmosphere.

reflection of the sun's rays from the dust in the air, thus making the sky bright as do the particles of dust in a room reveal the path of a sunbeam in it. One can easily see that since the light of the sky and the loss of heat by reflection into space both depend on the presence of the particles of dust in the atmosphere, an increase of the dust must make the sky brighter and the loss to space of sun heat greater.

In the main it is this that interested the observers for they wished to inquire how much heat was lost to the earth by the reflection of the atmosphere, owing to the dust which came from Katmai volcano. Abbot and Fowle constructed a formula involving the following factors: (A) is the direct solar beam; (B) is the skylight; (C) the rays absorbed by atmospheric water; (D) rays reflected into space from upper atmosphere; and (E) heat of solar beam outside the earth's atmosphere, approximately the sum of A, B, C, and D.

Measurements of (A), the direct sun rays, and (C), the absorbtion by water and other atmospheric vapors, are made each day. Abbot built an apparatus to measure (B), the direct light of the sky. Knowing, then, the value of (E), (D) could be found readily by subtracting from (E) the sum of (A), (B), and (C).

Following this proceedure, the results obtained at Bassou on the 5th, 6th, and 7th of September, 1912, were as follows, stated in calories per square centimeter per minute:

(A) Heating effect of direct beam of zenith sun.. 1.250
(B) Heating effect of entire sky ..... .245
(C) Heating effect of rays absorbed by atmospheric vapors ..... .175
Total of (A), (B), and (C) 1.670
(E) Heating effect of sun outside earth's atmosphere 1.950
(D) Heat lost by reflection from dust in atmosphere 0.280

Thus 0.280 calories per square centimeter per minute represents the heat reflected to the atmosphere in 1912. In previous years, it was found from experiments at Mount Wilson and Mount Whitney that this heat reflection was less than .050 calories. From these results, Abbot draws the following conclusion: "I am of the opinion that the difference between these results of 1912 at Bassou and those of earlier years at Mt. Wilson and Mt. Whitney (about 0.200 calory) represents approximately the radiation reflected away to space by the volcanic dust of 1912, or, in other words, the loss of heat available to warm the earth which we must attribute to the great haziness which prevailed in 1912. Hence I conclude that the dust of Katmai diminished the heat available to warm the earth in the north temperate zone about ten per cent during the summer of 1912. In accordance with the laws of heat and radiation, this might produce a fall of seven degrees Centigrade in the temperature of the earth as a whole if it were effective for a long enough period of time."

The question naturally arises as to whether volcanoes can really produce such world wide haze. Going back to the records of times of the great volcanic actions of the last 150 years, we have the eruption of Asama-yama, Japan, in the year 1783. In the same year occurred another extraordinary eruption, that of Skaptar Jokul in Iceland which took place on June 8 and 18th.

Arago records dry fogs in the upper atmosphere on about the same date at places distant from each other such as Paris and Avignon, Turin and Padua. It extended from the north coast of Africa to Scandinavia and lasted more than a month. In Languedoc, its density was such that the sun was not visible until it had reached a position 17 degrees above the horizon, and at the time of new moons the nights were so bright that small print could be read even at midnight.

In 1815 occurred the eruption of Mayou in the Philippine Isuands and on April 7 to 12, 1815, the eruption of Tamboro Sumbawa. For three days there was absolute darkness for a distance of 300 miles. Then came the long twilights and sunsets for which the year of 1815 is so notable in Europe.

Hecla and Vesuvius erupted in 1845 and 1846, and Merapi in 1872. In 1883 occurred the eruptions of Krakatoa and St. Augustine in Alaska. The extraordinary atmospheric phenomena which followed these remarkable volcanic eruptions were so in relation of effects to causes that there can be no doubt as to the reasonableness of ascribing the haze of the summer of 1912 to the volcanic eruption in Alaska.

Very great departures from the usual intensities of solar radiation occurred from 1803 to 1807, 1888 to 1893, and from 1902 to 1904. We have only to look back to the history of such volcanic eruptions as Wulano and Mayon in 1888, Meharaizan in 1889, Mt. Zoo in 1890, Bandaisan and Etna in 1892, Pelee and Santa Maria in 1902, Colnira in 1903 to see that the decrease in solar radiation over these periods had much volcanic action to cause it.

Abbot assembled data on recorded temperatures during the year 1912 which show that the surface of the earth was appreciably cooled, especially in the high mountain regions, by the haze from the explosion of June 1912.

He studied the temperature departures for Pic-du-Midi, Puy-de-Dome, and Lchneekoppe for the years 1882 to 1884 inclusive to determine the effect of the Krakatoa eruption. These results, however, were not so satisfactory, although, at some of the stations, daily temperature depressions were found beginning in September 1883. He says:

"The fact is that the temperature of the earth is a function of so many variable quantities that general or cosmical effects are often greatly obscured by local ones. Studies, however, are being made by several authors to detect if there is a periodicity of terrestrial temperature corresponding in time to the sun-spot cycle of about 11 years. It has been found that there is indeed an increased temperature at times of minimum sun-spots. This increase of temperature is greater than would be caused directly by darkening of the sun by sun-spots, so that it seems that there is accompanying the spots, some secondary influence affecting terrestrial temperatures."

These fluctuations in temperature not being accounted for by the variation of sun-spots, Abbot and Fowle have endeavored to see whether a combination of the effect of the sun-spot cycle with the effect of volcanic haze will produce a more exact correspondence between the cosmical phenomena and the temperature curve of the earth's surface.

Their work gives a set of curves comprising the sun-spot curve from 1880 to 1909, the curve of departures from the mean temperatures at 15 stations in the United States and a similar curve of departures for the world. These three curves show, quoting Abbot, "a considerable degree of correspondence yet it is not hard to see that there is also much discordance." This diagram tends to lead to the conviction that terrestrial temperature varies in accordance with fluctuations in the number of sun-spots and, in addition, that the intensity of the sun's direct radiation as measured at the earth's surface is much modified by such terrestrial phenomena as the dust of volcanic eruptions.

Humphreys follows a line of reasoning similar to the above writers though he carries his conclusions farther. The main differences between his views and those of Ellsworth Huntington (another student of the subject) are that (1) he regards variations in solar activity as of negligable importance so far as our present knowledge is concerned and (2) he strongly emphasizes the importance of volcanic dust. In his own words,

"Variations in the average temperature of the atmosphere depend jointly upon volcanic eruptions through the action of dust on radiation and upon sun spot members, through, presumably, some intermediate action they have upon the atmosphere.—Hence, as there appear to have been several periods of great volcanic activity in the past with intervening periods of quiesence, it is inferred that volcanic dust in the upper atmosphere was at least an important factor in some, if not all, the great universal climatic changes."

Huntington does not agree entirely with Abbot, Fowle, or Humphreys. After a lengthy discussion of facts, he

concludes that the variations in the sun are the main factor in modifying terrestrial temperature, but their effect may be much modified by the presence of volcanic dust in the atmosphere.

It is thought that if volcanic explosions continue active through a more or less long geologic time they could alone, or in part, cause cold or even glacial climate. We should, therefore, expect an extremely cold climate at the end of a mountain-making era during the "critical periods." Huntington points out that we have had ice ages at the close of the Paleozoic and Cenoxoic eras, but that the close of the Mesozoic (an era of extreme mountain making and volcanic activity in North America) did not result in a glacial but only a slightly cooled climate. There is also evidence that volcanism was renewed in the Cordillera of North America throughout much of the Eocene, and yet there was no glacial climate at the end of this time. In the same way there was a marked temperature decline at the close of the Cenozoic in the Pleistocene. Equally extensive movements were going on in Europe in the rise of the European Alps and earlier movements did not affect the climate.

It seems however, although there is some difference of opinion among the authorities on the importance of volcanic dust, that the most logical conclusion to draw from these discussions is that volcanic dust in the isothermal regions of the atmosphere has caused serious effects upon the temperature of the sun's rays at the surface of the earth.

References

National Geographic Magazine, February 1913, an article by C. O. Abbot.

Physics of the Atmosphere, by W. J. Humphreys.

Climatic Factor, Ellsworth Huntington, 1914.

KILAUEA REPORT No. 981

WEEK ENDING NOVEMBER 9, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge.

Halemaumau is still remarkably quiet. Steaming has been almost nil during the daylight hours of the week. A rather striking cumulus cloud was noticed above the pit the evening of November 4 which was formed when the column of warm air rising from the pit was interrupted by a layer of cold air blowing across the summit of Kilauea. No avalanches in the pit have been noticed or reported.

The seismographs recorded only one very feeble earthquake on November 9 at 5:14 a. m. The distance to its center could not be determined. Forty-four small tremors registered during the week and the non-volcanic microseisms have been of moderate size accompanying the rather heavy surfs which have been pounding on the coasts of the island.

The average of the week's tilt record shows a very slight tilt to the northeast, up and away from the crater. However, there has been no marked change in the tilting of the rim which would indicate a change of pressure conditions under the volcano.

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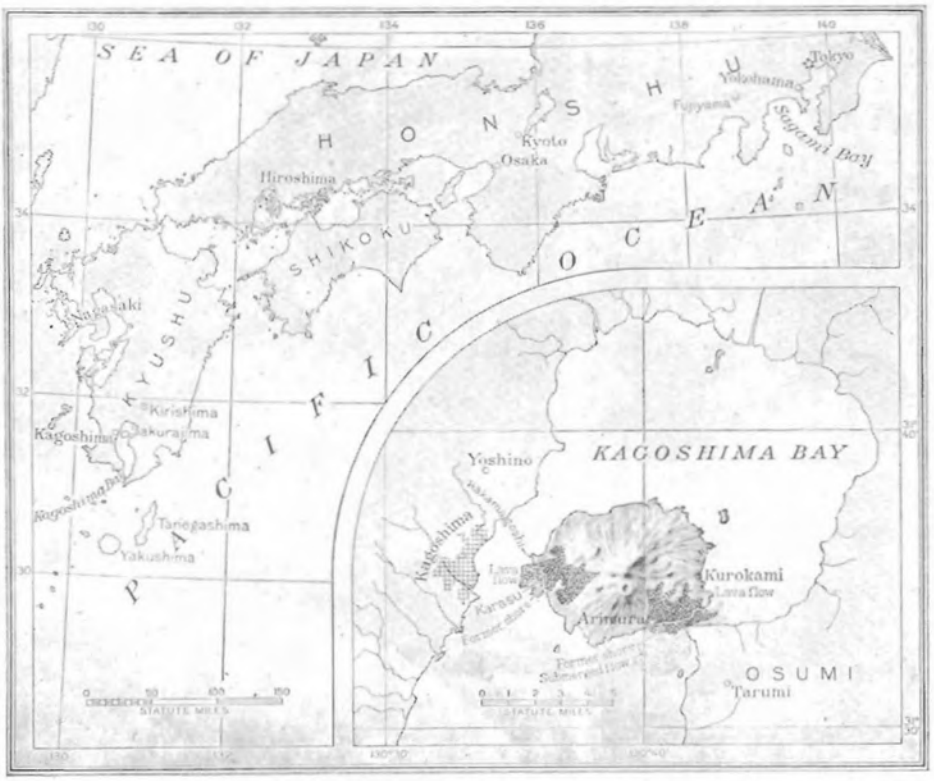
No. 308—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — November 21, 1930



Map of southern Japan and of Kagoshima Bay, showing Sakurajima and its 1914 lava flows. From National Geographic Magazine, April 1924.

ERUPTION OF SAKURAJIMA, 1914

Review by K. Onishi of F. Omori's article in the Bull. of the Imperial Earthquake Investigation Committee, Vol. VIII, No. 1, Sept. 1914.

Sakurajima volcano forms a small island in Kagoshima Bay on Kyushu, the southermost island of Japan proper. It is located on the great Kyushu rift, a crack which runs in a southeasterly direction from Japan to the Bonin Islands. The volcano has two high peaks, Minamidake and Kitadake, and a parasitic cone on the eastern flank called Nabeyama. A number of hot springs rise from its slopes. At the time of the eruption, the population of the island exceeded 23,500.

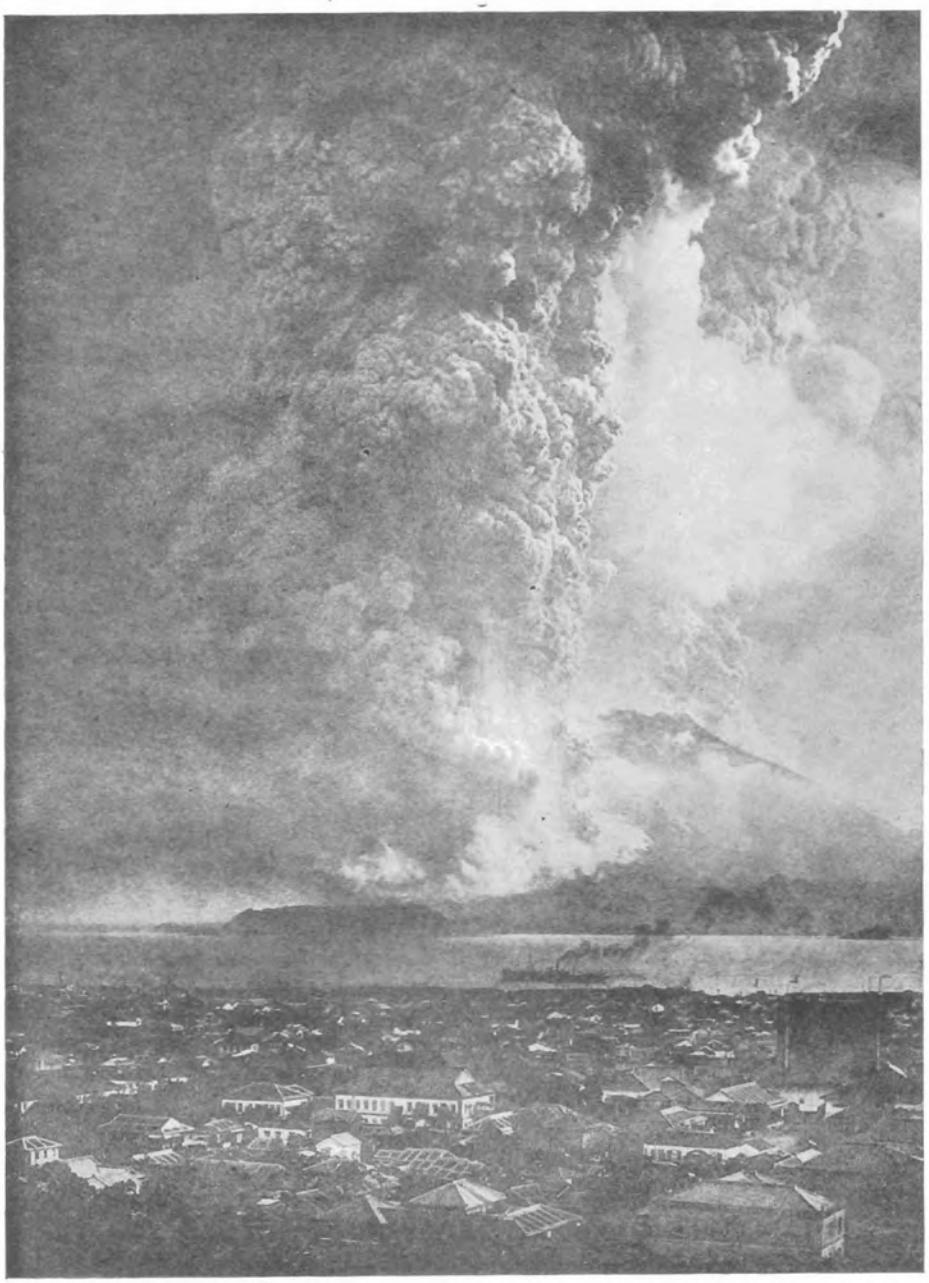
Investigations of the occurence of volcanic activity seem to point to a cycle of about 130 years in the Japanese volcanoes. In the years 1777-92, about 130 years previous to the year 1914, Oshima, Sakurajima, and Asama-yama had had tremendous outbreaks. Since Asama-yama, in 1908, and Oshima, in 1912, had produced numerous earthquakes and lava flows, Sakurajima was expected to follow suit not long after. Kirishima-yama, some 45 km. to the north of Sakurajima, finally burst out in November and December of 1913, and Sakurajima followed with an eruption two months later.

Warnings that Sakurajima was ripe for an eruption came in the forms of smoke, earthquakes, and an increased flow of water from the springs on the mountain. On the island, earthquakes were felt from the night of January 10, while the city of Kagoshima (on the shore of Kagoshima Bay) was mostly unaware of them until early in the morning of January 11. The frequency of the shocks increased with the progress of time, the greatest hourly numbers 28 and 27 being reached resepectively at eight to nine p. m. on the eleventh and three to four a. m. on the twelfth. As many as 66 shocks in one hour were felt on Sakurajima.

Early the morning of the 12th, the people noticed that water with a high temperature had started to issue from a number of places, and more could be seen bubbling up through the sea. On the opposite end of the island, the volume of water from the natural cold springs increased considerably while many wells had their water levels raised two to three feet.

At 8:00 a. m. on the 12th, a column of white smoke was seen rising from the top of Minamidake. Earlier in the morning, observers from Kagoshima had noticed slender filaments of white vapor above the mists that shrouded the mountain. Two hours after the smoke from Minamidake was seen, the first eruption occurred.

The unmistakable signs of the approaching disaster were sufficient to alarm the inhabitants who immediately began to desert their homes and seek refuge in Kagoshima



The eruption of Sakurajima on January 12, 1914 as seen from the heights back of Kagoshima. The peak is clear and the smoke and ashes are rising from rifts on the near and far sides of the cone. After Omori.

and the neighboring villages. The evacuation of the island was so exceptionally well handled that the whole population of over 23,500 was safe from harm when the final break came.

The first outburst came from the western side of the mountain facing Kagoshima about 500 meters up the slope, at 10:00 a. m. July 12. An interval of some 10 minutes followed when the east side of the island burst open with huge columns of smoke which rose to a vertical height of over 20,000 feet above sea level. This explosion completely enveloped the island in a mass of white and black smoke within a few hours.

On the evening of the first day of the outbreak, at 6:30, a strong quake took place. After this shock, the hot lava became stronger, reaching its maximum between 11:00 p. m. of the 12th and 5:00 a. m. of the 13th. After ten o'clock of the morning of the 13th, the violence of the explosions gradually decreased.

On the eastern and western sides of Sakurajima were formed seven small craters from which issued a lava of very high viscosity. The stream on the west reached the sea on the 16th, averaging 45 meters per hour during the first two and a half days. The lava continued to flow into the sea until it had invaded about two and one half square kilometers of former sea-bottom. The flow on the eastern (Nabayama) side was much faster, the lava finally blocking the narrow strait and joining the island to Osumi, intensity of the volcanic noises and the projection of red converting Sakurajima into a peninsula.

The total area covered by the western flow amounted

to 8.33 sq. km., while the eastern portion covered approximately 15.41 sq. km. The estimated total volume of lava that was ejected was 1.6 cu. km., the western half contributing .33 cu. km. and the remaining 1.27 cu. km. being the contribution of the eastern flow.

The showers of hot pumiceous lava fragments and ashes did considerable damage to the whole island, the villages of Koike and Akobaru on the west and Kurokami being especially hard hit. The ash precipitation was slight in Kagoshima (about 3mm, deep) whereas the northern and central parts of Osumi on the opposite shore of the bay received from 3 inches in places to over 3 feet. The total amount of pumice and ashes which fell has been estimated to be in the neighborhood of .62 cu. km. or 40 per cent of the total volume of the lava output.

The total amount of material exuded from Sakurajima is thus 2.2 cu. km. which is equivalent to one twelfth of the volume of the whole mountain.

The strong quake of January 12 must have been one of very deep origin and not a shock immediately connected with the eruption, because the intensity of motion was nowhere in Kyushu excessively severe. It was probably caused by the stress accumulation along the whole volcanic chain in southern Kyushu. This quake took the only lives which were lost in the activity, 19 persons being killed.

Considerable excitement prevailed in Kagoshima during the course of the eruption. The fear of asphyxiation by the poisonous volcanic gases was reason enough for immediate evacuation. Rumors of a huge tidal wave helped to aggravate the fears of the nearly panic stricken people. The only real source of danger came from the one great earthquake. This quake was registered on very distant seismographs in Europe and America.

ACTIVITY OF A CALIFORNIA VOLCANO IN 1786.

The following quotation was brought to the attention of the writer by Dr. Max Ferrand, Director of Research of the Huntington Library and Art Gallery.

La Perouse, in voyaging along the California coast in 1786 witnessed a volcanic eruption, and the location given on his map is roughly in the Lassen region. A direct quotation from his observations is as follows:

> " . . . . our latitude, observed at noon, was 40° 48′ 30″ north; our longtitude, according to the timekeeper, was 126° 59′ 45″ west. I continued my course to near the land, from which, at night-fall, I was only four leagues distant. We there perceived a volcano on the top of a mountain, which bore east of us; its flame was very lively, but a thick fog soon deprived us of this sight. . . . "

As Mt. Shasta might be visible from a ship at sea in the position given, it, as well as Lassen Peak, should be considered as a possible source of the witnessed eruption. Both peaks would be nearly east from the stated latitude. If the eruption were from Lassen, nothing but an explosion cloud would have been visible. Considerable volcanic activity occurred at the summit of Mt. Shasta since the time of general glaciation, and nothing on the peak at present indicates the impossibility of there having a minor eruption in 1786. R. H. Finch.

LASSEN REPORT No. 27

Lassen Volcano Observatory

R. H. Finch, Associate Volcanologist

The western half of the Lassen edifice was shaken by a series of earthquakes on October 29, 1930. The shocks were strongly felt at Redding on the west and as far southeast as Mineral. The distance to the origin of the shakes from Mineral as determined by the seismograph of the Lassen Volcano Observatory was 27 miles, which makes the seat of the shaking to the northwest of Lassen Peak, or in the vicinity of Millville. Press reports indicate that the shake were stronger at Millville than elsewhere.

The series was ushered in by a very small and not generally felt shake at 4:10 a. m. The plainly felt shakes occurred at 4:34 a. m., 11:48 a.m., and 8:28 p. m. A light roar accompanied the shaking at many places.

On the 29th of April, 1930, a shake that was much stronger than any of the recent series occurred in the same region.

KILAUEA REPORT No. 982

WEEK ENDING NOVEMBER 16, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge.

Steam has risen from the floor of Halemaumau and the amount of visible steam from the wall and floor cracks of Kilauea has increased several times during the heavy rains of the week. A few rocks have been heard tumbling from the walls of the pit, but there have been no avalanches large enough to attract attention.

A distant earthquake wrote a very small record on the seismogram at 8:57 a. m., November 12. There were ten local shocks of very feeble intensity timed as follows: November 11, 11:26 a. m.; November 12, 5:38 p. m.; November 13, 8:50 a. m. distance 22 miles, and 10:11 p. m.; November 14, 2:57 a. m., and 1:30 p. m.; November 15, 6:57 a. m.; November 16, 3:52 a. m. center in Halemaumau, 1:34 p. m., and 7:55 p. m. The Observatory seismograph on the rim of Kilauea crater also recorded 48 small tremors, of which 30 occurred during the last four days of the week. During these same days, the instrument at Halemaumau recorded 42 tremors. Many of them were stronger at the pit than on the Kilauea rim, suggesting that they had their origin in Halemaumau. The non-volcanic trembling of the island was moderately strong during most of the week.

The average tilt for the week showed a slight movement in an east-northeast direction, all of which was gained through a marked tilting of the Kilauea rim up and away from the pit during the last four days. During this same period, the Halemaumau seismograph indicated that the rim of the pit was also tilting up and away from its center.

The latter half of this week showed the first definite change of conditions from the "stagnation" which has existed since the earthquake of October 20. The tilt change and the increase of tremors suggest an increase of pressure and movement of lava under Kilauea.



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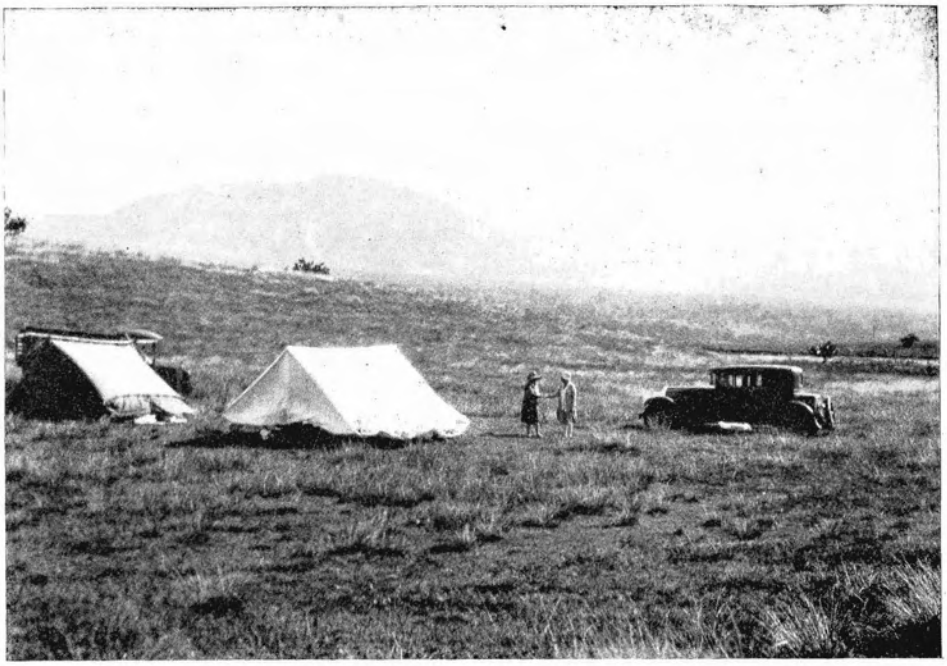

Camp of ranch people at Puu Anahulu during the earthquakes of October, 1929. Looking toward Puuwaawaa from the northwest, with Hualalai volcano in the haze at the right. Photo Jaggar.

THE HUALALAI EARTHQUAKE CRISIS OF 1929

What Happened

During the week ending September 18, 1929, the seismographs at Kilauea Volcano. at Hilo and at Kealakekua on Hawaii island registered nothing remarkable. Then came a really tremendous swarm of earthquakes in North Kona on and near Hualalai volcano. Sudden shaking began September 19 and continued, racking the countryside, reaching culmination in big earthquakes September 25 and October 5, and destroying hundreds of thousands of dollars worth of property in houses, walls, tanks, stone fences and roadways. No volcano eruption followed on Hawaii until now, November 19, 1930, when lava returns quietly into the bottom of Halemaumau pit of Kilauea volcano, on the opposite side of the island from Hualalai.

The spasms of earthquake September 20 and 21, 1929 were at intervals of several hours. Then the intervals shortened and the spasms lengthened in duration. The area of felt earthquakes extended itself. Maximum motion was within a circle of 35 miles radius around the summit of Hualalai. The force of shaking increased. The strongest motion and greatest destruction was near Puuwaawaa. The highest frequency of shakes was on the southwest flank of Hualalai. Rumbling was heard there but not at Puuwaawaa.

At Kilauea 221 shocks were recorded for the week ending September 25, as compared with only 9 for the previous week. As to epicenters or places of origin measured from the seismograms by the distances from the instrument station indicated by formula: at the Kilauea Observatory, for four weeks to October 16, the successive average weekly distances of epicenters were 23, 28, 35 and 44 miles. This looked like a progression of underground jolts from about Mauna Loa to about Hualalai.

Big earthquakes of Grade IX Rossi-Forel occurred at Puuwaawaa September 25 and October 5. These were felt throughout the Hawaiian Islands.

Airplane inspection of all the craters revealed no eruption of lava. The shaking continued for a month but gradually quieted down in November.

Statistical Data

At Kilauea the weekly frequency of shocks as indicated by numbers of earthquakes counted on the seismograms, beginning with the week ending September 25, was as follows for four weeks: 221, 244, 129, and 97. The maximum was thus the week ending October 2, between the two strong earthquakes. The frequency and intensity varied together. The Kilauea total of shocks to October 16 was 691, many of them felt.

For the four days between the two greater earthquakes different places with seismometric instruments registered the following numbers of shocks:

	Oct. 1	Oct. 2	Oct. 3	Oct. 4
Kilauea	19	13	15	18
Hilo	38	26	13	74
Kealakekua	155	110	96	138
Puuwaawaa	241	117	97	114

The frequency increases just before the big shock of October 5. The geographical gradation is not wholly accordant with distance form Hualalai. Thus Hilo has more shocks than Kilauea, yet is farther from Hualalai.

The instrumental record of decline in frequency was as follows:

	Oct. 8	Oct. 9	Oct. 10	Oct. 11	Oct. 12
Kilauea	16	15	14	10	9
Kealakekua	94	61	42	41	43
Puuwaawaa	387	353	235	203	139

This is reasonably consistent as a decline with the passage of time, and as showing geographical decrease of numbers with distance from the center.

The shock recorder at Puuwaawaa of the type described in Scientific American for November, 1929, with magnification x25. registered numbers of shocks as follows during the first part of the time of maximum frequency:

September 26	599	shocks
September 27	541	"
September 28	400	"
September 29	334	"
September 30	321	"
October 1	241	"

The computed instrumental total for the central region for 26 days from Sept. 21 to Oct. was 6211 shocks. This averages 239 per day or 10 per hour. Most of these could have been detected by a person at rest indoors. Much of the time there was continuous jiggling of windows. Puuwaawaa registered nine times as many earthquakes as Kilauea. And that in a place not known as an earthquake district before this year.

The average of felt shocks listed by observers September 23-24 was 2.2 shocks per hour at Huehue, 3.3 at Puuwaawaa. and 6.0 at Honokahau on the southwestern slope of Hualalai. Observers listed about a third as many as the shock recorder.

Theoretical

The big earthquakes of September 25 and October 5 showed no preliminary tremor on seismographs forty and sixty miles apart. Both Hilo and Kealakekua in Kona behaved as though they were right over the center of the earthquake. So did Kilauea. In this they behaved quite differently from their registration of the ordinary earthquakes of the period, these always showing a preliminary tremor accordant with the theoretical distance of the focus or origin.

The absence of preliminary tremor is usually explained on the ground that these greater earthquakes are very deep. If such jolting is profound in origin, it may shake the whole of a small area like the island of Hawaii equally.

But even if the earthquake were a hundred miles underground the horizontal impulses at the pendulums of Kealakekua, Hilo and Kilauea would have been sufficient to exhibit **something** of the preliminary if the compressional waves had been present. There was no slightest trace of them, unless they were so enormous that they themselves dismantled the seismographs. This is improbable, by analogy with other records of earthquakes of like intensity, showing preliminaries, which have clearly registered with small ampltiude before the long waves dismantle the instrument. The pens at places sixty miles apart simply shot off the drums at the first impulse. Meanwhile the Honolulu seismograph registered a preliminary accordant with the distance of Hawaii.

If this failure to record preliminaries were due to depth of focus, the depth would have to be several hundred miles, and even in that case a vertical component instrument ought to register an excellent preliminary, characteristic of compressional elastic waves arriving vertically. There is no suggestion that such waves were present. Even a horizontal pendulum would give some thickening of the line.

There is another possibility. If hot magma were present under Kilauea. Mauna Loa and Hualalai equally, like a vast cake of dough, with localized injections of its substance as protuberances with each mountain, it is conceivable that the protuberance under Hualalai moved to make the localized earthquakes; and that the larger mass shifted the whole island shell for the greater and more generalized shocks.

Comparison with 1868

The 1868 cataclysm on Hawaii was a parallel to this. A new series of eruptions at the southwest was then begun, unheard of before. A great earthquake swarm began on the south flank of Mauna Loa culminating in a terrific shock.

On March 9 of 1868 there was an earthquake in Kona. On March 27 in Kau quaking became continuous and the next day there was a big shock of Grade IX. On April 2 came the big earthquake of Grade X, making a landslip back of Pahala, a tidal wave along the Honuapo shore, and bringing about the immediate collapse of very active lava in Kilauea Crater. April 6 the south rift of Mauna Loa vomited lava to the sea, the eruption lasting six days. Other big shocks occurred and a lot of aftershocks.

This combination of clustered quakes, big shocks and lava outpouring in a new district suggests that the underground shift of magma from the old northern district made the mountain labor. The same thing is suggested in 1929. There is a shift of activity from south to north. Recent Mauna Loa flows have all been in Kau. The Hualalai earthquake swarms were quite like those of Kau in 1868. But lava outbreak has not yet occurred on Hualalai. Presumably lava intrusion did occur.

In both 1868 and 1929 there were big shocks that were different from the small ones. Probably the small ones accompanied shifting of the blocks of the smaller mountain, and were shallow. Probably the big ones accompanied a shifting of the whole island shall and were relatively deep. But it may well be that mere depth was less important than the size of the shell which was shifted.

The present outbreak of Halemaumau November 19, 1930 is the first eruption in Hawaii which has followed the Hualalai earthquake crisis of September-October, 1929. The last outbreak known at Hualalai volcano was in 1801, about a decade after an explosive eruption which occurred at Halemaumau. A decade after our last explosive eruption of Halemaumau will be 1934. Is the present return of lava in Halemaumau preparing for a new activity on the north or northwest sides of Mauna Loa or Hualalai?

T.A.J.

THE CURRENT ACTIVITY IN HALEMAUMAU

Lava came back in Halemaumau at 1:29 p. m.. Wednesday, November 19. It broke through first in two fountains about one hundred yards out in the pit floor in front of the horn between the two grotto niches of 1929. According to Craik. of the National Park, the floor started to swell rapidly under this spot, then huge blocks of the old crust were thrown into the air by the first gush of fountaining lava. Craik immediately left to spread the news so he did not see the next fountains break through. When next seen half an hour later, lava was spouting perhaps fifty feet high from these two fountains; from twenty to fifty feet high from seven fountains closely grouped near the edge of the 1929 flow about half way between the old 1927 cone and the sulphur stain on the south edge of the pit floor; and about 150 to 200 feet high from a main fountain through the sulphur stained patch about 100 feet out in the 1929 floor from the edge of the south talus. The whole southwest corner of the old floor soon was covered by flows from all of the fountains, but the main flood came from the large fountain and spread rapidly out to the center of the floor.

By 4:00 p. m., the old cone peak of 1927 had disappeared in the south cove, and the main flow had reached a point three fourths of the way across the old floor. New lava covered about half of the area of the 1929 floor at this time. One fountain had disappeared from the south-southwest group leaving six small ones together, also the two near the 1929 grotto, and the main fountain. The small ones showed about their original strength, but the large one had increased so that it was throwing slag over 200 feet into the air. A crack opened along the contact of the northern small 1929 grotto and the talus behind it. and it was soon filled with a small ooze of glowing lava. All of the fountaining activity was still concentrated in the southwest part of the 1929 floor.

As the depth of the lava around the fountains increased, some of the smaller ones were drowned, so that by 6:00 p. m. only two remained of the original group of seven. The two near the 1929 grotto had built up spatter cones through which they only occasionally were able to spout visible spray. The main fountain had become more constant, and was throwing slag steadily to heights of about 100 feet. The main flow was still very strong, but was beginning to pile up on top of itself rather than spread farther over the old floor.

The main fountain was slowly building a crescent shaped grotto on its south side which had reached a height of about forty feet by 8:00 p. m. At this time only one fountain remained of the original cluster of seven. and the two near the 1929 grotto broke through their "hoods" only at long intervals. The activity of the main fountain remained constant throughout the evening. The big flow was definitely building a rampart over which small flows were cascading to the lower level of the floor. The main overflow seemed to concentrate on the northwest and the southeast sides of the lake near the main feeding fountain,

with only an occasional flow over the northeast wall most distant from the fountain. The situation did not change materially during the rest of the night.

At 7:00 a. m., November 20, the vigor of the main fountain had not changed, but the smaller ones showed only an occasional spurt. They continued to smoke vigorously. The main flow from the big fountain was feeding a well defined lava-lake which covered approximately 25 acres, a little over one million square feet, of the 1929 lava floor and was oblong in shape with the long axis running northeast from the main fountain. The greatest overflow still took place near the fountain over both the northwest and the southeast ramparts. The level of the lake had been rising more rapidly than the grotto was being built by the main fountain so that it was not as conspicuous as it had been during the previous evening.

A measurement at the end of the first 24 hours, 1:30 p. m. November 20, showed that the surface of the lake at the big fountain was 90 feet above the level of the old floor at that point. The surface of the lake still sloped away considerably to the rampart walls so that there was a constant but slow movement of the cracking crust away from the big fountain. Overflows from the lake had covered about ten acres (435.000 square feet) of the old floor, so that flows and lake of new lava together covered an approximate area of 35 acres. The big fountain continued its steady spouting, throwing slag from 60 to 100 feet in the air. The two fountains near the 1929 grotto still smoked but no fountaining was visible. The one isolated small one had built a cowlshaped hood with the opening to the northwest so that its spray could not be seen from the main observation point.

It was reported that nine noisy explosions occurred at regular intervals of a few seconds about 11:00 a. m. No unusual behavior was noticed in the fountain but the sound seemed to have come from the large fountain.

Shortly after noon, a large stream of lava began to cascade over the southeast lake rampart and flowed toward the base of the east talus. It kept up a steady flow till after 6:00 p. m. and gradually formed a secondary lake between the talus pile and the main lake-rampart. Secondary flows from this small lake poured out along the flat between the east talus and the old pressure ridge and by 8:00 p. m. had covered the rest of the 1929 floor in this part of the pit. More overflows from the northeast end of the lake occurred during the late afternoon and evening, and slowly crept toward the north and northeast talus. By midnight November 20, only a few acres of the north part of the old floor remained visible.

This steady fountaining and overflowing from the main lake characterized the activity during the next morning, November 21. A second lake rampart had been built up inside of the northeast end of the lake during the night. Its location probably was determined by the position of a number of pressure ridges and domes in the old floor which may have obstructed the free flow of new lava and piled up blocks of the new crust. This inner rampart was built to a point at which the surface of the inner lake was very nearly level. As a consequence the migration of the cracking lake crust became so slow that it was not noticeable to the eye.

At the end of 48 hours of flow, 1:30 p. m. November 21, the surface of the lake at the fountain was 100 feet above the old floor, and the whole lake averaged a depth of almost 100 feet. It covered an area of about 15 acres (about 650,000 square feet). The overflows had encroached on the talus walls on the south side of the pit behind the big fountain, and had nearly covered the old 1929 lava floor. Thus the total area covered by new lava was about 50 acres (over two million square feet).

The main fountain began to show a tendency to break into two separate fountains of about equal size and a third one of small size and irregular frequency. The vigor of the fountaining appeared to remain the same. The activity of the afternoon and evening continued after the fashion of the previous day, with most of the overflow occurring on the northwest and the southeast sides of the lava-lake.

About 11:30 p. m. of November 21, a large cascade broke over the rampart at the far northeast end of the lake. It was falling down a steep incline of nearly fifty feet so gained in size very rapidly. Within fifteen minutes it had become the most spectacular feature of the eruption to date. It yielded a flow of such velocity that no crust had a chance to form, so that more than five acres was soon covered with the glowing red lava.

This river was still flowing the forenoon of November 22, but had split into two main branches, one of which was flooding the low area toward the northeast talus and one was pouring new lava into the depression at the foot of the northwest cliff.

Spouting from the small south-southwest fountain was no longer visible, but it and the two near the 1929 grotto still emitted a continuous volume of fumes. The large fountain continued its constant activity but the amount of lava taken from the lake by the three main overflow channels equalled the amount fed in by the fountain so that the level of the lake became fairly constant at 90 feet above the old floor.

During the evening of November 22, the spouting of the big fountain became slightly irregular. For a period of several minutes it would spout huge fans of slag over 300 feet in the air, and then it would relax for a time and resemble a bubbling mass of porridge. In these periods of relative calm, it could be seen that as many as seven separate spots were bubbling, which united in the larger spurts to give the appearance of one huge fountain. Overflow still continued from all three sides of the lake,, first one side showing the most active flow and and then another. The same general condition held during the night and all of the next day, Sunday, November 23. H.A.P.

SEISMIC FEATURES OF THE ERUPTION

The seismic events leading up to the eruption of lava in Halemaumau were not unusual but are none the less of interest. On November 13, the seismograph on the rim of the pit began to register a definite tilting of the rim up and away from the pit. It also recorded many small tremors which were not of sufficient strength to influence the instruments at the Observatory on the rim of Kilauea crater. These facts supplied the information that lava was moving and pressure was increasing under the volcano.

During the six days previous to the appearance of the lava, the rim of Halemaumau pit was tilted upward and outward through 10 seconds of arc. Half of this accumulated slowly, while the balance of 5 seconds of tilting took place in an interval of one hour and fifteen minutes immediately preceeding the gush of lava. As soon as the outlet to the surface was gained, the lifting force of the rising lava was lost and the pit rim tilted back through 7.5 seconds of arc during the first 18 hours of lava activity. Since then, equilibrium has been maintained and the tilting of the pit rim has been negligible.

On the morning of November 19, the pit seismograph recorded a series of 18 small shocks which culminated in a very feeble quake at 11:06 a. m. There was a slight tilting of the rim in toward the pit accompanying this quake. A series of 30 small shocks followed in rapid succession, many of them producing a little inward tilting. At 11:42 a. m., a quake of feeble intensity occurred under Halemaumau, causing a slight sudden inward tilt of the rim. During the next half hour eight small tremors were recorded, but no tilting took place. Then, between 12:15 and 1:29 p. m., 35 small shocks occurred and at the same time the rim of the pit was tilted up and outward through 5 seconds of arc.

Continuous tremor began at 1:29 p. m. and gradually increased for nine minutes. Then, at 1:38 p. m., the amplitude of the tremor suddenly increased. This sudden increase may mark the breaking of the lava through the bottom of the pit and the beginning of surface fountaining. The tremor continued with a constant intensity till about 4:00 p. m. when it gradually moderated until 7:00 p. m. From that time on it has continued evenly, except for an occasional more violent burst of a few moments duration. H.A.P.

KILAUEA REPORT No. 983

WEEK ENDING NOVEMBER 23, 1930
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar. Volcanologist in Charge

Lava appeared in Halemaumau at 1:29 p. m. November 19. It broke through in three fountain groups, two of small size which disappeared during the first two days, the third remaining as the main fountain which is still spouting vigorously. Lava from the fountains spread rapidly

over half of the 1929 floor in the first four hours. Then a central lake of molten lava was formed which is being fed by the main fountain. The lake rapidly built its ramparts upward until a depth of molten lava of about 90 feet was reached. This depth has been maintained, with overflow on three sides of the lake removing the new lava as rapidly as it is supplied. These overflows have completely covered the old floor of the pit and are encroaching on the surrounding talus piles.

During the two and one half days of the week preceding the appearance of lava on November 19, the Observatory seismographs recorded seven very feeble earthquakes: November 17, 2:29 a. m., 2:56 a.m., centering in Halemaumau, 8:11 p. m., and 8:19 p. m.; November 18, 5:47 a. m. distance to center 4 miles; and November 19, 8:13 a. m. and 11:06 a. m. One quake of feeble intensity, felt at Uwekahuna, was recorded at 11:42 a. m., November 19, with a distance of 4 miles to its origin. One very feeble shock was recorded after the eruption started, i. e. at 7:34 p. m., November 19. There were thus nine earthquakes for the week at the Observatory. A total of 24 short tremors were recorded before the lava broke out, and 17 minutes of continuous tremor registered during November 18. Continuous tremor caused by the fountaining of lava is accompanying the eruption. The non-volcanic microseisms were slight during the entire week.

The average tilt for the week shows a slight westward tilting of the Kilauea rim compared to last week. Some southward tilting has accompanied the flow of lava as the lifting force of the lava is lost by its access to the surface.



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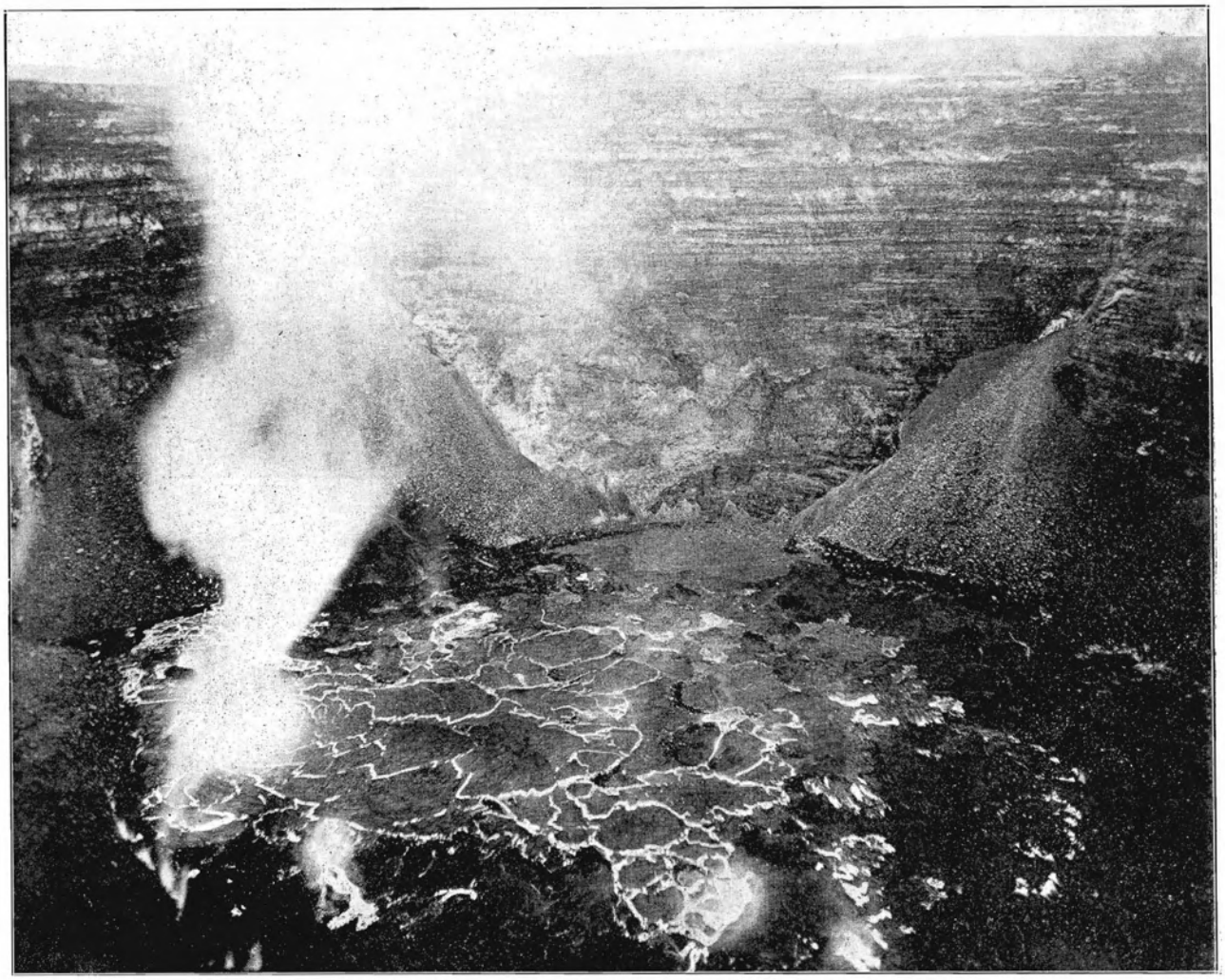
No. 310—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — December 4, 1930



New lava in Halemaumau November 20, 1930. Photo Maehara.

HUALALAI EARTHQUAKE CRISIS
(Continued)

The earthquake crisis of 1929 on Hawaii, as described statistically in Volcano Letter No. 309, produced two earthquakes of grade IX Rossi-Forel. Grade ten is the intensity of a great disaster like those of San Francisco and Tokyo. Nine is disastrous; there are many grades of quick jerking between nine and ten, as represented by the earthquakes of history, some of them slow with wide amplitude and fatal continuity, others very sudden and quick with terrible results on weak structures. The greater earthquakes of the Hawaiian crisis were always led up to by numbers of minor ones, and by more or less continuous tremor which culminated from time to time in increasing numbers of large shocks, which happened both before and after the major ones. The earthquakes of this crisis were very impressive in demonstrating to an observer the difference between experiencing a large earthquake in a house or on the ground out of doors. In a house with an iron roof the rattle of the roofing, of the furniture, of the doors and windows, and the creaking of the timbers all made the quaking perceptible to the ear. Also the artificial structure acted as an inverted pendulum and magnified the motion. The writer was kindly permitted to dwell at Puuwaawaa Ranch House during the period of greater shaking, and to make experimental tests of earthquakes indoors and out. Shocks that were considered strong indoors, with much preparatory rattling leading up to a culminating jolt, were wholly imperceptible to an observer standing on the grassy lawn outside, except for a slight upward thudding sensation at the moment of the final jolt. Meanwhile the outdoor observer, with his feet planted firmly on the sod, could hear the roof of the house roar, and feel nothing during the rattling stages.

An interesting experience during the greater earthquake of 6:20 p. m. September 25, 1929, demonstrated that even a disastrous earthquake in a wooden house might go unperceived in an automobile in motion. This earthquake was so strong that it seriously damaged the Kealakekua



King residence, Honokahau, after the earthquakes of September and October, 1929. The retaining wall of the terrace was shaken down, being built at too steep an angle. Photo Jaggar.

seismograph, stone walls were thrown down, furniture was displaced and overturned, some buildings were moved, landslips were produced on steep slopes, masonry was cracked, and some water tanks burst. The road fills on steep hillsides were generally cracked and in many cases retaining walls on the downhill slope collapsed. The damage was enhanced by the weakening effect of the hundreds of large and small earthquakes, mostly with vibration from the mountain outward which preceded the larger shock for six days. These had loosened foundations, cracked the soil, and by minor damage had weakened structures through much swaying. The writer in his car was driving northward through Honokahau along the government road north of Holualoa and turned into a private driveway to stop for a moment at a residence there. He had felt nothing. The big earthquake had happened a few minutes before, and he found the house in a turmoil, with furniture overturned and strong aftershocks still in progress. It was demonstrated later, when many people left their houses and slept in their automobiles, that a modern car is an admirable earthquake-proof building. Even at rest a sedan on springs and rubber tires produced almost no sensation to the occupants, while adjacent homes were rattling and roaring with the aftershocks.

Prior to the big shock of October 5, 1929, there was a marked lull in frequency during the daylight hours, the big earthquake coming at 9:22 p. m. The effects of this shock were stronger than those of September 25, and the damage to buildings was extended northward into Kohala. Conspicuous effects were the cracking of road fills in new places, the overthrowing of embankments at the tips of road spurs, and the sliding downhill of rocks and vegetation on cliffs.

The intensity relations, obtained by counting the numbers of strongish shocks, indicate that these clustered around September 26 and October 5. There were about 200 earthquakes recorded as sharp between September 19 and October 5 in the North Kona region. September 23 at Puuwaawaa there were nine, September 24, twenty-six, with one in the morning described as the strongest yet, and the next morning came one described as still stronger.

The following figures show three series about the frequency maxima, September 26, October 5, and October 8. The lists show computed numbers of earthquakes as registered instrumentally at Puuwaawaa, and in each case the figures rise to a maximum on the date above mentioned, and decline afterwards.

First Series		Second Series		Third Series	
Sept. 21	39	Oct. 3	97	Oct. 7	136
" 22	237	" 4	114	" 8	387
" 23	258	" 5	141	" 9	353
" 24	432	" 6	89	" 10	235
" 25	513			" 11	203
" 26	599				
" 27	541				
" 28	400				

In the first and second series, the dates September 25 and October 5, both in the evening, were the occasions of great earthquakes. For the third series there were one strong and five moderate quakes October 8, one strong and one moderate October 9, two strong October 10, and one moderate October 11. There was an increase in numbers of strongish shocks October 14-15 accompanying a slight increase in frequency. It is worthy of note in the above second series that the total frequency on either side of the day of the biggest shock (Oct. 5) is much less than the daily frequency of the earlier and later periods.

There is reproduced on the last page the photograph of a model of Hualalai Volcano by kind permission of Mr. W. T. Pope of Honolulu. The scale of the photograph is approximately four miles to the inch. The model shows the linear character of the belt of cones that constitutes the summit ridge of Hualalai, and the trace of an old sink crater at its summit. The two recent lava flows indicated on Hualalai are both believed to date from 1800-1801. The fluted cone at the northeast is Puuwaawaa; and the hill north of it Puu Anahulu is made of very old basaltic

rocks extending in a curved ridge southward through Puuwaawaa, as though the latter were a parasitic cone built on the edge of part of an old sink crater. The 1859 flow from Mauna Loa is shown at the northeast. The regions tremendously shaken in 1929 lay on the north and south slopes of the Hualalai ridge, and it may be seen from this model that these two regions are symmetrically balanced about a volcanic fissure. It seems reasonable, therefore, that the disturbance was due to intrusion.

It may be remarked that this region and these earthquakes of 1929 were the theme for the story recently published, "Lava" by Armine von Tempsky. T.A.J.

LASSEN REPORT No. 28

Lassen Volcano Observatory
R. H. Finch, Associate Volcanologist

On November 3 and 4, 1930 a spasm of small earthquakes were recorded on the seismographs at Mineral. The shaking began at 11:39 a. m. November 3, and when the trembling ceased at 3:31 a. m. November 4, ten shakes had been registered. None was reported felt though three showed an intensity well within the range of perceptibility. The indicated distance to origin was 11 miles or nearly equal to the distance between Mineral and Lassen Peak.

TILTING OF THE GROUND DURING NOVEMBER

The following presents a record of the tilting of the ground at the Hawaiian Volcano Observatory on the northeast rim of Kilauea Crater, showing the net amount for each week computed from the daily seismograms obtained by platting a curve which is smoothed by overlapping progressive seven-day means. As shown in Volcano Letters 302 and 306, the tilting of the ground in September and October was generally northeastward, as is usual for the autumn season. Therefore the tilt to the southwest for the week of the outbreak of Halemaumau (November 19) may have been stimulated by the release of gas and the inward dip of the country resulting therefrom.

Oct. 27-Nov. 2	0.72 second	N.
Nov. 3 - 9	0.48 second	S.
Nov. 10-16	1.57 seconds	NE.
Nov. 17-23	1.20 seconds	SW.

KILAUEA REPORT No. 984

WEEK ENDING NOVEMBER 30 ,1930

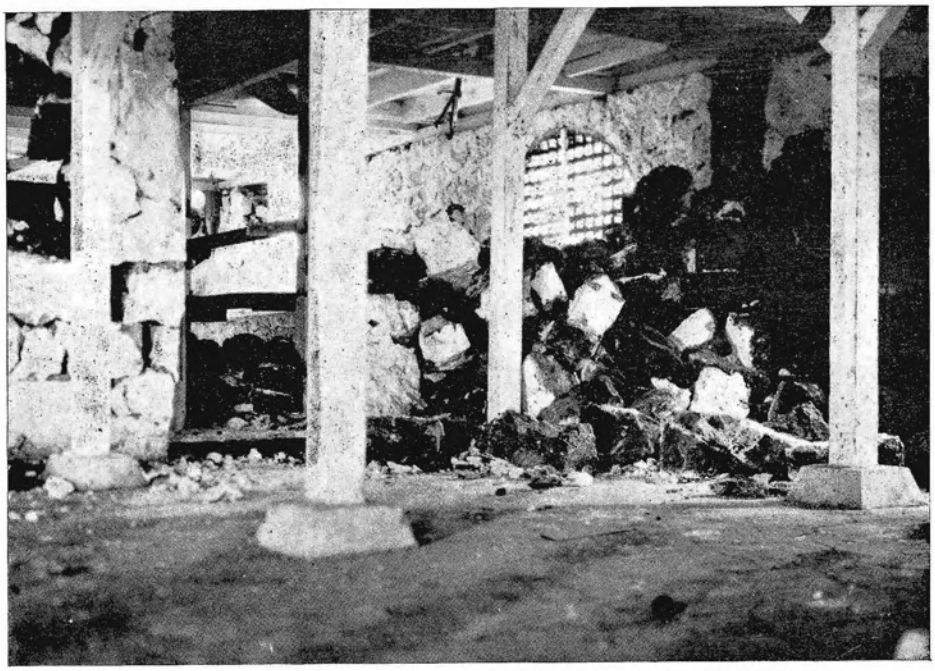
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar. Volcanologist in Charge

The pouring in of basaltic lava at the bottom of Halemaumau pit has continued during the week. On November 24 the fountain was building outer spatter ramparts on the side of the lake preparatory to formation of a spatter cone. The lake lava showed pahoehoe skins which wrinkled like satin. Festooned pahoehoe flows poured voluminously to the northeast and northwest. Small typical aa streams were sluggishly pushing out from the floor slag heaps in two places. The great delta-like fronts of the flows against the talus were half aa carrying pahoehoe crusts. Such crusts were cracking and sinking at the edge of the lake and elsewhere as the liquid lava welled up and weighted down the hardened surfaces.

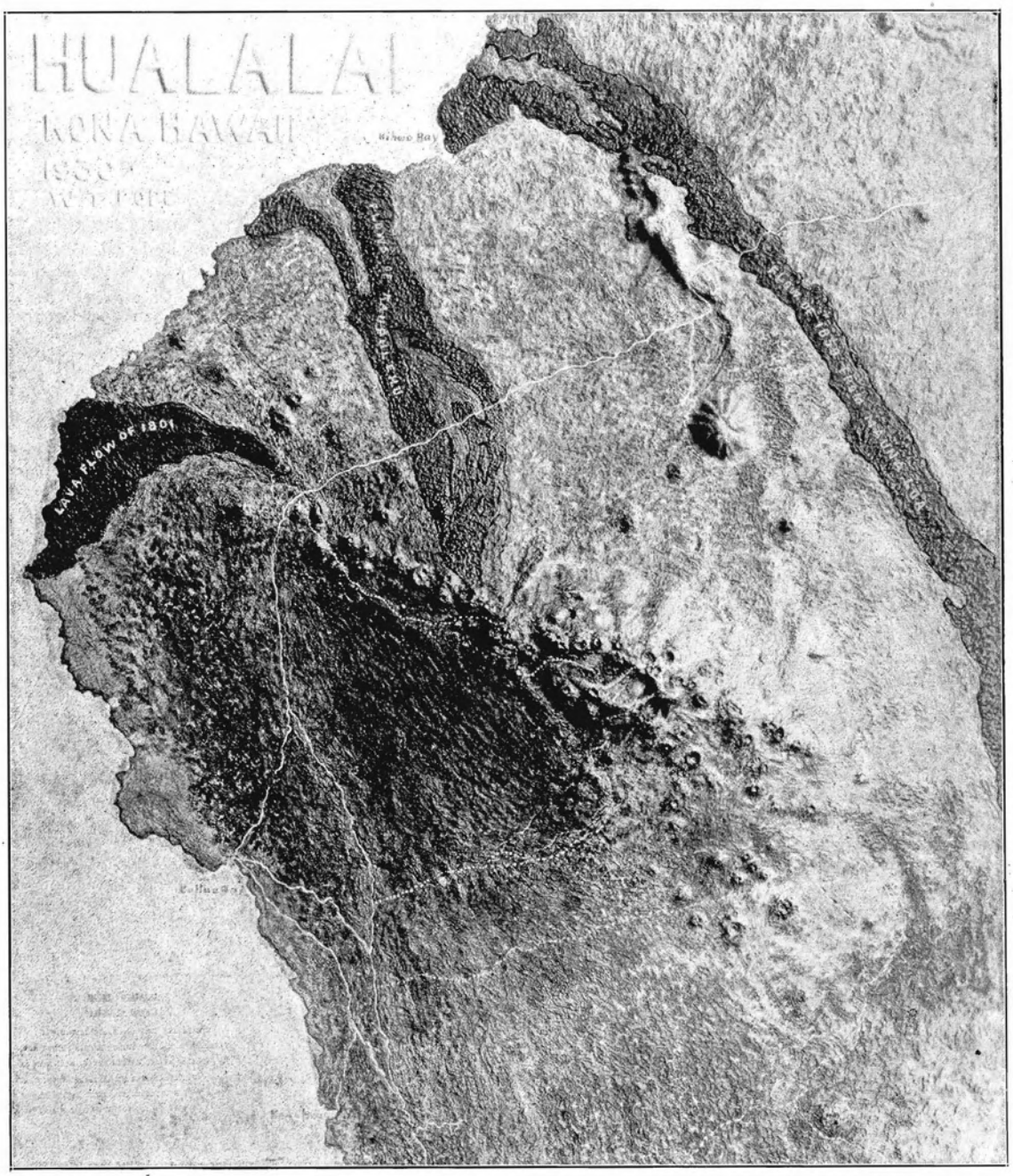
Measurements made the floor 2,200 feet long south to north by 1,800 feet wide. The lake was one-fifth as large as the floor. The total area of new lava was 55 acres, covering the 1929 bottom 15 feet deep about the edges and 90 feet deep at the lake. The lake was thus at the top of a heap 100 feet high.

The same type of activity continued during the week, the heat diminished, the fountain enclosed itself with a spatter dome more than 100 feet high, the overflows of the lake rim dwindled, and the glow of the outer slopes of the slag heap became less. Sulphur stain increased along a steaming crack at the southeast edge of the floor.

The Observatory seismographs registered feebly two teleseisms at 9:22 p. m. November 27 and 11:23 a. m. November 30. There were no local earthquakes. Volcanic tremor was harmonic and continuous throughout the week, with a spasm at 5:56 a. m. November 29 accompanied by easterly tilt, and another spasm at 6:55 a. m. November 29. The tremor was weaker November 30. Tilt was very slight to the southeast, and microseismic motion was slight but somewhat increased November 26-28.



Collapse of partitions in cellar of Puuwaawaa Ranch House resulting from earthquake damage October 5, 1929. Note the wooden posts diagonally braced and footed in concrete, which saved the house when the cellar walls gave way.



Model of Hualalai Volcano, 1930, by Willis T. Pope Summit 8,251 feet. Shows trace of old sink crater and NW-SE summit rift marked by cones. Distance from Kailua bay to Keauhou in southwest corner six miles.

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The Volcano Letter

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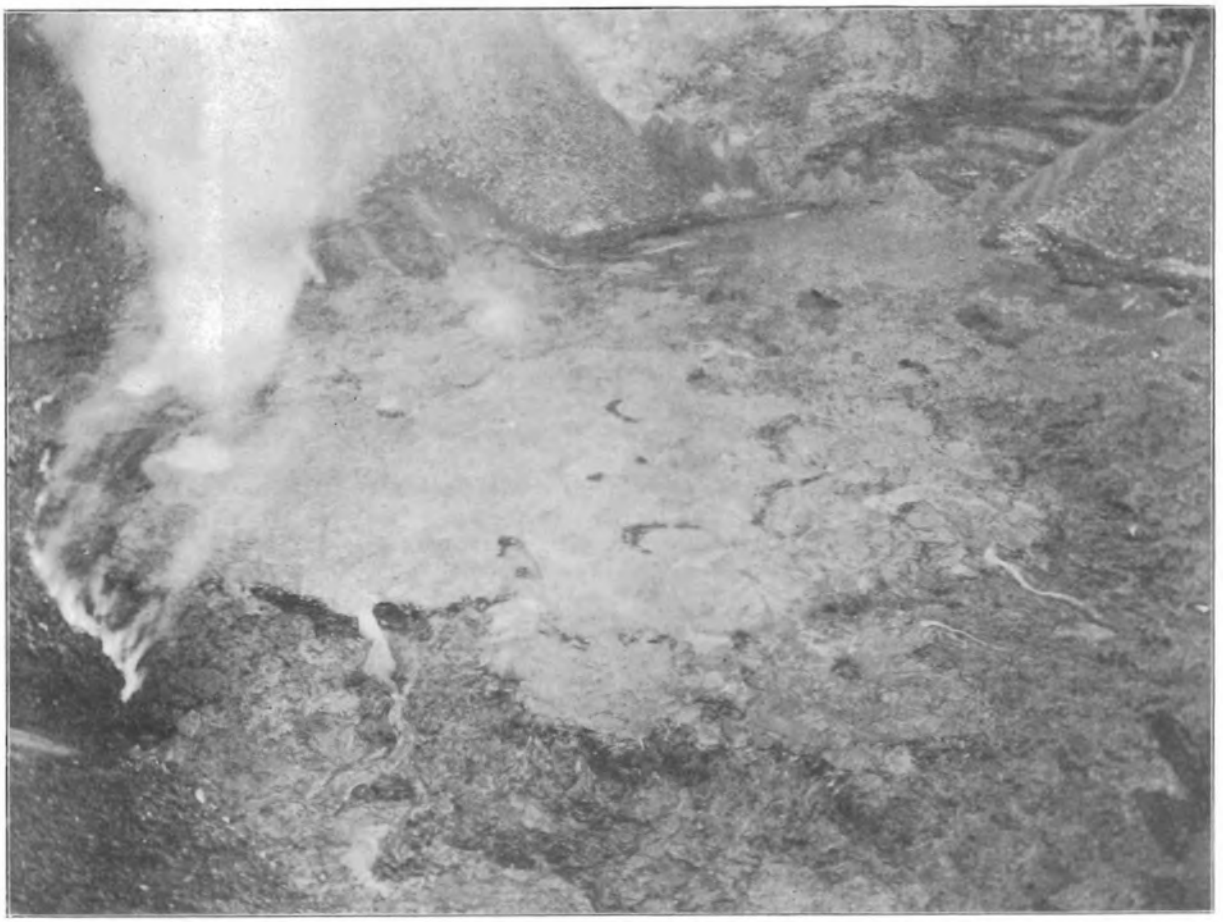
No. 311—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | December 11, 1930



Floor of Halemaumau from the east at 3 p. m. November 20, 1930. Shows the smooth lake area, the sulphur-stained crack with line of steam jets at the left, the fountain and its rampart under the large fume column, the 1929 lava heap against the talus at the back and numerous pahoehoe overflows from the terraced lake. Photo Powers

JOURNAL OF HALEMAUMAU ERUPTION 1930

As the eruption of lava in the bottom of Halemaumau pit of Kilauea Volcano came to an end so far as appearances go about noon December 7, 1930, it is appropriate here to show some pictures of special features and to review the daily sequence of events.

November 13. Pit seismograph recorded tilting of the ground away from the pit and many small tremors.

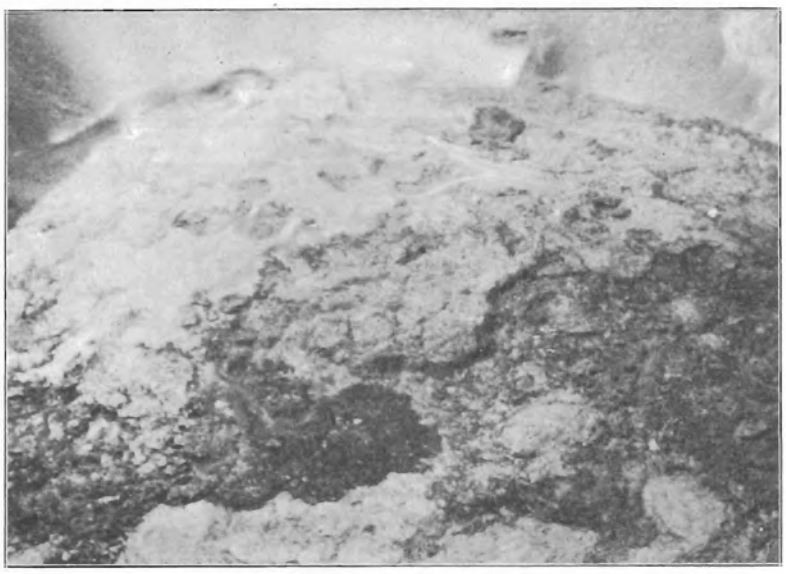
November 19. Tilt away from pit at 12:15 p. m. had accumulated to five seconds of arc. Then for an hour and a quarter 35 small earthquakes were registered and rim of pit tilted up and out five seconds more. This had been preceded in the forenoon by 57 small jarrings with slight tilting of the pit inward. This became continuous tremor after 1:29 p. m., becoming stronger at 1:38 p. m. moderating from 4 to 7 p. m., and thereafter continuing throughout the eruption, which had started with gushing of lava and gas at 1:29 p. m. Thereafter during the first 18 hours of lava activity the release of gas and escape of lava caused the pit rim to tilt back toward the center through 7.5 seconds of arc.

The lava broke its way up through the 1929 floor in the southwestern part of the pit. The floor swelled, broke, and the gush of lava carried up blocks of rock. Then seven fountains broke out southeast and finally a big fountain developed 100 feet from the south talus. The first fountains were 20 to 50 feet high, the big one was sometimes 200 feet high. The flood of lava spread over the 1929 floor and the smaller fountains dwindled. Oozing lava broke out back of the 1929 cone at the west. These events suggested that the new lava welled up through the 1929 paste, still hot under its thick crust.

The main fountain built a crescent grotto 40 feet high by 8 p. m., and the western fountains covered themselves with hoods. The outspreading flow began to pile up a slag heap with overflows northwest and southeast. Ramparts formed around a pool on the top of the heap.

November 20. At 1:30 p. m. the slag heap was 90 feet high, there was slow movement of crusting lava away from the big fountain, which now spurted from 60 to 100 feet into the air. The hooded vents of first action were smoking. About 12:30 p. m. a large flow cascaded over the southeast lake rampart and continued until the evening. By 8 p. m. most of the eastern remnant of the 1929 floor was covered, other flows crept toward the north, and by midnight only a little of the old floor was still uncovered.

November 21. The single large fountain continued its



Southwest corner of floor November 24, 1930, showing at the back the fume from the fountain vents which had sealed themselves, the 1929 heap at the right and the increasingly smooth lava from the border region in the foreground to the lake on the top of the heap. The small dark colored flow is the northeastern brown aa stream of November 24. Photo Powers.

activity and an inner lake rampart outlined an inner pond of lava with slow moving crust, the outer coves of the northern extension of the lake appearing like terraces at a lower level. At 1:30 p. m. the new lava covered 2,000,000 square feet and the lake was about 100 feet above the 1929 floor under it. The lake covered 650,000 square feet. The fountain was breaking up into two or three jets. At 11:30 p. m. a large cascade broke over the rampart at the northeast and produced a flow of such velocity that no crust had a chance to form so that 5 acres was soon covered with glowing lava.

November 22... In forenoon the northern stream on the floor was flooding in two branches northeast and northwest. The drainage of the lake and the settling of the slag heap had lowered the lake level 10 feet while the margins of the floor were building up against the border talus of the pit. The fountain had become a group of spraying jets of the Mauna Loa type. The lake was oval feeding a flow which poured downhill spreading like a delta northward in the forenoon, and to the WNW in the evening. The flows were pahoehoe above and half aa below with a coke-like appearance. The fountains were quiet, but sometimes made a surf-like noise and puffed up brown fume, spurting up from 50 to 100 feet. The fragments were light pumice, for they floated down slowly, and much of this material along with Pele's hair fell to leeward of the pit. In evening glow edges appeared under the western lake rampart. Lava toes pushed out at the edge of the floor all along its western edge. There were three or more crust islands in the lake and irregular elevations in the lava slope west of the lake. Some 1929 lumps and terraces were detectable at the north side of the bottom. Smell of sulphur dioxide rose with the fountain gas.

November 23. The fume from the pit rose in a transparent brown veil these days, with a moisture cumulus above varying at different times and sometimes disappearing. The fume was blue in reflected light. A brown trail of smoke spread westward and northward over the valley between Mauna Loa and Kilauea. The glow at night over the pit was sometimes yellow, and at other times rosy. Large crowds of people visited Halemaumau.

At 9 a. m. the fountains continued with a deep rumble and occasional very high spurts. A scar up the west wall of the pit had been left by avalanches of November 20-21. The grotto at the fountain caved in continuously. Overflows from the lake poured south as well as north and northwest, the last appearing as a big stream. A protruding spur extended the slag heap of the lake toward the northeast, where chasms were caving in leaving red-hot aa walls, and lava trickles pushed out at the edge of the floor. The floor edge was building up so as to touch the WNW, S, and SE walls between the taluses. Bright yellow sulphur stain extended along a steaming crack at the edge of the floor nearest to the fountain to the south of the lake. Bluish-white salt appeared at seven steaming cracks in the slag heap to the NW and NE. Pumice of mossy green apparance lay on the backslope of the fountaining grotto.

At 5 p. m. the northwest stream had crusted, leaving V-shaped bright areas. The lake was covered with bright lines in flow pattern without apparent motion. The fountain showed none of the inrush and foundering of crusts toward its center characteristic of the old Kilauea fountains. The puddle around the fountain was thinly liquid on the side toward the grotto, but otherwise the jets seemed to rise from stiff quickly congealed material, sometimes flinging fragments in a high spire apparently 150 feet into the air. The glow of the crack pattern in the aa slag heap to the northeast was different from the lake. An aa flow from it to the northeast talus was like a forked coral or fungus with a herring-bone pattern which remained glowing like a coal quite different from the festoons of pahoehoe. The whole floor looked rigid but very bright, a fan of flows with two outstretched arms enclosing a dark space. The foundering blocks of the rampart next to the fountain rolled over and grounded on a shallow bottom. The dark areas of the floor were W and S and N.

November 24. Measurements at noon made the lake 90 feet above the former bottom and 435,600 square feet in area. The outlying slag heap was 40 feet deep, covering 1,306,800 square feet. The edge flows averaged 15 feet thick, covering 653,400 square feet. The total volume was estimated at 93,000,000 cubic feet. The diameters of whole floor were 2,200 by 1,700 feet.

At 10 a. m. two sloping ramparts outside of the fountain marked its enclosure by a cone. The lava was changing to true pahoehoe with spatter of glistening black glass. The lake was covered with pahoehoe festoons, but on the outer slag heap northeast and west two short brown typical aa flows emerged from cracks. Otherwise the pahoehoe overflows from the lake turned into large semi-aa areas at the edge of the floor NE and NW. The continuous fountaining of the active center was more suggestive of

1917 Kilauea activity than anything yet seen. All the 1929 floor was now covered except the big west spatter heap. At 5 p. m. the glow pattern was darker than before owing to the pahoehoe skins. The rampart around the fountain was closing in to a horseshoe and the overflows were dwindling.

November 25. Activity was more sluggish, flows were shorter. and the edge of the floor was building up.

November 26. The fountaining niche was becoming a cone, there was fresh lava along the east and northeast edge of the floor and also against the south wall of the pit. A new overflow from the lake poured NW.

November 28. The fountain had spells of high spurting and other times of unusual quiet. Flowing was weaker. The fountain cone was growing.

November 29. Weakening action continued. Fumes were strong. Eastern lobe of floor had raised 50 feet while the lake level remained the same; an intervening point stood 64 feet above the 1929 floor. The horseshoe cone around the fountain stood 75 feet above the lake with an opening toward the west and a frothing pool which cascaded steeply through the opening to the lake of cloverleaf shape. The cone had an outer crescent ridge at the south. There was glow around edges of the floor, strong at the NE and weak at the W and N. A flow broke out through a crust on the northeast side of the fountain cone. A dull flow pattern extended from the lake across the northeast floor, but outside pahoehoe flows had ceased. The glow and fume were lessening.

November 30. The fountaining cone was now the main feature. The heat at the edge of the pit had greatly diminished. There was festooned skin streaming across the lake. The edge of the floor had risen all around and the steaming sulphur crack southeast had increased in sulphur deposits. The cascade poured out of the cone growing weaker and crusting over, and the top of the cone caved in. The border lava was rising around the 1929 heap at the west.

December 3. After two weeks of action the area of the top of the slag heap containing lake and fountaining cone was roughly 500 by 800 feet. The cone was about 75 feet high and 200 feet in diameter at the base. The entire new bottom area was leaf-shaped 2,300 feet long by 1,700 feet wide and covered 62 acres or 2,710,000 square feet. The deepest fill was 175 feet at the top of the cone, or 100 feet at the lake level. The shallowest fill over the 1929 floor at the north side of the bottom was 50 feet. The volume of molten lava was 229,000,000 cubic feet which had come in during the first three days of the eruption at the rate of 25,000,000 cubic feet per day, and the last 11 days at 14,000,000 cubic feet per day. The process had been first piling up the center, and then spreading out at the edges. The weight of new lava was slightly more than 15,000,000 tons.

KILAUEA REPORT No. 985

WEEK ENDING DECEMBER 7, 1930

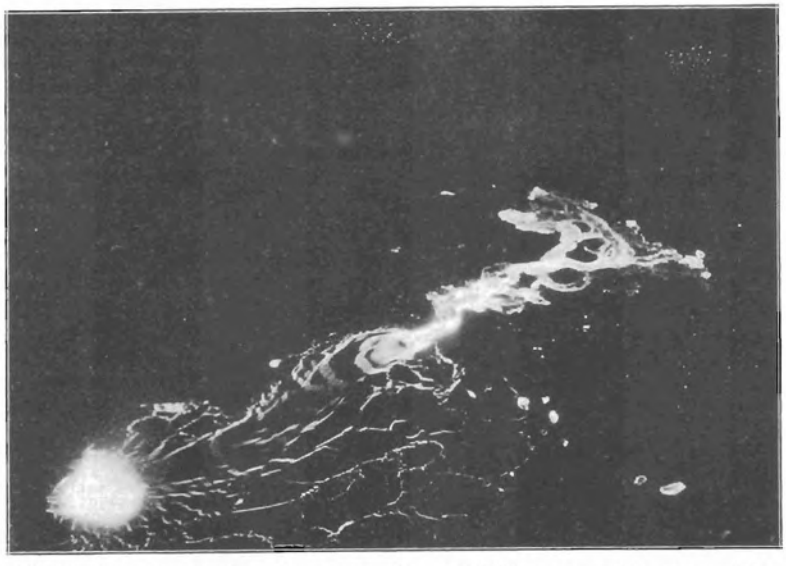
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar. Volcanologist in Charge

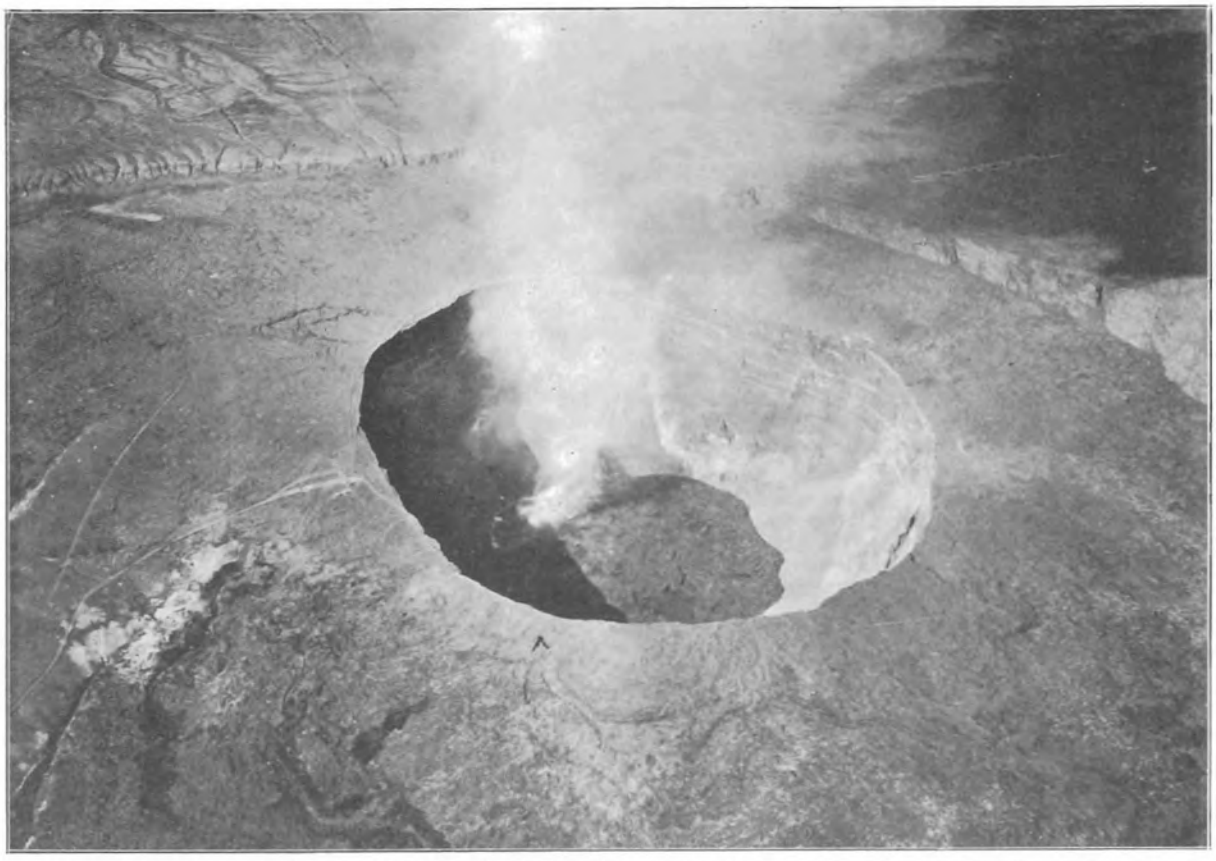
On December 1 the fountain in a cone of lava at the bottom of Halemaumau about 900 feet down was spouting variably. Its cone had grown big and the cascade down its side tended to crust over. The spectacular activity of the week came at times when the crust over the lake broke up and a rapid seething of glowing lava extended itself all over the surface along with sinking of the crust blocks. This process at intervals of from three-quarters of an hour to two hours continued until the evening of December 6, with increasing intervals. December 2 a stream from the big cone poured in a loop northward across the lake. December 3 a flow was building up the south edge of the floor. December 4 the cone was breaking down the edges of its cup. The break-up spells of the lake crust were brilliant accompanied with crackling noise. Bright yellow sulphur made a spicy smell at the southeast edge of the floor. The cascade from the fountaining cone renewed itself and poured flows over the lake crust. The fountain occasionally revived to high spurts. Then it dwindled to mere bubbling last seen the morning of December 7, and about noon that day all action ceased.

Volcanic tremor at the Observatory seismographs gradually weakened and stopped about 3:30 a. m. December 7. Two very feeble local earthquakes occurred December 1, one of these 8:55 p. m. indicated origin distance 32 miles and was felt from Hilo to Kona. Spasmodic tremors occurred four times December 4 to 7. Microseismic motion was moderate and tilting of the ground was moderate NE.

The action of tilting and trembling on the Halemaumau seismograph showed none of the sudden phenomena accompanying the end of the eruption which were observed when the lava ceased action in February, 1929. Strong trembling ended about 8 p. m. December 6, but minor tremor gradually dying away continued on December 7. At the end of that day it was nearly gone. There was no pronounced tilt of any kind. The effect is as though the lava pressure were still there without evident fountaining.



Night view of eruption November 21 at 11:30 p. m. This shows the spectacular cascade over the rampart, the bright line pattern of the lake, and the streaming away from the fountain. Photo Powers.



Halemaumau from the air at 9:30 a. m. November 25 showing the new fill in action burying up the talus slopes. The crescent at the base of the great western talus is the 1929 lava heap. Note the concentric cracks close to the rim of the pit showing how perfectly the caving tends to maintain a circle. All of the layers shown in the walls poured out during the 19th century. This picture shows that the floor of Kilauea crater is a dome. Photo by 11th Photo Section, Air Corps, U. S. Army.

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The Volcano Letter

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No. 312—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — December 18, 1930



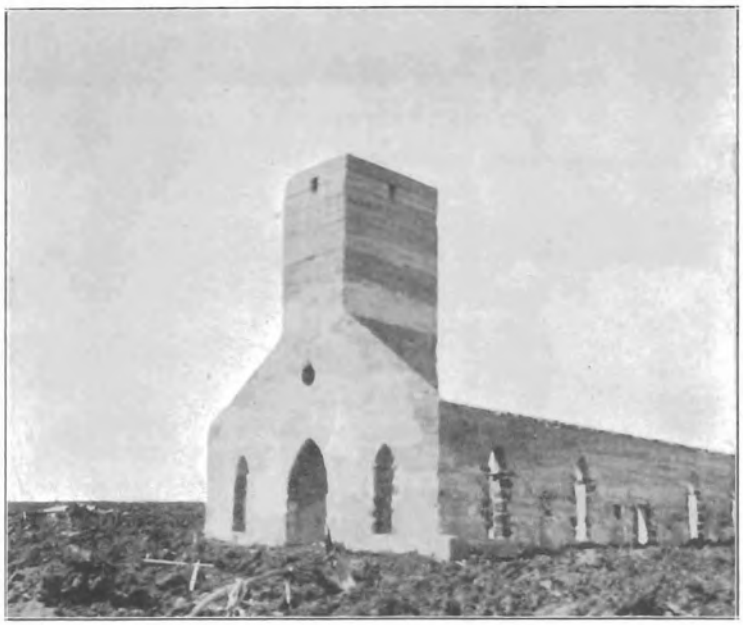
The great lava rift 30 feet deep back of Futu on the northwest side of Niuafoou Island, source of the destructive flows of 1929. The lava floods poured down to the right, and on the left are the unijured cocoanut palms of the ring ridge. There are spatter heaps on both sides of the chasm. Photo looking south September, 1930, by Jaggar.

THE ISLAND VOLCANO NIUAFOOU

Niuafoou, an active volcanic island belonging to Tonga, was described in Volcano Letter No. 265 in connection with the eruption of lava that poured out on the west side of the island and destroyed the village Futu July 25. 1929. The writer was privileged to visit the island as a member of the joint eclipse expeditions of the United States Naval Observatory and the New Zealand government from August to October, 1930.

Niuafoou is a splendid example of a crater ring, with lake in the crater, crowning a 6,000-foot volcano, most of which is below the level of the sea. It stands on the northeastern corner of the submerged portion of the Australian continent between Samoa and Fiji. It is an inhabited island, a paradise of cocoanut palms, the soil wholly volcanic, and lies 15½ degrees south of the equator. It is almost a perfect ring five miles across. The lake inside the ring is three miles across, of brackish water, surrounded by a ridge 600 feet high, with cliffs facing the lake and a gentler slope outside. It has islands and is much like Crater Lake in Oregon. Outside of the ring ridge there is a wider lava platform with cliffs facing the ocean. It is on this platform most of the people live in nine villages traversed by lovely avenues amid coconuts, ironwoods, mangoes, and other tropical trees and shrubs, and the usual pandanus near the shore. Copra is the principal crop, but there is much planting of yam, taro, papaia, sweet potato, bananas, melons, and manioc.

Seven villages are a short distance inland from the shore, two are on the ocean, one was destroyed by lava in 1853, one by hurricane in 1909, and Futu by lava in 1929. Futu is at the west, where the eruptions of the 19th century had created a lava desert with eruptions creeping northward. There are no lava flows about the crater lake, but here in 1814 and 1886 there were steam-blast eruptions which piled up sand islands and peninsulas, strewed the island with heavy blankets of dust and sand, and broke down the coconut trees with plastered mud that destroyed the crops and occasioned much suffering. About 1840, 1853, 1867, 1912, and 1929 the lava eruptions broke out along cracks trending chiefly north and south at the base of the ring ridge on the west side of the island and sending short flows for from half mile to a mile into the ocean. The 1853 eruption broke up through the center of the village Ahau and killed half the inhabitants. In 1929 the natives of



Church of the Marist Catholic Mission at Futu, a stone structure which was surrounded by aa lava and burned out July 25, 1929, and all the village houses around it were buried. Only a cross in the graveyard was left standing intact. Photo Jaggar.

Futu saw the fiery cracking of the flank of the hills in the distance, and fled to the heights in time to save themselves. But the northern half of their cluster of warehouses, churches, and habitations was buried under aa lava. They removed to a new village near Angaha on the north shore.

A remarkable adaptation of natural history to the uses of warm volcanic sand is the malau bird, a unique inhabitant of this island. At several places around the lake, and especially where the afternoon sun heats the explosion-made sand hills of 1886 this bird dwells amid the ironwoods and other growth. It is a small bush hen of the tribe Megapodius, meaning "big footed," which has another representative in Australia. It has large, yellow legs and claws adapted for digging in the sand. Its body is black, its head small and scrawny, and its size that of a small Leghorn hen. It whistles like a quail.

The malau hen digs a hole three to five feet deep in the sand slope, lays her egg in the bottom, scratches her way out filling the hole behind her with sand, and Nature does the rest. The sun heats the sand to from 85° to 95° F. Different hens reoccupy the same holes over and over again, even though the natives dig up the eggs for food. When a more fortunate egg hatches, the young bird digs its way out and is said to fly at once. The egg is long and pink, as big as a goose egg.

The people of Niuafoou are Polynesians with a civilzation much like that of Samoa, and they are strictly governed by a high chief, a magistrate, and police service representing the Queen of Tonga. There are usually seven or eight white people at Angaha, the principal port, where a rough landing may be made with boats. The people are completely Christianized, members of three denominations, are constant church attendants and lovers of religious music. The population is about 1,100, there are several motor cars, and the trails are broad and kept in good condition. Every man has his plantation, the people are splendid physical specimens, they are fond of tennis, cricket, croquet, boxing and swimming, and are very hospitable and friendly. They are not afraid of sharks, and meet the mail boat with swimmers. Hence the name "Tin Can Island."

The geology of Niuafoou indicates that it is the peak of a big lava dome under the sea, and thus it represents a more advanced stage of the same kind of volcano growth as White Island in New Zealand, or Falcon Island (Volcano Letter No. 265) farther south in the Tonga group. The central crater has been engulfing its walls along with explosive eruptions in recent geological ages. The lava plug under the crater tends periodically to erupt around its edges, or along the 'wall-crack" as we say at Kilauea, but the fractured caldera rim makes it easier to find a fissure up a crack in the outer lava platform than in the crater lake. Once in a long period, just as at Kilauea, the lava pressure is relieved and the plug lowers, letting in water and making a steam-blast eruption through the crater lake. The known last interval between these steam eruptions for Niuafoou was 72 years, whereas for Kilauea it was 134 years.

The ring ridge is made up of lava layers alternating with ash dipping a little more steeply away from the center than the heavy lava layers shown at the foot of the cliffs around the crater lake. The history, therefore, implies a lava dome below, becoming an alternation of lava and explosive eruptions in the later stages.

The eruption of 1929 was typical of all the western lava eruptions. The lava is a feldspar basalt similar to those of Hawaii except that olivine is not conspicuous. The southwestern desert of Niuafoou is what Kahuku and the Kau Desert are to Hawaii. In 1929 the old NNW-trending rifts of 1853 and 1912 at the inner border of the southwestern lava platform of the ring island were suddenly extended northward with an unheralded splitting of the mountain athwart its flank. Fiery slag shot up the crack without warning except for a few tremors. The frothy outflow swept west down to the sea. This happened about 4 a. m. July 25 by Tongan time, almost exactly 24 hours before a similar lava eruption occurred in Halemaumau pit.

The rifts in Niuafoou propagated themselves northward in overlapping gashes. These gashes showed such sympathy with the wall-cracks of the caldera as to indicate that if the intervening ring ridge broke down, the lava source cracks would promote the natural enlargement of the crater lake basin. The lava floods were pahoehoe above and aa near the sea. A dozen of them reached the water with islands of untouched forest in between. The length of the active spouting belt was approximately three miles. About 4,000 acres of coconut plantations were destroyed and traders' property estimated at $10,000. The eruption lasted only a little over a day.

The action was quite like the Kilauea flows of 1920 and 1923, fountains shooting up 20 to 50 feet, making Pele's hair and glassy needles, and building, as shown in the photographs herewith, long spatter ridges along straight chasms, fields of pahoehoe and aa, multitudes of coconut tree molds, and sand heaps along the sea front which were later converted into beaches. There was a little steam-blast action at the southern end of the rift belt, flinging up pieces of coral along with clinker. There were burning hydrogen and other gases at the vents making secondary glazes of many colors.

The straight wall of vents along the source crack was frequently double with heaps of glistening slag on both sides of the crack except where a torrent had maintained a flow gap. Steam still rises back of Futu and deposits sulphur and sulphates. The lava heaps there are 6 to 20 feet high above the former surface of the country, the visible V-shaped chasm in places is 30 feet deep, and collapse has revealed a cross section of old lava and ash beds where the original slope was rent asunder when the rift opened.

The explosive eruption of 1886 was a great event in the history of Niuafoou. It ranks the volcano in Class II among about 43 of its kind including Vesuvius. There was no direct loss of life owing to the good fortune, probably due to the trade wind, which forced the great cauliflower clouds of debris westward over the lake so that only 2½ feet of ash fell on the settlements. An earthquake gently swayed the island at 7 p. m. August 31, 1886, and shocks continued until midnight causing great alarm. Then with detonation a "rocket" ascended from the lake 3,000 feet, the shaking ceased, violent lightning storms developed striking the trees in many places, and big steam-blast vents piled up sand hills and shut off lagoons about an engulfment notch that was formed in the rim of the caldera on the northeast side of the lake. On the leeward side the deposits on the ring ridge were 20 feet deep. The material was broken fragments of rock, pumice, sand, and fine dust. The hills of this next to the lake are 200 to 400 feet high. The eruption lasted 18 days. It was accompanied by subsidence of border benches of the caldera. The Tarawera eruption in New Zealand happened only two months before, in June, 1886, was similarly explosive, and on the same line as the Tonga islands to the south. Here was another of the many cases of volcanic sympathy hundreds of miles apart where the same rift in the earth's crust is concerned. Falcon Island and submarine eruptions in Tonga were in action in 1927 and 1928, this activity continued into 1929 and so was sympathetic with Niuafoou in that year. Similarly Falcon Island had begun eruption in October, 1885, preceding Niuafoou in 1886.

The writer carried a shock-recorder this year to Niuafoou and set it up in a quiet place on concrete, and operated it in September and October. The records in 1930, 13 months after the activity of 1929, were singularly free from earthquakes, none was felt by any member of the expedition from August 19 to October 22, and earthquakes were not reported by the natives. They did, however, report underground rumbling in the lava belt October 3, and 9 small shocks during 4 minutes following 6:38 p. m. that day were registered on the shock-recorder. Felt earthquakes had been more numerous during the last half of 1929 and were reported as late as January, 1930, but thereafter seismic quiet ensued. T.A.J.

KILAUEA REPORT No. 986

WEEK ENDING DECEMBER 14, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar. Volcanologist in Charge

The week at Halemaumau pit following the recent lava eruption in the bottom of this inner cauldron of Kilauea Crater has produced no new visible activity, but the glow of the hot basaltic fill may still be seen in cracks through the floor, and the bluish fume continues to rise around the vents and at the sulphurous wall-crack at the southeast.

On Monday December 8 there was abundant fume rising from the pit as seen in the afternoon light when the sun is on far side of the vapor as seen from the Observatory. With the sun behind the observer in the morning



Interior of a coconut tree mold showing the bark pattern made by the pahoehoe lava of 1929 on Niuafoou. Thousands of coconut trees were molded so as to leave groves of stone trees 5 to 13 feet high. Photo Jaggar.



Glimpse of the crater lake of Niuafoou from the largest island, showing the eastern ring ridge in the distance, the ironwoods and coconuts on the island, and the black sand beach. Singular limey concretions are deposited on these lake beaches, containing tiny crabs a half inch in diameter. Photo Jaggar.

light the fume is less evident. At 8 p. m. there was no glow over the pit, but from the edge the recent lake area was seen to be well marked with orange-colored incandescent cracks. One spot at the northwest emitted a trail of light as though from an open grotto. There were small glow spots at the edge of the floor, N, NE, SW, and W. There was no noise. Fume rose from the side of the fountain cone, the southwest side of the floor, and at the bright yellow sulphur SE. December 13 there appeared to be settling of the lake area. Glow in cracks was still visible at night.

The pit seismograph December 8 showed no sign of inward tilting toward the pit and recorded spasms of tremor. At 3:45 a. m. December 13 it recorded an immediately local shock with tilt away from pit. At 5:07 a. m. December 14 a tremor at the Observatory was accompanied by east tilt. The Observatory instruments registered three very feeble local earthquakes for the week, one at 6:18 p. m. December 13 with origin 9 miles away. Four spells of continuous tremor occurred and 29 spasdomic tremors, probably a continuation of eruption tremor. Microseismic motion was moderate on the 8th and otherwise slight. Tilt was very slight north. The evidence suggests continued lava pressure upward.

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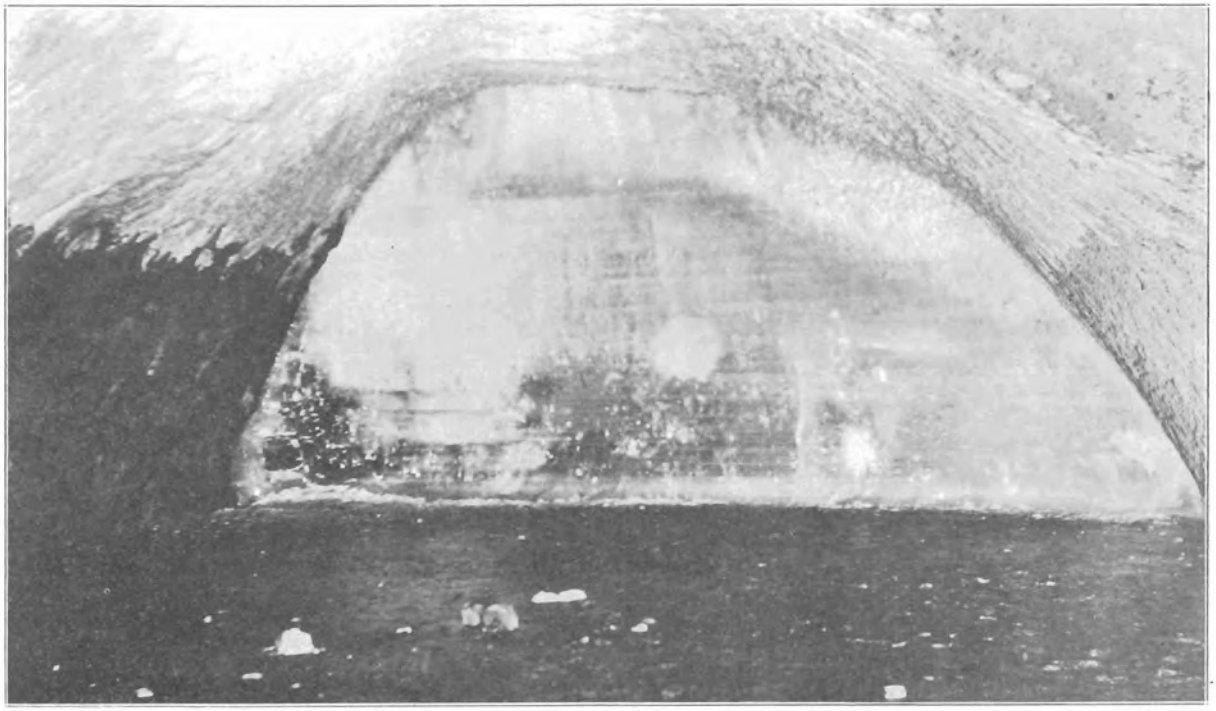
No. 313—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — December 25, 1930



Flash light photograph of ice wall 30 feet high and 40 feet wide at inner end of Shoshone Ice Cave. Note horizontal stratification, ice floor, and ice crystals on roof and on the face of the ice wall. Photo February 15. 1930, by Bruns.

NOTE BY THE EDITOR

The following paper may be prefaced by a brief summary of the ice cavern situation. This lava tube in recent basalt is 30 miles north of Shoshone in Idaho. It is 80 miles south of the Craters of the Moon National Monument. It is a pahoehoe flow with tubes leading from collapse-basins. Several of them foster ground ice in roof crystals, stalactites and stalagmites, and floor coatings.

The ice cave is 400 feet long in a southwesterly direction from one of the sinks, where it starts 100 feet below the level of the country, and progresses underground downward in steps at a flat angle. The inner part is floored with several inches of ice, the roof variously develops hoar frost and ice crystals, there is a rock pile 80 feet from the inner end, and at the end the cavern is abruptly terminated by a wall of solid ice. This wall of ice is 30 feet high, according to Miss Robinson's diagram (Volcano Letter No. 296), 40 feet wide. and its middle is 100 feet underground. There is a drop with a ladder 50 feet from the entrance. The coldest air temperature was always found just inside the entrance chamber, about 32° F. The innermost chamber was usually 2 to 5 degrees higher. On summer visits there was some water on floor and water drip. Accumulation of ice 4 inches deep went on between two visits of February and April, over paper which had been left.

It may be mentioned that the excessive radiation of solar heat at night, with rapid evaporation if the nights are dry, in contrast to solar melting of ground ice from snow in cracks and chasms daytimes, would be assisted by convection in a cavern system. The finding of the lowest temperature at the narrow entrance, the highest part of the floor of the cave, implies a rush of cold air confined in the narrow passage from within outward. This was found in daytime when the outside air was at 80° F. This shows that an ice box circulation is maintained with seepage of air from outside refrigerated along the same passages that bring down the water in daytime. Probably the night reaction freezes this new water at a lower level, and possibly the convectional circulation. aided by evaporation chilling, becomes stagnant or changes direction. It seems certain that the ice wall is fed by an unseen ground ice reservoir, operated by some such mechanism, and it would be interesting to know what air currents are present, night and day.

T.A.J.

THE SHOSHONE ICE CAVE, IDAHO

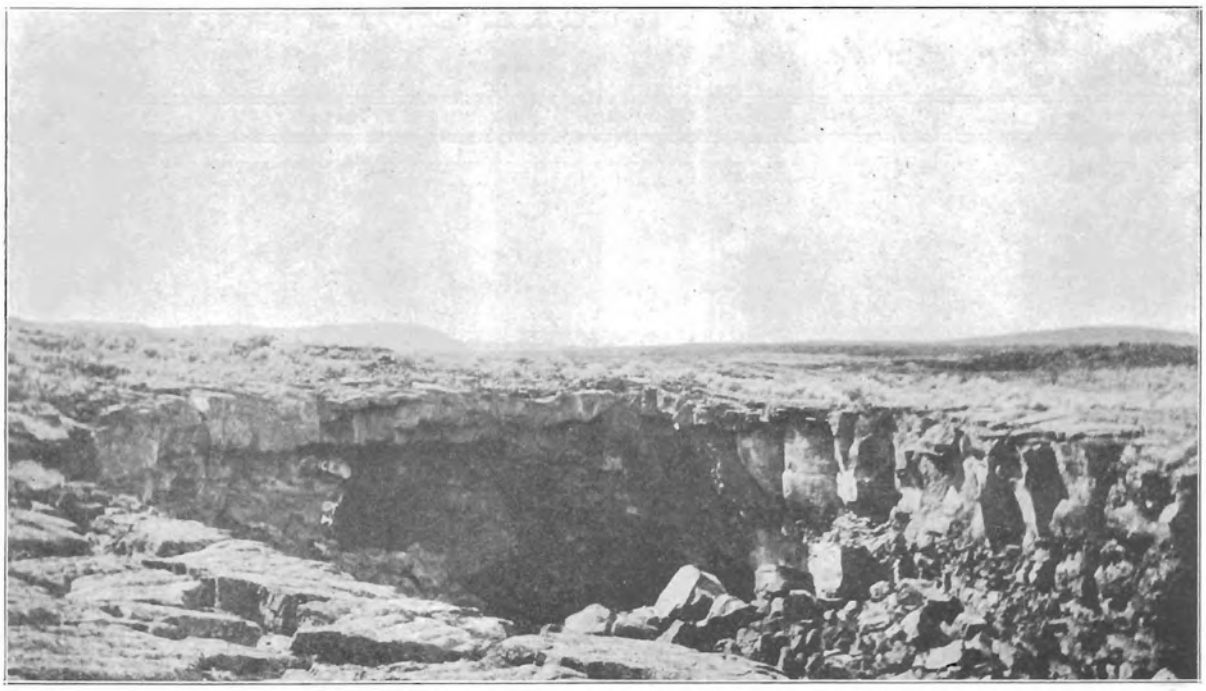
(Second Paper)

By H. G. ROBINSON

In the Volcano Letter for August 28, 1930, this ice cave was described briefly, and an account was given of a series of visits paid to it in the early part of 1930. Since then another trip has been made which resulted in the discovery of several additional facts.

This last visit was made on Sunday, September 7, 1930. The outside temperature was approximately 80° F. The day was clear and hot. In the outermost entrance cave, the ceiling was very damp, and water was constantly dripping. Deep in the cracks which crossed the roof at intervals could still be seen slushy ice crystals. Since there had been no rain for a long while, the water must have come from the melting of those crystals deep in the wall. The floor was still covered with ice, but on top of this ice was a thin film of water which in places measured as deep as half an inch. At the sides of the entrance cave, where the ceiling is very low, formerly there had been thick deposits of clear ice.

It was at once apparent that much melting had taken place at these points, and the ice which remained was no longer clear but looked much like slushy snow. As we approached the ladder we noticed water-cut channels in the ice of the floor, through which small streams of water were running rapidly toward the ladder. They formed a very considerable water-fall just behind and beside the ladder. Right at the foot of the ladder was a depression in the floor ice, worn by the constant stream of visitors usual in the summer time. This depression was filled with



Outer sink and entrance to Shoshone Ice Cave. Photo May 18, 1930 by Bruns.

water. But the floor elsewhere, between this point and the rock pile, was dry.

In view of the amount of water constantly pouring over the edge by the ladder, this indicates rapid freezing conditions in the cave. The floor, previously of clear ice, was now covered with a thin film of ice crystals which sparkled faintly in the flashlight. As we neared the rock pile, a slight film of water was again noticeable. It was not more than a quarter of an inch deep, except in depressions apparently caused by the drip of water from the ceiling, or by melting about some foreign object. Just the other side of the rock pile the drip from above was again noticeable. The stalagmites had in all cases melted away until only slight humps could be distinguished.

Over the rock pile the ice which had been clear enough to enable us to read the newspaper a few months ago was now crocked like old china, forming a mottled pattern all over the surface. It was thinner than before also, for the paper, one which was left behind by accident in January and noticed in April, covered to a depth of about six inches with crystal-clear ice, was now only a few inches below the surface. Nowhere was the ice as slippery as it had been on the previous trip.

The ice wall at the rear was much the same as usual, except that a large part of the wall near the bottom had been dug away, apparently with a pick-ax. Like all other such efforts made in the past, it proved useless, and rather worse than useless, since it revealed no end to the wall and helped to destroy a thing of beauty. We found also that all of the iron stakes driven in at various places to aid us in measurement of the ice thickness had been removed, except those on the right and left floors which were so well concealed as to be unseen by the average sightseers.

There were no ice crystals at all on the ceiling of the entrance cave. At the foot of the ladder the roof was covered with ice which had lost its crystalline form, having apparently melted and refrozen into clear ice drops. Farther back in the cave the percentage of real ice crystals increased, and their presence was noticed much farther back than on any previous visit. It was also noticed that they were much more abundant and extended farther back on the left, or inside, curve of the wall than on the right.

The temperature of the cave at the foot of the ladder was almost exactly freezing. This fact explains the freezing of the water flowing in from the entrance cave, and the reformation of the drops of ice from the crystals on the ceiling. However, the crocked condition of the ice at the rock pile, the original melting of the crystals, and the slushy, snowlike appearance of the ice at the entrance, certainly indicate that considerable thawing had taken place during the summer months.

On this visit a survey of the ground above the cave was attempted by a rough estimate of distances and compass readings. At the point where we believed the underground rock pile to be the ground surface was much disturbed, being composed mainly of loosely piled chunks of lava rock which left many cracks, crevices, and holes leading downward. Though there was a party in the cave at the time, no sound of their voices or other noise could be heard at this place, thus showing that though these cracks are extensive, they do not form any open channel into the cave. Just the same, a network of cracks leading into the cave is almost certain, and the outer loose rock would form, of course. an excellent reservoir for snow, which on being melted by the sun's rays would find its way into the cave below, thus forming the persisent drip at the inner rock pile.

Farther on outside, at the place where the ice wall starts underneath, a sharp V-shaped depression cuts across the surface at right angles to the general direction of the cave. This depression is about 20 feet across and about 50 feet long. It looked as though support had been withdrawn from beneath a crack at right angles to the cave direction, thus causing the two sides to slope in gently toward it. However, no opening could be detected at this point.

On following across country the line of the cave still farther, a very small cave was located. In the eastern wall of this nearest the ice cave were several very small tunnels leading downward and eastward. From these there came drafts of very cold air. By much effort Mr. Bruns, our photographer, wriggled into one of them for some little distance, but saw no ice. However, several other small caves in the vicinity had a little ice in their far recesses. The discovery of these other caves, with their possible connection with the ice cave on the other side of the ice wall, together with the very small opening of the ice cave itself to the exterior, makes one wonder whether the original formation of the ice wall might not be explained by the hour-glass theory advocated by Balch, although the fact that the ice wall is now entirely solid makes the theory of little value in explaining present conditions.

The absence of all ice crystals in the roof in the dead of winter and their appearance later in the spring may be accounted for as a phenomenon of condensation. The cool moisture-laden air of the cave coming in contact with the roof, which has been warmed both by penetration of the

sun's rays and by convectional circulation, deposits moisture on the roof where it immediately freezes into crystals. This will of course take place only when the cave air is cooler than the outside air.

As a result of this study, the method by which the ice on the floor is renewed is plain. Its source is ground water from snow and rain, and the presence of the ice wall itself is at least one factor in maintaining a freezing temperature. And yet air currents must play a considerable part, too, since the table of temperatures indicates that the coolest place is always just at the foot of the ladder. From a study of the stake measurements a constant very slow melting may be observed during the interval of study, which is what one would expect.

Though the cave has been observed during the greater part of a year's cycle, the seasonal changes of the local accumulations being roughly recorded, still the phenomenon of the ice wall is not yet explained, and the only conclusion is that detailed and careful study is needed before it can be. Such study might prove to be profitable in opening up new possibilities in refrigeration.

KILAUEA REPORT No. 987

WEEK ENDING DECEMBER 21, 1930

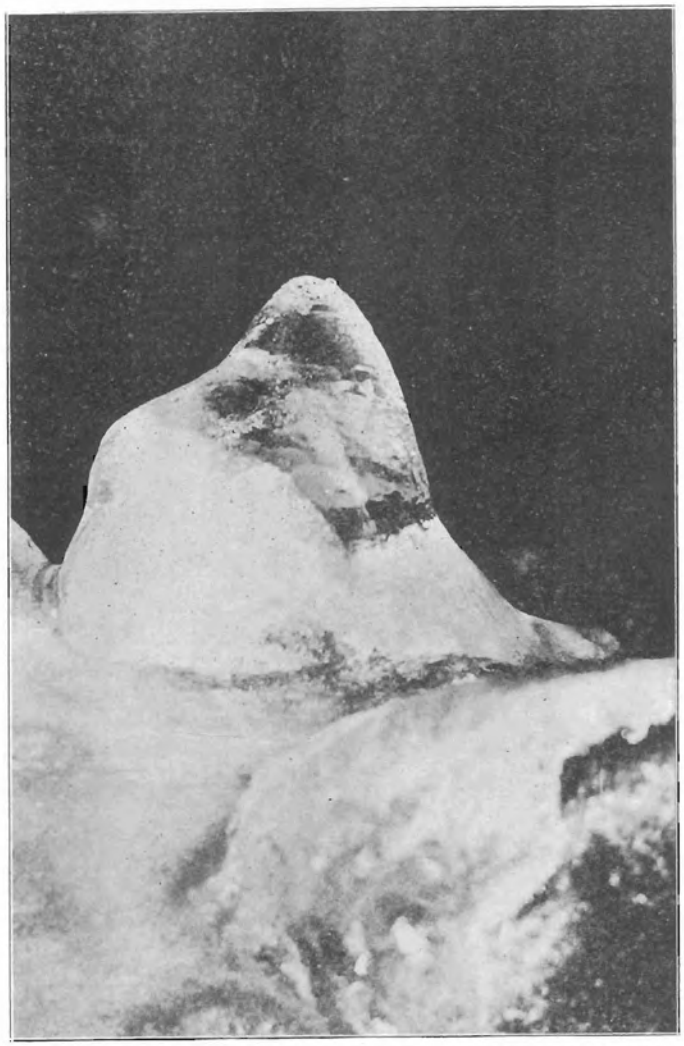
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The fuming from the new lava fill in Halemaumau has been somewhat less during this past week, but has been constantly noticeable. The fume cloud has been added to by clouds of steam on several rainy days. There has been no further slumping of the surface of the new lava, though a few more fragments from the rim of the spatter cone have collapsed. A feeble earthquake was felt by several persons in the National Park at 4:24 a. m. Saturday, December 20.

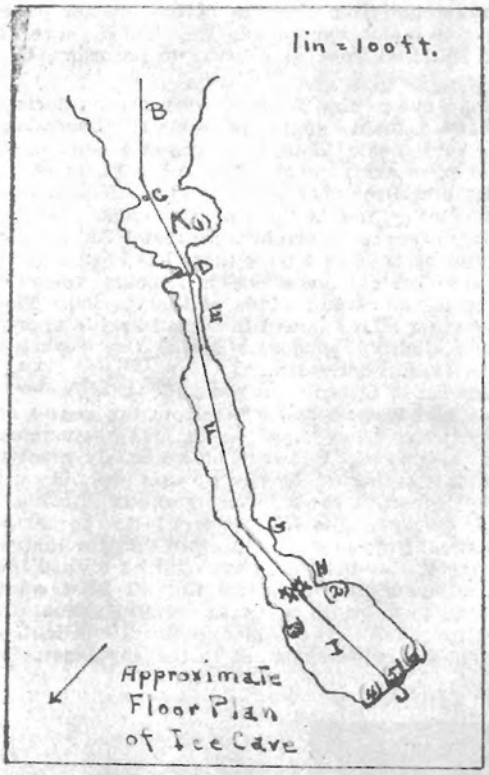
The seismographs at the Observatory recorded 3 very feeble shocks and 1 feeble quake as follows: December 17, 12:21 a. m., very feeble, distance to origin 9 miles; December 18, 8:49 p. m., very feeble; December 19, 11:42 p. m., very feeble; and December 20, 4:24 a. m., feeble, distance to origin 4 miles, felt in the National Park. Thirty-six small tremors of volcanic origin were registered during the week, and during the last 3 days there has been a good deal of tiny spasdomic tremor which appears volcanic but may be due to the strong winds of that period. The non-volcanic swaying of the island indicated by the microseisms has been slight to moderate during the week accompanying the trade-wind storm.

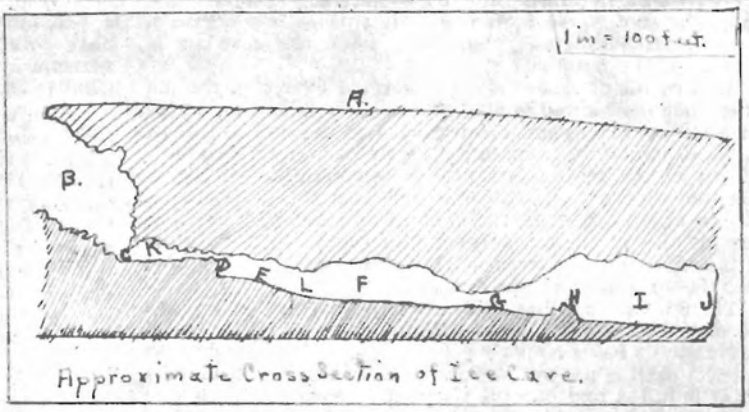
The average tilt of the Kilauea rim under the Observatory has been slight NE, up and away from the center of the crater. During the same time, the rim of Halemaumau has been tilted upward and outward by a slightly greater amount. A notable tilting of the rim upward and outward from the pit accompanied the Kilauea quake of Saturday.

The normal tilting of the Kilauea rim is to the northeast at this season of the year, but the fact that the instrument on the edge of Halemaumau shows tilting toward the southeast at the same time indicates that at least some of the tilt is due to volcanic pressure under Kilauea. If the tilt was entirely due to the seasonal effect, both instruments should show simultaneous tilt to the northeast.



Giant stalagmite of ice two feet high on the rock pile inside of Shoshone Ice Cave. Photo. May 18, 1930, by Bruns.





Key

A - Surface
B - Part of "Crater"
C - Where Ice Begins
D - Abrupt Drop
E - Incline
F - First "Room"
G - Tunnel
H - Rock Pile
I - Second Room
J - Ice Wall
K - Entrance
L - Foot of Slide

Date	Temperatures in Degrees Farenheit. Outside	Entrance K	Foot of Ladder D	Foot of Slide L	Tunnel G	Rock Pile H	Ice Wall J	Amount of Stake Protruding in Inches. Entrance (1)	Left Floor (2)	Right Floor (3)	Right Wall (4)	Center (5)	Left Wall (6)
Jan. 4	13°	32°	35°	39°	34°	34°	34°	Flush	1 1/4"	1"	4 1/2"	3 3/4"	1 3/4"
Feb. 15	50°	28°	30 1/2°	33°	31 1/2°	33 3/4°	31°	1/4"	1 3/4"	7/8"	2 1/4"	3 1/4"	1 1/8"
Apr 6	78°	32 1/2°	35°	—	—	34°	33 1/2°	1/2"	1 3/4"	1 1/2"	2 3/4"	Removed	2 1/8"
May 18	80°	34°	35°	—	—	—	37°	3/8"	1 3/8"	1 1/4"	Removed	"	2 3/8"

Plan and section of Shoshone Ice Cave. Scale reduced here to 7/8 inch to 100 feet. Statistics of earlier visits in 1930. By H. G. Robinson.

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No. 314—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — January 1, 1931



One of Dr. Stone's photographs made during his ascent of Calbuco January 19, 1930, a year after the eruption described by Dr. Reichert on January 6, 1929. This is looking down into the new crater of the volcano, from the north side of the summit, showing thick white fume issuing from the bottom.

1929 ERUPTION OF CALBUCO, CHILE

By Dr. Federico Reichert

(Translated by J. B. Stone from Riel y Fomento, No. 87, July 1929).

It was in the afternoon of the 5th of January, 1929, when, accompanied by a friend, I undertook to climb the peak Derrumbo situated to the south of Lake Todos los Santos, a body of water well known to those making the trip between Bariloche and Puerto Montt. On the accompanying map of the Pacific Ocean these places may be found just where the longshore islands begin on the west side of South America, in the great valley of Chile, about 600 miles south of Valparaiso.

The prospect for the projected climb was very favorable. The sky was completely clear. The sun was brilliant and the calm absolute. Only the barometer marked an extraordinary and inexplicable minimum. In spite of this abnormal low pressure we resolved to begin the trip, and were able to climb that afternoon to an altitude of approximately 1,200 meters, where we stopped and were overtaken by night.

At about 2 o'clock of the following morning we were awakened by a strange noise and, on looking toward the horizon, we saw a thick mass of clouds, which was approaching rapidly from the west. The rarefaction of the atmosphere was clearly manifested. We supposed that a storm was approaching, a phenomenon often occurring in these regions. The stars still shone. Believing that it was a temporary atmospheric disturbance, we decided to wait until the clouds should discharge themselves, and then continue the interrupted ascent.

But this plan was rudely changed at 5 a. m. when we saw that the clouds were taking forms ever more curious and strange, and were approaching our position like phantasms, threatening to envelop the whole neighborhood and the summit of the peak we were trying to scale. At the same time there was heard a distant detonation different from the report of thunder, and the sky darkened thickly. We thought it would rain, but it did not do so. We decided then to abandon our plan and to return to the shore of the lake, where we had left a boat tied. This we did.

After setting out downhill and about 7 a. m., we found ourselves faced by a strange condition. At first we had the sensation that it was raining, but very quickly found we were mistaken. We looked up and verified the fact that it was a volcanic eruption, which in my judgment proceeded from the mountain Calbuco, situated some fifteen or twenty kilometers distant from the spot, and the only volcano at that time characterized by periodic activity in this region.

Little by little the sky was darkening more. The south



Overturned trees in the valley of Rio Caliente half buried in ash and swept by the blast that had rushed out from the eruption of Calbuco. Just such effects were found on the west side of Sakurajima in 1914. Photo Stone.

cove of Lake Todos los Santos was wrapped in an impenetrable blackness. Only in the north there were seen patches of faint light which quickly disappeared. At 9 a. m. we reached our moored boat. Meanwhile volcanic ash fell intermittently. We embarked at once bound for the south corner of the lake to seek refuge. We rode ten minutes and found ourselves in the dark, as in the middle of a starless night. Something marvelous! In the north, too, were extinguished the little lights gleaming until then in the bosom of the cloud masses. Under such conditions like blind men we kept on rowing anxious to gain the shore.

Ordinarily this could be done in 20 minutes, but now we rowed madly for two hours and a half. We seemed to navigate in a vacuum. The rain of ash bathed our bodies and faces and hindered our looking upward. The situation became complicated a little later by another pheonomenon no less strange. We were wrapped in the "fire of Saint Elmo" produced by the high electric tension. From our clothes and flesh we gave off sparks, and our heads seemed to be surrounded with aureoles. Suddenly the lightning flashed, followed immediately by thunder. The light of the celestial dischange, however, was not bright enough to tear the curtain of ash and nocturnal darkness which covered everything. Simultaneously the discharges from our bodies stopped and we found ourselves again in a chaos. We went on for a stretch and the phenomenon of the "fires" was repeated.

Without warning we reached the shore. To orient ourselves we lit matches and debarked not without difficulty. We were absolutely ignorant of the point where we had arrived. At last at 11:30 a. m. the sky began to clear and we distinguished smokily some outlines of the vicinity. To our surprise we found that we were scarcely 100 meters from the place where we had set out.

The spectacle which presented itself to our gaze was breath-taking. All the landscape, usually so magnificent, was covered by the gray colors of mourning. The fresh green forest had disappeared under cloaks of volcanic ash. The panorama was like a desert. The summits of the mountains Ozorno, Puntiagudo, and Tronador, so majestic, had also received the rain of ash from the volcano. The snowy whiteness of their snow-clad peaks was now blackened. Carried by the blast from Calbuco the ash had traveled to the end of the state railways of Argentina, covering all the region of Lakes, Gutierrez and Mascardi of the Argentine Southern National Park. An area consequently of thousands of square kilometers.

Our expedition had aspects, therefore, that were unexpectedly dramatic, but it served for scientific observations. We analyzed the ash which had encircled us for so many hours, to see if it contained fertilizing substances. From this study we can say that it has a specific gravity of 2.66, and that the average thickness of the blanket was 1.5 centimeters. Thus every square meter of surface received about 40 kilograms of ash, contributing lime and phosphoric acid in appreciable quantities. For the 40 kilograms of crude ash will eventually add to every square meter of ground 740 grams of lime and 84 grams of phosphoric acid in the form of easily assimilable compounds.

(Dr. Stone points out that no rain fell at Calbuco for two weeks after this eruption, confirming Finch's conclusion (Amer. Jour. Sci. Feb. 1930) that steam from volcanoes is not the cause of accompanying showers, which depend rather on atmospheric humidity.)

VOLCANOES AND VOLCANOLOGY IN KAMCHATKA

The following is summarized from an interesting letter sent by Dr. P. T. Novograblenof, Director of the Kamchatka Museum, Petropaulovsk, Kamchatka, U. S. S. R.

Writing May 5, 1930, he states that in September, 1929, a great eruption began of Gorely Volcano, a peak 1,830 meters high lying 85 kilometers southwest from Petropaulovsk. The eruption reached its maximum December 30-January 2, and ended in March, 1930, lasting nearly seven months. Gorely, like most of the Kamchatka volcanoes or "sopka" as they are called there, is in uninhabited country. The result of this eruption was that a large area of southern Kamchatka was covered with ash. This is not to be confused with Gareloi of the Aleutian Islands.

Kluchevskaya Volcano, the Vesuvius of Kamchatka, was in a severely active condition throughout the whole of 1929. There were, however, no considerable earthquakes at Petropaulovsk. There are 18 active volcanoes in the peninsula and one in eastern Kamchatka. In the beginning of 1930 the massive northerly volcano Shiveluch, 3,291 meters high, began to throw up clouds of ash and lapilli. It is not known whether there were lava flows.

The Academy of Sciences of U. S. S. R. proposes to establish two volcano observatories in Kamchatka, one near Avachinsky Volcano, the other near Kluchevskaya. The Geological Committee of the Union has informed the Kamchatka Scientific Society that a volcanological expedition is being sent to Kamchatka under Professor A. N. Zavaritsky for exploring Avanchinsky Volcano (elevation 2,720 m.) and Koriatsky (3,462 m.), both these cones being near Petropaulovsk. This expedition will work for two years. It will be the second volcano expedition sent to Kamchatka, as the first one under Conradi and Kehll worked there in 1908-10. T.A.J.

KILAUEA REPORT No. 988

WEEK ENDING DECEMBER 28, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

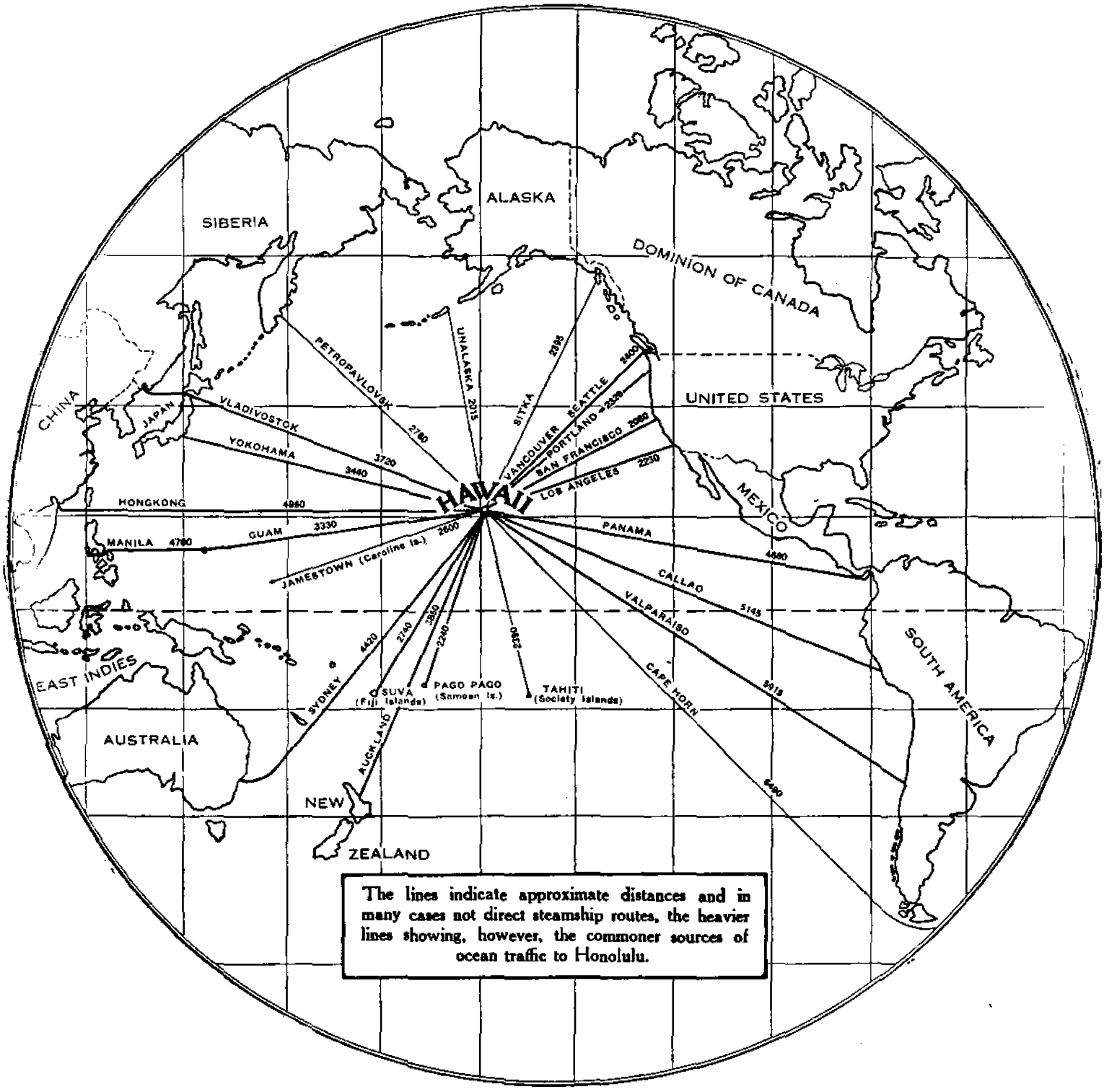
The situation at Halemaumau pit after the recent eruption of lava which filled the bottom and ceased activity December 7, 1930, still suggests continued upward pressure of the lava without sufficient gas potential to make it break out with visible lava flowing. This is indicated by tilt eastward at the pit seismograph and northward at the Observatory instruments, both of these directions implying a tipping away from the volcanic center; also bluish sulphur fume continues to rise.

December 24 the fume had greatly diminished in quantity as seen at 9:15 a. m. when one looked down at the side of the new cone and the sulphur crack at the southeast edge of the new floor. The lava December 26 seemed to have settled and cracked a little at the aa area. The pit seismograph showed tilt away from the center. December 28 at 4 p. m. fresh red debris was conspicuous on the north and east taluses. The pit as seen from a distance showed faint blue fume rising, otherwise was clear. This was identified as coming actively from the base of the outer ridge around the new lava cone, from the southern end of the sulphur crack, and from whitish spots at the southwest. The lava lake area has slumped as much as would be expected from loss of gas in the underlying lava pool.

The seismographs have registered 42 tremors, two of them continuous for several minutes, and two accompanied by easterly tilt. One feeble earthquake was registered at 12:55 a. m. December 25. Tilt at the Observatory was moderate north and microseismic motion was slight.



The eruption of Calbuco January 6, 1929, looking east from Puerto Varas on the morning of the day described by Dr. Reichert. Puerto Varas is on the railway at the south end of Lake Llanquihue, and the pall of ash is here shown at the north in the direction of Lake Todos los Santos. Photo Karl.



The lines indicate approximate distances and in many cases not direct steamship routes, the heavier lines showing, however, the commoner sources of ocean traffic to Honolulu.

This map of the Pacific Ocean shows one radius leading to Petropaulovsk 2,780 nautical miles from Honolulu, and another to Valparaiso which is 600 miles north of Calbuco Volcano. Niuafoou, described in Volcano Letter No. 312, is midway between Suva and Pago Pago.

The Volcano Letter

Two dollars per year — Ten cents per copy

No. 315—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — January 8, 1931



The eruption in Halemaumau November 19, 1930, at about 5 p. m. The smaller fountains directly in front of the large talus in the center background, and the main fountain to the left, are pouring out lava which is rapidly spreading over the old floor formed in July, 1929. Photo Maehara.

LAVA IN HALEMAUMAU SINCE MAY, 1924

It may be of interest at this time to review briefly the stages of the volcanic activity of Halemaumau since the great explosive eruption and collapse of May, 1924.

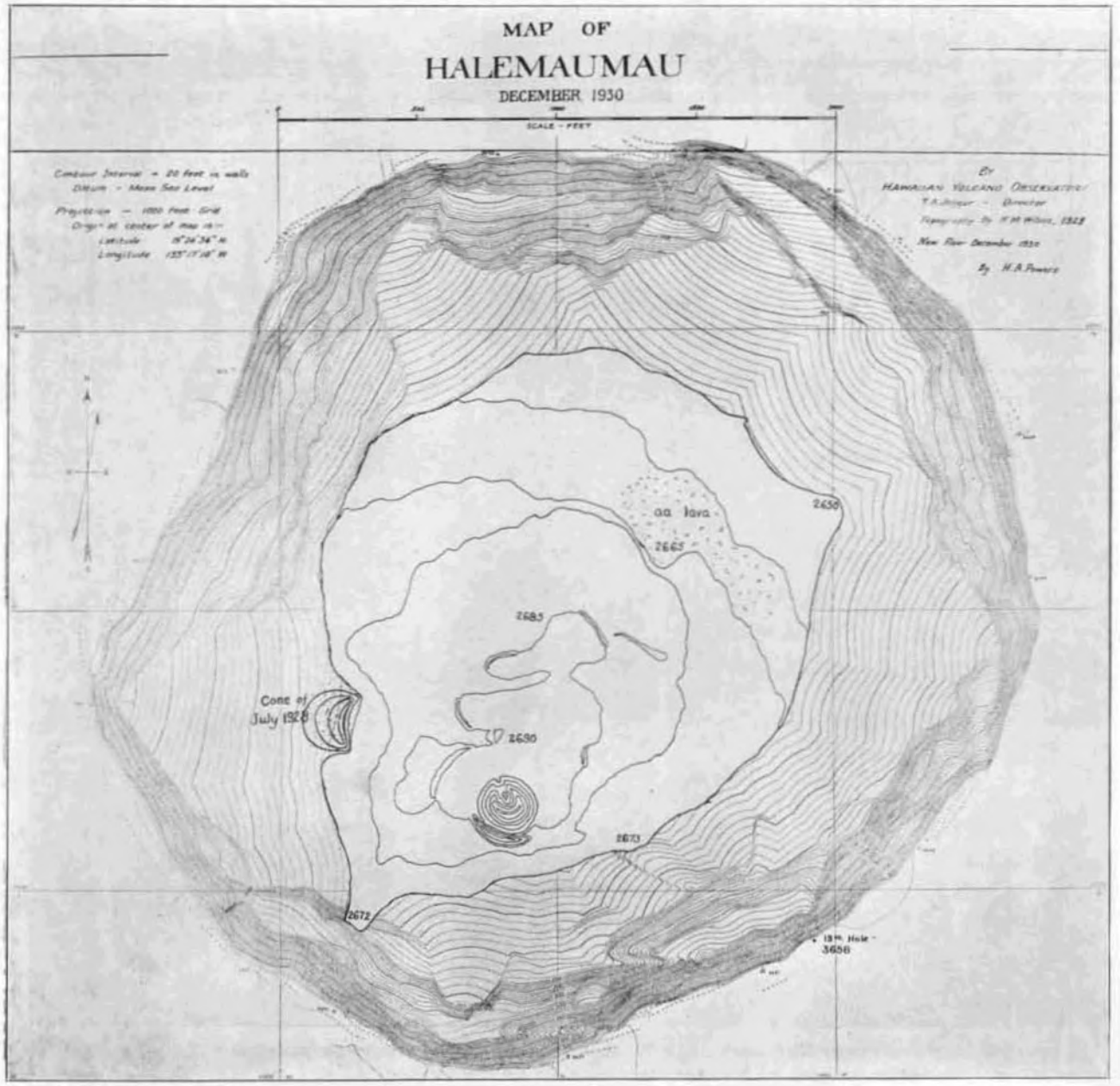
At the end of this explosive phase, no live lava was visible in the pit. Its appearance may be described by quoting from the Monthly Bulletin of the Hawaiian Volcano Observatory for July, 1924:

"The cauldron left by the May eruption was at the upper rim by measurements platted early in July, 3,400 feet long northeast-southwest by 3,000 feet wide. It remained an irregular oval with edges that had gone back about equally in all directions. The lowest part of the bottom flat was towards the north apporximately 1,335 feet below a datum station on the eastern rim. This bottom area was diamond-shaped and gravelly, of dimensions 1,000 by 700 feet. . . . . The site of the center of the new pit was indentical with the old Halemaumau, which had merely been enlarged and deepened."

Shortly after 1 o'clock on the afternoon of July 19, 1924, live lava appeared in the new pit, breaking out in a source fountain through the west talus at a point about 125 feet higher than the bottom of the pit. The lava flowed from the source fountain down the talus slope and then outward over the floor of the pit. This activity continued 10 days, until July 29. The new lava floor built by this eruption was 1,100 feet long by 800 feet wide. The center of the floor had piled up some 25 feet higher than the margins to a point 1,305 feet below the station on the east rim or about 2,390 feet above sea level. Thus the new lava floor was 35 feet thick in the center over the lowest point of the old rock floor.

Lava did not reappear in the pit until July 7, 1927, almost exactly three years later, but during all of this interval the pit was being enlarged by cracking and avalanching of the rim.

About 1 o'clock the morning of July 7, 1927, lava broke out in four fountains aligned along the edge of the 1924 lava floor at the base of the southwest talus. The southern-



Map of Halemaumau revised to show the shape and elevation of the 1930 lava floor.

most fountain broke through the talus above its base in the manner of the 1924 fountain. This eruption came to an end on July 19, after 12 days of moderate but continuous activity. The new floor formed by the lava which poured over the bottom of the pit was 1,700 feet long and about 1,400 feet wide at its greatest dimensions, with its long axis lying in a northeast-southwest direction. It covered a space of approximately 30 acres. An average elevation of the center of the floor was 2,515 feet above sea level. Thus somewhat over 100 feet of new lava had been deposited on top of the old floor by this eruption.

The last of the year (1927) was marked by a series of very heavy avalanches. After one enormous slide from the north wall of the pit, live lava oozed out from several cracks in the floor at the edge of the avalanche debris. No fountaining accompanied this gush of lava, and many other facts seemed to indicate that the activity was no more than a squeezing-up by pressure of remnant liquid lava from the July eruption. This gush of lava took place on January 11, 1928.

The collapse of the rim of the pit by avalanching continued with some violence during the early months of 1928. In the summer of 1928 a survey of the pit by Mr. Wilson showed that it had changed somewhat in shape since the summer of 1924. Quoting from the Volcano Letter No. 184: "In its (the pit's) present condition it is almost circular in shape, though the northeast-southwest diameter is slightly greater. Its diameters are 3,240 by 2,980 feet. The perimeter is 1.96 miles. The depth of the lowest part of the floor below the average rim elevation is 1,170 feet. The area of exposed lava floor and the cones with their spatter is now about 19 acres. The horizontally projected area of all the taluses is 87 acres, and the area of the horizontal projection of all the walls is 81 acres; the slope areas are of course much greater. This makes the total area of the pit 187 acres.

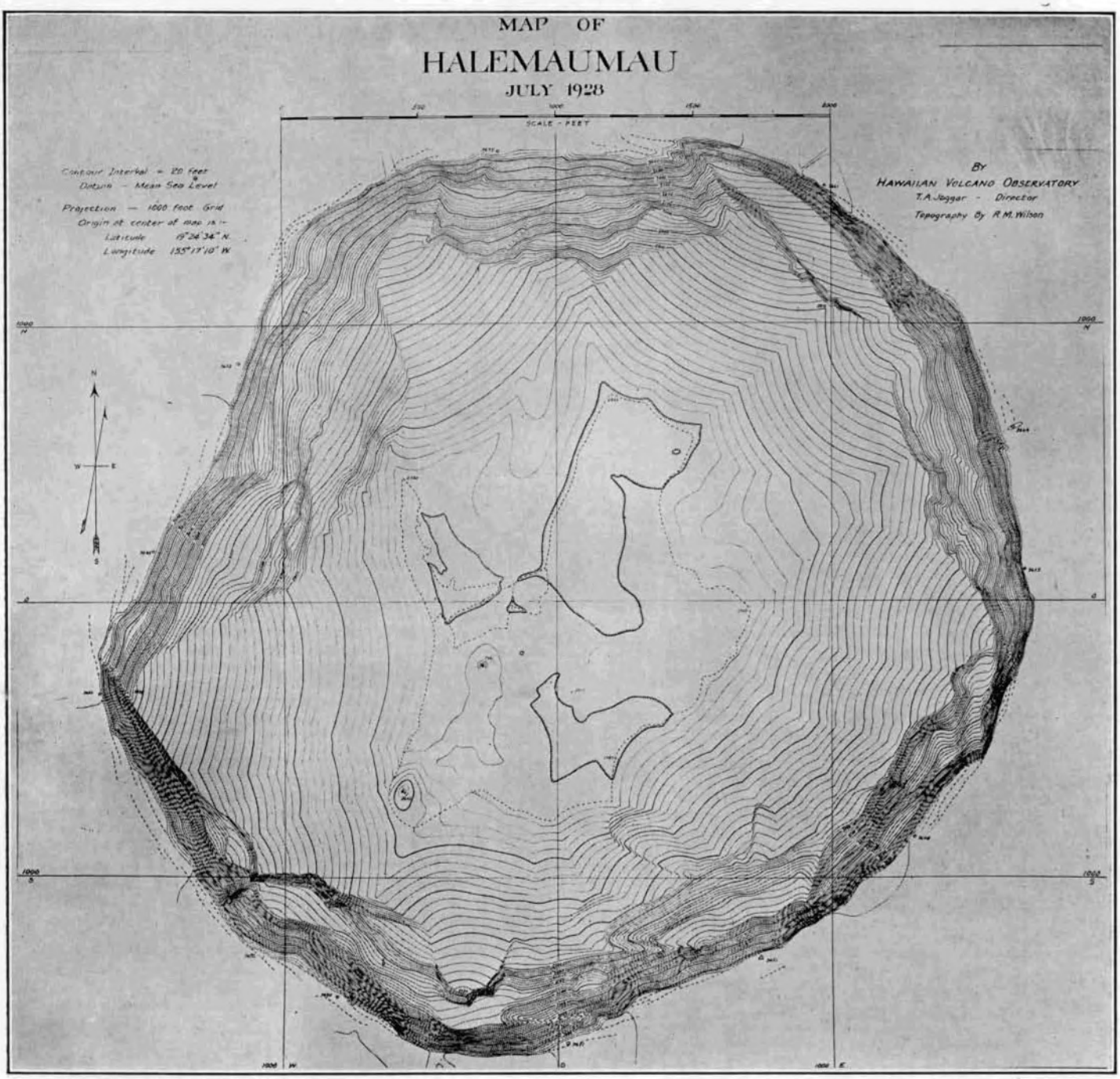
Lava reappeared in the pit at 12:45 a. m. February 20, 1929, and the fountaining occurred along a thousand-foot rift in the old floor trending N. 63° E. about 270 feet out from and parallel to the northwest edge of the floor. The activity continued until 1:15 p. m. February 21, about 36 hours. The new lava spread completely over the old floor and extended itself up on the bounding talus slopes.

At the end of the eruption the new lava fill had an average diameter of 1,600 feet and covered 40.5 acres. After solidification of the new fill, the surface averaged 45 feet above the average surface of 1927 lava.

After a much shorter period of repose. fountaining lava again appeared in the bottom of the pit about 6 a. m. July 25, 1929, the source fountains breaking through the southwest edge of the old floor near the big talus very close to the center of the 1927 fountaining area. Lava flowed from the source fountains until 7:42 p. m. July 28. During the first 24 hours the lava rose 44 feet above the level of the old floor. At the end of 48 hours, the depth had increased to 77 feet, and on the morning of the fourth day. July 28, the pit had been filled 88 feet. The maximum elevation of the surface of new lava was reached at the end of 85 hours activity, 94 feet above the old floor and 2,640 feet above sea level. Withdrawal of some molten lava, and shrinkage due to crystallization. caused some collapse of the surface of the new lava after the eruption stopped. The final cooled fill of new lava had a surface area of 55 acres and an average depth of 55 feet. The average elevation of its surface was 2,600 feet above sea level.

The recent activity, November 19 to December 7, 1930, has been the longest of this series of intermittent eruptions, and it has also brought a much greater amount of lava into the bottom of the pit. The new floor formed during this activity covers 62 acres and has an average depth of about 70 feet. It was estimated that somewhat over 15.000,000 tons or about 229,000,000 cubic feet of new lava is contained in this fill. The surface of the new fill varies from 2,650 to 2,690 feet above sea level.

In the six years from 1924 to 1930 the dimensions of the flat bottom of the pit have been increased from 1,000



Map of Halemaumau as drawn in 1928, showing the elevation s and shape of the floor of lava formed by the 1927 eruption.



New National Park Service lookout house on Mount Harkness, California. The Lassen Volcano Observatory has installed a two-component seismograph in the basement of this building. (See Volcano Letter No. 305, October 30, 1930.) Photo Finch

by 700 feet to 2,200 by 1,700 feet by the rise of the level of the lava fill. The elevation of the lowest point of the bottom has changed from 2,360 to 2,650 feet above sea level, giving a lava fill of 290 feet. Thus a total volume of over 463,000,000 cubic feet of lava has been poured into Halemaumau by the five eruptions which have a combined duration of 46 days of activity. In a circular pit 1,000 feet in diameter, about the size of Halemaumau before 1920, this volume of lava would make a column about 600 feet deep. H.A.P.

KILAUEA REPORT No. 989

WEEK ENDING JANUARY 4, 1931

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

The strong trade winds blowing across the dry crater and the edge of the Kau Desert during the first three days of the week whipped up huge clouds of dust which gave a fair imitation of the dust clouds from Halemaumau during the explosive eruptions of May, 1924. Then during the latter part of the week, beautiful cumulus clouds formed above the pit at night which lacked only the glow on their under side to duplicate the steam cloud of the recent eruption. Within the pit the emission of blue fume from the fountain site has ceased entirely, and but a small amount of steam is now being given off from the cracks in the new lava floor. Steaming was fairly strong from the south talus and the big southwest talus during the later part of the week.

One feeble quake was recorded on the Observatory seismographs at 4:01 p. m. December 30 which had a distance to its origin of 9 miles; and one very feeble shock was registered on January 4 at 9:33 p. m. On January 1 the seismograph was disturbed at 11:39 p. m. by the preliminary wave from a distant earthquake, and the stronger shock waves from this quake kept the pens in motion for 55 minutes. The Observatory instruments recorded 56 small tremors of probable volcanic origin during the week. The non-volcanic microseismic motion was moderate during the first three days, then dwindled to slight intensity for the last four days.

The average of the tilt record for the week shows a very slight inclination to the west since last week. This average gain was made up of several slight tiltings in various directions, showing that no single strong factor is controlling the tilt at the present time. There still has been no sign of a notable decrease in the pressure under Kilauea since the end of the last eruption which would have been indicated by a notable tilting of the ground in toward the pit.

THE VOLCANO LETTER

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The Volcano Letter

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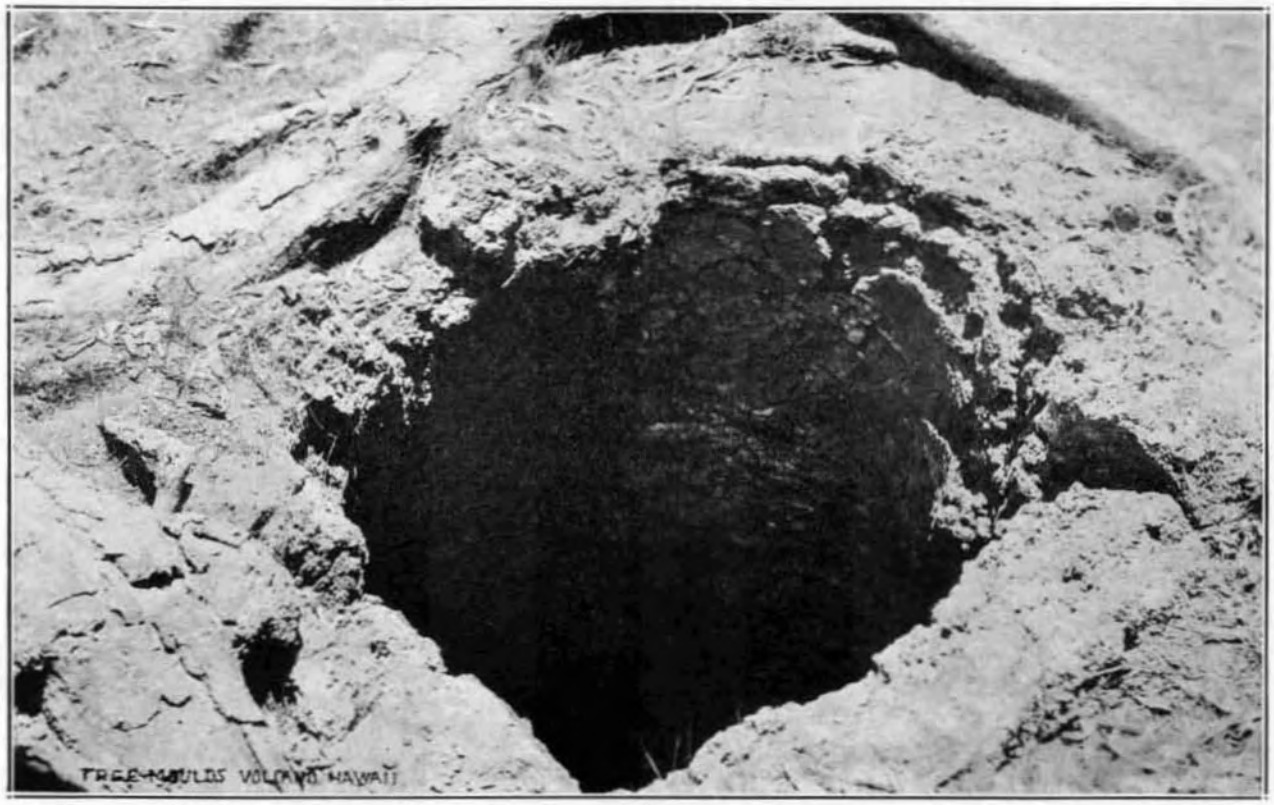
No. 316—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — January 15, 1931



Lava tree with wooden trunk still standing in it, formed by flow enwrapping the base of tree from left to right and then lowering. 1923 flow from Kilauea, Chain of Craters Road. Photo Boles.

LAVA TREE CASTS AND TREE MOLDS

Lava trees, Figure 1, and tree molds, Figure 2, are very much the same thing, but the one stands in relief, while the other is left a hole in the ground. To understand these tree molds we must remember that lava is very stiff and plastic when it is flowing, like molasses candy, and that contact with any cool substance like wood may, it is true, set fire to the substance, but none the less the lava will instantly congeal. It is really a glass, and molten glass solidifies very quickly. When the wood which is surrounded by lava flames up and burns away, the glass mold may retain very perfectly the pattern of the bark (see Volcano Letter No. 212, Page Three). Both lava trees and tree-molds contain cavities where the wood has burned out. There is a possible third type which would be formed where fresh lava filled up one of these cavities and made a true cast or stone tree by utilizing the natural mold created by the earlier lava flow. A fourth type was described by Mr. Bartrum in Monthly Bulletin of the Hawaiian Volcano Observatory for July, 1925. Here in the North Auckland district of New Zealand a carbonized tree trunk had been trapped by very liquid lava. by shrinkage radial cracks had developed the ring structure and radiation



Tree cast making a well three feet across, with bark pattern molded on the walls. Roots of a modern tree shown above. Here the lava surrounded a tree that burned out. Golf links at Kilauea Volcano. Photo Kanemori.

structure of the wood, the molten glass had penetrated these cracks forming lamellae of finely vesicular basalt in a sort of honeycomb preserving the texture of the original tree. Some of the partitions are no thicker than a sheet of paper.

Both lava trees and tree-mold wells are formed when a fluid lava flow invades a tree-covered area. The lava is chilled upon surrounding a tree and solidifies. If the flow is one of great fluidity, the level of the lava surface is apt to lower greatly after the source of supply has given out. This is because the flowing does not cease, out from under the high crust first attained. Consequently this flood level of the lava in the forest leaves its mark on all the trees, and its mark is nothing less than a casing or shell around each trunk. The original crust over the flow as a whole sinks much lower than the level where it stood when the hot lava was impeded by the forest. The outer edges of the flow during the closing stages sent out tongues which drained away the under substance. Hence the casts of trees, or better the frozen shell of lava around trees, remain to mark the original height of the flow.

Figure 3 shows the southern edge of the floor of Kilauea Crater in March, 1921, where the level of the lava was adjusted after the source fountain ceased action. No trees were present, but the lava plaster on the cliff marks the height of the flood when the fill was made. The cliff is composed of old horizontally bedded ash layers. At the foot is seen the downward broken or slumped field of lava, robbed of its under substance by outflow from under the crust.

If a flow is not so fluid and there is no way for the lava to escape around the edges, the surface does not lower so much after activity at the source has ceased, and instead of a plastered rock tree above the surface, there may be left merely a well or hole in the rock, molding the tree that has burned or rotted away after being surrounded by the melt. Figure 1 shows the wooden bole of the tree still standing in the embrace of the plastered layers of lava which are wrapped around its base.

Occasionally tall lava trees are found on hillsides for which fantastic explanations have been offered. It must be remembered that a grove of trees is a substantial and resistant object in a landscape. A lava flow is a sluggish mass of porridge which will pile up against such an obstruction. This is illustrated by Figure 4 where the obstruction was a cone on the southwest slope of Kilauea. The flow of 1823 plastered the slope of the cone to a considerable height as the flood divided around it. The cone is about 30 feet high and if trees had existed at its base so as to be trapped in the lava, these might have been molded and stand as monoliths today of considerable elevation, while but a few feet away other trees might have escaped uninjured.

Tree casts and molds are found in many places. In the Craters of the Moon National Monument in Idaho there are excellent examples. In the "Burnt Lava Flow" south of Glass Mountain in northern California there are several tree casts. most of which were pushed over by later flows. These casts of woody matter by lava are not confined to recent volcanic activity. for they are found preserved in ancient volcanic strata.

The tree molds near the golf links at Kilauea Volcano are wells lined with a selvage of glassy lava which often preserves the pattern of the bark of the koa trees which were molded by an ancient Kilauea flow. These wells where the tree has burned out are from 6 inches to 6 feet in diameter and from 3 to 12 feet deep. The ground round about is covered with ash soil, and this somewhat obscures the real significance of these molds. This ash was the fallen volcanic dust of the explosive eruption of Kilauea in 1790. Where the original lava shells around the trees stood slightly in relief in these places. the ash drifted over the country in sufficient volume to fill up the ground around the tree casts, but not sufficient to fill up the holes themselves. Therefore the shells do not appear to stand up, but are preserved merely as pits in the ground modelled after the original single, double, or triple trees whose roots were far below where the tourist stands today. On the nearby slopes of Mauna Loa there are some of these tree molds shaped like a trough, where the lava trapped a fallen or recumbent tree, and the divergent roots at the end are now marked by divergent tubes where the roots were modelled in stone and then burned away to ashes.

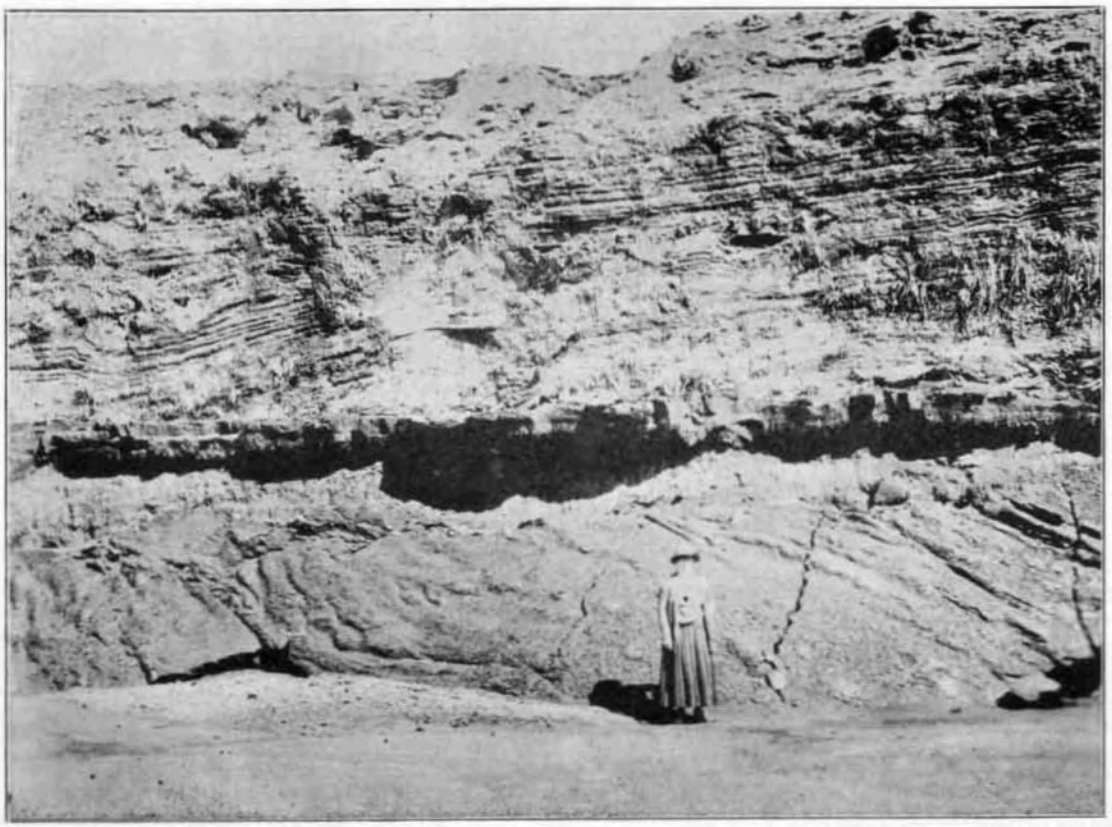
R.H.F.

TILTING OF THE GROUND FOR DECEMBER

The tilting movement of the ground under the Hawaiian Volcano Observatory during the month of December, 1930, and following the eruption of lava in the bottom of Halemaumau pit beginning November 19 and ending December 7, has amounted to more than 5 seconds of arc in a northeasterly direction. This is a tilt away from the pit and it will be seen that it increased during the eruption and increased greatly the second week after the eruption. While still being northerly the tilt had a westward trend during the last week of December. The suggestion is strong that the upward pressure of the lava continued after the visible outflow ceased. There has been nothing around Halemaumau as yet to indicate that the lava column is lowering.

The following figures show the net amount of tilt on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms, by platting a curve smoothed by overlapping progressive seven-day averages.

November 24-30	1.2 seconds	NNE
December 1-7	1.8 seconds	NNE
December 8-14	0.2 second	NNE
December 15-21	2.5 seconds	NE
December 22-28	1.2 seconds	WNW



Lava bench at base of ash cliff, south bay of Kilauea Crater. The 1921 flow slumped after rising to the level of this bench, as the feeding source had become inactive. Photo Finch.



Lava plastered cone where the 1823 Keaiwa flow from Kilauea piled up on the hillside and then lowered. Photo Emerson.

KILAUEA REPORT No. 990

WEEK ENDING JANUARY 11, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar. Volcanologist in Charge

There have been no changes at Halemaumau during the week. Steam is as usual at the vapor vents. No renewal of fume has occurred.

The instruments at the Observatory recorded a total of 28 seismic disturbances. Of these 25 were tremors and 3 were very feeble local earthquakes, all unfelt. One shock occurred at 6:27 p. m. January 6 with indicated distance 18 miles; another was at 7:38 p. m. January 7, indicated distance 37 miles.

Tilt for the week accumulated moderately strong SSW, a change from the prevailing northerly direction during previous weeks. Microseismic motion was stronger than normal, probably due to high winds at the end of the week.

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HAWAIIAN VOLCANO OBSERVATORY

Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Lorrin A. Thurston, President; Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

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The Volcano Letter

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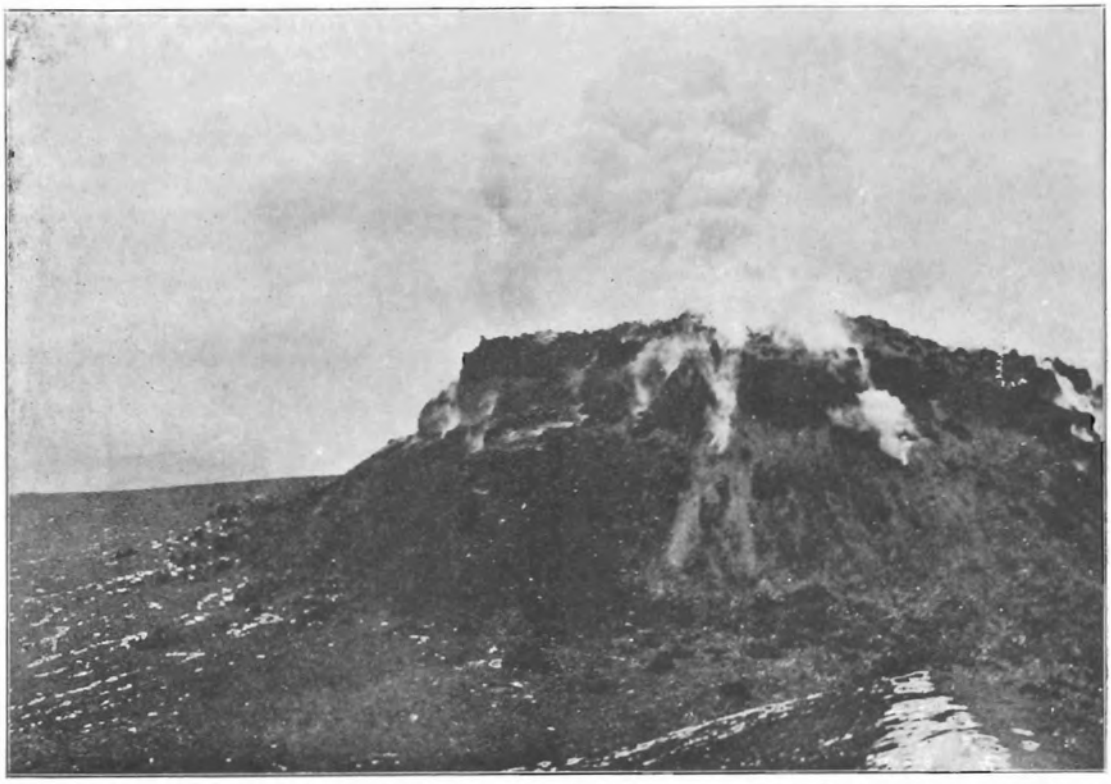
No. 317—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — January 22, 1931



Lava dome of Tarumai Volcano in Hokkaido, the north island of Japan, two hours after the eruption of October 30, 1926. The dome was formed in 1909, but was rent asunder by a new gas eruption in 1926. Photo K. Shibahara.

THE LAVA DOME ERUPTION OF TARUMAI

In Volcano Letter No. 276 an airplane photograph of 1926 was shown exhibiting a new gas outbreak through the crater dome of Tarumai Volcano in Hokkaido, the north island of Japan. Tarumai is 3,300 feet high amid the forests and lakes of the "Canadian" wilderness of Japan. The map on Page Three shows the four islands of Japan and the black lines represent the arcuate rifts in the crust of the earth along which are grouped the belts of active volcanoes. The southwestern curved line follows the arc of the Riu Kiu islands, which passes through Sakurajima Volcano in the southernmost bay of Kiushu (Volcano Letter No. 308). This ends with subordinate offshoots in the west end of Japan proper, and then comes the arc of that island, with eastern and western belts of volcanoes at the north. These belts converge at Yakedake Volcano (Y in cut), and there meet the great arc extending to the south which passes through Asama Volcano in central Japan. (Volcano Letter No. 297) Fujiyama, (F in cut), Oshima in Sagami Bay southwest of Tokyo (T in cut, see Volcano Letter No. 299), and the Ogasawara volcano islands and the Bonin group far to the south in the direction of Guam. Another bend starts a new arc in western Hokkaido and this extends outside of the map to the northeast along the line of the Kurile island volcanoes which lead in turn to a new arc in Kamchatka. Tarumai is at the southwestern end of the black line marking the Kurile arc, and not far east from Usu Volcano, described in Volcano Letters 298 and 302. (See Simotomai, Zeitchr. fur Erdkunde zu Berlin, No. 9, 1912).

The eruption which lifted the crater floor of Tarumai and converted it into a lava dome occurred in the spring of 1909, and the writer was privileged to make the ascent of the mountain and study the dome while it was still hot and steaming on May 9 of that year. He carried with him a Bristol pyrometer for measuring high temperatures in the cracks of the lava dome. He was accompanied by Professors Oinoue, Sato, and H. Tanakadate, who furnished valuable photographs and information. He stayed at the sawmill and match factory in the forest at the base of the mountain, operated by Mr. Haruta, who had watched the activity from its beginning.

We arrived by rail May 8th at Nishitap near the south shore of Hokkaido, and walked two miles across open flats to the mill which is on a brawling trout stream. The valley is enclosed by a marked marine terrace at least 200 feet above sea level. In the afternoon the clouds rose and showed the east rampart of Tarumai to be saddle-shaped, with pure white steam clouds rising behind it. The mill is 7 miles from the crater, and its function is to make thin strips of pine for match boxes.

At 6:30 a. m. we started on foot through the woods for the mountain, and after leaving the forest crossed several step-like ridges at the base of the outer cone, these being followed by a 35° slope of pumice and cinder which made laborious climbing. Arrived at the high rim of the outer crater we were surrounded by clouds, but saw a great fallen block of andesite in the inner crater. In the afternoon the summit cleared and the huge lava dome was revealed 1500 by 1800 feet in diameters and 600 feet high above its visible base. There was an inner crater pit 2200 by 1300 feet in diameters, and the dome of the new lava was west of the center of this inner crater with its talus overlapping the crater edge on the southwest. The whole surface of the dome was pinnacled with many small pillars rising all over it. These dimensions were from a survey by Oinoue of April 23 and there had been some changes during the fortnight succeeding. The picture on Page One shows the general aspect of the dome, but with much more talus than was present at first. The writer had studied the dome of Bogoslof in 1907, and was impressed by the greater height and steepness of the Tarumai dome, and the protruding crags of hot lava.

At the north where the lava dome was rounded and did not overlap the rim of the inner crater, no falling of rocks was observed, but at the south the dome was very steep and overlapped the rim, there were great fallen blocks at its base, and Dr. Oinoue reported he had seen a block 30 feet in diameter come down. Several rocks were heard falling. At a sulphur patch amid the cracked andesite of the dome, a maximum temperature of 457° C. was measured, while the steam temperature gave 430° when the terminal did not touch the rock.

The history of the eruption was as follows: On the night of January 11, 1909, a column of fire rose over the crater, in the night of January 22 ash fell on the snow at the mill, in the morning of February 6 there was an ash fall and smoke was visible over the mountain, and at 3 p. m. February 10 sounds were heard twice, much steam arose, and ash fell. At 1 p. m. February 18 much steam was visible, and on March 3 rumbling noises were heard three times by the miller Haruta. In the morning of March 30th detonations began at 7:18 a. m., rumbling continued for an hour, stones fell the size of peas, and the smoke from the crater rose in a very slender whitish column which later became darker. After an hour the activity diminished, and in the afternoon the eruption ceased.

April 12 at 11:40 p. m. came loud rumbling and lightnings, at a place two and a half miles from the crater stones fell 5 to 7 inches in diameter, and an earthquake occurred lasting two minutes. April 15 and 17 the column of brown smoke was seen at Sapporo in central Hokkaido. Close at hand strong rumblings, smoke, and glow were perceived, and April 18 with southerly wind the ash fell to leeward 25 to 30 miles away. The cauliflower clouds rising above the mountain assumed wonderful spiral form. There was no life lost in the eruption. The glow increased and the explosive activity dwindled to steam jets April 22.

April 23 Oinoue climbed the mountain, found the steaming dome, and made photographs and sketches. The dome had first been noticed by a fisherman on Lake Shikots on April 20 and had developed at some time after the explosions of April 12 and 17. On April 4 the inner crater pit had been 200 feet deep, floored with gravel, the floor sloping gently toward the north, and steaming chiefly around the west and southwest borders. The pit had shown lava sheets in its wall. There was a small depression in the northern part of the bottom. The lava dome had come up through this bottom. Mr. Oinoue observed glow in the crevices of the dome. Several cracks were found in the rim of the inner crater near the edge of the dome. Rocks were constantly falling off the western side from the many pinnacles of this rude aa of andesite lava, of which the dome was formed. When a huge block fell away from the upper part of the dome a glowing spot was left where it broke off.

On May 1 a sketch from the western mountain showed increased talus all around the dome, except on the northeast side where the jagged rock ledge extended all the way to the base. The profile had become flatter on top, but still showed pinnacles, and an inner comb or fin rose slightly above the flat top. There were many immense fallen blocks, but the slides of rock matter were small and few.

When I saw the dome on May 9 the sulphur-coated blocks of rock near the level of the edge of the crater on the south side of the dome averaged 2 to 3 feet in diameter and the odor was of sulphur dioxide. Quiet steam was rising. There was an area of sulphur stains 30 feet across. The wind was from the south, and a faint crackling was audible in the hot rocks.

The following notes on temperature of crevices in the dome, made with the thermo-couple, indicate the heat at this time:

(1) The base-metal couple was inserted without touching the rock one foot into a cavity nine inches in diameter full of rising steam. The terminal was at least three inches from the rock in four directions. Temperature 430° C.

(2) A narrow steaming fissure was measured, the terminals touching the rock, and inserted 24 inches from the outer surface. Temperature 450° C.

(3) A big wedge-shaped cavity was measured, under a large bowlder, with a very large opening on the outside. Temperature 390° C.

(4) A small cavity, lower down the slope under No. 2 above, received the terminals 12 inches inside laid against the rock. Temperature 457° C.

(5) A small cavity 6 inches across the mouth, admitted the terminal for a distance of 4 feet. Temperature 398° C.

(6) A small area of secondary solfataric action, stained rocks across an area 7 feet in diameter, a 2-inch fissure among the fragments, the terminal inserted one foot. Temperature 200° C.

This volcano is famous for the large amount of pumice which it has ejected. It has an outer ring wall like Somma at Vesuvius. There was a faintly defined inner cone surrounding the inner pit. In July of 1739 the mountain rumbled and emitted fire, volcanic ash fell heavily during two or three days and nights, all this being preceded by a

shock of earthquake. In 1804-17 there was a great eruption of fire, sand, and ash, many lives were lost and some people were wounded, and the emission of smoke continued for 40 years. (This record is somewhat doubted.) December 25, 1871, Tarumai vomited sand and ash for three days and two nights; this destroyed a small cone on top, left a cavity 100 meters deep with a small pond in the bottom, and changed the summit in other respects. February 8, 1874, there was another eruption lasting three days with a revival February 16. Ash fell in Sapporo November 5, 1883, from another eruption, and there were two other outbreaks during that decade. There was unusual black smoke August 17, 1894, and thereafter there was always steam at the crater until the big eruption of 1909. T.A.J.

KILAUEA REPORT No. 991

WEEK ENDING JANUARY 18, 1931

Section of Volcanology, U. S. Geological Survey

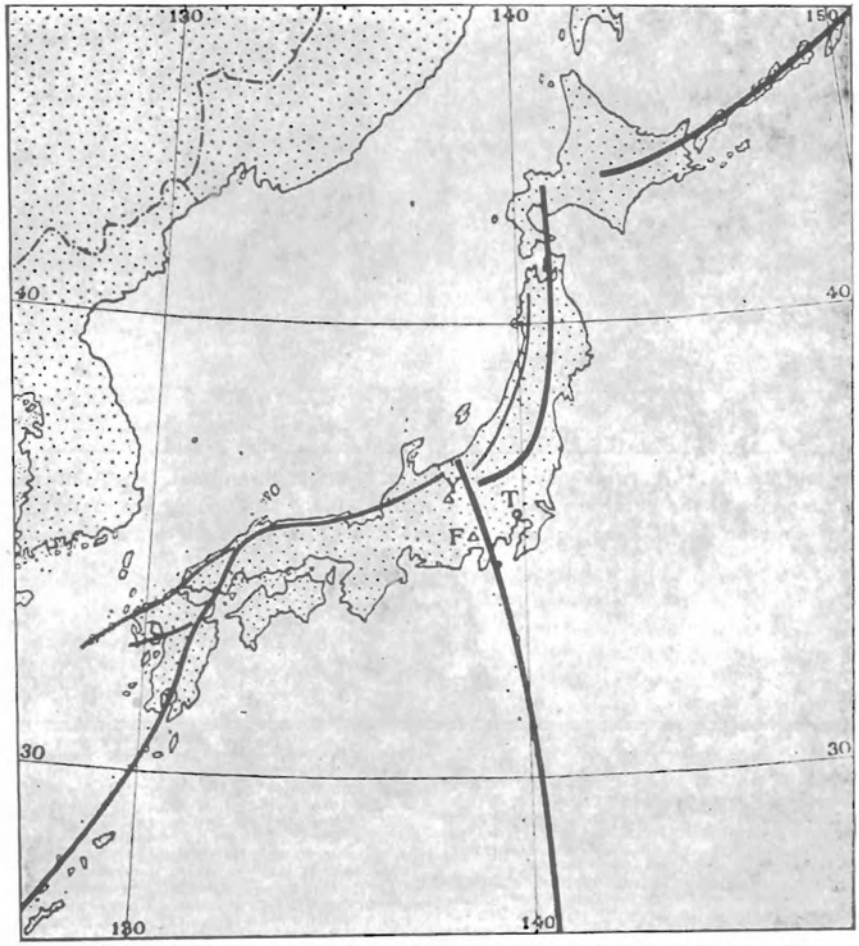
T. A. Jaggar, Volcanologist in Charge

Few notable changes have occurred at Halemaumau during the week. Fume remains absent at the 1930 vents. There are many scattered sulphur areas with whitish coatings, but the main area southeast is bright yellow. On the 14th steam was strong on the south talus.

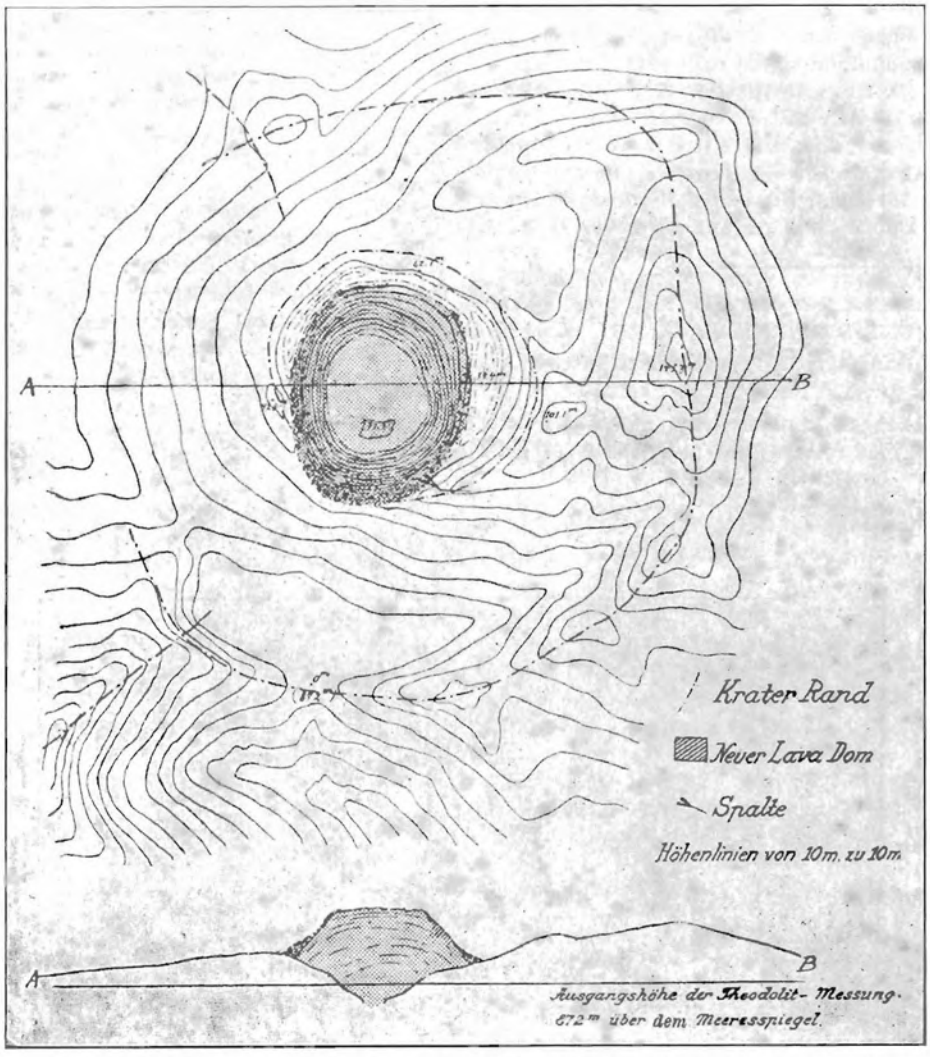
Thick dust clouds over the region southwest of the fire pit, caused by extremely high trade gales, gave rise to rumor of an eruption January 12.

The seismographs registered 29 local tremors and earthquakes and 2 teleseisms during the seven-day period ending at midnight January 18. Two of the first group had indicated distance to origin 18 miles, and another (3:03 a. m. January 12) was reported felt in Hilo. A local earthquake at 8:44 p. m. the 16th originated 30 miles from the Observatory, apparently under the center of the island. It was felt generally, and was more perceptible in Hilo and Hamakua districts than elsewhere. The first of the two teleseisms registered 3:31 p. m. to 4:04 p. m. the 14th; its indicated distance was about 6,000 km. ESE (Oaxaca, Mexico). The second recorded feebly 4:40 p. m. the 16th, duration 21 minutes.

The direction of tilt again changed, accumulating slight NNE. Microseisms were moderate at the beginning of the week, decreasing to slight.



Map of Riu Kiu, Japan, Bonin, and Kurile arcs and their volcanic rifts.
T=Tokyo, F=Fujiyama, Y=Yakedake. After Omori.



Map and profile of Tarumai lava dome of 1909, after Simotomai (H. Tanakadate). The diameter of the outer crater is more than a mile. The figures are meters above the contour line 872 m. Contour interval 10m. The new lava dome is shaded

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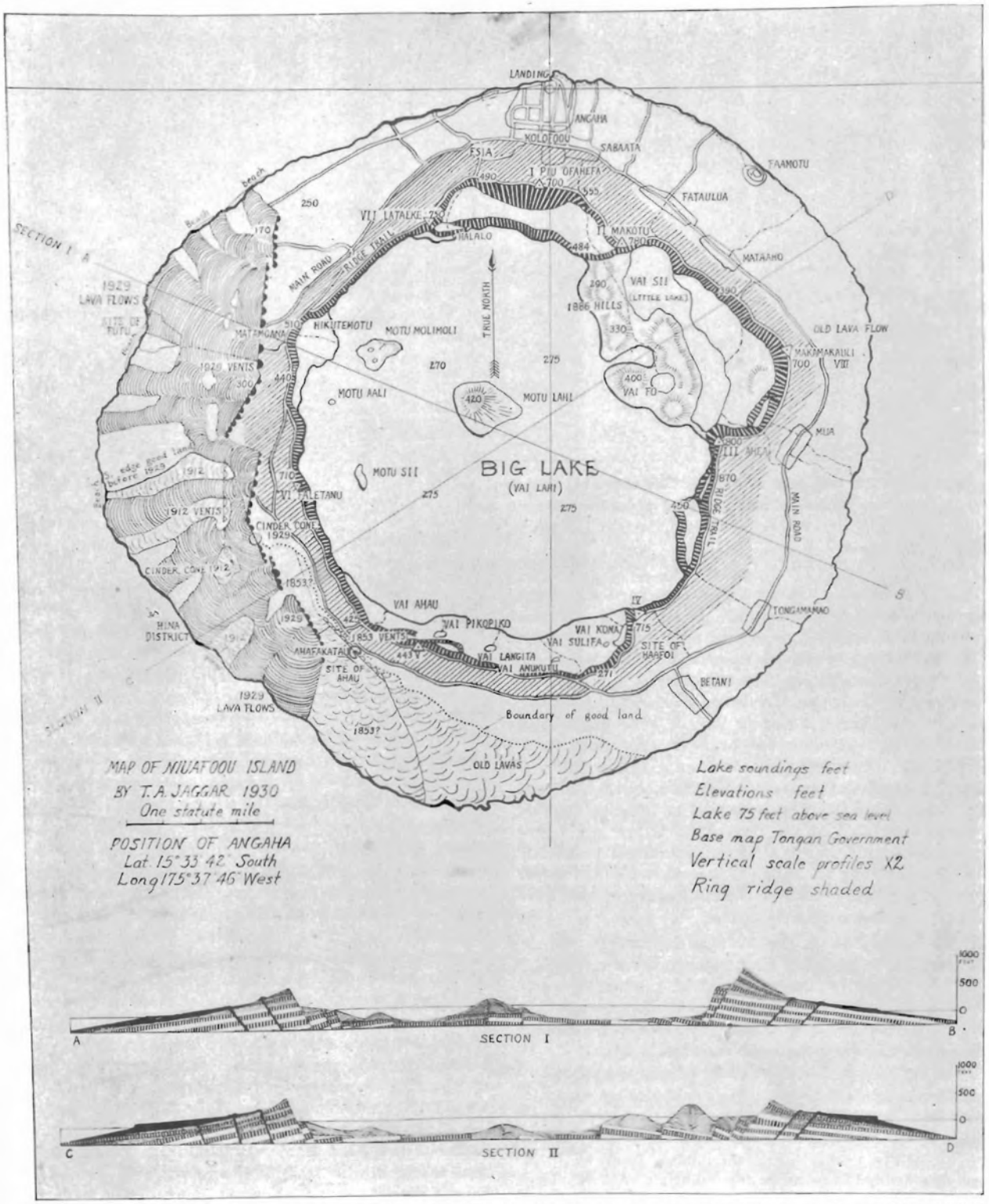
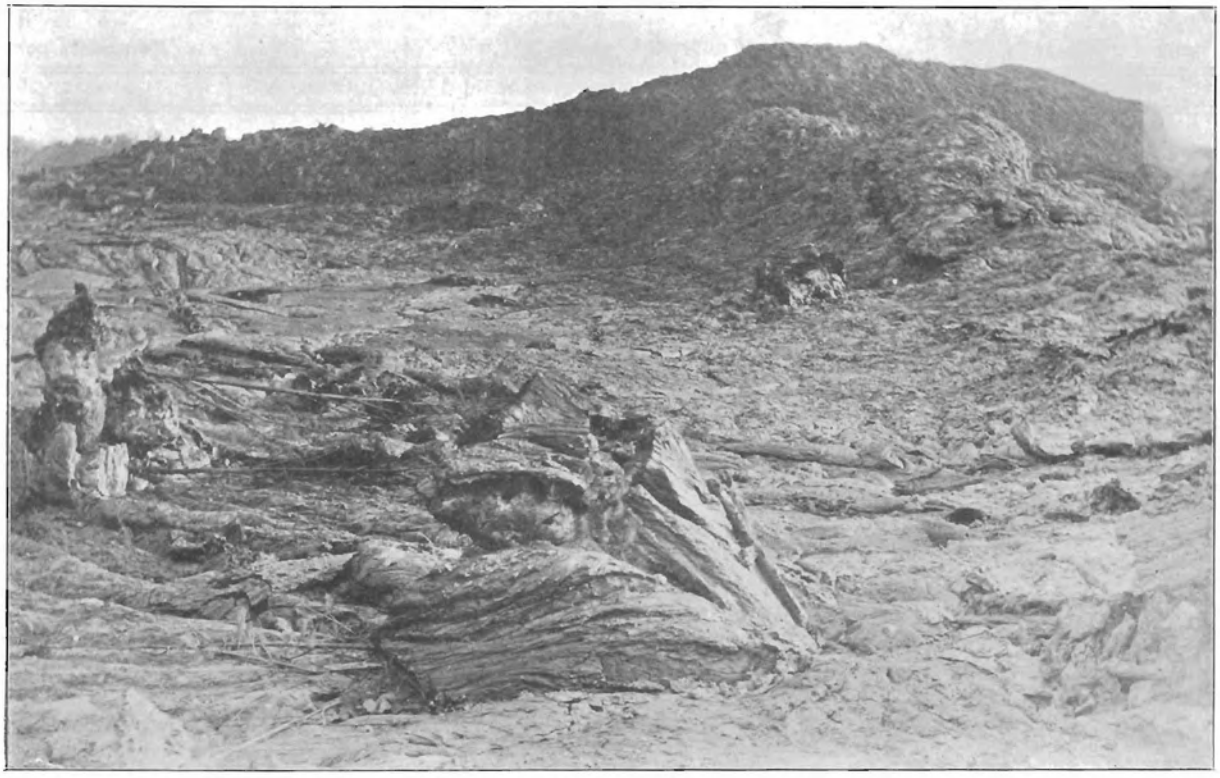
No. 318—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — January 29, 1931



Volcanologic map of Niuafoou Volcano, a ring island in the Pacific Ocean visited by the U. S. Naval Observatory Eclipse Expedition in 1930. Shows profile structure sections, the positions of the villages, roads and trails, and the lake soundings and land elevations in feet. Survey by T. A. Jaggar.



Pahoehoe lava and spatter ridge, with some coconut tree molds of 1912, photographed in 1913 when the lava was fresh. Compare 1929 eruption Volcano Letter No. 312. Photo from Captain Crawford.

GEOLOGY AND GEOGRAPHY OF NIUAFOOU VOCANO

The accompanying map and profiles were made by the writer on the basis of a recent outline map of the Tongan government and serve to show the perfect ring shape of the island Niuafoou, which as described in previous numbers of the Volcano Letter (265 and 312) is a prosperous copra island in the triangular space of the South Pacific Ocean between Samoa, Fiji, and Vavau. The big lake in Niuafoou is a crater sink fed by rain water and made somewhat brackish by hot volcanic gas springs, by evaporation, and probably by more or less connection with sea water. The lake is 275 feet deep and stands only 75 feet above sea level, so that 200 feet of its waters are below the ocean level, and that in a porous basaltic dome greatly cracked. As there is no drainage, and salt water is heavier than rain water, the bottom of the lake might be salt without that fact showing on the surface.

It will be seen by the profiles that the structure of the fisland, here shown with the slopes and dips exaggerated to double their normal inclination, and the heights to double the true elevation with reference to the horizontal scale, is that of a very flat lava dome. The island is entirely basaltic and the submarine slope seaward is from 4° to 7°. The cross sections of the inner cliffs around the lake show very massive columnar sheets of basalt at the bottom of deep sections 600 feet thick. The upper ring ridge shows mixed eruption with alternations of about 20 feet of ash and agglomerate representing one phase, followed by 20 feet of thin-bedded lava flows representing another phase. These upper beds have dips of from 13° to 18°, whereas the lava layers seen in the sea cliffs of the border platform dip radially away from the center at from 4° to 8°.

This implies that the lower dome of Niuafoou was built up of heavy sheets of liquid basalt, and that the development of explosive eruption was a later feature recorded chiefly in the upper layers. The angle between outer platform and ring ridge is accented by the modern flows of lava which have come up concentric fractures as shown in the profile, but this angle is also produced structurally by the presence of the steeper mixed cone of the ring ridge resting on an older dome pediment of lava, like the present Vesuvian cone. This angle is probably a belt of weakness concentric to the crater lake, as indicated by the western 1929 fractures shown on the map with lines of black half-domes along the rift fissures from which the flows poured to the sea.

In the ejecta of the two most modern eruptions of Niuafoou, those of 1912 and 1929, both of which emerged through what appear to be tension fractures of northerly trend on the southwest side of the island, pieces of coral were thrown up. This ejection was during a minor steam-blast phase at one locality ("cinder cone" on map), all the rest being pure lava flow. The coral fragments are mixed with dike rocks and lava clinker, at cinder cones containing unusually deep circular pits along the line of lava source vents, and at the 1929 locality three-quarters of a mile from the sea. Ash and sand accumulated to leeward. This ejection of coral fragments recalls Vesuvius, which flings up limestone, and the 1823 explosions along the lava rift near the sea at Kilauea. The coral at Niuafoou indicates that coral rock exists under the southwest slope of the island, though there is no coral reef around the island at the present day. Coral does not occur in the explosive fragments of the 1886 hills, produced by the big eruption of that year northeast of the lake. There may have been a fringing reef at some inactive stage when

the island was smaller. The elevations of the two vents where the coral fragments were found are approximately 150 and 200 feet above sea level.

The cross section of the island shows an outer lava slope all around, (black in the profiles) the ring ridge, the inner cliff, three platforms of explosive materials making islands and sandy hills at the lake level, and the lake bottom. The latter is probably floored with down-sunken blocks of the former cone, overlaid by explosive fragments and sand. This material is shown in heaps in the sections. The outer lava slope at the west and south is modern. It will be seen that each of the three inner lake shore lowlands, including the islands as attached to the northwestern one, is backed by a notching outward of the ring of cliffs. Each of these lowlands stands for an explosive eruption, the northwestern one prehistoric, the southern one probably 1814, and the northeastern one 1886. These steam blasts probably represented subsidences of the lava column at the end of a cycle of upward pressure and outflow. Ground water entered the void, the retreat of the lava into the depths being along the wall-crack of the more or less circular plug under the lake, steam blast shot up and loosened fault blocks, and the sinking of these notched the ring of cliffs outward. The biggest notch is that back of the 1886 hills.

The modern lava flows of the last century started at the south and extended the process of opening fissures northward up the west side of the island. The mechanism of breakage of the cone appears to be by lava flows outside the ring ridge and engulfment eruptions of steam inside of it. There are no fresh lava flows on the lake side of the ring ridge. There are only minor evidences, as cited above, of steam-blast cinder cones on the ocean side of the ring ridge. The cycle at Kilauea appears to involve shorter pulsations of lava flow at 11-year intervals, and a longer cycle of six or twelve of these (66 or 132 years). This longer cycle may culminate in explosion, which means lava subsidence. Something of the same sort exists at Niuafoou.

Summarizing the list of eruptions of Niuafoou we find known outbreaks in 1814 (steam blast), 1853 and 1867 (lava flows), 1886-87 (steam blast), 1912 and 1929 (lava flows). Apparently the 1814 eruption was a steam-blast phenomenon, and it seems likely that its center was at Vai Kona, on the south side of the lake, for there are still warm gases there smelling of hydrogen sulphide, depositing alum, and bubbling up through lagoon waters. Like the Kilauea eruptions of 1790 and 1924, the years 1814 and 1886 may mark the opposite ends of one supercycle, in which case the next explosive eruption for Niuafoou might be expected 72 years after 1886, or about 1958.

It will be seen that the doubt about lava flows on Niuafoou (Thomson, N. Z. Jour. Sci. Tech. 1926, p. 369) is definitely dismissed. The modern lava flows of 1853 and 1867 were at the south (see map), 1912 farther north, and 1929 much farther north. Naturally the clustered settlement at Angaha is anxious about the next eruption, which is likely to extend the concentric fractures around the northwest side of the island in the direction of the villages. The explosive eruption of 1886 notched the rim of the big crater outward where that rim was highest, and therefore heaviest (over 800 feet above sea level). It followed lava flows of the 19th century on exactly the opposite side of the island. If this mechanism maintains a balance of concentric breakage about a cone, it is logical for the explosive eruption about 1958 to follow after flank outflows on the opposite side of the volcano. The highest and heaviest rim of the caldera next to be expected to subside in a steam-blast eruption is southeast (870 feet high). The flank outflows then to be expected between now and 1958 will be at the northwest. As the maximum lava gushing of 1929 was west-northwest, and the trend of a century appears to be extension of cracks northward, there appears to be every reason to expect the next lava eruption to invade the lands west of Angaha.

Sapper (Vulkankunde, p. 336) cites a doubtful date 1840 for a Niuafoou eruption. Supposing this to have been a lava flow, there were six volcanic events in the 115 years following 1814, with intervals respectively:

After 1814 explosive eruption: 26, 13, 14, 19, years
After 1886 explosive eruption: 26, 17, ? ? years

It thus appears that an extra long interval may follow an explosive eruption, and this is true of other volcanoes. The average interval otherwise for Niuafoou by this table is 16 years. This would place the next probable lava flow following 1929 about the year 1945. If the eruption is normal it will fracture open a fissure about a mile long, and if it should start at the big steam vent back of Futu, and spread a mile to the northeast, it would do no damage to Esia, nor to Angaha, but it would be much too close for safety. The next eruption after that is likely to be ejection of steam and ash about 1958, possibly at the Ahea ridge, with damage like that of 1886. The records are very imperfect and it should be understood that there is a range of from three to five years on each side of the year mentioned for the expectancy based on statistics.

These forecasts are not accurate, for our knowledge of the 19th century is very imperfect. They are merely suggestive experiments in volcanologic reasoning, based on such imperfect data as those figures by which the 1924 explosive eruption of Kilauea was forecast on historical data in 1918, with an error of four years (Bull. Hawn. Volc. Obsy., Jan. 1918, p. 17). They may rightly be used by those governing Niuafoou as stating facts based on past statistics. T.A.J.

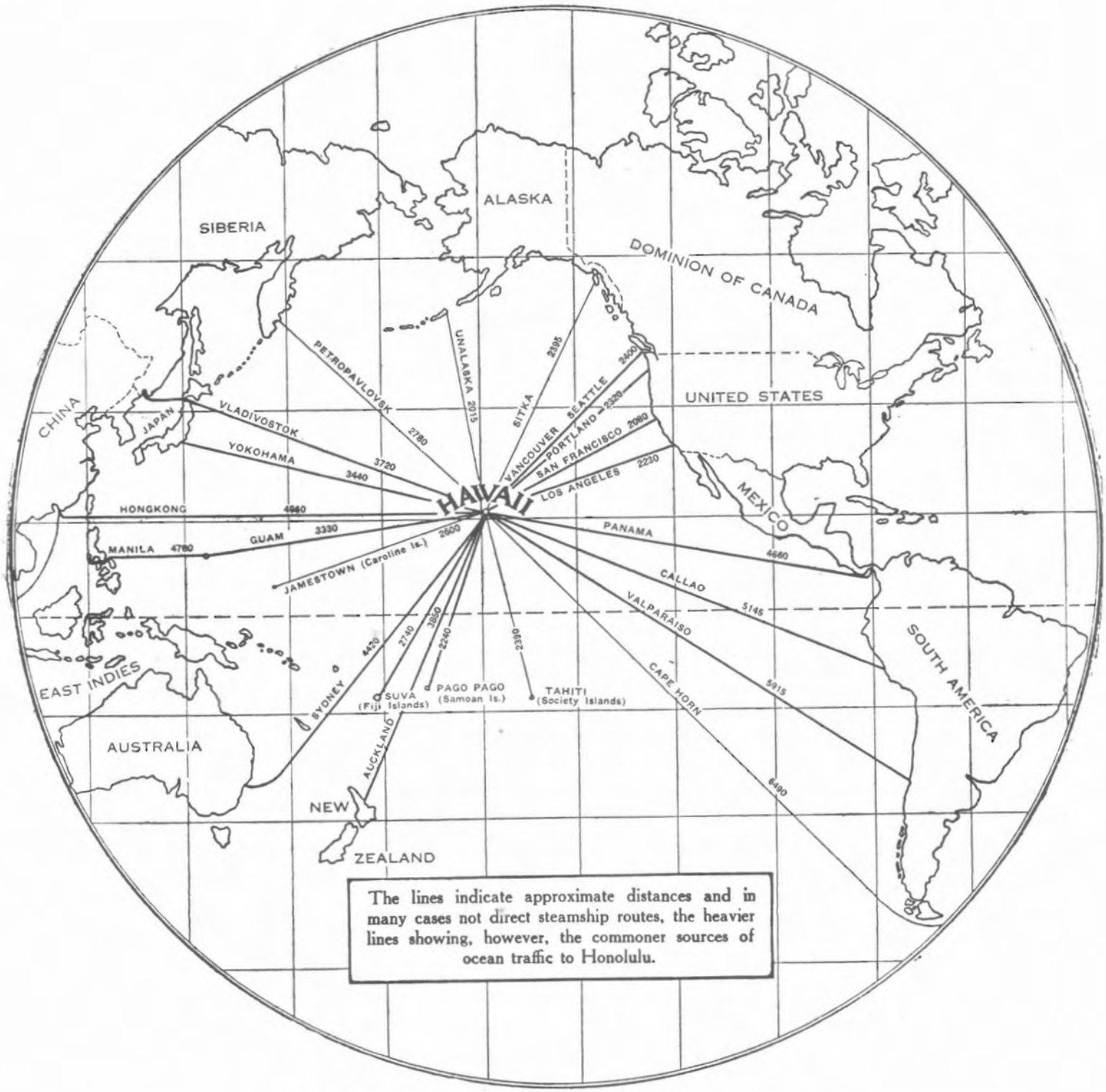
KILAUEA REPORT No. 992

WEEK ENDING JANUARY 25, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On January 19 no changes were observed at Helamaumau and steam rose from the south talus as usual. The pit seismograph indicates that conditions are quiet. A little dust rose from the north rim of the pit at 3:45 p. m. January 22. This was seen to have been a slide at the north talus and on January 24 a little fume rose at the southeastern sulphur crack and the pit seismograph showed a few volcanic tremors.

The Observatory seismographs for the week ending midnight January 25 registered 30 tremors, one of which lasted two minutes. Fourteen very feeble local earthquakes occurred, three of them on January 25 indicating origin about 30 miles from the station. Tilting of the ground was slight to the WSW, and microseismic motion was slight.



Map of the Pacific Ocean. Niuafoou is between Pago Pago and Suva.

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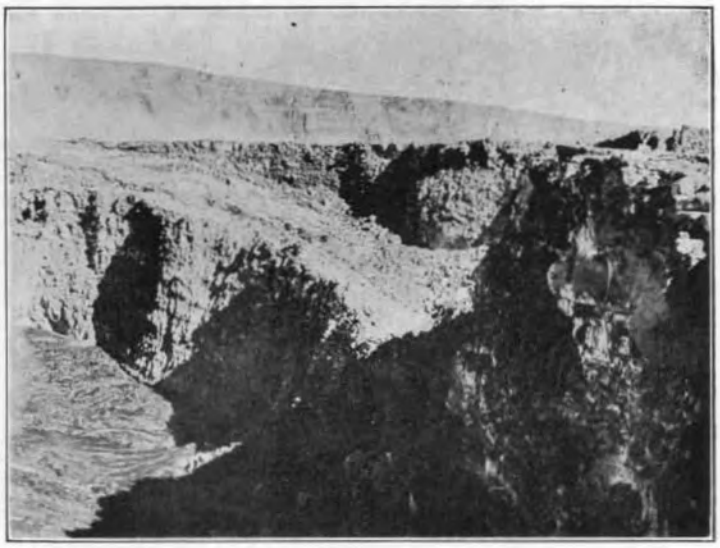
No. 319—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | February 5, 1931



Halemaumau looking north from the southeast rim December 15, 1916, showing the northeastern inner shelf which had been left for many years as a feature of the pit rim by the collapse of 1894. The pit circle measured only 1300 by 1400 feet at this time. The inner lava is seen below, and in the background is Uwekahuna bluff of Kilauea Crater. Photo Jaggar.

TWENTY YEARS OF HAWAIIAN ERUPTIONS

The Hawaiian Volcano Observatory, which was first financed in 1909 and began research in the summer of 1911, has observed about twenty important crises in the three volcanoes Kilauea, Mauna Loa, and Hualalai in the course of twenty years. This means an average of one a year, and with each new event the public is apt to forget the vastly important and exciting events that went before. Therefore very briefly we recount here the sequence.

Kilauea Activity of 1909-13

After the southwestern Mauna Loa flow of 1907, lava rose and fell in Halemaumau pit, then much smaller than at present, at depths 200 to 300 feet below the rim. In 1910 and 1912 three remarkable risings occurred with hundreds of roaring liquid lava fountains. Then came subsidence with much smoke, the lava 600 feet down, from May 1913 to May 1914.

Mauna Loa Summit Eruption 1914

Slowly the melt rose with glowing trickles, sputter, and fume in Halemaumau. In November 1914 Mokuaweoweo, the summit crater of Mauna Loa, suddenly split athwart its bottom and gave vent for two months to high spurting fountain jets of frothy lava, which flowed in the crater only, and became dormant.

Kilauea's Rising 1914-16

Halemaumau now began a cycle of steadily increasing inflow of lava, which was destined to last for 10 years. There was sinking just after the Mauna Loa event, then the upbuilding of a lake in the Kilauea pit, with overflow floor, crags and islands.

Southwest Flow Mauna Loa 1916

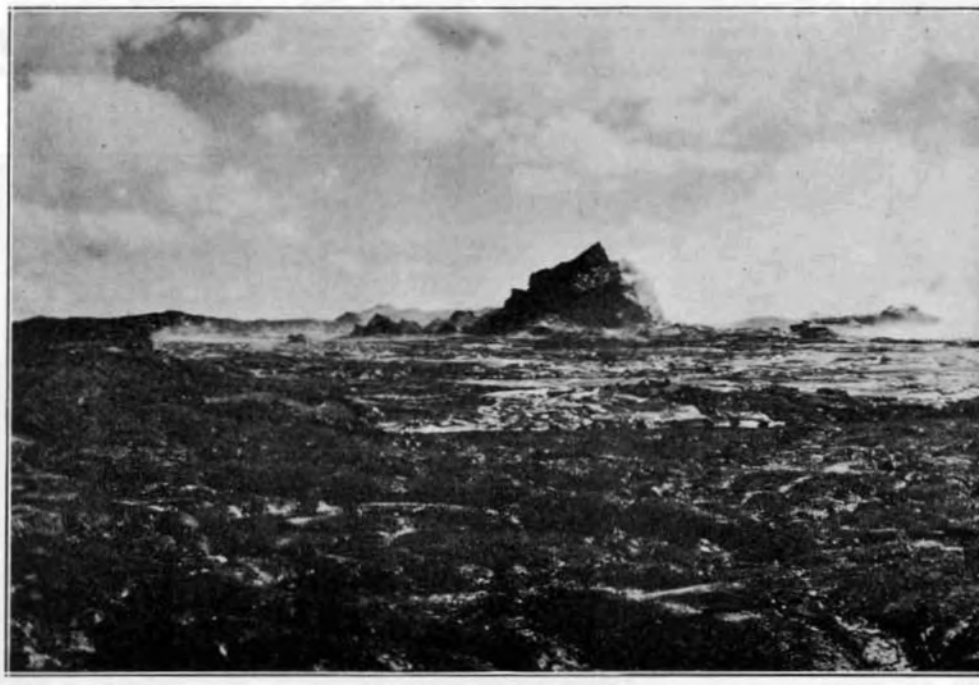
With an astonishingly beautiful mushroom of fume that shot up from about the 10,000-foot level southwest on Mauna Loa May 19, 1916, a new lava flow began making short streams of aa into the forest of Kahuku and Honomalino. This never reached the road and ceased about June 5.

Kilauea Subsidence and Recovery 1916-18

On the same day the lava of Halemaumau, which had just shown a spurt of rising, with the Mauna Loa eruption, sank nearly 400 feet in 24 hours with a magnificient display of red-hot avalanches tumbling into the void 673 feet deep. Immediately lava boiled up in the bottom, and with chiefly rising tendency built up lakes, platforms and crags to the point of overflowing the rim of Halemaumau in February 1918.

Overflows Into Kilauea Crater 1918-19

These two years exhibited the lava in Halemaumau with huge craggy peaks of uplifted floor between the lakes, and whenever there was overflow, reactions of subsidence followed. Overflowing was continuous for seven months in 1919, flooding the Kilauea floor north.



Halemaumau brim full of lava December 31, 1920. This photograph shows the whole p it toward the south. Where the photographer was standing would now be about 600 f e

Alika Flow Mauna Loa 1919: peak of the Cycle 1913-1924

Kilauea flows spurted when Mauna Loa erupted again September-November, 1919, beginning with gushing near Mauna Loa summit southwest. The Mauna Loa flows came out about the 8000-foot level above Puu o Keokeo and poured to the sea at Alika in south Kona.

Kilauea Grand Subsidence 1919

About when Mauna Loa ceased action, Halemaumau, when full to the top, on November 28, 1919 suddenly withdrew its lava column like a piston into a cyclinder 400 feet in an hour. The lava lowered farther for a few hours, immediately recovered, then rose 30 feet a day.

Kau Desert Outflow Kilauea 1919-20

Halemaumau lava rose to the top again December 15, 1919, flooded the southwestern Kilauea floor, burst open the mountain in the Kau desert 6 miles away, and during the next 8 months built the slagheap hill there Mauna Iki, making aa and pahoehoe flows five miles long. Lava in Halemaumau lowered.

Kilauea's Great Overflows March 1921

From 320 feet below rim Halemaumau executed a tremendous rise again for its inner lava lakes between October 1920 and March 1921. There was increasing effervescence, gigantic fountains spouted up in myriads, crags, floors, lakes and wells rose en masse, and the pit overflowed to the Kilauea floor in three great floodings with 5 overflows at one time on March 18, 1921. A small flow went out through the southern Kilauea wall to the desert.

Chain of Craters Outbreak from Kilauea 1922

Kilauea lava subsided three times, with intervening rises, during 1921-22, the last being the greatest engulfment of the Halemaumau walls which had yet occurred in this century. This in May 13-27, 1922, enlarged the pit from a diameter of 1400 feet to 2000 feet. Then May 28-29 came short-lived outflow in Makaopuhi and Napau pits in Puna 9 miles from Halemaumau.

Second Chain of Craters Outflow 1923

Kilauea pit was dormant until lava burst from the talus and began to fill Halemaumau July 17 and September 2, 1922. Then came pulsations of rising to a point 127 feet below rim July 4, 1923, followed by another big subsidence in August and an outflow up a long crack in the forest near Chain of Craters trail west of Makaopuhi. This is the flow shown to tourists where the vent is still hot and lava spatter clings to the trees.

Great Rise and Collapse of Kilauea 1923-24

These oscillations of rising and sinking at Halemaumau, with outflow somewhere down the mountain, reached a grand climax in 1924. This was the end of the eleven-year cycle, and this cycle was the end of an 134-year super-cycle. In the pit greatly enlarged by numerous collapses, the lava rose to within 121 feet of the rim January 27, 1924, making the largest continuous sea of lava ever measured by the Observatory. Then it lowered to dormancy February 15-21, 1924, left a collapsed tumble with a glowing hole about 400 feet down, leading to a demonstration on the eastern or Puna rift of Kilauea Mountain.

Kapoho Coast Subsidence April 1924

This eastern rift crack extends beyond the Chain of Craters through the forest to be crowned with a line of clinker cones 30 miles east of Kilauea. Here at Kapoho April 21, 1929, began continuous shaking, then extensive



rim with the enclosed liquid lava lake and a high crag standing in its midst, looking t inside the north rim of the present pit, and 30 feet up in the air. Photo Jaggar.

cracks opened with settling of the country along a four-mile strip to the coast. There was possibly slight increase of steam there at the always steaming Puulena pit craters. No heat was detected in 20 new chasms. The country sank 11 feet, at the ocean a new salt water lagoon extended 200 feet inland, and coconut trees stood in eight feet of water.

Kilauea Explosive Eruption 1924

The series of subsidences in Halemaumau was now breaking down the mountain, the lava retreated into a deep void, and immediately after the eastern rift subsidence Halemaumau pit began to cave in with increasing avalanches beginning April 28, 1924. Through the cloud of rising dust steam blasts began to fling up rocks May 11, this accentuated the collapse of the funnel and the breaking down of the walls, and a grand climax of explosive eruption was reached May 18. The steam blasts came in pulsations like geyser eruptions every few hours. One man was killed through being too venturesome. The pit was enlarged from 2000 feet to 3500 feet diameter and was left 1300 feet deep. Red-hot walls were revealed below. Steam blasts ended May 27.

Return of Lava July 1924

Except for avalanches Kilauea was dormant until July 19, 1924, when frothy pumiceous lava shot up through the talus of the bottom of Halemaumau with much burning gas, made torrents of melt into the cup of debris at the bottom of the pit, and kept up the action gradually declining for two weeks. This was followed by prolonged dormancy at Kilauea for three years. T.A.J.

(To be continued)

KILAUEA REPORT No. 993

WEEK ENDING FEBRUARY 1, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The week was notable on Hawaii for two felt earthquakes noticed generally all over the island suggesting origins under Mauna Loa. These in sequence upon the similar earthquake of January 16, which by careful analysis showed signs of originating deep under the northeastern slope of Mauna Loa, make the watching of that mountain for possible volcanic activity a matter of interest in the near future.

During the prolonged slight earthquake of 11:39 p. m. January 29 rocks were heard falling in the direction of Halemaumau. Prior to that time there were no changes at the pit, but the seismograph there had recorded a few slow-period tremors. At 9:30 a. m. January 30 a few rocks fell from the north wall of the pit where there was a small red scar from earlier falls. The steaming at the south talus was slight and no fume was detected at the sulphur crack south.

The seismographs at the Observatory registered 1 slight earthquake January 29, 11:39 p. m., 1 classed as feeble 11:56 a. m. February 1, the former showing distance 14 miles, the latter 55 miles. Very feeble shocks were registered to the number of 26 as well as 39 tremors. Ten of the minor shocks indicated distances around 30 miles, as in the case of the earthquake of January 16. The increase of total frequency over the preceding week is from 44 to 67 disturbances. Microseismic motion for the week changed from moderate to very slight. Tilting of the ground was strong to the east.

THE VOLCANO LETTER



Halemaumau brim full of lava December 31, 1920. This photograph shows the whole p it rim with the enclosed liquid lava lake and a high crag standing in its midst, looking toward the south. Where the photographer was standing would now be about 600 f eet inside the north rim of the present pit, and 30 feet up in the air. Photo Jaggar.



Halemaumau on the forenoon of November 28, 1919, just after the early morning subsidence which had lowered lakes and crags like a piston drawn into a cylinder. The previous evening the lava had been up to the level of the rim shown so that one could walk out on the inner floor. Ridge in background was the pressure rim crushed up during the previous year. Photo Jaggar.

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No. 320—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — February 12, 1931



How the old lava mountain of the Kau Desert split open December 22, 1919 through sand and rock and the roots of a tree, in order to give vent to the lava which later piled up into Mauna Iki.

TWENTY YEARS OF HAWAIIAN ERUPTIONS

(Continued)

Hoopuloa Lava Flow Mauna Loa 1926

While Kilauea remained dormant, Mauna Loa on April 10, 1926, opened its southwestern rift about 3 a. m., with lava splitting its way upward and gushing at first just outside of the summit crater. Frothy pahoehoe flows from this summit source poured several miles southward. Then at about 8,000 feet elevation and east of the Alika source cones of 1919 three cups opened along the southwestern rift of Mauna Loa, a big brown fume column shot up, and lava flows started along the rift 15 miles southwest of the Mauna Loa summit. The flood of slag spread both east and west from the rift crack, the western flow finally taking control, pouring down through the forest in South Kona, crossing the main road at 12:22 p. m. April 16, pooling back of Hoopuloa village at the coast as a mass of heavy aa, and completely burying the village, wharf, and harbor between 4 and 9 a. m. April 18.

The source region on top of the southwest ridge of Mauna Loa had developed a line of activity along the rift five miles long with cones and fountains 50 to 100 feet high, the activity progressing along the crack from above downward, and settling down to steady flow at one of the lower cones. Flowing stopped at the Hoopuloa shore April 19, but continued in new streams in the upper Honomalino forest until April 30, when the eruption ceased. There were swarms of earthquakes during and after the outbreak, the frequency diminishing after April 17.

Return of Lava Kilauea July 1927

Halemaumau remained dormant until July 7, 1927, when lava returned to the bottom of the pit, declining in activity to dormancy July 20. The spraying fountains of pumiceous lava attracted attention by their illumination at 1 a. m., and were found to be in a line of four vents trending northeast-southwest across the lava floor of 1924. The persistent vent which became the main source of the bottom fill originated up the southwestern talus and built a pumice cone. About 100 feet of new lava was deposited over an area in the bottom of the pit 1700 feet long northeast-southwest by 1400 feet wide.

Return of Lava Kilauea January 1928

After a series of heavy avalanches in Halemaumau culminating in a monstrous one which caused the north-



Halemaumau Pit during its recovery September 7, 1920, showing the rising pahoehoe liq
Taken from an inner s

western talus to develop into a landslip over the lava floor at 12:26 a. m. January 11, 1928, glow suddenly appeared at the pit coincident with this landslip. New lava had spouted up cracks in the 1927 floor which was brightly incandescent at first, but the rosy over the pit disappeared in 20 minutes. By 1 a. m. the glowing areas indicated cooling flows with a hint of blue flame at a northern cone vent, but there was no observable motion. Slides from the walls continued on all sides. There was no fountaining seen, but no observer was present during the first half hour.

This upflow was believed at the time to be the result of loading down the crust of July 1927, and squeezing up the lava that remained still fluid below. This explanation is doubtful as the frequency of volcanic earthquakes had been unusual for two months, and an eruption was expected.

Return of Lava Kilauea February 1929

Halemaumau was dormant until February 20, 1929, when inflow of lava in the bottom of the pit lasted a day and a half. This was heralded by a striking record of tilt with small earthquakes at the pit seismograph. The ground suddenly tilted away from the pit, and at the end of the eruption tilted back again. Again the outbreak was just after midnight, in the early morning hours of February 20 along a fracture in a straight line across the northwestern side of the bottom lava in Halemaumau. As the landslip of January 1928 had diminished the size of the cup of talus, the new fill, only 45 feet deep, was smaller than that of 1927, measuring only 1600 feet in diameter. The action was marked by a line of continuous fountains with a big fountain of the Mauna Loa type shooting up frothy lava 200 feet at the north end of the live crack, and making a streaming with bright line pattern out into the lake which covered the bottom. There was a steady roar, blue fume arose, while pumice and Pele's needles fell outside of the pit. There was almost no avalanching. The northern fountain built up a pumice and lava heap from which cascades poured down, and this broke down to an "arm-chair niche" at the end.

Return of Lava Kilauea July 1929

After a shorter period of dormancy Halemaumau again produced a spurting eruption in its bottom lasting three days July 25-28, 1929, so as to diminish the depth of the pit by another layer of lava 55 feet deep. This left Halemaumau approximately 1,000 feet deep. Again the outbreak was in the early morning. The time was about 4:35 a. m. as shown by sudden tilt and earthquakes. The center of activity was a fracture through the western talus tangential to the bottom plug. Big fountains spouted up there, and the seismograph at the pit showed inward tilt toward the center on the first day, followed by outward tilt thereafter. In all these short eruptions of lava in Halemaumau a characteristic harmonic tremor of the ground was registered at the Observatory during the days of actual fountaining, and was absent before and afterwards. At the end of July there remained visible glow from cracks in the floor for a few days, as usual with these eruptions, but none of these outbreaks left hissing gas or other signs of continued activity. The eruption stopped abruptly and the new lava solidified.



d lava of the lakes making overflow platforms as the lake lava gained upon the crags. elf looking south.

Hualalai Earthquake Crisis Autumn 1929

Suddenly small earthquakes began to be felt in North Kona near Hualalai Volcano September 19, 1929, though Kilauea remained dormant, and no volcanic activity appeared elsewhere. Puuwaawaa, a large cone on the north flank of Hualalai, became the center of maximum motion. Large destructive earthquakes about Grade IX Rossi-Forel occurred September 25 and October 5. Six thousand two hundred eleven earthquakes were registered in Kona between September 21 and October 16. Great damage was done though no lives were lost: houses, roads, stone fences, fills, tanks, and masonry of every description were broken. Exerything indicated that this seismic spasm was connected with volcanic movement of lava underground tending to shift from the Mauna Loa region to the Hualalai region. An Hualalai outbreak was expected, for this volcano had been active in 1800. No lava flow came and the seismic movements gradually died away in November.

Return of Lava Kilauea November 1930

Another eruption began in the bottom of Halemaumau at 1:29 p. m. November 19, 1930, and this proved to be the longest of this series of intermittent eruptions, bringing also a much greater amount of lava into the bottom of the pit. The activity lasted until December 7 and added a layer to the bottom averaging 70 feet deep. The bottom floor was greatly enlarged to become a leaf-shaped structure 2200 feet long northeast-southwest by 1700 feet wide with a large source cone near its southern margin. The remnant half cone of July 1929 still persists at the base of the western talus.

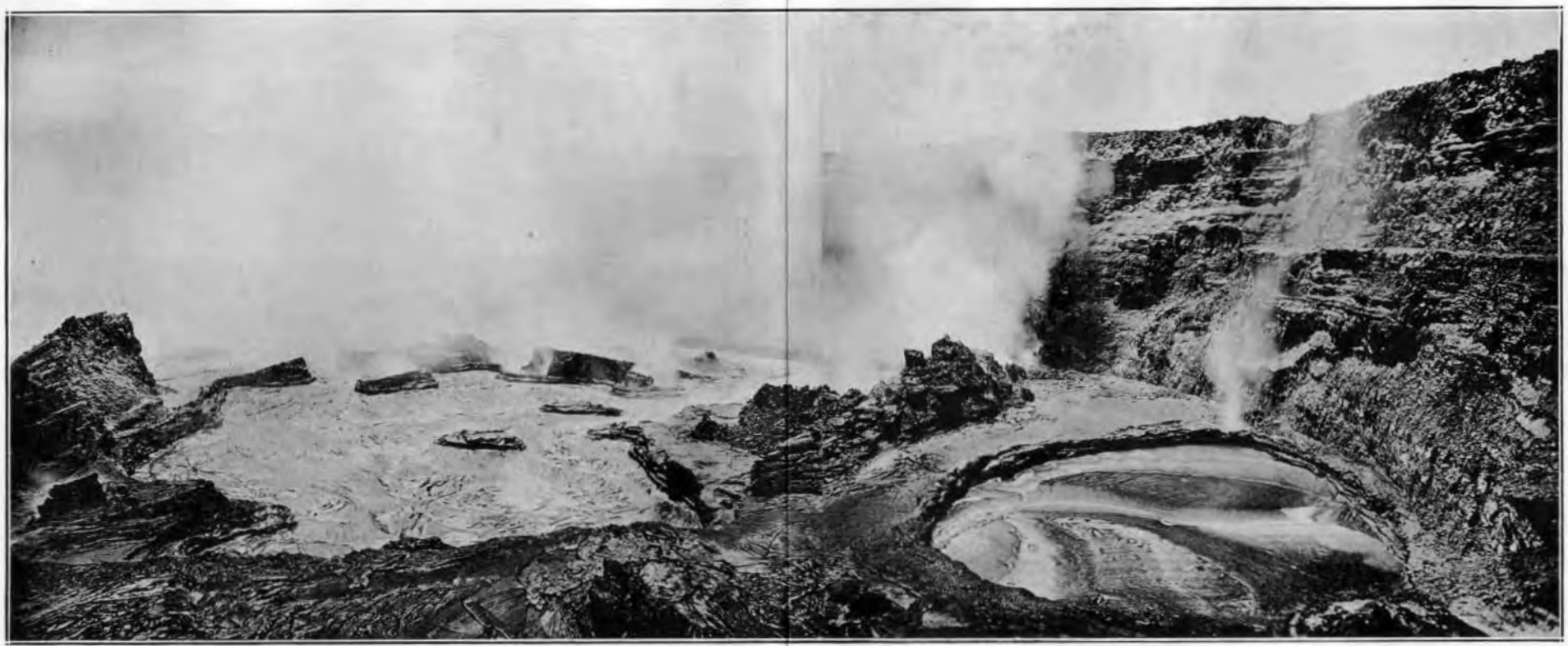
The new lava fountains broke through the floor in front of the grotto niches of 1929 and several fountains developed, one dominating the others as usual, and this in the region of the south edge of the 1929 floor. Here there were developed spraying jets 100 feet or more high, pumice and Pele's hair fell outside of the pit, a crescent heap was built around the south side of the fountain and this gradually enlarged to become a big cone more than 100 feet high. A lake was developed north of the source cone with changing ramparts around its margin, and this at the top of a slag heap which constituted the entire fill of 1930. From the lake the slag heap sloped down in all directions, steeply at the south and more gradually at the north. The activity developed streaming across the lake from the source cone, and trickling flows now here, now there, from the lake out to the margin of the fill. The decline of activity was gradual, and the region of lake and source cone was left thicker and higher than the border fill. Halemaumau was now 930 feet deep, and at the top 3400 feet long by 3000 feet wide. T.A.J.

KILAUEA REPORT No. 994

WEEK ENDING FEBRUARY 8, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar. Volcanologist in Charge

Conditions at Halemaumau remained without change during the week. A few quick-period tremors recorded on the pit seismograph early in the week.



Halemaumau Pit during its recovery September 7, 1920, showing the rising pahoehoe liquid lava of the lakes making overflow platforms as the lake lava gained upon the crags. Taken from an inner shelf looking south.



Upper part of one of the flows from Mauna Iki January 9, 1920, showing a bend in the lava stream, placidly flowing along like a river. This lava had come out of the same crack shown on Page One, and six miles away was draining the pit shown on Pages 2-3. Photos Jaggar.

Fourteen local disturbances and one distant shock were recorded on the instruments at the Observatory, the former classified as follows: 11 tremors, 2 very feeble seisms, and 1 feeble seism. The feeble shock occurred at 7:10 p. m. February 4 and had an indicated distance of 23 miles from the Observatory. It was felt at Kapapala, Hilo, and vicinities.

The teleseism, which began recording at 12:27 p. m. February 2, had an indicated distance of 8,040 kilometers; direction as determined by the record of the vertical component was south-southwest (New Zealand disaster).

Tilt for the week accumulated strong northwest Microseismic motion mas slight.

THE VOLCANO LETTER

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Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Lorrin A. Thurston, President; Frank C. Atherton and Walter Dillingham, Vice-Presidents; L. Tenny Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

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The Volcano Letter

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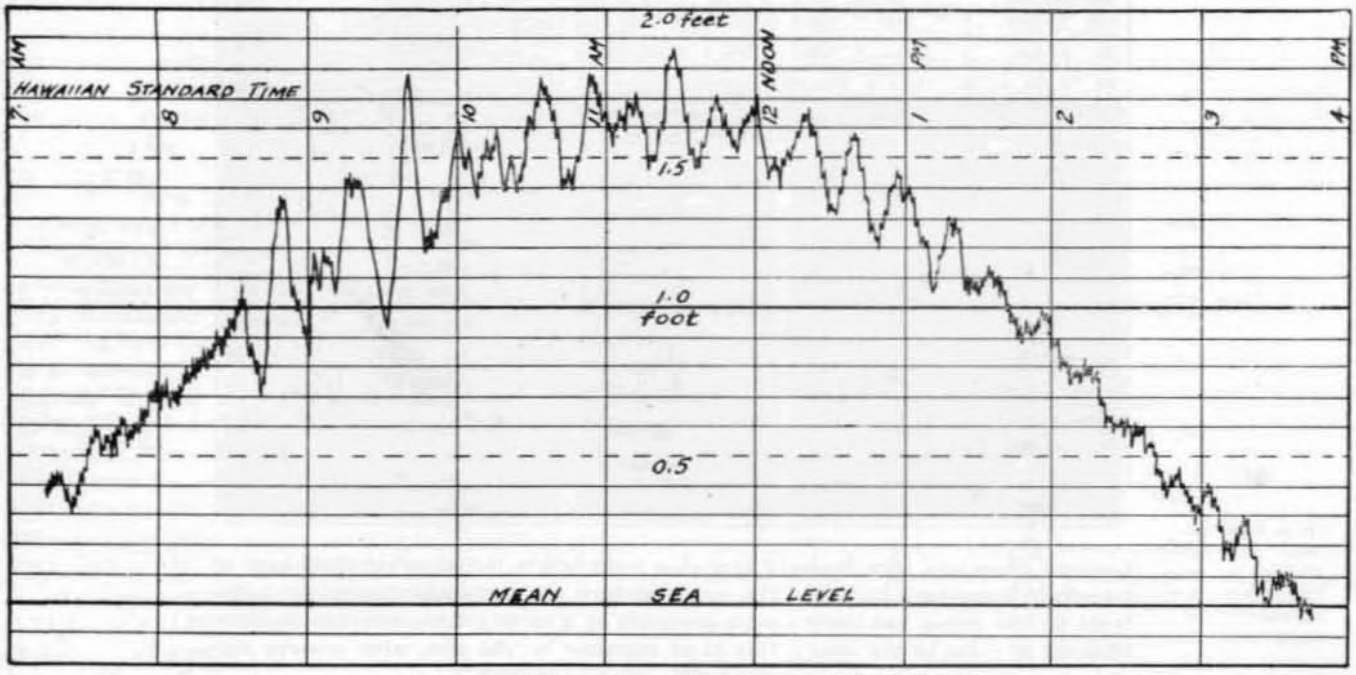
No. 321—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | February 19, 1931



TIDAL WAVE, NOVEMBER 4 1927
HILO, HAWAII.

Tide gauge record showing the beginning of an earthquake wave series at 3:30 a. m. with maximum range of about a foot, from an earthquake under the sea off the coast of California November 4, 1927. This earthquake was 3,925 km. from Hilo, and the sea wave traveled 7.8 statute miles per minute, The quake was felt in California and on a ship at sea.

HAWAIIAN DAMAGE FROM TIDAL WAVES

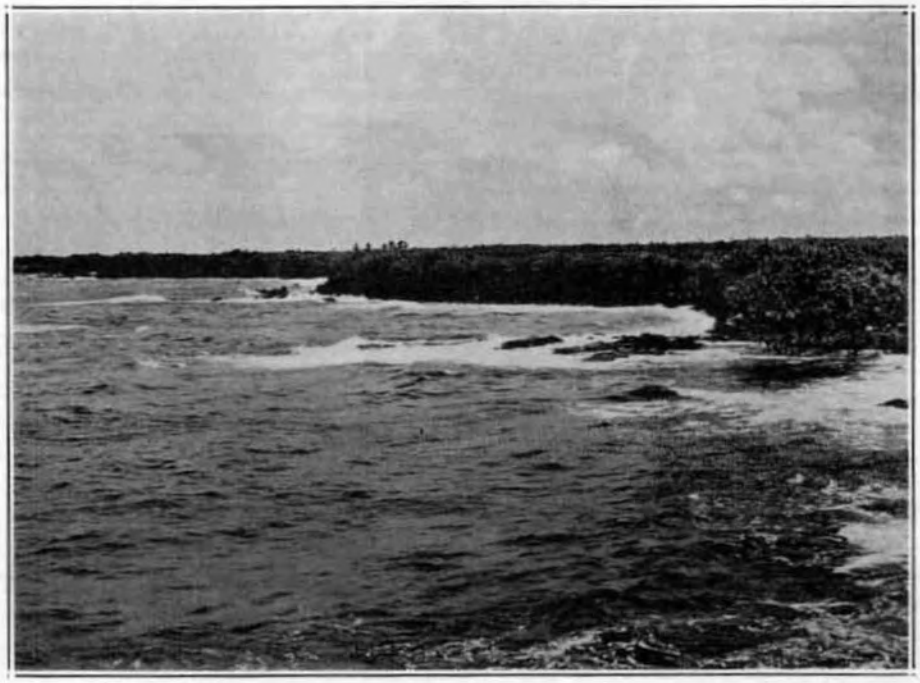
In Volcano Letter No. 274 the general conditions, under which a "tsunami" or earthquake wave is generated by a seismic movement of the sea bottom, are reviewed. These are commonly called tidal waves, a name protested by geologists, but after all not wholly inappropriate, for tides do enter into resonance with the harmonic oscillations of water that make catastrophes popularly called tidal waves. Moreover not all such damaging movements are due to earthquakes, as this piling-up of rhythms to make flood on a shelving shore may be due to landslip, to volcanic engulfment under the sea, to submarine lava flow, or to hurricane. In the earthquake wave proper, a sea-bottom shift like the dropping of a fault block of earth crust sends an impulse across the deep ocean, the trough or crest of which travels from 300 to 500 miles an hour, and so is quite comparable to the travel of the crest of the tide actuated by the pull of the moon. We have proved here in Hawaii that two tremendous deep-sea earthquakes off the Aleutian Islands in one case made disaster in Kahului and Hilo, in the other did not. Both made measurable waves, but probably the one augmented a tide, and the other was in some way compensated by a tide.

Facts about tsunami in Hawaii may be found in the well known books of Brigham, 1866 (Mem. Bost. Soc. Nat. Hist., Vol. I, pt. 3), Hitchcock, Hawaii and Its Volcanoes (Honolulu, 1911), and Brigham, Kilauea and Mauna Loa (Bishop Museum 1909).

In May 1819 the ocean was seen to recede in Hawaii and executed about 13 oscillations before it came to rest again.

On November 7, 1837, a big earthquake off the Chile coast made a disastrous wave about the shores of the Pacific Ocean which was described by Coan as arriving at Hilo so as to cause retirement of the sea about 7 p. m. The surge returned in a few moments "breaking on the beach with a noise like thunder." Lowlands were submerged. Houses were swept away. People were left struggling in th water. The sea remained high for 15 minutes. Then a series of oscillations occurred, the water moving slowly out and in again. There was a meeting of the natives on the shore at the time, and the flood caused great consternation, the people shouting to find their lost relatives and rushing about in panic. An English whaler which was anchored in the bay lowered boats for relief. Canoes were all washed out to sea. The water ran past the ship with an eight-knot current, and soundings were reduced from five to three and a half fathoms, so that much of the bay was dry.

At Kahului in Maui the water retired widening the beach 120 feet so that the delighted natives ran out on the reefs that were left bare in order to pick up stranded fish. But they were terrified to see a wall of water returning



Lowered shore line with drowned pandanus trees where the coast subsided east of Kapoho in Puna April 23, 1924. The land back from the shore was cracked for a distance of four miles, and these events preceded by a fortnight the collapse of Halemaumau 30 miles to the west. This coast subsided in 1868 also, when a wave disaster was produced. Photo Emerson.

which engulfed them and the village. As they were good swimmers only two lives were lost. The back-and-forth disturbance of the water continued for more than 24 hours.

At Honolulu this 1837 tsunami lowered the water eight feet so as to leave the reef dry; returned slowly in 28 minutes; then fell six feet again; and the ebb and flow continued at intervals of about 28 minutes. The third of the flood-water spells reached about four inches above high water mark.

The next account is of a retirement of the waters at Honolulu May 17, 1841, at 5:20 p. m., when the ebb was sudden, leaving the reef bare, and the movement occurred twice in 40 minutes. This earthquake wave was especially sudden at Lahaina in its sucking down of the sea level, and it was reported as affecting the coast of Kamchatka also.

The year 1868 produced two disastrous tsunami on the island of Hawaii, the first accompanying the terrific local earthquake in Kau in April 2, the second from a submarine shock off Arica, Peru, August 13.

The local disaster of April 2, 1868, made a wave on the shore all the way from Kahuku to Kapoho, swept away the houses on the Puna shore, the Pahala shore, and the Honuapo shore, and with the earthquake the Puna coast subsided from four to seven feet. At Punaluu the stone church, the wooden houses, and all the coconut trees except two were washed down. Floating rubbish was driven inland "about a quarter of a mile," and large bowlders were washed in at Pohoiki. On the whole coast 108 houses were destroyed and 46 persons perished by the sea wave. At Hilo the sea receded horizontally 150 feet and when it returned rose about 10 feet above high-water mark.

The big Pacific wave of August 13, 1868, from near Peru, reached Hilo in about 14 hours, traveled about 350 miles per hour, and was reportedd to have been marked on a coconut tree somewhere near the present railway station as reaching 15 feet above ordinary low water and 5 feet above the ground. Hilo is 5,460 miles from Peru. At windward Maui the flood of this tsunami was reported 12 feet high. The damage was of the usual sort and must have been considerable in Waiakea and Kahului. The records of it are probably to be found in the newspapers of the time.

On August 27, 1872, just after a remarkable lava outbreak had begun in the summit crater of Mauna Loa which was destined to last some years, a small tsunami occurred at Hilo during calm weather, the water rising four feet, then six minutes later three feet, and diminishing for about 14 oscillations. The short period of this water wave, six minutes as contrasted with 20 to 30 minutes for the ones of distant origin, makes it likely to have been a local disturbance on the sea floor.

The earthquake wave of 1877 was the most disastrous on record for Hilo and closely resembled that of 1837. Like that one and the one of August 1868, it originated off the coast of South America between Chile and Peru in the evening of May 9, 1877, and reached Hilo at 4 a. m. May 10. At 5 a. m. it penetrated the shops on Front Street at a height reported by Luther Severance 12 feet 3 inches above ordinary low water. Every house within 100 yards of the water was swept away in Waiakea. Five lives were lost, seven persons were injured, 163 were left destitute, and 17 horses and mules were drowned. A vessel which had been anchored in four fathoms of water found itself on the

ground. The rise and fall of the waters continued all day. At 7 a. m. one complete swing from low to high was measured 14 feet vertically. The sea swept completely over Coconut Island. Thirty-seven dwellings were destroyed and 17 badly wrecked. Lumber was washed away to the value of several thousand dollars, and the total damage was estimated at $13,000.

There have been several small local waves doing some damage in Hawaii, occasioned by submarine volcanic disturbances, of which the wave at Hoopuloa in 1919, at the time of the nearby Alika lava flow into the sea, is typical. There was a succession of short period shallow tidal waves ranging from 3 to 14 feet in height, with maximum nearest to the flow delta on the third day of the eruption. The Hoopuloa wharf was flooded.

On February 3, 1923, a destructive tidal wave at Kahului in Maui and at Hilo occurred about seven hours after a big earthquake under the Gulf of Alaska, 2,500 miles away. In Honolulu the waters receded revealing the reefs for 20 minutes and then there were in-and-out surges at intervals of 15 to 20 minutes. In Hilo sampans in the Wailoa River were smashed over the railroad bridge, the bridge was destroyed, a man was killed, and the railroad embankment between Hilo and Kuhio Wharf was washed down and houses and wharves were upset. The major wave was the third of the series and was said to pile up more than 20 feet in the funnel of the bay at Waiakea.

We have mentioned pronounced damage in 1837, twice in 1868, again in 1877, and 1923 in Hilo, say five times in the century or an average of once in 20 years, mostly waves from Alaska or South America. One great disaster in Puna and Kau was due to a local submarine disturbance. Nine measured large or small waves between 1918 and 1929 on the Hawaii coast have been discussed in publications of the Hawaiian Volcano Observatory, and only since 1927 have we operated the Hilo tide gauge. Probably waves occur to the number of more than one a year, disregarding the question of damage. There is no record yet of serious tidal wave damage in Honolulu, but waves from the west and northwest have recorded as strongly on the Honolulu tide gauge as on the Hilo gauge. T.A.J.

TILTING OF THE GROUND FOR JANUARY

The following figures show the net amount of tilt per week at the Observatory on the northeast rim of Kilauea crater, and its direction, computed from the daily seismograms, by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the direction given.

December 29-January 4	0.97 seconds	W
January 5-11	0.96 seconds	S
January 12-18	0.91 seconds	WNW
January 19-25	1.33 seconds	WSW
January 26-February 1	1.33 seconds	ENE

KILAUEA REPORT No. 995

WEEK ENDING FEBRUARY 15, 1931

Section of Volcanology, U. S. Geological Survey

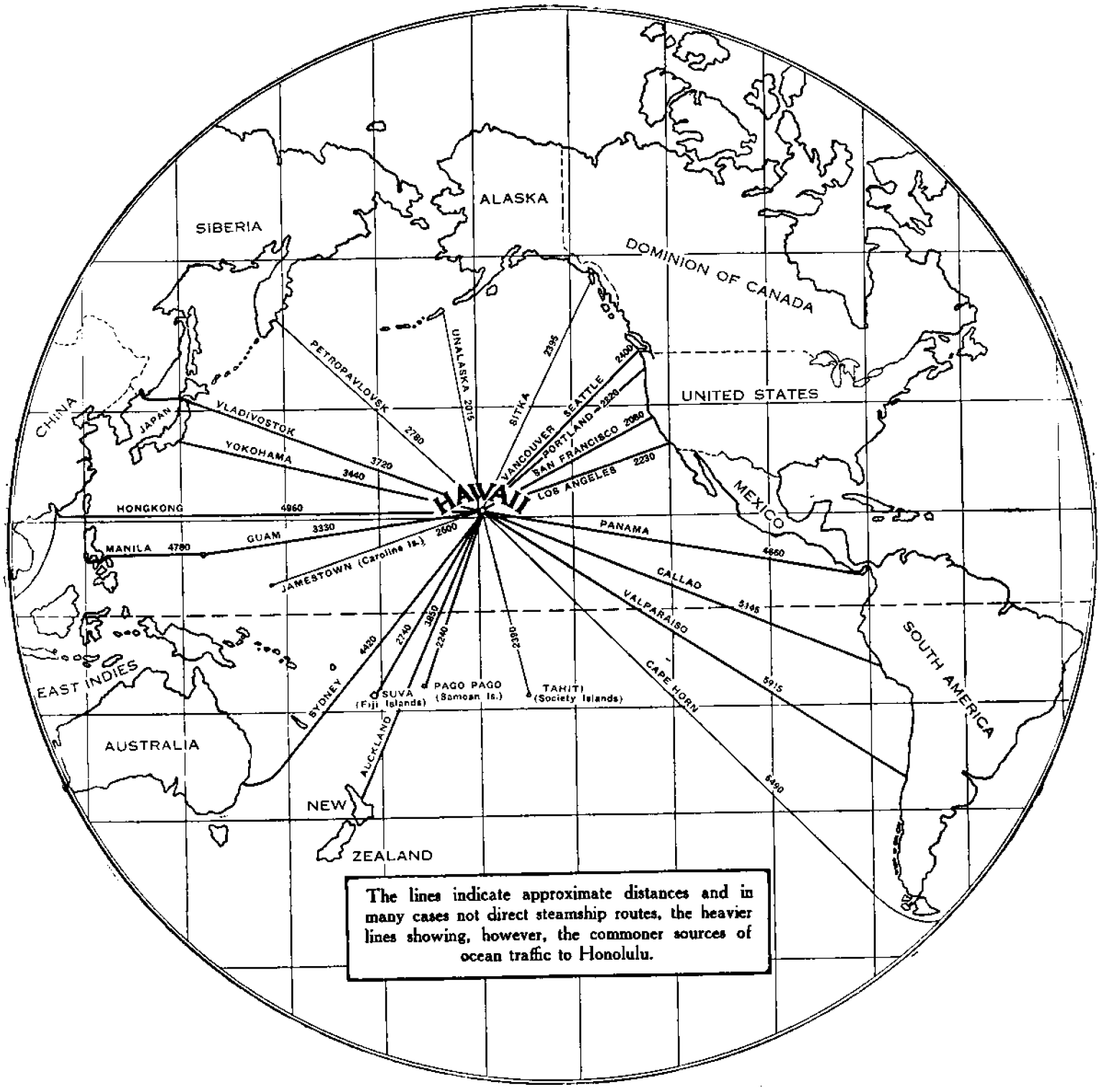
T. A. Jaggar, Volcanologist in Charge

The island of Hawaii is at present very quiet and practically no changes have occurred during the week at Halemaumau pit of Kilauea Volcano. Measurement of cracks at the edge of the pit on February 10 revealed a very slight widening. There is but little steam on the south talus and a few rocks have slid down to the edge of the lava floor at the south.

Only two very feeble local earthquakes were registered at the Observatory, of which one at 4:51 a. m. February 11 indicated distance of origin 28 miles. In addition 12 tremors were recorded. Tilting of the ground was slight NNW, and microseismic motion was very slight.



Detail of lowered shore line of 1924 near east point of Hawaii showing new lagoon of salt water over 12 feet deep with submerged coconut palms. Photo Emerson.



Map of Pacific Ocean. Submarine earthquakes making destructive tidal waves in Hawaii originate generally in the northeastern semicircle of the ocean from Kamchatka to South America.

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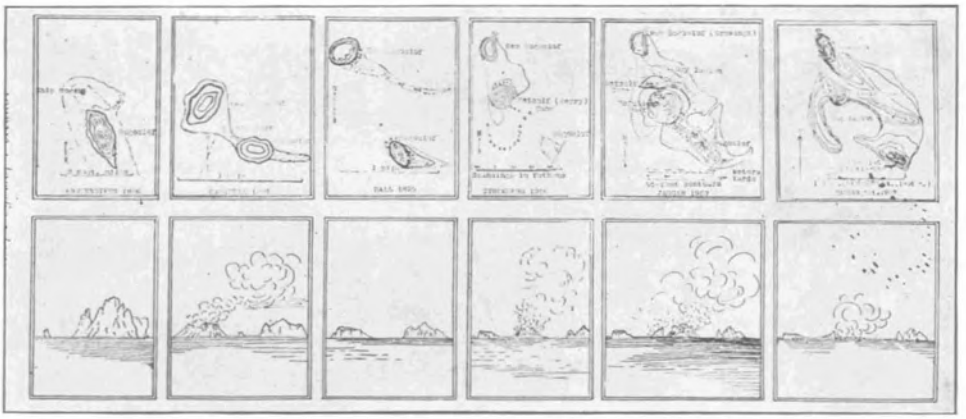
No. 322—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — February 26, 1931



Sketch maps and profiles of Bogoslof of dates from left to right as follows: (1) Krusenstern 1826, (2) Cantwell 1884, (3) Dall 1895, (4) Stromberg 1906, (5) Jaggar 1907, (6) Camden October 1907. These show the gradual growth of the island, and the lower cut in each case is the view from the south.

EVOLUTION OF BOGOSLOF VOLCANO

The scientific investigation of our vast American domain of active volcanoes in the Aleutian Islands and the Alaskan Peninsula is the largest task before the Section of Volcanology of the Geological Survey. Gradual advancement of this work is provided for by act of Congress, and during the coming summer Akutan Volcano, which has exhibited frequent activity, will be investigated. Akutan is next to the east of Unalaska (see map Page Four), and just to the northwest of Unlaska Bogoslof has been building up during the last 150 years by processes of squeezing up of lava domes similar to that of Tarumai Volcano (Volcano Letter No. 317).

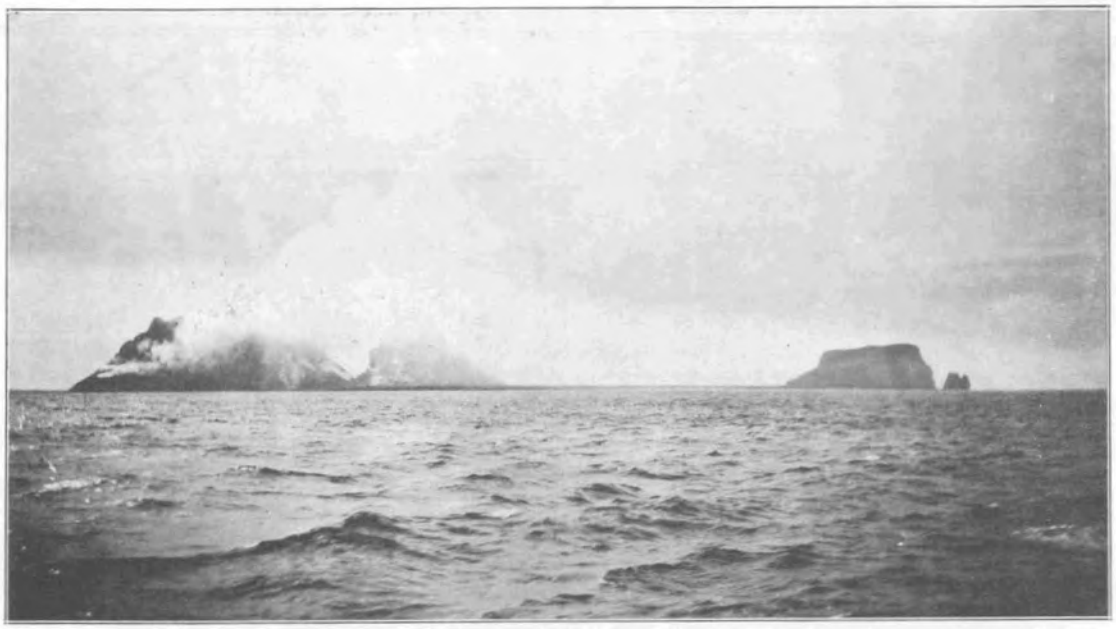
The gradual enlargement of Bogoslof island from 1826 to 1907 is shown in the succession of maps and sketches illustrated on Page One. Bogoslof is a big cone on the sea floor like Falcon Island and Niuafoou in Tonga, but only the tip of it is building above the waves. Under the ocean it is 6,000 feet high. The group of rocks that make the islet have been enlarging by alternations of rising lava and explosive steam jets, the former making domes, and the latter spreading gravel.

Ship Rock was first noticed by sailor men in 1768. Bogoslof proper or Castle Rock was thrown up in 1796. Grewingk or New Bogoslof rose about 1884 and the older Ship Rock was demolished, but Castle Rock still remained in 1891. In 1896 and 1899 there were two islands with water between. In May 1906 the "Albatross" reported a new volcano Metcalf Cone midway between Castle Rock and Grewingk, and attached by an isthmus to the latter. The cutter "Perry" in July 1906 reported 40 feet of water between the new dome and Castle Rock.

In July and August 1907 the writer visited the islands. A new cone McCulloch Peak had risen south of Metcalf Cone and adjacent to it. Metcalf had split in two showing an andesite horn rising through the split cone. This closely resembled the Pelee spine of Martinique. The rock was hornblende augite andesite with inclusions of sulphides and of diorite, some forms resembling pumice. There were also horn-like processes projecting from the summit of McCulloch dome, which was approximately 450 feet high above the sea. The channel between the islands was entirely filled so that Castle Rock, McCulloch, Metcalf, and Grewingk formed a single island a mile and a half long. McCulloch Peak was nearly surrounded by a steaming salt-water lagoon at about 90° F. and was itself steaming quietly. The following describes the adventures of the writer's party from the schooner "Lydia" of the Technology Expedition (Technology Review Vol. X, No. 1, 1908):

"Wednesday August 7, 1907. At 8 a. m. Bogoslof was in full view ahead, the weather fair, a steady southwest wind blowing. It was determined to land two dories and have the vessel stand off, while three or four hours if possible were spent in examination of the island. (The photograph on Page Two was made from the "Lydia" at this time looking west, and corresponds to the next to the last map of the series on Page One.)"

"The landing was made at 10:30 a. m. Hundreds of immense sea lions, bellowing with voices that well justify their name, swam within a stone's throw of the dories, when they would raise themselves high in the water, stare at the boat, and then plunge frantically beneath the waves. When we landed on the beach, most of the animals there had floundered into the water; but one immense bull re-



The northern hills and connecting sand bars of Bogoslof Island, looking west August 7, 1907, showing McCulloch dome on the left, Metcalf half-dome, and Grewingk. Castle Rock is out of the picture at the left. Photo Jaggar.

mained, apparently asleep. One of the party ran toward him with a camera, the monster awoke, and with awkward gait flopped down into the sea.

"The hours spent on Bogoslof were the most interesting of the whole expedition. The rocky cliffs are covered with millions of birds, their eggs and their chicks, chiefly murres and herring gulls. On startling them from the face of the cliff of Castle Rock, the swarm of winged creatures literally darkened the air. To members of the party climbing among the rocks the stench from offal and decayed eggs was intense. The island exhibited four rocky hills 350 to 500 feet high, Castle Rock peaked and prominent at the southeast, McCulloch dome circular and steaming actively in the middle, Metcalf crag half destroyed and adjacent to McCulloch on its north side, and Grewingk a flat table rock at the northwest end of the group. These were all connected by continuous gravel and sand strips where a year before there had been a broad channel and seven fathoms of water about the site of McCulloch dome."

"Around the base of McCulloch hill was a lagoon of hot salt water steaming quietly and yellow with iron stained mud. This hill was 450 feet high at the time of our visit, conical in outline by reason of the talus slopes, and showing great lumps or horns of what appeared to be ledge rock jutting out from the upper slopes, while the slide-rock slope of bowlders all around the base was straight in profile standing at 30 degrees. The entire mass was steaming from many fissures, and in places there were bright yellow sulphur coatings at the steam vents."

"Metcalf hill was a half-cone with its south side broken down where an explosion had destroyed it prior to the beginning of the welling up of the McCulloch lava. This rupture left Metcalf with a vertical precipice on the side opposite the remnant of its cone slope still steaming on the north side. Neither Grewingk at the north nor Castle Rock at the south was volcanically active at the time of this visit. The steep cliff of Metcalf revealed in cross section up its middle a great horn of congealed lava, which had risen into the midst of the cone with a smooth curved surface toward the west, and at the top a broken vertical surface toward the east. Seen from the north, this horn looked like a shark's fin or a parrot's beak; seen from the west like the horn of a rhinoceros."

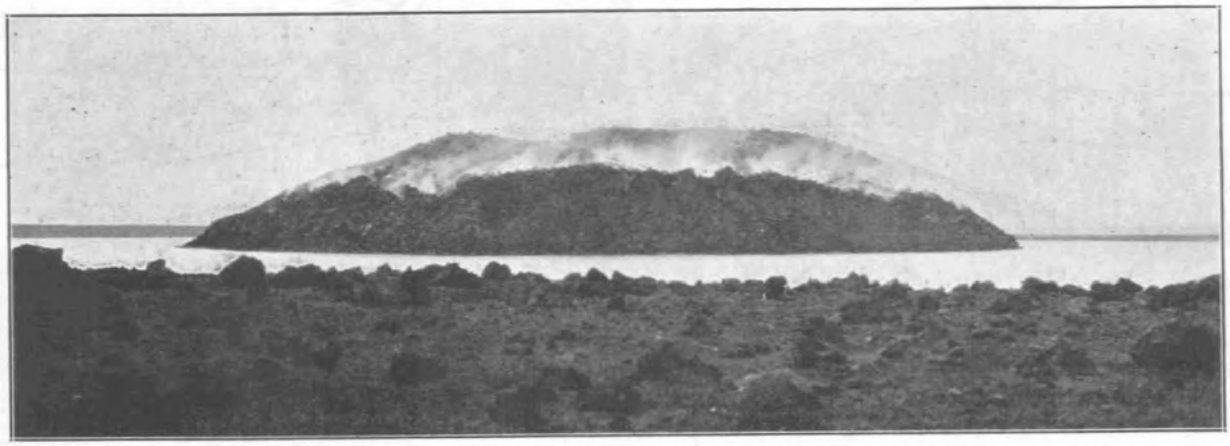
"McCulloch and Metcalf domes were both products of the slow pushing up from beneath the waves of a mass of refractory lava, semi-solid, crusting and breaking into blocks as it rose, with only the central portions retaining a semblance of fluidity. The horns were doubtless such central portions. The same mechanism produced the extraordinary spine which rose 1,000 feet above the dome of Mont Pelee in Martinique in 1902."

"Between 1891 and 1895 Grewingk had changed its form from a large irregular cone to a small flat-topped table. I believe this change was due (1) to its being leveled by the waves and covered with beach deposits, and (2) to its being subsequently uplifted. Beach bowlders and sands could now be seen in 1907 on its flat top and in section at the edge of the top of the cliffs. An extraordinary feature of the rocky wall of Castle Rock was a sea cave at the north end surmounting a rock bench or platform 25 feet above the ocean level. This notch and floor had evidently been made by the surf, but the present surf was beating the strand at a much lower level. On comparison with photographs of 1906, a year before, it

was found that the uplift of 25 feet had taken place during the last year, for those photographs showed the same rock bench and cave at sea level. Evidently Castle Rock had been rising slowly during eight months, while the lava pressure under McCulloch hill was heaping up that dome over 400 feet, with a base measuring 2,000 feet across at the beach level. The effects of mass uplift were in evidence all over the island. While a half plastic lava was pushing up rapidly in the middle cone, the adjacent, older, hard rock summits of the submarine mountain were slowly heaved up."

"On September 1, 1907, after we had left the islands, a steam blast and an engulfment destroyed McCulloch hill, sand and dust fell 100 miles to the eastward, and a visit by the Coast Guard cutter in October 1907 revealed a watery lagoon at the south base of the Metcalf remnant, McCulloch dome was gone, and all of the rocks were shrouded in a heavy mantle of volcanic debris."

There was probably another explosion lowering the remains of Metcalf hill in 1908, leaving a bay surrounded by beaches between Castle Rock and Grewingk, and in September 1909 two small lava islands arose here, a new lagoon was formed shut off from the sea, and these in June 1910 had united into a single lava hill standing 178 feet above the sea. A true crater was opened by explosion in this hill September 18, 1910, which ceased fuming in 1914. This Tahoma hill, as it was called, had been eroded away in 1922 and a channel was again opened between Castle Rock and Grewingk so that a boat could sail through. Grewingk had diminished in size and Castle Rock was changed to two rocky horns with a big accumulation of sand and gravel piled round about which trailed off into a long sand spit at the north. In July 1926 an explosive eruption heralded new activity, another occurred in December, and then a new lava dome piled itself up in the middle region within a warm salt-water lagoon at 70° F. completely shut off from the ocean by a ring of sand and bombs, and gravel heaps connecting Castle Rock and Grewingk as before. Since that time the island has quieted down. T.A.J.



New lava heap of Bogoslof Volcano about June 28, 1928, looking southwest showing warm salt lagoon and ring of explosion debris in about the same location as the active domes of 1907. Photo Wheeler.

KILAUEA REPORT No. 996

WEEK ENDING FEBRUARY 22, 1931

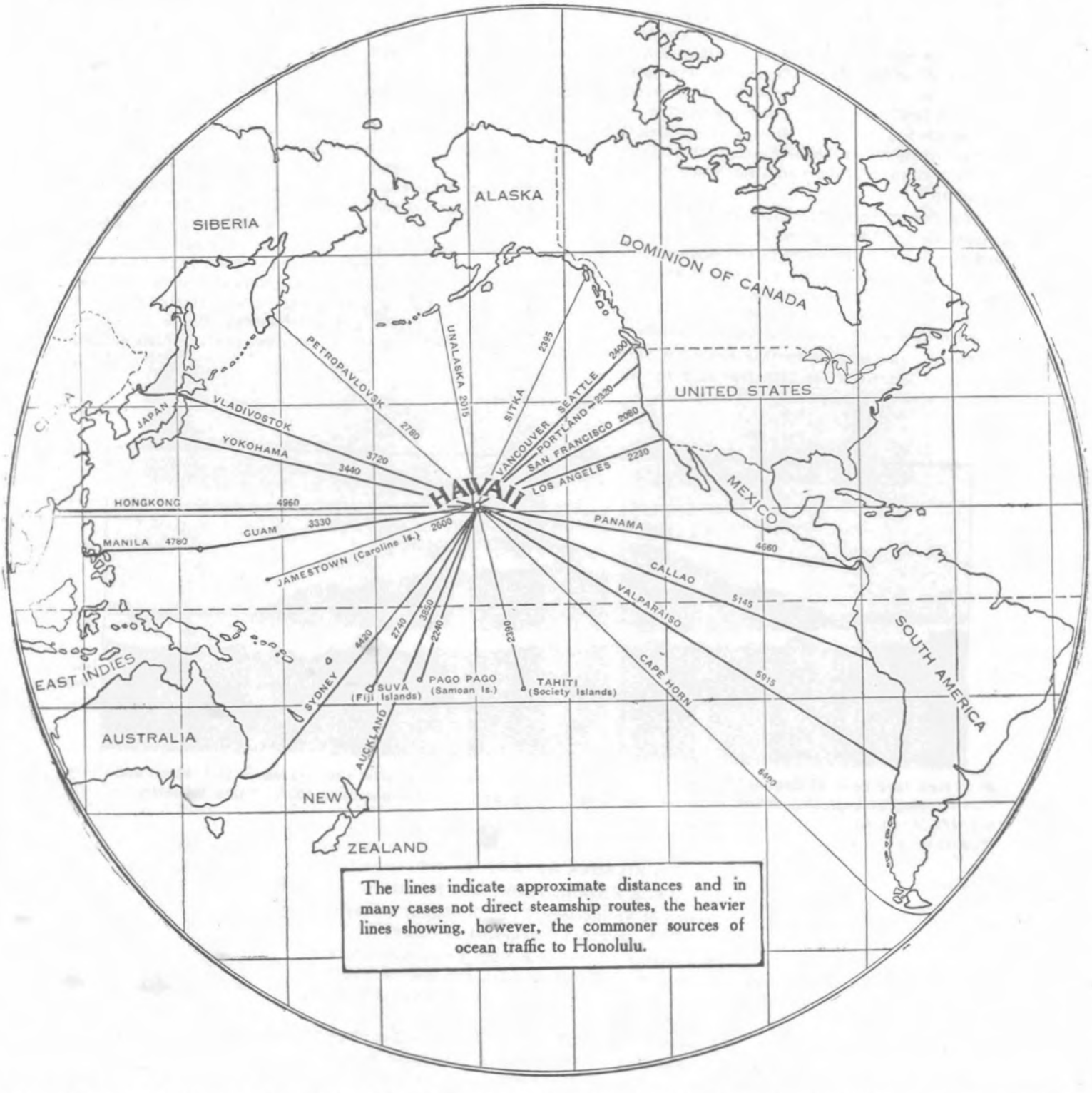
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Halemaumau pit remains very quiet, there is only slight steaming on the south talus, and dust was noticed from slides at the north wall of the pit about 3:10 p. m. February 19.

Eighteen tremors and one very feeble local earthquake were registered at the Observatory during the week, the earthquake at 12:56 a. m. February 20 indicating distance of origin nine miles. Another at 12:26 a. m. February 21 was only a tremor at Kilauea but was felt as a single bumping jolt at Kealakekua in Kona accompanied by a slight noise.

Tilting of the ground was moderate to the southwest at Kilauea, and microseismic motion was slight.



Map of the Pacific Ocean showing position of Unalaska southwest of Alaska in the Aleutian Islands. Bogoslof is 40 miles northwest of Unalaska.

THE VOLCANO LETTER

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The Volcano Letter

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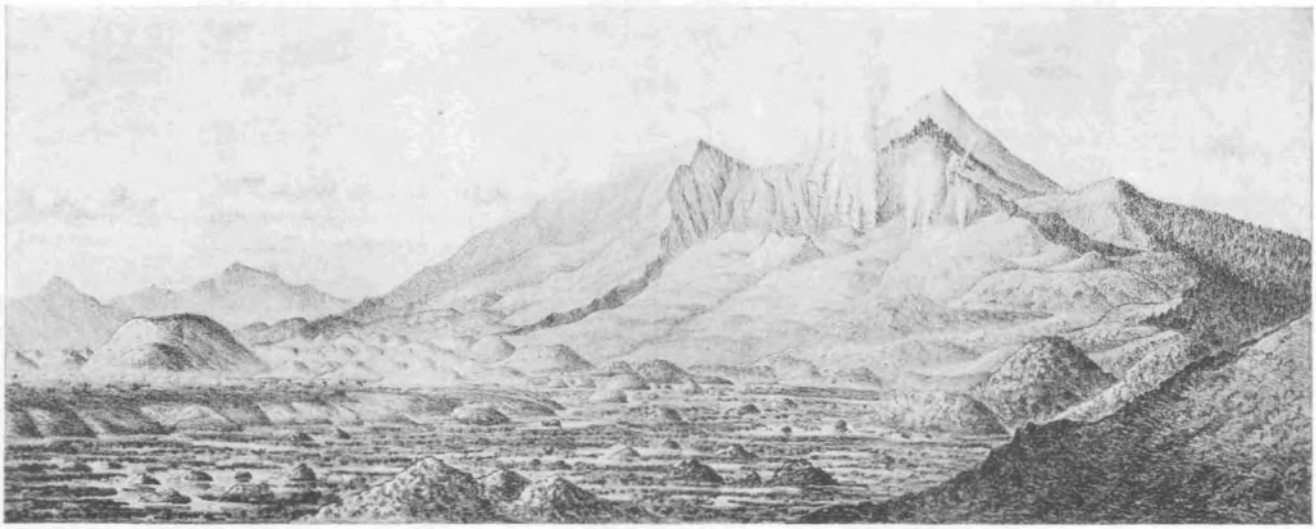
No. 323—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | March 5, 1931



Crater of Bandaisan after eruption of 1888 showing the steaming cleft in the mountainside, bare hillsides that were scored by the terrific avalanche, and mounds left by settlement of the debris. After Sekiya and Kikuchi.

JAPANESE VOLCANOES ARRANGED IN SERIES

In order to classify volcanoes intelligently it is necessary to know the deeper mechanism that gave birth to the crater or mound or mountain. In Volcano Letter No. 164 was reviewed the classification given by Sapper, (1) Hawaiian liquid lava flow, (2) liquid lava combined with steam jet as at Stromboli, (3) stiffer lava combined with steam and black dust as at Vulcano, (4) stiff lava plug combined with Vulcanian paroxysms of steam and dust as at Pelee in Martinique, and (5) steam explosion alone throwing up fragments of old rock as at Bandaisan in Japan. These are usually described as (1) Hawaiian, (2) Strombolian, (3) Vulcanian, (4) Pelean, and (5) Bandaian. Numerous unhappy Greek words have been invented by Schneider and others, which unfortunately some Japanese geologists are repeating, but clear descriptive language is best in the present stage of the science.

A recent essay by H. Tanakadate (Eruptive Types of Japanese Volcanoes in recent Years, Proc. Fourth Pac. Sci. Cong., Java, 1929, p. 621) is a sound attempt to arrange the eruptions of Japan in series. The author uses some technical terms which would much better be replaced by plain language. He distinguishes eleven types as follows:

Bandaisan	1. Sudden explosion without lava.
Shiretoko	2. Sulphur eruptions.
Kusatsu-shirane	3. Crater lake eruptions.
Tokachidake	4. Explosive avalanches with explosive lava.
Ususan	5. Swelling mountain with explosive lava.
Tarumai	6. Explosive jets and rising plug.
Asama	7. Aa lava in crater with explosive jets.
Sakurajima	8. Ruptured mountain flank with aa outflow.
Oshima	9. Fluctuating crater lava and flows.
Minami-iwo-shima	10. Submarine eruptions.
Hakone	11. Subterranean lava movement making earthquakes.

(1) **Bandaisan** in interior central Japan had some solfataras on top of one of its peaks, elevation 1840 meters. July 15, 1888, subterranean roaring began at 7 a. m. and three-quarters of an hour later a gigantic steam blast rushed out at these solfataras and engulfed or threw out about half of this particular peak, avalanching 1700 million cubic meters of rock down the northern foot of the mountain, leaving a horseshoe crater 1 km. wide, 400 m. deep, and open to the north like a quarry with rushing steam in its bottom. The process dammed a river and made a lake. If there were fragments of new lava, they were in small amount.

(2) **Sulphur eruption.** In the eastern part of Hokkaido, the north island of Japan, Shiretoko-Iwo-san is a volcano of active solfataras where sulphur was mined. August 9, 1889, at 1 p. m. an explosion in a solfatara threw out sulphur both as blocks and liquid, forming a craterlet 40 m. long. The activity decreased at the end of two weeks, leaving a lake of boiling water, but sulphur production augmented. The next year on June 15, boiling water was thrown out. The accumulating and melting of sulphur coupled with geyser action influence such eruptions; the liquifaction temperature of sulphur is 114.5° C.



North side of Asama Volcano, central Japan, showing the great aa lava flow of 1783 and the fuming crater in the background. After Omori.

(3) **Crater lake eruptions.** Kusatsu-Shirane is a volcano 2,162 meters high in central Japan with three circular crater lakes and hot gases, amid sulphur mines. In July 1897 there were earth tremblings, a steam blast occurred in the middle of the largest lake and continued to mid-August. There were similar outbursts in 1900, 1902, and often between 1905 and 1925. Such eruptions in crater lakes are not rare in Japan. An explosive paroxysm of subterranean gas burst through Noboribetsu crater lake in southeast Hokkaido in the spring of 1927. The lake shows a temperature of 50° C. on the surface and 133° C. at the bottom. This place contains melted sulphur.

(4) **Explosive avalanches.** Tokachidake is a volcano in central Hokkaido 2,077 meters high with fumaroles so active that sulphur could be extracted from the fume by condensing it. Explosions began December 23, 1925, and culminated in two blasts May 24, 1926, upsetting the western half of a solfataric hill and causing it to avalanche down so as to leave a crater 130 by 300 meters and 50 meters deep. On May 25 a new sudden explosion threw up fresh lava and was accompanied by an earthquake, the scoriae falling on the avalanche debris. The activity waned except for renewed explosions September 8 and 10 ejecting high-temperature ash. Asosan in Kyushu and Kirishima are similar volcanoes beginning eruption by ejection of old rocks, ending with red-hot scoriae, this last phase continuing for a long time and declining gradually.

(5) **Swelling mountain.** Usu Volcano of elevation 725 meters in southern Hokkaido lies between the sea and a volcanic depression containing Lake Toya. After numerous earthquakes in 1910 it cracked along its flank for three kilometers, developed 45 explosive craterlets, and lifted a hill 700 meters long and 200 meters wide to a height of 100 meters (Volcano Letter No. 302). The lapilli thrown out were of new lava, and it is conceived that an intrusive mass of magma was pushing its way like a lens outward and upward, and by occasional recession permitting ground water to fill voids and turn to steam.

(6) **Rising plug.** The activity of Tarumai was described in Volcano Letter No. 317. This volcano also is in Hokkaido, is 1023 meters high, and after 15 years repose sent up a steam blast in 1909 with increasing violence for three months accompanied by the rise of 20,000 cubic meters of lava that formed a dome. This dome was quite like the andesite domes of Bogoslof, described in the last Volcano Letter (No. 322). The dome was 134 meters high, and several explosive outbursts have traversed it since April, 1917.

(7) **Lava in crater and gas blasts.** Asama Volcano in central Japan is the type, a big cone 2,542 meters high, much like Vesuvius, and in 1783 one of the greatest eruptions in the history of Japan spread volcanic detritus and ashes over a large area, followed by an aa lava flow. In recent years, between 1910 and 1915, and again 1919-23, the crater bottom welled up slowly by accumulation of new lava and there were repeated explosive eruptions proportional in frequency to the pulsations of rising of the lava. After big eruptions the bottom lava sank. There was a new eruption in September 1929.

(8) **Lava outflow from mountain flank.** Sakurajima is the type, described in Volcano Letter No. 308. This volcano is a peninsula in Kagoshima Bay at the south end of Japan and stands 1,060 meters high. It was shaken by earthquakes for two days in January 1914, then great cauliflower clouds arose, and two stiff, blocky lava flows of andesite poured from newly formed craterlets on both sides of the mountain. The volume of lava was estimated at 1.56 cu. km., the explosive materials 0.62 cu. km., and the area covered with lava 23.73 sq. km. The lava flowed for several months and the effusion ended gradually with weak explosions in the craterlets.

(9) **Crater lava and flows.** The volcano Miharayama,

755 meters high, constitutes the island of Oshima in Sagami Bay southwest of Yokohama. It had eruptions from 1912 to 1923 just before the Tokyo earthquake. In 1912 explosions of incandescent scoriae began in the central crater, in April it was filled with lava, in July its central part lowered 30 meters, in September pahoehoe lava poured up filling the crater by mid-October, fed by a cone of scoriae just as at Vesuvius at present. Then the lava field sank, on May 15, 1923 a Strombolian steam eruption occurred; thereafter the crater bottom rose and this was followed by a sinking and active border fissures in 1915. Lava eruptions were repeated in 1919, 1920, and 1923. In January of 1923 the lava field in the crater rose, with a cone 40 meters high standing upon it. Then there was a lowering, followed by the Tokyo earthquakes which had some of their epicenters close to Oshima. As shown by the changing pattern of the pit, the lava activity of Mihara is more like Kilauea than most Japanese volcanoes.

(10) **Submarine eruption.** In the ocean to the south of Oshima extends a line of volcanic islands. At Minami-Iwoshima a small island was built up after detonations and uprush of fume for 20 days in 1904. This was December 5, and in February 1905 the circumference was 5 km. and height 150 m. The cone was crowned with a crater of 120 m. diameter. It was eroded away soon after June 1905. In 1911 the water there was 400 m. deep, but on January 25 after two days of explosions a new cone arose, similar to the former one, and this had disappeared by June 1915. There were other eruptions along this line of the Ogasawara islands, making banks of pumice in 1906 and 1915.

(11) **Volcanic intrusion.** As a last stage in manifestation of magmatic energy, the Hakone Volcano, 1,439 meters high, near the beautiful lake of the Miyanoshita district so much visited by tourists, has been the scene of many earthquakes. Disastrous ones have occurred in the last few weeks. They were numerous in 1917, and also this district was terribly shaken by the great Tokyo earthquake of 1923. It lies on the Fuijyama volcanic zone. The earthquakes at Hualalai in Hawaii in 1929 marked another case of volcanic energy underground.

Professor Tanakadate shows analyses of lava from all these volcanoes, with silica increasing from No. 9 to No. 1, alumina decreasing, and decrease also in iron, magnesia, and lime. In other words the series is more basic the greater the fluidity of the lava. T.A.J.

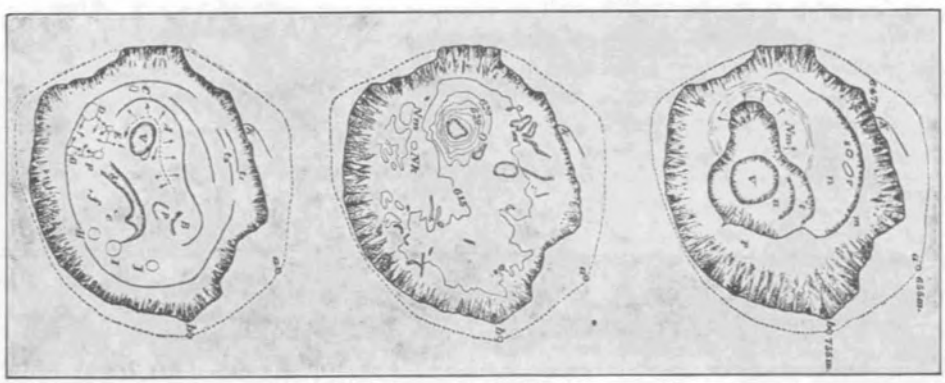
KILAUEA REPORT No. 997

WEEK ENDING MARCH 1, 1931

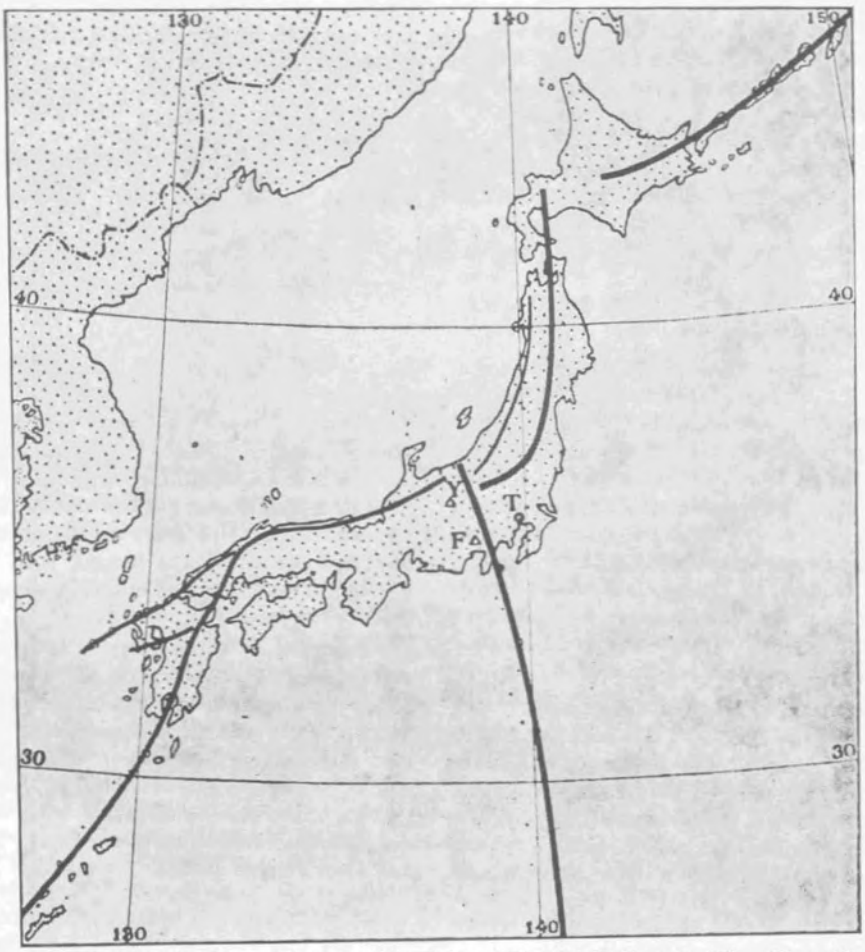
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On February 23, 1931, no changes were observed at the pit Halemaumau of Kilauea Crater, the pit seismograph showed no tremors, and the tilting of the ground at the pit since the activity of November 1930 has been very gradually away from the center. It has never shown backward tilting toward the center such as would happen if the lava column subsided. On February 26 after heavy rain there was much steaming on the new crater floor near the cone of 1930 and some of the sulphur spots were somewhat washed away. Two spots on the northwestern part of the new floor appear to be fuming with blue sulphur smoke, the one in puffs and the other continuous, first observed on the afternoon of February 25.

Observatory seismographs have registered 25 tremors, one feeble local earthquake, and two very feeble ones, the distances shown being 9 and 11 miles from the station. Tilting of the ground was moderate to the south, a direction seasonally expectable at this time of the year. As a whole however this seasonal tilt has been delayed, as though upward pressure away from the volcano had been maintained here since December. Microseismic motion has been almost absent.



Three maps of the crater pit of Mihara Volcano in Sagami Bay near Tokyo. North is at the right. Right-hand sketch is the summer of 1907, in the middle is shown the condition of January 1, 1913, and on the left the block lava, terraces, spatter cones, ditches, pits, and fuming holes of 1916. After Tsuboi.



Map of volcanic rifts of Japan with Tokyo (T) and Fujiyama (F). The rift extending southeast underlies from north to south Asama, Hakone, Oshima, and Minami-Iwo-shima. The rift at the left underlies Sakurajima and Aso-san. The rift at the extreme northeast underlies Usu, Tarumai, Tokachi, and Shiretoko. Shirane and Bandaisan are over the rift north of Tokoyo. After Omori.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildinks, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Lorrin A. Thurston, President; Frank C. Atherton and Walter Dillingham, Vice-Presidents, L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

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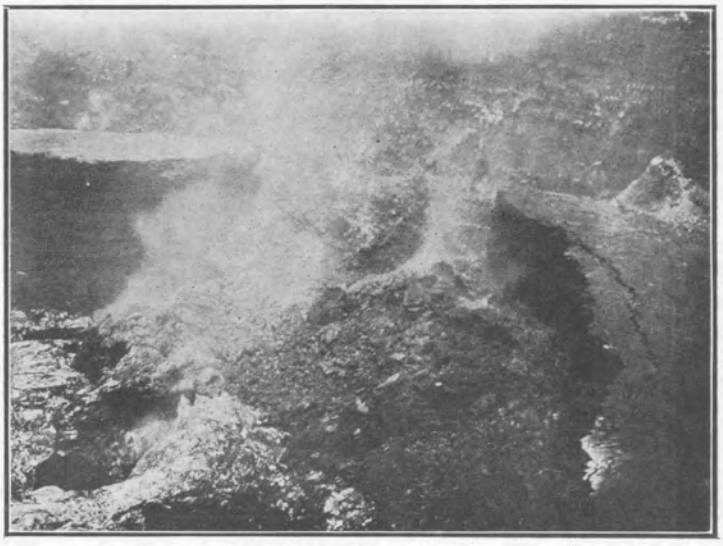
No. 324—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | March 12, 1931



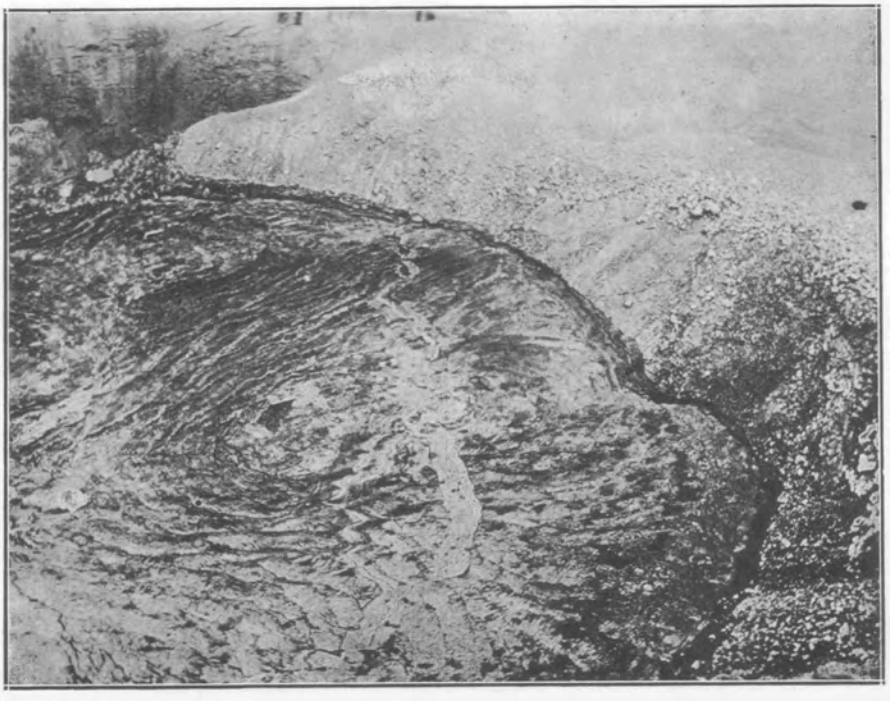
Looking down into the pit about noon on the day of the great subsidence of June 5, 1916. The east bench had collapsed, and a small island was shown to have a large extension of its mass under the lake which toppled over sideways as the lake sank. This is shown on the left. Bench cracking on the right.

WHEN THE PIT LAVA SINKS

In another number of the Volcano Letter (No. 291) the flooding action of boiling slag rising into Halemaumau pit was reviewed. Gas effervescence was shown to be the impelling agent. The question was asked, "Is the sinking of lava a reversal of the process that makes it rise?" The rising process is dependent on expansion and combustion of gases in the slag, a foaming up along with extra heating. It was shown that the foaming depends on release of pressure that otherwise confines gas in solution. Deep pressure is maintained by the weight of the accumulated mountains of lava, and these in turn are supported by blocks of the crust of the earth believed to rest on a substratum of basalt. Release of pressure is attained by periodic or occasional yielding of fault blocks of the mountain, or yielding of the crust blocks of the globe. The mountain is a strained heap of lava we call a volcano. The straining of the crust of the earth is complicated with the trigger-pulling forces of the tides, the atmosphere, and of the sun, moon, and earth.

When the lava subsides in Halemaumau pit, there are several explanations, and they may all apply at different times. If the slag loses its gas the remaining glass shrinks, and if the glass crystallizes underground, it shrinks still more. It changes from a foam to a rock. If a flank of the mountain opens a deep crevasse, or a fault block thousands of feet deep slips a little toward the sea, the lava which has been standing in the pit may drain away into an underground fissure. If a crust block of the earth hundreds of miles long and 30 miles deep moves ever so slightly by some tidal breathing of the globe, with its equatorial protuberance, its northing and southing of the sun, its fluctuations of the moon, its approach and recession to the sun in its orbit, and with the possible but unsolved mysterious relations of sunspot periods to magnetism and gravitation, it is likely that an increased pressure on the substratum would quickly show itself by a lessening of gas at the relatively tiny lava column represented by the pit.

The loss of gas and reestablishment of deep pressure to make the lava column recede should be gradual. The opening of the mountain to drain the lava into a crack, or through a fissure out to a submarine lava flow should be rapid. The diminution of gas, followed at other times by its increase, owing to astronomical controls, should be periodic and rythmical. The actual movements of the lava column when it subsides have suggested all three of these processes at different times; in 1912 there were striking quarter-yearly changes from high to low as though equinox and solstice were in control. Again and again a period of about three weeks has been observed from one sinking spell to the next. Earthquake frequency has shown a similar periodicity. From 1914 to 1917 during general rising of the lava there was a systematic series of risings and fallings with each complete wave about eight months long, each rising higher than the one before, and each sudden sinking lower than the one before. There were similar movements punctuated by sudden sinkings between 1917 and 1924. And in 1919 a critical investigation gave evidence of a daily tide in the lava.



New pool of lava in the bottom of Halemaumau November 30, 1919, after subsidence, looking southeast. The lake was rising very rapidly and the talus at the right turned out to be a ring crag of the bench magma which has subsided November 28, developing within two weeks into the ring island (Volcano Letter No. 282).

The sudden sinkings are accompanied by marked increase in numbers of local earthquakes. Four specially conspicuous ones were in 1916, 1919, 1922, and 1924. The first two were immediately after a lava flow from Mauna Loa, as though the sinking back of the lava in that volcano tended to drain Kilauea. The last two accompanied times when Kilauea itself tended to make lava flows, in 1922 a visible outpouring at the chain of craters, in 1924 a probable outpouring under the sea to the east. We may conclude that sudden subsidences justify the suspicion that the mountain mass has opened somewhere and created a true hydrostatic drainage of the lava. The seismical proof of this is illuminating. Earthquakes are few during the rising. They come in swarms during the sinking and in 1916 they showed Mauna Loa distances on the seismograms in May, and much shorter distances as though Kilauea Mountain were breaking on June 5.

On May 21 and thereafter, 1916, lava flows broke out on the southwest rift of Mauna Loa preceded by an explosion of gas and foamy lava high up the mountain May 19. The flows ceased about June 1. Kilauea lava had been rising vigorously for three months until May 25, when it was 265 feet below the rim of the pit. It then turned and lowered a little, and fluctuated until June 5. There was a ring-shaped lake with two islands within a black ledge of overflow. On June 5 the lake started to lower along with the islands, red-hot falls of bench matter from the black ledge crumbled and flowed into taluses around the receding pool of liquid, and finally terrific avalanches of old wall material made purple, white, brown, and black cauliflowers of dust that boiled up from the funnel below. The depression of the lake was 302 feet June 4, 340 feet 8:30 a. m., 380 feet 10:30 a. m., 540 feet 3 p. m., June 5, and 673 feet at noon June 6. There were occasional perceptible earthquakes, but a remarkable feature of the whole cataclysm was the rigidity of the upper walls.

In October 1919 Mauna Loa gave vent to the Alika flow southwest. Some time in November the flowing stopped. On November 28 a sudden, quiet drop of the Kilauea lava column took place amounting to at least 600 feet in a single morning. The subsidence was accompanied by almost continuous light local quaking of the ground, again with distances of origin shown on the seismograms much shorter than those which had indicated a distance of 35 miles or more for the earthquakes of Mauna Loa a month previously. It was as though the sinking back under Mauna Loa had brought the full force of the lava column to bear upon splitting open Kilauea, and then after filling the split by drainage, the lava column began to rise under Kilauea. The same thing had happened in 1916, for a very rapid Kilauea rise had followed the June subsidence. Now in December 1919 the rising in Halemaumau amounted to 30 feet a day after the drop of 600 feet mentioned above. This continued until in mid-December the rising wedge split the mountain clear to the surface, and the Kau Desert flow of Kilauea built up the slag heap Mauna Iki.

The 1922 subsidence in Halemaumau was so exactly parallel in its happenings to these two subsidences which had accompanied the termination of Mauna Loa eruptions, and the occasion of the subsidence was so clearly a Kilauea outflow accompanying a splitting open of the deep mountain mass, as to contstitute a proof that the connection between Mauna Loa and Kilauea need no longer be doubted. With each flow from Mauna Loa, the Halemaumau

subsidence followed; with each flow from Kilauea, the Halemaumau subsidence preceded.

The liquid lava May 13, 1922, was less than 50 feet below the rim of Halemaumau. By May 21 the lake level had dropped 300 feet with a steady but majestic sinking carrying down peaked crags, lava lakes, and adjacent floors. Avalanches from crags and walls were numerous. Swarms of earthquakes were registered by the seismographs. On May 26 began spells of general caving in of the pit wall, sending up cauliflower clouds of brown and salmon color, and making a thunderous roar. This continued for two days, and the pit was greatly enlarged. A swaying earthquake about 8 p. m. May 28 heralded the appearance of bright glow over Makaopuhi Crater nine miles away in Puna. A crack in the side of this pit, on the Chain of Craters rift line leading from Kilauea, was vomiting up the lava stolen from Halemaumau by the splitting open of the mountain along the rift. Cascades poured from the top of the talus in Makaopuhi and made a pool in the bottom. This flowing dwindled, but a new eruption broke out in Napau Crater farther east and in the upland beyond for two days, showing that the rift was splitting open eastward.

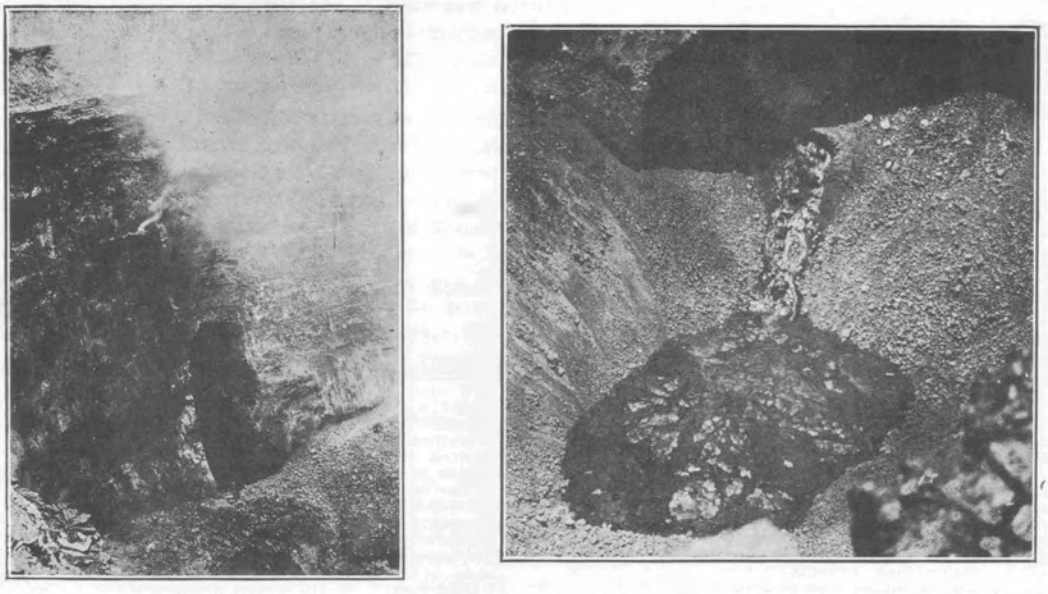
This underground wound healed, the lava rose in Halemaumau, and again it lowered suddenly and split the eastern rift with outflow in the forest near Makaopuhi in August 1923. Then the rift healed again and by January 1924 an enormous lake of liquid lava filled Halemaumau pit, now 2,000 feet across, to within 121 feet of the rim. Here were pulsations year by year, of this wedging agent, the basalt of the crustal substratum, welling up into the pit, and then splitting open the eastern rift, after the work for the cycle was finished in building at the higher rifts of Kahuku on Mauna Loa, and of the Kau Desert on Kilauea. The final splitting open of the eastern rift was exhibited by cracks in the ground and swarms of earthquakes at Kapoho on the extreme eastern point of the island in April 1924, after the lava in Halemaumau had sunk more than 300 feet.

Then came the grand crash of lava subsidence and engulfment of the walls of Halemaumau in May of 1924, with every episode closely parallel to what had happened in 1922 and 1923 except that the outflowing lava on the rift did not appear above sea level. There could be no question but that it did flow out a few miles beyond the east point of the island under the deep cold water of the Pacific. Each incident of breakage of the island mass 1919, 1920, 1922, 1923, and April 1924 had been farther downhill, and eastward from Mauna Loa to the sea. The swarms of earthquakes and their distances on the seismograms plainly told the story of the splitting open of the eastern rift in the depths of the mountain mass. There was added the episode of steam explosion, (the great cataclysm of 1924), then the lava rose and appeared 1300 feet down Halemaumau in July 1924, and the system entered into repose. T.A.J.

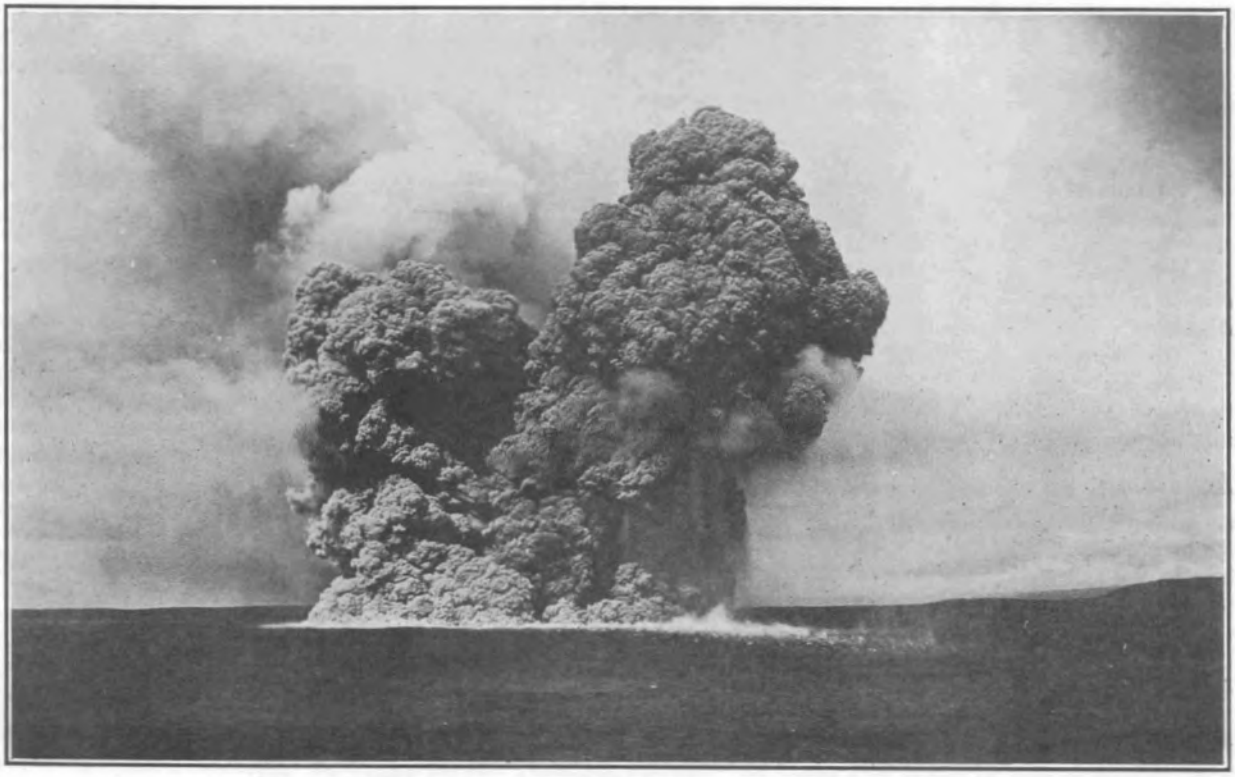
TILTING OF THE GROUND FOR FEBRUARY

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the direction given.

February	2-8	0.36 second	ESE
February	9-15	1.21 seconds	WNW
Feburary	16-22	1.31 seconds	SSW
February	23-March 1	1.74 seconds	SSW



The left-hand cut shows southwest wall of Halemaumau May 25, 1922, when the great subsidence had revealed a tunnel on the Kau Desert rift line through which the lava had flowed in 1920. The right-hand picture is the bottom of Halemaumau July 17, 1922, when the lava returned through a cup at the top of the talus slope pooling in the bottom. Photos Jaggar.



Halemaumau from Volcano House, 8:15 a. m. May 22, 1924, showing cauliflower cloud of one of the paroxysms of explosion and engulfment with bowlders bombarding the Kilauea floor. Photo Tai Sing Loo.

KILAUEA REPORT No. 998

WEEK ENDING MARCH 8, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Very slight fuming continues in the bottom of Halemaumau. New debris material was seen at the southeast edge of the floor on March 2, and on the 7th rocks were heard falling from the north rim. The pit is otherwise quiet.

A total of 19 seismic disturbances were recorded on the instruments of the Observatory during the week, as follows: 16 short tremors; 2 very feeble seisms, one at 9:04 a. m. March 7 originating 32 miles from the station; 1 slight shock at 6:53 a. m. March 8, 30 miles distant, felt in Hilo.

Tilt for the week accumulated slight NW. Microseismic motion was slight.

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The Volcano Letter

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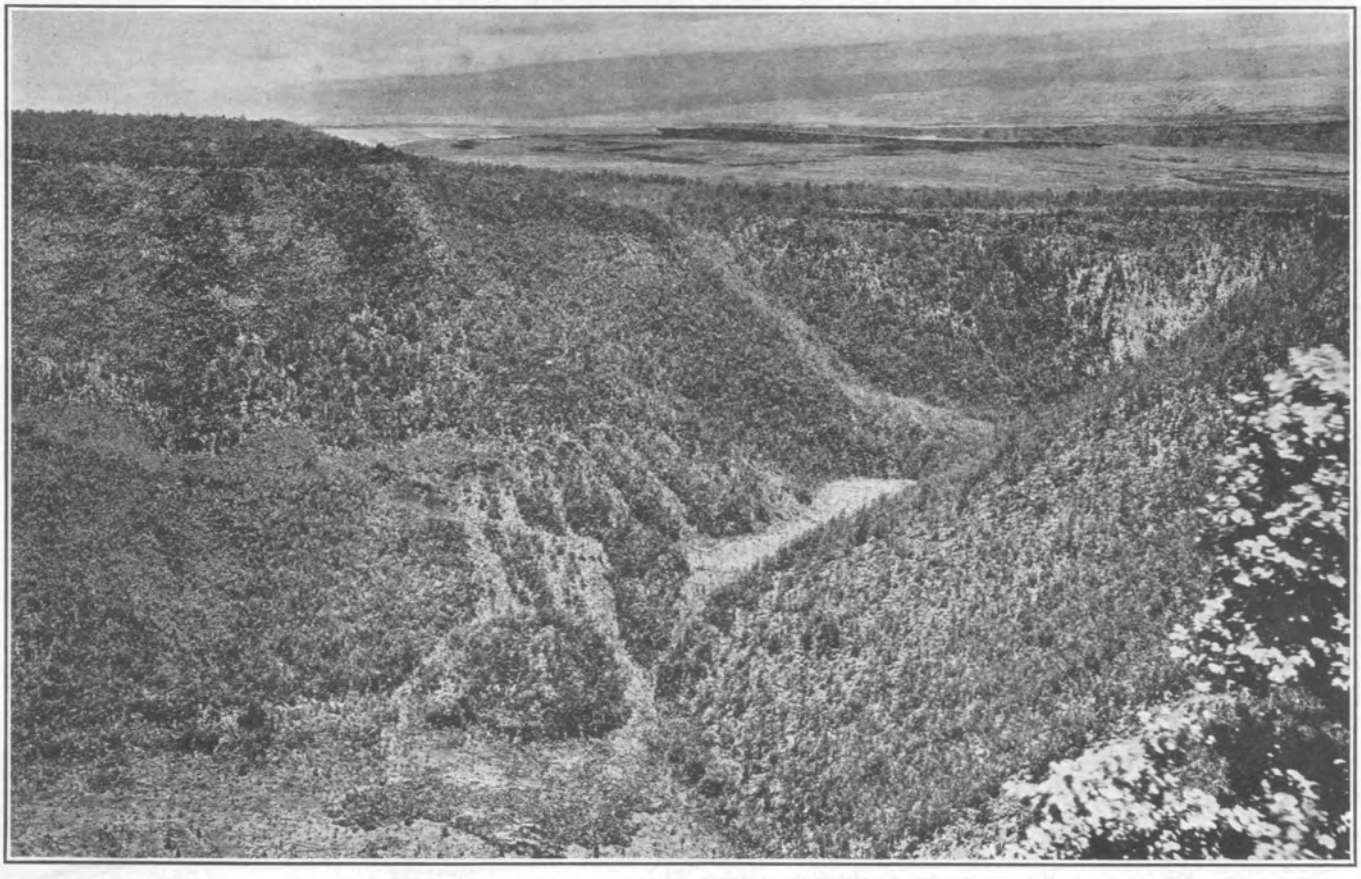
No. 325—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — March 19, 1931



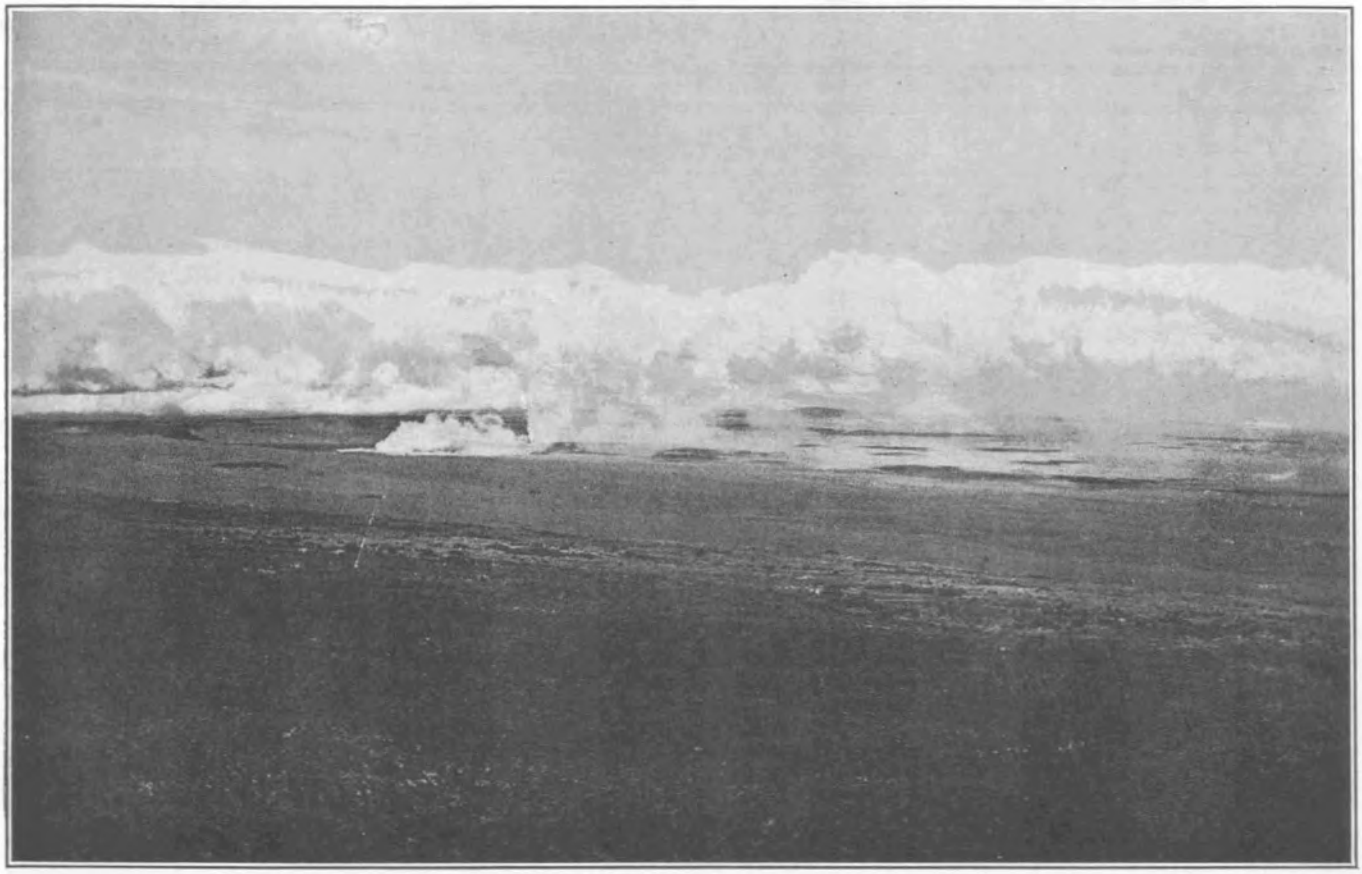
Looking across Kilauea Iki and Kilauea craters. The 1832 flow broke out on the ledge between the two. The 1868 flow made the frozen cascades shown. Photo Wilson.

THE HAWAIIAN VOLCANIC CYCLE

The summary of 20 years of Hawaiian eruptions in Volcano Letters Nos. 319 and 320, and the account last week (Volcano Letter No. 324) of the somewhat systematic repeated sinkings of the lava in Halemaumau pit from 1916 to 1924, naturally suggest to the reader the inquiry, "What can be made out of the sequence to suggest a definite cycle of accumulation and release of lava gas?"

William Lowthian Green (Vestiges of the Molten Globe, Honolulu, 1887), and more recently Wood (On Cyclical Variations in Eruption at Kilauea, Second Report of the Hawaiian Volcano Observatory, Cambridge, Mass., 1917), have commented on possible periodicities of 7 years, 9 years, 18.6 years, 65 years, and 130 years, and Wood has also suggested a semi-annual variation, or a possible variation during a term of about 14 months. Astronomical causes have been suggested. The possibility of a 9-year period, or roughly a decade, involving both Mauna Loa and Kilauea, became more and more plain after the Hawaiian Volcano Observatory was founded. The history of a century and a quarter from the end of the 18th century to 1925 strongly suggested a long term between explosive eruptions, here recorded about 1790 and in 1924, and a maximum volume of lava flowing (1855) in the middle of the term.

When we talk about cycles it is well to have a definite idea of what we mean. What was said in Volcano Letter No. 324 of the weight of the mountain bearing on one body of lava, of the weight of crust blocks of the earth bearing on a substratum of lava, and of the globe as a whole warping under the pull of the sun and moon, involves at least three possible units of volume to heave and sink, to be compressed and be released, and so to produce three different orders of magnitude of eruptive cycles at the same group of vents. It is thus entirely possible at the Hawaiian volcanic system, involving both Mauna Loa and Kilauea, to have a shorter cycle of puffs of the engine, so to speak, about 11 years long; and this superimposed upon a much longer cycle about 132 years long, at the end of which the engine opens its safety valve and produces a prolonged steam blast. Just this, to put the matter in round numbers, is the theory of cycles on which we are working at present, and if it is true, then the 12 episodes of 11 years each from 1792 to 1924 should approximately cover twelve similar eruptive periods of Mauna Loa and



Looking down on Kilauea, with Halemaumau smoking from 7000 feet elevation on Mauna Loa. Photo. Wood.

Kilauea combined. And if the 132-year cycle is itself made up of prolonged accumulation and release, then its first half for 66 years might well be expected to show increasing lava flow with perhaps some logical geographical sequence from Kilauea to Mauna Loa, and its last half should show decreasing lava flow with a progress to lower levels from the top of Mauna Loa downward past Kilauea to the east. It is also conceivable that the quarter period of 33 years may have some significance, for it happens that 1823, 1855, and 1894 produced extraordinary crises of eruption, the first and last on Kilauea, and the middle one on Mauna Loa.

Now let us examine the individual eleven-year cycles:

For the cycle 1781-1792 we know only that a lava flow in Puna east of Kilauea is reported for 1788, and that a major steam-blast eruption killing natives occurred at Kilauea about 1789-90, marking the end of one of our assumed supercycles approximately 132 years long. We thus begin a new supercycle.

The cycle 1792-1803 (end of each year named) involves report of a Puna lava flow 1793, and the very exceptional events which occurred on the west side of the island, lava flows from Hualalai Volcano in 1800 and 1801, the former at Huehue and the latter at Kaupulehu.

The cycle 1803-1814 we know nothing about, except that mariners reported fume continuing at Hualalai, and it is even said that fume was seen near Molokini west of Haleakala. Kilauea was presumably piling lava into its crater.

The cycle 1814-1825 was certainly a time of construction by lava up-building in Kilauea Crater, for the early missionaries after 1823 found a black ledge around the crater not covered with the debris of 1790. Therefore this was post-1790 lava. The year 1923 produced a tremendous breakdown in Kilauea, with the Keaiwa flow into the ocean below Pahala and low crater levels for two years thereafter.

The cycle 1825-1836 was a time of great activity and rising in Kilauea, a remarkable eruption on Byron's Ledge with lava flowing into Kilauea Iki and over the cliff into Kilauea Crater in 1832, a flow for three weeks on the top of Mauna Loa the same year, and a Halemaumau breakdown followed by recovery. Here is our first mention of Mauna Loa since 1790, and it will be seen that for 40 years the outpouring of lava had been from low levels in Kilauea and Hualalai.

The cycle 1836-1847 begins with Kilauea dull and unmentioned, then follows a rising to "terrific" effervescence there in 1840 and a breakdown with outflow far to the east in Puna, the lava reaching the sea at Nanawale. Kilauea pit recovered but slightly when Mauna Loa again took part, making a big northern flow piling a huge volume of lava in the saddle between Mauna Loa and Mauna Kea.

The cycle 1847-1858 involves the most tremendous flooding of lava which occurred in the nineteenth century. There were over 400 days of lava flow from Mauna Loa between 1851 and 1855. This was led up to by a dome forming over Halemaumau 1848, fluctuations of Kilauea activity until 1854, excessive flooding of Kilauea Crater in 1855, and lowering thereafter. Mauna Loa had outbreaks in 1849, 1851, 1852, and 1855, the last flowing for 13 months toward Hilo.

The cycle 1858-1869 is the beginning of the decline, showing 307 days of flowing lava, but is still characterized by enormous flooding from Mauna Loa. Kilauea was quiet, but Mauna Loa in 1859 made a big flow for seven months into the ocean in North Kona. Then Kilauea revived, the lava in Halemaumau rose and overflowed, the summit crater of Mauna Loa broke out for four months 1865-66, and in 1868 came a startling crisis with flows into Kilauea Iki, a world-shaking earthquake, a big breakdown of the

Kilauea floor, and outflows for the first time from the southwest flank of Mauna Loa, with a small outflow southwest from Kilauea. These events were accompanied by landslips, tidal waves, and shore lowering.

The cycle 1869-1880 was distinguished by great flooding of Mokuaweoweo, the summit crater of Mauna Loa, at the very top of the volcanic system. Kilauea recovered to low levels, then Mokuaweoweo was reported active in 1871, 1872, 1873, 1874, 1875, and 1876. Kilauea came to an overflowing with great activity in 1874, broke down and recovered in 1875, fluctuated and erupted at the small pit Keanakakoi in 1877. In that year Mauna Loa produced a submarine eruption in Kealakekua Bay on the west side of Hawaii. Then Kilauea built up crags and lakes and overflows with a collapse in 1879 followed by recovery.

The cycle 1880-1891 like the preceding produced more than 200 days of lava flowing, with Kilauea hard at work building up its floor until 1886, when it reached a crisis of breakdown. Mauna Loa in 1880-1881 produced the great flow that almost destroyed Hilo. Again in 1887 Mauna Loa had a short-lived but voluminous southern flow, Kilauea recovered and reached a breakdown in 1891.

The cycle 1891-1902 was distinguished by a great decline in numbers of flow days (only 37), yet there was activity in Mokuaweoweo in 1892 and 1896 and a northern flow from Mauna Loa in 1899. Kilauea increased its crateral activity to immense floods in 1894, when it broke down completely and remained dormant or very dull for 13 years. There is good reason to think that Kilauea had an outflow under the ocean.

The cycle 1902-1913 was marked by summit crater activity of Mauna Loa in 1903 and a flow to the southwest in 1907, only 28 flow days in all. Kilauea revived in 1905, reached very high effervescence in 1910 and 1912, and then lowered to a dormant year.

The last cycle 1913-1924 had somewhat higher flow duration, 71 days, and was the concluding cycle of the supercycle that led to the Kilauea explosive eruption of 1924. The lava pressure was marked by a steady climb of the lava in Kilauea fire pit from 1914 to 1919, and a pulsating subsidence with outflow from 1919 to 1924. Meanwhile Mauna Loa was active on the summit in 1914, and on the southwest flank with increasing floods in 1916 and 1919, but all small as compared with 1855. Kilauea exhibited increasing breakdowns until the grand crisis of 1924 when the east point of the island sank, Halemaumau exploded and probably there was submarine outflow. T.A.J.

KILAUEA REPORT No. 999

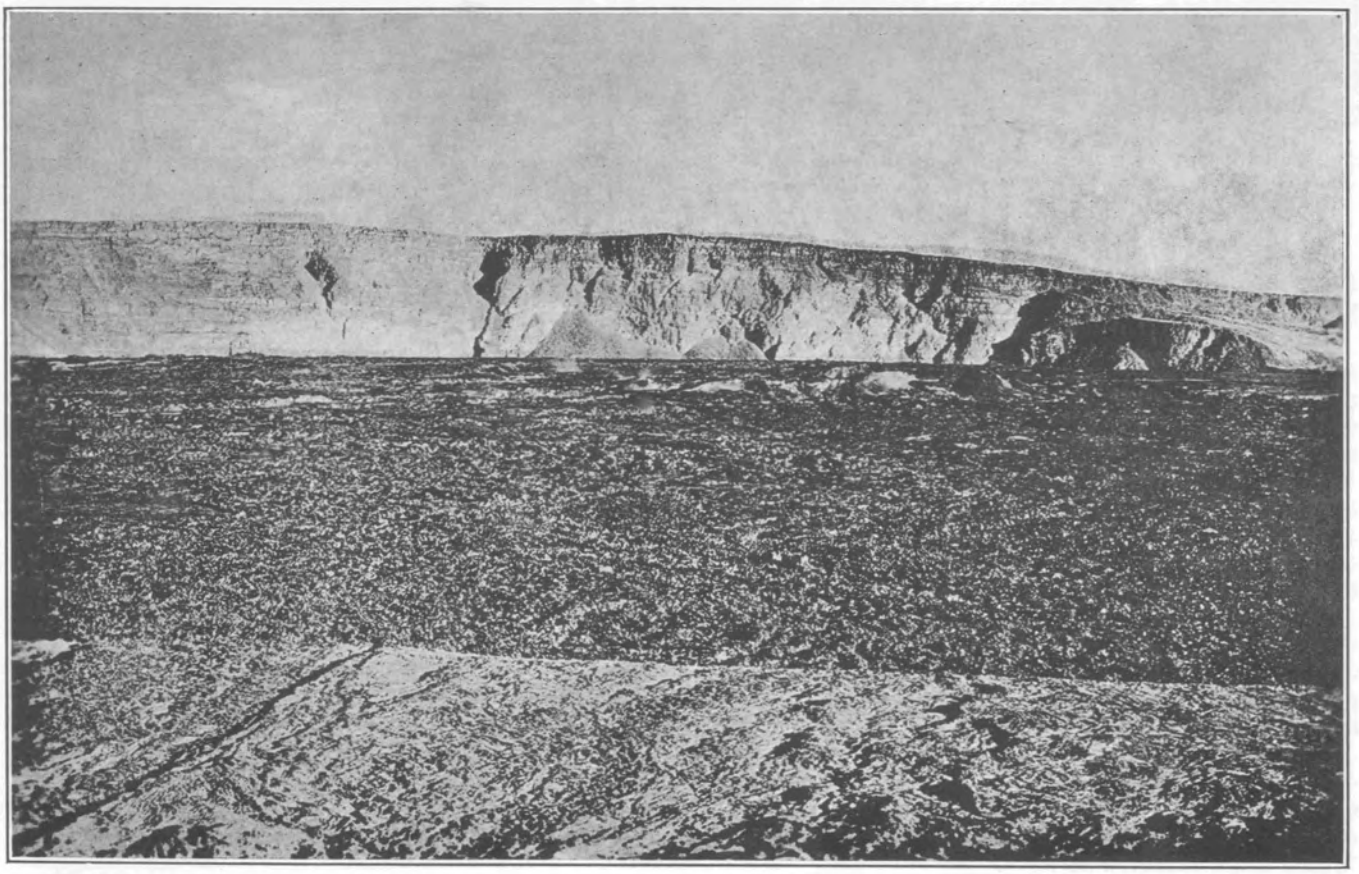
WEEK ENDING MARCH 15, 1931

Section of Volcanology, U. S. Geological Survey

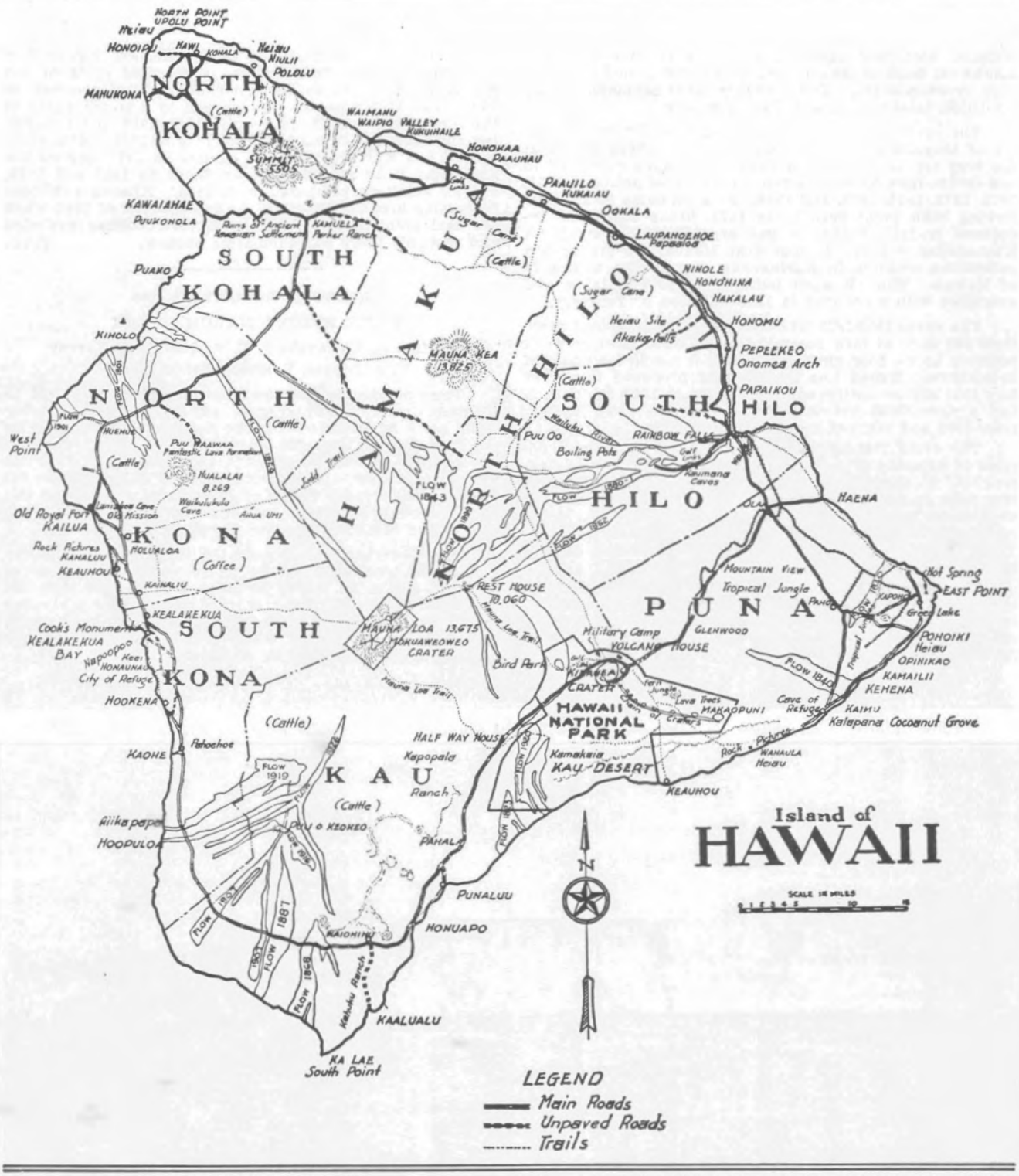
T. A. Jaggar, Volcanologist in Charge

The only noteworthy features of Halemaumau pit in Kilauea Crater which suggest any change are sulphur spots north and west of the cone that was left standing on the lava floor of 1930. These spots on March 12 were observed to be fuming steadily. A small slide was observed at the southwest. The seismograph at Halemaumau indicated rather rapid tilting of the ground away from the pit between February 28 and March 3, and a gradual accumulation of tilt away from the pit at other times.

The Observatory seismographs registered 34 tremors during the week and 3 very feeble local seisms, one of these at 4:43 a. m. March 14 being accompanied with tilt to the southeast. Tilting of the ground was otherwise moderate SSW, and microseismic motion was very slight. The fluctuation of tilting within a few days was strongly marked during the first half of March.



West wall and floor of Mokuaweoweo, the summit crater of Mauna Loa. Photographed 1915 by Wood.



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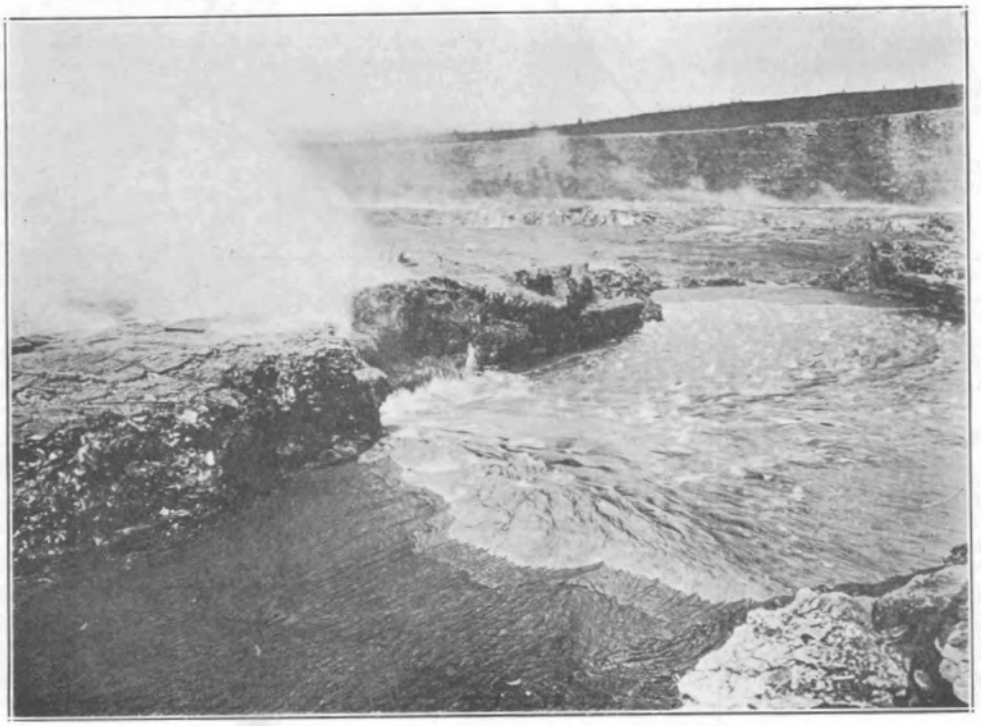
No. 326—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — March 26, 1931



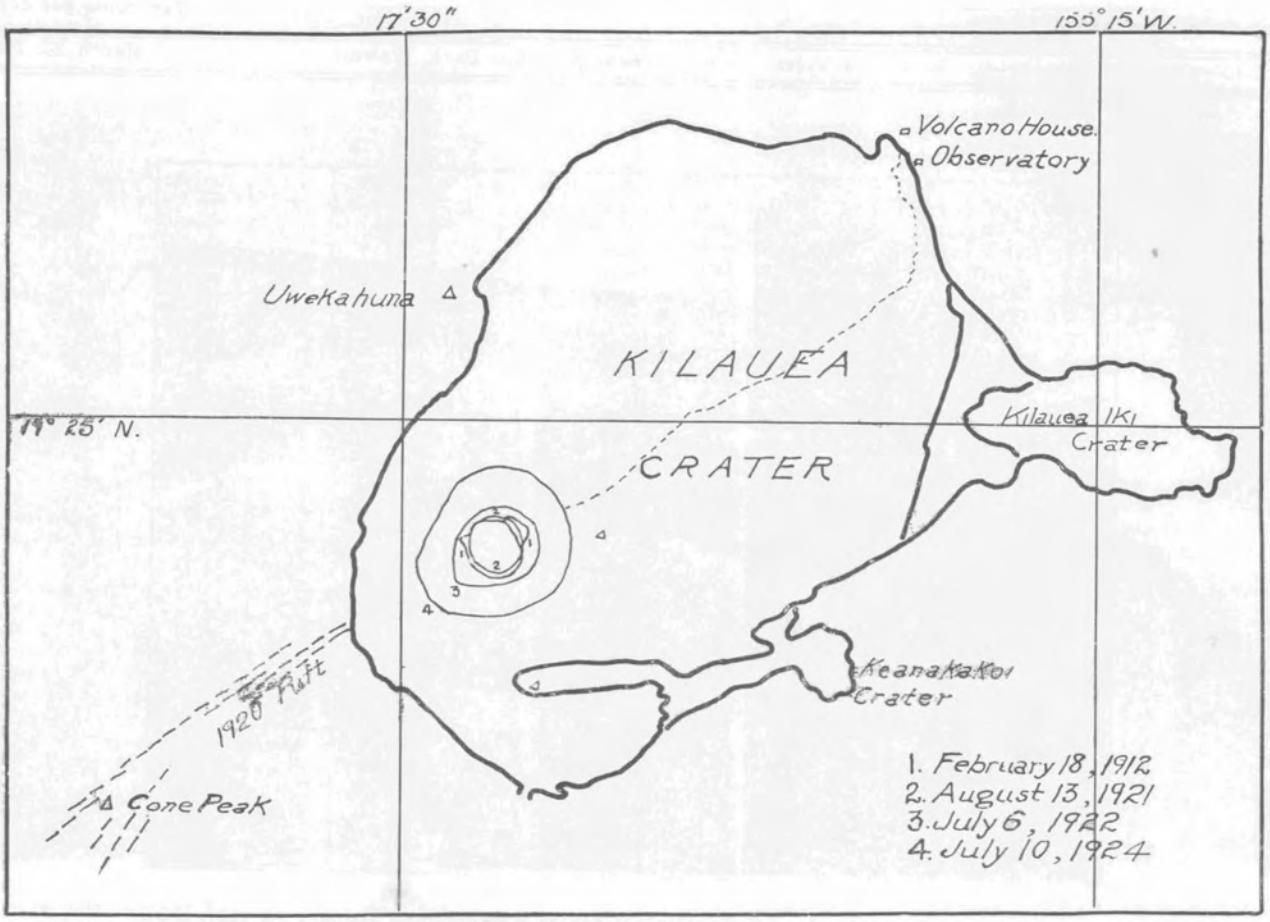
A high level in the cycle. Looking northwest across Halemaumau January 23, 1921, showing the rush of surface currents of bubbling lava into a grotto. Shows the fuming surface of the half solidified lava column, and in the background the Halemaumau wall and the Kilauea wall. Photo Jaggar.

VOLCANIC CYCLES AND SUNSPOTS

In the Volcano Letter Nos. 172 and 302, some notes are presented concerning a general similarity between curves of frequency of sunspots and of frequency of volcanic eruptions. Students of this subject who have taken the volcanic eruptions of the whole earth have published contradictory results, some finding more eruptions and some finding less eruptions for the time of sunspot maxima. Sapper found that gigantic volcanic explosions sometimes correspond with either high or low numbers of sunspots, but his curve shows a number of good correspondences between eruption frequency maxima and sunspot minima. For the period between 1790 and 1825, when sunspots were notably infrequent, volcanic eruptions were unusually inconspicuous.

Confusion in attempting to compare statistics is bound to result if such a word as "eruption" remains undefined. To take the great lava-flooding cycle of Kilauea 1913-1924 as an example, the peak of the lava pressure was 1919 when both Mauna Loa and Kilauea were vomiting floods of slag. This was also a time near sunspot maximum of frequency. To the layman, however, or to the ordinary geological traveler, the crisis of "eruption" was 1924 when Kilauea made tremendous steam explosions. And this was the time of sunspot minima. Which was the "eruption" of the decade for the statistician of the textbooks?

This leads us to examine critically the list of eleven-year cycles for Hawaii cited in last week's Volcano Letter, and to ask, "What are the distinguishing features of a cycle?" Probably Mercalli in his Italian book on "Active Volcanoes," and with his many years of experience as an observer of Vesuvius, hit the nail on the head when he said that the most distinctive feature of a volcanic cycle is the short repose period at its end. And this repose is often initiated by explosion, so as to be called "eruption" popularly. It is only on volcanoes such as Vesuvius and Kilauea, where the magma is visible most of the time, that these repose periods become striking. It is only when we can see the repose period in contrast to a high pressure period that has preceded, that we recognize its existence. If the high pressure has asserted itself by intrusion under a dormant volcano, seemingly always in repose except for a sudden explosion which goes unexplained, nobody will know about it. There may be a tide of flux and flow in the underground magma which has lifted the mountain and let it down again, but nobody has measured it. The sudden explosion may be the let down, as it certainly was at Kilauea in 1924. It is clear that even for the well recorded



Map showing successive outlines of Halemaumau pit in the southwest part of Kilauea Crater during a cycle. (1) Pit of 1912 with niches northeast and west. (2) Smaller pit of 1921 after nine years of building up. (3) Larger pit of 1922 after the first big collapse. (4) Very large pit of 1924 after steam-blast eruption and breakdown.

century of Hawaiian events, the only cycles that will bear intimate analysis are the recent ones where the descriptions are full.

The first reason for adopting eleven years is that this figure exactly fits the carefully observed cycle between two times of complete repose in 1913 and 1924 at Kilauea. The second reason for approving eleven years is by trial and error; if we apply nine, ten, twelve, or thirteen years as possible cycles for the events between 1790, the last great explosive eruption, and 1924, the newest one, none fits so well the division based on recorded repose periods as the number eleven. The third reason for approving eleven years as a cycle is that if we divide the 134 years from 1790 to 1924 into twelve cycles, we get 11.1 years as the average for each cycle, and each group of about three cycles leads to an unusually big crisis of lava breakdown or subsidence. And a reason for taking an interest in the sunspot analogy is that 11.1 years have been found by astronomers to stand for the average interval between sunspot maxima.

If we take the cycles at Kilauea and Mauna Loa immediately preceding the 1913-1924 period, we find 1902-1913 beginning and ending with complete repose, exhibiting Mauna Loa lava first in the summit crater and four years later pouring out of the south flank, and Kilauea lava rising to repeated maxima with effervescence and then sinking away. We find 1891-1902 beginning and ending with complete repose, exhibiting Mauna Loa lava twice in the summit crater and fianlly pouring out of the north flank, and Kilauea lava rising to a tremendous maximum so as to break the mountain and drain off. We find 1880-1891 following a repose in 1879 and leading to one at the end, exhibiting Mauna Loa lava twice in the summit crater and then pouring out of both the north and the south flanks in discharges six years apart; Kilauea builds up its floor with one of the greatest pressures of its history and then executes a series of breakdowns. These histories accord with the eleven-year cycle as a time of stress followed by a time of release, and with the conception that this cycle commonly involves both Mauna Loa and Kilauea as outlets for the same lava column. The details of sequence vary to such extent as the breakage of the island varies in yielding to the internal stress. The remarkable feature of these histories is that in spite of the incompleteness of the observations, there is such striking accord in showing two repose periods separated by an intervening high pressure period for both Mauna Loa and Kilauea.

Now when it comes to sunspots, let us keep in mind Mercalli's principle that the breakdown, whether it be explosive and conspicuous or not, begins a repose period, and the short repose or low period is the important punctuation mark in the cycle. The following two tables serve to compare low level quiet times in Hawaii with years of minimum numbers of sunspots:

Low Levels Hawaiian Lava	Sunspot Minima
1924 End of supercycle	1924
1913 Quiet year	1913
1902 Quiet year	1901
1891 Kilauea breakdown preceding great drainage of 1894	1889
1880 Follows Kilauea breakdown, starts Mauna Loa floods	1878
1869 Follows big breakdown both mountains	1867
1858 Quiet year following greatest lava floods of history	1856

1847	Quiet year	1843
1836	No mention in records, therefore quiet	1833
1825	Quiet year after great drainage of Kilauea 1823	1822
1814	Unknown	1810
1803	Quiet time following Hualalai outflows	1797
1792	Repose following supercycles crisis of 1790	Declining Sunspots

In these tables the Kilauea years are at arbitrary regular eleven-year intervals beginning at 1924 and going backward, and it will be seen that for this century the intervals between sunspot minima where notably longer than eleven years. In most cases if the actual years given in the sunspot column had been taken for the Hawaiian low levels, they would have been as near to the lava breakdowns as the years given in the Hawaiian column, but some of them would have preceded the breakdown instead of following it. If the observational data for Hawaii in the early years were as good as in the later ones, the bends of the Hawaiian curve might match many of the sunspotless years more perfectly. But the volcano record is very imperfect. What this shows is that the repose periods are remarkably systematic.

When it comes to the sunspot maxima, we find them in the midst of the Hawaiian periods of lava pressure, when within a cycle both Mauna Loa and Kilauea were flooding:

High Pressure Hawaiian Lava		Sunspot Maxima
1917-20	Kilauea and Mauna Loa flooding	1918
1903-07	Two flows Mauna Loa and Kilauea rising	1905
1892-99	Three flows Mauna Loa, Kilauea 1894 maximum	1893
1881-87	Kilauea and Mauna Loa big floods	1884
1869-77	Kilauea rising, continuous summit eruption Mauna Loa	1870
1859-68	Three flows Mauna Loa, Kilauea rising, overflowing	1859
1851-55	Mauna Loa maximum, Kilauea maximum	1848
1836-47	Kilauea flood 1840, Mauna Loa flood 1843	1837
1825-36	Kilauea and Mauna Loa floods 1832	1828
1814-25	Kilauea flood 1823, Mauna Loa unknown	1816
1803-14	Unkown, but Hualalai floods 1800-01	1804
1788-93	Probable Kilauea floods preceding 1790 explosions, and two flows reported in Puna	1787

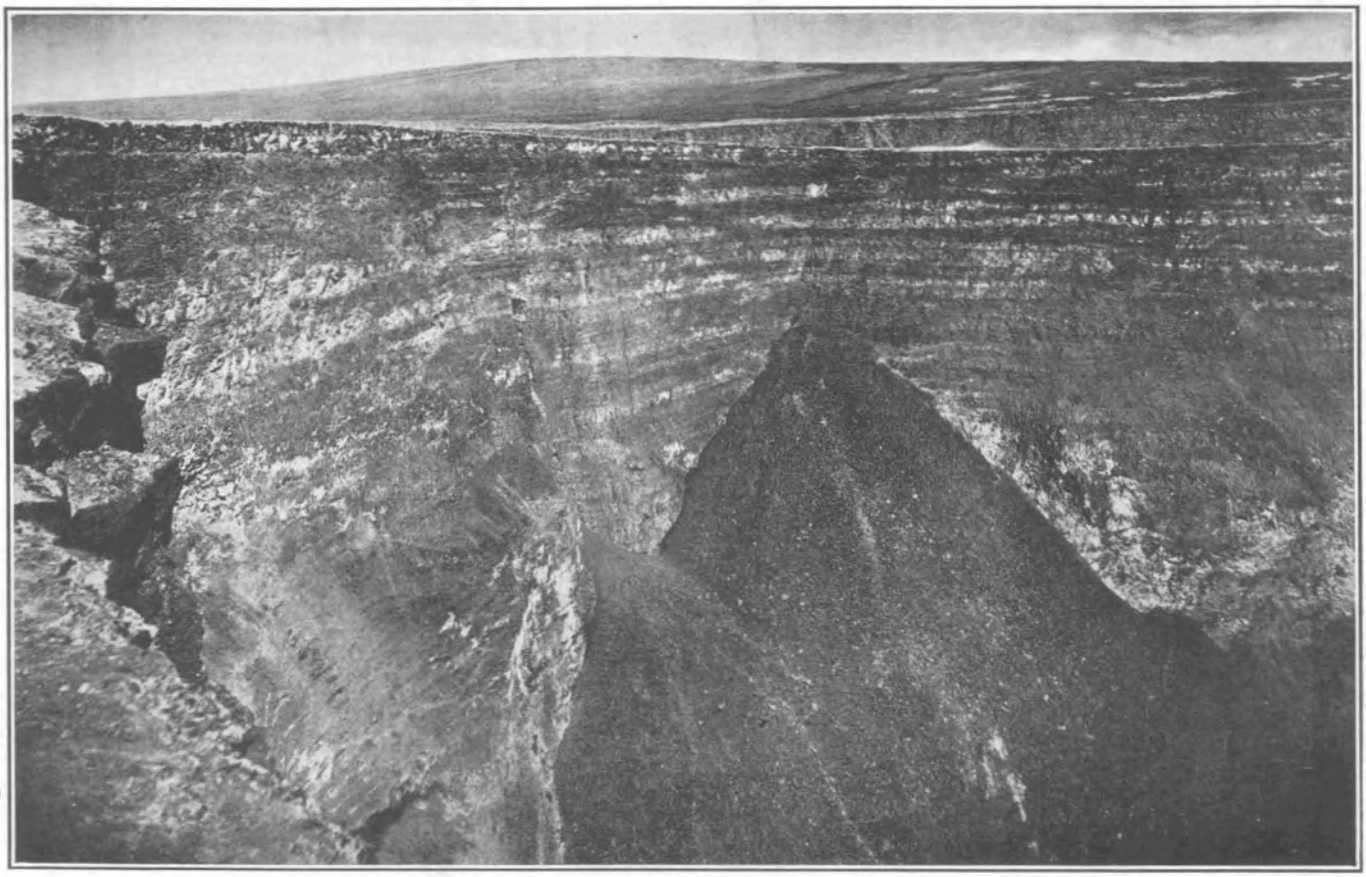
The sunspot maximum exhibited a very long interval between 1787 and 1804, and this was a turning point from high numbers to low numbers of sunspots for the maximum years. It was also the turning point at Kilauea for the supercycle that ended with the explosive eruption of 1790.

Referring to the low numbers of sunspots for some sunspot cycles and high numbers for others, the Humphreys curve (Sapper, Vulkankunde, page 272) shows low values 1790-1820, increasing values 1820-30, very high values 1830-80, declining vaules 1880-1920. The Hawaiian number of flow days roughly figured from existing descriptions was very few 1790-1820, about seven 1820-30, 132 1832-43, 411 1852-55, and then for six eruptive periods from 1859 to 1923 the figures 307, 207, 247, 37, 28, and 71. In other words the flooding of lava in Hawaii to the high maximum in the middle of the supercycle about the year 1855 corresponded to the higher maxima of sunspots in the nineteenth century.

If the reader asks why sunspots should have anything to do with volcanoes, the answer is that nobody knows. Times of maximum sunspots affect radio reception on the earth, magnetism on the earth, and auroras in the arctic regions. Sunspots are accompanied by gigantic eruptions of gas on the sun and colossal electrical phenomena in the solar system. If earth magnetism and electricity are in some way associated with gravity, volcanism may be affected. If heat by the earth's radio-activity affects volcanism, the sun may in turn affect the earth's radiations. Finally, if volcanic emanations on the earth are a last remnant of solar processes here, those processes by unknown means may be sympathetic with the sun. T.A.J.



Looking toward Kau Desert from high bluff west of Kilauea Crater January 3, 1921, when the white glistening flows from Halemaumau were filling the southwest corner of the crater. A maximum of flooding. Photo Jaggar.



Looking west across the vast void of Halemaumau in 1928, after the breakdown of 1924 was complete, showing the distant wall of Kilauea Crater beyond the Halemaumau wall, and still farther away the snake-like flow of 1881 on the smooth dome of Mauna Loa. Photo Wilson.

KILAUEA REPORT No. 1000

WEEK ENDING MARCH 22, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The pit Halemaumau Crater continues very quiet. A slide on the north wall was observed at 3:10 p. m. March 18. Fuming was observed at the two recently developed sulphurous spots on the north side of the 1930 floor the forenoon of March 19, and some rocks were heard falling on the north wall. The pit seismograph indicated two very small tremors about March 15.

The seismographs at the Kilauea Observatory registered a slight earthquake felt at Kilauea, at Hilo, and in Kona at 5:29 p. m. March 20, with indicated distance of origin 28 miles from the Observatory, and strong enough to dismantle the east-west stylus. Very feeble shocks were registered at 3:09 p. m. March 20 and 6:57 a. m. March 16, the last accompanied by tilt to the southeast. Twenty-two local tremors were registered. Weakly recorded distant earthquakes occurred at 10:47 p. m. March 17, at 9:56 a. m. March 18, this indicating a probable distance of origin of 800 miles; and at 8:08 p. m. March 18. Microseismic motion was slight with some increase March 19-20, and tilting of the ground was slight SW.

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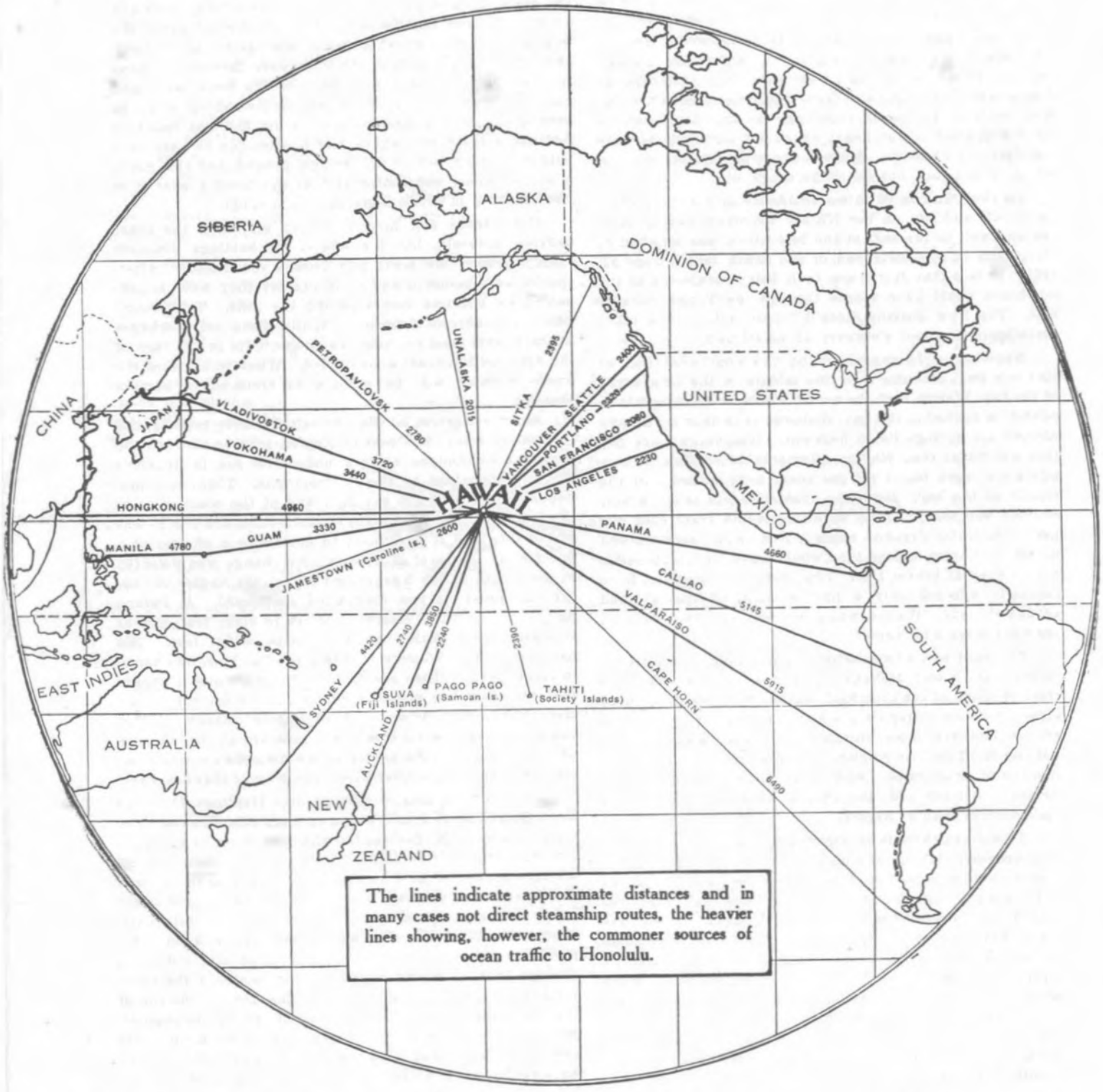


The lines indicate approximate distances and in many cases not direct steamship routes, the heavier lines showing, however, the commoner sources of ocean traffic to Honolulu.

Map of the Pacific Ocean showing New Zealand at the southwest. Hawke's Bay is at the southeastern end of the North Island. Napier is at the southwestern end of Hawke's Bay. This is the eastern border of a continental mass which falls off to deep water east of New Zealand.

GREAT NAPIER EARTHQUAKE NEW ZEALAND

On Frebruary 3, 1931, at 10:47 a. m. local time, a terrific earthquake occurred destroying the cities Napier and Hastings at the southwest end of Hawke's Bay, an indentation in the middle of the southeastern end of the North Island of New Zealand. This had been registered perfectly on the seismographs at the Hawaiian Volcano Observatory with indicated distance 8,040 km. SSW., which checks satisfactorily with the New Zealand location.

Seimographs at the Dominion Observatory in Wellington show that 588 shocks originating in the Hawke's Bay district occurred during February, the after-shocks diminishing more quickly than those recorded after the Murchison earthquake in 1929. For the first day following the initial mark of the heavy shock 151 earthquakes were registered in 24 hours. Most of the after-shocks were not felt in Wellington, but the large shock was.

Hawke's Bay is 60 miles southeast of the Taupo volcanic belt and lies on the NE-SW mountain axis of New Zealand well to the east of the belt which was stricken at Murchison in the north end of the South Island June 17, 1929. In fact that Murchison fault belt if projected to the northeast would have passed through the Taupo volcanic belt. The New Zealand Herald reports official and other investigations about February 21 as follows:

Napier and Hastings are at the southwest end of Hawke's Bay, Mohaka is in the middle of the long curve of the bay, Wairoa is at the north, Mahia is at the northern peninsula enclosing the bay, Gisborne is farther north, and Morere hot springs lie in between. Waipukurau lies farther southwest than Napier. Remarkable changes in configuration were found on the coast near Mohaka in the middle of the bay. Here the coast line has taken a new contour and owing to its uplift, residents state that one may now travel dryshod along a new, wide, sandy beach as far as Napier, a feat that would have been impossible before even at lowest tide. The upheavals, however, have seriously affected only a narrow strip of coastal land around the bay. Wairoa was much less seriously afflicted than Hastings and Napier.

The land was most shattered along cliffs and hills between Napier and Mohaka. Inland a short distance no trace is found of the crumbled hilltops with deeply fissured sides which are conspicucous at the shore. In some of the gorges, however, loose hillsides have fallen away, just as did the Bluff Hill at Napier. In these places the road is blocked or annihilated. Alluvial formations in rivers have subsided and cracked, and this is what happened to the embankment road at Napier.

At Mohaka there is evidence of a strong upthrust. The correspondent felt an earthquake while there, giving the sensation of somebody tapping upward beneath the earth's crust with a huge hammer, and workmen said that was how all the shakes had felt around Mohaka. There was direct evidence of an upward and downward movement. In the hills above the Maori village the floor of an entire valley has sunk at least 50 feet in a crumpled mass. Many of the ridges for miles around resembled newly made fillings, while the main road has disappeared entirely for about half a mile. The most remarkable evidence of the tremendous forces brought into play is seen near the mouth of the Mohaka River. Within a distance of about five miles three new peninsulas have been thrown out from the shore, and there has been a general rise in the level of the beach. Where the river enters the sea a bluff has been shaken down into a heap of dust and clay bowlders.

A huge area of the sea is discolored with the discharge from the river which, after the middle of February, began to overflow a huge landslip dam which had blocked it for about 10 miles inland. Northward there juts out a promontory of what was formerly about 200 acres of pasture, and southward a bluff lies in ruins on one of the longest peninsulas formed by the upheaval. There are several of these upheavals along the coast. On the bluff in question about 160 acres of land were lost, and plants which originally grew just above the water level at the foot of the cliffs, were subsequently found growing near the top of the landslip. This indicates that the hills were thrown out from the base dropping down a block of the back land, and carrying beach shingle, sand, and driftwood up so as to overlap the sunken land behind. A big fish was found 50 feet above the water, shells and flotsam can be seen at a height of about 70 feet on the new ground, and this earth is so convulsed and contorted that the journey over it is like climbing in a miniature mountain range.

Homesteads and farm buildings all along the coast suffered severely, but the effects on buldings diminish rapidly toward the north and toward the interior Aftershocks were common and residents say they were accompanied by booming noises among the hills. They sound like heavy objects dropping. While there are blockages in the rivers, most of them are open except in the case of the uplift of the coast above noted. When rain comes the whole country will be subject to tremendous surface changes.

An investigation by the Geological Survey reports that the main fracture lies east of Napier, passing through the principal earthquake centers under the sea in Hawke's Bay as determined by the seismographs. There is a prounounced uplift of the sea floor and of the coast west of the fracture line. "So many factors influence the height of the tide that it is difficult to determine a change of a few feet in the level of a coast. No change was detected at the mouth of the Ngaururoro River. At Napier the uplift was about six feet decreasing southward. At Petane just to the north of Napier it is six to eight feet, and at Whakaari still farther north, perhaps seven feet. The harbormaster at Wairora is sure there has been no change in level there. These scanty observations make it appear that the coast has arched gently on a northeast line, the crest of the arch being north of Napier. Assuming that the amount of coastal uplift is a measure of the violence of the earthquake, the center of the disturbance was some miles northeast of Napier below the floor of Hawkes Bay."

Napier suffered greater damage than Hastings, Hastings more than Waipawa, and Waipawa more than Wairoa. The report states that fissures in alluvium were remarkably abundant along rivers and in localities where there was no lateral support for filled-in material. In places the ground had stretched 12 feet in a few score yards, water and sewer pipes having been disrupted, and dwellings greatly damaged. The West Shore causeway built across a mud flat area had spread and the roadway split and collapsed through lack of lateral support. The banks of the chief tidal channel had closed in on a bridge, forcing the top of one set of piles from under the ends of the girders supporting a span of the bridge. At many points along the coast shingle beaches had slumped either toward the sea or backward toward the lagoon behind them, and the surfaces were ridged by a series of parallel steps and trenches.

The displacement of alluvium narrowed the river channels, and raised their beds, making it likely that their discharging capacity during floods will be seriously dimin-

ished. During the earthquakes large quantities of water, sand, and silt issued from fissures in the ground. The origin was a water-saturated sand layer below the surface. Land slides were not nearly so prominent as they were in the Murchison district in 1929, where the hills were steeper and the climate wetter. Their distribution showed that they depended largely on local conditions ranging in quality from vast landslips involving many millions of yards of rock to mere downward creep of the soil mantle on the hills. Pressure ridges appear to mark the surface trace of an important earth fracture through the Poukawa Valley extending northeast about six miles. The ground northwest of the fracture is fissured and swollen and that on the southeast side unaffected. It appears probable that the earth block on the northwest side moved. The movement was toward the east. Probably it follows a weak layer interbedded with the strong limestone bands. Probably also, movement occurred along several weak layers. This suggests that the movement was distributed over a zone several miles wide.

An investigation by a government vessel taking soundings for three days north from Napier indicated that the bed of the roadstead had risen in parts from six feet to seven feet, but in places the soundings gave the same depth of water as is shown on the charts. Nothing less than 33 feet of water was found from two miles off shore to half a mile from the breakwater at Napier, the sounding being on the line of beacons leading to the roadstead. The investigations show that the anchorage in the roadstead is just as safe for shipping as it was before the earthquake.

With reference to earthquake-proof construction, the following quotations from a sensible article by Archdeacon K. E. MacLean are pertinent quite as much to other places as to New Zealand. The Archdeacon asks whether sufferers by the earthquake need believe that the disaster was a divine punishment. He cites the case of a man who gets sunstroke by going out without his hat. We are sorry for him, but we say bluntly, "It was his own fault."

"To be quite honest is not our position much the same? We know what earthquakes are. We know a good deal about how and why they happen. We know there are faults in the earth's surface and that the countries near those faults are liable to earthquakes. We know—we always have known—that New Zealand is one of these countries, and that a bad earthquake might come at any time. Yet we came knowing this and lived here and shrugged our shoulders about earthquakes."

"Our fathers, who remembered the earthquake in Wellington in 1855, warned us against brick houses and high chimneys, but the years went by and more and more brick houses and tall chimneys were built, and the years went on and they stood. It was quite possible to build earthquake-proof houses in wood or brick, or concrete, but it was expensive, and we wanted money for other things. It was quite possible to build chimneys in ordinary houses which had not got a tight collar of wood around them at the flashing, but we did not bother."

"It was quite possible to follow sound principles of construction in building shops and offices, but no one cared and no one asked for it. So up went the flimsy, showy walls and the heavy copings. It is not the fault of anyone in particular. Architects, builders, and workmen just shared the common mind and built their own houses in just the same way that they built houses for other people. We are all in this together. It was public opinion that it did not matter."

"Two years ago the Murchison earthquake happened and we said, or nearly all of us said, 'Poor beggars! Come and live in Hawke's Bay and be safe.' And we went on living happily in the death trap we had built. Then, on February 3, the earth wriggled for a minute. The fault settled down a bit more. Who caused the death and suffering? Only if we face this honestly shall we live more wisely in the future."

This wise comment applies equally to all lands around and in the Pacific Ocean. T.A.J.

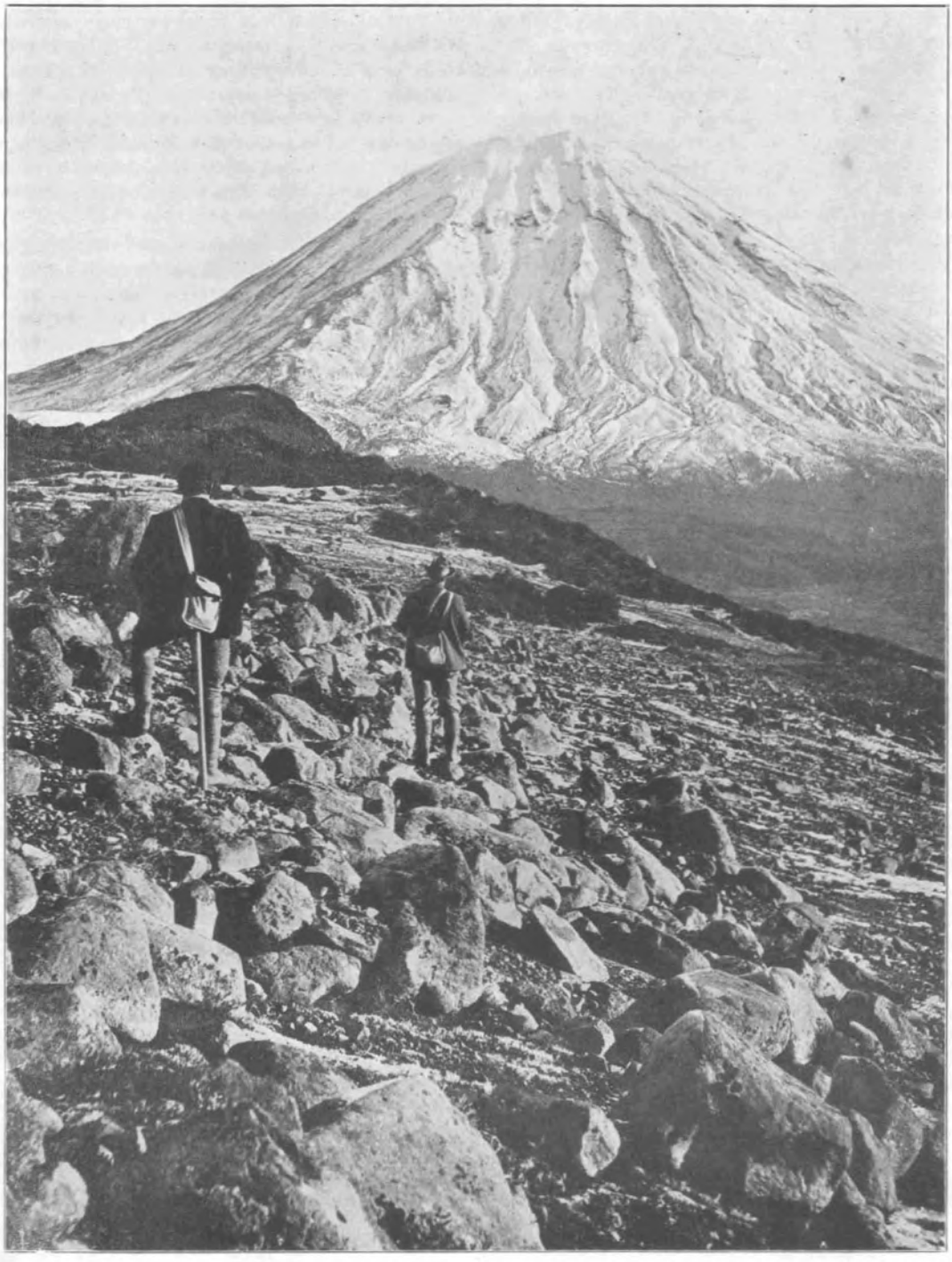
KILAUEA REPORT No. 1001

WEEK ENDING MARCH 29, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

No significant changes have happened at the Hawaiian volcanoes and the fire pit at Kilauea is quiet. Thirty tremors were registered on the seismographs of the Observatory at Kilauea and three very feeble local seisms, one of these at 7 p. m. March 25 indicating origin distance 28 miles, and one at 8:11 a. m. March 29 a distance of five miles. A tremor at 9:05 p. m. March 27 lasted eight minutes. A strong distant earthquake began at 2:21 a. m. March 28 local time (10 hours, 30 minutes slower than Greenwich) and indicated origin distance 8,830 km., apparently WSW. from station, which would locate it near the west end of New Guinea or the eastern part of the Dutch East Indies.

Tilting of the ground was moderate to the south, and microseismic motion was slight for the week.



Ngauruhoe Volcano in the Taupo belt of the central part of the North Island of New Zealand. This shows the volcano as seen in winter from the east, marking the line of active volcanoes which lie 60 miles northwest from Napier.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

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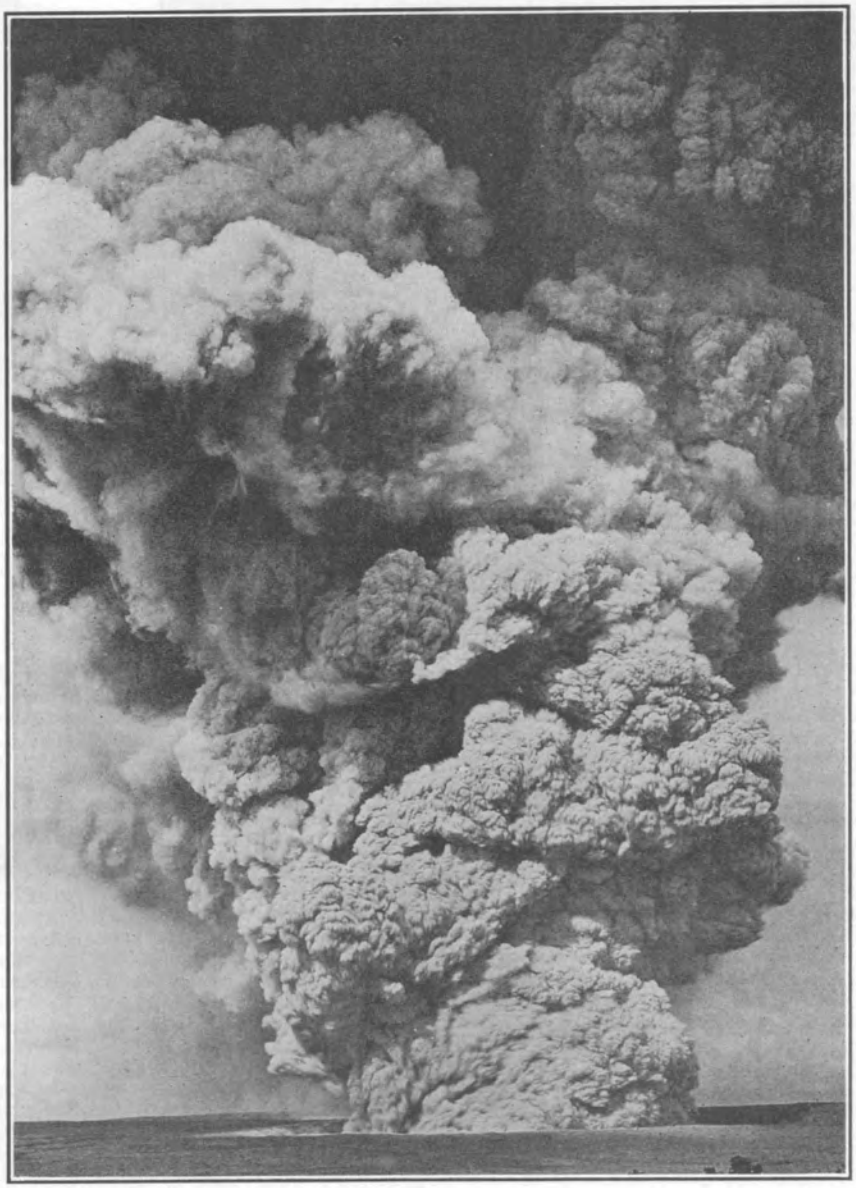


Steam-blast eruption at Halemaumau pit about 8:30 a. m. May 22, 1924, showing tendency to spiral vortex and dark electrical cloud forming above. Photo Tai Sing Loo.

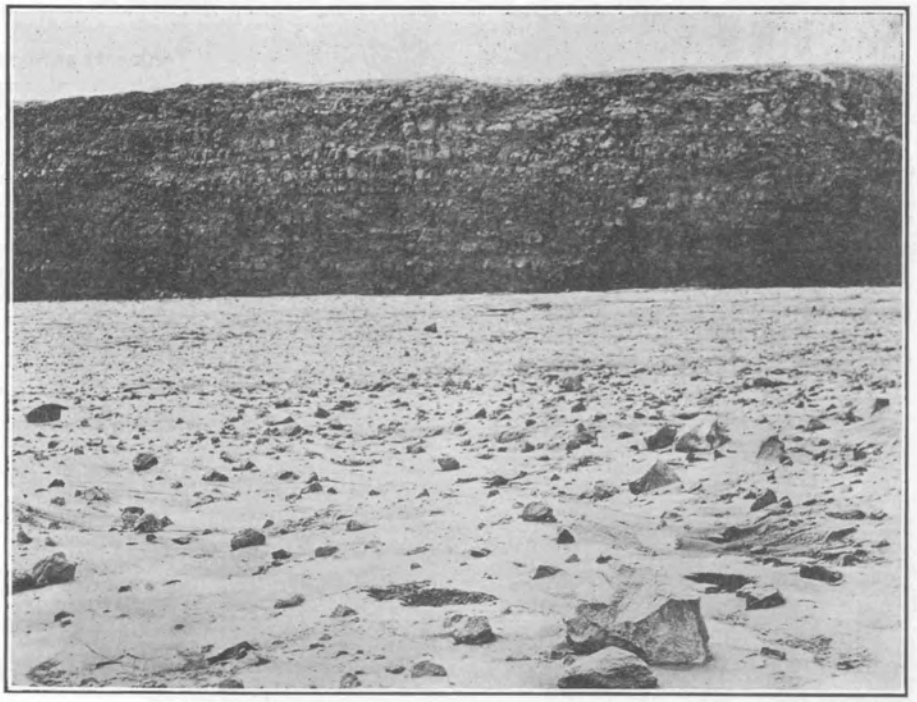
THE GREAT ERUPTION OF KILAUEA IN 1924

Much has been said in recent numbers of the Volcano Letter about the supercycle of 134 years which ended in the tremendous steam-blast eruption of Kilauea in the month of May 1924. The present covering of gravel and bowlders on the lava around the sides of Halemaumau was all thrown out during those three weeks in a series of violent upward jets of steam charged with rocks and sand, something which none of the present generation had ever seen in Hawaii. A much bigger ejection of this kind happened about 1790, and in 1823 there were steam jets that threw up gravel in the lava-flow crack east of Pahala. There are some fragmental stones evidently thrown out explosively around the crater Mokuaweoweo on top of Mauna Loa: no one knows their date.

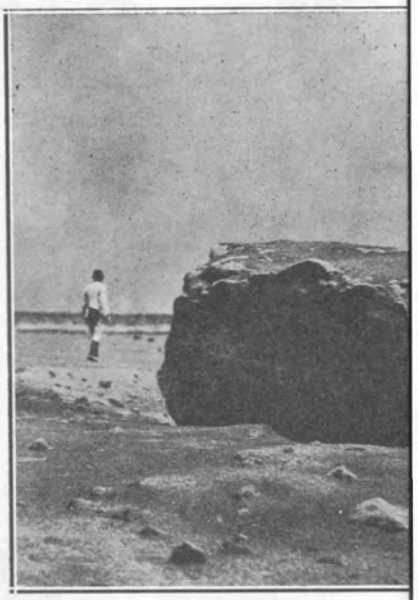
The sequence of events in 1924 was like what had happened in May 1922, when there had been:

(1) Sinking of the lava column.
(2) Great enlargement of Halemaumau pit with avalanches.
(3) Cracking open of the Puna rift to the east.
(4) Southerly tilt and many earthquakes at Kilauea.
(5) Cauliflower dust clouds rising.

What was different in 1924 was the subsidence farther away along the Puna rift (and no lava flow such as had broken out at Makaopuhi in 1922), this occurring in April of 1924 at the east point of the island with lowering of a big block of country, spreading open of cracks, and sinking of longshore vegetation below sea level. Then after the cauliflower clouds had been rising for several days from



Kilauea floor west from Halemaumau May 31, 1924. Shows bowlders and ash covering the lava surface. Photo Emerson.



Eight-ton bowlder thrown 3500 feet May 18, 1924. Photo

huge avalanches tumbling into Halemaumau early in May, people began to notice a booming concussion in their ears, and stones began to be flung up and out, instead of merely falling down and in. The so-called eruption was therefore a gradual growth beginning the end of April with a collapsing bottom of the pit that was not at all unusual, producing ejection of rocks first on the night of May 10-11 that was very unusual indeed, and then exhibiting a series of violent steam blasts, at intervals of several hours, for 10 days following May 13. This crumbled away the edge of the pit so that the former rim migrated back on all sides for 700 feet, as the geyser-like steam blasts accompanied gigantic engulfment of the walls of the shaft. May 24th was the last peak of explosive intensity, and thereafter the new type of activity waned and ended about May 28, with avalanches and earthquakes all that remained, these dwindling during June.

The summary of the 1924 sequence was then as follows:

(1) Sinking of the lava column in March.
(2) Cracking open of the Puna rift far to the east April 22.
(3) Subsidence of a fault block at Kapoho in Puna.
(4) Southerly tilt and increasing earthquakes at Kilauea.
(5) Great enlargement of Halemaumau pit in May.
(6) Avalanches at Halemaumau making cauliflower clouds.
(7) Same cauliflower clouds containing steam blasts upward, May 11.
(8) Engulfment of pit walls in May.
(9) Steam-blast spasms two hours apart May 13, thereafter less often.
(10) Ejection of stones, maximum May 19.
(11) Duration explosive spasms, maximum seven. hours May 19.
(12) Electric storms maximum May 17-19.
(13) Felt earthquakes maximum May 22.
(14) Total earthquake frequency maximum May 24.
(15) Cessation of steam-blast phase May 28.
(16) Glowing intrusive body exposed in pit wall June 12.
(17) Adustment of pit walls June-July.
(18) Liquid lava in pit bottom July 19-31.

The diagram on Page Four shows how these various features waxed and waned between May 10 and May 27, the numbers of explosive spasms taking the lead at the beginning of the eruption and the numbers and intensity of earthquakes dominating the situation at the end of the eruption, when the other features were declining. The conspicuous mud rains accompanied electric storms of the period between May 15 and May 19. The caving-in of the rim of the pit began at the southwest where lay the Kau Desert rift of 1920, and where the enlargement had taken place in 1922. Then the breaking-in of the rim followed around the circle to the south, southeast, northeast, and north until the breakdown was balanced by collapse at the northwest. Then there was more collapsing all around the previous outline of the pit. The greatest engulfment was accomplished during the times of maximum steam blast, maximum duration of spasms, and maximum intensity of earthquakes. The greatest break-down of the walls observed took place May 21-22 when there were incessant avalanches. These were the two days following the explosive maxima.

To give the reader an idea of what happened we may quote from the journal of the Observatory a few items of May 17-18: "A station was occupied during the night May 16-17 on the gravel spit southwest of Keanakakoi. There were explosions at 1:20 and 1:27 a. m., a continuous roar from 2 a. m. on, an avalanche cloud at 2:28 a. m., increased roar 3:19 a. m., and at 3:20 a. m. the noise increased, an explosion occurred, a few red-hot rocks were thrown out southeast from the pit, and one minute later a few came out from the east side. At 3:32 a. m. the cloud had become enormous, the roar was continuous, pisolitic mud began to fall, and at 3:35 flashes were seen in the cloud over the pit. At 3:42 there was a roar lasting four seconds accompanied by a slight earthquake, and by now the cloud had spread out like a fan over almost the entire sky."

This sort of record was maintained for many days at the Observatory, and the seismographs showed tilts, prolonged tremblings, and numerous earthquakes, and required incessant attention restoring the pens to the drums. During the month ended May 31, 1924, 3,961 local earthquakes were registered, the maximum being 467 in 24 hours on May 24. Harmonic tremor appeared on the seismograms April 19, becoming moderate to strong after May 6, and decreasing May 16 so as to become very slight before the maximum of explosive activity was reached May 19. Probably the harmonic tremor was due to lava surging, which had receded to such great depths by May 17 that it



southeast from Halemaumau
Tai Sing Loo.



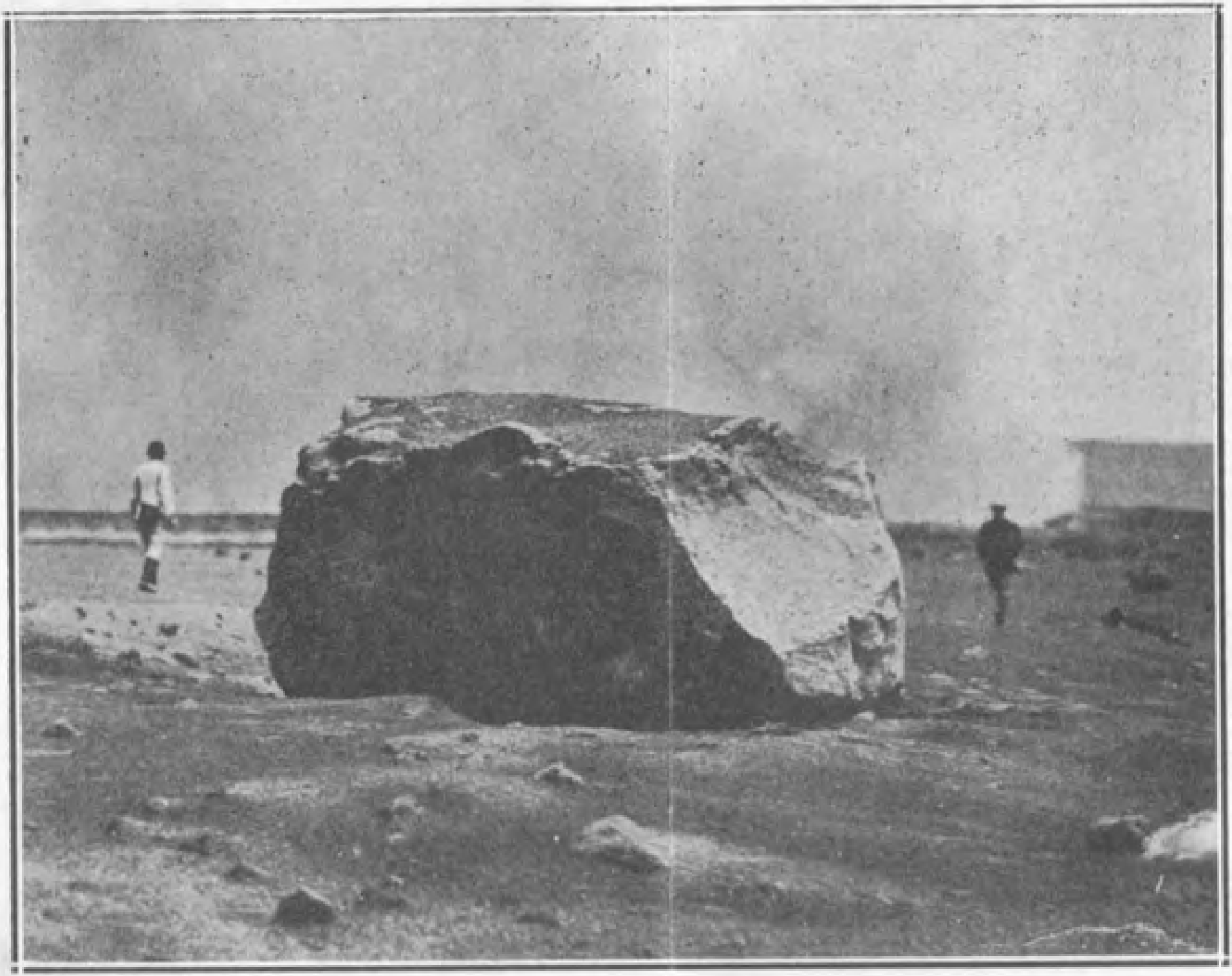
Rill-marked new ash May 29, 1924, south margin of Kilauea Crater. This ash lay over the country like drifted snow, and the rain gullies trench through to the old ash of 1790. Photo Emerson.

did not register. In 1924 the tilting of the ground at the Observatory in a south and southwesterly direction amounted to 88 seconds of arc between January and June, 58 seconds of this was during May, and the most rapid tilting took place just preceding, during, and immediately following the great engulfments and steam blasts. There was no good correlation between the number of earthquakes and the explosion days, true earthquakes increased on days when the steam blasts were inactive, but a peculiar shaking accompanied the explosions which gave long drawn out seismograms that built up gradually, without a preliminary tremor like a true earthquake, continuing for half a minute or so, with a period of 0.5 second, and then died away gradually.

Continuing the journal of May 17: "The pit was visited after 9 a. m. and found greatly enlarged so that rim had gone back 200 feet. Depth appeared over 1,000 feet, bottom was flat and covered with talus material, steam was rising without pressure and creeping across the floor irregularly in small continuous cottony clouds. The upper walls of the pit appeared to slope inward at 60°, approaching verticality farther down, so that the avalanches had a free fall to land with a tremendous crash at the bottom. Often the rocks fell with a pattering sound. The cracks across road 2,000 feet southeast of Halemaumau had widened and there were numerous other cracks between there and the pit. The Kilauea floor near the pit was now covered with bowlders in large numbers, locally extending a half mile from the pit and in places there was at least one fallen fragment for every square foot. Some bowlders weighed several thousand pounds."

"At noon came one of the impressive explosions, causing great consternation among visitors. At 12:02 p. m. came a roaring noise and a big dust cloud, accompanied by a moderate earthquake. At 12:32 p. m. there was a roar with sharp crashing noise lasting 50 seconds, and a very heavy black cauliflower cloud rose, much bigger than the one of the early morning hours. At 12:35 p. m. 15 explosive outbursts rose in the course of 11 minutes, accompanied by continuous roaring, and loud crashes of thunder made frequent lightning flashes very low over the Observatory. Showers of rocks were heard falling heavily. At 12:45 p. m. dust and sand fell for 25 minutes. A visit to the pit after this explosion showed newly fallen hot dust in a thick layer near the rim of the pit which had singed the grass farther away. The only gas noticed in the steam exhaled was a small amount of sulphur dioxide."

"May 18. At 11:07 a. m. began a great culminating explosion with tremendous dust cloud and ejected rocks. At 11:09 there was a second explosion plastering the area northeast of the pit with hot sand for several hundred yards. At 11:20 a. m. there was a steady loud roar and a fall of pisolitic mud at the Observatory. There was an Observatory party near the pit, and during the barrage of 11:09 a. m. Mr. Truman Taylor was fatally stricken down by bowlders and sand on the Kilauea floor about 1,800 feet southeast of Halemaumau. He was rescued, but died after being removed to a hospital. The observers were on the sand flat farther to the southeast and when sitting on the ground one could feel numerous quakes and a rumbling was heard. At the 11:09 explosion came a wave of increased air pressure that was painful to the ear drums. One of the rocks weighing over 300 pounds landed on the 1921 lava of the south embayment of Kilauea Crater, and another bowlder weighing eight tons feil at the landing field, made a deep impact cavity, and broke, the fragments bouncing and partially burying themselves on the side remote from the trajectory. An intense electrical storm followed." T.A.J.



Eight-ton bowlder thrown 3500 feet southeast from Halemaumau May 18, 1924. Photo Tai Sing Loo.

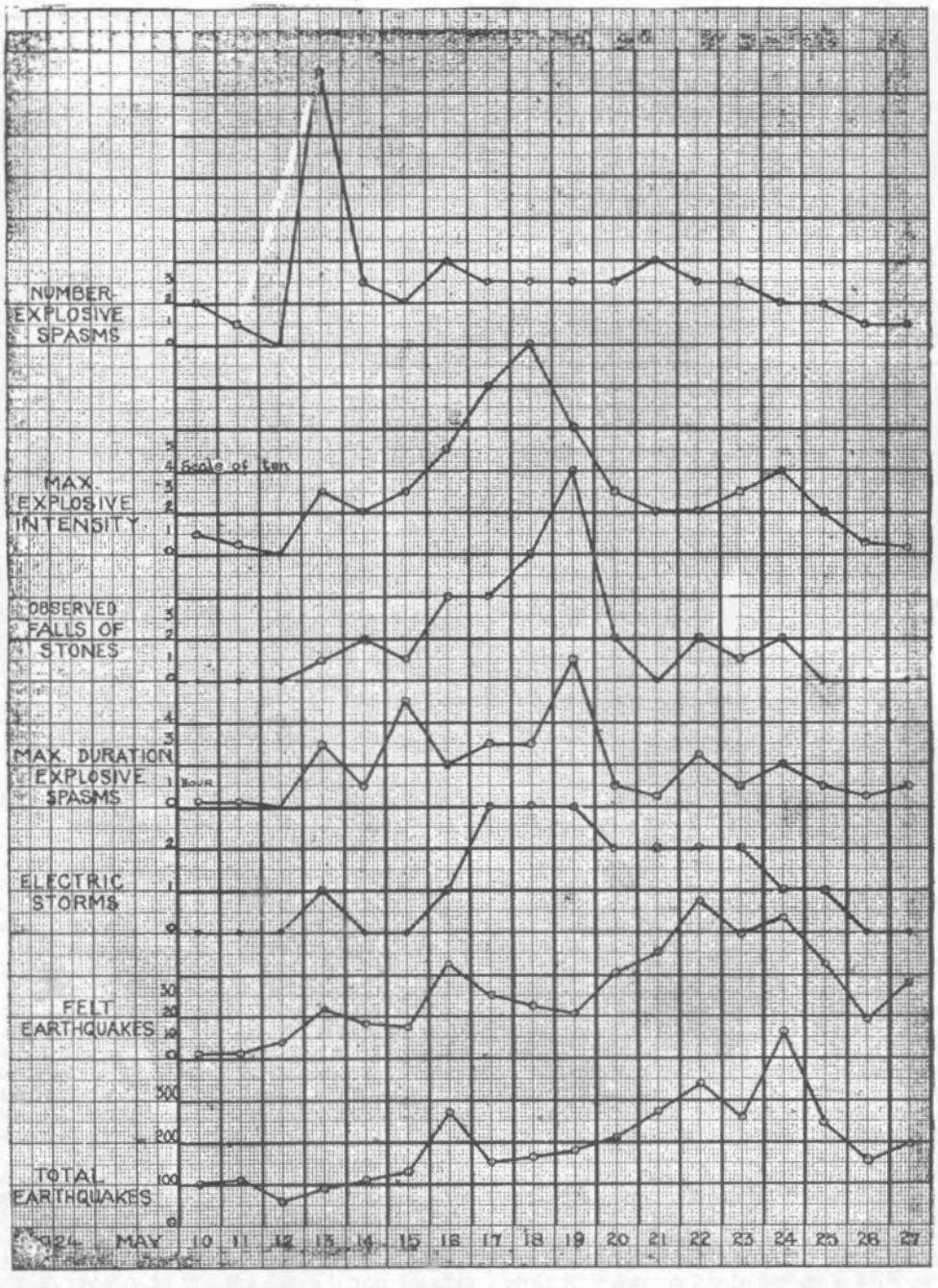


Diagram showing curves of measured activities taken from the tabular summary of the Kilauea steam-blast eruptions May 10-27, 1924.

KILAUEA REPORT No. 1002

WEEK ENDING APRIL 5, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Kilauea remains inactive and without noteworthy changes at the lava pit Halemaumau. There is still steady fume from vents near the north-central part of the pit floor. Steaming has lessened on the south talus.

A peculiar slow-period tremor recorded with more or less regularity on the pit seismograph 4 to 10 a. m. April 2 and again April 4. These were also noted on the instruments at Uwekahuna and the Observatory.

The seismographs at the Observatory recorded an increased number of disturbances during the week. There were 57 tremors, including 5 minutes of continuous tremor April 3 and 20 minutes of continuous tremor April 4; and there were 3 very feeble seisms, and 1 feeble shock occurring at 12:20 p. m. April 4. Phases of the last indicated 32 miles distance to origin. In addition on April 5 a very weak teleseism recorded at 8:30 p. m.

Tilt for the week was moderate to the south. Microseismic motion was moderate March 30 and 31 and at other times slight.

The Volcano Letter

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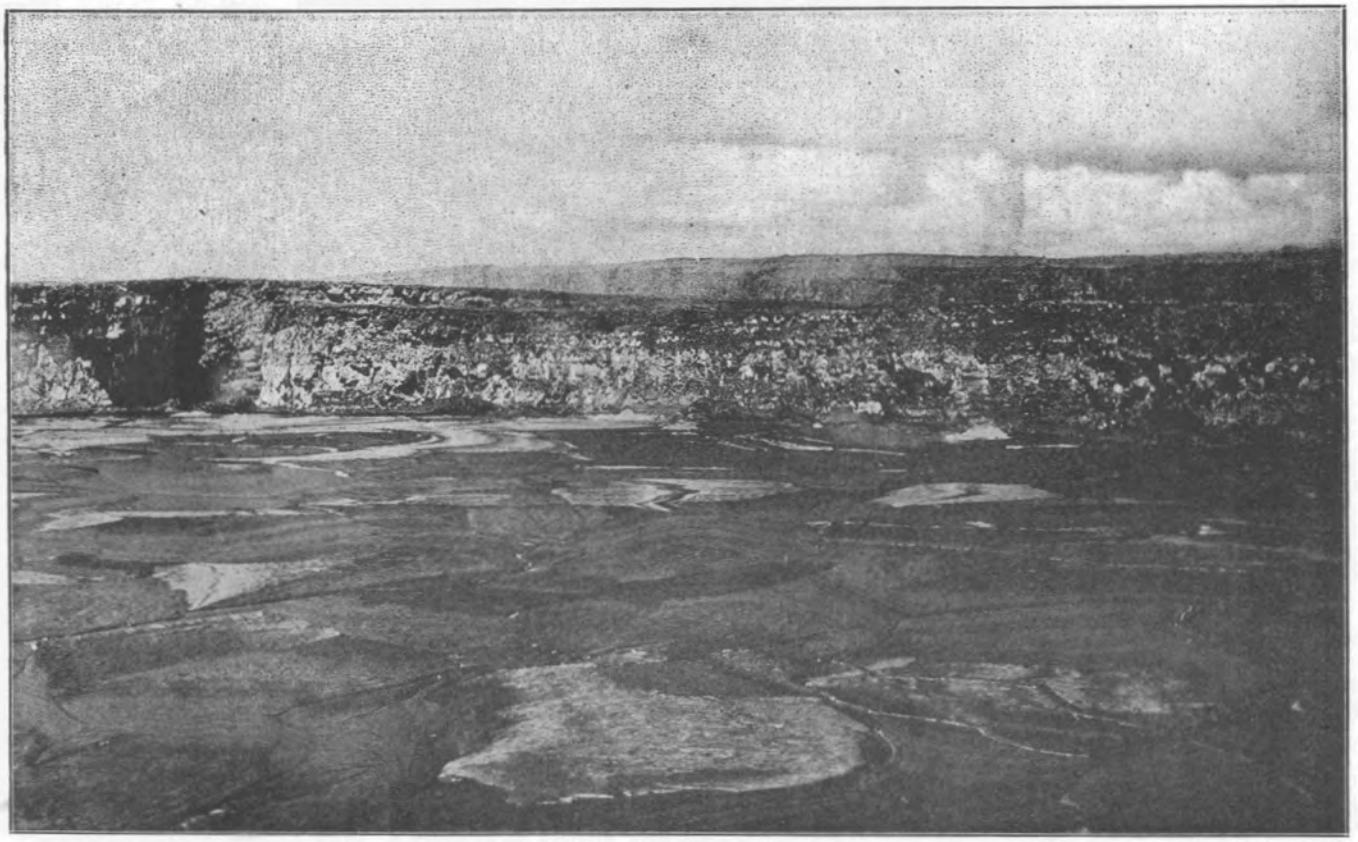


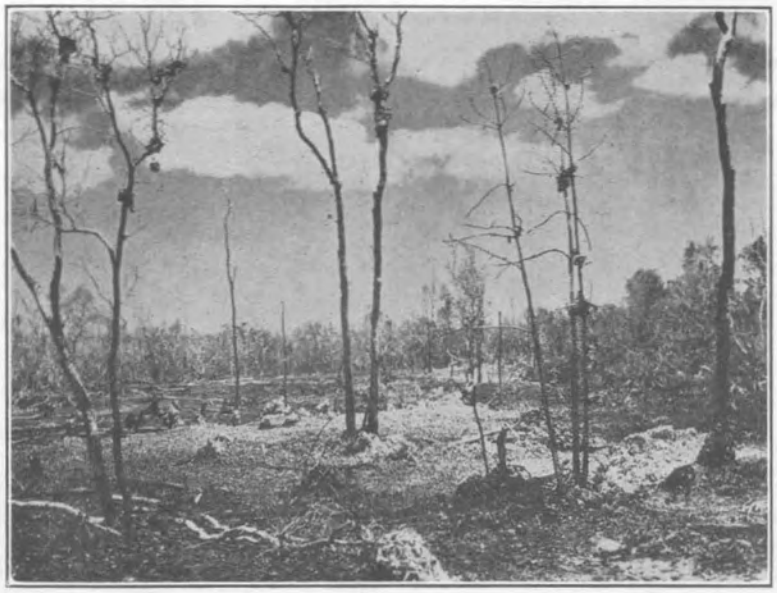
Halemaumau from the northeast rim, June 30, 1923, when t he lava was liquid from cliff to cliff 129 feet below the edge. Photo Jaggar.

EVENTS PRECEDING THE GREAT ERUPTION 1924

As the steam-blast eruptions of Kilauea in May 1924 represented the end of the supercycle of 134 years and of the last of the 12 eleven-year cycles with its peculiar terminal characteristics, it is profitable to inquire what prophetic occurrences filled the years just preceding the eruption. For the similar eruption of 1790 we have only the hint in the tradition of the natives that there was a lava flow in Puna off to the east of Kilauea about 1788.

Until 1921 when in March there was a maximum of overflow from the actual lip of Halemaumau pit inside of Kilauea Crater, no very marked breakdown of the rim of Halemaumau had occurred, the pit outline enclosing the overflowing lava column was about as small as it had been in 1919, and the only outflow from the flank of Kilauea Mountain had been the Kau Desert activity of 1920. After the 1921 overflows the lava of Halemaumau subsided twice moderately with recovery of the lava following the sinking. Thus it may be said that until May 1922, or just two years before the great steam-blast eruptions, the only events that predicted those eruptions were (1) the supposition of a supercycle about 132 years long after 1790; (2) the general decline in volume of Hawaiian flows for the last half of the supercycle after 1855; (3) the down-hill progress of flank outflows from Mokuaweoweo 1914, to Puu o Keokeo 1916 and 1919, and then to Kau Desert 1919-20; this outflow from the flank of Kilauea was a suspicious new feature.

We read in the journal of the Observatory May 13, 1922, "This day was the end of the prolonged rise." The liquid lava had risen to a point 49 feet below the rim, fountaining and splashing activity varied, outer pools of lava between inner crags and the rim of Halemaumau often overflowed their banks, flames were abundant, and an oven cone on a crack outside of Halemaumau in the floor of Kilauea Crater showed glowing slag about 50 feet down. Then in the third week of May the rising which had started in November 1921 ceased, and by May 21 the lake level had dropped 300 feet steadily and majestically, the crag peaks between the pools maintaining their identity as they went down. Avalanches from crags and walls were numerous. There followed swarms of earthquakes, many of them perceptible over the island of Hawaii. The shelf of new lava caved away, making glowing avalanches. The crags and lava lakes were enveloped in debris slopes. Avalanches increased and sent up cauliflower clouds of dust. On May 26 this made a thunderous roar heard many miles away, the rim of the pit was generally carried away, and at the southwest the collapsed rift made a smoking



The Chain of Craters rift of August 25, 1923, with lava spatter in the trees and sulphur along the flow-crack in the forest. Locality west of Makaopuhi. Photo Emerson.

canyon extending Halemaumau 500 feet in that direction. The pit was enlarged from an oval of maximum diameter about 1,400 feet to an irregular cavity 2,000 feet long by 1,500 feet wide. By May 31 the top of the lava column had subsided at least 1,000 feet and the vacant cauldron was floored with debris 861 feet down. At 8 p. m. May 28 lava fountains broke out on the side of Makaopuhi Crater (end of Chain of Craters Road) along the rift east, and it was evident that the great eastern rift was receiving the underground drainage from Halemaumau and vomiting up a little of it in these local eruptions. This outflow was all at lower level than the Kau Desert outflows of 1920. In the map on Page Four Makaopuhi is near the letter "P" of Puna.

The lava column was executing pulsations of subsidence, but the mountain edifice had not yet yielded sufficiently to let the lava of Halemaumau escape under the ocean to the east. Superficially the lava crust solidified in Makaopuhi and Napau, in July and September of 1922 the liquid slag burst through the talus slopes of Halemaumau and started to fill the bottom of that pit, and pulsations of rising followed so that at the end of June 1923 a sea of lava with a narrow shelf around its border extended from cliff to cliff only 129 feet below the edge of Halemaumau. The sequence of events always suggests that the basaltic melt has an unconquerable gas potential actuating it, but the pressure of the big mountain slabs, now yielding a little to the gas expansion, and now again reasserting itself under gravitation, controls what the gas in solution can do. According as the edifice breaks down or splits apart in spasms through the ages, the so-called eruptions of lava break out or fill the pits as directed by the yielding of the mountain slabs. A glance at the map of Kilauea shows that it consists of a series of big slabs on the southeastern slope of Mauna Loa which have been slipping seaward for ages.

On August 24, 1923, the lava in Halemaumau was still high, only 220 feet down, but a subsidence had begun. Local earthquakes became numerous, by August 26 the bottom of the pit was full of enormous jagged and tilted blocks and hardly any fire was visible except where lava was streaming out of a crack at the southeast. By August 28 Halemaumau was floored with a tumbled mass of broken blocks 564 feet down, and a new crack in the Chain of Craters country was spouting lava and sending up white fumes full of poisonous sulphur vapors. This was in the forest west of Makaopuhi, and the photograph on Page Two shows the sulphurous stain along the flow-crack and the lava spatter in the trees. The belt of cracks extended north and south for a width of 500 feet and a length about 2,000 feet. Patches of sluggish pahoehoe developed at both ends of the crack belt, round holes were produced along the rift lined with new lava, small cones and innumerable tree molds were formed, and patches of sulphur appeared in certain places. In September the lava reasserted itself in the bottom of Halemaumau and began to rise. The oozing up of lava near Makaopuhi lasted only a few days, the visible steam there continued for months, and hot vapor along the crack developed blue-green algae, these hot places still persisting in 1931.

Again there was revival in Halemaumau, and again the great sea of lava was only 121 feet below the rim of the pit on January 27, 1924. This was followed by the same kind of lowering which had occurred in August of 1923, leaving in February and March a collapsed tumble of debris with a glowing hole about 400 feet down.

The event of April 21 at Kapoho near the east point of the island of Hawaii was unprecedented for the present generation of men. Prolonged, mild quaking began, there were several hundred shocks for three days, the ground cracked open in several directions, cracks from six inches to nine feet across yawned athwart the roads with a gradual process of opening, and the principal movement proved to consist in a lowering of the fault-block south of the Kula cliff shown in the photograph on Page Three. This was an old fault-scrap facing southward. The block which moved was about four miles long east and west, by a mile wide north and south, and it apparently hinged

about the cracked zone on its south side near Kapoho village, and lowered the most along the Kula cliff on its north side, where the ground at the foot of the cliff gently dropped in the course of a few hours from 9 to 13 feet. This movement extended all the way to the sea at the east, with gaping cracks along the line of the cliff, and the lowering at sea level made new salt water lagoons and drowned the longshore vegetation. There was not a single big earthquake in the whole series of shocks. The fault block moved almost as though it were plastic. Houses and tanks which stood at a quarry against the fault cliff were lowered bodily and remained erect. Releveling of the ground showed a new profile 9 feet lower than before south of the quarry, and one foot lower than before at Kapoho station.

This April crisis at the east was the last premonitory happening before the Kilauea steam-blast eruption. It was led up to by earthquakes along the eastern rift which seemed to indicate that the lava was splitting its way in that direction. When the great crash came in Halemaumau in May, the supposition appeared to be justified that the lava escaped under the ocean to the east. The diagram at the top of Page Four exhibits one of the characteristic lava pulsations that led up to the great engulfment. T.A.J.

TILTING OF THE GROUND FOR MARCH

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the dirction given.

March 2-8	0.7	second	SSW
March 9-15	2.5	seconds	SW
March 16-22	1.0	second	S
March 23-29	1.9	seconds	SSW
March 30-April 5	1.1	seconds	E

KILAUEA REPORT No. 1003

WEEK ENDING APRIL 12, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

On April 7 at 3:30 p. m. no changes were observed at Halemaumau pit, no tremors were recorded on the pit seismograph, and there was a little steam on the south talus. On April 8 at 2:40 p. m. a small avalanche caused dust to rise from the pit. A little fume still rises from the sulphur spots, and the western of these is brighter yellow than the others. On April 11 at 10 a. m. the 1930 cone at the top of the new lava heap of last November had caved in a little at its upper edge. The pit seismograph indicated a sudden tilt away from the center between the 7th and 9th of April.

The Observatory seismographs indicated 17 tremors for the week ending at midnight April 17, two of these on April 10 being continuous for periods of 2.5 minutes and 7 minutes, respectively. Tilting of the ground was very slight NNE, and microseismic motion very slight.



Kula fault of April, 1924, near Kapoho, east point of Hawaii. The foreground dropped about 10 feet, the country was seamed with cracks, and scores of earthquakes occurred. Photo Emerson.

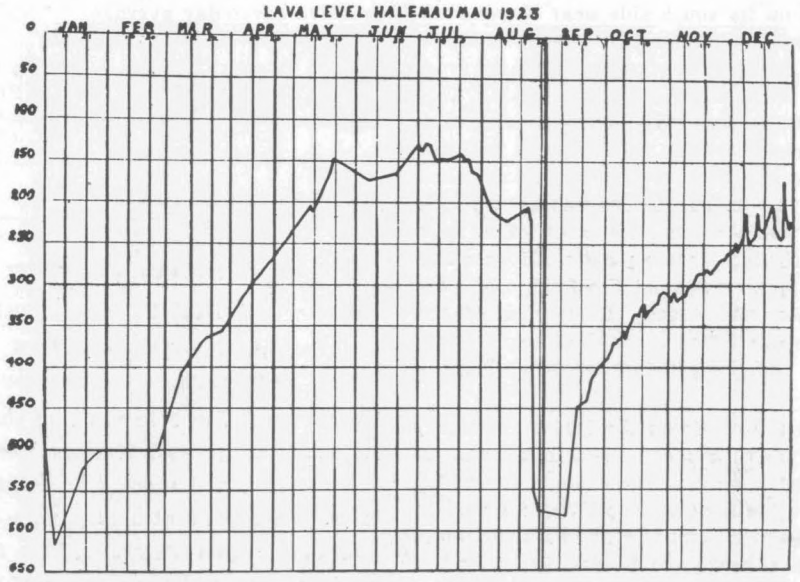
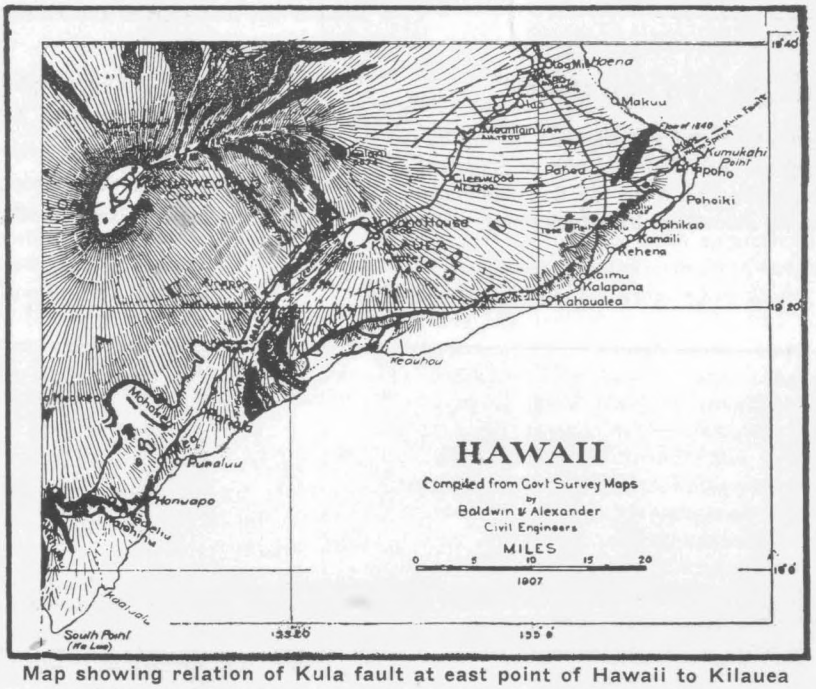


Diagram showing depression in feet of lava level below rim of Halemaumau during 1923. Shows sudden depression to 575 feet before the Chain of Craters outflow.



Map showing relation of Kula fault at east point of Hawaii to Kilauea and Mauna Loa. Here occurred the depression of April 1924.

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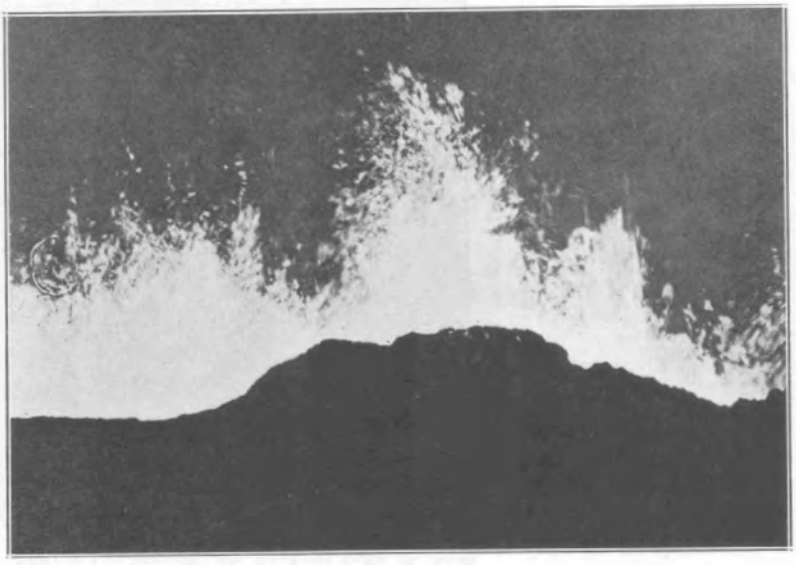
The Volcano Letter

Two dollars per year — Ten cents per copy

No. 330—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — April 23, 1931

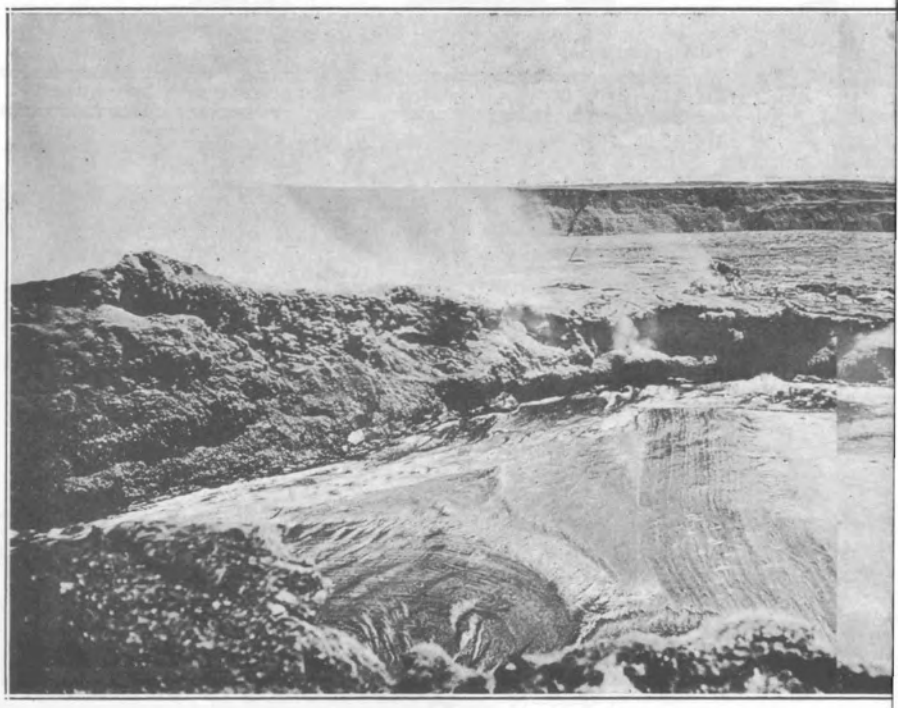


Source fountains of the main lake in the rift crack of the Alika flow, October 1, 1919, SW flank of Mauna Loa, 7000 feet elevation. Photographed by T. A. Jaggar 600 feet away, at night. "The great fountains 200-300 feet high were spouting continuously along the fissure for a thousand feet of length like a wall of red flames. In detail they were made of incandescent, light, crumbly material, yellow when it shot up, red when it came down. The noise was a roar like surf."

THE PEAK OF THE VOLCANIC CYCLE

In recent numbers of the Volcano Letter, beginning with No. 319, there have been reviewed the events of the last twenty years of Hawaiian eruptions, this review leading to a discussion of the eleven-year cycle from 1913 to 1924 as a type of twelve such cycles since 1790. Last week we discussed prophetic events which preceded the great steam-blast eruption of 1924, and in No. 328 that remarkable eruption was described. Pulsatory risings of about a year each followed by collapse and flank outflow were the features forecasting the grand crisis, and that crisis itself was an unusual collapse over lava that receded deeply. The immediate recovery of the lava and its appearance in the bottom of Halemaumau in high spouting fountains within two months after the time when the steam blasts ceased inaugurated a new cycle. We are living in the midst of that cycle, now characterized by small manifestations of spouting lava in 1924, 1926, 1927, 1928, 1929 (twice), and 1930. The 1926 happening began at the very top of Mauna Loa, so that the conclusion seems justified that the gas energy within the underground lava itself was not exhausted in 1924. Within two months hot and very vigorous lava was spouting in the Kilauea pit, and within two years it was bursting out through cracks 13,000 feet above the sea in Mauna Loa. What was exhausted, then, was the patience of the mountain in consenting to yield, now here, now there, more and more until 1919-21 when both Mauna Loa and Kilauea were inflated and let the lava squirt up through cracks. Then the great mountain blocks had been so uplifted and loosened that they even let the lava ooze out under the ocean somewhere east of Puna in 1924 about May and June, when the ground water flowed into the chamber under Halemaumau, and the steam puffed up like a freight engine. But the coldness of the Pacific conquered the submarine oozing slag, the frothing melt backed up into the Halemaumau conduit and reappeared in July 1924, the mountain blocks settled down hard owing to what had been withdrawn, and to their enormous weight, and the gas in the deeper magma was no longer able to lift them. The weight control of gravitation had again asserted itself.

This weight control of gravitation in a volcanic mountain, or better in a volcanic island consisting of several mountains, is like the spring control of a safety valve on an engine, opening only when the internal lava pressure has passed a certain minimum. The internal pressure under the volcanic island may be thought of as accumulating at a steady rate through the ages. The island safety valve has two or three openings, Mauna Loa, Kilauea, and Hualalai, with a heavy shell over cracked blocks determined in weight by the accumulation of the ages. This weight accumulation is operating against the pressure accumulation. Once in eleven years the underground lava gradually and irresistibly forces itself up into cracks under the several openings and extends out along the rift belts that break up the mountains into blocks. How this hot matter grades down into a pudding having horizontal extension we do not know. There may be subordinate puddings under each volcano dome led up to by old cracks extending down into bigger and deeper puddings representing



May 10, 1919 looking NE. across main lava lake in Halemaumau from the top of th and indistinguishable. The photographer was thus standing on the top of the mo right and left are live lava, wholly inside the pit. Central part of lava dome

ancestral domes. The height and size of the mountain puddings inside the island, and their supply of gas from the larger and deeper pudding, are what determines whether Mauna Loa or Kilauea shall erupt. If the weight control of Kilauea, the lower mountain, relative to its private pudding, is greater than that of Mauna Loa relative to its higher and larger internal pudding, it will be the higher mountain Mauna Loa which erupts. The yielding of each particular edifice relative to its internal lava expansion is what determines eruption. For the lava is not to be thought of as a rising liquid, but rather as a local expanding body of paste full of frothing gas.

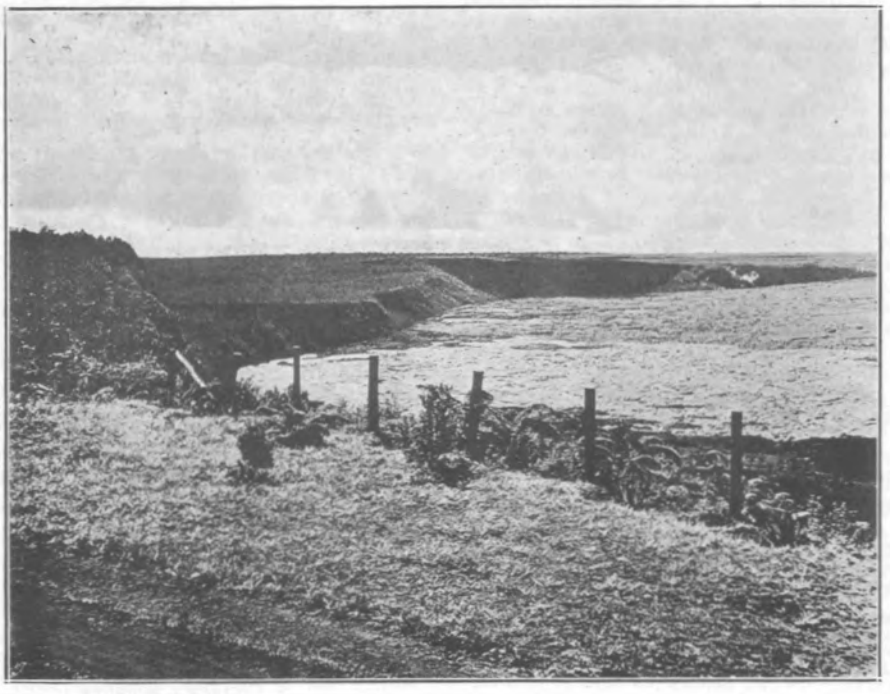
The yielding of the edifice needs clear definition. If a mountain block merely lifts on the flank of a pudding of underground slag, it does not weigh any less, and moreover solid basalt is heavier than pasty lava. Therefore what happens is an arching up or a tilting of blocks, and if new lava from below inserts itself into a mosaic of blocks up vertical cracks, it must spread the mountain apart horizontally. The eleven-year yielding is merely an average resultant of arching and tilting of blocks, swelling and penetrating of the lava, permission by the blocks to be pushed sidewise, slipping downward of those blocks which are on the slope toward the sea, breaking open of cracks at the surface to release pressure and start foaming in some parts of the lava, letting out of a large volume of paste, and re-assertion of weight to restrain the foaming by new flows on the upland or settling of crater fills. By "blocks" are here meant the big slices of mountain shell that lie between the important fault-rifts. These shells are miles wide and tens of miles long.

As there are big blocks of rock in this sense between the flow rifts of Kilauea and those of Mauna Loa which tip and squeeze the Kilauea pudding when Mauna Loa outflows come to an end, having lifted the shells and released the Halemaumau lava while the Mauna Loa flows were in action, it is easy to understand underground connection between the two volcanoes such as was described in the subsidences at Kilauea of 1914, 1916, and 1919 (Volcano Letter No. 324). Each of these sinkings came just at the end of a Mauna Loa flow period. Each Muna Loa flow period was accompanied by a gradual gushing of lava and rising in the Halemaumau pit of Kilauea.

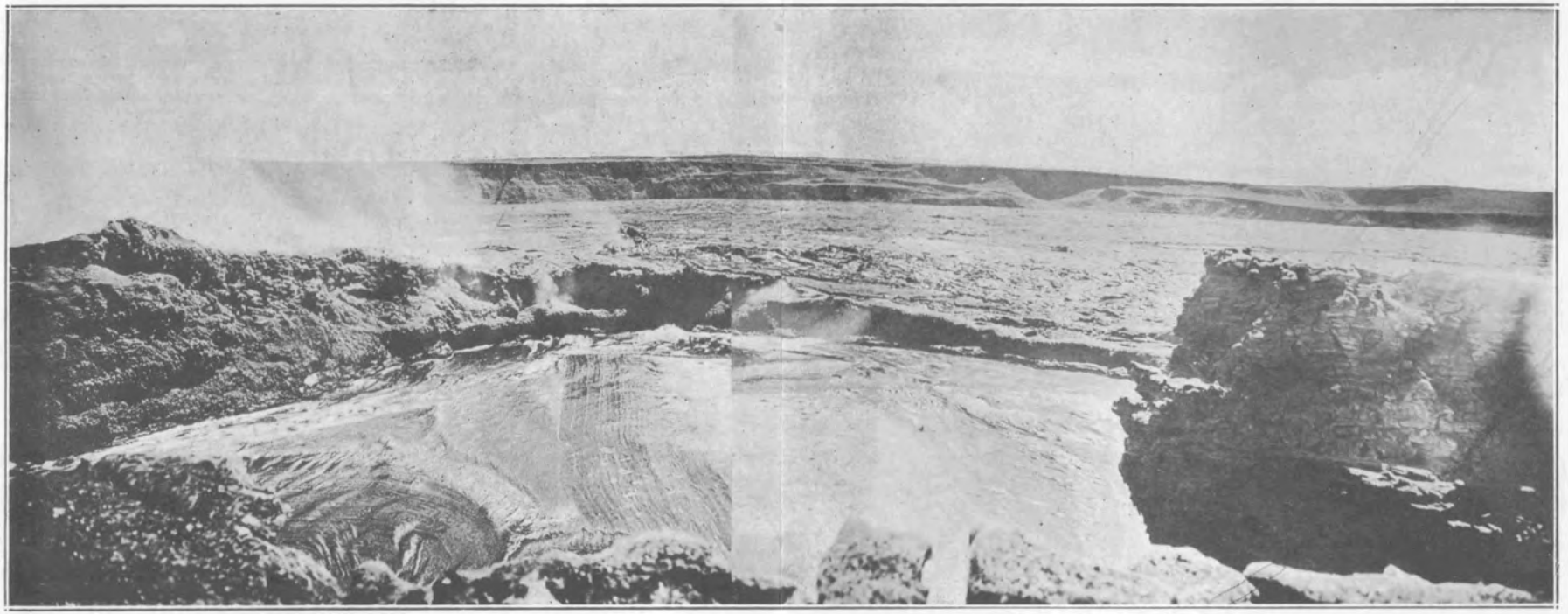
The peak of the volcanic cycle 1913-24, measured by internal pressure, was the intense gushing of lava over the Kilauea floor from Halemaumau pit, full to overflowing in October-November 1919. During this same time Mauna Loa was giving vent to the Alika flow. Throughout 1919 this flooding of the Kilauea Crater floor had been going on, with very slight ups and downs in the central pit, but from the very day when Mauna Loa broke out at the end of September, the Kilauea flooding increased. The process that led up to the nearly continuous overflowing of Halemaumau had been a very strong rising of lava in the pit at an increasingly rapid rate after the subsidence which had followed the 1916 outbreak of Mauna Loa. The year 1917 was intensely spectacular at Halemaumau, the observers could walk down on the lava floor surrounding the liquid lakes, and many experiments were made of taking temperature, collecting the gases, and sounding the slag pools with steel pipes. The year 1918 began a series of overflows of Halemaumau, first in one direction, then in another, from the lip of the pit, so that by 1919 the overflowing was virtually continuous. This all culminated in the Mauna Loa eruption of the autumn, which came to an end gradually, and at no very definite date, some time in November. It is impossible to name the day when such an eruption comes to an end, for the lava is flowing in tunnels beneath surface shells of hardened slag, the rift-source region is usually crusted over and may show glowing cracks for



e dome of live lava, when the eastern edge of the pit was completely overflowed
ving lava column. Edge of pit underlies small cone in background. Benches
was at this time 87 feet above what had been hitherto the edge of the pit.



November 30, 1919 looking south from Observatory across Kilauea crater. The light colored nearer part of the crater floor is the fresh, then-glowing frontal portion of the live overflows from Halemaumau which had been pouring forth for seven months. The flows went west, north and bent east, filling the north corner of Kilauea crater 60 feet deep. Photos Jaggar.



May 10, 1919 looking NE. across main lava lake in Halemaumau from the top of the dome of live lava, when the eastern edge of the pit was completely overflowed and indistinguishable. The photographer was thus standing on the top of the moving lava column. Edge of pit underlies small cone in background. Benches right and left are live lava, wholly inside the pit. Central part of lava dome was at this time 87 feet above what had been hitherto the edge of the pit.



Middle stream of the Alika flow of 1919 early in October at road crossing in South Kona, showing the standing waves of rushing golden melt travelling eleven miles per hour. This stream was forty feet wide, within fields of consolidation of its own aa overflooding. These fields also moved, but very slowly. Mauna Loa flow, elevation 1570 feet above sealevel.

weeks, and there is no evidence left of any particularly sudden down-sinking at the source cone of the flow. Possibly some such reaction would be seen there if there were inhabitants.

At Kilauea, however, as has been often described in these pages, a remarkable, quiet, and sudden sinking 600 feet of the entire lava column in Halemaumau pit occurred November 28, 1919, as though it were a definite reaction from the Mauna Loa cessation. Then immediately the violently foaming Kilauea lava rose in the bottom of Halemaumau pit until in three weeks it was nearly at the top, then in three weeks more it had burst out in the Kau Desert southwest of Kilauea, and a long series of flank outflows of Kilauea began which lasted seven months. This, however, was not the end, for in 1920-21, December to March, there were again very intense overflowings of Halemaumau, after temporary reactions of subsidence. The March gushing of 1921 was accompanied by a flooding of the entire southern part of Kilauea Crater, so that one flow passed through a gap in the sand hills which bound the crater on that side. The fountaining was so violent that forty-pound blocks of crust were flung up into the whirlwinds over the fountains and dropped 300 feet away. Halemaumau was a surface saucer full of rushing, golden melt, building up a big spatter rampart at one side, with islands out in the middle. Then there came moderate subsidences, followed by the big ones of 1922 and 1924.

T.A.J.

KILAUEA REPORT No. 1004

WEEK ENDING APRIL 19, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

At Halemaumau pit in Kilauea Crater the only change observed on the forenoon of April 13 was that the sulphur spots on the new lava floor of 1930 seemed brighter yellow. The weather was dry and no steam was observed on the south talus. Dust from a slide rose at the pit at 3:30 p. m. April 13, and at 10:30 a. m. April 17 a fairly large avalanche fell from the middle of the wall above the northeast talus, sending up a thick cloud of dust.

A slight earthquake at 5:58 a. m. April 17 was strongly felt in the Volcano District and in Hilo, observed near the volcano as a slight preliminary bump followed in about two seconds by a stronger shaking occupying several seconds. This was sufficient to alarm a dog and in the region three miles toward Hilo from Kilauea the motion appeared to be northeastward. The Observatory seismograph indicated distance of origin 14 miles. Another feeble earthquake felt locally indicated distance of origin 23 miles, at 10:09 a. m. April 16. In all the Observatory instruments registered 26 local disturbances, of which six were very feeble seisms and 18 were tremors. A very feeble shock at 10:23 a. m. April 14 indicated origin distance 12 miles. Tilt for the week was slight WNW, and microseismic motion was slight.

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The Volcano Letter

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No. 331—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — April 30, 1931



Northeastern corner of Halemaumau pit showing lava overflows, from northern and eastern sides of the lake, uniting to fill the wall-valley depression. Lava lake outside of picture at the left.

RISING OF PIT LAVA KILAUEA 1917

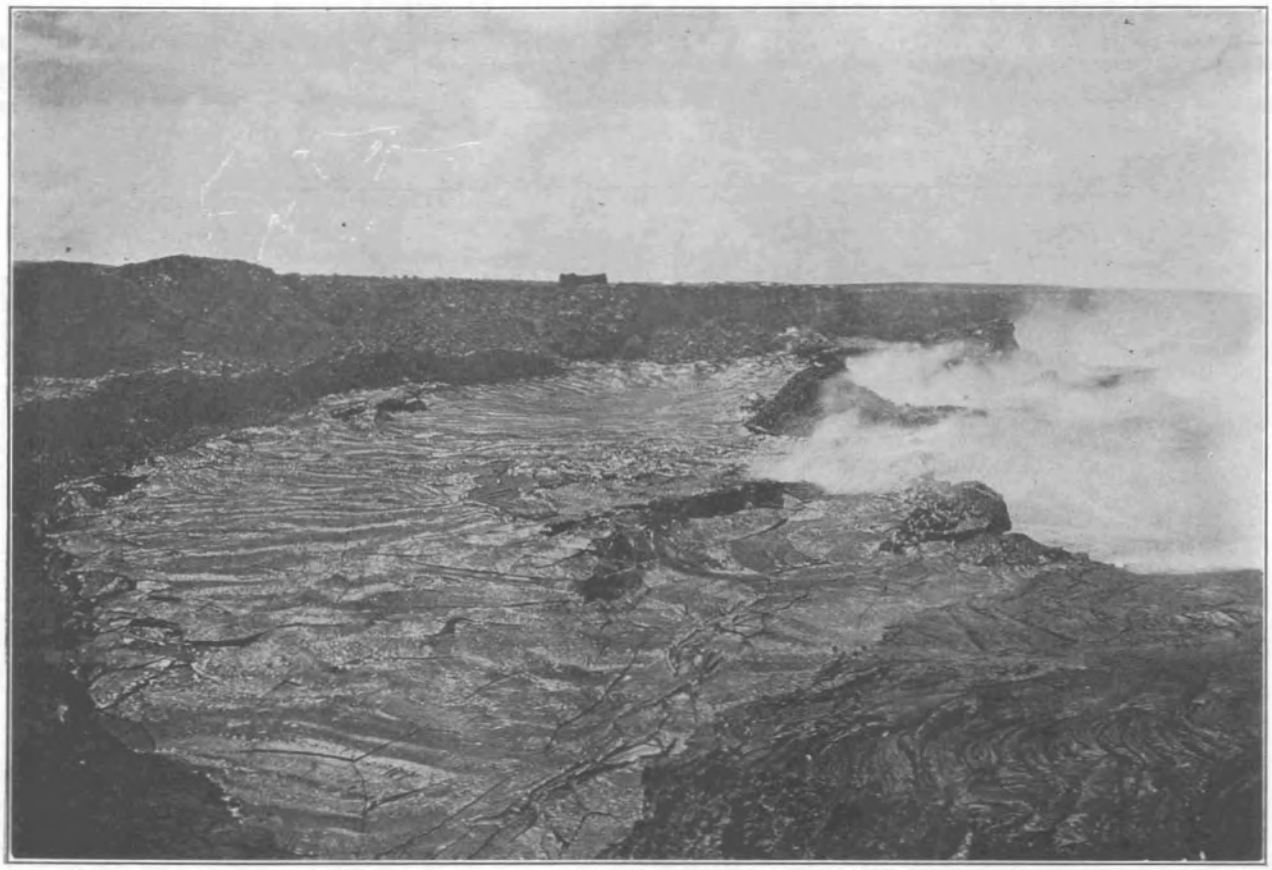
The first half of the cycle 1913-1924 was characterized by increasingly rapid rising. This showed itself by three, progressively more voluminous, lava ejections from Mauna Loa, and by a general rising of lava in Halemaumau pit, the inner well of Kilauea Crater. In order to understand the detail of the processes involved in the spectacular overflows of the inner lava lakes of Halemaumau pit, alternating with recessions of the lava from month to month, we here present a map and some photographs to exhibit the relation of the bench magma to the liquid lava. This is one of the hardest subjects for an outsider to understand.

The outline map of Halemaumau on Page Four has below it a true scale structure section showing what we saw and measured at the Observatory January 12, 1917, when with transit we went from one trig station to the next, as indicated by the little triangles around the rim of the pit. At the bottom of the structure section there is indicated a true scale extension downward of the pit profile as it was June 23, 1916, just after the liquid lava had come back vigorously, following the subsidence of June 5, which was described in Volcano Letter No. 324. The liquid lava at that time had filled a saucer in broken rocks, and then made its own spatter bench around the edges. The shape then of the liquid shown in black if we filled in the bottom would be that of the contents of a saucer, and as the lava was fed upward through small holes in the talus below, the only wells extending downward would be those holes, and everywhere else the liquid would be streaming over a hardened shell of its own glassy substance which had congealed against the cold broken rocks beneath it. The bench around the edges, then, was nothing more than the border expression of the hardened bottom lava.

What happened thereafter when the lava rose 500 feet filling the pit nearly to the top? The supply of liquid lava up the wells carries a certain amount of gas in vesicles which is reacting to keep it hot, but the air above, the sides of the pit, and its own congealed bottom lining are all tending to freeze the hot froth. The heat energy available can keep a saucerful liquid and streaming, the saucer in question being roughly of the size of the first pool. The rest that congeals under the pool is like the lava fields, that congeal on either side of a small medial stream, in a Mauna Loa flow. The congealing may be only partial so that this semicongealed substance is still mobile, and the upright wells are maintained through it. The rising then resolves itself into an uprush of the liquid froth through the wells, an overflow in pulsations of the liquid in the top saucer, and such additions of gas and heat to the under substance, as will cause it to swell or tumesce, under the hardened shells of overflow, that form the benches or platforms around the lava lake, or lakes.

If now we examine the map and section of January 1917, we see the main lava lake in black streaming from three coves at the west, and back of these, two source ponds, which are over wells. At the north, and at the south, there are overflow benches, the northern ones wide, and the southern ones narrow. There is a small wall pond at the south. There is a big crag-mass between the northwest pond and the lake which exhibited a tendency to rise gradually, as the tip of a northwestern sector of overflow shells. There is another such crag at the east, and a more complicated group of them making a peninsula, and southward tilted hills of uplifted overflow lava, at the southwest. At the southeast there is a line of big spatter grottoes along the edge of the lake, with inflowing liquid lava, as indicated by the white arrows. There is the same thing at the northeast. During subsidences these were revealed to be cascades into sinkhole wells, and the bottom of the lake of liquid was revealed to be a paste only 45 feet below the overflow bench.

This paste, under the shells of overflow, and under the crags created by the swelling up from day to day of the shells of overflow, is the substance spoken of as bench



Depressed northeastern floor of overflow in Halemaumau pit May 16, 1917, from north station, to be compared with elevated floor northwest shown on Page Three. These illustrate the balance whereby the weighted side of the floor goes down and the other side comes up creating a tabular crag of bench magma. The lava lake is in the fume at the right.

magma, and this semicongealed substance rises and falls from week to week as constituting the greater part of the lava column, apart from the mere wells, as shown in the section under the map. The depression of the lava at this time was 87 feet below the southeast trig station, and the bench marks (B.M.) east and north of the pit on the floor of Kilauea Crater stood at elevations 3,697 feet and 3,700 feet respectively above sea level.

The Journal of December 30, 1916, says: "The lava lake is a very different object from the elliptical pool of last June. It appears like a mighty river of fire amid hills and tilted crags, shaped in general like a "W." Roundish coves are bordered by high ramparts built up by overflow and by splashing fountains which have constructed huge domes, with glowing grottoes inside. Back of these ramparts, the overflow surface slopes back to the walls of the pit, so that the lake is really at the top of a low, flat, inner cone. Higher than these floors on three sides of the lake, but wholly within the pit, are craggy hills benched and fissured, which stand from 40 to 80 feet above the liquid lava."

"Other irregularities which add interest to the scene are high, flaming and puffing chimneys, outlying ponds of lava, and driblet cones built up over fissures in the floor. Following all the bends the lake is fully 1,800 feet long, with channels varying in width from 50 to 200 feet. The scene is magnificent from any side of the pit, and there is hardly any obstructing fume."

On April 6, 1917 we find the statement, "The rising of the crags is symmetrical about a central point in the pit, where the three arms of the lake lie at about 120° to each other. The sectors of bench, between these arms, are sinking around the circumference of the pit, and lifting their convergent points near the center. The marginal sinking is started by weight of the overflows, and increased by weight of debris fallen from the outer walls. As a result the south island peninsula, the crag-mass, and the east island are now all rising, and the floors are sinking. The inner bench confining the lake is therefore highest near the center of the pit. As usual the northwest and west ponds are the conduits of uprising liquid lava."

The beautiful symmetry of tumescence or swelling in the center, overflow of the lakes to weight down the wall valley around the edges, and up-tilting of the crag sectors to rise highest in the center, has appeared again and again, during the measurements conducted by the Observatory, so that the sectors of shell may be thought of as eternally overturning, away from the center of the pit. No solidified lava, except possibly light pumice, is capable of floating on liquid lava. The solidified crags, however, in some sense do float upon the bench magma paste beneath, or are of almost the same specific gravity, but this paste is not liquid lava. in addition to the circular symmetry, however, there would often develop a bilateral symmetry as shown on the map, whereby the three source wells are in the southwest half of the pit, and this southwest half was uplifted; whereas in general the northeast half was covered with overflows and tended to subside, except for the temporary east crag, which afterwards became overwhelmed and sank down.

The picture on Page One gives a clear idea of the northeast quadrant of the pit being filled by lava overflows from the lake in May 1917, the observation hut of the Observatory, and the old horse corral, showing in the background. This heavy flow is weighting down the wall valley, and tending to lift up the crag shown on the left-hand side of the photograph. If now we turn to the photo-

graphs on Pages Two and Three, we see a very striking illustration, on May 16, 1917, of a downweighted northeastern overflow bench (Page Two) which by a series of floods from the lake had subsided. This is looking from the north station straight southeast across the northeast overflow bench. The photograph on Page Three is looking from the same place straight southwest, across a new elevated northwest table crag, which for many days was in process of mass uplift. The following are Journal quotations from the history of this uplift.

"On May 12, 1917, the lakes had risen from 11 a. m. to 12:30 p. m., the main lake much faster than the southeast pool so that the northwest cove and the southwest shore were overflowing. The west cone was gushing incandescent lava and the crags had continued to rise. The tabular northwest crag was rising strongly while the north chasm was sinking. This was shown by a cracked ridge of fresh flow lava, lifted on the side of the crag, and though only two days old it showed a vertical displacement of about six feet from its original position. On May 25 the northwest table crag showed an extraordinary uplift of 15 feet since the previous day, carrying with it a bench of fresh flows around its base on the east and north. Instead of tilting, this tabular mass is rising bodily owing to inflow beneath it of pasty bench magma impelled by the weight of lava floods much larger than it in area in the lake basin itself and on the floors northeast and northwest. On May 28 a sudden readjustment of the bench magma was accompanied by a brilliant flare with opening of crevasses into which perhaps the lake magma flowed so as to lower it temporarily while the central crags were uplifted. The east crag rose bodily 10 feet, and the northwest tabular crag was now above the rim of the pit. The large crag-mass rose so much with westward tilt that its northeast peak suddenly became its summit, whereas only that morning the middle peak had been the highest. The spatter markings along its base on the lake side were fully 40 feet high."

The northwest table here referred to, and shown on Page Three, occupied what in January was the north-northwest overflow bench, between lake and rim of pit (map Page Four). The photographs on Pages Two and Three were taken from the trig station, on north rim of pit, south of the letter "N". The balance between the rising crags and the weighted portions of the pit floor might be called "isostatic," but not because the crags are lighter. T.A.J.

KILAUEA REPORT No. 1005

WEEK ENDING APRIL 26, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Practically no changes have occurred at Halemaumau during the week ended at midnight April 26. Fume continues to escape steadily from the sulphur area north of the 1930 cone, which area is bright yellow. The instrument at the pit showed no volcanic tremors.

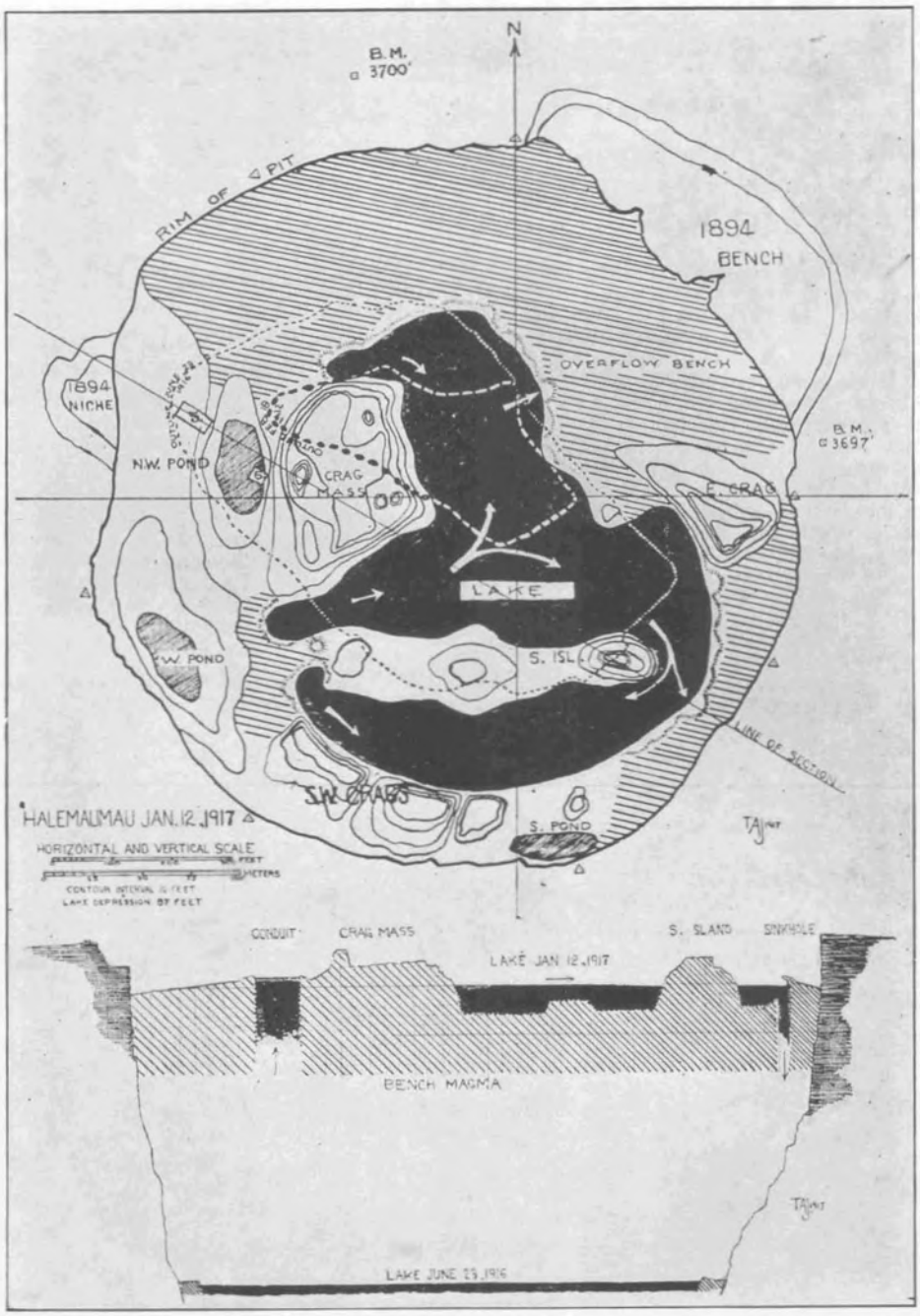
A total of 27 seismic disturbances were registered at the Observatory. Of this number were 23 brief tremors, three very feeble shocks, and one distant earthquake. The last recorded on April 24 for 10.5 minutes following 7:03 a. m. One of the very feeble shocks, at 11:25 p. m. April 25, indicated 25 miles distance to origin and was accompanied by tilt to the north; it was not reported felt.

Tilt was moderate WSW. Microseismic motion increased on April 21 from slight to moderate.



Elevated northwest table crag May 16, 1917, from north station, showing a block of bench magma in process of rising bodily by tumescence, or by the flowing in of paste beneath it, so that in two weeks its top was above the rim of the pit. This side of the floor rose, while the portion shown on Page Two was overflowed and subsided.

Photos Jaggar.



Plan and profile of Halemaumau pit January 12, 1917, when the great rise was in progress. Dotted outlines in map show progress of the rising and enlarging February 18, 1912, and June 23, 1916. Lower profile in section shows lake of June 23, 1916, in contrast to great development of bench magma, at higher level, six months later. Liquid lava black, source ponds shaded. Lake level 87 feet below southeast trig station. Crags with ten-foot contours.

THE VOLCANO LETTER

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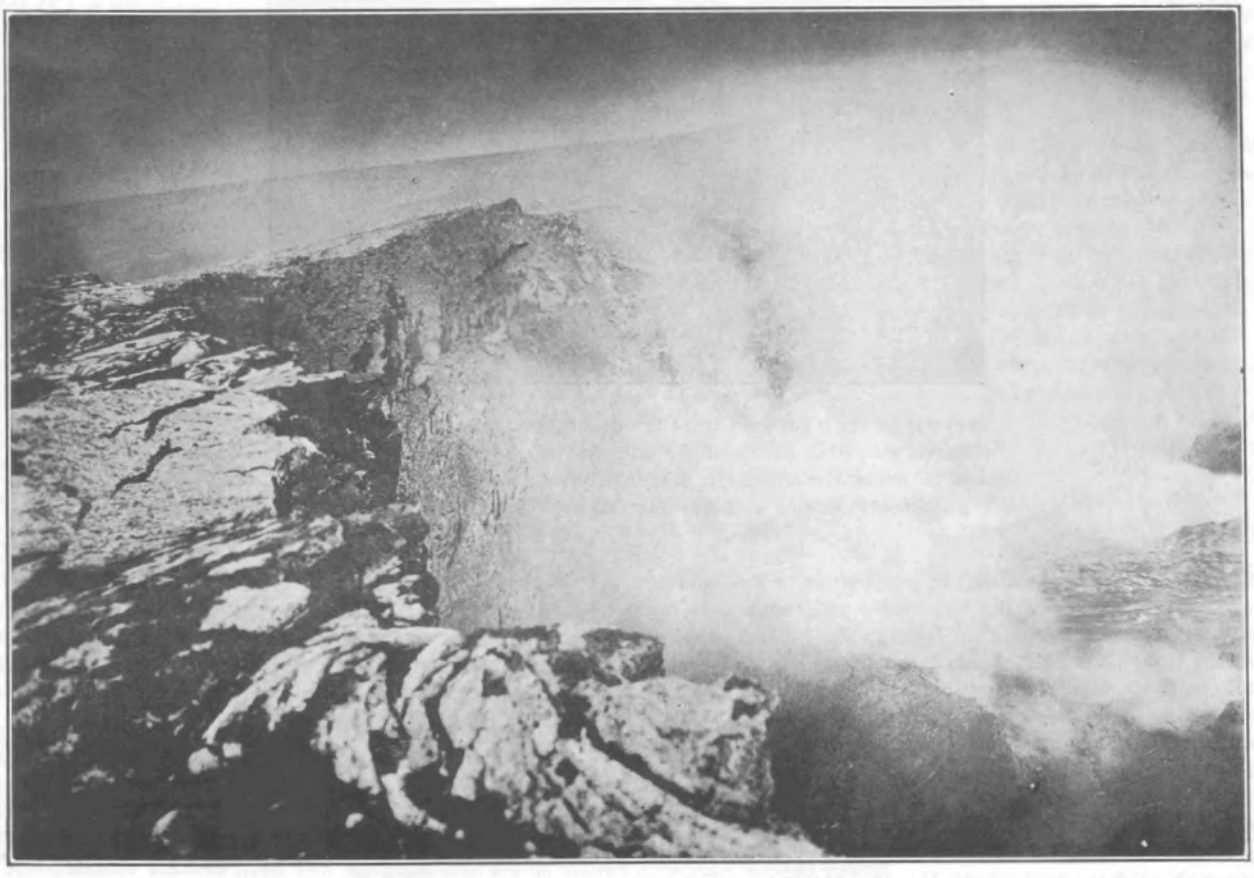
No. 332—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — May 7, 1931



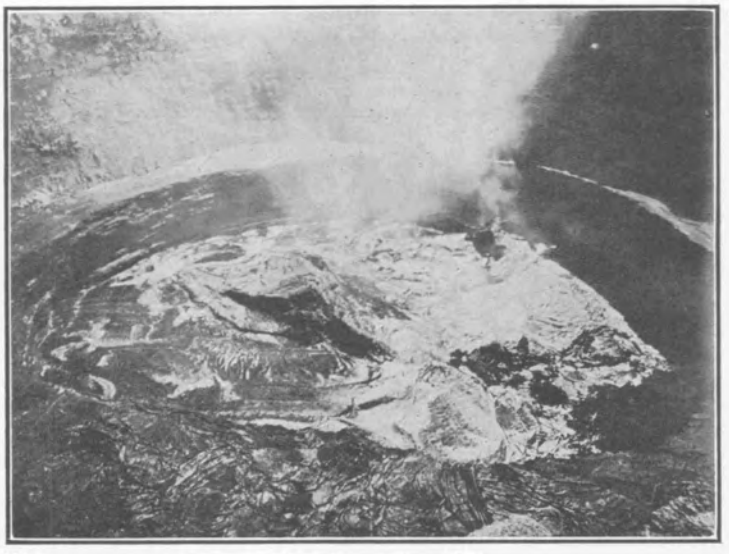
West rim of Halemaumau showing smoky conditions which were prevalent during the early years of the volcanic cycle 1913-1924. Taken from the south edge of the pit looking toward the region of the western source ponds, October 24, 1916.

BEGINNING OF THE VOLCANIC CYCLE

After reviewing twenty years of Hawaiian eruptions (Volcano Letters Nos. 319 and 320) and showing that the last cycle was 1913-24, we have recently described some details of this cycle, beginning at the end and going backwards. (Great Eruption 1924, No. 328, events preceding it, No. 329, Peak of Cycle, No. 330, rising of 1917, No. 331.) The beginning of the cycle was accompanied by two outbreaks of Mauna Loa in 1914 and 1916, and we have already described the remarkable subsidence of the latter year in Halemaumau (Volcano Letter No. 324). We have reason now in the cycle that began with influx of new lava in the bottom of Halemaumau July 1924, to make comparisons with the beginnings of the next preceding cycle. This might tell us something prophetic. But in doing so we must remember that 1913-24 ended with a gigantic collapse of about seven thousand million cubic feet of broken rock that fell down the Halemaumau shaft. This material is in the Halemaumau shaft now. No such fall of material occurred in 1913. At that time there was a solidified crust of live lava 600 feet down and the preceding cycle had been marked by slow risings with activity around the 300-foot level, and several sudden sinkings to depths not usually greater than 600 feet. Around the 300-foot depression level the lava column, therefore, of both bench lava and lake lava, was highly mobile, with an open shaft below into which it could sink. Now in 1931 the lava column 900 feet down is a pile of crusted layers, each not more than 60 feet thick, heaped up in five different years, and all comparatively stiff as a cake resting on top of the rock fill of 1924.

Such is the difference between the beginning of a new eleven-year cycle following the close of a supercycle, and the beginning of an eleven-year cycle which has many decades of mobility behind it. It is natural, therefore, that to some extent the years 1924-27 should be different in action from the years 1913-16. Both these periods, however, have been marked by gradual and somewhat intermittent rising of lava in the bottom of Halemaumau pit and by one or more outbreaks of frothy lava at the summit of Mauna Loa with eventual drainage in a Mauna Loa lava flow on the southwest flank of that mountain.

From May 1913 until just a year thereafter the lava lay 600 feet down in Halemaumau pit with great volumes of fume and steam making the bottom invisible. Slowly the lava rose in 1914, building spatter cones with glowing



Interior of Halemaumau from the southwest at 9 a. m. June 5, 1916, showing elliptical lake and the islands which on one occasion were seen to move horizontally. Depression of bench 253 feet, of lake 300 feet. Entire lava surface 780 by 675 feet in diameters.

trickles, the fume diminishing in proportion to the volume of lava fountaining. In the top crater of Mauna Loa big fountains burst out along a lengthwise north-and-south crack in November 1914, flooded the bottom of the crater and kept it up vigorously until the beginning of January 1915, the lava in Halemaumau meanwhile rising. There was no lateral outflow from Mauna Loa. When the summit activity of this big mountain ceased, Kilauea lava went down in Halemaumau 175 feet, but not very suddenly. This was the first of the occasions, that came under the observation of the Observatory, when in both rising and sinking, Kilauea showed sympathy with Mauna Loa.

The year 1915 produced a rising of lava in Halemaumau to a higher point than had been reached in 1914, and the peak of the rising in September was at the depression level 360 feet below rim of pit.

This September of 1915 produced a crisis of subsidence accompanied by many small earthquakes whereby the lava receded, the marginal bench cracked funnelwise and caved in, and the entire lava column lowered so as to leave a surging, liquid puddle in the bottom, destroying the integrity of the partially congealed saucer of bench magma. This saucer had consisted of four things: (1) The old slide-rock slopes of 1913, (2) the new liquid lava, (3) the overflow products of the lake, forming a bench, and (4) the partially congealed bottom material of the lake sometimes seen as shoals and islands. The measurements proved conclusively that these islands were part of the lake bottom and were not floating. The temperature of the liquid lava was proved quite incapable of melting the old slide-rock slopes of 1913. If we picture a cross-section of the top of the lava column at this time, we must imagine a stiff paste rising with the old talus breccia cemented in it, with a ring platform carried on its crest, the whole somewhat cylindrical in shape, and a shallow inside cup containing the lava lake fed by a well leading downward through the midst of the column of stiffer lava. Up the feeding well was coming the hot gas froth, which broke through the crust of the lake periodically about once a minute in what was known as "Old Faithful" fountain. This froth imported new fundamental magma from the depths, heated by gas reactions, and thereby this material was liquified and vesiculated to a fluid condition very different from the fundamental magma deep down under pressure, where it is presumably stiff, rigid, and heavy.

The September lowering was from depression 360 feet to depression 480 feet. The subsidence was like the one that had followed the Mauna Loa eruption in January of the preceding winter, but there was greater lowering in just such proportion as there had been greater clearing out of the throat below. The talus fragments had in a measure been appropriated as part of the bench magma column. This column had risen from a narrower throat below to a wider funnel above. Consequently with the uplift liquid lava occupies the ring channel and discharges through a border well into the upper saucer. By this process with every pronounced rising the throat is cleared bigger, and the pulsations of subsidence are permitted to go deeper. The lava entering loses its gas, becomes heavier and pours downward in some sinkhole wells, and the "Old Faithful" central well may reverse its flow and become a sinkhole at times.

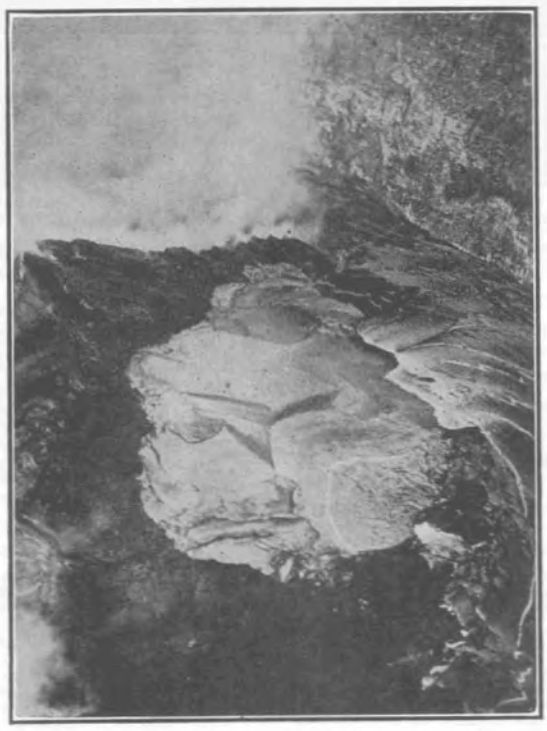
The curve of rising and falling showed sudden drops in January of 1915, September 1915, and June 1916, each drop being bigger than the one preceding. As the first and the third of these followed the recession of lava into Mauna Loa after an outflow there, it appears altogether probable that the middle one of September stood for the same process. That is, lava rising into cracks under the center of the island, then escaping laterally by extending the cracks farther, thereby lowering its hydrostatic level, while Halemaumau as a gauge off to one side recorded the movement.

In early autumn of 1915 the circulation developed fiery cascades pouring into eastern coves and into a small outlying east pond connected by a tunnel with the main lake. At the west end was a source pond of rising lava, whence the lava streamed eastward to splashing border grottoes. Rising of liquid overflowed the floors around the lake after

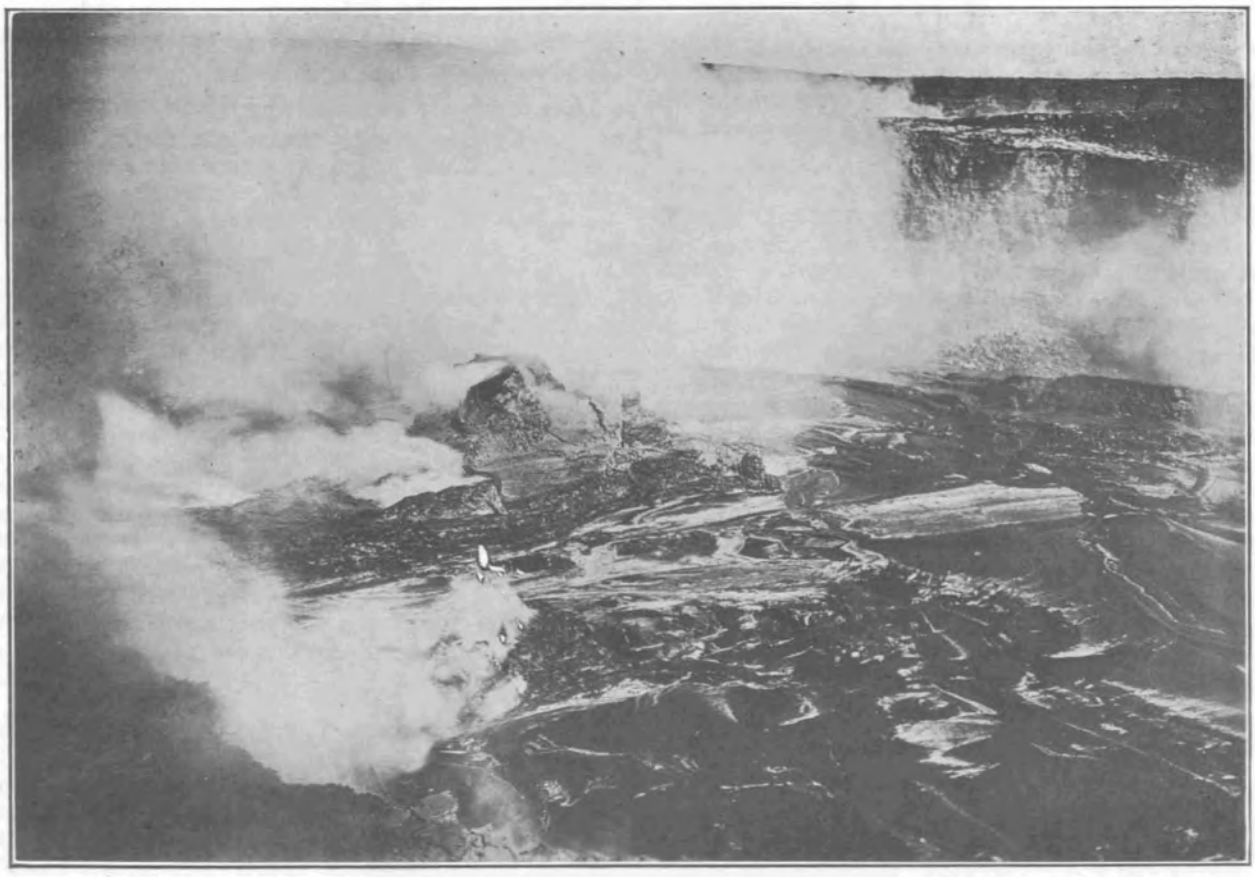
October, and the floors as part of the fabric of the bench magma showed tendency to lift and tilt away from the lake while heavy floods weighted the margins of the floor so that the crags became escarpments with steep faces toward the center of the pit.

Watching the action of the upward pouring slag in Halemaumau pit in 1915-16 led to a fruitful conception to the effect that a lava lake in a pit is nothing more than what would be a flow if it were on a monutain side. In a pit, however, there comes about heat conservation and long preserved internal glow of the bench magma which is different from the overflow fields of the mountain flank. As the front can go nowhere, being confined in a pit, we get a side vent or well, several tunnels as crusts form, and an overturning circulation due to upflow of the light and gassy, downflow of the heavier gas-free fluid. The resemblance of the lake in 1915 to a lobate flow from west to east across the bottom of the pit was striking. The spring of 1916 developed tremendous overflows of the lake which poured between two broken halves of a crag seen gradually to split in two. The overflow on the bench duly became a pool with definite rounded shape in plan, until finally it appeared that the lake had changed its outline, and had developed a big extension. The temperature of the rising melt is not high enough to fuse the banks, but the gases and their reactions are what produce melting. When a mixture of gas and slag comes up rapidly, it enlarges the wells and lakes partly by gas-melting, partly by convectional erosion, and largely by determining the boundary change between two viscosities, that of the more liquid gas-charged lava, and that of the stiffer relatively gas-free paste.

From January to May 1916 the lava of Halemaumau rose rapidly so that the overflow of the floor, and the breakage of the bench magma column below developed in April a big S-shaped lake, then two crags became islands, and lastly the rising lake developed elliptical form around them. Finally the island crags exhibited horizontal movement, which is rare in Halemaumau. One of them migrated north bodily with rotation around its west point as a vertical axis. As the rate of rising was very rapid it seems probable that the island blocks of bench magma were undermined so as to execute a rotatory tilt, partially buoyed, and breaking away from a narrow stem. May 19 came the southwestern Mauna Loa eruption, and on June 5, after Mauna Loa ceased action, came the great subsidence in Halemaumau. T.A.J.



The western source pond filling the wall valley under the northwestern cliff in Halemaumau August 23, 1916, after recovery from the great subsidence. This shows a typical source well and the process by which crags of bench magma were tilted up.



Halemaumau from the south-southwest when the lava bottom was 225 feet below rim, fume was diminishing, lava was flooding, and benches and crags were being elevated bodily around the lava lakes. Photos Jaggar.

KILAUEA REPORT No. 1006

WEEK ENDING MAY 3, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Conditions at Kilauea remain with little change. Fuming is steady at the yellow sulphur area north of the 1930 cone. A few falls of rock and dust from slides were noted at the north wall on April 27. On this date a southerly wind storm doing much damage in Kau District blew thick dust clouds from the desert over Kilauea Crater in the early forenoon.

Cracks paralleling the southeast rim of Halemaumau were measured on the 27th. Nearly all the marked points showed widening, the greatest being 1 7/16 inches at a place in the roped-off area near the tourist shelter.

A total of 39 seismic disturbances were recorded on the instruments at the Observatory, viz: 33 tremors, 4 very feeble seisms, and 2 feeble seisms, all local to the island of Hawaii. The greatest number of disturbances in one day was 11 on April 27. One very feeble shock at 12:18 p. m. April 28 was felt at the Observatory as a sudden jerk, the record indicating a close origin.

Tilt for the week was moderate SW. Microseismic motion was slight.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

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The Volcano Letter

Two dollars per year — Ten cents per copy

No. 333—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — May 14, 1931

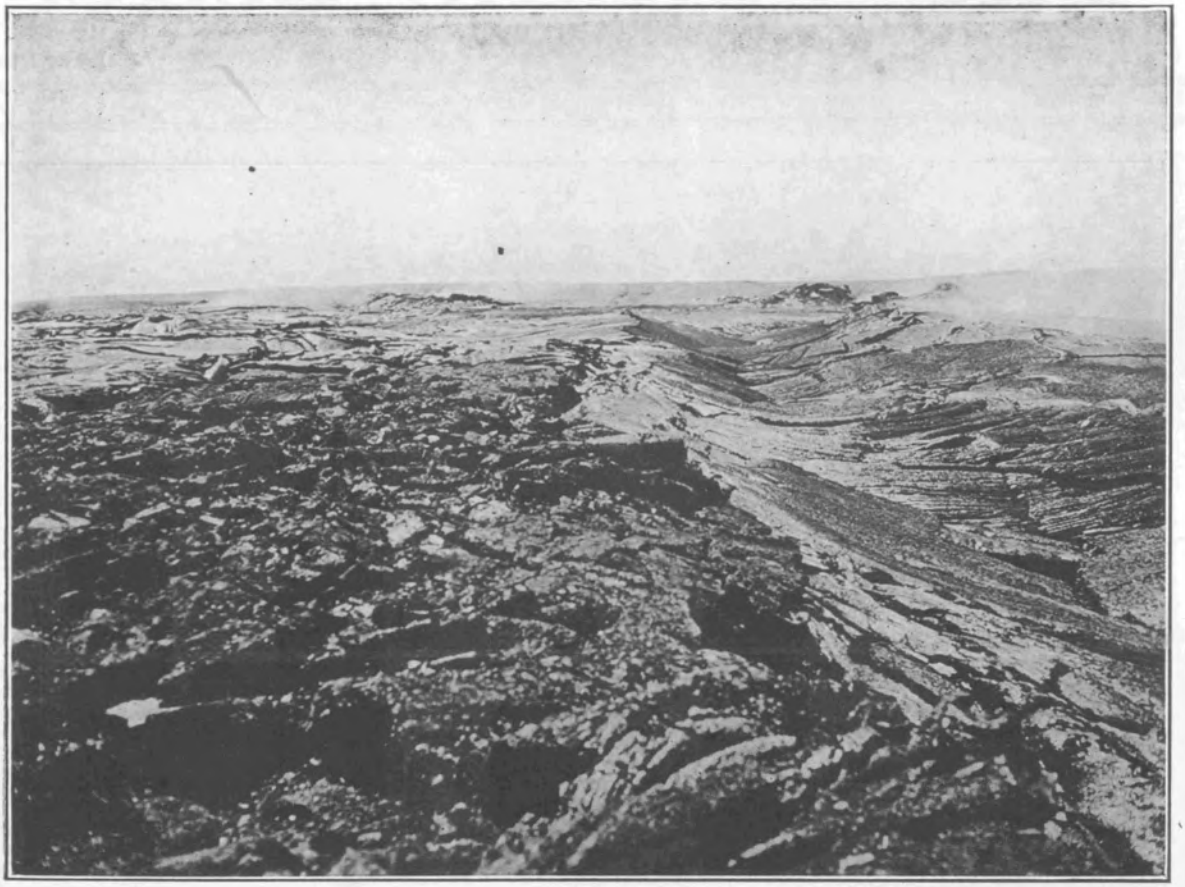


South rim of Halemaumau February 3, 1919, when it had begun to swell faintly, and on the right are seen live flows pouring along the wall crack from a small cone inside the pit. The live lava column of the pit is on the right. This margin of the pit was thrust up as the great pressure ridge February 25 and later.

HEAT AND UPLIFT AT KILAUEA 1919-21

In discussing the cycle of eleven years from 1913 to 1924, the story would be incomplete without a clear statement of the observed effects of increase of underground heat and the consequent uplift which was measured at the rim of the inner pit Halemaumau, and at the rim of the outer crater Kilauea. It is difficult for any one, who has not actually lived on the edge of such an active sink crater, to visualize as an actual fact the uplift of a mountain top by several feet in a few days. This is what truly happened at the edge of the pit Halemaumau when between February and May 1919, as shown in the sequence of pictures herewith, the liquid lava overflowed the rim of the pit, and a heaped tumescence from below swelled up the rim into a pressure ridge 15 to 20 feet high. And this was merely an index of what was happening on a larger scale to the whole inner floor of Kilauea Crater, and on a still larger scale to the whole top of the mountain outside of Kilauea Crater for a radius of 20 miles. (Tilt Records for Thirteen Years at the Hawaiian Volcano Observatory, by T. A. Jaggar and R. H. Finch, Bull. Seis. Soc. Amer. Mar. 1929.)

The swelling of volcanoes was reviewed in Volcano Letter No. 264, but it may be of interest here to summarize the facts about the top of Kilauea at the time of the peak of this active cycle. Leveling measurements of the summit in 1912, 1922, and 1926 showed that the top of the mountain rose two feet before 1922 and subsided from two to nine feet after 1922, the larger figure being that of the inner crater floor. We have seen that seven thousand million cubic feet of rim rock fell into Halemaumau pit during the explosive eruption of 1924. Taking the leveling data and assuming symmetrical subsidence about Halemaumau as a center for the 1921-24 period, the volume of land withdrawn amounted to twenty thousand million cubic feet. This is nearly three times the amount engulfed in Halemaumau. The weight of such decrease of volume of the island above sea level would amount to one and one-quarter thousand million tons. Adding the volume of rock engulfed at the pit we would get a void space created inside the mountain when the lava withdrew of twenty-seven thousand million cubic feet. The down-warping was at a maximum about the crater and the form of the area lowered, with gradual decrease of lowering twenty miles out from the crater center, suggests a horizontal lens of lava evacuated under the shell of the mountain. The suggestion for



Same view as Page One five days later, February 8, 1919, showing the overflow which destroyed the trail, and the sagging crusts of new lava inside the pit on the right.

the whole period of rising and falling is that the dome of Kilauea behaved like a boil or pustule, filling and swelling during the first half of the cycle, and evacuating through an underground crack below sea level at the end.

Early in February 1919 the lava lakes of Halemaumau exhibited brimming and overflowing conditions, and a southern heap inside the pit overflowed the rim February 7 (see cut Page Two) so as to pour across country 400 feet damaging a trail at the road terminus. The liquid lava was rising and the bench magma was sinking. An earlier January overflow had abstracted weight from the top of the lava column and deep effervescence followed as in the overflow of a geyser pool. A northeastern slag heap next took its turn of building up 27 feet just inside the rim of Halemaumau and flows from it threatened the eastern stone tourist shelter. The last week of February produced mass swelling of the lava column, eruptions of standing fountains of melt, extended overflows on three sides, the lakes as well as the slag heaps contributed to the flows, and all the lakes stood as ring-shaped basins, six in number, above the rim level of the pit.

Mashing of the previous rim upward and outward next occurred at the southwest, south, and east, so as to make a pressure ridge from eight to fifteen feet high of what had been the rim before, illustrated by comparing the photograph of February 3 on Page One with that of May 6 on Page Three. The formation of this ridge, however, occurred within a few days at the end of February and the beginning of March. The ground begins to smoke and becomes stained around such a trig station as is shown as a white, circular concrete platform on Page Four. This same southeastern station and all the ground about it then rose and tilted back gradually but very rapidly in the course of a few days, so that it was sloping away from the center of the pit. The ridge formed was 20 feet wide in places, with an elephant's back curve on the side away from the pit. The three most used surveying stations were destroyed, and the net rise of the eastern side of the lava column inside of the pit at the same time was from 10 to 15 feet.

Moderate flowing during the first half of April 1919 gave place to mass swelling the third week of the month, ending in strong overflow that broke up the wall crack through the south pressure ridge, itself the edge of the pit, and this produced the longest and most liquid flow of 1919 to date. It covered the trail and reached the road terminus, and was the third flow of the year that had extended about a half mile from the Halemaumau center.

Within the year prior to February of 1919, Halemaumau had exhibited overflowing of its rim on eleven separate occasions and at nine different places Six of these extended more than 100 feet away from the pit, and of these the southeast flows of February-March 1918 had been the most extensive, reaching a half mile or more in length. Those of November 1918 came next in volume, and the flows of January-February 1919 tended to fill the gaps between the two earlier localities. August of 1918 had produced some driblet overflows at the north and southwest.

The appearance of Halemaumau in April 1919 was that of a smooth curved dome 1,200 feet across, rising from the base of what was left of the northwestern rim cliff of the pit. The swollen top of the lava column rose 50 feet above the general level of the former rim, and fell off abruptly as an escarpment 40 feet high on the southeast at the pressure ridge (see Page Three). Known landmarks on the pressure ridge measured in profile on a telescope scale from the Observatory two miles away, were seen to move horizontally easward within a few weeks. The old edge of the pit after being raised bodily was then mashed until it fell backward in a talus, and the upper part of the escarpment was now the cross-section of the inner live lava layers of the stiff lava column, where the pit floor had been lifted clear above what was left of the pit rim.

April 20, 1919, inaugurated a series of big flows from cracks in the Kilauea floor outside of Halemaumau at the north. These flows were destined to continue pouring across the northern part of the Kilauea floor throughout most of the year. They were called the Postal Rift flows because they originated at a hot crack where travelers formerly scorched postal cards. The swelling up of the rim of the pit was now extended around to the west and north, tilting the west station 4.5 degrees to the southwest, and the north bench mark 8.5 degrees to the north, so that it was lifted approximately eight feet in the course of a few days. This lifting up of old rim rock was accompanied by more or less heating and smoking of the cracks, and the outflow of liquid lava 800 feet back of the pit occurred without seismic disturbance, and was unquestionably connected through cracks with the same lava column that occupied Halemaumau. The Halemaumau lakes did not lower, but rose and increased their gas pressure while the tumescence of the inner bench magma lessened. The Postal Rift flow had advanced 1.4 miles across the Kilauea floor by April 25. T.A.J.

KILAUEA REPORT No. 1007

WEEK ENDING MAY 10, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On May 6 in the forenoon at Halemaumau pit of Kilauea Volcano there was little fume that could be detected at the sulphur spots on the floor of the pit, and very little steam appeared at the south talus. The pit seismograph indicated a gradual tilt away from the pit until May 2 and thereafter motion in the opposite direction. On May 9 some newly fallen rocks were observed at the base of the north talus.

The Observatory seismographs registered 38 tremors



May 6, 1919, showing the same southern edge of Halemaumau as in the photographs on Pages One and Two, but now quite unrecognizable. Halemaumau had become a dome, the rim had become a pressure ridge, the former eastern stone shelter lay under the flows in the foreground, and the main lake was in a hollow at the top of the dome on the right. The trig station shown on Page Four was lifted up until it fell to pieces on the "elephant's back" shown here on the left.



Southeast trig station at rim of Halemaumau when the ground was beginning to be heated, fumed, and stained by tumescence, February 21, 1919. This within two weeks was lifted up and overturned backwards away from the pit on the pressure ridge shown at the left of cut on Page Three. Photo Jaggar.

during the week and a very feeble distant earthquake was recorded at 9:24 a. m. May 10. Tilting of the ground for the week was slight ENE, and microseismic motion was slight but increased somewhat May 4-5.

TILTING OF THE GROUND FOR APRIL

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the direction given.

April 6-12	0.3 seconds W.
April 13-19	1.3 seconds W.
April 20-26	2.5 seconds SW.
April 27-May 3	1.4 seconds SW.

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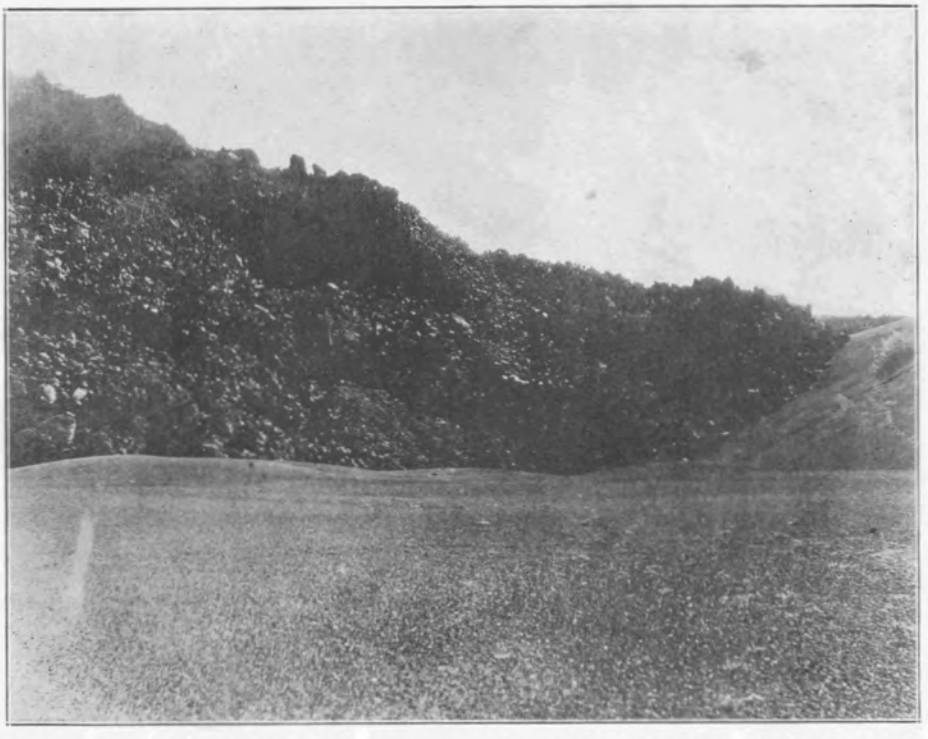
No. 334—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | May 21, 1931



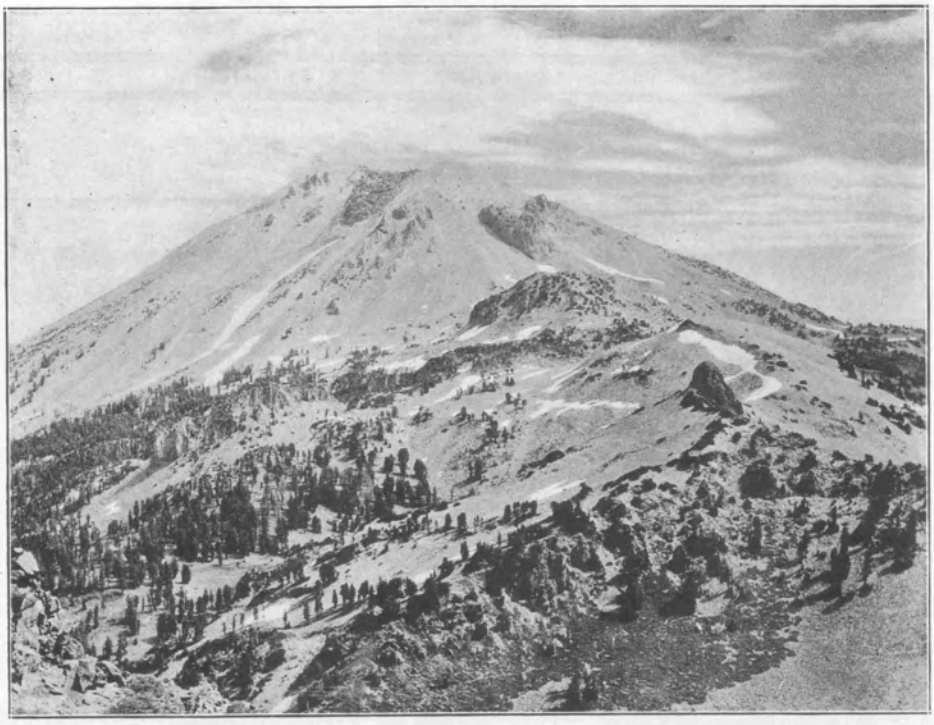
Edge of lava flow that poured out during the winter of 1850-51 at Cinder Cone, Lassen Volcanic National Park. Photo Finch.

THE YOUNGEST LAVA FLOW ON THE MAINLAND OF THE UNITED STATES

In the northwestern part of the United States there is a volcanic area covering about 25,000 square miles that extends from Lassen National Park, on the south, northeastward to Yellowstone National Park and northward to British Columbia. The eastern part of this volcanic area is the Columbia Plateau lava field, and the western part is the Cascade Range. In this range are Lassen Peak and other volcanoes that have been active in recent times. Mount Baker and Mount St. Helens were reported to have been smoking in 1843. Mount Rainier is said to have been feebly active in the nineteenth century, and steam still escapes from its summit crater. A volcanic eruption, possibly from Mount Shasta, was reported from a ship at sea in 1786. At the present time there are steam vents near the summit of Mount Shasta, 14,000 feet above sea level, so active that in a small area around them no snow can accumulate although a short distance away several glaciers have their sources.

In Arizona, New Mexico, and southern California there are very fresh-looking volcanic formations. The lava flow in the valley of the San Jose River in New Mexico is so fresh in appearance that it lends support to Indian traditions of a "river of fire" in this locality. Near Glass Mountain, in northern California, and at places in Oregon and Idaho, there are lava flows that appear to be less than 500 years old (Volcano Letter No. 292). At Cinder Cone, in Lassen National Park there are several recent lava flows, the latest of which (Page One) is believed to have poured out during the winter of 1850-51 (Volcano Letter No. 306).

It really was no surprise to those informed about the volcanic region of the northwestern United States when Lassen Peak became active in 1914. For a year the activity was largely confined to small explosions. Then during the night of May 19-20, 1915, Lassen produced the youngest lava flow on the mainland of the United States. The main crater was filled with new lava, and there were small overflows through low notches in the rim both to the east and to the west. The western branch of the flow is still in place, as shown on Page Two. Only remnants of the eastern branch of the flow remain, though there is good evidence pointing to the conclusion that it was the larger branch. Part of the eastern branch of the flow slid down the mountain shortly after it had been poured out, at the time of a mud flow during the same night. The photograph reproduced on Page Three, taken May 22, shows a remnant of the eastern flow, but most of this also slid down the steep mountain slope a few hours later. The most forcible explosion of the series took place during the after-



Lassen Peak from Mount Diller at the southwest August 27, 1927. The western branch of the youngest lava flow in the United States, produced in 1915, is the dark mass extending a short way down from the notch in the summit. Photo from Finch.

noon of May 22, 1915, after this photograph was made. Activity continued in varying degree until August 1917, but since then there have been no true volcanic eruptions of Lassen Peak.

Earthquakes that have their origin in the Lassen edifice are rather common as shown by the seismographs of the Lassen Volcano Observatory of the U. S. Geological Survey at Mineral, California. The fact that from 36 to 266 earthquakes are recorded each year at Mineral indicates that Lassen Peak is still somewhat uneasy.

Some references on Lassen Peak are as follows:

U. S. Geological Survey, Geologic Atlas, Lassen Peak folio (No. 15), by J. S. Diller, 1895.

The Volcanic activity and hot springs of Lassen Peak, by Arthur L. Day and E. T. Allen, Carnegie Institution of Washington, Publication 360, 1925.

Pictorial history of the Lassen Volcano, by B. F. Loomis, Anderson, California, Anderson Valley News Press, 1926.

The kingship of Mount Lassen, by Mrs. F. H. Colburn, San Francisco, Nemo Publishing Co.

The quartz basalt eruptions of Cinder Cone, by R. H. Finch and C. A. Anderson, Univ. Calif. Publ. Geol. Vol. 19, No. 10, 1930.

R.H.FINCH

HOT VOLCANISM OF NORTHWEST UNITED STATES AND CANADA

The article which precedes this is of great interest in presenting a newly discovered photograph (Page 3) by Mr. Loomis taken on May 22, 1915, at the same time as the one reproduced in Volcano Letters Nos. 266 and 304. The new one is different in showing the east side of the crater region of Lassen Volcano so clearly as to make it plain that the summit dark area is an unmistakable aa flow.

Lassen Volcano, therefore, produced in the end phases of its eruption May 19-20, 1915, stiff lava flows from its crater lips both east and west, and though the explosion of May 22 destroyed part of the eastern flow, fortunately Mr. Loomis was there in time to record its presence, and the remaining lava in the crater and on the west side was left in place to cool off where it may be seen today.

The history of the Cinder Cone and of Glass Mountain in that same volcanic district shows the area capable in recent times of pouring out extensive flows into the forest. It is still possible that within a few years activity may be renewed somewhere in northern California from the volcanic system represented by Lassen and Shasta, so as to pour out fresh lava flows. Mr. Finch shows how many places in the northwestern United States are active volcanoes with evidence of volcanic heat.

In addition to these places there may be mentioned the numerous hot springs of California thoroughly investigated by Waring (U. S. Geol. Surv., Water-Supply Paper No. 338, 1915), and some of these are boiling and accompanied by steam jets, as at Devil's Kitchen in Lassen Park shown on Page 4. Especially noteworthy is The Geysers canyon where steam is used for power north of San Francisco in the St. Helena range. Near Clear Lake there are old volcanoes, and there are boiling waters at Calistoga, and at the Little Geysers, and fumaroles at the sulphur bank, which is near to The Geysers. At The Geysers there is super-heated

steam and volcanic gases, pointing to a magmatic origin (Steam Wells at The Geysers, California, by E. T. Allen and Athur L. Day, Publication 378 Carnegie Institution, 1927). This can only mean excessively hot gas-charged magma under the Coast Range close to San Francisco and not far from the center of the earthquake of 1906.

In addition to the abundant volcanoes of the Sierra Nevada and the Cascade Range from Lassen Peak to Mount Baker in Washington, Professor R. W. Brock (Proc. Third Pan-Pac. Sci. Cong. Tokyo 1926, Volcanoes of the Canadian Cordillers, p. 688) reports the discovery in 1909 of volcanic cones and lava flows 40 miles north of Vancouver, and also hot springs, marking an extension northward into Canada of the active volcanoes of the United States. The volcano Garibaldi is a cone rising 3,500 feet above the plateau to a total elevation of 8,700 feet, made up of cinders with some interbedded lava streams. In the Lillooet District there is andesitic pumice covering 1,500 square miles. On Naas River in British Columbia there is a lava flow consisting of olivine basalt, 20 miles long, and said by the Indians to be less than 200 years old. It dammed a river forming what is called Lava Lake, and there are explosion cones five in number, the description of which closely resembles that of Cinder Cone at Lassen. On the Unuk River there are other recent lava flows and vents so fresh that the volcanic ash can still be seen as black patches on the glaciers. Craters and flows on Ruby Creek in the extreme north of British Columbia, vast deposits of volcanic ash on the Yukon plateau, a volcanic cone north of the Pelly River, and some other places, lead Brock to the statement, "Complete exploration may show as much recent volcanic activity in western Canada as in most sections of the Pacific volcanic girdle." T.A.J.

DEATH OF PRESIDENT THURSTON

The editor records with the utmost grief the death on May 11, 1931, of the Honorable Lorrin Andrews Thurston, President of the Association, in Honolulu.

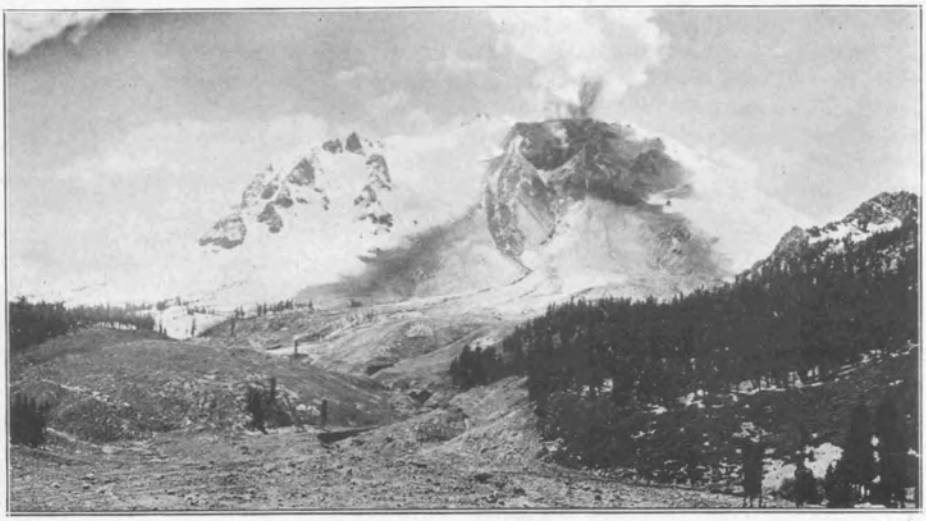
KILAUEA REPORT No. 1008

WEEK ENDING MAY 17, 1931

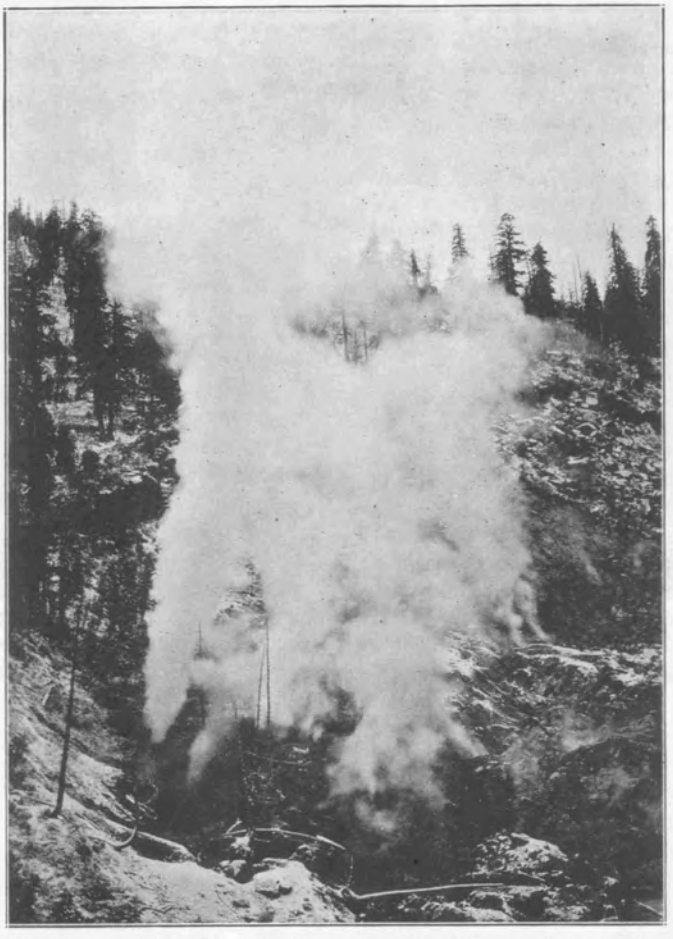
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanic conditions are very quiet at the Hawaiian volcanoes and at Kilauea the only seismic movements of any consequence are very slight tremors. At Halemaumau pit on the inner floor of Kilauea Crater a visit at 10 a. m. May 14 showed everything quiet about the bottom lava of 1930, no steam was visible at any vents, and a little fume was infrequently detected at a yellow sulphur spot near the middle. One or two rocks were heard falling at the northeastern and northern walls of the pit. The same conditions were noted at 9:15 a. m. May 16, and a small slide occurred at the north wall at 9:25 a. m.

Twenty-eight tremors were registered on the Observatory seismograph during the week ending midnight May 17, and one very feeble local seism at 4:41 p. m. May 13. Tilting of the ground accumulated slightly SW, and microseismic motion was slight.



Lassen Peak from the northeast May 22, 1915. The dark area under the steam cloud is a part of the eastern branch of the lava flow that came out during the night of May 19-20, 1915. Photo B. F. Loomis.



Steam escaping with velocity in Devil's Kitchen, Lassen National Park, November 14, 1930. During the summer the seat of the principal vent was a boiling pool of water ten feet in diameter. The steam was above the boiling point for that elevation. A cold, disagreeable rain was always falling under the vapor cloud. Photo from Finch.

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No. 335—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — May 28, 1931



South end of St. Paul Island in the Pribilofs showing Gorbat rookery and Reef Point rookery with Otter Island in the extreme distance and St. Paul village beside the salt lagoon on the right. Photo Rauch.

ST. PAUL ISLAND IN THE PRIBILOF GROUP

During the writer's visit to the Aleutian Islands in 1917 he had the privilege of meeting Mr. William P. Rauch who kindly gave him specimens he had collected on St. Paul Island, the larger northwestern member of the seal islands, or the Pribilofs, where the fur seals are protected by the United States. St. Paul lies 200 miles north-northwest from Unalaska Island in the Bering Sea, and off the line of the Aleutian Islands. Mr. Rauch took photographs, some of which are reproduced herewith. The rocks of the Pribilof Islands have recently been described by Washington and Keyes (American Journal of Science, November, 1930). One of the pebbles collected by Mr. Rauch is described by these authors as hyalobasanite, a basaltic lava which would have contained much nephelite if the lava had been completely crystallized. This rock also contains olivine. Other specimens are ordinary fine-grained basalt.

Mr. Rauch writes: "I obtained a small piece of sedimentary rock containing shells, and have turned it over to Dr. P. S. Smith, Alaskan Branch, U. S. Geological Survey. This sedimentary rock was some ten to twelve feet above high tide, embedded in the perpendicular cliff just to the right of what is known as East Landing on St. Paul Island. I should judge that weathering and heavy seas had exposed it. The whole island gives one the impression of a sort of volcanic fairyland so many diminutive volcanic cones and craters, so small, and so different."

Black Bluff, a sea-dissected cone on the eastern coast, contains tuff with rounded, calcareous, or marly clay fragments with fossil shells of post-Pliocene age and of species now living including walrus bones. There is no glaciation. The island is volcanic and according to Stanley-Brown (Bul. Geol. Soc. Amer., Vol. 3, 1892, p. 496) was built up after the Tertiary with outpouring of lava from a central vent in a submarine eruption. "Its surface is diversified by at least a dozen cones and vents of unusual symmetry, surrounding in irregular fashion a true crater dome some 600 feet in height called 'Bogoslof'" (not to be confused with Bogoslof, the active volcano near Unalaska). Washington and Keyes say, "The island of St. Paul, the largest of the Pribilofs, has a greatest length of about 13 miles between its northeast and southwest points, and widths of from 6 to 8 miles. Its area is about 33 square miles. In its early stages it may have consisted of a group of 10 or 12 small islands, now joined together. The lava flows gradually built up the basement floor of the island, and these were vesicular basalt rich in olivine. There followed from the central vent great flows of basalt, with others from smaller cones, all together constituting an overlying sheet. It is more crystalline than the basement lava. The marked contact of the two sheets is near sea level. There are thin, unbroken lava domes" and small spatter heaps. No andesitic nor trachytic lavas are present and tuffs are rare. An analysis of the nephelite basanite by Washington and



Reindeer herd on St. Paul Island, looking southwest on the south side of the island in the region north of the salt lagoon. Photo Rauch.

Keyes shows a composition rich in iron, titanium, magnesia, lime, and the alkalies, with 44 per cent of silica.

St. George Island, about 40 miles southeast of St. Paul, reaches a height of a thousand feet, is bordered by bluffs, has a basement of dark basalt, and contains many breccias and tuffs as well as some non-basaltic lava. There is andesitic ash and possibly trachyte occurs.

As to activity in recent times, flames are said to have been seen to rise from the sea northeast of the Pribilof Islands, and a submarine eruption is recorded for 1815 northeast of St. George, where there are small circular shoals at depths of from three to eight fathoms. Out in the middle of Bering Sea Pinnacle Islet five miles south of St. Matthew Island, was cited by Elliott as having been in an almost constant state of activity since its discovery, and as being active at the time he was there in 1874. This author also thought Otter Island, a small rock southwest of St. Paul (faintly visible in the distance in the photograph reproduced on Page One), had been recently active. All of these facts are culled from Washington and Keyes.

Mr. Rauch made the accompanying sketch map on Page Four to express roughly the position of his photographs. The map should be turned so as to make the long right-hand point turned northeast, and not east. St. Paul village is thus at the south end of the island, Rush Hill 665 feet high is the highest point on the island at the west end, and the principal anchorage is in English Bay west of the village. The photograph on Page One shows Reef Point which projects south of the village, on the right are seen the village houses, and in front of them is the salt lagoon bordered by tundra flats. The entire island is grassy, without shrubs or trees, and the same is true of the Aleutian Islands. A considerable herd of reindeer is maintained on the island as shown on Page Two. There are two fur seal rookeries on the two points near the village, and on the lowland bars of the northeast point there is the largest seal rookery ground. Formerly a drum tractor was used for hauling the pelts across the island, now there is a wire cableway.

Looking into the interior of St. Paul Island from the village northward, one sees flat, grassy, rolling country with the salt lagoon in the foreground and four or five cones beyond, of which Bogoslof is the most dome-like. Standing on the top of Bogoslof and looking westward we see six or seven cones with marked tendency to horseshoe shape, the opening of the horseshoe generally facing toward the north as though the prevailing wind tended to build the higher heapings of the lava fountains toward the south. This is the scene photographed on Page Three. From this elevated point the expanse of flat tundra to the northeast covers about one-seventh of the island, all very slightly elevated above the sea. A large triangular lake of brackish water is inclosed by two bars which have shut off the lake by connecting an outlying islet with the main island at the northeast point. Such ponds are common partly as fresh water crater lakes and also as longshore lagoons as shown on the map by L. The letter V on the map indicates volcanic hills and craters. Looking southward from the summit of Bogoslof one sees a broad slope leading down to the southwestern embayments, all grassland over lava, with small lava pits in the foreground, the topography suggesting the pahoehoe of Hawaii. The lava conelets of the Pribilofs are much more Hawaiian in quality than the eastern islands of the Aleutians, but in some of the western Aleutian islands there are wide lava flats greatly resembling the photographs of St. Paul.

With reference to the opening northward of the horseshoe cones and the sweep from northeast to southwest of the barrier beaches that trail to the main island from the northeast point, it seems probable that the constructional action of the sea has been from northeast to southwest with the prevailing winds, thus smoothing the northern and

southeastern shores, and leaving bays at the southwest. As there are three distinct embayments and two of them fairly deep on that side, it may well be that the volcanic tumescence which accompanied the outpouring of lavas had a tendency to uplift at the northeast and some drowning of topographic depressions at the southwest. The salt lagoon next north of the village, and the topography of the three bays adjacent to it, suggest drowned valleys among lava-flow ridges. T.A.J.

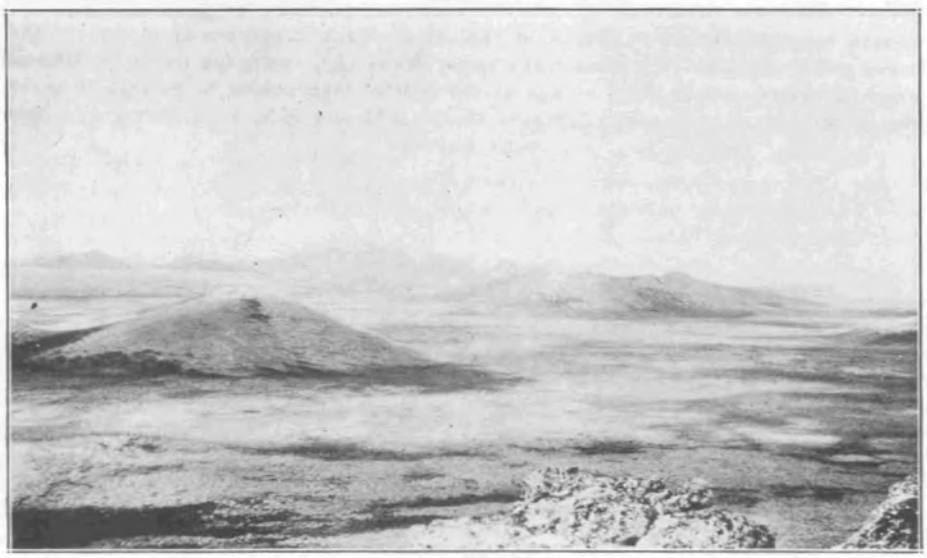
KILAUEA REPORT No. 1C09

WEEK ENDING MAY 24, 1931

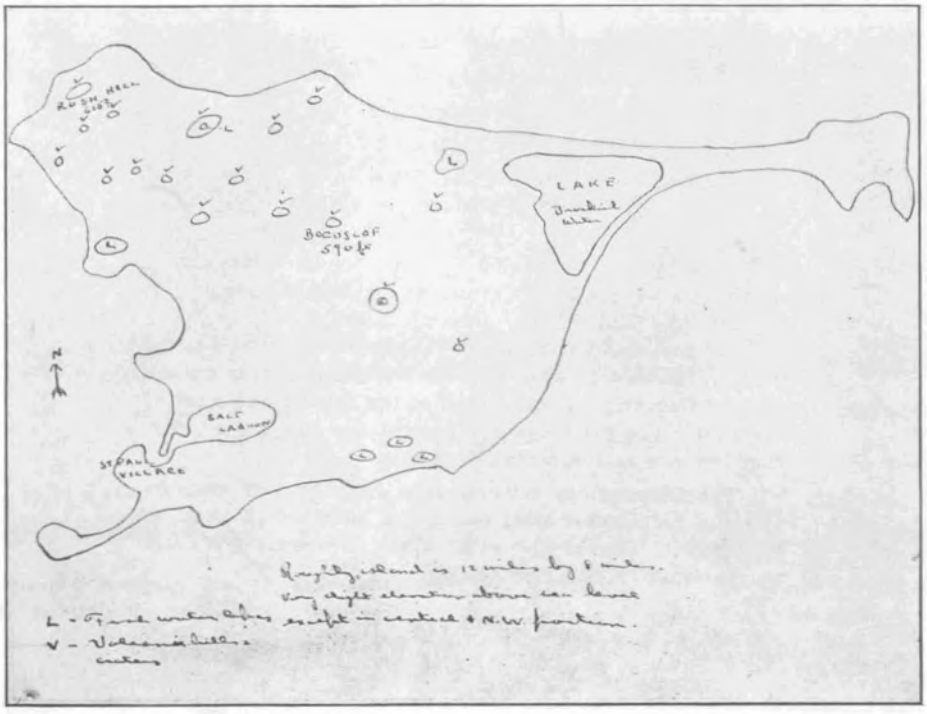
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

At Halemaumau pit of Kilauea Crater a slide occurred on the northwest wall about 9 a. m. May 18 sending up a dust cloud. At 10:30 a. m. fume at the larger sulphur spot on the floor had slightly increased, but there was very little vapor rising from the wet area of the south talus. The avalanche was seen to have left a slight scar on the wall. Other sulphur spots besides the fuming one west of the center are bright yellow against the black floor, particularly one at the far western side.

The Observatory seismographs registered 25 tremors and one very feeble local seism, the latter at 12:18 p. m. May 23. Tilting of the ground was moderate SW, and microseismic motion very slight.



Photograph taken in July 1927 from the summit of Bogoslof hill in the middle of St. Paul Island looking westward toward Rush Hill in the extreme distance, that being the highest point of the island. At the right is shown a horseshoe cone resembling Diamond Head at Honolulu. Photo Rauch.



Sketch map by William P. Rauch in 1927 at St. Paul Island showing roughly the many volcanic cones (V), little fresh water lakes (L), the large northern lake of brackish water, and St. Paul village at the south. Map should be rotated to make the eastern point northeast. Compare charts 8802 and 8995, U. S. Coast and Geodetic Survey.

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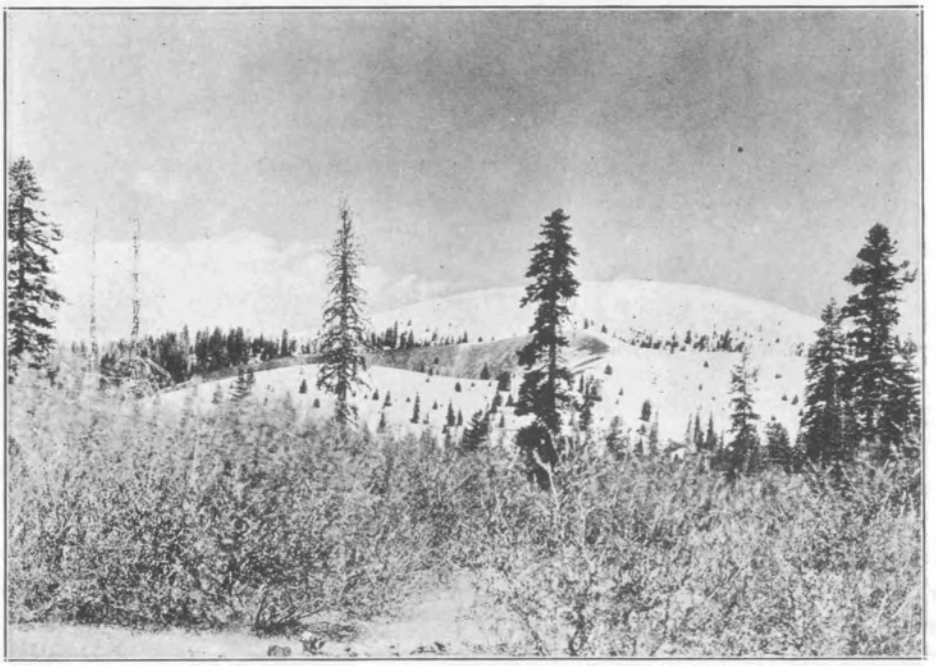
No. 336—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | June 4, 1931



Pumice Stone Mountain, west of Medicine Lake, California, seen from the south. The white pumice closely resembles snow. Photographed July 13, 1930.

LASSEN REPORT No. 29

SOME WORK OF THE LASSEN VOLCANO OBSERVATORY 1930

R. H. Finch, Associate Volcanologist.

Mount Harkness Seismographs

A two-component Hawaiian-type seismograph has been installed in the basement of the fire lookout observatory of the National Park Service on the summit of Mount Harkness, 12 miles east-southeast from Lassen Peak, California, elevation 8,039 feet. The instrument was started in operation on August 21, 1930, but owing to early snows Mr. H. C. Lind, the fire lookout and seismograph operator, was called away a little before the last of September and only a little over a month's record was obtained. The observatory building is located near the summit of a cinder cone that rests upon a lava base. Some earthquakes were recorded better on the Mount Harkness instruments than on the ones at Mineral.

Tilt

All instruments needed occasional attention to correct for tilting. The accumulation of tilt from the Mineral seismographs appears to be less during 1930 than in former years. Coincidental with a southwest tilt at Mineral there was a southeast tilt at Harkness. Of course, it is not yet know whether the Harkness tilt is local or not.

Earthquakes

The seismographs at Mineral recorded 74 earthquakes during the year. These disturbances by month were as follows:

January	5 shocks	July	7 shocks
February	7 "	August	5 "
March	5 "	September	4 "
April	4 "	October	4 "
May	5 "	November	14 "
June	0 "	December	14 "

The numbers recorded during the last four years are as follows:

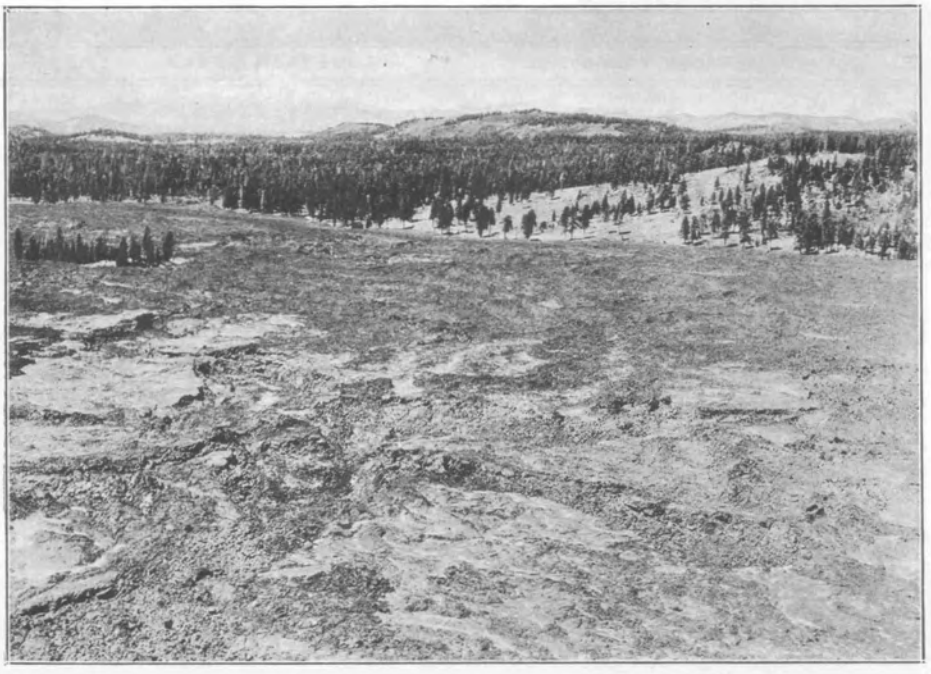
1927	266 shocks
1928	37 "
1929	96 "
1930	74 "

As in the preceding years, nearly all of the shakes had their origin in the Lassen massif.

Rainfall

The total precipitation for each of the last four years was as follows:

1927	43.32 inches
1928	42.10 "
1929	38.65 "
1930	38.94 "



View taken July 12, 1930, looking westerly across Burnt Lava Flow from edge of High Hole Crater.

Burnt Lava Flow

In July a topographic map of Burnt Lava flow, to the southwest of Glass Mountain and south of Medicine Lake, and 80 miles north-northwest from Lassen Peak, was made and specimens collected. Dr. C. A. Anderson, of the University of California, is to make a study of the specimens and a report of the flow will be prepared for publication.

Hot Springs Temperatures

Temperatures of springs at Morgan Springs on August 6, 1930, air temperature 88° F. follow:

Spring	Temperature	Remarks
No. 1	156°F	Algae and encrusted salts.
No. 2	125°	Very sluggish. Algae present.
No. 3 upper	196°	Less than normal flow. Some larvae present.
No. 3 lower	178°	
No. 4 east	195°	Flow very slight.
No. 4 west	164°	No. 4 area has been drained by ditching.
No. 4 clear pool	162°	
No. 9		No flow.
No. 17 steam at top	200.5°	
No. 17 hot water	201°	Volume as usual.
No. 20	200.5°	
No. 23 south	200°	
No. 23 north	196°	
Geyser	202°	Volume normal.

At Boiling Lake August 12, 1930, air temparature 82°:

Large mud pot northwest	196°
Boiler southwest edge of lake	195°
Boiling pool south edge of lake	194°
Dry steamer above south end of lake	201°
South end of lake	133°
North end of lake near outlet	121°

The water of boiling lake was about 12 inches below outlet. The lake level is the lowest it has been for several years according to Mr. Roy Sifford.

Temperatures at Devil's Kitchen August 12, 1930, were:

Mud pot northeast side	198°F
Mud pot north side	188°
Boiling pool north side, clear water 5 feet deep, small inflowing stream, no visible outlet	190°
Boiling pool north side, no visible inlet or outlet	196°
Large boiling pool north side with pyrite scum	194°
Steamer northwest end (poor exposure)	198°
Big boiler southwest side	196°
Steamer southeast side	198°
Big boiler east end. Pool 10 feet in diameter. Main part of boiling jets goes to a height of 46 feet, small jets reach 10 feet	196°
Steamer below Big Boiler	198.5°

At Bumpass Hell, air temperature 71°, the following were obtained August 14, 1930:

High western pool	193°
Mud pot west of No. 1	194°
No. 14, East pool	188°
No. 14, Middle pool	191°
No. 14, Big steamer	201°
No. 16	193°
Steam vent Bumpass Creek below Bumpass Hell	196°

Little Hot Springs Valley, August 14, 1930:

Clear pool east terrace	194°
Mud pot, east terrace	194°
Yellow pool	187°
Steam vent creek edge. Only fair exposure, steam emerging with considerable noise and pressure so that it was difficult to hold thermometer in vent even when tied rigidly to a stick	211°
Boiler surrounded by cold water in edge of stream	188°

At Supan's, August 15, 1930, air temperature 82°:

Big steamer (sometime in July this vent became more active and scattered mud for a distance of 40 feet from its edges)	194°F
Big steamer on October 31, Spring overflowing	192°

At Lassen Crater, August 20, 1930, air temperature 58°:

East vent near center of crater	132°
Middle vent under large rock	120°
Vent between two rocks north side of central area	162°
Steam vents above west edge of lake	146°

For earlier measurements of these temperatures at the various Lassen localities, see Volcano Letters Nos. 110, 162, 236, 238, and 279.

Land Slipping at Supan's

So many of the stakes were broken off that it was not possible to retape this area. Transit observations, however, failed to show any down-slipping. A new set of iron stakes was installed.

KILAUEA REPORT No. 1010

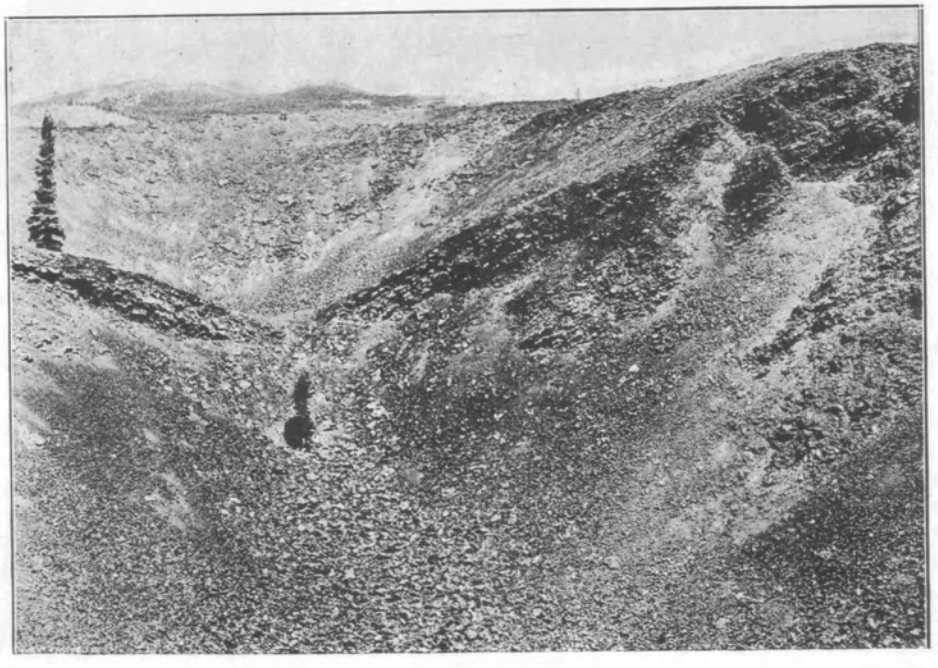
WEEK ENDING MAY 31, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

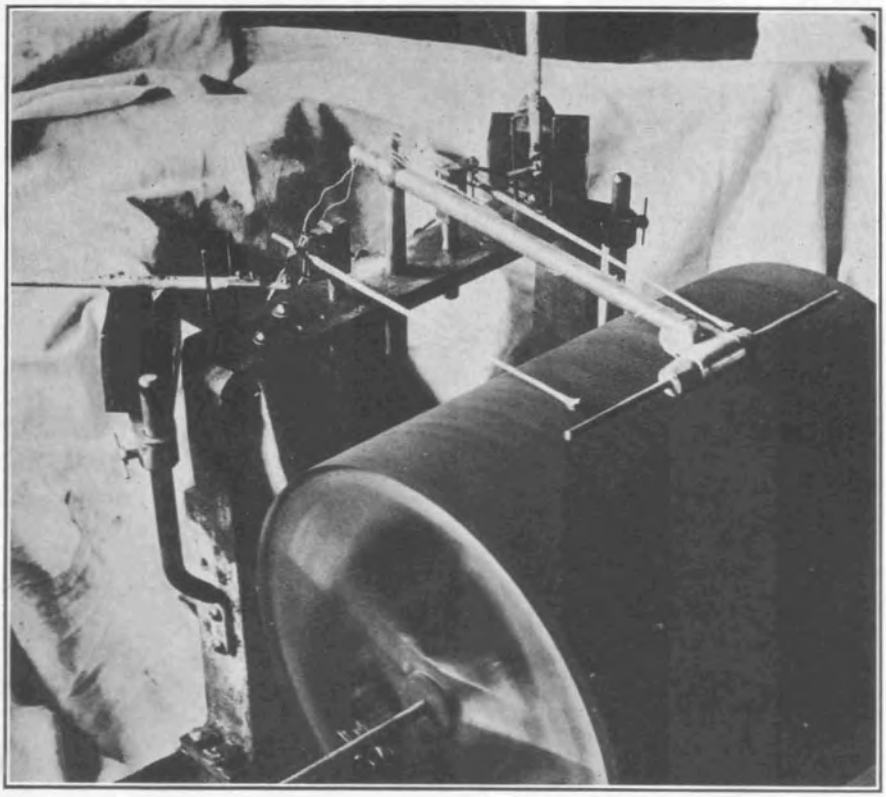
At the Kilauea fire pit on May 27, 11 to 11:15 a. m., steaming was slight at all the active vents, no steam showing on the south talus, a little on the west talus, and vigorous on the southeast rock bank. Fume was slight but steady at the west central sulphur area. A large scar from a slide showed on the north wall at the rim. At 1 p. m. a large dust cloud was seen rising north. On May 30 a very little steam showed on the south talus. Other conditions remained without changes.

The Observatory instruments registered 1 very feeble local seism and 33 volcanic tremors, including two and a half minutes of continuous tremor on May 25 and harmonic tremor from 4:06 to 4:24 p. m. May 29.

Tilting of the ground was moderate ESE. Microseismic motion was slight.



View showing the two parts of High Hole Crater in Burnt Lava Flow. Photographed July 12, 1930, by R. H. Finch.



Recording drum of Hawaiian Type Seismograph as installed at Mount Harkness. Drum covered with smoked "glassine" paper. Two pens write under the electromagnet, which lifts them every minute. They are connected with N-S and E-W arms. These are horizontal pendulums damped at the two small oil tanks. Drum moves along on its spindle.

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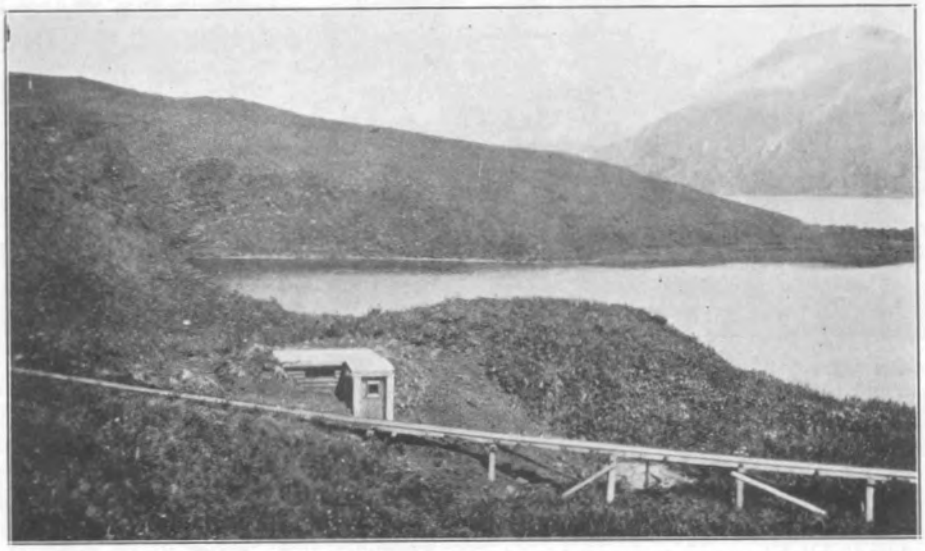
The Volcano Letter

Two dollars per year — Ten cents per copy

No. 337—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — June 11, 1931



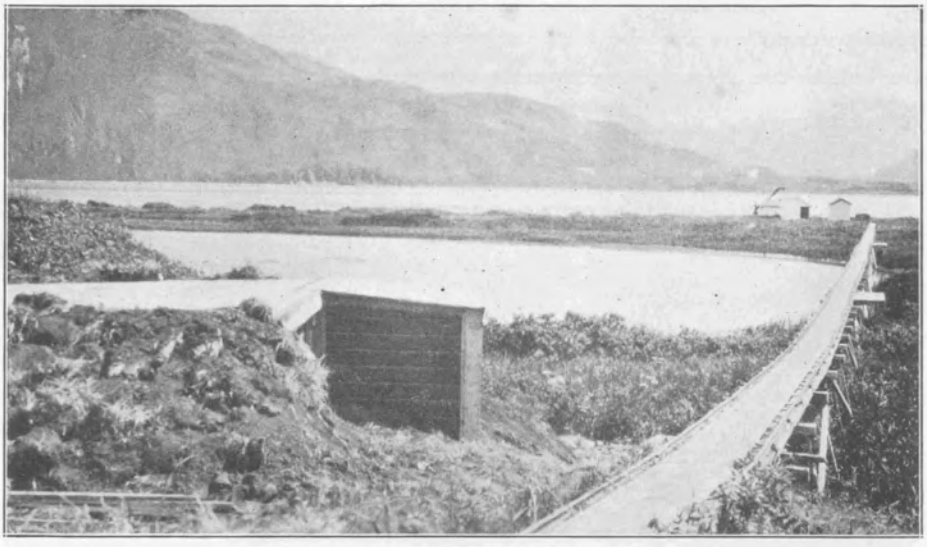
Dutch Harbor seismograph hut beside wharf tramway of Naval Radio Station as installed July 1929 by Austin E. Jones, so as to place instruments at some distance from the machinery. Looking east on Amaknak Island toward the entrance to Unalaska Harbor.

DIFFICULTIES OF ALASKAN EARTHQUAKE STUDY

The United States possesses one of the most important Volcano belts in the world in the Alaskan Peninsula and the Aleutian Islands. For a length of eighteen hundred miles from Attu at the west the ridge which separates Bering Sea from the Pacific Ocean extends in a pure curve northeast to Mount McKinley, rising higher and higher from islands at the west to the mightiest mountain in North America at the east. At the north is a shallow ocean, which is just as much a part of the combined Asia-America continent as is the Yukon Valley. It merely happens to be flooded with salt water in the present episode of geological time. At the south is the great Aleutian Deep reaching four thousand fathoms, a cleft or valley or sunken trough trending parallel with the Aleutian ridge, and in some way compensating the mysterious curved elevation. In like manner Japan is a curved ridge with the Tuscarora Deep east of it, with the outside of the curve toward the Pacific. Both places are famous earthquake belts with lines of volcanoes along the ridge. There are forty volcanoes reputed active in the Aleutian belt, many of them snowy peaks of greater and greater elevation as the line is followed northeastward to the upper part of the Alaskan Peninsula. The geology of the Peninsula and the islands shows folded sedimentary rocks of Mesozoic and Tertiary age, broken through by many igneous rocks, and overlaid by volcanic lavas and other accumulations along with glacial deposits.

The problem confronting the student of volcanology in such a place is to lay out a campaign for making use of the resident population to discover how many eruptions and how many earthquakes occur, where they occur in great number, what other movements like tilting of the ground are present, and in addition to explore individual volcanoes, promote mapping on land and sea, and gradually to acquire knowledge of places that may be used as strategic centers for continuous study of earth movements, hot springs, hot gases, and the action of lava underground.

The Section of Volcanology of the United States Geological Survey made a beginning in 1927 by establishing an Hawaiian-type seismograph in the Agricultural Experiment Station on Kodiak Island, shown on map of Alaska as the large island lying southeast of the upper part of the Alaskan Peninsula. In 1928 the volcanic area around Pavlof Volcano was mapped by the writer through an expedition conducted under the National Geographic Society. In 1929 another seismograph of the same type was established at the Naval Radio Station in Dutch Harbor on the island Unalaska (see Volcano Letter April 2, page one). Meanwhile an exploration had been made by way of reconnaissance all around the Peninsula and away out to Attu, in sequence upon a journey in a schooner through some of the eastern islands which had been made in 1907. All of this has shown us what the Aleutian lands are like, vast tundra flats with meandering streams on the north side of the Peninsula, rugged mountains and fjords crowned with



Seismograph hut at Dutch Harbor looking south, showing the harbor and mountains of Unalaska Island. Unalaska village just outside of picture on the right. Photo Jones.

volcanoes at the south, and these extending west through the grassy islands amid a climate of storms and fogs all the year around. There are a few villages of Aleut Indians and Eskimo, some canneries, huts occupied by winter trappers, and two or three sheep stations. Kodiak and Unalaska are the largest villages. In a few places there are resident white traders and officials throughout the year.

Until the present time, with between two and three years of record for the two seismographs at Kodiak and Dutch Harbor, there have been registered on the seismograms a few score local earthquakes and a very few distant ones. As a whole both places are disappointing in seismicity. Interruptions in operation due to storm and mechanical difficulties have been frequent. Storm microseisms are often so bad as to make seismic movements unrecognizable. Winter cold and wind and deep snow have produced rust and leakage and heaving at the unheated concrete huts, making endless trouble with the delicate clockworks, time pieces, electric contacts, wire connections and pivots which are essential parts of a complete two-component high-magnification seismograph. Neither Kodiak nor Dutch Harbor is actually at an active volcano, Kodiak being about 110 miles from Katmai and Dutch Harbor some twenty-five miles from Makushin.

The observers employed to tend the seismographs have all been devoted, conscientious women who were wives of officials or business men, and who do their utmost to keep the machines going even though the seismograph huts are buried under snow. The duties of these observers are fourfold: (1) to tend the seismographs, (2) to keep seismographs in repair, (3) to file and mail the seismograms, (4) to keep notes on volcanic happenings reported. It seems simple to anyone trained in physics to test the period, the damping ratio, the magnet adjustment, the tilt changes, the battery decline, and the time error of a pair of pendulums and an electrically connected eight-day regulator pendulum clock marking minutes and hours. It does not seem simple to untrained people buffeted by one of the most rigorous climates in the world, and with inspection by seismologists only at intervals of a year or more. All of this in a place without electric lights or watchmakers, where procuring supplies is difficult, where the building is unheated and the cold is intense, makes seismological registration a very different matter from Hawaii or California where supplies and assistance are abundant.

The following is from Mrs. M. V. Watkinson, the operator at the Kodiak station, who has to walk from her dwelling a mile or so up a hill to the seismograph chamber in an abandoned milk house of the Agricultural Experiment Station:

"February 21, 1930. We have had a great deal of trouble with the seismograph. The weather has been very severe, the natives say the worst for the last 40 years, so that all the water mains have been frozen. The storm has been almost continuous for twenty-eight days and has not broken yet. The time lift of the pens is not working right. The annunciator wire became saturated with moisture, in fact moisture was dropping down from walls and ceiling of room, and there were beads of water making a short between the wires. I changed the wires to waterproof covered ones, but this did not remedy the trouble. We found that the contact points of the clock were sticking, and fixed that. On February 4 and 5 the weather was so bad it was impossible to make my way up the hill. I started but had to turn back. Finally the seismograph went out of commission altogether owing to the heaving of the posts by frost. I have the machines running again, but not properly as the posts heaved diagonally. Yesterday I made the bumping test for period" (this is made by a light hanging weight giving a measured acceleration to the heavy mass).

"March 22, 1920. The continual severe weather has driven a number of halibut boats into port for repairs. The

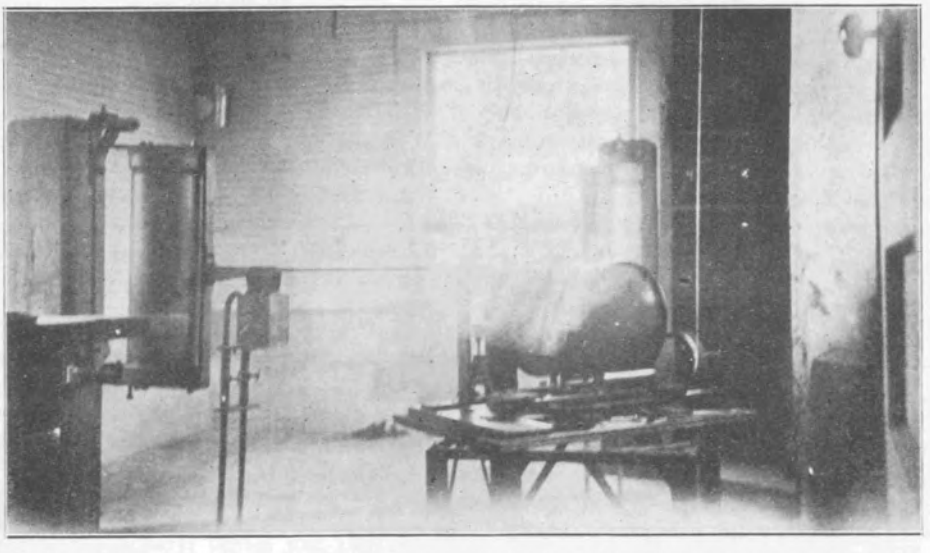
weather has been so extremely cold, with regular blizzards of snow, that it has been impossible to stay in the chamber more than a couple of hours at a time in spite of the oil heater. The records I am now sending do not mean much beyond recording the process of trying to get the machine to run properly.' On another day came the news of an epidemic of influenza with the operator and her two sons ill. In January another violent storm was reported "raging so that it was impossible to face it up the hill." A note of December says "there is no record for the 15th as the new driving clock would not fit. We were so disappointed as there were earthquake shocks next day, and we had numerous inquiries from up and down the coast as to whether they were recorded here, and it kind of hurt to have to tell that our instrument was out of commission."

The following are human documents from the journal of Mrs. Esther Wendhab, wife of Naval radio operator at Dutch Harbor, who tends the seismographs:

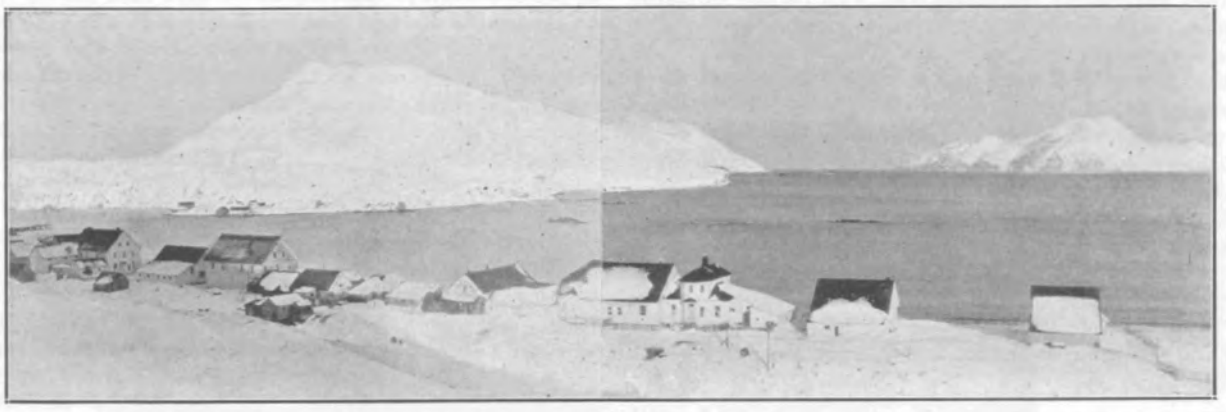
'March 18, 1931. Got 'stormed in' away from home and was unable to change the records. March 23: Was afraid to go out in the northwest wind on the icy trail. Captain Nelson of the Eunice reported a volcano smoking terribly with thick black fumes, where before he has only observed white steam, at Tulik on Umnak Island. He passed it March 21 and so unusual was its action he believes it is about to erupt. There was no record on the seismograph. March 29: Two earthquake shocks this morning, and the needle that has been causing trouble made the best record. April 2: The clock is going wrong again. The minute contact points are worn and get dirty very fast. I believe it will keep causing trouble, but I will do my best."

"February 18, 1931. Took mail to town and it stormed so badly I could not get home at all, so did not change record until following monrning. February 20: No trace of the seismograph building, had a hard time finding it, as all landmarks are under snow. Found it by the huge bank of snow that I've been piling up to get to the door recently. February 23: No chance of getting down to change record today. Terrible storm and blowing SE at seventy-five miles per hour. Will have to use the long stick again, to prod around to find the building, because even the snowbank will be gone now. February 26: The pen point came out again and stopped writing. Weather so bad nearly impossible to get down trail. Natives born and raised here (a year later than Mrs. Watkinson's report) call it the worst winter they ever witnessed, with the most snow, twenty feet deep in many places and getting worse. Have to find the building and dig it out every time now. March 2: Worked all day yesterday and fixed the arm. Put it on this morning after I finally got in. March 14: Had to fix the clock again as the points were dirty, but have it going. Weather still bad and sorry I have the work to do in such bad weather. They tell me this is the last month of that and then I believe it will be a pleasure again. It will be so much easier that it will make up for some times I've nearly frozen getting there, I'm sure. There is no news locally about any disturbances."

This sort of heroism in the cause of science deserves going on record, and was not contemplated when these stations were established in summertime. These documents show why the writer is so anxious to perfect a simple seismograph to register numbers and intensities of local shocks. Geographical distribution of shock-recorders is more important than attempts at precision where precision is impossible. Twenty shock-recorders placed with school teachers or trappers in different places in Alaska, some of these living very close to an active volcano, will tell more than precision instruments, until such time as a large observatory may be established there. T.A.J.



Early model Hawaiian-type, two-component, horizontal pendulum seismograph installed in dairy house Agricultural Experiment Station, Kodiak. In this model the damping vanes, in adjustable oil tank, are near the heavy masses, which are filled with sand and weigh approximately 160 pounds each. Magnifying levers write on smoked paper on the drum. Paper changed and shellacked daily. Time clock in same room, corrected by telephone from radio station. Photo Jones.



Unalaska in winter time. Seismograph station of U. S. Geological Survey is among the snowy hills on the left. Photo Yatchmeneff.

KILAUEA REPORT No. 1010

WEEK ENDING JUNE 7, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On June 1 at Halemaumau pit of Kilauea Crater very faint fume could be seen at the sulphur spot on the floor, and vapor was thicker at the southeast rock wall at edge of floor than at the south talus. On June 3 the pit seismograph indicated quiet conditions and the rock wall steamed less. At 9:30 a. m. June 6 a slide occurred at the north wall.

Thirty tremors and one very feeble local seism were registered at the Observatory, the latter at 8:41 a. m. June 6, indicating distance of origin 25 miles. Tilting of the ground was slight WSW., and microseismic motion was slight.

TILTING OF THE GROUND FOR MAY

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the direction given.

May 4-10	0.9 second	E.
May 11-17	1.8 seconds	SW.
May 18-25	1.1 seconds	SSW.
May 26-June 1	7.7 seconds	SSW.

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No. 338—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | June 18, 1931



This map should be corrected by showing a broad strip of Hawaii National Park between Kilauea and Mokuaweoweo craters. The 1855 flow is between the flows of 1880-81 and 1899. About the Mauna Loa center there were flows at the beginning of the nineteenth century to NW, in the first half of the century to E, then a big series to N, and an increasing series from 1868 to 1926 to SW. The 1868 earthquake centered about Pahala, the 1929 about Hualalai. ("Flow 1901" at West Point is misprint for 1801.)

PREPAREDNESS AGAINST DISASTER

Address before Hilo Chamber of Commerce June 9, 1931, by T. A. Jaggar.

Recent Disasters

Recently there have been earthquake disasters in Japan, Mexico and New Zealand. The Napier earthquake in New Zealand has awakened the world again to the problems of fire following terrific earthquake at a place of population congestion, just as at San Fancisco in 1906, and at Tokyo in 1923.

Hilo, Hawaii

To the Associated Engineers of Hawaii January 16, 1918, I talked on the "index of danger from volcanoes," showing that the four classes of disaster to a volcanic land had happened in Hawaii. These are:

Class I, Explosion and volcanic blast
Example, Kilauea in 1924
Class II, Lava flow
Example, Hilo in 1881, Hoopuloa 1926
Class III, Earthquake
Example, Kau 1868, Puuwaawaa 1929
Class IV, Tidal wave, Example Puna shore 1868, Hilo 1877, 1923

As each of these is represented by damage in this century, the topic is a live one. We have recently seen in addition terrific wind storms in Honolulu and rain floods damaging shops in Hilo. The wind combination along with lava flow or earthquake might be very serious for Hilo.

The 1918 lecture was published in Bulletin of Hawaiian Volcano Observatory January 1918, tidal wave damage in Hawaii was reviewed in Volcano Letter No. 321, and the cycles of Hawaiian volcanic happenings in Volcano Letter No. 325.

Napier Earthquake

The best way to envisage preparedness at Hilo is not to speak in hushed whispers because we are timid about frightening tourists away from our real estate. This is the attitude of some mainland cities. The insurance attitude is the correct one, expect fires, but put them out. If a terrific earthquake wrecks Hilo, let us in Hilo make a perfect demonstration of calm, unruffled preparedness, with the ready service of supplies that General Pershing had when he jumped in and helped at Chateau Thierry. There is no use in having hysterics about these things nor in publishing anything. The thing to do is to keep quiet and get action.

Now let us see what happened at Napier. Wherever you were, in your car, on the road, standing indoors, standing outdoors, suddenly there comes a tremendous crash like and explosion and down you go. Everything goes down, houses, bridges, gulches, cliffs, fires start, road fills crack open, automobiles fall into the cracks, wharfs are all down, some of the shipping is grounded, the breakwater has settled out of sight in places. In other words, the enemy has hit Hilo with a Big Bertha. The railway is out of commission, emergency telephones are called for as the wires are all down, the water mains have burst, the sewage is interrupted, the fire engines are pinned in their houses, the roads are interrupted by landslides. More than all, the people are struck dumb with shock, and until a warship arrives, to which this sort of thing is all in the days work, the population is dependent on whatever leaders happen to be soldiers.

Rescue parties are organized to dig out the wounded, portable cranes are in demand. Explosives must be used to demolish tottering masonry, which is likely to kill more people with the thousands of aftershocks that are coming along. Temporary wireless is one of the first requirements as the radio masts are down. Airplanes are summoned to rush anesthetics and medical supplies, for these things have given out. They have to be carried by air. A large number of tents are needed for temporary hospitals, and the roads interrupted by slides and cracks are not immediately available for carrying people to towns which suffered less. Sea transportation is organized as fast as possible by wireless, but that takes some time. The water supply being cut off, it is necessary to get in a chlorinating plant, organize a road survey immediately, and start work on pipes for an auxiliary water supply from a place where fresh water is available. The contents of the banks are laid wide open as well as many other valuable safes and cash drawers, and martial law is immediately organized by soldiers and constables who understand such things, a ring of pickets is run around the city, looters are shot on sight by marine guards. The jail prisoners are called out for digging, and do heroic work of rescue. Many motorists are caught in gorges and gulches and search parties have to be organized to seek them. The post office department is entirely disrupted and a quick reorganization is called for, as inquiries begin to pour in by mail as soon as any partial organization has been made; people inquire for the safety of their relatives. All lights go out at the very beginning and the organization of a temporary lighting plant and the cleaning up of wires is of first importance when the darkness of night settles over ruins, where work has to continue with the aid of flares, and where valuables have to be guarded.

Necessarily the Navy and shipping are of great use, and there were three ships which reached Napier. A small, compact, efficient, relief committee was found to be the first requirement at Napier and the organization of an information bureau to answer inquiries. Within a week when outsiders arrive to bring relief, there is need of quarters to correspond with the destroyed hotel, and there is need of increased wharf facility. Free meals have to be organized with the relief funds. Now there is need for a card record of hospital cases, of which there were 2,200 at Napier. The stoppage of the sewers and the bad water supply made it necessary to get together as many trucks as possible as soon as the road gangs had opened a way to get out of the district, and 5,000 people were evacuated from Napier and Hastings to a neighboring town which had not suffered, Palmerston. Palmerston organized itself to receive the transport of refugees. There was an acute clothing shortage, and notices had to be placed in newspapers of other towns instructing the public what to send, for they sent too many groceries and too little clothing. The loss at the central towns was of the order of $15,000,000. Fire insurance was simply not paid, for the situation was just the same as at San Francisco and Tokyo, and companies when they do write risks involving conflagration always reinsure with other companies. Only when earthquake is specified, and fire resulting from earthquake, and when these risks are paid for, can there be any expectation of restoration by insurance. **After the event** in all these cases, San Francisco, Tokyo, and Napier, insurance companies wrote earthquake risks. This is always done without any logic, on the part of the owners seeking insurance, who try to save the horses after the barn is burned down. Then after 45 or 50 years when there is real danger, everybody has forgotten it, insurance has been withdrawn, the

building code has been relaxed, and it all happens over again. Such is human nature.

Organization for Preparedness

Every city should have a small committee of far-seeing men accustomed to administer discipline, representing commerce, public health, police and national guard, transport, and statistics. These people should have a clean-cut war problem with map of the city, just as war problems are worked out by General Staffs. The needs in time of disaster may be small or big, local or general, but the big possibilities should be looked at so that nobody will be surprised. The needs are:

(1) Organization of discipline and communication.
(2) Organization of rescue.
(3) Organization of relief.
(4) Organization of relief funds.
(5) Organization of camp for refugees.
(6) Organization of rebuilding.

(1) **Discipline and Communication**

This in Hilo would naturally fall to the Police service and the National Guard, and the communication side of it would call for the assistance and representation of the Naval and commercial wireless. Public Health agencies would be needed right away, and a representative of everybody possessing motor trucks.

(2) **Rescue**

This calls for large forces of laborers and truckmen, the National Guard to protect property, Boy and Girl Scouts to act as messengers, all the auxiliary police available, and all the resources of the Red Cross, including everybody who has had any nurse training.

(3) **Relief**

The prompt selection of camp grounds, creation of sanitation, and finding of auxiliary water, light if the main sources are destroyed, and assembling of food supplies have to be governed by circumstances. This sort of thing is best directed by some one familiar with organizing a camp on military lines and capable of enforcing martial law. There are needed food supplies, tents, surgical supplies, washing appliances, utensils. fuel, stoves, and competent cooks. Don't say 'get them at the hospital.'

The natural reaction of a committee is to say, "We have camp supplies in the armory, surgical things at the hospital, and trucks in the county stables.' Remember that for the extreme crisis contemplated, all three may be toppled over and burning, or under a lava flow, with 500 people dead, 1500 needing hospital treatment, and 5,000 homeless. The thing to face is the extreme possibility, the resources in water and supplies of Olaa and Hamakua, evacuation by sea to Maui or Kona, the place for a sanitary refugee concentration camp.

(4) **Relief Funds**

There have been cases of disaster where relief funds have been misapplied. One of the first things to happen when a catastrophe is announced is for subscriptions from elsewhere to pour in. The Red Cross is the proper center, with reputable financiers to act as custodians of money.

(5) **Refugee Camp**

Supposing Hilo partially destroyed under some great calamity, it is a matter of debate where to put a relief camp. The requirements are access to transportation, good water, supplies of food and clothing, policing, and communication by telephone and radio. If the wharves at Hilo were not destroyed or buried under lava, the place might be Waiakea or the airport. If a lava flow came through that side, the place would have to be in Hamakua.

(6) **Reconstruction**

The rebulding after disaster has been a remarkable feature at San Francisco and Tokyo. The same is promised for Napier. As in the case of war, there are improvements in civilization, as well as evils, that result from a general clean-up.

One can imagine a new Hilo with a beautiful park all along the beach from the Wailuku River to the Wailoa, and with the railway moved back. One can imagine taking pride in a new city with no advertising signs visible from the harbor.

Actualities on the Island of Hawaii

Hilo is peculiar among cities in the world in that it is squarely in a volcanic belt, but happens to have been largely spared until now. So far as strong earthquake is concerned, this is equally true of Honolulu. Both of these places are liable to a terrific earthquake, when everybody will be surprised, and say, "This is the first we have ever had." Just that was said by the living generation at Charleston, Santa Barbara and San Francisco. The reason is that the earthquake interval overlaps several generations, and in Hawaii earthquakes in the 18th century before the coming of the whites made no impression on grass houses.

Hilo is definitely committed to future lava flows. The years 1801, 1843, and 1859 sent flows northwest, two of them building new land in the sea, from Hualalai and Mauna Loa. The years 1852, 1855, 1881 and 1899 sent flows towards Hilo, one reached Waiakea, and the one before it reached Kaumana (1855). The years 1868, 1887, 1907, 1919, 1919 and 1926 have sent flows at short intervals to the southwest from Mauna Loa, always different places, three of them reaching the shoreline, all destructive of ranches or roads or villages or all three. Earthquakes destructive and dangerous came in a swarm in October, 1929, shifting the area of underground activity of the enemy from Kahuku to Hualalai, and suggesting that the north side of Muna Loa as the center of it all will probably be the sector where he will concentrate his artillery for the next attack.

Apart from these dates history indicates that Mauna Loa will average activity about every four and a half years, so that we now are on the verge of a new outbreak. There are pros and cons that argue for a long interval in some parts of the century, but we know too little to apply them here. The fact is inevitable that Hilo will look up some evening and see what resembles a bright star on the northeast rift line of Mauna Loa, and a flow will start following the hollows among the flows of 1852, 1855, and 1881 in the direction of the valley of the Wailuku River. After it has been going a month we shall know whether it is likely to keep going for a year. It begins with rapid aa flows, the source cones make pahoehoe, the aa ceases, then the pahoehoe slowly tongues out from above past the earlier aa extremities, and pushing through tunnels to spreading leaflike fronts, the pahoehoe may creep through the forest downward for many months. This would invade and dry up the Hilo water supply. The lava would be fed through a source tunnel up around the nine thousand foot level, forking out into many tubes down below. If a flow once got started between the 1855 and the 1881 flows, or on the north side of the 1855 flow, it would pour down the line of the waterfalls of the main valley of the Wailuku, as it has done in prehistoric times in the past, and as it did in 1881.

The waterfalls were made by many lava dams. The visible tributaries are mostly from the north, those from the south being buried under lava, and flowing underground. On this course the lava flow would pour straight through Piihonua, and the fate of Hilo would depend on how long the tunnel supply of pahoehoe kept on flooding at the source.

Just at this point could be applied the project to stop a lava flow advocated by the late honored L. A. Thurston. And only at this point. No aa flow in its early and rapid stages could be arrested. A pahoehoe flow in the later stages of an eruption, by reason of the tunnel mechanism, could be blown up at the source tunnel about the nine thousand foot level, or just below the source cone, so as to dam the lava stream with rock and force it to start fresh. The eruption would continue just as before, with the lava starting to flow anew out of the blocked channel over the surface of the country by a slightly changed course. If the previous pahoehoe flow took five months to get down near the Hilo level, the renewed flow 30 miles up the mountain would require as much or more, and the city would be given five months respite. The main source would go out of action in that time, and Hilo would be saved. There would be no necessity of employing the army or "T.N.T." Any contractor with a couple of men and some blasting powder, carried by pack mules from the ranch, and guided by the volcanologists, can do the job. If the 1881 or 1855 situation were exactly repeated, this diversion of the flow at the source could be done. It could not possibly have been done for Hoopuloa or Alika. The 1855 flow lasted 15 months, the 1859 ten months, and the 1881 nine months. Such durations are quite possible now, for the tunnel flows on the Kilauea floor in 1919 lasted seven months, and so did the Kau desert flow in 1920.

The Observatory asks from the Chamber of Commerce its complete cooperation, with as many members of the Chamber becoming members of the Hawaiian Volcano Research Association as possible, and taking a real interest. Meantime we are devoting all our energies to learning how to predict volcanic eruption.

Contemplation of these possibilities is thoroughly sound economics for this community, and should make each firm ask, "Is our office earthquake-proof in its construction? Are our investments, our insurance, and our influence all they should be to prevent congestion, flood, or conflagration? Are we assisting those who are working on this problem? Or are we saying, "This is all nonsense. Life is too short. Such a thing couldn't happen to Hilo."

KILAUEA REPORT No. 1012

WEEK ENDING JUNE 14, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On June 8 at 9:40 a. m. seismic conditions were quiet at Halemaumau pit and the sulphur spots on the floor and small steam vents at edge of floor were as usual. The sulphur spots have gradually increased since December 1930.

A notable slight local earthquake was felt generally on the Island of Hawaii at 6:51 p. m. June 11, with motion stronger and quicker in North Kona near Honokahau than elsewhere. This was the only place where one or two small objects were overturned. The shock was felt as a slow motion at Waimea, Hilo, Kilauea, and in Kau, and the evidence of distance on the seismograms made the origin probably under Mauna Loa. There were other very feeble shocks felt at Keauhou Ranch at 4:29 p. m. the same day and at 9:03 p. m. felt in Hilo.

The seismographs of the Observatory registered four other very feeble local seisms at 9:08 p. m. June 12 with distance of origin 14 miles, at 9:22 a. m. June 8, at 3:06 p. m. June 13 and 6:11 June 14. In addition 28 tremors were registered during the week. The total of seismic disturbances for the week numbered 35. Tilting of the ground was slight WNW, and microseismic motion very small.



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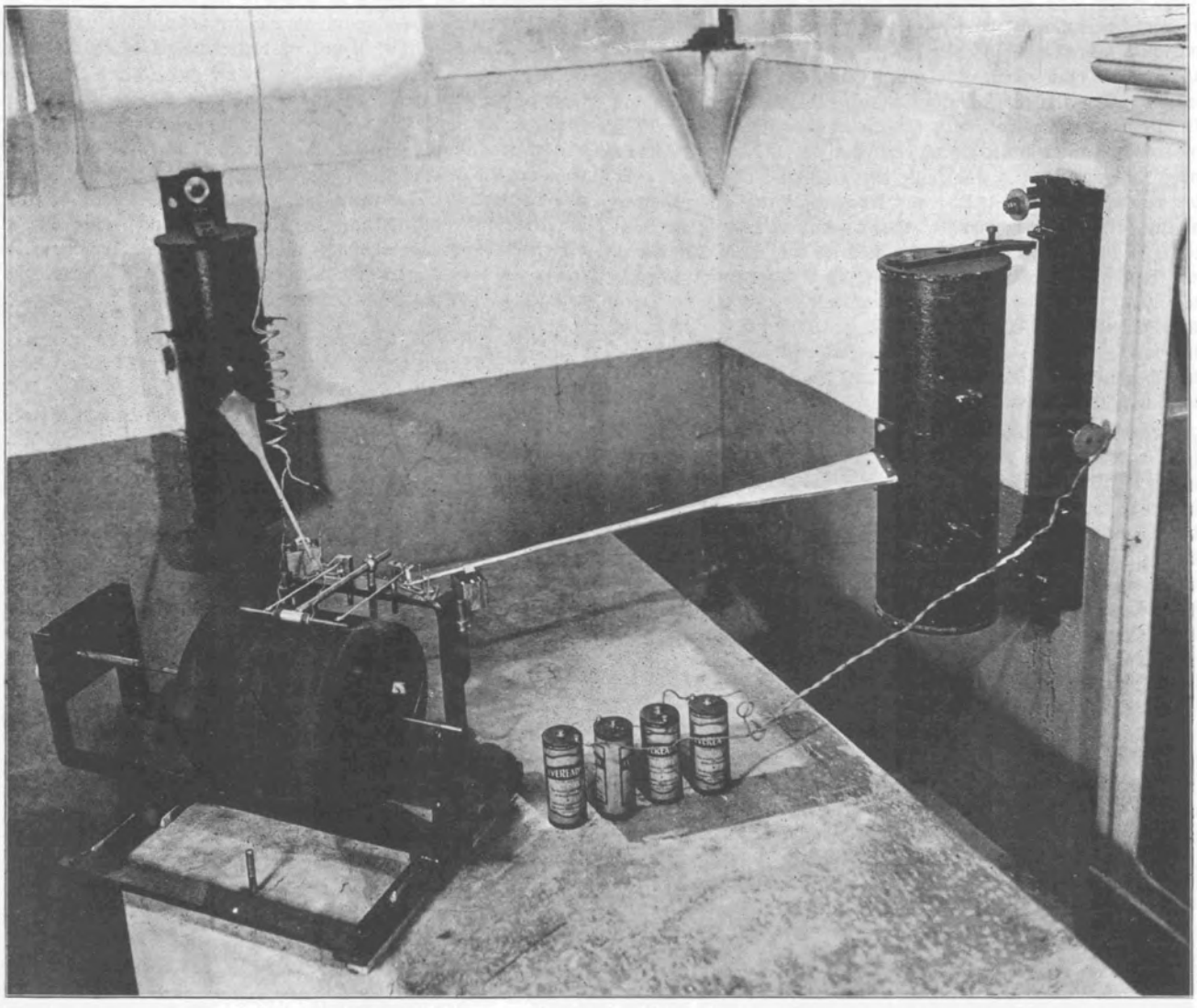
No. 339—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — June 25, 1931



Pair of Hawaiian Type horizontal pendulum seismographs, designed and built at the Hawaiian Volcano Observatory. Two heavy masses are hinged against plates on the wall east-west and north-south. Aluminum pens connected with booms from these masses write on a drum driven by clockwork and moving along on a screw. Paper is smoked and changed on the drum every day. The cross-bar electro magnet lifts the pens every minute and hour. The paper is shellacked and stored as the seismogram of the day. Photo Maehara.

EARTHQUAKE INSTRUMENTS HAWAIIAN VOLCANO OBSERVATORY

When the original building of the Hawaiian Volcano Observatory was constructed in February 1912, a preliminary equipment of instruments had been secured through the Massachusetts Institute of Technology, and by a special order placed in Japan. There were a pair of 100-kg. Bosch horizontal-pendulum seismographs made in Strasburg, an Omori portable two-component small seismograph for ordinary earthquakes, an Omori strong motion seismograph recording three components with an automatic starter, and a large one-component Omori horizontal pendulum of high magnification for distant earthquakes. A cellar 18 feet square and 9 feet deep was finished in concrete under the Observatory on the northeast edge of the greater Kilauea Crater. This was equipped with several concrete tables adapted to the instruments. During the first year of occupancy the instruments were set up and tested for the peculiarities of the Hawaiian ground, and the portable seismograph was used for a time in the

hut built near the north rim of Halemaumau. Mr. H. O. Wood had charge of seismology from the summer of 1912 to 1917.

The tests at the fire pit showed that the insensitive Omori portable pendulum would yield nothing distinctive of that place. A high magnification instrument was needed. Mr. Perret in the summer of 1911 with a delicately poised seismoscope had shown the presence of tremors at the pit edge when lava was fountaining inside the cauldron, and special pulsations recording the heavier gushes of the periodic fountain then called "Old Faithful." In September 1928 a one-component horizontal pendulum was installed in a shallow depression dug in lava 450 feet southeast of Halemaumau, covered with a very small shelter hut. This instrument was built at the station, and had first been used in Kona on the west side of the Island of Hawaii. It hangs so as to record tilt away from or towards the center of the pit, its heavy mass weighs 30 kg., and its magnification is 70. It records on smoked paper, and the drum covered with paper is smoked at the Observatory, is protected by a special box, and is carried to the pit by automobile and changed every two days. This pit registration has made valuable records at times of outbreak, and shows tremors and tiltings different from those at the Observatory two miles away.

This sort of evolution, with gradual change of instruments suited to special needs, has gone on with all the instruments. Seismometry on an active volcano is quite different from that of a station which devotes most of its energies to distant earthquakes. Most of the seismometric stations of the world are of the latter type. In Japan for many years the meteorological stations and other establishments have maintained instruments for the study of local earthquakes, but the main purpose of these stations in Omori's time was to record "ordinary" earthquakes, meaning registration of frequency, time, and intensity of the shocks that would ordinarily be felt, so that some scientific data could be gathered on the subject. This led to the making of more sensitive instruments of higher magnification and to the attempt to make a "universal" seismograph, which would satisfactorily record both local and distant shocks. Most of the German instruments make this attempt, and most of the earthquake lists do not distinguish satisfactorily between distant and local shocks. The "local' shock is a phenomenon still dubious and obscure, for if it is intense enough and deep enough to register on distant instruments, it may be "felt" over a wide area, and on the other hand very intense disastrous earthquakes like the one at Managua recently may be very local in perceptibility, and fail of registration at the remote stations. An earthquake may be accompanied by a massive movement of the ground with actual faulting of the sod at the place of sensation. What is felt in this case is not an "elastic wave." Many felt earthquakes are entirely elastic waves, with no discovered faulting of the ground. The natural history of this subject needs much research.

From this the reader should understand that it is an actual fact that no one knows what an earthquake is. Waves of compression, transverse waves due to the rigidity modulus of the rock, surface waves involving an up-and-down movement, waves reflected at different surfaces of change of density within the crust of the earth, waves traveling at different speeds, the ground or hill or cliff or plain under foot oscillating with its own period as an independent pendulum, spells of tilting, places of local tilting, mass movements of sideways shifting, mass movements of sudden uplift or depression, mass movements of sudden tilting—all of these things are supposed to exist in the crust of the earth, and a one-component pendulum, meaning a pendulum capable of swinging in only one direction, does not tell much about them. What little is known indicates that a house totally distorts the motion of the ground. The one-component pendulum totally eliminates all but one set of motions of the ground, tends to swing on its own account, and tells nothing by itself as to whether the motion is massive or elastic, irregular or harmonic, until subjected to rigorous experimental criticism. The result of years of registration of many local earthquakes on the Island of Hawaii quite denies the notion of an epicenter. The epicenter is supposed to be a place right over the source of a shock. At the epicenter the shock should be felt most strongly. It is quite true that on the Island of Hawaii many shocks are felt which are not felt in Honolulu 200 miles away. There is thus localization. But within the island there are hundreds of shocks felt equally at many places, with the seismographic evidence pointing to epicenters where there is no more intensity of perception than anywhere else.

Now what is this seismographic evidence? This is clearly important, for if we may harness an island with instruments, and that island has many earthquakes of a small and harmless type, we may really study the nature history of the earthquake. From the beginning this was the aim of the Hawaiian Volcano Observatory. People think they can tell the direction of an earth shock which they feel. All they can tell is the way the maximum of a hundred motions affected the particular room or chair or bed where they were placed. The seismograph is a rocking chair specially placed in a chosen room in the rock of the earth itself where the vibration of the building will not create a separate pendulum. The writing of the seismograph on smoked paper, when a little earthquake occurs, begins with a preliminary tremor as the paper moves along under the pen, then a movement of greater amplitude follows, or the "long waves,' and this is the part which is felt. This tails off to nothing in the course of minutes. A sensitive person standing outdoors might feel very faintly the preliminary as a mere tremble because it is quick. The long wave he would feel as a thud. The tail portion is slow and not usually felt. The writing levers of a seismograph, after magnifying the motion 100 times, have hardly any energy, hence the tiny pen tip pivotted and touching lightly a smoked surface to avoid friction. Even the restraint of a spider's web on the pen may spoil the record. The preliminary quick tremor has been proved to be a combination of the compressional and rigidity waves which reaches the instrument more quickly, by faster travel, than the long waves. The long waves are a combination of mass movement and wave motion. The sharp change from the preliminary to the long waves makes it possible to measure in seconds the duration of the preliminary. The longer its duration the farther away the place of origin of the disturbance. Hence with several seismographs in different places we may triangulate on the origin location underground. If we can find the origin location underground we do not need to trouble about "epicenters."

As shown in the accompanying pictures, the seismograph chamber at the Observatory contains now horizontal pendulums built right here registering all components, the electrically connected clock registers time on the drums, and there are other stations with similar instruments in Hilo and Kona for triangulation. The horizontal pendulums also record tilting of the ground. T.A.J.

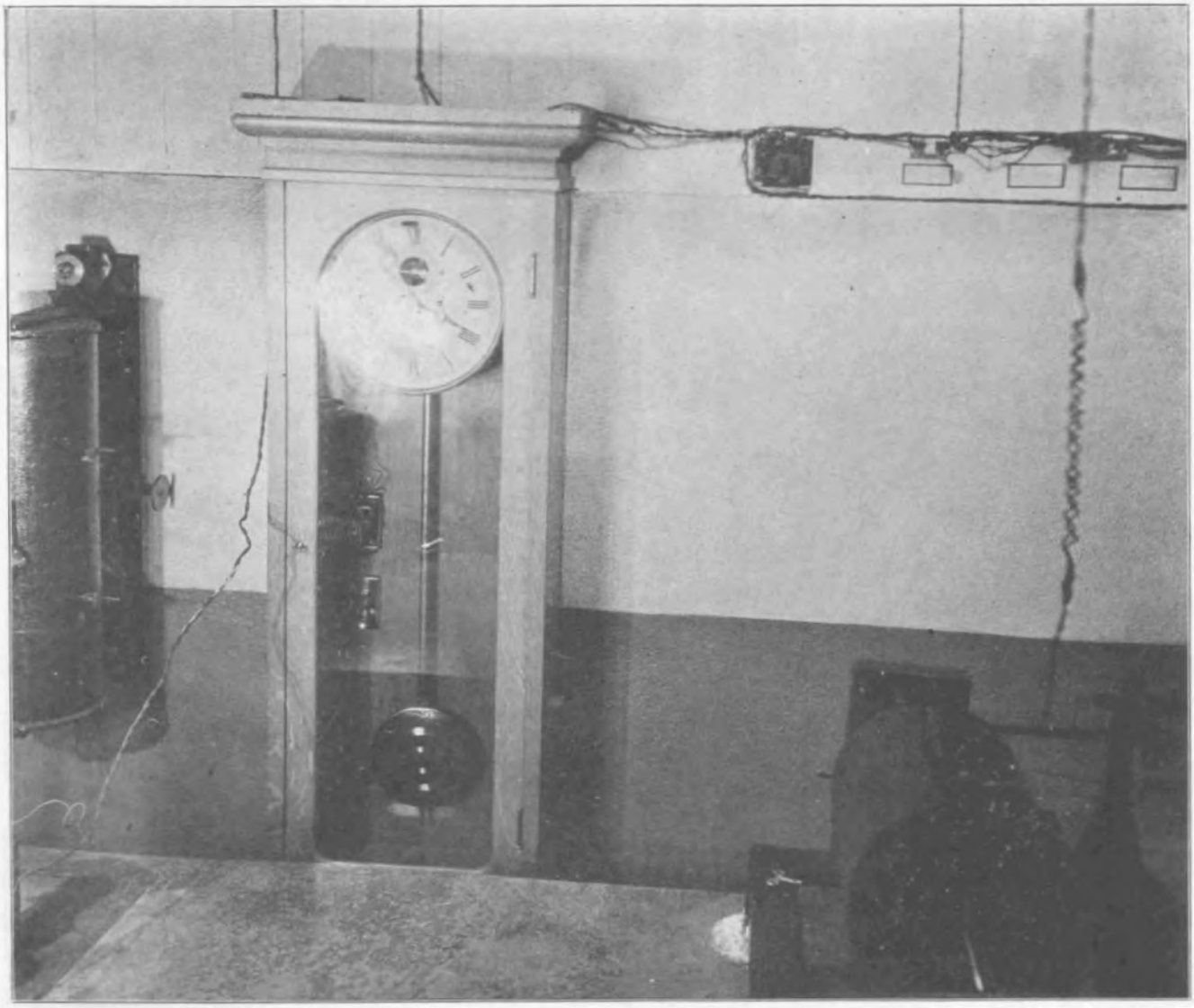
KILAUEA REPORT No. 1013

WEEK ENDING JUNE 21, 1931

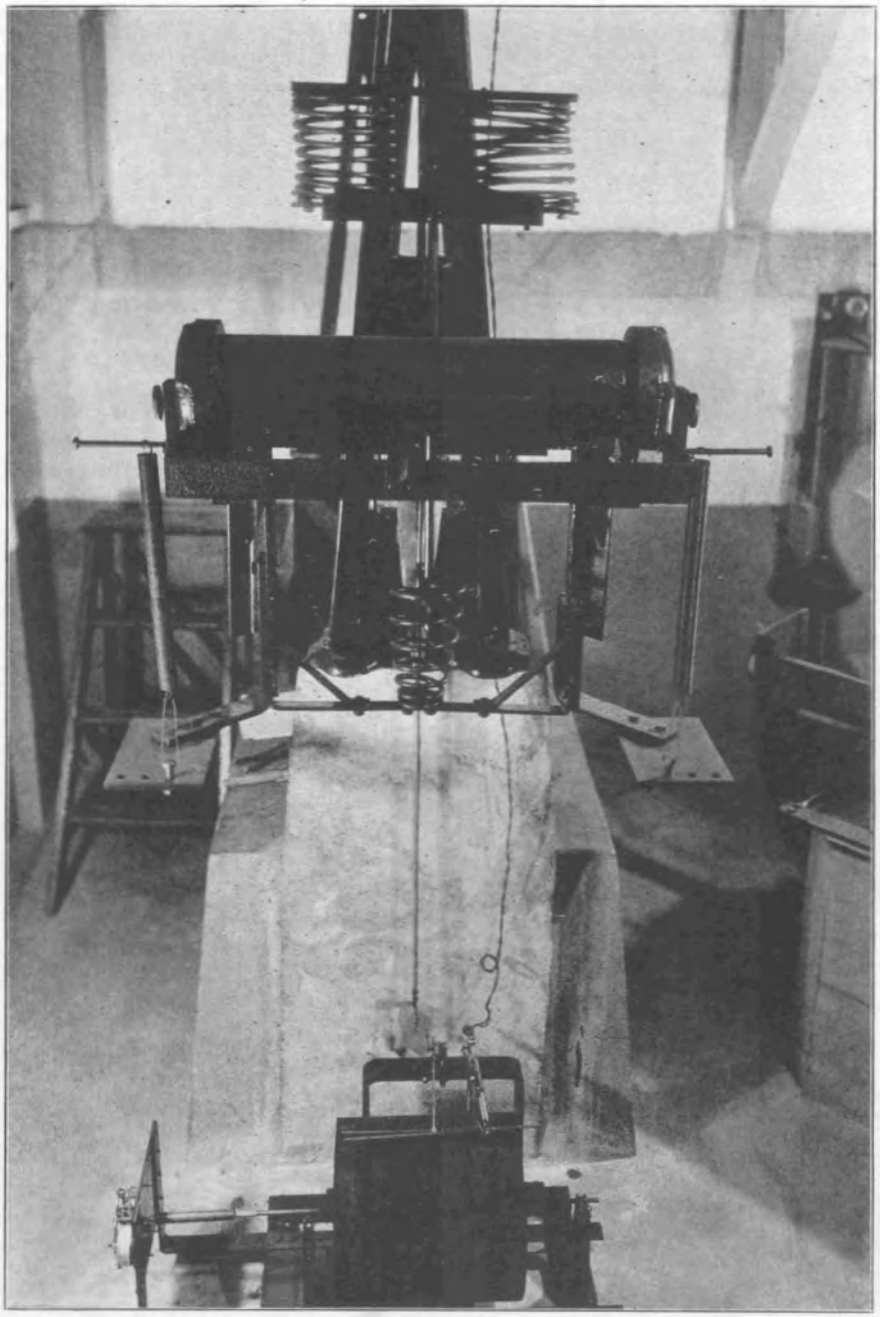
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On June 15 at 9:15 a m. a small slide occurred at the north wall of Halemaumau. Steam is emerging at the southeast rock bank. Fume is notably absent at present.

The Observatory seismographs registered 26 tremors, one very feeble local seism, and one feeble shock felt locally. The last was at 10:45 a. m. June 16, with indicated distance of origin 11 miles. Tilting of the ground was slight ENE, and microseismic motion was slight.



Howard electrically fitted regulator clock connected with all the self-recording instruments of the Observatory. The error of the clock is compared with wireless time every day. The wireless signal is impressed with telegraph key on all the seismograph drums. The clock is compared daily with a chronometer, and the temperature of the chamber is recorded.



Vertical component seismograph built at the Hawaiian Volcano Observatory. The heavy mass is here hung on spiral springs, with temperature compensation from small springs. The heavy mass is free swinging and registers the up-and-down motion of the rock under the concrete cellar. The up-and-down motion is smaller than the horizontal motion in earthquakes. Photo Maehara.

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No. 340—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — July 2, 1931



Myrtledale Geyser near Calitoga, Napa County, California. Made artificially by casing a well 180 feet deep, where a stratum containing boiling water is reached. The spouting occurs once every 45 minutes, when the release of steam pressure is satisfied, and it takes another interval to bring the replacement underground water to the boiling point.

VOLCANIC WATERS OF NAPA COUNTY, CALIFORNIA

In the Coast Range north of San Francisco, on the border between Lake and Sonoma counties, stands the St. Helena range marking some recent volcanic activity where there are hot gases and steam and sulphur which have been pouring forth from Teritary time until the present. "The northern and western ranges in these counties are composed largely of altered sedimentary rocks that probably belong to the Franciscan (Jurassic or Lower Cretaceous) formation. Glaucophane schists and serpentine are associated with them. The age of other altered sedimentaries here" is unknown, some geologists thinking them Lower Cretaceous.

"In Napa County and the southern part of Lake County several peaks and ridges are formed of lava that is probably of Teritary age. This lava overlies the altered sediments, and tuffaceous phases of it form prominent cliffs at a number of localities. Numerous carbonated springs of slight flow issue in this region north of San Francisco Bay, both from the sedimentary rocks and from the lavas, and hot springs exist in several places. A few springs of noticeably sulphureted water have also been examined but are less numerous and less important than those of the carbonated type."

So wrote Waring (Springs of California, Water-supply Paper 338, U. S. Geological Survey) in 1908, pointing out that upright fault or fracture lines have close relation to the hot springs of California. "At Calistoga, near the head

of Napa Valley" (three to four hours' journey north of San Francisco) "are several hot springs at which during the seventies there was a large resort. The hotel burned in the early eighties, however, and since that time the springs have not been of more than local importance. The name 'Calistoga' is said to be formed from the words California and Saratoga, but the springs are not at all like those of Saratoga Springs in New York. In 1910 the caretaker of the property had provided two bath-houses of two tubs each, half a dozen small cottages on the place were rented, and a few campers had pitched their tents nearby. Hand pumps supplied hot water directly to the tubs, and cool water was piped from a tank.

"Four main springs rise at the base of a knoll of buff-colored tuffaceous material at the northern border of the meadow land, and a few pools and seepages appear in the meadow itself. The observed temperatures of the principal springs ranged from 126° to 173° and their flows from about one-fourth gallon to five gallons a minute. The hottest spring, which yields about one gallon a minute, appears to be the most strongly mineralized, though its mineralization is only slightly perceptible to the taste. Algae probably give it the slight flavor that has caused it to be called a "chicken-soup" spring.

"At Calistoga Hotel, about 400 yards west from the springs, a dug well supplies warm water for tub baths and a swimming plunge. Warm water is also obtained in several other wells nearby, and there is one strongly flowing artesian well."

The following analysis of the swimming pool water, having a temperature of 122° Fahr., is characteristic, made by W. Anderson in 1888; constitutents are by weight in parts per million:

Sodium	212.0
Potassium	8.2
Calcium	12.0
Magnesium	5.7
Iron	6.0
Aluminum	2.4
Manganese	Trace
Sulphate	110.0
Chloride	255.0
Iodide	13.0
Carbonate	27.0
Silica	62.0
	713.3
Hydrogen sulphide	42.0

Concerning the geology of the hot springs Waring writes: "The position of the springs near the base of the knoll of volcanic tuff that rises in the valley land and the fact that a fault has been traced along this part of the valley furnish suggestive evidence that faulting has here provided escape for deep-seated water. The lava may also produce a high temperature gradient that aids in giving the abnormal temperatures to the water. The amount of heated water that rises is probably better indicated by the area of meadow-land that is formed than by the visible flow of hot water, for there is doubtless much seepage that is not observable."

This last conclusion has been borne out by discoveries since 1910 which prove the valley to be underlaid by boiling water instead of hot water (Waring maximum 173° F.). The writer visited Calistoga July 31, 1926, and learned that in 1915 borings 180 feet deep in the flat valley floor produced artificial geysers which spout up through the casings of wells 100 feet or more at intervals of 45 minutes to two hours. One of these, the Myrtledale Geyser, is shown on Page One. For a mile of length the east side of the valley is over an artesian basin of boiling water, whereas the springs are cold on the west. Mr. Finch determined the temperature of Plummer's Geyser March 22, 1927, to be 218° F., and Pacheteau's capped geyser 213.5° F. (Volcano Letter No. 236).

On the mountainside, five miles to the west of Calistoga, in Sonoma County, is the Petrified Forest where immense sequoias have been silicified in volcanic ash, mostly fallen in pairs, and with their butts toward Mount St. Helena. The suggestion is strong that St. Helena was the source of a volcanic blast that overturned them in prehistoric eruptions. The fossil tree shown on Page Three is 110 feet long with a diameter of 12 feet. There is a crater higher up the hillside.

Finch reports (Volcano Letter No. 236) that Mount Konocti, near Clear Lake north of this Napa country, is the most recently active volcano in this part of California. It is believed to have erupted somewhat over 1,000 years ago, or well within the historic period of Europe. The hills east of Sulphur Bank, itself east of Mount Konocti, contain a fairly well preserved crater, there is one on the south peak of the mountain, and between this country and Calistoga the lava flows capping the hills appear progressively older. Across the hills to the west at "The Geysers" in Sonoma County is superheated steam used for power (Volcano Letter No. 62, Allen and Day Publication 378 Carnegie Institution) believed to rise from hot underground magma.

It is worthy of note that the San Francisco earthquake of 1906, apart from the massive shift of terrain from Santa Cruz to Point Arena on the great fault, the greatest intensity was at Santa Rosa, with extensions of the belt northward toward Geyserville and southward to Petaluma. In the Napa valley and about Clear Lake there were other belts of apparent intensity VIII-IX R. F. This region of present-day volcanic heat of highest temperature for California, and of volcanoes active in the historic period, made localized centers of disturbance of enormous intensity. Therefore we should not treat too lightly the possible connection between underground magma and great earthquakes. (Map 23, Carnegie Institution, California Earthquake.) T.A.J.

KILAUEA REPORT No. 1014

WEEK ENDING JUNE 28, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The week at Kilauea has been quiet and uneventful. On June 22 there was a little steam on the south talus of Halemaumau, but none elsewhere. On June 23 no steam was seen. Dust was dense near the north talus, probably due to air currents, there having been moderately strong trade winds, without rain, blowing and creating much dryness. On June 27 the pit remained unchanged. Sulphur areas appeared less conspicuous except a bright spot on the west side of the floor.

Twenty-two very feeble tremors were the only seismic disturbances recorded by the instruments at the Observatory. Tilt was slight NW. Microseismic motion was slight.



Silicified big tree at the petrified forest in ash beds five miles west of Calistoga, California. This tree, "The Queen," is 110 feet long and 12 feet thick... The replacement of the wood fibre by silica was accomplished by hot waters. These sequoia trees were overturned in pairs, their tops pointing away from St. Helena volcano. Probably an ancient steam blast eruption did the work.



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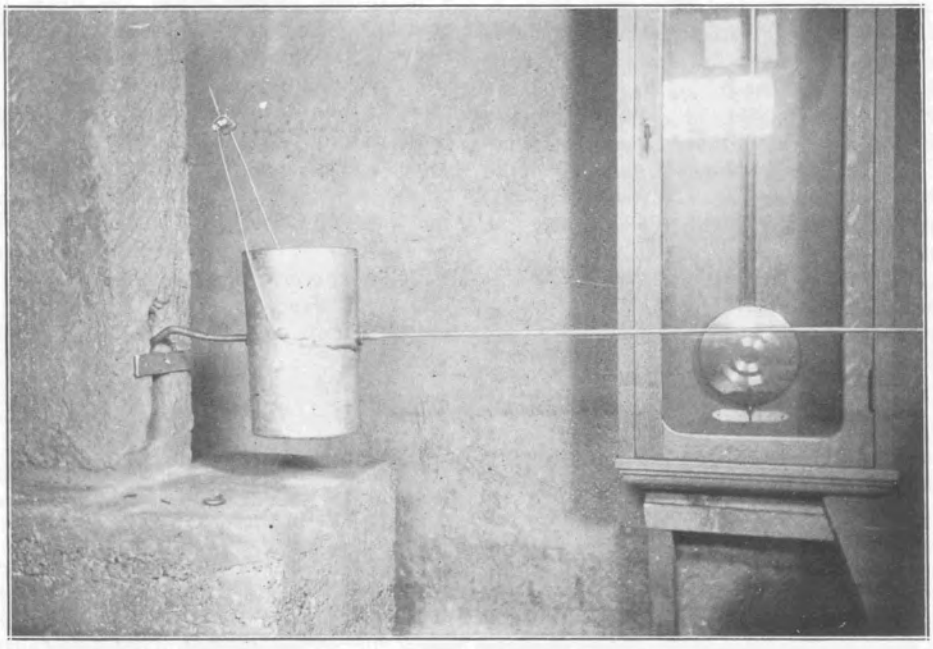


Experimental seismograph built of homemade materials at the Lassen Volcano Observatory by R. H. Finch, showing heavy mass, suspension and boom, the concrete pier and post, and the Howard clock.

MAKING A SIMPLE SEISMOGRAPH

The seismograph in most common use is a horizontal pendulum. The photograph shown on Page One is the hanging part of such a pendulum which anyone with a little ingenuity might make for himself. The machine shown in our illustrations is in fact one constructed by Mr. R. H. Finch in two months in the autumn of 1926 for preliminary tests of earth motion at the Lassen Volcano Observatory in California. This instrument was made entirely out of materials and labor available in any country town. There is here shown a clock on the wall which is a good timepiece made by the Howard Company in Boston, Mass. This is fitted with electrical contacts closing the circuit of a four-cell dry battery for about two seconds every minute and about six seconds every hour. It is a weight-driven pendulum regulator with eight-day movement. The electrical contacts on the minute and hour are for marking the time continuously on the smoked paper which covers the drum of the seismograph, so that any hour or minute may be identified on the paper for discovering the time when an earthquake has marked the paper.

On the left is shown a concrete post in a basement room with an upright hollow or groove cast at the bottom where the post rises from a concrete table or pier. It is better to have the cylinder as shown hanging from an isolated post than to hang it from the wall. We have tried both plans for different instruments at the Hawaiian Volcano Observatory. As the hanging cylinder is very sensitive to the slightest tilt given to its supports, walls are not desirable. The upper part of the concrete wall of a cellar on the outside of the building is heated by the sun for some parts of each day. The heating expands the wall and it cools at night, thereby contracting. The seismograph is so sensitive, magnifying earth motion some two hundred times in case of a horizontal displacement, that the distortion of the wall under expansion and contraction will cause the writing pen to swing sidewise an inch or more in the course of a day. This causes the lines to interfere and interlace with each other. A certain amount of normal tilting of the ground is to be expected in the course of each day anywhere, and it is likely to be exceptionally big at an active volcano. Therefore we do not want any tilting due to solar heating of the house. What tilting we get, measured by the swinging apart or the close approach of the lines, should be indicative of what the actual ground is doing under the whole country, and therefore is measurable for the particular two directions in which a single horizontal pendulum swings.

The dimensions of the cellar shown in the picture are ten by ten feet, and the general plan of the instruments followed the lines of the Omori seismograph. The concrete post, ten by ten inches square, stands 27 inches high above the pier which is 18 inches high above the floor and two feet square. The cylinder consists of a cast-iron container holding nine circular lead discs, which

make the whole weigh 225 pounds. The lead discs are each bored and threaded in the center to take a large screw-eye, so that the container can be handled by one man by lifting the discs out or putting them in separately.

An iron rod, bigger near the post, and smaller at its outer end, passes horizontally through the middle of the heavy mass or cylinder. This protrudes 52 inches from the center of the cylinder. The big end of the rod is bent and lies in the niche at the base of the post, supported by a short hinge of spring-steel wire. This wire hinge is terminated by metal balls in two slots cut with a hack-saw. One of these slots is in the flat iron strap shown pinned across the niche, the other in the bent end of the rod. The heavy cylinder is supported by a stirrup hanging from a piano wire which is made fast to a simple adjustable bolt in two angle irons pinned to the top of the concrete post. For these attachments to the post it is convenient to use expansion bolts, which are readily put in holes drilled in the concrete. The adjustments of the upper attachment of the piano wire permit of winding it up to lift the mass, and of moving it right and left to bring the outer end of the rod or boom to a medial position.

From all this there results a mass hung like a door with a boom protruding out from it, designed to record those oscillations or tilts of the earth at right angles to the plane of the suspension. The boom is braced by fine steel wires extending from its outer end to the cylinder. If the boom points to the east, the inertia of the mass registers the north-south earthquakes. Another similar pendulum is hung north-south to record the east-west earthquakes. Or better, for the same earthquake, two such pendulums register the north-south and the east-west components of the motion. Under each pendulum the system is damped, or prevented from free swaying on its own account, by sheet-aluminum vanes attached to the boom, protruding downward into a metal tank of automobile oil, so that with swinging of the pendulum, the vanes move edgeways in the oil. The little oil tanks, four or five inches square, not shown in the illustration, are supported by a removable stand in front of the pier.

The registering mechanism is shown in the figure on Page Three. The recording drum is built on a steel spindle threaded with ¼-inch worm at the end away from the drive-clock. This moves the drum lengthways in a sleeve at the driving end. The drive-clock is a Seth Thomas two-barrel power movement with rotation of spindle once in 30 minutes. The inner sleeve of the drum is set by a screw on the clockwork spindle. The worm end of the drum spindle rests on knife-edge wheels. Glassine paper is wrapped around the drum, pasted at the ends, smoked over a kerosene lamp, and the drum is set in place with the set-screw locking it to the clock. The writing lever-pen from the pendulum has a hinged stainless steel tip which rests on the smoke surface. The lever pens are made of aluminum. They are pivotted about a vertical axis near the end of the booms. The pen tips and the levers have pivots made of standard clock and watch balance staffs. Motion is transmitted from the boom to the lever by light metal T-bars, with the ends of the cross-bar in the boom and the lever respectively. The drum ends are made of ply-wood and the surface of pasteboard. The pen tips are magnetized, lifted to make a gap in the written line on the smoked paper every minute by an electro-magnet connected with the time-piece on the wall. The drum surface moves 30 mm. to the minute. The static magnification of the boom is five and of the writing lever forty, making the total 200. A marker pen attached to the plate supporting the drum and lever system, is made to write a line for a few minutes once a day on the side of the smoked paper, to be used as a datum line for measurement of wandering of the pendulums under tilting of the ground.

The free period of the pendulums is adjusted to seven seconds by moving the upper support of the piano wire in and out from the posts. The pen tips are laid back with a horseshoe magnet when the drum is changed. The change of paper is made once a day and the seismogram removed is passed through a bath of very dilute shellac and denatured alcohol, which fixes the smoke image of the line written by the pens. In the second photograph there is shown the second boom vanishing into the foreground, connected with the second pen by its T-bar impinging on an angle piece in the lever at right angles to the lever. In this way both pens, north-south and east-west, write during the day bands of lines side by side on the same paper. The paper is 12½ by 38 inches. Each line is interrupted by its minute and hour marks, the operator indicates the time of the starting mark by scratching it in the smoke, and simple counting of the succeeding hour marks on the smoke is all that is needed for timing an earthquake autograph that may appear. The light pasting of the ends of the paper on the drum is easily separated by a slender paper-cutter. The seismogram is dated and marked with its location before shellacking.

It will readily be seen from this account that any amateur with mechanical aptitude can build for himself a senstitive seismograph, and he can learn all about the technique of the science if he will consult the back files of the Bulletin of the Seismological Society of America, the headquarters of which are at Stanford University, California. T.A.J.

KILAUEA REPORT No. 1015

WEEK ENDING JULY 5, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Conditions remain unchanged at Halemaumau pit. The cauldron is quiet and dry. Strong northeast trade winds continue.

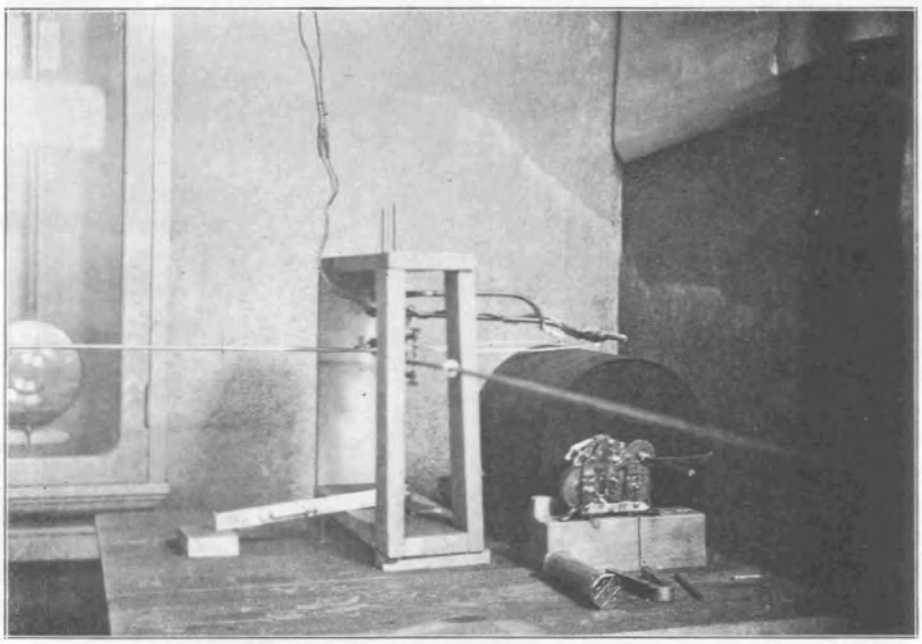
Seismic disturbances recorded during the week included 34 tremors and two very feeble local seisms. One of the latter at 12:08 a. m. July 4 indicated origin distance 23 miles from the Observatory.

Tilt for the week was slight NNW. Microseismic motion was slight.

TILTING OF THE GROUND FOR JUNE

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the direction given.

June 1-7	0.1 second	W.
June 8-14	1.4 seconds	NE.
June 15-21	0.3 second	ENE.
June 22-28	1.4 seconds	NNW.



Recording end of homemade seismograph, showing booms of both north-south and east-west pendulums, pivot connections with writing levers, straight wound electric magnet for marking time, and the driving clock and drum, the latter with smoked paper.



Interior of seismograph cellar at St. Mary's School, Hilo, Hawaii, showing two-component seismograph hung on wall of chamber, with recording drum in middle of room.

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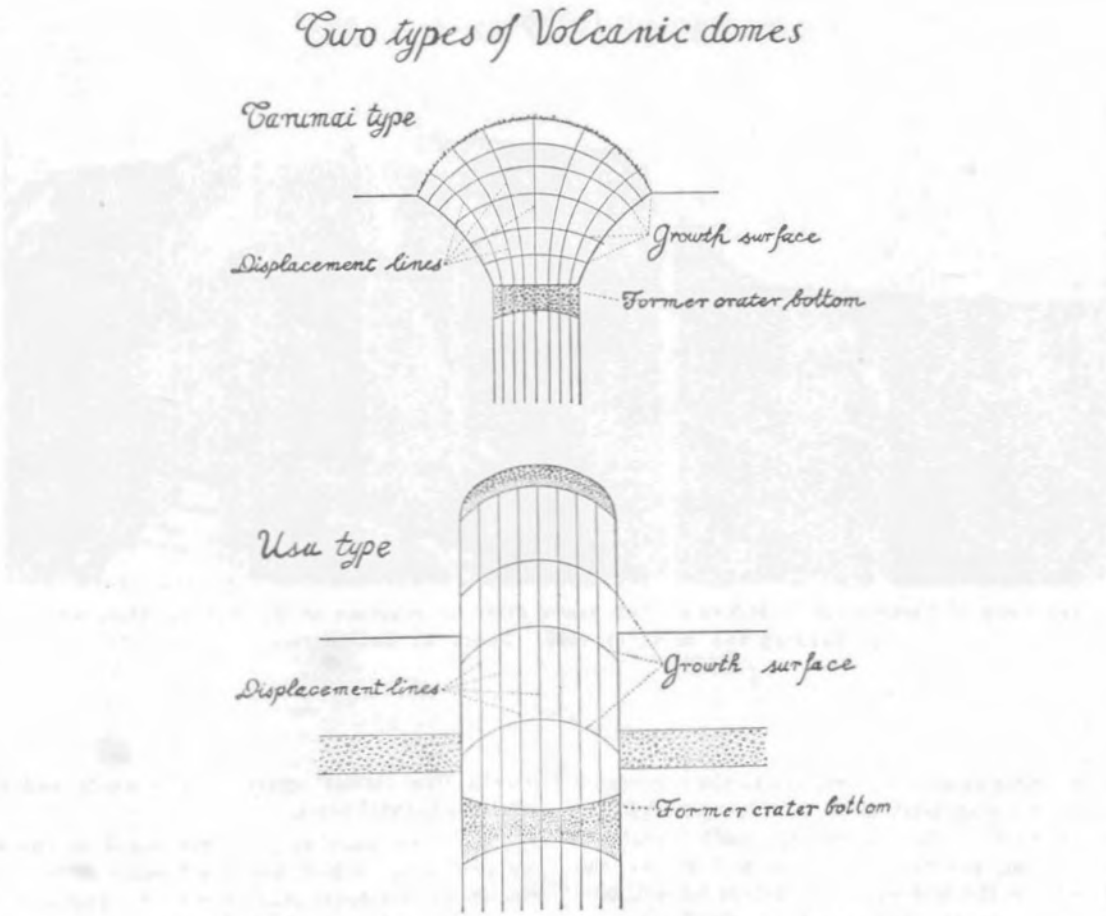


Sections by Tanakadate showing the two types of lava domes and their structual characters.

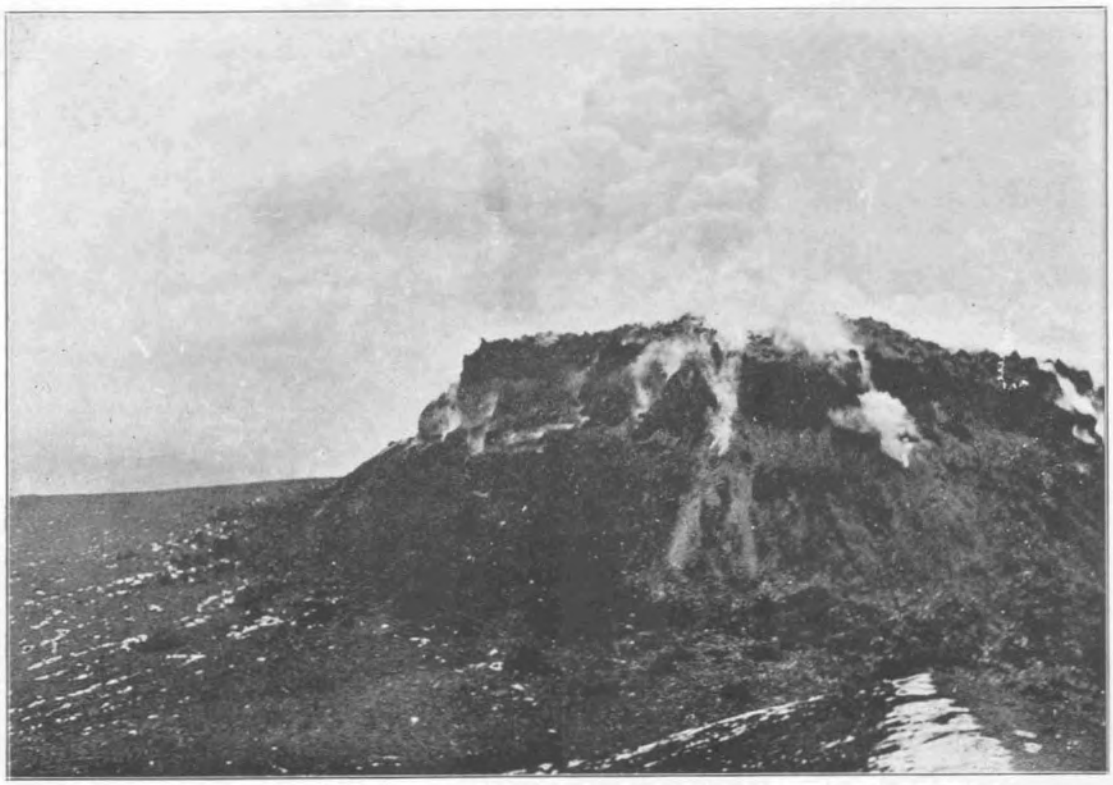
TWO KINDS OF LAVA DOMES

A clear analysis of the materials and the rising of stiff lava into two kinds of lava domes in Japan has been made by Tanakadate. (H. Tanakadate, Imperial University, Sandai, Japan. Proc. Fourth Pacific Science Congress Java 1929, pp. 695-703.)

The first is the Tarumai type, based on the Volcano Tarumaisan in the north island of Japan, which pushed up its crater floor into a dome in 1909. Before the eruption the crater was a funnel 600 meters across, gently sloping inward above and precipitous within. The funnel was 65 meters deep with a bottom 60 meters across, exhibiting active solfataras there and in the wall.

March 30 to April 12, 1909, there were big steam-blast eruptions, lava then filled the funnel, then the pudding rose into a dome reaching its maximum at the end of April, finishing its growth in mid-May, and remaining there ever since. Tanakadate expresses the mechanism by the upper diagram on Page One. By expressing the original crater bottom as a horizontal line in section, lava covered with gravel, the successive stages are shown by the **growth surface** lines, when the gravel must have been scattered on the increased area of the top of the dome. Such loose materials were found sparsely scattered on the slaggy surface of the dome when it was explored after it had cooled off between 1909 and 1917. Explosive eruptions in the latter year through fissures in the dome flung out fragmental materials on to the dome. At present detritus and lava blocks caught in the lava are found on the dome.

The **displacement lines**, radiating from the former



Lava dome of Tarumaisan in Hokkaido, two hours after an eruption of October 30, 1926, which fissured the dome of 1909. Photo K. Shibahara.

bottom of the crater upward, correspond to the successive positions in lateral displacement of equally spaced points on the crater floor at the beginning. Each imaginary vertical filament of lava in section rises and widens, the more in the center, the less where restrained by wall friction. The displacement lines are perpendicular to the growth surfaces.

The lava developed prismatic structure, mostly at right angles to the growth surface, with columns parallel to the displacement lines. In crater pits and fissures of the dome can be seen the chasms bounded by columnar joints, caused by contraction when the surface cooled, making upright parting planes.

In the large caldera of Usudake Volcano, near Tarumaisan but farther south (see map Page Four), is found the second type of lifted plug or dome, illustrated by the lower diagram on Page One. There are two domes on Usu (see map Page Three), and three crater lakes. Taking the bigger one called O-usu, it is 725 meters above sea, 350 meters high about its base, and is smoothly round like a cathedral. The top of it is not a round shell of rock, but is composed of gravel, sand, and clay 3 to 6 meters thick. The gravel contains fragments of quartzose rocks, crystalline schist, and several old volcanics; there are andesites with pyrite and hematite. The pebbles are reddened with oxidation, as though through the heating effect of the dome lava, and are sometimes bowlders a foot in diameter. They are smooth and scratched with parallel streaks like glacial erratics. The sands and clays are baked to natural brick.

The dome itself of rock is exposed on one side with the surface scratched, and a structure of parallel shells. Elsewhere fragments mask the rock. The sectors of the dome are cracked and faulted so that one sector may have been thrust up, another has lowered.

If the dome was regular on its rising, the volcano may have formed its caldera of subsidence in the course of a river, which deposited ordinary gravel, sand, and clay in the crater lake. The highly viscous lava rose and congealed under these deposits. The lava continued rising, lifting the plug, and heaving up the overlay of sediments. This made a structure with vertical side walls and dome-shaped top. The friction on the confining wall produced the streaks and striations. Just the same thing was shown by the Pelee spine. The lava and sediments agglutinated and formed a hard crust. The lava core pushing into the gravel layers produced the striations in the pebbles.

The parallel-shelled structure gives evidence that at first the growth surface was horizontal, later the viscous sides lagged and the center rose most, arching the top. Sinking of parts of the magma below, and renewed pressure, bring about the splitting into separate sectors or columns with differential lift at the top.

In the case of the Tarumai dome of the first type, the recession of magma caused a flattening of the top of the dome. (See Page Two).

The O-usu dome is much more siliceous than the Tarumai dome. The O-usu rock is a dacite with 68 percent of silica, that of Tarumai on augite andesite with 61 percent. The O-usu rock is fine grained, light gray, with few and small porphyritic crystals and a trachytic groundmass. The Tarumai rock is coarsely porphyritic with large anorthite feldspar prisms, and smaller augites. The lava shows fluidal streaks of red and gray.

The old outside lava wall of the caldera of Uusu is basic, and so was the new lava of the lower slopes of Usu, thrown up as bombs in the uplifting eruption of the outer flank in 1910. Both of these have only 51 percent of silica (see Volcano Letter No. 302).

Other volcanoes which have produced the low-dome type of eruption are Bogoslof, Katmai, and Galunggung. The spine or plug has been upraised in Pelee, Lamongan, and in the inner fin of McCulloch dome at Bogosloff in 1907. T.A.J.

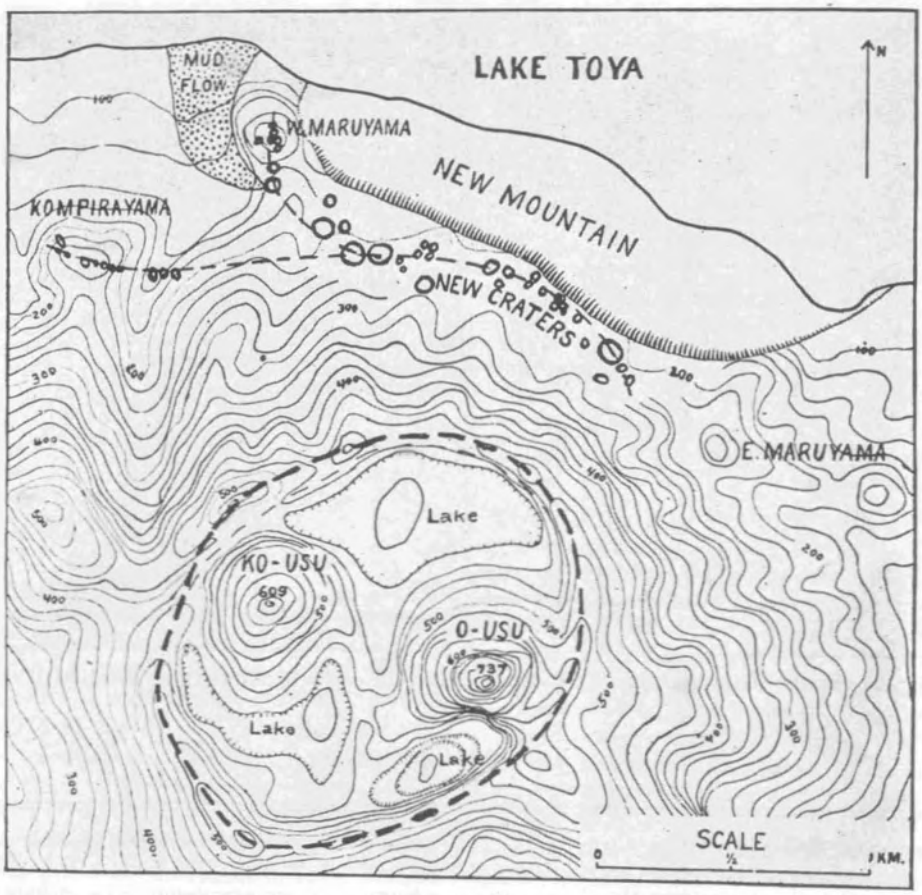
KILAUEA REPORT No. 1016

WEEK ENDING JULY 12, 1931

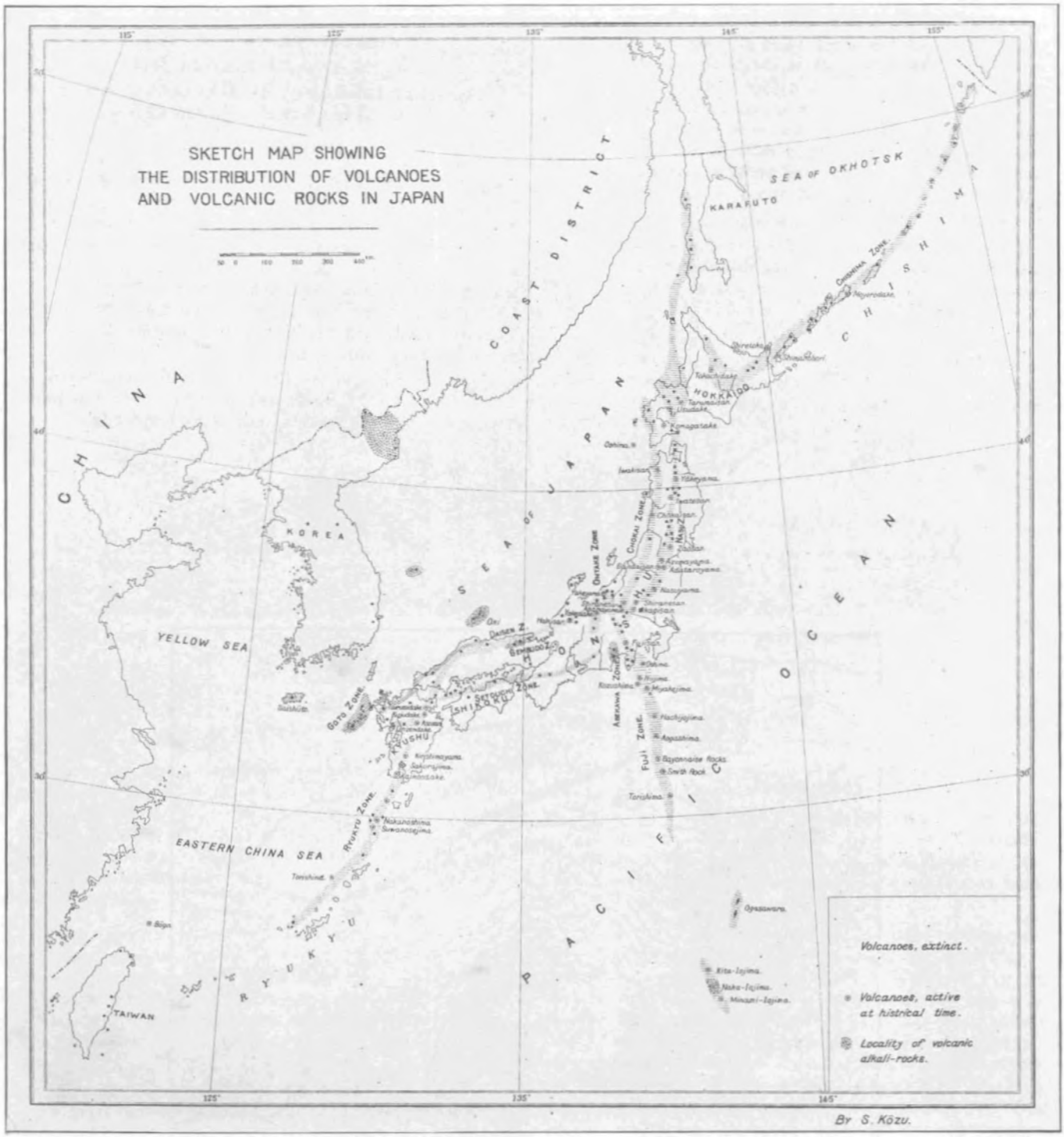
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Halemaumau has shown a few changes of interest. Blue fume has reappeared on the bottom in two new places, directly north of the 1930 cone in a sulphur area, the edge of which has caved in, and at the bright sulphur spot on the far northwest side. Dust from an avalanche was seen rising from the northeast rim of the pit at 4:30 p. m. July 10 in a compact cloud which gradually thinned. The seismograph on the crater floor recorded a few slow motion tremors without tilt.

The instruments at the Observatory registered 18 tremors and 5 very feeble local seisms during the week. Tilt was slight W. Microseismic motion was slight.



Map showing old caldera ring and domes of Usu, the active craters of 1910, and the uplifted "New Mountain" of 1910. After Daly.



Map of volcano belts in Japan by S. Kozu, showing extinct, active, and alkaline lavas.

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No. 343—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | July 23, 1931



Haleakala seen across Hawaii Channel from the summit of Hualalai. Photo Emerson.

HAWAIIAN VOLCANO LANDSCAPES

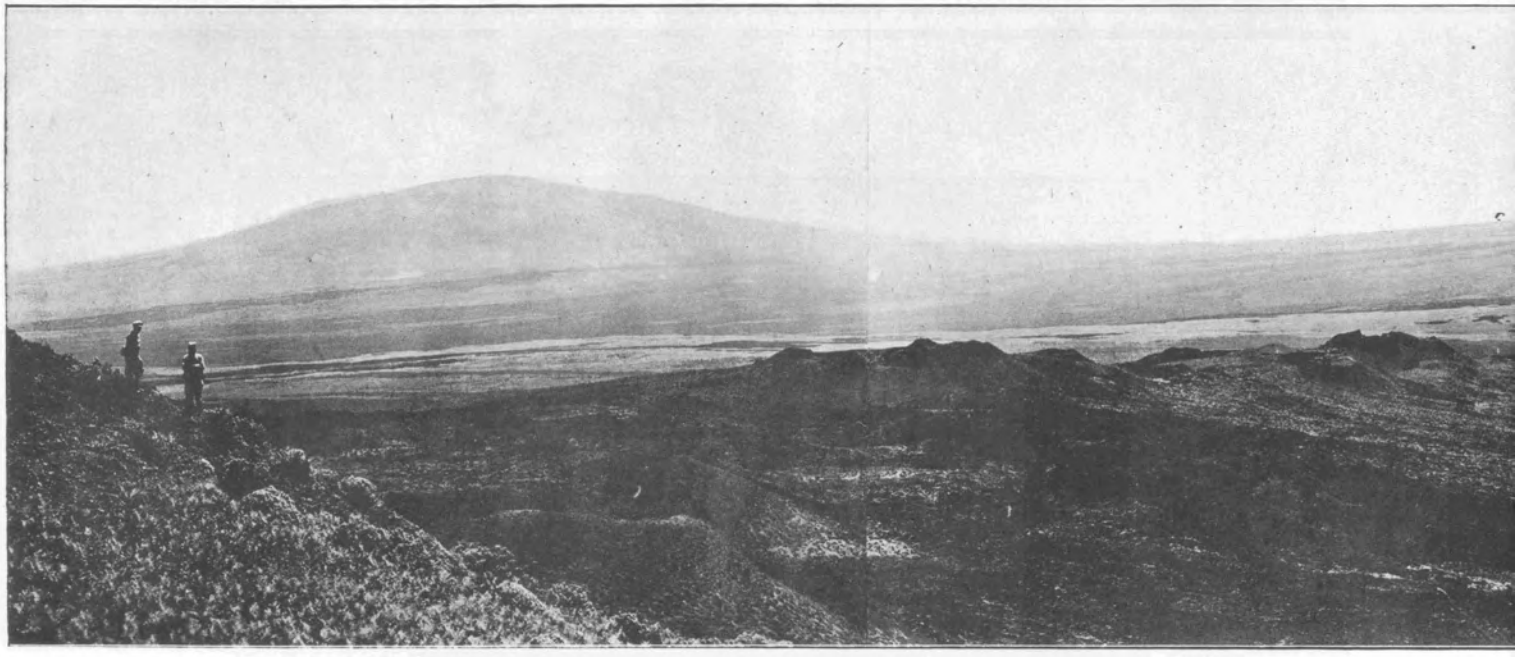
Professor Norman E. A. Hinds has produced an interesting paper on "The Relative Ages of the Hawaiian Landscapes" (Univ. of Cal. Publ. Bull. Dept. Geol. Vol. 20, No. 6, pp. 143-260, pls. 15-42, 13 text-figures; Berkeley 1931). He reviews the evidence for the supposition that Kauai is the oldest of the windward group of Hawaiian Islands, and points out that the extra heavy rainfall there, to speed up erosion, has not been sufficiently allowed for. Kauai may be younger than Oahu. He also accents downfaulting of island blocks along shore-lines which has robbed some islands of their mass. The text by Wentworth on quantitative estimates of marine and fluvial erosion in Hawaii (Jour. Geol. Vol. 35, 117-133, 1927) and Wentworth's Bishop Museum papers come in for criticism, and it is refreshing to note that both Hinds and Wentworth attempt to evaluate erosion on the basis of rainfall and drainage, and even to make some estimates of rate of removal of soil in carving landscapes. This is the beginning of a science of erosion.

Hinds writes: "According to Wentworth, the depths of material removed from the various mountains by streams stand in the following order: (1) East Oahu; (2) Kauai; (3) East Molokai; (4) West Maui; (5) Mauna Kea; (6) West Oahu; (7) East Maui; (8) Lanai; (9) Niihau; (10) Kahoolawe; (11) Kohala; (12) the rest of Hawaii. The estimates for East and West Oahu and Kauai apparently neglect extensive loss of bulk by downfaulting, hence the amounts of removal by rivers in these three cases are excessive. On East Molokai, Kohala, and Niihau, streams have eroded a residual of once larger domes since about half of these mountains has been carried below sea level by downfaulting. It is not improbable that faulting may have been partly responsible for the development of some of the great canyons on Kohala, East Molokai, Kauai, and Oahu."

Hinds uses the term "engulfment" for downfaulting, but this word "engulfment" is a volcanologic term for downbreak in volcanic craters or underground conduits, and is hardly identical with graben downfaulting.

"For Lanai, Wentworth has calculated the average rate of removal as one foot in 5,000 years, and from this he has estimated the approximate age of the landscape of that dome to be 125,000 years. Using the same rate of removal, he obtains figures of 225,000 years for Kohala and 2,090,000 years for Kauai." Hinds objects to applying a dry island rate to a wet island.

"According to wentworth, the relative amounts of



Panorama of Mauna Kea and Mauna Loa from a summit cone on Hualalai. The near foreground of Hualalai shows a slope of 35°. I foreground cones extend the Hualalai rift toward Mauna Loa. The left of this picture

material removed by wave action from the various islands stand in the following order: (1) Hawaii; (2) Kauai; (3) Molokai; (4) Niihau; (5) Maui and Kahoolawe; (6) Oahu; (7) Lanai." Hinds objects that the several domes on Hawaii are of different ages, and have been cliffed by the sea in different amounts. And that the formation of cliffs by faults has not been recognized. "The determination of relative amounts lost by downfaulting and by later marine erosion probably is impossible, though approximate values may later be obtained."

The point of this discussion is that the Hawaiian Islands form an excellent field for measures of erosion in time, if some one will only go at it experimentally by the observatory method.

Hinds arrives at the following conclusions:

The order of extinction of the younger Hawaiian mountains apparently has been: (a) Haleakala, (b) Mauna Kea, (c) Hualalai. Mauna Loa and Kilauea are still in process of construction, hence their landscapes will undergo certain changes before their major activity ends." (With Haleakala known to have made lava flow about the middle of the eighteenth century, and Hualalai in 1800-1801, one wonders why these two should be considered extinct.)

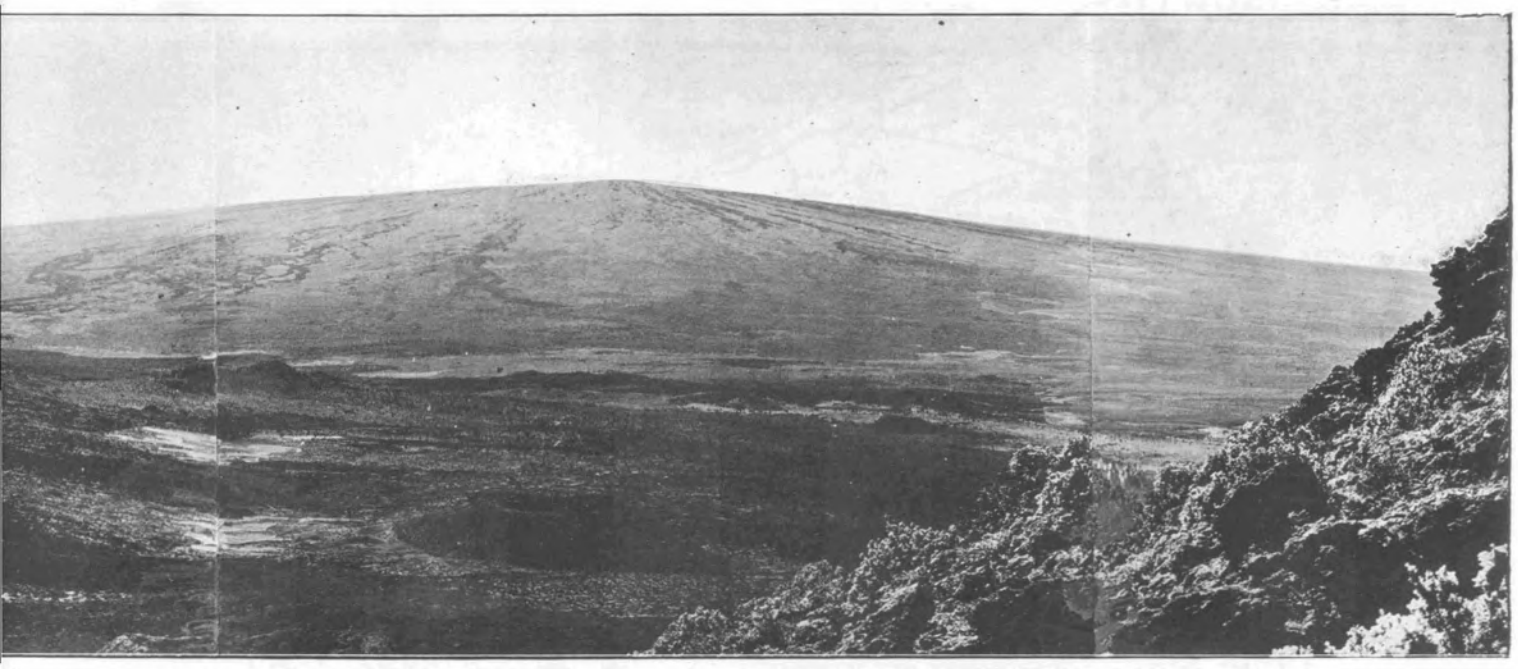
"The constructional surfaces of the old, high domes have been largely destroyed either by erosion alone or by erosion and downfaulting. On all the mountains either major or minor features of the relief have been formed by faulting, and in the ultimate destruction of the domes, faulting is one of the chief agents.

"West Oahu, West Molokai, and West Maui each became extinct before the eastern member of these doublet islands. The landscape of Kohala is the oldest on Hawaii."

Probably both of the Oahu domes are older than Kauai since the close of the last principal volcanism. The more rapid rate of fluvial erosion on Kauai, owing to the climate, does not establish the greater age of the landscape. The relatives ages of the landscapes of the high old domes appears to be: (1) West Oahu, (2) East Oahu, (3) Kauai, (4) East Molokai. West Maui and Kohala are younger, but their sequences is yet to be determined."

"Neglecting buried landscapes, the oldest landscape in the windward Hawaiian Islands is that of the Penguin Bank The final products of the destruction of lava domes are the volcanic stacks like Nihoa, roof islands, calcareous sand islands, and submarine banks without islands which make up the leeward group."

Hinds disagrees with Wentworth in the latter's belief that the Hawaiian Islands emerged in the late Tertiary. "The destruction of the leeward islands suggests that volcanism ceased there well back in the Tertiary, hence the mountains must have risen above the ocean long before, perhaps even in Mesozoic time. Buried erosion surfaces in the windward volcanoes prove that interruptions in the volcanic cycle took place and that there was deep erosion before the renewal of eruptions. The erosion of the present landscapes of the older domes probably began in late Tertiary or early Pleistocene times. The time required for the cutting of the great cliffs of Kauai very likely took at least two million years." T.A.J.



auna Kea has slopes of 12° to 40°, and Mauna Loa on the right 3° to 8°. The long 1859 flow sweeps to the left from Mauna Loa. The Mauna Kea) is incorrectly named "Hualalai" in pl. 16 of Hinds. Photo Emerson.

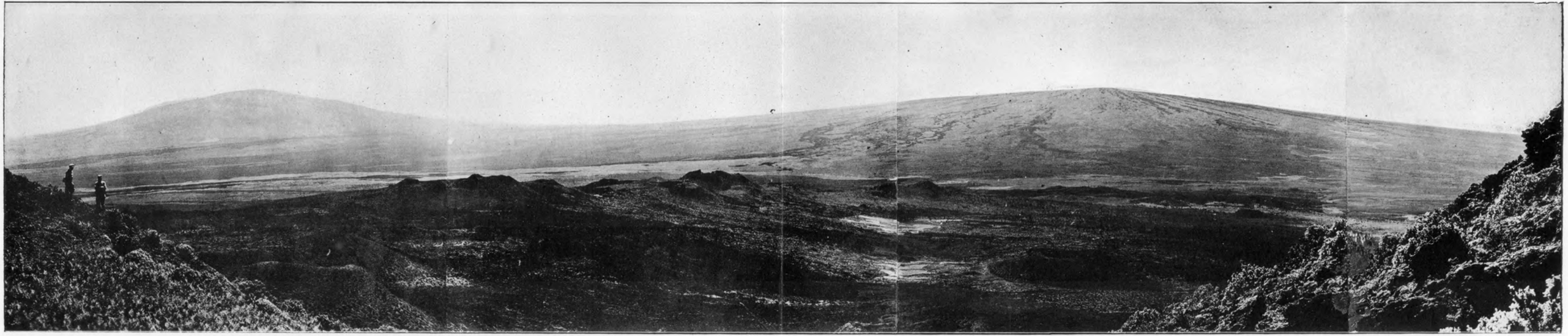
KILAUEA REPORT No. 1017

WEEK ENDING JULY 19, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Kilauea Volcano remains dormant. A few rocks were heard falling north at 11 a. m. July 16. On July 17 dust clouds from avalanches were seen at 5:30 and 9:40 a. m., and a scar showed on the northwest wall of Halemaumau. No fume or steam was reported visible during the week.

The instruments recorded 18 tremors and 3 very feeble local seisms. The average tilt movement for the week was slight northwest. Microseismic motion was slight.



Panorama of Mauna Kea and Mauna Loa from a summit cone on Hualalai. The near foreground of Hualalai shows a slope of 35°. Mauna Kea has slopes of 12° to 40°, and Mauna Loa on the right 3° to 8°. The long 1859 flow sweeps to the left from Mauna Loa. The foreground cones extend the Hualalai rift toward Mauna Loa. The left of this picture (Mauna Kea) is incorrectly named "Hualalai" in pl. 16 of Hinds. Photo Emerson.



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THE LANDSCAPE OF MAUNA LOA

Hinds speaks of Mauna Loa and Kilauea (Hawaiian Landscapes, Bull. Geol. Univ. of Cal. Vol. 20, No. 6, 1931) as being still under construction, with shallow weathering, and stream gulches only where eruptions have not recently taken place. "On certain parts of the rainy, windward side of the mountains, where flows have not been erupted for long periods of time, the lavas are decomposed enough to allow the growth of a heavy jungle forest in the soil cover. The more recent lavas are virtually untouched by ground water or atmospheirc solutions, and even in the rainest sections, have little or no vegetation on them."

This last statement is not correct for the 1881 flow at Hilo, where the rainfall is 200 inches, and good sized trees and bushes cover the flow.

"Where the climate is dry, weathering is much slower and there is little soil on any of the flows." This is particularly true of the Kau Desert on the southwest side of Kilauea, of Kahuku on the southwest side of Mauna Loa, and of the northwest flows of Hualalai. These places have rainfalls of 30 to 70 inches.

"Only a few permanent streams are present, and these have not cut deep valleys. Most of the constructional surface is unbroken. The eruption of new lava apparently is sufficiently frequent to cover most of the exposed surface before any considerable amount of weathering or erosion can take place.

"Short stretches of the coast are cliffed to heights of 50 or 60 feet, since flows apparently do not reach sea level often enough to prevent some inroads by wave abrasion. The occasional flows which pour into the ocean repair in part destruction thus caused. Low fault scarps are present, especially on the southeastern flanks of the domes, and part of the cliffed southeastern coast (of Hawaii Island) has been developed by faulting.

"Parasitic cinder cones in considerable numbers dot the flanks of the dome; part of these show rude linear arrangement as though erupted at various points along radial fissures.

"At the summits of both Mauna Loa and Kilauea are volcanic sinks, in which the principal eruptive center is located," Mokuaweoweo the Mauna Loa crater being 3½ by 1¾ miles in dimensions and 800 feet deep; Kilauea Crater 2 by 1¾ miles and 500 feet deep.

"The sinks are depressions resulting from the collapse of the crust in the vicinity of the principal eruptive center as liquid material has been emitted from below the surface. Small step-faulted blocks are present locally about the walls of the sinks." Near the middle is the conduit pit through which the lava rises and falls, in the case of Kilauea. Mokuaweoweo has cones and pits in the middle.

"As long as activity prevails at the central vents or eruptions take place from lateral fissures, the surface may be periodically renewed and the pre-existing topography blotted out. The final constructional outlines therefore are not complete.

"Kilauea is a small mountain far down on the southeast side of Mauna Loa at an elevation of about 4,000 feet. The relative ages of the two domes has been disputed. Jaggar formerly held that Kilauea is the older of the two, and that Mauna Loa has grown up in a great vale between Kilauea and Mauna Kea. Daly believes that Kilauea is fed by a laccolithic offshoot from the larger volcano, and now is independent of the main reservoir because of the sealing of the connecting channel. **It is now generally accepted that Kilauea is the younger mountain."**

"Field evidence supporting this view has been presented by Stone, who has recently described the general features and the geology of the volcano. Stone notes that Kilauea is an independent dome on the flank of Mauna Loa, but because of the very gentle slope of both Mauna Loa and Kilauea its domelike character is not apparent in some parts of the area. Important data are given by Stone proving the superposition of the Kilauea volcanics on older lavas from Mauna Loa and the association of the Kilauean series with faults which developed in the side of the greater mountain."

With reference to the general acceptance of the youth of Kilauea, the reviewer does not know what this statement is based on. Mr. Stearns in his "Geology of Kau" (Water-supply Paper U. S. Geological Survey) leaves the question open. In Kapapala and along the valley between Kilauea and Mauna Loa it is Mauna Loa flows which are overlapping the Kilauea slopes. The great sink of Kilauea is an old-age feature of a major dome. It was not the vale between Kilauea and Mauna Loa, but rather between Kilauea and Hualalai, that appears to have lain under the modern slagheap of Mauna Loa. Mauna Kea was the ancestral dome at the northeast which blocked any growth of Mauna Loa in that direction. Hence the pronounced development of a long lobe of Mauna Loa into the sea at the southwest. Both Kilauea and Mauna Loa have parallel lava rifts, starting at their craters, and trending respectively southwest and northeast.

The history, however, was not so simple. Both Kilauea and Mauna Loa appear to be over an older topography. Kilauea sink is in line with two other sunken amphitheatres southwest of it, Wood Valley and Mohokea, back of Kapapala and Hilea. These three sinks appear to lie along a common rift in the ancient land which the new dome volcanoes are burying. The live Mauna Loa of the present day has three centers of lava heaping, northeast, on top, and southwest. The accompanying panoramas show something of this vast bulky mass. T.A.J.

KILAUEA REPORT No. 1018

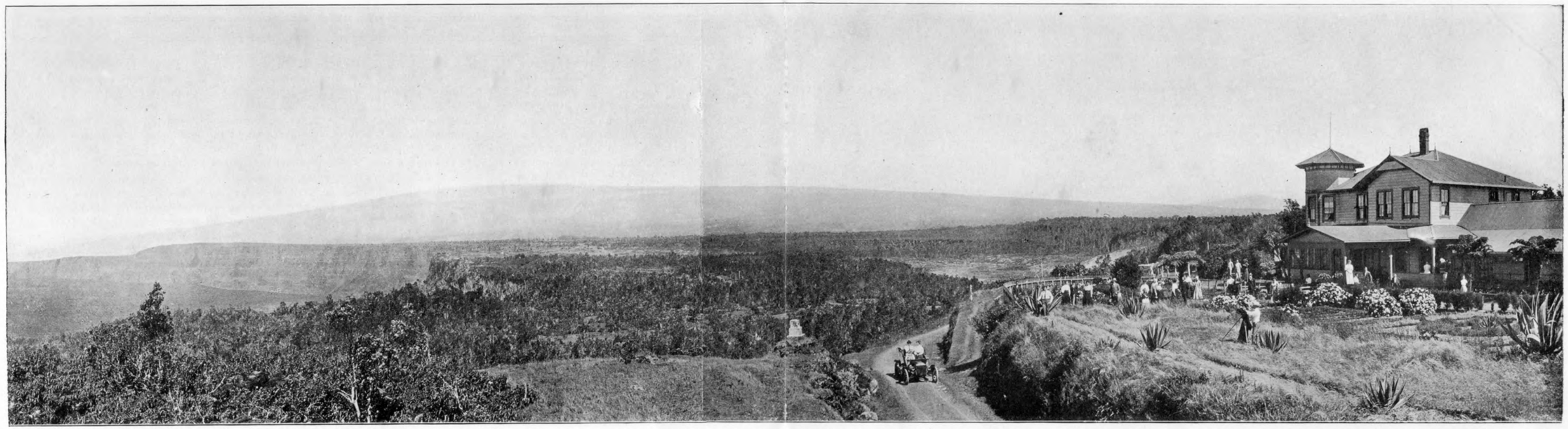
WEEK ENDING JULY 26, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

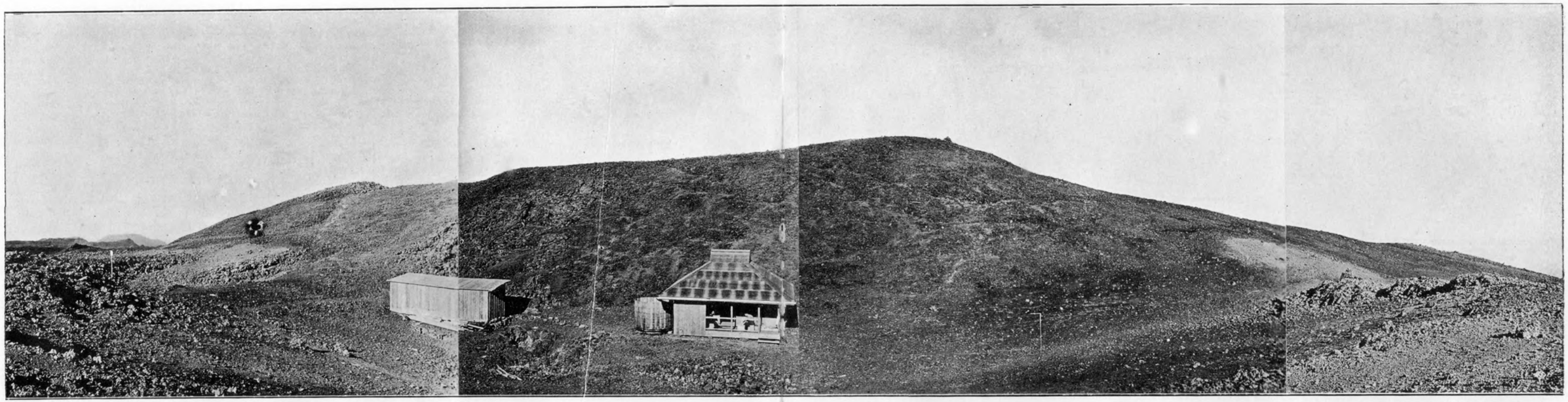
On Monday, July 20, the interior of Halemaumau was partly obscured from view by fog and light rain. Some steam was seen at the southeast rock slope. Heavy rains Tuesday caused great steam clouds to rise from the pit. All vents within the pit were steaming actively on July 22. Fuming was also strong at two places north of the 1930 cone. The pit seismograph showed heavy tilt due to the weight of rain water in the vicinity.

The seismographs at the Observatory registered three spells of strong continuous tremor on July 23: 6:43 to 7:05 a. m., 7:49 to 8:02 a. m., and 5:31 to 5:45 p. m. In addition there were 16 tremors and 2 seisms.

Average tilt for the week was slight NE. Microseismic motion was strongish on July 21 due to windstorm, and thereafter slight.



Panorama of Kilauea Crater, Mauna Loa, Mauna Kea, and Volcano House, looking west. Shows the three lobes of Mauna Loa and the valley between Mauna Loa and the foreground ridge of Kilauea. Mauna Loa slope 6° on left, 4° on right. Photo Gartley about 1912.



Puu Ulaula, or Red Hill, looking north, showing the rest house on the northeast rift of Mauna Loa. A characteristic old clinker-lava cone at elevation 10,060 feet. Center of the northern lobe of Mauna Loa. Photo Wood in 1916. Slope 20° on left, 10° to 19° on right.



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No. 345—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — August 6, 1931



Toes of pahoehoe lava on north floor of Kilauea in 1919 lava. Photo Maehara.

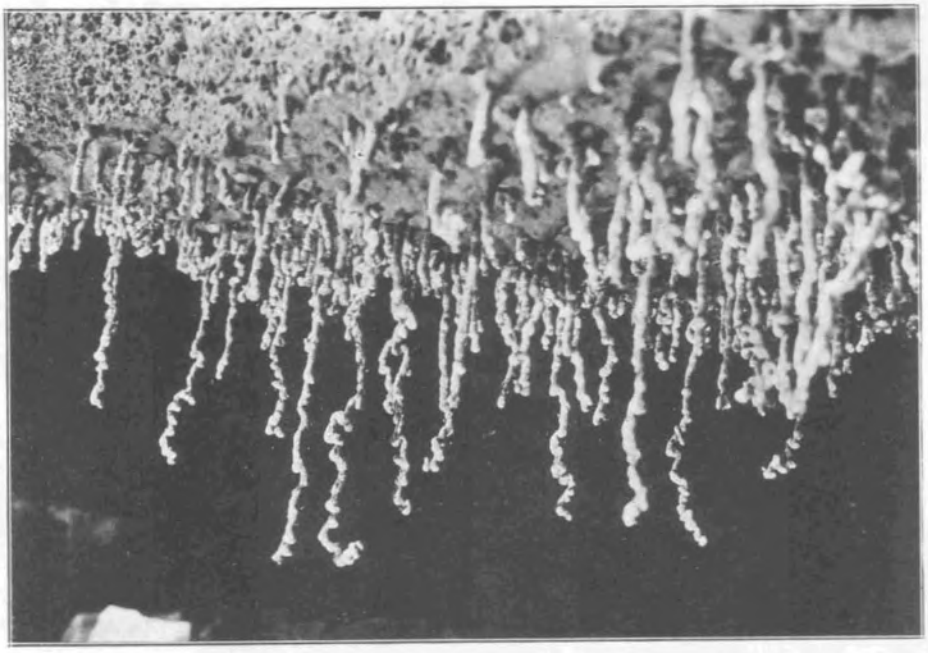
LAVA STALACTITES, STALAGMITES, TOES, and "SQUEEZE-UPS"

In Volcano Letter No. 300 Professor Colton described "squeeze-ups" in lava fissures whereby basaltic magma plastic like stiff clay has been forced up a crack several feet into the air, with sides of the solidified paste grooved like slickensides as it scraped past the roughnesses of the walls of the fractured rock. As something of this kind occurs in Hawaii on both big and small scales, and in addition we have stalactites and stalagmites of entirely different origin which have been erroneously attributed to water, it would seem of interest to review the subject.

The supreme "squeeze-up" of history is the Pelee spine in Martinique. All lava dome eruptions are similar in origin and one may quite justifiably inquire whether "squeeze-ins" as well as "squeeze-ups" do not constitute many of the intrusions of geology. The hydrostatic pressure of granitic intrusions at Schneeberg in Germany is such that it split folia in slate, penetrated between the thin paper-like layers of the slate, and recrystallized the clay to hornstone. The Pelee spine was a central pencil of paste in a cumulo-dome, scored vertically on the outside as it scraped the walls of its container and rose 1,000 feet into the air. Then its top curled over and spalled off. It was never sucked back, but flaked away to a stump. Its composition was a hypersthene andesite, and so it was more viscous and refrectory than basalt.

In the history of "bench magma" inside Halemaumau pit there have been many occasions when the crags of semi-solidified basaltic paste at 900° C., forming the walls of the container of the lava lakes—not the walls of the pit—have risen as separate pencils of paste within other material of greater hardness. When they did this they showed scraped surfaces. When the entire lava column of this bench material has lowered rapidly, it has fractured into terraces on the insloping funnel wall of old rock, and the terrace faces show scraping made by the sinking block of the next terrace below.

In the filling of basins with pahoehoe lava by overflow



Worm stalactites from glaze of roof of cavern, Kilauea floor. Photo Maehara.

in the larger craters, there are built "schollen-domes" or hillocks of swelling crust. What was a puddled flat. with ropy lava shell, begins in the course of hours to swell up. A laccolith of basalt paste is rising inside, because of some equation between resistance to further spreading and resistance to upward lift. If upward lift is the easier for the onflow of the feeding stream which is pouring through a tunnel to feed the flat, there will be no further escape of "toes" pushing out from under the skirt of crust. When the swollen dome, 50 to 100 feet across, lifts a shell 3 feet thick, there finally arises a star-shaped opening between sectors in the top of the dome. The dome gets to be 10 or 15 feet high. Then the paste "squeezes up" through the opening on top. It either trickles down and skins over, or it sputters up and builds a spatter cone. If it has partially crystallized inside the heap it may rise as an "aa" or clinker lava pudding and so produce a stiff plug or spine or "squeeze-up," to use Colton's expression.

The picture on Page One shows four toes with festooned skins of pahoehoe lava which has welled up from a crack in the floor of Kilauea Crater in 1919. Each toe is derived by squeezing out from under the skirt of the toe next preceding. The festoons are convex downstream. The farther toe welled up a crack, the next two were progressively formed by swelling and rupturing fronts, and the long one in the foreground is double and exhausted the lava available. While incandescent and in action these toes or "pushes" as Brigham called them resemble a bag of red jelly. They are a foot or two in diameter.

Stalactites and stalagmites in grottoes and caverns tell quite a different story. Here again there are some which are products of splash phenomena, and are nothing more than lava drip where a stream has vacated its banks and left pointed glassy shreds hanging from shelves. Not so with such vermiform or rod-like stalactites and driblet spires as are shown on Pages Two and Three. These photographs were taken by flashlight in a cavern on the Kilauea Crater floor. Such caverns were in 1919 red hot and full of flowing lava. They were formed by streams which crusted over and then kept on flowing under a bridge of crust. These same streams in tunnels of their own congealment are what lead at the front of a flow to the escape of toes such as are depicted on Page One.

But there comes a time in every flow where the supply of lava diminshes. In such case the amount flowing from the source does not equal the capacity of the tunnel. Accordingly the river of melt bubbling along inside the tube lowers so that the upper half of the pipe is full of gas or air, the walls are of bright yellow incandescence, and the gases escaping from the lava are continually burning to maintain a very high temperature on the ceiling of the cavern. With this temperature above 1,200° C., air being sucked in below as the hotter gas escapes through cracks and windows in the roof, there is set up a blast furnace condition often maintained for weeks or months on the inner rock lining of the cupolas in the ceiling and of the side walls of the tunnel. This flow of gas quietly burning with great volumes of excess oxygen dragged up the tunnel from inumerable holes, cracks, and pores, melts the tunnel walls to a glaze of quite different crystallinity from normal lava.

In 1919 it was repeatedly possible to go to the "windows" of collapse in the roof of the "Postal Rift Tube," where from Halemaumau a torrent of lava was flowing through a tunnel, and to look inside and see an orange-hot cavity with a golden river sweeping by underneath, little bubbles continually breaking the surface of the glowing stream, and adding gas to the evenly brilliant walls. On these walls hung motionless stalactites, some like currants, some like grapes, some like walking sticks, and some like worms. These are what are shown in the photographs. They are the material of the gas-melted glaze. They form very slowly. When incandescent they may be rocked back and forth like macaroni before it has dried.

If the heat has fallen below their formation temperature, a touch will break them off. They do not trickle. They form by accretion.

If we take one of the worm stalactites and examine it with a lens, its outer skin has very delicate tracery of ripples in a silvery coating of magnetic oxide of iron. If we break a worm stalactite it has vesicles inside lined with crystals of feldspar and augite. If we make a thin section of a solid part it is crystalline, but different in texture from crystalline basalt. If we break a rod stalactite it may be hollow like a pipe-stem. The stalagmites underneath must be made by drip in some early high-temperature stage of the stalactite formation above them. I have never seen worm stalactites so hot that they were visibly dripping. In any case the drip is melted rock, and has nothing to do with water. These stalactites are sometimes two feet long.

There are two kinds of extrusion within caverns which are direct squeezings of molten slag. One is a "miniature volcano" of the cavern floor. Types of these are seen in the innermost recesses of Thurston's tube at Hawaii Natoinal Park. It is cone or pie-shaped with slopes like a miniature Vesuvius. Another is the "barnacle stalactite" squeezed through pores or cracks in the cavern walls while all are incandescent. These things are all products of pressure adjustment between cracking shell of cavern and molten matter in the flow beyond the shell. The barnacle stalactite has striations on the sides and may even be a thin papery layer which has oozed through a small crack and stands out from the wall. Lastly, there are glaze stalactites which take massive forms like udders and teats. T.A.J.

KILAUEA REPORT No. 1019

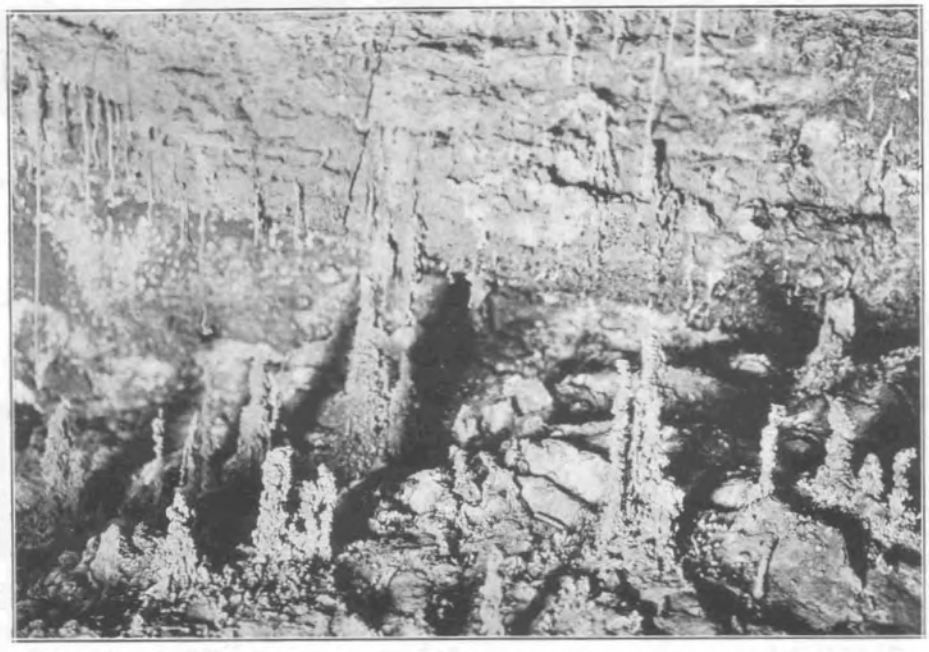
WEEK ENDING AUGUST 2, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The volcano remains inactive. On July 27 some sulphur spots on the Halemaumau bottom seemed a little brighter yellow. No steam or fume was detected. Crack measurements near the southeast rim showed no noteworthy changes. A local earthquake at 2:43 p. m. July 30 was felt at the Observatory and by a few people in the near vicinity. It has not been reported felt elsewhere on the island.

The instruments at the Observatory registered 15 tremors, one very feeble seism, and one feeble seism. In addition there was one spell of continuous tremor 4:43 a. m. to 5:09 a. m. July 30.

The avarage tilt movement for the week was slight NNW. Microseismic motion was slight.



Worm and rod stalactites, and stalagmite spires below, inner recesses of cavern, Kilauea floor. Photo Maehara.



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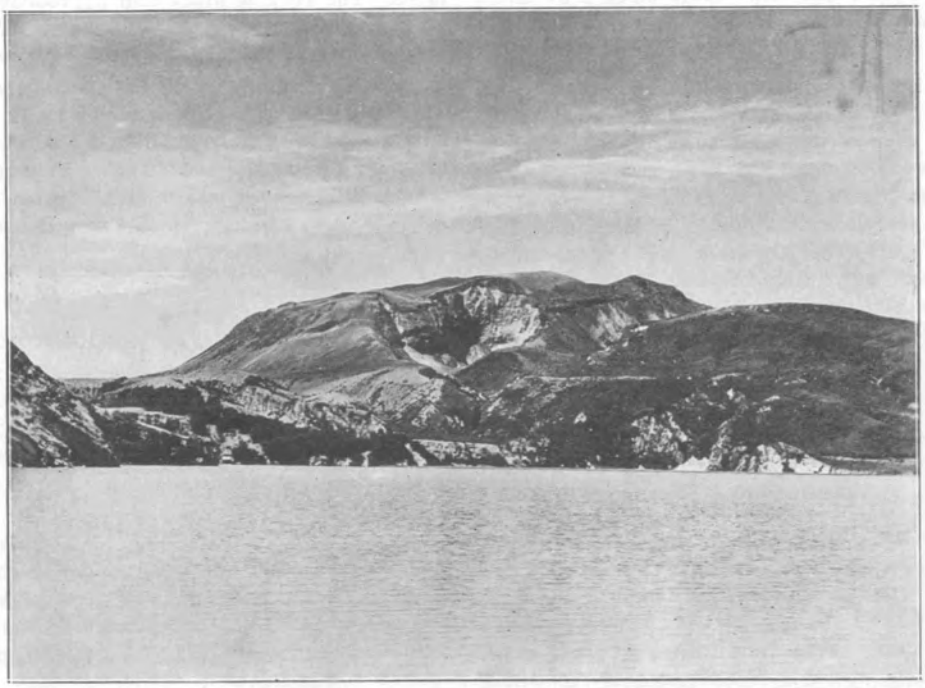
No. 346—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | August 13, 1931



Tarawera Volcano and the Tarawera chasm of 1886, showing the refilled Rotomahana Crater in the foreground. Country covered with ash. Photographed in 1925 by Baker.

ERUPTION OF TARAWERA

In June of 1886 a steam-blast eruption took place from the old volcanic mountain Tarawera and the geyser basin Rotomahana. This event in the thermal springs district of the North Island of New Zealand is worthy of review. The volcano region lies 60 miles to the west of Napier, which was stricken by earthquake February 3, 1931 (Volcano Letter No. 327).

Tarawera lies in the Taupo volcanic zone trending N. 38° E. from Ruapehu to White Island. This zone is famous for many hot springs, geysers, mud volcanoes, and solfataras. Masses of heated magma must exist at no great distance below the surface. Ruapehu, Ngauruhoe. and Tongariro, in the southern part of the zone, are definitely active volcanoes 5,500 to 8,900 feet high. Lake Taupo is in a subsided area north of these volcanoes and covers 242 square miles. About midway between Lake Taupo and the Bay of Plenty is Tarawera Lake, northeast from Lake Taupo. Tarawera Mountain is next to the lake, a flat-topped mass of porous rhyolite lava of light gray color, standing 3,606 feet above sea level, and 1,040 feet above the lake. It was not known to be an active volcano, but studies of its structure show that it is a true cone, with beds dipping outwards, lava streams on its lower slopes, and a plug of what was viscid lava from a former eruption in a NE-SW fissure on its top. There is something of concentric structure in this lava cap.

The warm lake Rotomahana lay two miles southwest of Tarawera, bordered by hot springs and jets of steam. The siliceous sinter of the White and Pink Terraces was on ground which sloped down to the shores of this lake. Water which overflowed the terraces boiled as geyser in the basins above. Rotomahana with its terraced sculpturing, azure warm waters, flocks of dainty terns, and greenery amid steam jets was one of the fairylands of the globe.

At the top of the White Terrace was a snow-white geyser bowl 90 feet broad full of clear blue water boiling up violently in gushes 15 feet high. The basin became dry when south wind blew, but filled again when the wind changed. When the basin was almost full on these occasions, columns of boiling water 20 feet in diameter were hurled 60 feet into the air. In November 1885 there were unusual eruptions of this geyser sending a column of water up 150 feet and of steam 1,020 feet, unheard of in the experience of the resident Maoris. This was the prelude to

the great eruption eight months later. The acid waters of the crater basin on White Island Volcano in the Bay of Plenty disappeared in the middle of 1885, leaving the bed dry. In April of 1886 Ruapehu sent up unusual steam jets, At the beginning of June, 1886, a creek went dry on Lake Tarawera, then with a rushing sound the lake water came running up, overflowing the creek bed, and thereafter retiring twice after the fashion of unusual flood waves. No earthquake was noticed, but some fault block movement in Tarawera Mountain may have caused the retirement of the waters.

The district is thinly populated. Natives on Lake Tarawera did not survive to relate what happened. The nearest observers were at the Wairoa, eight miles west of Tarawera. The previous year had been very dry. After a fine evening June 9, 1886, earthquakes occurred at 12:30 a. m. June 10 and increased in violence for an hour. The northern part of Tarawera Mountain split open and a column of black ash-laden steam arose. This spread to other parts of the plateau summit of the mountain. At 2:10 a. m. there was a violent earthquake, followed by a loud and prolonged roar. A black cloud ascended and spread outwards. Red-hot fragments were seen darting from the cloud. Lightning began to appear, there was rumbling, a red glow lit the scene and as fresh outbursts occurred the clouds were lit up with stronger glow. Fireballs fell about the summit.

The fissure probably split its way southwest through Lake Rotomahana soon after 3 a. m., for about that time earthquakes were especially severe, the heaviest one happening at 3:20 a. m. Engulfment on a big scale probably occurred at this time. This continued southwest from Rotomahana to other craters. By 3:30 a. m. the whole line was in violent eruption for a distance of nine miles from beyond Tarawera on the northeast to Lake Okaro on the southwest. Glow was seen only at the Tarawera end. The clouds spread out, stones and sand began to fall at Wairoa about 3 a. m, then at Rotorua about 4 a. m., and a fierce southwest gale at this time drove the ash-laden cloud away from Rotorua in the direction of the Bay of Plenty. It dropped its ash over all the country between Rotorua and the sea. The chief violence of the eruption was over before 6 a. m. At Rotorua darkness lasted until after 9 a. m. At Wairoa ash fell until 9 a. m., and about Lake Tarawera many people were killed. In the direction to which the ash cloud was blown, at Opotiki, 47 miles away, it was pitch dark until 10:20 a m., when the fall of dust became lighter, and daylight gradually appeared. Detonations were heard even as far away as Hokianga (253 miles) and Auckland (133 miles).

Along the line of the great fissure a series of steam-blast craters was formed. The greatest was the Rotomahana Lake crater, with a hot lake left at the south and another at the north. A great chasm was left in the southern face of Tarawera Mountain, shown in the photograph on Page One, with the Rotomahana lake refilled. There were lines of pits at the north and at the south. The Pink and White Terraces were blown out, with fragments left in the debris. Bold Pinnacle Rocks of rhyolite stand near where the White Terrace geyser was. The southern portion of Rotomahana Crater is bounded by high cliffs of horizontal strata. Tarawera chasm in the hillside is a gash a mile and a quarter long. The bottom is marked by crater-like hollows. The largest hollow has a thousand-foot wall at its back Large trees were blown off the mountain and their stubs were found near Rotomahana. Molten augite andesite was believed to rise in the fissure during the glowing stages of the eruption, and was ejected explosively as scoriae, sand, and dust. There were also bombs one to eight inches in diameter, with cracked surfaces. The rock is black and approaches basalt, with sp. gr. 2.93. Olivine occurs sparingly. The only ryholite ejected was fragmental from old country rock.

At the south end of the Rotomahana Crater there developed in later years the famous destructive mud geyser Waimangu, irregular in its outbursts and at times behaving like a steam-blast volcanic eruption. On several occasions it caused loss of life. (From A. P. W Thomas, Eruption of Tarawera. N. Z. Gov't Report, 1888.) T.A.J.

TILTING OF THE GROUND FOR JULY

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily sesimograms by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in the direction given.

June 29-July 5	0.9 second W.
July 6-12	0.4 second NW.
July 13-19	0.7 second NNE.
July 20-26	0.4 second NNE.
July 27-August 2	0.8 second WNW.

KILAUEA REPORT No. 1020

WEEK ENDING AUGUST 9, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

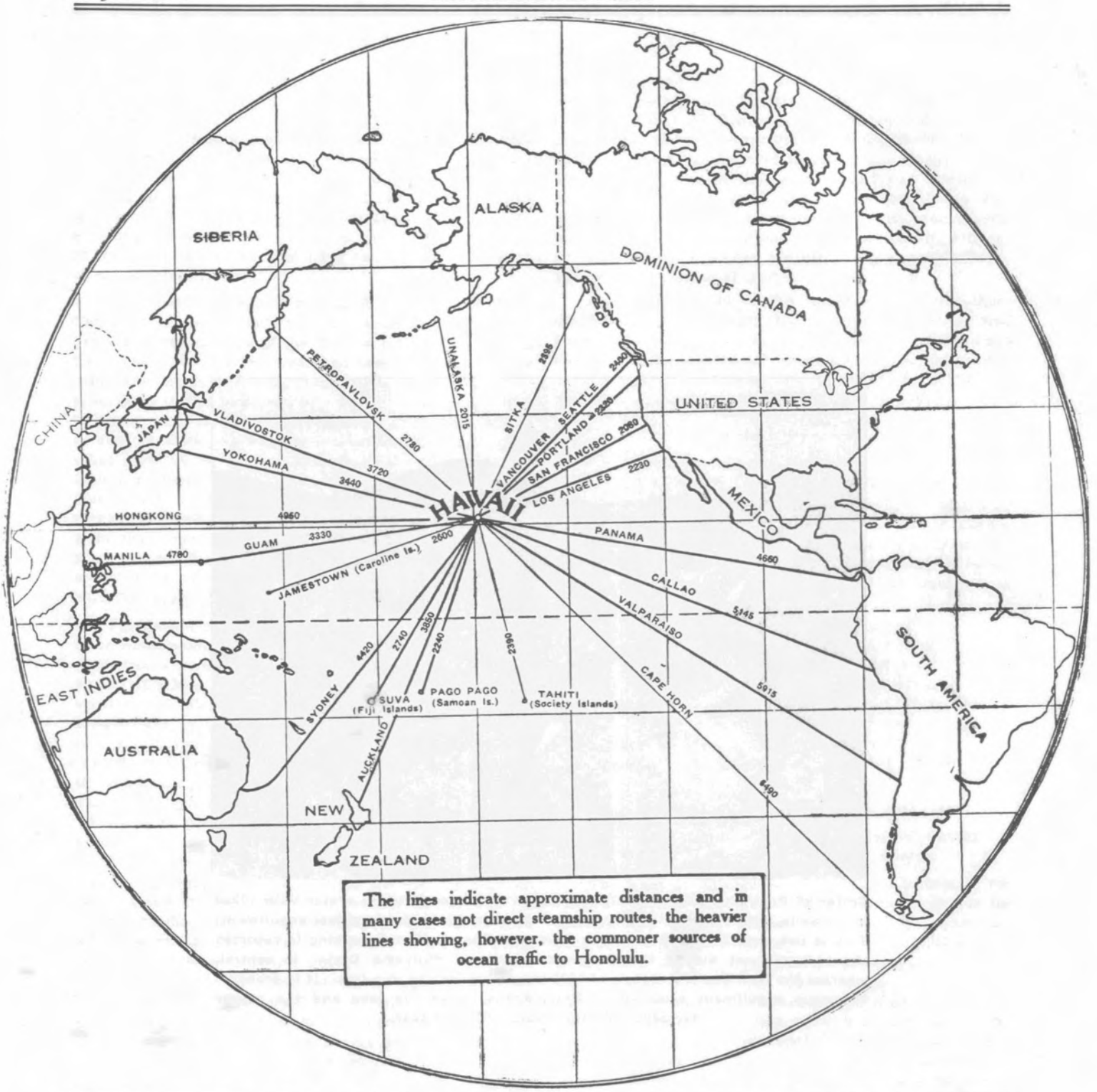
The week at Kilauea passed without changes in volcanic conditions. On August 3 no fume was visible on the Halemaumau bottom. Steam showed at the southeast rock slope but not at the south talus. A strip of sulphur at the lower edge of the south talus appears to be spreading in the direction of the 1931 cone. Rim cracks were measured and showed no changes. On August 4 fume reappeared at the sulphur spot north of the 1931 cone. The pit seismograph had registered two small tremors with slight tilt toward the pit. On August 8 steam and fume were absent from the interior of the pit. A few rocks were heard falling on the north talus at 9:30 a. m. The pit seismograph recorded a few slow-period tremors.

There was a very considerable increase in the number of seismic disturbances recorded by the instruments at the Observatory, including 39 tremors and 6 seisms. One of the latter at 1:43 a. m. August 3 showed distance to origin 23 miles; another at 4:22 p. m. on the 8th showed distance 14 miles and was felt locally. In addition there was a teleseism at 3:54 p. m. August 6 feebly recorded.

The average of accumulated tilt was slight NE. Microseismic motion was slight.



Crater of Fujiyama, August 1917, showing a typical engulfment crater with dikes in its walls, with a section of a lava fill, and inner debris slopes of last engulfment. This is not especially different from Tarawera Chasm, though nothing is reported about engulfment during the Tarawera eruption. Fujiyama Crater is central, whereas the New Zealand craters of 1886 are numerous and in a line. It is probable enormous engulfment occurred at Rotomahana, when the lake and the geyser terraces fell into a void. Photo Baker.



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No. 347—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — August 20, 1931



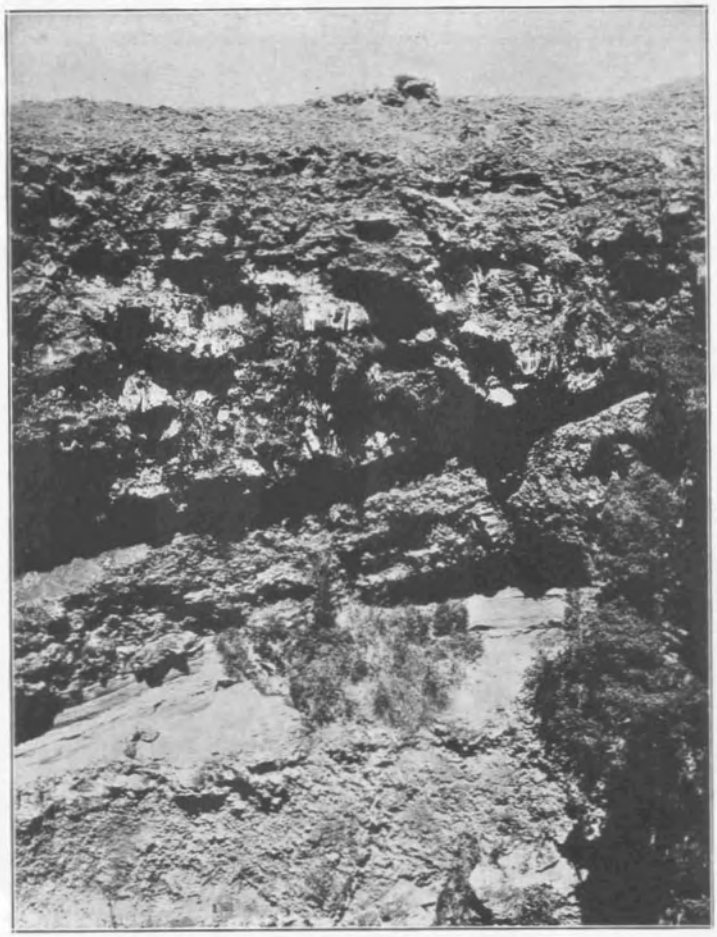
Hualalai as seen from the southeast. The two prominent points are large cones of cinder and slag. The largest summit pit crater is not visible but is located just over the skyline formed by the saddle between the two cones. Photo O. H. Emerson.

HUALALAI

Hualalai Volcano lies entirely within the bounds of the North Kona District of the Island of Hawaii. It has the shape of an elongated dome with the longer dimension of the dome lying almost on a line drawn due northwest from the summit crater of Mauna Loa. The belt road around Hawaii follows the slopes of Hualalai for a distance of more than 30 miles between Kealakekua and Waimea, half encircling the volcano. The broad fan-shaped plain which culminates in Keahole Point, the westermost point of the Island of Hawaii, is formed of pahoehoe flows from this volcano.

The summit peak of Hualalai has an elevation of 8,251 feet above sea level, more than twice the elevation of Kilauea Crater, but lacking more than 5,000 feet of attaining the extreme altitudes of Mauna Kea and Mauna Loa. Because of its moderate height, the mountain is covered with vegetation almost to its very summit. There is a remarkable contrast in type of vegetation on the two opposite slopes of the mountain due to different conditions of rainfall. The northeast slopes, the trade wind side, are reached by trade winds only after they have crossed the broad plains of Waimea and have lost most of their moisture. As a consequence, the entire northern slope of Hualalai has a relatively small rainfall, probably nowhere exceeding 40 or 50 inches of rain a year. The vegetation of this slope accordingly is made up of the kinds of plants which exist on a small amount of moisture, but it is sufficiently luxuriant to provide pasture for cattle so that most of the northern slopes are utilized as range land by the Huehue and Puuwaawaa ranches.

Conditions on the southwest or leeward slopes are very different. The area is sheltered from the trade winds by the mass of the mountain, so that a true land and sea breeze is characteristic. During the night, the slopes of the mountain cool off more rapidly than does the ocean which causes a breeze to blow from the colder mountain slope toward the warmer ocean. Then as the sun warms the mountain slope more rapidly during the morning hours than it does the surface of the ocean, the wind reverses and blows



A small pit crater near the summit of the mountain. In the wall is exposed an old lava flow (at bottom of picture) covered with several feet of bedded cinders from a nearby cone, and over all two or three flows of recent lava which have been poured out since the cinder cone activity. Photo O. H. Emerson.

from the sea onto the land. This day breeze is laden with moisture from the ocean, and as it cools on its way up the mountain side, it drops its excess moisture in almost the same general area every day. As a consequence of this combination of conditions, the rainfall gradually increases from sea level up the slope of the mountain till it reaches a maximum (over 100 inches a year) at an elevation between 2,500 and 3,000 feet, then decreases gradually from this rain belt to the top of the mountain. Thus the vegetation of the southern slope of Hualalai changes with this distribution of rainfall from the semiarid plants at sea level, through fern jungles in the rain belt, then back to the forests and grasses of the dry lands on the higher slopes. The belt road passes through a region of moderately heavy rain and the lands accessible from the road are used for coffee and other planted crops. The lower and upper dryer slopes are used almost entirely as grazing lands by the ranches of the area, but the narrow belt of highest rainfall is too wet and swampy for human use, so in the main is left as native fern jungle.

Hualalai is by far the most "climbable" of all the volcanoes of Hawaii. The ascent to its summit and side trips over its slopes are pleasure jaunts compared to the gruelling climbs to the summits of Mauna Loa or Mauna Kea or to the arduous wanderings through the jungles on Kilauea. It also is an extremely interesting volcano from the standpoint of the geologist or volcanologist.

The first mystery of Hualalai is the question of its relation to Puu Anahula and Puuwaawaa. These two areas are located on the northeast slopes of the mountain and are kipukas, or islands, left in the younger floods of lava from the top of the volcano. From their position so near to Hualalai, they would seem to be a part of that volcano, yet the lava of which they are formed is very different from all the other lavas of Hualalai, but very similar to some of the lavas of the Kohala volcanoes. So far the question has not been answered whether Puu Anahula and Puuwaawaa belong to a very old stage of the activity of Hualalai or whether they really are parts of the Kohala mountains.

Leaving this question open, it is known that the volcano as we see it began its activity by pouring floods of aa and pahoehoe lava out of a number of vents arranged along a fissure line or zone of cracks which is almost straight in a northwest-southeast direction. As more and more of these flows were poured out they built an elongated dome. Activity was more pronounced at one particular part of the fissure line so that the dome of flows was built up to a greater elevation at this spot. There may possibly have been a summit crater similar to Mokuaweoweo on the top of this Hualalai dome. Certainly the structure of the Hualalai dome, elongated along a line of cracks, is very similar to the structure of Mauna Loa as it exists today.

Gradually the eruptions from the Hualalai dome began to change from quiet outpourings of lava flows to eruptions which were more violently explosive and which broke up the molten lava into small particles of cinder and ash. These cinder eruptions broke out in many places along the main rift line and built up huge conical piles of cinders and ash, as well as poured out smaller flows of aa lava. Many of these cinder piles can be seen on the lower slopes of the mountain below the Huehue Ranch, and the two most prominent ones form the two highest points of the mountain.

After these explosive eruptions, for some reason the activity changed back again to the more quite type, and the later flows have been poured out with less explosive activity at the source vent. Accompanying this change in type of activity, the main activity seems to have shifted from the center of the volcano out along the rift line in both directions from the center. There has been a moderate amount of the later activity at the top of the dome, enough to pour out a few small flows and to build several large pit craters at the top, but by far most of the later flows have been poured out from points on the rift line down both slopes from the center. Most of the pit craters and slag cones which show up so well along the rift line on the relief map which was made by Dr. Pope have been formed during these later eruptions.

This type of activity has continued into historic time. There have been apparently several flows from Hualalai since the occupation of the island by the Hawaiians according to accounts given by natives to Ellis in 1823. He says: ". . . . the traditional accounts given by the natives of the eruptions, which, from craters on its (Hualalai) summit, had in different ages deluged the low land along the coast; . . . ." (Ellis, p. 53). The only activity which has occurred since the arrival on the island of English settlers took place in 1800-01. On Dr. Pope's relief map two recent flows are shown on the north slope of the mountain. The western and shorter one of these is marked as the flow of 1801, and the other as the flows of Kaupulehu. There has been a considerable discussion as to whether or not both of these flows are of the same date, i.e. 1801. In a personal communication Dr. Pope states that he is convinced that the Kaupulehu flow belongs to the 1801 eruption.

Ellis' description of a visit to the source crater of the 1801 activity certainly seems to indicate that the Kaupulehu flow is the one in question. Parts of his description follow:

"Having traveled about 12 miles in a northeasterly direction, they arrived at the last house on the western side of the mountain." (Probably Huehue Ranch) ". . . . Leaving the path, the party began to ascend in a southeast direction and traveled about six miles."

At this spot the party spent the night. The location of their camp probably was on the northwest ridge of Hualalai, a few miles above the present belt road.

"Having united in their morning sacrifice of thanksgiving to God, and taken a light breakfast, they resumed their laborious journey. The road, lying through thick underwood and fern, was wet and fatiguing for about two miles, when they arrived at an ancient stream of lava, about twenty rods wide, running in a direction nearly west. Ascending the hardened surface of this stream of lava, over deep chasms, or large volcanic stones imbedded in it, for a distance of three or four miles, they reached the top of one of the ridges on the western side of the mountain.

"Between nine and ten in the forenoon they arrived at a large extinguished crater, about a mile in circumference, and apparently 400 feet deep, probably the same that was visited by some of Vancouver's people in 1792. The sides sloped regularly, and at the bottom was a small mound, with an aperture in its centre. By the side of this large crater, divided from it by a narrow ridge of volcanic rocks, was another fifty-six feet in circumference, from which volumes of sulphureous smoke and vapour continually ascended. No bottom could be seen; and on throwing stones into it, they were heard to strike against its sides for eight seconds, but not to reach the bottom. There were two other apertures near this, nine feet in diameter, and apparently about 200 feet deep.

"As the party walked along the giddy verge of the large crater, they could distinguish the course of two principal streams, that had issued from it in the great eruption, about the year 1800. One had taken a direction nearly northeast; the other had flowed to the northwest, in broad irresistible torrents, for a distance of twelve or fifteen miles to the sea, where driving back the waters, it had extended the boundaries of the island. They attempted to descend this crater, but the steepness of its sides prevented their examining it so fully as they desired." H.A.P.

KILAUEA REPORT No. 1021

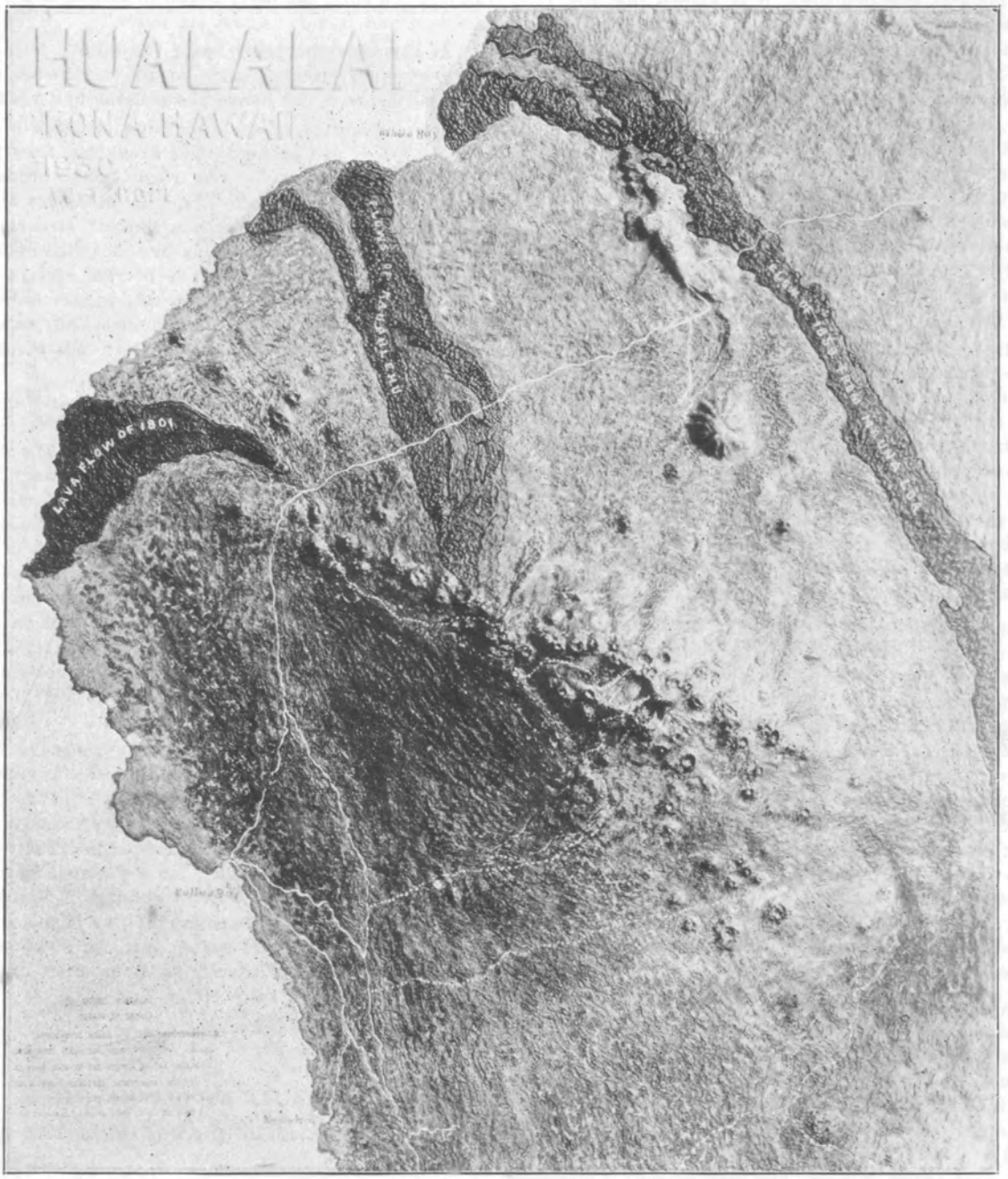
WEEK ENDING AUGUST 16, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

There is nothing new to report. Steam and fume were detected occasionally at vents within Halemaumau, usually very thin as dry weather has prevailed. On August 13 about 9 a. m. there was a large avalanche from the middle of the northwest wall, causing much dust. Another avalanche dust cloud was observed from Uwekahuna about 9:20 a. m. August 15.

The seismographs at the Observatory recorded 23 volcanic tremors, six very feeble local seisms and one teleseism. Three seisms gave indicated distances as follows: August 12 6:11 a. m., 4 miles; August 13 6:20 a. m., 11 miles, and 7:03 a. m., 5 miles. None was reported felt. The teleseism registered at 11:04 a. m. August 10 without distance phases.

Tilt for the week was slight NNE. Microseismic motion was slight.



Model of Hualalai, 1930, by Willis T. Pope. Shows recent flows and the northwest-southeast summit rift well marked by cinder cones and pit craters. Distance from Kailua Bay to Keauhou Bay (southwest corner) is about six miles

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No. 348—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — August 27. 1031



A typical pahoehoe surface on a lava flow. The skin of vesicular glass which forms rapidly is often wrinkled and contorted into curious shapes. Flow from southwest flank of Kilauea December 1919. Photo Finch.

VOLCANIC PRODUCTS

The statement is often made that the islands of the Hawaiian group have been formed by volcanic action. In other words, the islands are built of materials which have been thrown out from a number of separate volcanoes. It may be of interest to consider in some detail what these volcanic products are of which the Hawaiian Islands are made.

Geologists who have studied the question are rather well agreed that the basin of the Pacific Ocean is made up largely of a kind of rock known as basalt. One of the facts on which this statement is based is that most of the material thrown out of the numerous volcanoes in the Pacific Ocean basin is basalt of nearly uniform composition. This is certainly true in the Hawaiian Islands. All of the volcanoes in the Hawaiian group have drawn the materials for their eruptions from a common, deep-lying supply of basalt. Geologists do not agree as to the exact physical condition in which the basalt exists under the ocean. However, for the study of volcanic products it is unnecessary to determine this original condition. We are interested in the basalt only after it begins to be erupted from one of the volcanoes.

Under appropriate conditions of heat and pressure, part of the deep supply of basalt under a volcano becomes liquid, and then is capable of being erupted from the volcanic vent at the surface of the earth. When it is in this liquid condition it is called "magma." Magma may be defined simply as liquid rock. In more detail it may be defined as a solution of a number of chemical elements in different chemical combinations just as sea water is a solution of many chemical elements, the most important of which are sodium chloride (common salt) and pure water. Chemists express the amounts of the different elements in a rock in terms of their weight when combined with oxygen. A typical basaltic magma would be made up of the following principle elements in the given proportions:

Oxide of silicon	50%
Oxide of aluminum	14%
Oxide of iron	10%
Oxide of magnesium	8%
Oxide of calcium	10%
Oxide of sodium	3%
Oxide of potassium	1%
Other substances	4%

In addition to the main elements, the magma contains very small amounts of many substances such as water, manganese, titanium, phosphorus, sulphur, nickel, chromium, copper, chlorine, carbon, and molybdenum. Thus we see that a magma is a very complex liquid made up of a large number of elements in solution.

The magma can exist as a liquid only at very high temperatures. Dr. Jaggar made a number of measurements of the temperatures in different parts of the magma lake ranging from about 750 degrees Centigrade to 1,500 degrees Centigrade. Iron in a blast furnace would be white hot at the higher of these temperatures.

When the magma begins to rise in the throat of the volcano, some of its elements begin to combine to form gas such as water vapor, sulphur dioxide, and carbon



The lava flow from Mauna Loa in 1926 as it crossed the road like a moving cinder pile. The clinkery, broken surface of the aa flow is radically different from the smooth, glassy surface of the pahoehoe flow, yet the lava forming the two different flows may be of exactly the same composition. Photo Boles.

dioxide. The gas comes out of the magma solution, begins to expand and form bubbles, and cause the whole mass of the magma to swell and froth like soda water in a bottle after the cap is removed. The expanding gas makes pressure within the liquid magma which helps force it to the opening in the crater of the volcano and makes the magma erupt. If the gas pressure is relatively low and the opening to the volcanic vent is fairly open, the escaping gas makes fountains of liquid lava at the vent such as are seen in Halemaumau or at the heads of the Mauna Loa flows. However, if the gas pressure is great and the escape of gas is partly obstructed, the lava may be thrown out of the vent with great violence. These stronger gas explosions break the lava up into drops and fragments of different sizes so that, instead of a lava flow, an eruption of volcanic ash and cinders will result. Such activity has formed the large cinder cones on Mauna Kea and such craters as Diamond Head on Oahu.

Going back to the magma, as the gas begins to bubble out and the lava rises in the volcano, its temperature is lowered by radiation of heat to the rocks forming the throat of the volcano and to the open air. As the temperature drops, some of the constituents of the magma combine and crystallize from the solutions as minerals which can become solids at high temperatures. Olivine (Hawaiian diamond) is one of these minerals which begins to form crystals while most of the magma is still liquid. Some of the liquid lava dipped from Halemaumau had large crystals of olivine floating in it. Since the olivine crystals begin to grow before the lava is erupted, many of them attain a large size and are conspicuous in some flows as large greenish crystals known as phenocrysts Olivine is made up of magnesium, iron, and silica and is called a magnesium-iron silicate.

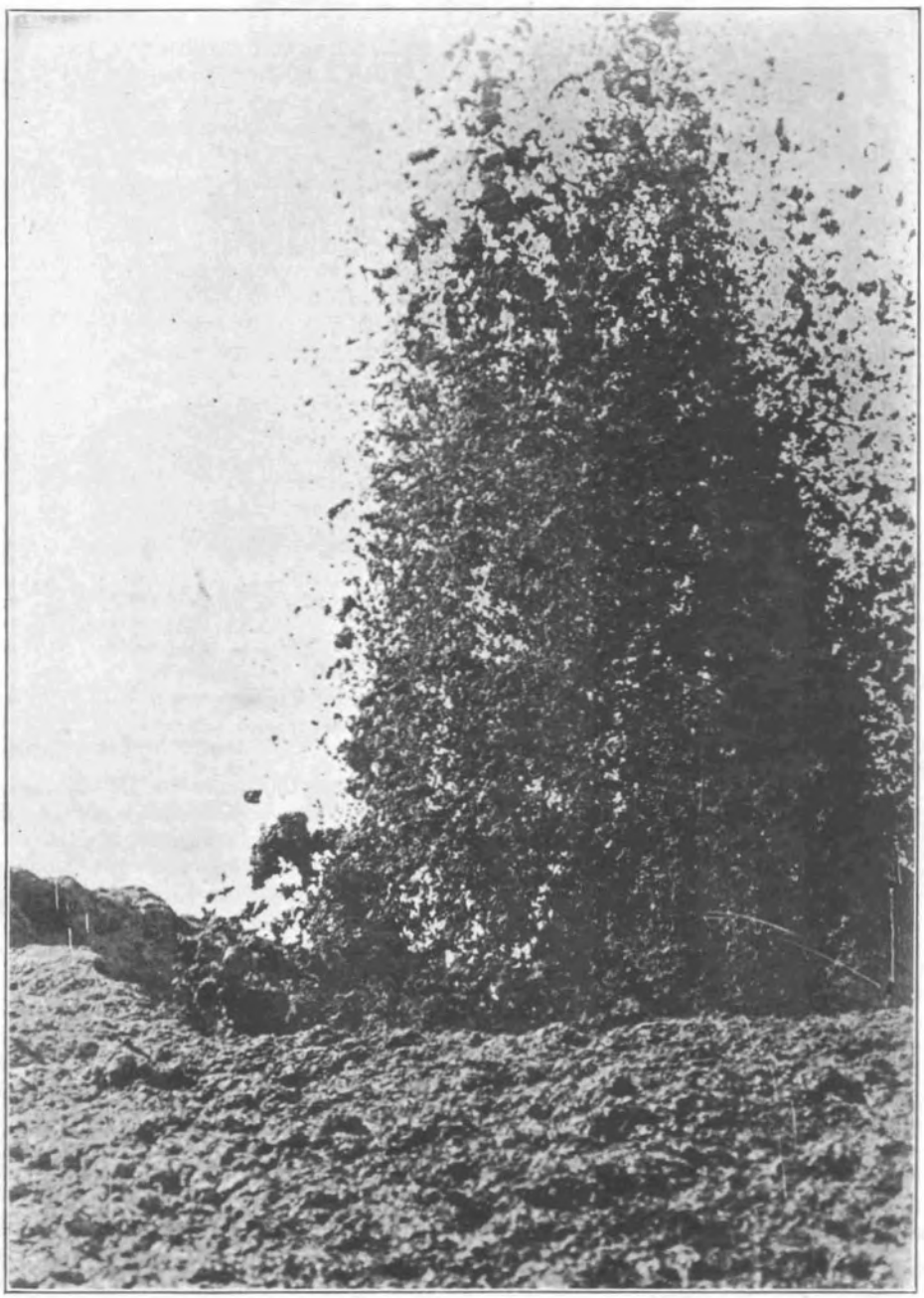
Other minerals begin to precipitate from the magma when the temperature drops still lower. The two other important minerals which form from basaltic magma are pyroxene and calcium feldspar. Proxene is made up of calcium, magnesium, iron, and silica. Calcium feldspar is made of calcium, aluminum, silica, some sodium, and a little potassium. Proxene and calcium feldspar are the most abundant minerals in basalt, olivine is third in abundance, and the only other common mineral of much importance is magnetic iron ore which is present up to 5 or 6 per cent in some basalts. Though olivine is the most common phenocryst in the Hawaiian basalts, occasionally pyroxene and calcium feldspar are found as black and white phenocrysts, respectively.

If magma cools fairly slowly, there will be time enough for all of its constitutents to combine in crystals of the above mentioned minerals. However, if the liquid magma is cooled very rapidly it may freeze to a solid form without giving the elements time to form crystals. This rapidly frozen magma is a volcanic glass which is called basaltic obsidian.

If the magma is thrown out in explosive eruptions, such as have occurred on Mauna Kea, the small drops of magma which are suddenly blown out into the air cool very rapidly and form small particles of basaltic obsidian. Many of these particles are full of gas bubbles and so form a sort of glass sponge which is called pumice. The larger fragments or blebs of magma may be big enough to cool more slowly and so have time to crystallize to some extent. Many of them are full of bubble holes also and so form slag-like pieces which are called cinders. An explosive eruption thus produces fine grains of glassy ash or pumice and coarser fragments of partly crystalline cinders.

A small part of the magma which comes out in a quiet eruption is blown into the air by the fountains at the source vent. This part freezes rapidly and forms a little pumice and Pele's hair which is basaltic glass drawn out into fine threads. However, most of the magma from quiet eruptions pours out as lava flows. These are of two types, aa and pahoehoe, which are distinguished by the character of the surface of the lava flow and not by any difference of composition of the lava.

If the magma which flows out is so hot that it contains very few crystals, the surface of the flow rapidly freezes and forms a thin skin of basaltic glass on top of the flow. This skin acts as an insulator and permits the rest of the lava in the flow to retain its heat and so to cool slowly enough for complete crystallization. A flow



Fountaining lava at the source of the 1919 flow from Mauna Loa. The force of the rising gas throws the lava into the air and blows it full of bubble holes. Pumice and Pele's hair are formed by this sort of fountain. If the explosive force becomes much greater, all of the rising lava may be blown into the air to form cinder and ash cones. Photo Jaggar.

which has formed such a glassy skin on its surface is called a pahoehoe flow.

In contrast, if the magma has been cooled enough before exposure to the air so that it is full of tiny crystals, as soon as it is exposed to the air all of the magma crystallizes rapidly. Thus, instead of forming a glassy skin on its surface, the flow forms a top layer of crystalline clinkers. This clinkery surface also is an insulator so that the inner part of the flow loses its heat slowly and has time to crystallize completely. A lava flow with a clinkery surface is called an aa flow.

Aa and pahoehoe flows make up most of the rock of the Hawaiian Islands. Cinders and ash are present in appreciable quantity on the islands of Maui and Hawaii, and are fairly conspicuous as building material in the make up of Oahu. For example, Punch Bowl and Diamond Head on Oahu are craters made up largely of ash and cinders.

H.A.P.

KILAUEA REPORT No. 1022

WEEK ENDING AUGUST 23, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

There are no visible changes in volcanic conditions at Kilauea. Halemaumau remains quiet and with the usual vapor activity. The records of the seismograph nearby indicate quiet conditions.

There were 21 short tremors registered by the instruments at the Observatory, one two-minute tremor, and one eight-minute tremor; and three very feeble local seisms. One of the seisms, occurring August 21 at 12:09 a. m., and having close epicentral distance, was felt locally; another at 11:05 p. m. August 22 showed distance to origin 32 miles.

The average tilt for the week was very slight NE, with a decided trend to N toward the end of this period. Microseismic motion was slight.

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No. 349—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | September 3, 1931



Marked crack where it emerges at southeast rim of Halemaumau, showing method of measurement with wooden calipers at painted spots.

VERTICAL AND HORIZONTAL GROUND MOVEMENT

"Tilting of the ground as recorded by the slow and persistent wandering of the recording pens of the seismograph has been found through past years at the Observatory to be well worth observation. Such tilting away from the pit of Halemaumau has in general been correlated with rising of the lava column, while tilting towards the pit has usually come with retirement of the lava or at times of general collapse. The tilt at the Observatory appears to have a normal annual range of about 10 seconds of arc towards the pit (southwest) during the first half of the year, and a recovery during the second half. This normal movement and some other shorter period variations may not be strictly due to volcanic causes. General temperature changes either of the instrument room, of the ground upon which the Observatory stands, or of the face of the cliff near the Observatory may produce tilting effect and so account in part for this annual change, though experi-

ments show that it certainly is not a purely local movement. Volcanic conditions are known to produce tilt also, and these volcanic tilt effects are superimposed upon the tilts produced by other causes." (R. M. Wilson in "Review of Local Seismic Features for the Year," Monthly Bulletin of the Hawaiian Volcano Observatory, Vol. XV. No. 12, December 1927.)

Quantitative measurements of the uplift and depression of the Kilauea dome have been made on several occasions in the past by means of precise spirit levels and horizontal movement detected by a careful retriangulation of a network of stations about the pit also connected by precise levels. The first spirit levels were run in 1912 by the U. S. Geological Survey and subsequent runnings of this line by the same organization in 1920 and the U. S. Coast and Geodetic Survey in 1927 have shown the value of spirit levels as a means of detecting even small amounts of vertical displacement. The methods used are fully described in Monthly Bulletin of the Observatory Vol. XV, No. 6, 1927.

The net of triangulation stations about Kilauea was first established in 1920 and the connecting levels run during the same period. Final adjustments of both surveys by the method of least squares was made by the computing section of the Geological Survey in Washington, D. C.

In 1927 and 1928 Mr. R. M. Wilson, engineer and mathematician of the Observatory at that time, who was also the author of the 1920 surveys, made an identical resurvey of this net. The results correlated satisfactorily with the general breakdown and depression of the Kilauea dome during the seven-year period which they covered. Horizontal movement was shown to be a general pull-in of all points towards Halemaumau as a center.

Similar repetitions of surveys have also been extensively made by the Japanese government in their quake-stricken provinces and the U. S. Coast and Geodetic Survey has retriangulated the area along the San Andreas rift in California. ("Earth Movements in California," by William Bowie, U. S. Coast and Geodetic Survey Special Publication No. 106.) The results of these measurements as of those in Hawaii show clearly and accurately the amount of displacement of the earth's crust which took place during the period of the cataclysm. Now as has been said some of these displacements were very small and required the most accurate of modern engineering methods to detect, also the surveys were made after the greatest movement had occurred. The question arises since such small movements have been measured after a quake has occurred, would it not be possible to apply these same methods to the prediction of quakes, or as more closely concerns us in Hawaii, the rise of the Kilauea or Mauna Loa lava columns?

The measurements in California and Japan have been concerned partly with quakes of tectonic origin, and as such quakes are caused by continued long strain and warping of the earth's crust over a number of years until it has reached the breaking point. it would seem that here a periodic survey of known active fault areas would be of value. This in Japan is called "chronic tilting" by Imamura. (Topographical changes accompanying earthquakes or volcanic eruptions, by A. Imamura, Publ. E. I. C. No. 25, Tokyo, 1930.)

Here in Hawaii any such measurements would have to be correlated with data from the seismograph or tilt-meter and continued through two or more active phases, since the actual tilt of the ground from day to day is small and not perceptible except by magnification. However, cumulative tilt is undoubtedly a measurable quantity and since accumulated tilt away from the pit has been shown generally to precede an active period, it is possible that measurements of the relative change in elevation of established bench marks together with the measurement of the horizontal angular change between such points would give a more firm basis for prediction.

With this end in view, and for general engineering use, four new stations marked with standard U. S. B. M. tablets have been established about the rim of Halemaumau. One is a few feet from the seismograph cellar at the pit and the other three form a rough square spanning the crater. Triangulation of these points has been made for any immediate emergency. Later they will be connected by precise levels to the 1927 circuit and a more accurate triangulation made with perhaps an especially measured base.

Horizontal angles are observed by a repetition with a Berger transit graduated to 20 seconds. Each angle is observed 12 times, six times in a clockwise direction, three settings made with telescope direct, and three reversed, both verniers being read. The angle is then measured in a similar manner but in a counter-clockwise direction, the mean of the 12 readings giving the correct angular value free from instrumental errors. Horizon closures are made in the same way. Particular care must be given to the centering of the instrument over the station and of the signals over their respective marks.

The larger net of Kilauea stations will also be reoccupied and identical angles measured as the loss of any lines from the previously adjusted figure would necessitate an almost complete new adjustment and much of the value of the work lost from its intended purpose, a comparative study with the two older surveys, together with the accumulated data for the same period from the seismographs.

A similar resurvey with the spirit level would give a means for study of any relative changes of elevation among the several stations in the net.

The measurement of rim cracks about Halemaumau has in the past proved of interest, as well as of value to the public in marking off weak or dangerous sections about the pit. The measurements, however, have not been very refined, instrumental errors amounting to as much as two or three millimeters due partially to uncertainty of exact points of measurement as well as the inaccessibility of some of the points. These measurements are to be resumed with new points added from time to time and the methods of measuring revised. Tumescence of the Kilauea dome as the result of rising lava has its effect on the more deep-seated fractures; a lift of this lava column before eruptions in 1927 and 1929 caused a widening of the superficial rim cracks with sections breaking off and avalanching into the pit.

Kilauea, due to its accessibility, is ideally situated for observation and measurement of tilt. Mauna Loa, on the contrary, presents a problem. Previously established triangulation points of suitable accuracy are scarce, and the precise spirit levels to the summit run by the U. S. Coast and Geodetic Survey in 1926 provide the only accurate datum bench marks on the entire mountain.

Mauna Loa above timber line alone comprises an area of over 500 square miles and is really accessible only by means of three trails; one on the Kona or west side and two on the southeast side. Water is obtainable only at

the summit from melted ice or snow in the cracks and from scattered water holes along the forest edge.

Most of the historic activity, however, with a few exceptions has occurred along the two rift zones or ridges and at the summit crater, and all of the flows since 1881 have commenced within a relatively small area along the southwest rift a few miles above Puu o Keokeo, though generally preceded by an eruptive period of several hours at the summit.

The establishment of a net of triangulation about the whole mountain similar to the Kilauea net would be of immense value for future study, but the expense of surveying such a net would be more or less prohibitive. Astronomic azimuth observations would have to be made, a base line measured, the present transit replaced by a repeating or direction theodolite, and the net carefully connected to the recent inter-island triangulation by the Coast Survey. However, small independent nets spanning the most active parts of the rift zones as well as the summit crater would not be prohibitive in cost, and like the small Kilauea net would be readily subject to periodic remeasurement and hence comparative study. Extension to these nets of the existing levels could be made and vertical displacement measured from time to time.

Mauna Loa as a whole presents a problem of absorbing interest as yet practically untouched. Some sort of auto road to the summit and one from the Kona side to the southwest rift would go a great way towards overcoming the obstacles encountered by any one attempting observations on the mountain. The roads would also open an entire new field to the tourist. Seismograph and tiltmeter stations would be established at critical points and proper attention given them.

With its present inaccessibility Mauna Loa can be perhaps best studied through the means of small triangulation nets connected by levels and the construction of tiltmeter stations with a tiltmeter devised which would record its readings at the distant Observatory and require but infrequent field inspection. Dr. Jaggar is at present working on plans for such an instrument.

The Puna District and Hualalai have been scenes of recent severe shocks and also present fields for the study of tilt problems.

The above notes represent an outline of some of the work the Observatory has done in the past and what the writer hopes to take up in the future in the investigation of the horizontal and vertical movements or tilt of the ground about the several active volcanic regions in Hawaii.

E.G.W.

KILAUEA REPORT No. 1023 '

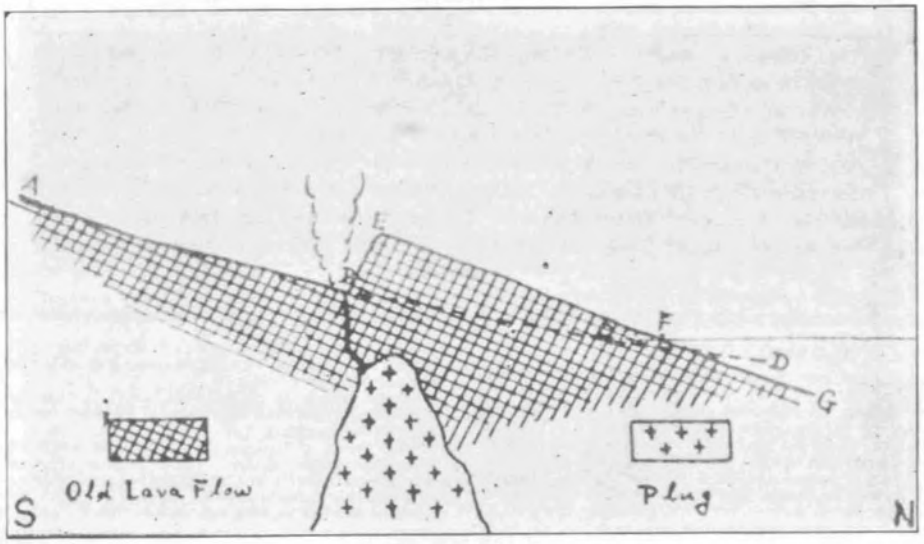
WEED ENDING AUGUST 30, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

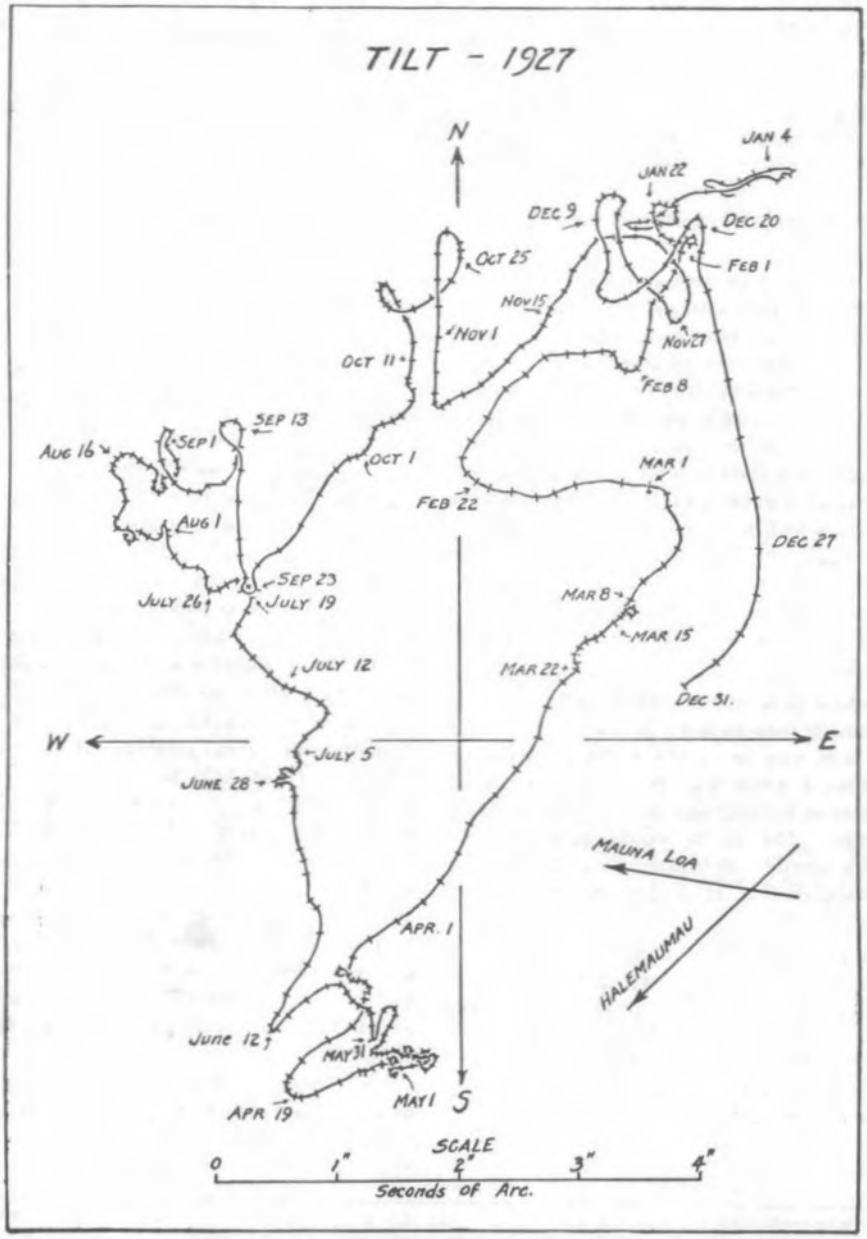
At Halemaumau pit slight fume was observed rising from a sulphur spot on the north side of the 1930 cone on the afternoon of August 23. Steam was notably absent August 24. A slide from the wall occurred about 9:40 a. m. August 26, and fume was observed on the floor. About 7 a. m. August 30, soon after the moderate earthquake recorded below, an avalanche at the pit on the northeast side sent up a thick cloud of dust.

The seismographs at the Observatory registered 19 tremors and 4 local seisms. Of these one at 2 a. m. August 25 was very slightly perceptible and indicated distance of origin 14 miles. A stronger earthquake was felt generally on the island at 7:53 a. m. August 30, dismantling instruments in Kona, Hilo, and at Kilauea, indicating distance of origin 15 miles from Kilauea and 35 miles from Hilo. It was felt as a slight and prolonged tremor near Kilauea, and more strongly in Hilo, Olaa, and Kona. The facts suggest an origin under the northern part of Mauna Loa, and this is confirmed by the vertical component seismograph which indicates an origin northwest of the Kilauea Observatory.

The average tilt for the week was moderate to the N, and microseismic motion was slight.



Profile of north slope of Usu Volcano in Japan where during a single eruption the block shown was lifted 500 feet and the whole mountain was affected by elevation and tilting. After Ouinoue.



Tilt diagram, Hawaiian Volcano Observatory, for 1927. On the scale in seconds shown, the line beginning January 1 in the northeast corner indicates daily amounts and directions of changes of a plumb line for the year, with tilting to the southwest in spring and to the northeast in autumn. The data are caculated from seismograph records. The bend northwest July 8 corresponds to an outbreak of Halemaumau the previous day. Arrows indicate directions of Mauna Loa and Kilauea from the Observatory. Comparing January 1 and December 31, net change for the year was four seconds south.

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The Volcano Letter

Two dollars per year — Ten cents per copy

No. 350—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — September 10, 1931



Figure 1. Looking north along the west-facing fault cliff, north of Ka Lae, Hawaii. In the main cliff may be seen the edges of many lava flows. The top of the lava cliff is backed by a gently-sloping terrace, back of which is a low cliff cut in loess. Back of the loess cliff is gently rolling loess grassland. In the distance, at the left, is down-faulted western block. Photo H. S. Palmer.

LOESS AT KA LAE, HAWAII

Ka Lae, the southermost point of the Island of Hawaii, may be reached by leaving the main highway about four miles west of Waiohinu, and driving southward about twelve miles over secondary roads. One first goes through the Kamaoa homesteads and then across open, strongly wind-swept grasslands to the Lighthouse Reservation at the extreme tip of the island. Ka Lae is bounded on the west by a west-facing fault cliff which, though low at the south end, increases in height inland to 500 feet or more (figure 1). The fault cliff extends inland at least ten miles from Ka Lae and is said by fishermen to extend also some distance southward under the sea. The block west of the fault has sunk and has thus formed a depression into and along which lava flows have poured on several occasions within historic times. The block east of the cliff, in contrast, has been freer of lava flows in recent times because of its greater elevation. Its coastline runs northeastward from Ka Lae and has been built out into the sea by prehistoric lava flows.

The block east of the fault cliff is entirely covered by variable thicknesses of a fine grained, yellow-brown material. In some places this has been drifted into sand dune ridges which parallel the direction of the prevailing trade wind (see figure 2). Along the top of the big fault cliff this upper fine grained deposit has been cut back slightly from the edge. This forms a small secondary cliff in which different layers of the upper material are exposed.

At many places there are small lenses of coaly or carbonaceous material at horizons in the little cliff which are below the present surface. Each coaly lens represents an accumulation of vegetable matter in a chance depression in what formerly was the land surface, but which has since been buried by new layers of silt. For the most part, nothing can be made out as to the nature of the plants that supplied the vegetable matter, but one block was found bearing the clear impression of a dicotyledonous leaf. The presence of the leaf print, as well as the presence of the coaly lenses, proves that the fine-grained material has been carried in in some way, and that it is not a residual soil formed by the weathering of the lava in place. Moreover, the fine-grained material rests on rather fresh lava rock and does not show the transition from surface soil to fresh rock, through various degrees of weathering, that residual soils show. Since wind is the only transporting agent that can be conceived of as having operated here, the material is properly classified as loess, a term that was originally applied in Germany to fine-grained wind deposited sediments.

For some miles east of the Lighthouse Reservation at Ka Lae, the actual shore line is of lava rock, largely pahoehoe lava. It is exposed as a rather uneven rock terrace, in places submerged and in places making a clifflet two or three feet high along the water's edge. The terrace rises inland to heights of four to six feet above sea level, and is from ten to a hundred feet wide. Back of the lava terrace is a single or compound loess cliff. In the few places where it is a single cliff it is in general about six feet high. Where it is a double cliff, the lower cliff is about four feet high and exposes a red-brown loess. The upper cliff is four to eight feet back of the top of the lower cliff and is about two feet high. It is composed of yellow-brown loess. In places there are low dune ridges of sand a short way back of the top of the upper cliff and resting on the finer-grained, yellow-brown loess (see figure 3).

The upper cliff is protected at its upper part by a good turf, the roots of which effectively bind the top few inches of loess and greatly retard its erosion. The lower part of the loess is not thus bound and therefore is readily cut away by windblown sand. Thus the turf layer is slowly undermined and is forced to collapse by the removal of its support.

In many places the red-brown loess cliff is double instead of single. The top of the lower red-brown cliff seems to be due to the slightly greater resistance to erosion offered by the remains of an old turf layer (see figure 3).

The ability of the lower or red-brown loess to resist erosion presented a different problem, for it lacks the protective network of roots, except at the one horizon mentioned in the preceding paragraph. Samples were taken near the top and near the base of the yellow-brown layer, and near the top, near the middle, and near the base of the red-brown layer. The samples were numbered from 1 to 5, in the order just named. Fair-sized portions of each were weighed and then dried to constant weight at 108° C., to determine the amount of moisture they contained. Smaller portions of each were then weighed out and leached with a fairly large volume of distilled water to extract the soluble salts. The extract was then analyzed



Figure 2. Low, grass-bound sand dunes, between and around which the road wanders, about five miles north of Ka Lae. Photo H. S. Palmer.

for chlorine, and the equivalent salt content of the original sample calculated. The results of these determinations are given in the following table.

Moisture and Salt Contents of Loess Samples from Ka Lae

Sample number	Position of sample	Per cent water lost at 108° C.	Per cent salt (NaCl) in sample
1	Top of yellow-brown loess	4.64	0.79
2	Base of yellow-brown loess	13.72	1.26
3	Top of red-brown loess	24.40	5.31
4	Middle of red-brown loess	22.36	5.46
5	Base of red-brown loess	21.62	2.16

It is clear that the red-brown loess is much moister than the yellow-brown loess. Except for its basal portion, it is also saltier than the yellow brown. The conclusion seems inevitable that salt water is carried up by capillary action into the red-brown zone. The upper limit of capillary rise appears to be the top of the red-brown loess. There appears to have been some reaction of the salt which has oxidized the iron of the loess so that the red-brown color has developed. The nature of the reaction is not known, but is presumably like the proverbially bad rusting of iron by salt spray. The new iron compounds thus formed seem to cement the red-brown loess a little and thus to give it some resistance to erosion.

Reference to the table will show one inconsistency in the preceding discussion, for the base of the red-brown loess is less than half as salty, though almost as moist, as the middle and top parts. One might expect the base to be the saltiest and moistest as it is nearest to the source of supply of salt water. A reasonable explanation of the greater saltiness above is that, as capillary action raises water and its dissolved salt, subsoil evaporation removes the water and leaves the salt behind. Thus there is a progressive accumulation of salt to such depth as evaporation can reach. In the lowest layer exaporation is virtually inoperative and no such concentration of salt has taken place.

The slightly greater moisture content of the middle and top as compared with the base of the red-brown loess is perhaps due to some retention of water by the hygroscopic action of the salts.

The accumulation of the loess has taken place in part since the occupation of the Hawaiian Islands by human beings. At one place, a hundred feet or so east of the Lighthouse Reservation, there is exposed in the loess cliff a pavement of wave-rounded bowlders. That they got here through the activity of human beings is shown (1) by their rather regular arrangement, (2) by the fact that the pavement consists of only one layer of bowlders, and (3) by the fitting of coral fragments into the chinks between the lava bowlders. All of these features are characteristic of the platforms made by the Hawaiians so often along the shores for use in ceremonies in connection with fishing operations. Waves would not select bowlders of such uniformity of size; they would not select coral for chinking; and they would not make a uniform layer only one bowlder deep. Clearly the platform is man-made, yet it is overlain by loess, so part at least of the loess has been made since the platform was made and therefore since human occupation of Hawaii.

The horizon of the bowlder pavement or platform is traceable as a somewhat pebbly and shelly layer for about a hundred feet. The pebbles and shells may well have been scattered by the persons who made and used the platform. If so, it is a sort of fossil kitchen midden.

It happens that the bowlder pavement lies between the yellow-brown and the red-brown horizons of loess. This may be purely accidental, but it may be that the coarse layer breaks up the capillary channels so that the reddening and cementing actions are stopped at their level.

The fact that the loess cliff is within ten to a hundred feet of the water's edge suggests that it is a wave-cut cliff. However, on July 12, 1930, there was a place at which some initials had been cut in the red-brown loess cliff. The date was illegible as it had been cut away by a little vertical groove due to run-off from above. At other places the cliff was similarly grooved. It appears, then, that waves are doing less at such places than is run-off. One might expect the energy of storm waves to be dissipated largely in crossing the lava rock terrace. In ordinary weather waves do not come near the cliff, even at high tide. Where the lava bench is narrowest (see figure 3) the loess is being cut back by storm waves, it would seem, and makes a single cliff in both the red-brown and yellow-brown loess layers.

Outcrops of the loess on top of lava rock are continuous along almost all of the shoreline from Ka Lae northeastward to Kaalualu. Puu o Mahana, three miles northeast of Ka Lae, is a tuff cone, the seaward part of which has been cut away by waves. Loess makes a rather deep mantle on its lower windward slopes, but seems not to have lodged readily on its upper windward slopes nor on its leeward slopes. Whether any loess underlies the tuff is not known.

About a mile and a half northeast of Ka Lae there is a young flow of aa lava, which divided a mile or so inland and reached the shore as two flows, leaving a kipuka in between. Underneath the southwestern of the two arms there is some loess, the precise relationships of which were not ascertained. This loess is believed also to underlie the northeastern arm of the aa flow. Much fuller observations were made on a similar occurrence of loess beneath another young lava flow about half a mile southeast of Kaalualu.

On the west side of Paiahaa Bay, the small bay just west of Kaalualu Bay, the shore line is cut for some distance in a pahoehoe flow which has the usual somewhat irregular upper surface. On this pahoehoe flow lies a bed of loess with a smooth wind-made upper surface. Since the lower surface of the loess follows the irregularities of the upper surface of the pahoehoe flow, the thick-



Figure 3

The ridge forming the sky-line is a sand dune ridge, resting on the yellow-brown loess, which extends down to the level of the man's belt. The separation of the loess horizons is lost in the shadow behind the man. At the left of the picture the uppermost clifflet is in yellow-brown loess, below which are two clifflets in red-brown loess. The lowest clifflet is in front of a broad bench and leads down to the terrace cut on pahoehoe lava. Quiet pools of sea water occupy depressions in the pahoehoe terrace. At the right, coral fragments and shells have been piled against the loess cliff. Photo H. A. Powers.

ness of the loess varies from eight to ten feet. The loess bed and the underlying pahoehoe curve downward in both directions till they are hidden beneath a heap of boulders at the foot of the cliff. This loess is older than most of the loess along the Ka Lae-Kaalualu shoreline. At a typical point its red-brown, lowest zone is about two feet thick and reaches an elevation of about seven feet above sea level. It is overlain by about six feet of loess which shades upward from darker to lighter yellow-brown. The topmost six-inch layer of the loess is very dark gray, in fact nearly black, in color because the vegetable matter that it once contained has been charred or carbonized by the heat of the pahoehoe lava that flooded over it.

Immediately overlying the loess is a pahoehoe flow about three feet thick; on this there is an aa flow, also abou three feet thick; and at the surface there is about two feet of loess which is continuous with the layer of loess that is so extensive. Perhaps the two lava flows are of approximately the same age as the artificial bowlder pavement at Ka Lae for the thicknesses of both the overlying and the underlying loess deposits are about the same at both places.

The lower loess deposit is much weaker than the overlying pahoehoe flow and has therefore been cut back farther so that for a distance of about a hundred feet the pahoehoe overhangs as a ledge with an average width of two and half or three feet. Thus between 250 and 300 square feet are exposed, which give some clues as to the nature of the older loess at the time that the pahoehoe lava flooded over it. A rather cursory examination revealed over 30 molds of trunks and limbs of trees. Half a dozen of the molds are vertical and represent growths which the pahoehoe surrounded but did not destroy. The largest of these erect molds has an elliptical cross-section which is 10 by 12 inches at a level 12 inches above the former ground level. The tree that made the mold had a gently fluted trunk. The other erect molds are from one to four inches in diameter. The erect molds extend through the three feet of pahoehoe but are capped by the overlying aa. They imply, without doubt, the existence of half a dozen trees or saplings in the 250 or 300 square feet.

Prostrate molds greatly outnumber the erect molds, and represent either dead wood that was lying on the ground or stems and trunks that were knocked over by the advancing lava. They range in diameter from one to three inches. One prostrate mold is two inches in diameter and five and a half feet long. Since some of the prostrate molds may well be the relics of trees that were alive until they were pushed over by the advancing lava it seems probable that the 250 or 300 square feet bore more than the half dozen that are definitely implied by the erect molds. There must, therefore, have been a fairly thick cover of trees at this place. This conclusion is supported by the presence of much charred vegetable matter in the black loess immediately underlying, far more than could be produced by the charring of the turf that now grows in this region.

We can reconstruct the following events in the history of this small area southwest of Kaalualu. Soon after the eruption of the lower pahoehoe flow volcanic activity ceased temporarily and was succeeded by wind work which brought in 8 to 10 feet of loess. The loess formed a fertile soil in which a fair growth of trees took root. The climate must have been somewhat moister than it now is to permit the growth of good-sized trees. Short-lived volcanic activity followed, and made two thin lava flows, the first of pahoehoe and the second of aa. Since then there has been no volcanic activity at this particular place, and winds have brought in two feet more of loess which supports a fair growth of turf-making grass. At present, wind is adding slowly to the upper surface of the loess, and is also, with the help of waves, exposing the edges of the various rock layers as a low cliff.

I am indebted to Dr. Howard A Powers, of the Hawaiian Volcano Observatory, for much help in the field study on which this paper is based. It is in fact a question where he or I should have written it.

Harold S Palmer.

KILAUEA REPORT No. 1024

WEEK ENDING SEPTEMBER 6, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Halemaumau pit continues to remain quiet with about a dozen stained spots on the floor of 1930, one of these yellow with sulphur showing very slight bluish fume. Older spots are whitish and dead ones are brown. After rain vapor mixes with the fume and very light vapor appears at the south talus. Measurement of rim cracks August 31 showed no widening.

Three tremors at the pit seismograph about September 5 indicated slight tilt away from the pit. The Observatory seismographs on the northeast rim of Kilauea Crater registered 37 tremors, of which one was accompanied with east tilt and another lasted two minutes. Five very feeble local seisms were registered, of which three indicated origin only four miles away. Average tilting of the ground was slight SW, and microseismic motion was slight.



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No. 351—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | September 17, 1931



Newly acquired Engineering Building of the Hawaiian Volcano Observatory, standing back in the forest east of the Volcano House garage. Photo Maehara.

VOLCANOLOGIC OPERATIONS OF THE U. S. GEOLOGICAL SURVEY AND THE HAWAIIAN VOLCANO RESEARCH ASSOCIATION, 1930-1931

The Geological Survey covers stations at Hawaii, Lassen, Kodiak, and Dutch Harbor; the Research Association supplements the work at Kilauea with stations at Kona and Hilo. The eruption at Kilauea November 19 to December 7, 1930 added 70 feet of lava to the bottom of Halemaumau. Such eruptions have averaged one a year at Kilauea for six years. The flow from Mauna Loa in 1926 and the earthquake spasm of Hualalai in 1929 add to the evidence that the Hawaiian volcanic system is fully alive. Mauna Loa in the twentieth century has had an outbreak once in four years, so that there is reason to be prepared for live lava in Hawaii within the next year.

Lassen station reports declining tilt and earthquakes. In the Aleutian belt Pavlof, Aniakchak, and Tulik have been reported active. The circum-Pacific region has produced disastrous earthquake at Napier, Oaxaca, Managua, and in the Izu Peninsula near Yokohama, and volcanic disturbances in northwestern Argentina, not far from the south Chile volcanoes investigated by the Research Association through Dr. John B. Stone. All the disasters mentioned are close to active volcanoes.

Growth of the Section of Volcanology leads to division in subsections as follows, with T. A. Jaggar directing the work, the Kilauea laboratories of the Hawaiian Volcano Research Association serving as headquarters, and a somewhat increased staff appearing in 1931-32:

Volcanology of Hawaii

T. A. Jaggar, Volcanologist in Charge
- Observation of volcanoes
- Designing and building instruments
- Preparation of publications
- Administration

Seismology of Hawaii

E. G. Wingate. Associate Topographic Engineer, in Charge
- Correlation of leveling and tilt
- Drafting and research in maps of crater
- Recording Hilo tide data
- Special investigations of Mauna Loa
- Special topographic mapping wherever required

Seismologic routine

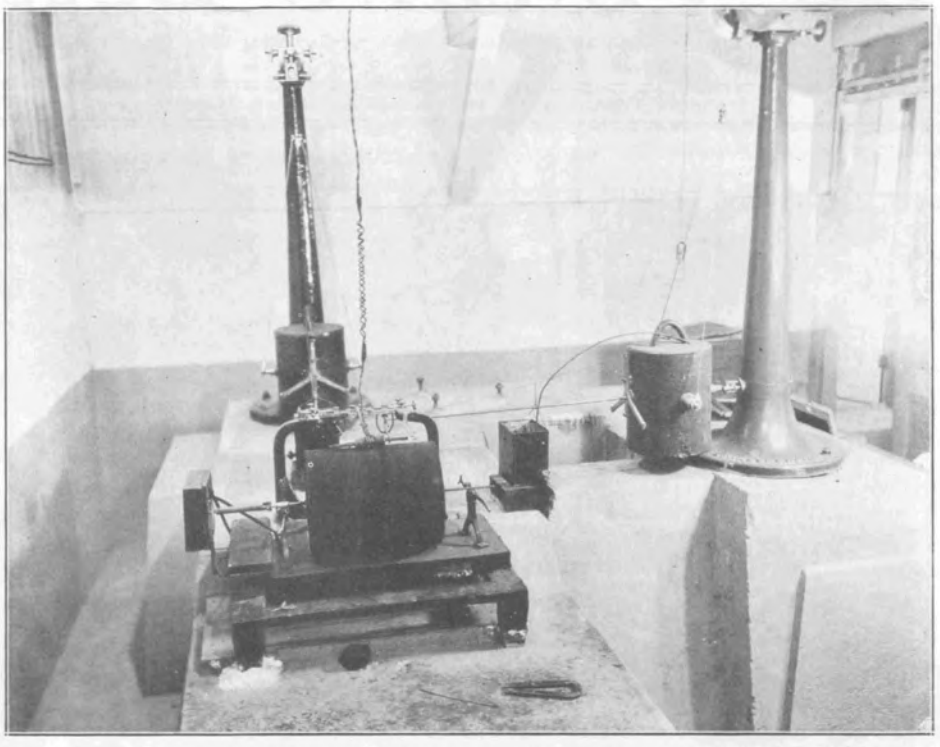
A. E. Jones, Assistant Seismologist, in Charge
- Operation of seismographs
- Measurement of seismograms
- Preparation of earthquake bulletins

Volcanologic Surveys of Hawaii

H. A. Powers, Assistant Geologist in Charge
- Field mapping of lava and ash formations
- Petrologic study of specimens and analyses

Volcanology of Northwestern United States and Alaska

R. H. Finch, Associate Volcanologist in Charge
- Operation of Lassen Volcano Observatory
- Operation of Alaska stations
- Investigation of northwestern volcanoes
- Installation of new seismometric stations



Bosch-Omori seismograph rebuilt at the Hawaiian Volcano Observatory with high-speed drum, damping tanks, both arms writing on a single smoked paper, and pen tips lifted by an electromagnet for marking minutes. This instrument has been most satisfactory for many years for registering tilt and local earthquakes in the cellar at Kilauea, and the records of this machine are the basis for new studies, of tilt, and depth and distances of earthquake origins. Photo Maehara

The Volcanologist has given a course in Volcanology at the summer sessions of the University of Hawaii for three years past, many of the students being teachers in schools in Hawaii. These persons will be useful volunteer seismologic observers. The Volcanologist represented the Geological Survey on the Naval Eclipse Expedition and studied the volcano Niuafoou in the autumn of 1930, leaving a shock-recorder there and supplying another to the Dominion Astronomer of New Zealand, Dr. C. E. Adams.

Messrs. Wingate and Jones joined the staff in July and September 1931. Dr. Powers has studied the shore line changes with Dr. Palmer, has mapped soils and loose deposits all over the island Hawaii, but especially in Kona in collaboration with Mr. J. C. Ripperton of the U. S. Agricultural Experiment Station, and has mapped in detail the lava flows and volcanic ash of the west slopes of Hualalai and Mauna Loa. As a petrologist he is studying these materials microscopically. This work of a geologist has in view extending our knowledge of the structure of Hawaii. (See Geology and Water Resources of Kau District, by Stearns, Clark and Meinzer, Water-supply Paper 616, 1930, U. S. G. S., and also Products and Structure of Kilauea, by J. B. Stone, Bishop Museum Bull. 33, 1926, Honolulu.)

The remaining members of the staff of the Hawaiian station are: R. B. Hodges, clerk and disbursing agent; Tai On Au, mechanic; H. Yasunaka. janitor; and M. F. Lacerdo, tide gauge operator at Hilo. R. V. Woods and J. B. Albert operate the seismographs at Kealakekua and Hilo.

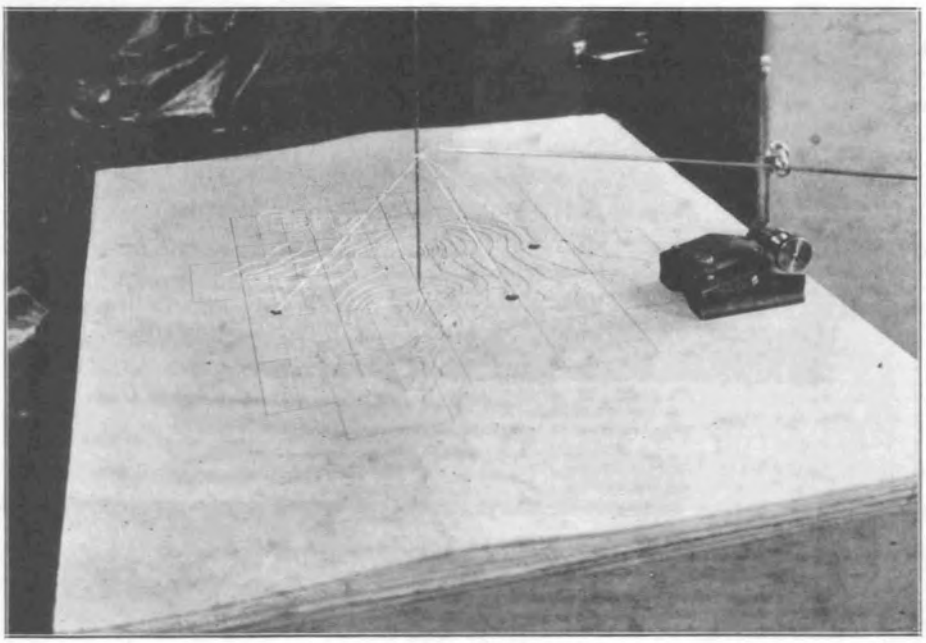
Associate Volcanologist Finch operates three seismograph stations near Lassen and with assistants studies the hot vents and the geology of old lava flows in northern California. The instrument at Mineral is operated throughout the year; those at Viola and Mount Harkness are discontinued in winter. Mr. Finch has spent the summer of 1931 inspecting the Aleutian seismograph stations, and making an exploration of Akutan Volcano and its hot crater. He left Kodiak for Seattle on September 6.

The study of local tilting of the ground in Hawaii, as correlated with faults, with earthquakes, and with volcanic centers of tumescence, has justified more men and instruments. One of the interesting developments has been the registration of "tilt earthquakes." These are seismograms of local earthquakes showing at several different instruments, not all at the same place, that the ground has tilted and offset the pens in the same direction, at the moment when the local shock occurred. In other words the creaking action of the motion of the fault block has been accompanied by a slight tipping. The direction of this tipping is a discovery of prime importance, and the coordination of many such tippings at the same place, occurring simultaneously with earthquakes, indicates the manner of action of the net tilt for a given period. It is obvious that to discover the geographic boundary of such tilting, distributed instruments are necessary, and these instruments should be simplified as much as possible so as to show graphically without computation the direction of the tilt, as well as its angular amount.

With this in view, an observation made several years ago with a small plumb line to which a vertical lever was attached was utilized in the spring of 1931 as basis for construction of a new tiltometer. The instrument was at first placed in a shallow well in concrete in the seismograph cellar of the Observatory, the device consisting of a heavy mass hung vertically on piano wires, with a magnifying boom rising vertically from the center of the mass so suspended and counterpoised that the faintest deviation of the mass as a plumb bob would be highly magnified at a pointer moving in a horizontal plane at the upper end of the sytem. This pointer is free to move in all directions in accordance with the absolute direction of tilt which disturbs the heavy mass as a plumb bob, and the linear amount of its motion radially from its adjusted center is a measure of the angle of tilt.

Another line of experimental investigation which was set in motion in January 1931 promises much for the location of earthquake centers. The determination of depth of origin for local earthquakes on the Island of Hawaii has puzzled us for many years. Mathematical methods of determining depth of origin for more distant or stronger earthquakes are in vogue in California and Japan, dependent on exact time-keeping. Omori used a simple method of determining distance by the preliminary tremor at several stations, and figuring the depth of centrum by the overlap of these distances beyond their point of intersection on a map. In other words, if the distances indicated are greater than their meeting point in plan, the origin is not in the horizontal plane, but is below the horizontal plane by the amount in which the distances are excessive. The determination of the meeting point of these lines underground, and the depth of that point below the local topography, is somewhat troublesome where a large number of earthquakes have to be investigated. The method, however. is good when the formulae for determining distance by the preliminary tremor have been checked for a given terrain.

In order to determine the depth of origin graphically by this method in Hawaii, a model was built showing the island as a hollow shell, as though the topography were seen from below. (See cut Page Three.) On this shell the several seismograph stations are accurately located and threads are carried through holes at these stations to weights hanging below. These several threads are drawn together at one point on an adjustable carrier which may be moved around until the lengths of the threads correspond to the centrum distances for a given earthquake indicated by the several seismographs. The threads are marked in miles to the scale of the model. A rod similarly marked may thus be placed against the meeting points of the threads, and this indicates vertically the depth of a given earthquake center. and the position of the epicenter, after the straight threads have been adjusted for any given earthquake. Thus the shell model (upside down) graphically exhibits the hollow space inside the island on a table, and the threads may be quickly adjusted to exhibit the point in space corresponding to the earthquake center, and their angles of emergence at the model should correspond to the angle of emergence of the earthquake wave. Tests with this model will show at once whether the several computed distances meet at a point or not, and so serve to check the theory of distance as applied to the preliminary tremor. Also the azimuth of the graphically determined center from each station may be checked against the theoretical azimuth determined



The inverse contour model of Hawaii, perforated to receive weighted threads at the spots marking seismograph stations The scriber shown has the three threads drawn together. By moving this junction point around until the three distances on the threads, on the scale of the model. correspond with the three distances to origin indicated by three seimograms for the same earthquake, the location of the centrum is determined graphically as though the observer were under the island. A brass scale rod as shown then determines the epicenter and the depth. The horizontal and vertical scales are identical in the model. Photo Maehara.

seismometrically. The preliminary trials of this graphic method for the same earthquake as registered in Kona, at Kilauea, and at Hilo have yielded promising results.

The third activity in our shops by way of seismometric experimentation has been the renewal of construction of shock-recorders as reported in 1929 in connection with the campaign of the Scientific American for enlisting amateurs in seismology, and in connection with assisting New Zealand in her earthquake difficulties. This last cooperation was given added zest by the terrible disaster at Napier in February 1931. after which the minister for scientific research, Dr. Marsden, of the New Zealand government, telegraphed to me asking for shock-recorders of my design. Through the Hawaiian Volcano Research Association, which furnished the materials, I at once set about new tests of an improved shock-recorder which registered several local earthquakes in our basement. The Research Association will supply the New Zealand government with eight of these instruments, and incidentally the Hawaiian Volcano Observatory will profit by this investigation, which is along the lines of what I did with similar instruments at Niuafoou in the South Seas on the Eclipse Expedition of 1930. Both in Alaska and in Hawaii it is becoming inceasingly evident that we need distribution of simple instruments, and in Hawaii there is a new demand through the school teachers who are distributed here, who have taken my course in Volcanology during three summers at the University of Hawaii.

The Research Association has added to the buildings of the Volcano Observatory the house shown on Page One, to be used for offices of the engineer and geologist. With this there is water supply and a garage. In addition a garage and carpenter shop have been rebuilt near the main observatory building.

A publication of interest to students of volcanology is Bulletin No. 77 of the National Research Council, "Physics of the Earth: I, Volcanology," Washington, 1931, by Day, Sapper, Friedlaender, and Jaggar. Dr. Day writes the Introduction; Dr. Sapper, "Volcanoes, their activity and their causes," covering the geographical aspects of the science particularly; Dr. Friedlaender, "The Present Condition and the future of Volcanology," reviews methods and theories; and Dr. Jaggar, "The mechanism of volcanoes," discusses experimental work, gas mechanism, and the relation of earthquakes to volcanic magma. There are long lists of references. T.A.J.

KILAUEA REPORT No. 1025

WEEK ENDING SEPTEMBER 13, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The bottom of Halemaumau pit shows nothing remarkable. Fume continues to emerge at a spot west of the 1930 lava pool. Vapor rises at the north end of the south talus and at the south wall above the floor. Dust rose from the pit at 9:20 a. m. September 7. The bottom fume smelled of sulphur at the southeast rim September 8. On this day new points were located at the rim cracks and an improved caliper was applied to these cracks. This work is in charge of E. G. Wingate, who has recently located datum stations near the pit for triangulation and leveling.

At the Observatory instruments 54 tremors were registered, but some of these may be occasioned by blasting by the road workers. One distant earthquake weakly recorded began at 10:18 a. m. September 9. One feeble local seism occurred at 5:19 p. m. September 12, was felt locally, and came from an origin close at hand. A very feeble shock was felt at 10:29 a. m. September 12. Four other very feeble seisms were registered, several showing easterly tilt, and two indicating origins very near. On September 7 nine tremors at the Halemaumau seismograph occurred in close succession, all indicating inward tilt toward the pit.

Tilt for the week at the Observatory was slight E, and microseismic motion was slight.



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The Volcano Letter

Two dollars per year **Ten cents per copy**

No. 352—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | September 24, 1931



A camp in the Aleutian lands showing country quite simi'ar to Akutan. (Captain Harbor, Natl. Geog. Exped. 1928)

ALEUTIAN EXPLORATION 1931

The increase in work permitted to the Section of Volcanology of the U. S. Geological Survey by Act of Congress in 1931, as shown in the organization outlined in Volcano Letter No. 351, is based in part on recognition of the importance of the Alaskan Peninsula and the Aleutian Islands. These are essentially a long interrupted line of volcanoes, many of them active, adjacent to the great Aleutian Deep where many major earthquakes occur. This is an extension of the series of Japanese and Kamchatkan volcanic arcs, and offers a most fruitful field of study, in which at present it is possible to do only the barest preliminary work, but this work should be done as a foundation for more systematic and detailed investigations in the future.

The Lassen Observatory will expand its work in the volcano areas of California and Oregon, and during each summer, field work is provided for, on one of the volcanoes of Alaska, combined with inspection of seismograph stations at Kodiak and Dutch Harbor. The volcano on Akutan Island was selected for exploration this year and Mr. R. H. Finch did the work, taking with him as guide and packer John Gardner of False Pass.

Akutan is the volcano, like Stromboli, which is often seen smoking by mariners, on the left of Unimak Pass as the ships for Nome pass through to Bering Sea. It is not far from the middle of the Aleutian arc, counting Iliamna as the easternmost volcano far up the Peninsula. The peaks of Akutan are 3170 and 4100 feet high. The island is 17 nautical miles long, and it lies next NE of Unalaska Island. As a volcano it is relatively accessible as compared with great snowy peaks like Shishaldin, it is close by Dutch Harbor, it possesses a village, a harbor and a whaling station, and close at hand is the hot sulphurous deposit of Akun Island. It is just north of the 54th parallel and in longitude 166° west.

Mr. Finch took the steamer "Catherine D.," thanks to the courtesy of the Pacific American Fisheries of Bellingham, leaving that port July 1, 1931. Arrived at King Cove, the seat of one of their salmon canneries, near the west end of Alaskan Peninsula, he embarked on the mail steamer "Starr" July 16, Gardner joined him at False Pass, and the two disembarked at Akutan July 17. Two ascents were made to the summit crater, and on the second the party was caught in a fog cloud, which is a serious matter in these mountains.

The ascent of July 24 proved very interesting and Mr.

Finch secured some good photographs. The crater is some two miles in diameter with a cone about 600 feet high near the center. "The cone is quite uniformly hot, though but little steam is escaping. The heat appears as a dry heat. The outer crater contains a lake in the southwest side. On one side of the lake there is ice, with small icebergs breaking off occasionally, while the temperature of the water on the other side averages 119° F., with small localities showing even higher temperatures, and there is boiling action."

"One vent in the central cone is still open. Rumbling was heard on August 11. Very recent lava flows occur in the crater."

Finch reports that he secured the services of Alec McGlassan, a resident of Auktan, to act as additional packer for a trip around the island on foot during the first week in August. Many photographs were obtained and most of the island was sketched topographically. A Jaggar shock-recorder was operated for ten days on Akutan, but on July 26 no earthquakes had been recorded so far.

Finch sailed on the "Starr" for Unalaska August 10th, inspected and overhauled the needs of the seismograph at Dutch Harbor, operated at the Naval Radio Station, then returned to Akutan on the "Victoria" August 16th. This gave him two days more to finish operations on Akutan, which island he left for the trip back to Kodiak on the "Starr" August 18th. He remained at Kodiak overhauling the seismograph there, in charge of Mrs. M. V. Watkinson, until September 5, when he sailed for Seattle on the Admiral Line steamer. His full report on the mapping of Akutan and the seismological work, with photographic illustrations, will be awaited with interest. T.A.J.

IMPROVED JAGGAR SHOCK-RECORDER

The photograph on Page Four shows a new form of the shock-recorder described first in the Scientific American, November, 1929. The original machine was set up horizontally, as though left side of picture were the bottom, a 10-pound lead cylinder being cast about two flat blades clamped in a vertical plane. This made a sensitive small horizontal pendulum hung like a door, with the blades as hinge, and a boom extending out from the weight has a brass pen pivotted at its outer end resting on a smoked cardboard disc. A common clock movement rotates the disc and moves itself along slowly so that a day's registration is like a gramophone record. The disc is changed every day, and fixed with shellac. The disc itself is a timepiece for subdivision into minutes.

This machine was of great service counting the hundreds of earthquakes that occurred near Hualalai in 1929. It was tested in the South Seas in 1930 and some models like it have been made in New Zealand. In Niuafoou I set up two complete weighted arms and clockworks at right angles to each other on the concrete floor of a warehouse. As each box was three feet long, this took much space. The object was to record separately east-west and north-south earthquake motion. There was also recorded the motion of rats, kittens, chickens, cockroaches and spiders, and these were not planned for. The apparatus must therefore be housed in a tight case, and tending such an extensive machine each day on the floor is laborious. Horizontal surfaces of the smoked cards are hard to examine and are tempting to insects.

An improvement in the machine, with the principle of action but slightly changed, is shown in the cuts. The cylindrical mass has its two flat hinge blades clamped horizontally below, the boom protrudes upward, and the recording disc is in a vertical plane like an ordinary clock. The pivotted pen on the top of the boom is arcuate and long, and may be tipped over against the smoked card at about 45 degrees to the disc surface. The blades are stiff enough to give the system a free period of nearly one second with only about one eighth inch of spring blades exposed between the lead cylinder and the clamps. At this period the inverted pendulum is stable and upright. If the exposed part of blades is shortened the period becomes shorter. This inverted pendulum system oscillates only in the azimuth at right angles to the hinge line, which was also true when the system was swung as a horizontal pendulum.

The advantages of the new system are that the clock can now roll along on pulleys on a rubber-shod track in the plane of the clock-work wheels. These pulleys are attached to the spring barrels and given a diameter appropriate to the travel-speed desired. The center sleeve of the disc plate slides on the minute-hand spindle, so that the card makes one revolution per hour. The whole apparatus is enclosed in an upright clock-case with glass front (not shown) and screwed against the wall. The boom is of balsa wood. The clock may be slid sideways on its tracks so as to move the disc under or away from the pen. When disc is removed the clock is wound, a new disc is smoked and screwed by a central button to the plate, and is slid back to the starting position under the pen. With a steel point the date and the time of starting and stopping are marked on the smoke. The card is smoked by twirling it over a smoking kerosene lamp until it is an even brown. The rear suspension of the clock is a free pulley on a second track. The pen and the top of the boom may be seen at the right in the cut on Page Three. A final advantage of this machine is that in the corner of a room two complete shock-recorders may be set up at right angles on the two walls, with their two dials side by side. Obviously the handling of the discs is easy, and almost no floor-space is required.

Several earthquakes have been registered and the seismograms are good. It is necessary to choose a very quiet cellar wall, as the instrument is extremely sensitive to the opening and closing of doors. T.A.J.

KILAUEA REPORT No. 1026

WEEK ENDING SEPTEMBER 20, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

There are no essential changes in the bottom of Halemaumau pit. There is a little fume on the floor and vapor at the edges of the floor, and these increase in visibility after rain. Measurement of the rim cracks shows little change.

The seismographs at the Observatory registered 43 counted tremors, of which three were continuous, and one of these spells lasted from 6:33 to 7:50 p. m. September 20. There were many smaller tremors September 18.

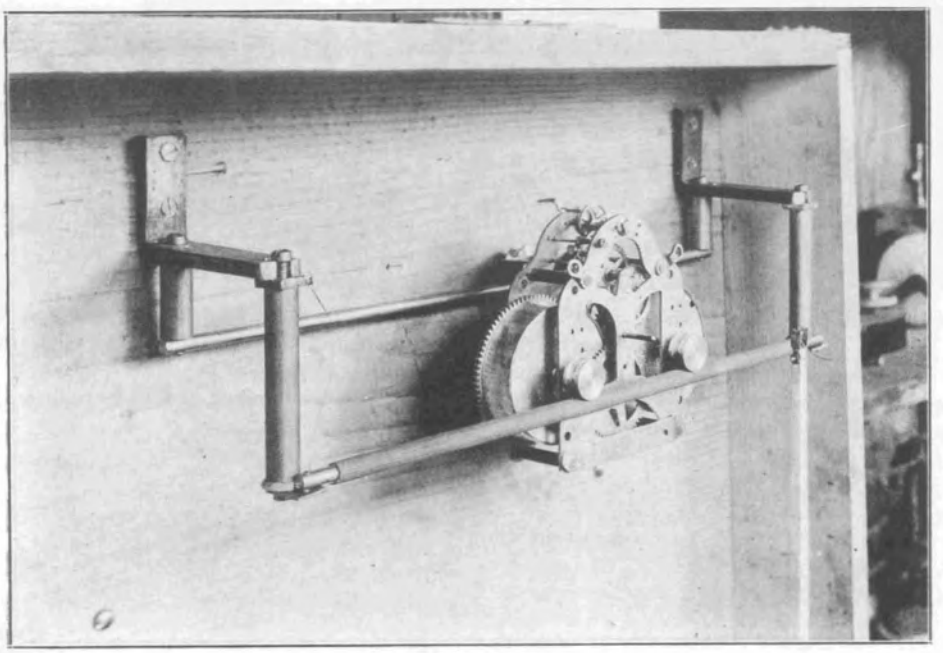
Two feeble earthquakes were felt at Kilauea at 4:23 a m. September 18 and 6:14 a. m. September 19. These indicated origin distances of six and four miles from the Observatory. The first was accompanied by tilt away from the pit at Halemaumau. Neither was observed in Kona,

and the indications suggested Kilauea origins. There was one very feeble quake September 14. Tilt for the week was slight NE, and microseismic motion was slight.

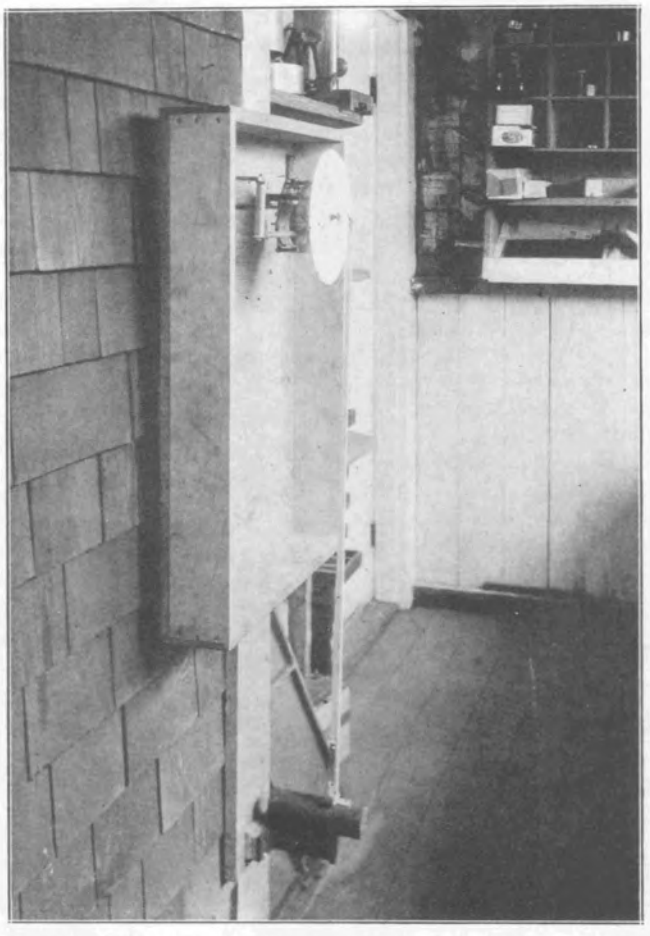
TILTING OF THE GROUND FOR AUGUST

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

August 3 - 9 .....1.3 seconds NE
August 10-16 .....0.4 second W
August 17-23 .....1.4 seconds NNE
August 24-30 .....1.0 second WSW



Seth Thomas clock on tracks with Jaggar shock-recorder boom and pen on right. A card disc is affixed to the central spindle, and the pen falls over on its smoked surface recording time and size of earthquakes. Photo Maehara.



New model Jaggar shock-recorder without case. Cylindrical weight below attached by flat springs to angle-iron clamps on wall. Boom and pen rise from weight, to write on revolving disc above. Clock and disc move along slowly so as to write circle in circle like a gramophone. An earth shock writes a zig-zag, and the clock disc times the occurrence.

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No. 353—Weekly Hawaiian Volcano Observatory, National Park, Hawaii October 1, 1931



Gorely Volcano seen smoking during its eruption January 1, 1931. View from Petropavlovsk, 67 km. from the volcano. The summit of Gorely is behind the range, and the conspicuous cone is Vilutchinsky, which is nearer. Photo I. Larin.

KAMCHATKA VOLCANOES IN 1931

Professor P. T. Novograblenof, Director of the Kamchatka Museum at Petropavlovsk, under date June 24, 1931, has kindly sent us the accompanying photographs and a description of volcanic activities in Kamchatka during the winter and spring. This material is of great value as hitherto the world of science has heard but rarely from this great volcanic region. In Volcano Letter No. 314 it was noted that the Academy of Sciences of U. S. S. R. is doing volcanological work in Kamchatka. Also the eruption of Gorely Volcano was mentioned, lasting from September 1929 to March 1930 and covering much of southern Kamchatka with ash. Also there was activity of Kluchevskaya and Shiveluch in 1929 and 1930. An excellent account of travels in Kamchatka, 1920-22, with two valuable maps and numerous photographic illustrations has been published in German by Sten Bergman entitled, "Volcanoes, Bears, and Nomads" (Strecker and Schroeder, Stuttgart, 1926).

The active volcanoes of Kamchatka extend NNE-SSW along the eastern side of the peninsula, and near the middle of the belt is Kluchevskaya in the midst of a mighty group of volcanoes rising to a height of 4,861 meters. About 60 km. to the south lies Tolbachinsky Volcano. Petropavlovsk, the capital, with a population of something over a thousand people, is on the north side of a bay in the southeastern part of the country, and across the bay from it to the southwest the southern end of Kamchatka is occupied by a belt of great volcanoes, and this is prolonged farther south in the arc of the Kurile Islands. Several of these big cones are in full view from Petropavlovsk, the most conspicuous being the pure cone of Vilutchinsky Volcano shown in the photographs. The white steam from Mutnovsky shown in the photograph on Page Three is about 66 km. from Petropavlovsk, where the picture was taken.

The following is an account by Bergman of his visit to Mutnovsky Volcano:

"On this day we reached an elevation of a thousand meters on the volcano which is here surrounded by a lava plateau which extends as a shoulder around the greater part of the volcanic mass. Here we were at the upper limit of vegetation, where the last scrubby alder thickets gave out. The crater of Mutnovsky lay on the other side of the cone, and we had now to follow this shoulder around the mountain until we were immediately under the crater.

"Toward evening a mischance that we had most feared occurred: the weather which during the day had been misty, closed in dense and it began to rain. Impenetrable clouds veiled the entire mountain. We were in a waste of lava, where there was not a stick of wood, and where it would not do to be overtaken by night. So we climbed down through rain and fog to the upper limit of the bushes and found after a long search a small thicket where we succeeded in pitching our tent, and after much labor ignited a fire. Since, however, our silk portable tent was not adapted for plateau rains, particularly where there was no opportunity to draw the surfaces tight, we were soon as wet as though we had been immersed in a lake with our

clothes on. In order to give the drops of rain as little chance to accumulate as possible, we sat huddled together surrounded by our sleeping bags and rain coats throughout the entire night, and had abundant time to repent us of our sins. I thought of my warm bed at home in Sweden, and during the long hours of this sleepless night had opportunity to appreciate how little we realize our blessings.

"Not until morning did the rain cease, but the fog still hung over the mountain, though not so low as on the preceding day. We saw nothing of the volcano, but the plateau shoulder of lava was free from cloud. We were about an hour getting a fire to going so that with its help and numerous cups of tea we acquired some warmth inside and out. We were not afraid of catching cold for we had long since proved that we were quite immune to such disease in that fine air free from bacteria. If it were not so it seems probable we would never have gone home to Sweden.

"After ridding ourselves of our wet clothes and donning from the packsacks some relatively dry ones, we were ready for the march. The weather cleared and a fresh breeze sprang up so that after some hours our outer clothing became perfectly dry.

"We had not proceeded far before the first bear appeared and I attempted to photograph him. He headed straight for us. Taking advantage of the unevennesses of the ground and crouching down, I succeeded in getting within 20 meters of him and made an exposure with my camera in one hand and the rifle in the other. As soon as I snapped the shutter the bear saw me and made off. Above the bushes the snow-buntings appeared, fluttering about and showing up sharply and beautifully in contrast to the black lava. We gave the day to studies of birds and enlarged our acquaintance wth them as compared with another volcano previously visited. The birds of the two volcanoes were strikingly alike.

"Just as on the previous evening we pitched our tent in the uppermost alder bushes, but we had made good headway toward the crater after this day of trudging across the treacherous lava waste. On the following mornng it was still cloudy, but the volcano was clear. We could have no question about the position of the crater, whence rose a frightful column of smoke. We headed for the crater at once, which was about 500 meters above our camp ground and 3 to 4 km. away. The sun came out during our climb and showed us a completely new and magnificent landscape, which had been hidden from us during the days of fog and rain.

"The nearer we came to the crater the more noticeable was the smell of sulphur, so that finally breathing was difficult, and made us all cough, including our little dog Kuma. In places fume came out of cracks in the ground which was so porous that it seemed as though we might break through and burrough underground like a sand crab. The extraordinary colors of the ground varied from sulphur yellow to deep red. At last we stood on the rim of the gigantic crater, the smoke of which we had so often seen from the window of our house in Petropavlovsk. The crater is not quite at the summit of the volcano, so that we could climb still farther and from above look down obliquely at the colossal spectacle; a frightful cauldron of boiling vapor. From this lava pinnacle we were able to see still more: adjacent to the smoking crater there was a still larger abyss where far below we saw a glacier and a small waterfall. These were several hundred meters down, and the cliff above them was almost vertical. Then the fog closed in on us and it was with great difficulty that we made our way back to the vegetation line."

Mr. Eric Hulten, botanist of the expedition, on another trip after waiting for many days for clouds and rain to cease, succeeding in reaching the crater with his party and in getting a better view of Mutnovsky and its outlook. The smoking crater lies on the west rim of a large cauldron, and the party followed a small ridge on which stands a number of knobs. From the highest of these the clouds were seen rolling in from the sea, and the volcanoes were beginning to don their cloud caps.

"It was a wild and wonderful panorama. Not less then 14 big volcanoes were in sight, from Schupanowa, ten miles north from Petropavlovsk, down to Kambolnaja, the southernmost volcano of Kamchatka. For a time the smoke of the crater blew directly over us, and a fine dust rain fell consisting of milky drops, which made small white spots on our clothing, presumably sulphur.

"As the wind veered and the smoke went in another direction we obtained a view that I shall never forget. It was as though we were permitted a glimpse of the workshop of the gods, where gigantic forces are at work such as began millions and millions of years ago when the first strokes of creation fashioned the earth. White jets of steam shot whistling and blustering out from holes in the cliff, hot water ran down from the walls and melted its way through a glacier whose sharp-edged broken green and crevassed blocks of ice were heaped together in a jumble at the mouth of a huge canyon that led away from this Hell cauldron. In the midst of the ice two mighty steam jets arose, and through the crooked tunnels that had been melted out of the ice one could see the bedrock of the mountain. Higher up the cauldron wall where its edge stood several hundred meters above the glacier the younger crater belched its smoke upward, as though a thousand locomotives were clustered together opening their safety valves—and yet we knew that this was but a weak imitation of what Mutnovsky once was.

"And how describe the cliffs themselves? They had not the common gray color of a mountain, but were painted over in fantastic shades. We sat on a minor cliff of bright colors which gave place below to a terra cotta precipice, and showed on the right a row of sharp pointed gray-blue pyramids which stood on an underpinning of white spotted with baked dark carmine and indigo blue points. Beyond the wall of the kettle was bright blue with big yellow areas of pure sulphur, which were bordered with green and orange rings. All of this, along with the gray-white rifted snow covering of the glacier, on which diamond shaped small black pyramids were strewn, and also the sharp green-blue ice pinnacles, left us with a memory never to be forgotten. Bornachoff, one of our companions, who had never known fear, became suddenly very anxious and careful, and it was with difficulty that I persuaded him to follow us down the yellow-white cliffs of the gorge. Possibly there awakened in him a trace of the terror his ancesters felt for the 'smoking mountains' that one dared not approach too near, lest the 'Gamuli,' the mountain spirits, might be cooking their whales, which nighttimes they go down and fetch up out of the sea, one on each finger, and flying bear them home.

"The stream pouring out below was buried under snow and ice blocks, and we reached the tunnels and got under the upright walls which lead down into the crater, out of the rifts of which small and furious jets of steam escape. There rose a thin knife-edged slice of rock out of the ice, from the walls and base of which hundreds of steam jets shot up. Warm water ran down carrying red-brown mud, and a grayish-yellow brook broke its way through the ice, the melted green walls of which could be seen transparent behind the vapor. The jets of steam so hissed and roared that it was necessary to shout in order to be heard. In such an environment one may believe anything, and none of us would have been astonished to look up and see an ancient mountain spirit of the Kamchadals sitting astride one of these cliffs holding out a whale on a spit wherewith to cook it in a steam jet.

"This devil's canyon under the glacier was near the summit. The veil of smoke hid whatever the crater might conceal in its depths, but there was no lava lake nor in-

candescence, but rather numerous holes some hundreds of decimeters across as sources of jets of steam."

1931 ACTIVITES

During the winter three big volcanoes, Tolbachinsky, Kluchevskaya, and Gorely, were in activity, all situated on the eastern shore of the peninsula.

Tolbachinsky, elevation 3730 m., had a magmatic explosion March 4, 1931. Its cone and the vicinity were covered with ash. In the village Tolbachik, 41 km. from the volcano, the ash was a few milimeters thick.

Kluchevskaya, elevation 4861 m., had a severe eruption on March 25, 26, and 27, 1931. All day March 25 this beautiful volcano was quiet, but after sunset in the village Kluchi, 32 km. from the crater, was heard a crash, and then a column of fire appeared upon the summit. The rumbling increased in successive periods of noise, and during the night the volcano thundered and several loud explosions were heard. In Kluchi next morning ash fell and the air darkened. The volcanic ash and sand were falling during three days. All traveling by dog sledge became impossible. The strip of country covered with ash on top of the snow was 240 km. long and 50 km. wide; the average depth of the ash was 1 cm.; therefore during this short eruption Kluchevskaya threw out approximately 120 million cubic meters of ash on the northern side only.

Professor Novograblenof describes the ash as consisting of freshly broken pieces of different sizes, a small portion of them appearing rounded as though melted. There are pieces of lava glass and pumice and fragments of the minerals pyroxene, magnetite, plagioclase, and colored undetermined substances.

Gorely Volcano, elevation 1831 m., has continued in activity since 1929. In the summer of 1930 it was more or less quiet, but in the autumn its eruptions were renewed. For example, on September 30, 1930, it threw out clouds of vapor and ash in large quantity. The dark blue masses of ash fell in South Kamchatka over a vast area. January 1, 1931, the column of gases and ash over the summit of Gorely was more than 5,000 meters high. The eruption lasted until January 17, when the column was 6,000 meters high. The volcano smoked like a battleship (cut Page One). The smoke extended toward the northeast for a distance of more than 90 km. (cut Page Three). There was some reflection of fire seen on the summit. When the atmospheric pressure was very low the activity increased.

Mr. V. S. Kulakof, geologist of the Kamchtka volcanological expedition under Professor A. N. Zavaritsky, visited Gorely in May. He states that on the summit there are five and possibly six craters. Only one of these, 250 m. in diameter, is in activity, and no lava flows poured from this last eruption. Bombs, lapilli, sand and ash fell. Ash was falling mixed with snow. One hundred meters from the edge of an eruptive crater a thermometer thrust into ash showed -2° C. Under the ash there were layers of snow. The bottom of the crater could not be seen owing to the clouds of fume rising from the chasm. We are greatly indebted to Professor Novograblenof for this information. T.A.J.

KILAUEA REPORT No. 1027

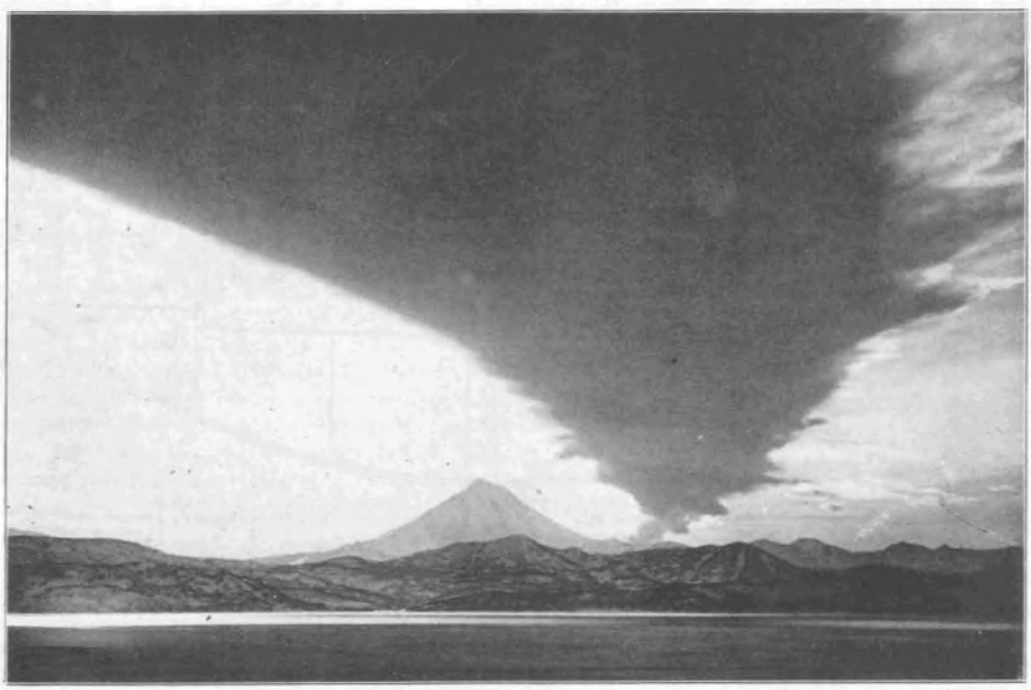
WEEK ENDING SEPTEMBER 27, 1931

Section of Volcanology, U. S. Geological Survey

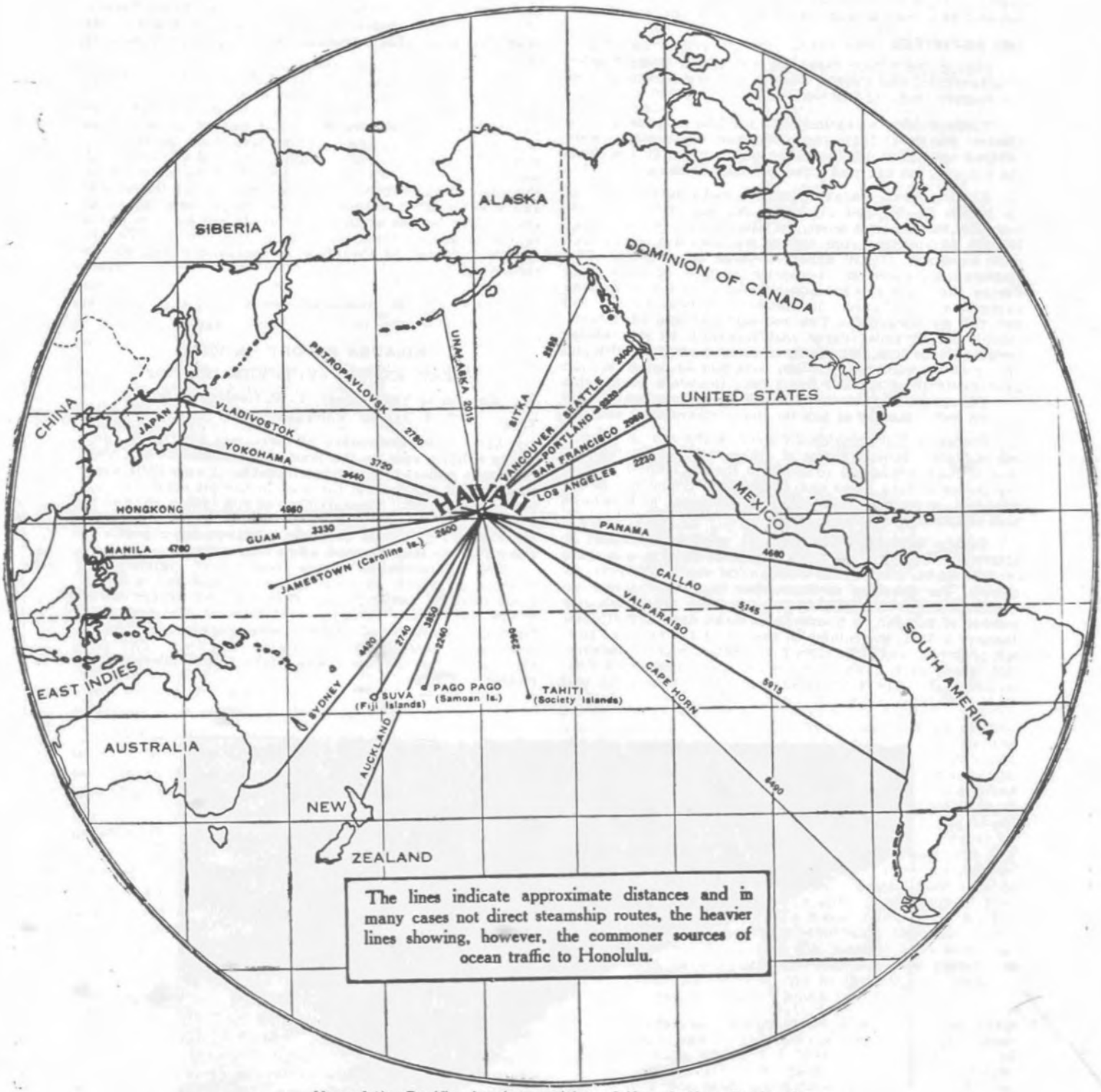
T. A. Jaggar, Volcanologist in Charge

At 10 a. m. September 21 there was very little fume at the sulphur spot on the floor of Halemaumau and what there was appeared to emerge in puffs. A very little vapor came out of the rock of the wall of the pit southeast just above the bottom. Measurement of rim cracks showed no widening. There have been no other changes during the week. Surveys are in progress to determine a profile of the pit which may be used when lava returns.

The seismographs at the Observatory registered 26 tremors, of which one was prolonged, and two were accompanied by easterly tilt. One doubtful distant earthquake was weakly recorded at 3:15 a. m. September 21. Four very feeble local seisms were registered, showing tendency to easterly tilt and origins very near. Tilting of the ground for the week was slight E and microseismic motion was slight.



Heavy column of smoke from Gorely Volcano as seen from Petropavlovsk 67 km. away, January 17, 1931. The white steam on the left is from Mutnovsky Volcano in the background, the sharp cone in the middle is Vilutchinsky, and Gorely is on the right. Photo I. Larin.



Map of the Pacific showing position of Kamchatkan Peninsula.

THE VOLCANO LETTER

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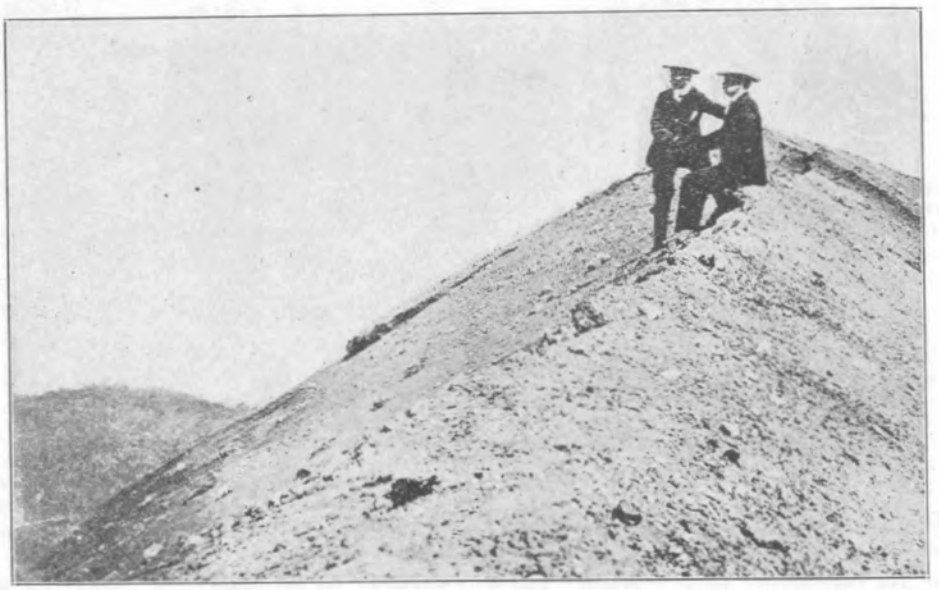
No. 354—Weekly Hawaiian Volcano Observatory, National Park, Hawaii October 8, 1931



Steep summit between the craters of Turrialba Volcano, Costa Rica.

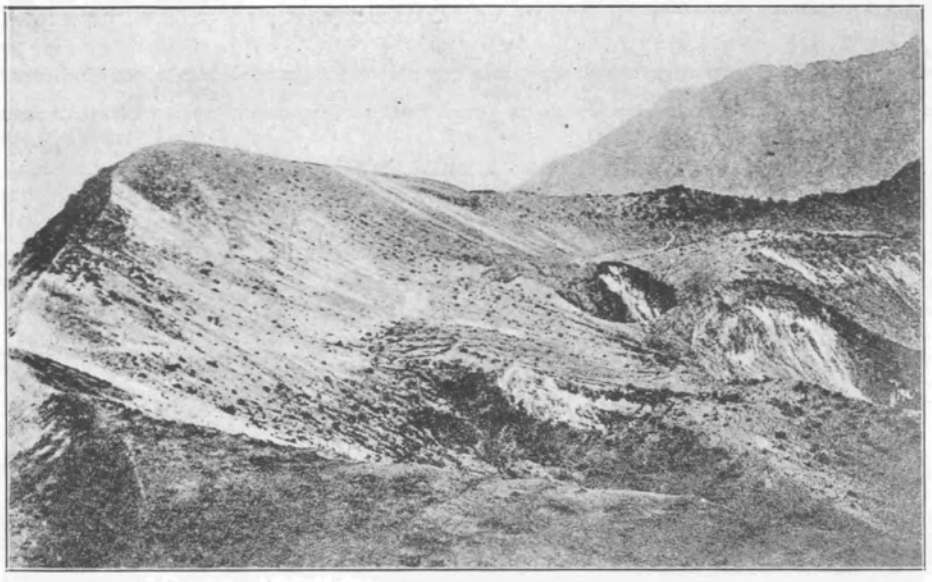
ACTIVE VOLCANOES OF COSTA RICA

Pittier describes the mountains of Costa Rica as divided into a southeastern system of old eruptive rocks without volcanoes, and one peak reaching an elevation of 12,467 feet; and a northwestern system with active craters. This chain of volcanoes begins with the conical peak of Turrialba, rising in an uninterrupted slope from the Santa Clara plains to a height of 10,965 feet. Going west from Turrialba we pass Irazu, Barba and Poas volcanoes, and from there northwestward the range diminishes in height past the less conspicuous volcanoes Tenorio, Miravalles, La Vieja, and Orosi, when we reach the Nicaraguan boundary (Costa Rica, Vulcan's smithy, by H. Pittier, Nat. Geog. Mag. June 1910).

Dr. Jaggar visited Costa Rica in the early summer of 1910 in order to study the effects of the terrible earthquake of May 4, 1910, at Cartago. He visited the craters of Irazu and Poas. President Jimenez kindly furnished the following account of a visit to the crater of Turrialba in 1864. The account states that at that time Poas, Barba, and Irazu were "not altogether dead," but Turrialba was in complete activity, and had been so for many years, sending out thick and high columns of smoke mixed with plenty of sulphur so as to destroy the vegetation on the slope of the mountain. Large deposits of sulphur of great purity were said to exist on the northeast side.

The biggest craters, more than 300 feet deep, showed black and yellow walls leading into the dèpths where more than a hundred mouths five to six feet in diameter, fringed with yellow layers of sulphur were hissing and sending up vapor with a noise like steam boilers. The roar of the steam was terrifying especially on the east and west corners of the crater where two larger vents sent up excessive vapor with a rush. All of the vents together made a large column of fume at the lip of the crater over 90 yards in circumference, and this made a high column above the mountain in calm weather as seen from the town of Heredia. The vapor was said to increase in winter time after heavy rain. There is an eastern extinct crater adjacent to the active one, and yet a third to the northeast where water collects in winter time. Between the three craters are three sharp ridges meeting in peaks of which th northern and eastern are the steeper. (See cut Page One). The circumference of the crater region is about 1,800 yards. Its shape is somewhat elliptical and irregular. Its inside walls are nearly vertical, covered in places with yellow layers of sulphur, and on account of the noxious fumes and the loose ground the descent is dangerous, and to return might perhaps be impossible. The outer wall of the crater to the west is peculiarly dangerous to walk upon; wherever one digs with a stick a small smoking chimney is created with deposits of sulphur and other salts, and in a short time the heat rising from the hole so made is excessive. The ground on the plateau about the summit is covered with lava fragments, sand, clinker, sulphur, and various salts, and there is little vegetation except to the south where the ground is not reached by fume. Here there are dwarf scrub and creeping plants. The walls show layers of rock of many different colors exhibiting the structure of the mountain, and there is sign of lava flows toward the north, where also the greatest devastation has been brought by fallen materials.

Pittier (1910) describes Turrialba as having a beautiful crater, forming a narrow elongated basin, in constant activity through the ejection of sulphurous vapors mixed with sand seen escaping noisily during recent years from the broad vent at its westernmost extremity. The only known violent eruption of Turrialba occurred in 1869 when



Crater of Irazu Volcano, showing part of cup and inner pits.

it threw out much explosive material and fine sand carried by the trade winds far to the west.

Irazu is about 360 feet higher than Turrialba, and a portion of its open crater, containing several interior pits, is shown on Page Two. The following is from my journal of 1910, when we started for the summit from a beautiful dairy ranch in the forest high on the mountain flank:

On June 3 we were up before the dawn, our hostess served coffee, and accompanied by a guide we mounted our beasts and entered a steep winding woodland path. Mr. Alfaro pointed out a rather large quick-flying bird which gave a plaintive whistling call: it was that rara avis the Quetzal which in Guatemala is regraded as the national bird. We passed from the tree line to a zone of shrubs and here the glorious summit view burst upon us, the Caribbean Sea far to the east and a dark Pacific loom under the clouds to the west. We were standing on one of the dividing peaks of the Central American watershed and viewing both oceans at once! Below us stretched the fair and fertile plains of Paraiso, Cartago, and San José, too far away to show any sign of the recent tragedy. Beyond to the south were the calm, dark mountains, as still, silent, and emblematic of **terra firma** as though earthquakes had never been. More tumultuous were the moving clouds, especially over the Pacific where they caught the high roseate lights and dark shadows of the dawn. Looking eastward towards Limon the rising sun made a trail of tropical glory along dim misty waters and pale pearl-gray clouds below, the foothills piercing the clouds like islets in a billowy sea.

As geologist I noted the much greater fall of the eastern streams, such as the Raventazon, as contrasted with the extended gently falling drainage of the broad valley to the west occupied by San Jose, San Domingo, Heredia, and Alajuela and other towns. The Raventazon shows a gorge just east of Paraiso and it is clear that if any massive uplift of this country is going on which causes the drainage to cut deeper, the maximum uplift is on the eastern side of the country. If the movement is a tilt, then it is a tilt **up** on the east, down to the west. This agrees with the appearance of elevated coral shelves and forelands in British Honduras and at Limon in Costa Rica, in that such raised oceanic formations give evidence of elevation on the east cost. And the west coast shows drowned valleys.

As one looks down from the summit of Irazu on Cartago and Paraiso, these towns appear to lie on an intramontane plain, and all about them are the evenly rectangular tilled fields of a fertile agricultural land. They are really on the pediment of the volcano, where the outwash from the gulches has built fan-cones of soil and bowlders onto the floor of a broad valley which originally drained **westward**; ie., towards San Jose and the Pacific. The evidence of this change of drainage is shown by a barbed stream beyond (S. E. of) Paraiso, in a deep gorge which now joins the Raventazon at an acute angle headwards, whereas its original junction with a normal west-flowing drainage was at an acute angle mouthwards. In other words, the Raventazon and its tributaries has robbed the waters of formerly west-flowing rivers and thereby has forced the continental divide to shift from a former position east of Paraiso to a present position west of Cartago. Cartago is thus practically on the continental divide, in territory where the divide is, so to speak, disputed by a conquering eastern drainage, which is cutting deep canyons, and a conquered western drainage which has lost volume and is losing rapidly its basin lands. This physiographic change may have significance as one of the many causes which serve as trigger to the earth stresses which make the earthquakes.

Continuing our climb, now in the bushy zone of the high summit, we came to bare patches of soft black cinder with new fractures in the earth. These fractures were marked by rows of caving holes—in one place two feet wide and another six feet wide and the rows trending WNW. Such cracks are not unusual in the crater region of a volcano and these in Irazu are not necessarily the product of the recent earthquake disturbance. The WNW trend is about parallel to the main fissure system which must underlie the chain of volcanoes of which Irazu is a part.

The summit of Irazu was soon reached. This is on the

south side of the crater and is merely the highest point of its rim. The crater north of us, as we stood on the peak in an uncomfortably stiff breeze, appeared to be an irregular drainless depression over a mile wide with two broad shelves of lava within it, one over the other like steps, on the side toward us, and a quantity of irregular deep pits in the opposite or northern side of the hollow. The effect is as though the whole cauldron had once been filled with lava to the level of the highest step; the lava seems thereafter to have hardened and tumbled in on the north and amid the tumbled blocks new explosion craters were formed at different times, making the several roundish or elliptical pits. The lower step would by this explanation be a piece of the frozen lava lake which had slipped down toward the convulsed northern half of the bowl. On the east there is the largest of the pits, which reaches almost the dignity of a subordinate crater. The northern rim is very low, and the northern side of the mountain is profoundly eroded in deep, steep furrows by the headwater branches of a muddy river, known as the Rio Sucio, by reason of its turbid waters This river is undoubtedly the main drain of the crater by underground channels. The crater had some shrubby and herbaceous vegetation. There is nothing immediately suggestive of recent activity or earthquake slides. The ground on the crater rim is covered with angular fragments of andesite and blackish gravel. The walls of the steps and of some of the pits show bedded sections of lava, hard rock, while the "treads" of the step-like terraces have "playas," dried mud ponds, on their surfaces. There are seven or eight pits, mostly choked at the bottom visibly by slide-rock, but one or two extend below into black holes which continue indefinitely. There is a shallow pond of milky water in one of the pits.

To the east rises Turrialba, a beautiful flat-topped cone, said by those who live on its flanks to be the theater of hollow murmurings from the bowels of the earth. These "retombos," or terrestrial grumblings, we heard described by all our friends resident in the vicinity of San Jose, and the residents had become so sensitive to these noises that they heard them constantly even during the time of our stay. We never succeeded in hearing them, or if we heard them, in distinguishing them from thunder, which we heard nearly every afternoon. We were also unfortunate in being unable to perceive any of the aftershocks of the earthquake, though they were felt by others and instrumentally recorded at the observatory.

At the headwaters of the Rio Sucio on the north side of Irazu there are bare brown landslide surfaces occasioned by the tropical rains and the steep slopes. The river has cut a canyon with vertical walls a short distance below the summit cone. A tributary waterfall cascades over the eastern cliff of this gorge. Just below the north rim of the outside surface of the mountain, and on the flanks of one of the gulleys that lead into the Sucio, there is a patch of bare sulphur-covered rock extending 200 yards down the mointainside. Mr. Alfaro informed us that the solfataric activity which generated this patch began about 1888 and that the sulphur, which may be removed in fairly thick cakes, is deposited from gases which emerge from pores of the rock. We saw no hot water or visible vapor, but recent photographs and records by other observers indicate that solfataric steam is ejected from time to time.

Some days later we took horses from the village of San Pedro for the ascent of Poas Volcano. Through country lanes we climbed, with the volcano ahead appearing as a mass of densely wooded hillocks. We entered the jungle by way of a narrow path over muddy hillslopes and muddier tangles of enormous roots. We frequently had to dismount and whip up the animals ahead of us. This jungle was remarkably different from the open groves of Irazu. There are here great trees with hanging vines, aerial parasitic flowers, some orchids, immense horn flowers and ferns, and all kinds of dense, shrubby undergrowth. We came upon a jaguar trap, and the guide told us that two of these cats had been caught in it. It consisted of a rectangular pen made by driving heavy sticks into the ground and roofing them with logs. A freshly killed fowl was placed as bait inside the pen, and provision was made for a heavy shutter to fall and close the opening when the bait was touched. Twice during the ascent we came to open meadows surrounded by elevated land which are possibly old craters. We passed wild cattle. Finally we dismounted and entered



Lake of steaming water, usually in effervescence, in crater of Poas Volcano. Photo Jaggar 1910.

upon the last stage of the journey on foot. The jungle thinned somewhat to a scrubby growth probably determined by occasional ashfall from the volcano. Poas is much lower than Irazu, its elevation approximately 8,000 feet. Bushes became open with a gravely soil between them, and then we came out on the edge of the greater crater at first obscured by clouds. We could smell sulphurous acid.

After a visit to a higher cold lagoon which fills a subsidiary crater, we returned to the edge of the greater crater and found it free from cloud. It proved to be a big cauldron filled with whitish water in constant ebullition, and bordered by bare, low banks of clay and bowlders radially trenched by hundreds of rain rills. The upper lip appeared to be half a mile in diameter; the depth from the rim to the water surface was perhaps 800 feet, and the distance across the pool 1,500 feet. On the north side of the crater a hill appeared. somewhat higher than the one we were on (see cut Page Three). Toward the west from the water-filled basin there is an irregular tract of "bad lands" drained westward by a gulch which shows a bedded section of agglomerates and tuffs towards its head. This gulch does not drain the boiling pool at the present level of the water, though it would do so if that level were raised a very few feet. There was evidently much relatively new sand and dust and gravel from the eruption of January 25, 1910.

The water in the muddy pool was bubbling up chiefly at one spot near the eastern side of the pool. It rose in a small dome of ebullition from time to time. There were sheets and tails of vapor rising from all over the surface of the water and the color was a pearly gray. The water appeared to be hot but not boiling hot, and the ebullition appeared to be the escape of vapors from a vent below. The eruptions of Poas are described by Pittier as geyser eruptions, and the column of steam and water, when a big jet occurs, is said to reach heights of thousands of feet, and to constitute the greatest geyser in the world. It is doubtful whether such eruptions may be described as a true geyser, for this volcano throws out bombs, ash, and mud, and the gases which rush upward through the water are highly sulphurous, and probably are not steam in the sense of being occasioned by the boiling of this same water column. It appears to be merely a case of a volcanic eruption making its way through a crater lake. In the bigger eruptions the lake is probably discharged completely. Such was the eruption of January 25, 1910, when stones fell on the edge of the crater, and the finer dust fell at San Jose, 20 miles to the southeast. Pittier states that the water of the crater lake "tastes like strong vinegar."

There was good evidence of the recent eruption on the rim of the crater. Lumps of gray ash, clotted by rains into the appearance of portland cement, were to be seen under the bushes where they had gathered in the branches and fallen off to the ground beneath. There were pumiceous bombs, large blocks of rock, which had fallen from great heights into the soft earth of the hillside. They had punched holes in the ground and buried themselves. We dug up several of these, in size from a few inches to two feet in diameter; one was found buried 38 inches below the surface of the ground. There were many stones coated with sulphur.

Pittier describes the eruption in question as follows: "At 5 p. m. January 25 a smoke-like column rose from Poas to prodigious height, estimated at no less than 13,000 feet. After reaching its higher point, the column spread into a mushroom-shaped grayish cloud, which, carried by the trade winds, soon covered like an immense screen the whole valley of San José."

"An hour after the first indication of eruption a rain of ash began to fall, increasing in coarseness as well as in quantity as the eruption proceeded.

"Near the crater volcanic mud was mixed with stones and the latter broke thick limbs and roots of trees and penetrated deep into the ground. When visited after the eruption, the boiling of the crater lake had ceased.

"This eruption was followed on April 13 by a serious earthquake over all the central plateau of Costa Rica, just after midnight. Everyone ran into the streets. There were numerous shocks the next day, and several public buldings were badly wrecked. Ground was rent and fissured in the neighborhood of Cartago. On May 4, at 6:50 p. m., came the terriffic jolt from the east which wrecked the city of Cartago, just at the foot of Irazu Volcano. This was one of the most intense earthquakes of modern times." (See Jaggar and Spofford, Costa Rica earthquakes, Jour. Assoc. Eng. Socs. 46, No. 2, (Feb. 1911). T.A.J.

KILAUEA REPORT No. 1028

WEEK ENDING OCTOBER 4, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Fume was fairly strong at the floor vents of Halemaumau early in the week, appearing irregularly in puffs, probably due to the strong NE wind. Heavy rain increased steam activity in the pit. Accumulation of water in a pool near the Halemaumau seismograph caused deceptive tilt of that instrument away from the pit.

On October 1 fume was plentiful at the SE sulphur spot. Two small slides from the north wall were observed at 7:35 and 7:40 a. m. There was the usual increase of steam after rain on this day and the next. A small slide also occurred on October 2 at 7:30 a. m. A faint smell of sulphur was noticed on the west side of the pit.

The instruments at the Observatory recorded a total of 19 very feeble tremors, one showing easterly tilt; 3 very feeble local seisms, one at 8:40 a. m. October 3 showing distance 4 miles and another showng easterly tilt; and a distant earthquake at 8:45 a. m. October 3 (uncorrected H. S. T.). The record of this shock is much larger than the Napier disaster of February 2, though the distance, 3750 miles, is not so great. Phases were as follows:

eP 8:53:42 a. m.
eS 9:01:17 a. m.

The average of accumulated tilting of the ground at the Observatory was slight ENE. Microseismic motion was slight

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Founded 1911

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It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

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No. 355—Weekly Hawaiian Volcano Observatory, National Park, Hawaii October 15, 1931



Lake Amatitlan and Agua Volcano in Guatemala.

VOLCANO ACTIVITY OF CENTRAL AMERICA

In some early numbers of the Volcano Letter the question was reviewed as to what constitutes comparative volcanic activity for different districts. Different methods suggested have been Von Wolff's "Index of decadence," where an index number is applied to the percentage of extinct volcanoes for the total number of new districts; the total number of historical "outbreaks;" the number of volcanoes active for the aggregate length of the volcanic zone; volume of output of lava; and lastly volume of output of explosive materials. It was found that the volume of output makes the most consistent table for a list of regions, but that the output of lava is at the opposite end of the list from the output of explosive material. Thus Iceland leads all other districts in output of lava and the Dutch East Indies lead the world very greatly in output of fragmental deposits for the period of human history. The oceans and subarctic regions are the great lava producers, the continental borders and the equatorial belt produce much explosion.

Reading by explosive output alone, we get the following series by Sapper's revised tables (Zeitschr. Vulk. XI, Heft 3, 1928):

		Cu. Km. Fragmental
1.	Java belt	185.0
2.	Central America	58.0
3.	Alaska-Aleutian	30.0
4.	Iceland	10.0
5.	South America	9.5
6.	Japan	8.2
7.	Philippines-Molucca	6.5
8.	Kamchatka-Kurile	6.0
9.	New Zealand-Tonga	4.1
10.	North America-Antilles	3.5
11.	Mediterranean	3.5
12.	Melanesia	3.1
13.	Atlantic Ocean	2.2
14.	Indian Ocean-Africa	2.0
15.	Central Pacific	1..5

Contrast with this the following list in the order of lava output:

		Cu. Km. Lava
1.	Iceland	15.5
2.	Central Pacific	11.0
3.	Indian Ocean-Africa	8.0
4.	Atlantic Ocean	5.5
5.	Mediterranean	5.1
6.	Kamchatka-Kurile	5.0
7.	Japan	3.5
8.	Alaska-Aleutian	2.0
9.	New Zealand-Tonga	2.0
10.	North Amerca-Antilles	1.5
11.	South America	1.2
12.	Philippines-Molucca	1.2
13.	Central America	0.6
14	Java Belt	0.5
15.	Melanesia	0.1

If we compare these two columns it is evident that for the geologist to whom explosive violence is characteristic of terrestrial activity, the Dutch East Indies stands at the top. And to him for whom magmatic outflow is all important, Iceland and Hawaii are the leaders, though Hawaii comes at the bottom of the list based on explosiveness. Japan occupies nearly the same position (Nos. 6 and 7) in the two lists, and the districts occupying the same position in both lists are New Zealand-Tonga and North America. It is clear that explosive violence and lava outflow are opposed, and that if either of these qualities is to be used as a measure of volcanic activity, the other should be in the nature of a measure of decadence.

If we grant that engulfment and the admission of ground water is what leads to explosion, and that on the other hand the rise of primitive magma and exclusion of ground water is what leads to lava flow, then it would appear that only the latter magmatic happening can be construed as a measure of pure volcanicity. Any magmatic vent in the earth-crust may enter into an explosive phase through the recession of the magma, this has happened in Iceland and Hawaii, and the fragmental output thus produced is merely a rearrangement of broken rocks.

On the other hand, it is quite possible that some volcanic regions are charaterized by intrusive magma in just as great volume as anything poured out in Iceland or Hawaii. These places would make steaming solfataras and boiling waters, would deposit much sulphur and other salts along cracks, and if the intrusive magma receded, would generate explosive eruptions, followed by an exhibit of little or no lava at the surface. The little lava exhibited might be a stiff plug or dome of highly siliceous magma at the crater. It happens that just such andesite or dacite domes are well known at many explosive volcanoes. This proves that these volcanoes are truly magmatic, but that they do not make lava flows.

Decadence of volcanism. then, as interpreted by explosion, may mean merely a transition from basaltic flow lava to andesitic intrusion lava. In this connection Central America is very interesting. Sapper lists 26 active volcanoes between Costa Rica and the Mexican border, averaging one every 50 kilometers when this line of activity is treated as a single belt. Central America ranks thirteenth in lava output among volcanic regions, but is second only to the Dutch East Indies in explosive output.

In a recent article on the most active "volcanic regions," Dr. Sapper has compared the strongly active districts of the world by density of clustering of volcanoes, by frequency, and by output, and makes the following remarks on the resulting tables:

"Iceland in the period since 1500 A. D. has exceeded all other places in output of lava, in that it has poured out a third of the world's lava output, or about 16 cubic kilometers out of a total of 50 cubic kilometers. Hawaii comes next to Iceland in lava output.

"In the production of broken material the Dutch East Indies have produced more than half of the 325 cubic kilometers ejected on earth since 1500 A. D., with Central America coming next and the Aleutian-Alaska system third." (These figures differ from the tables in Volcano Letter No. 12, owing to the inclusion of a large volume for Katmai in 1912. This illustrates how quickly proportions may change through a single volcanic event.) If one considers the great length of the Java-Sumatra and the Aleutian belts, respectively, as compared with the shorter Central American belt, and thus includes density of clustering as a measure of activity, it is found that the output of Central America per hundred kilometers of length is 4.6 cubic kilometers of explosive material, whereas that of the Dutch East Indies is only 3.7. This would make the Central American region the most productive of explosive material per unit of area, with the Dutch East Indies second and the Alaska-Aleutian belt third. It further appears that when these belts are examined in detail, the two ends are less productive than the middle. It is remarkable that the three most important regions on earth for throwing up explosive material, and so giving evidence of cycles of intrusive activity at the present time, all lie in inter-continental districts—Java between Asia and Australia, the Aleutian Islands between North America and Asia, and Central America between North and South America. The Central American belt is strikingly different in its volcanic activity from the much weaker volcanism of the mainland of North and South America. By this demontration, Sapper makes the Central American region one of the most important on earth.

In the map on Page Four there are shown many volcanoes between Turrialba in Costa Rica and Tacana near the Mexican border of Guatemala The last Volcano Letter discussed the moderate activities of the Costa Rican group. In Salvador and Guatemala there are volcanoes producing lava flows, and others producing extrusive lava domes. In Nicaragua there are volcanoes of first magnitude and very frequent activity represented by Masaya, whereas Momotombo and Coseguina are both distinguished for some of the greatest eruptions of history. It is worthy of note that two of these are on opposite sides of Managua, where the recent earthquake occurred, and that the proposed route of the Nicaragua Canal is in the midst of an earthquake and volcano belt.

In Volcano Letters Nos. 87 and 262 some description has been given of Santa Maria Volcano in Guatemala near the city of Quetzaltenango. This is the most interesting active vent of the Central American group at the present time, and will be treated in the next number. The illustration on Page One shows Agua Volcano, one of the beautiful cones near the capital, Guatemala City. There are three in this group, Agua, Fuego, and Acatenango. Here again it should be noted that some of the terrific earthquakes of history occurred right at the foot of all these volcanoes, and both of the cities named were recently wrecked, Quetzaltenango in 1902, and Guatemala City in 1917. Here and at Managua it is legitimate to inquire whether intrusive magma does not strain the earth-crust to make great earthquakes. There is no reason whatever for expecting

simultaneous "activity" at the nearby volcanoes if an intrusive mass, by spreading laterally far underground, suddenly breaks or splits the earth shell subterraneously.

Acatenango, elevation 3960 meters, is a double cone close to Fuego, and at the end of the nineteenth century it exhibited slight fumarole activity in its southern summit crater. At 8 p. m. December 18, 1924, an explosive eruption broke out and lasted 20 minutes. A crack opened about 300 meters north of this summit, in the saddle between it and the northern peak called Tres Marias. (See cut Page Three.) The crack was right on the line connecting the two cones. Fiery glow was seen and products of the eruption were water, sulphur vapor, and fine gray ash. There were 15 cups along a rift 75 meters in length; bright yellow sulphur deposits were formed along the crack. There were light falls of ash in three towns. An ascent of the volcano by residents January 5, 1925, discovered the straight line of vents steaming like an engine ending at the south with a new large crater 60 meters in diameter and 80 meters deep. The steam rushed out violently so as to eject small stones. The west slope was covered with ash, and one's feet sank in it 20 centimeters at each step. The individual fumaroles were 2 to 4 meters across and up to a meter and a half deep. The ash was dark and muddy and there were sulphur stains. The big new crater sent up dark, yellow, sulphur vapor, whereas at the north end of the row of small cups pure steam was rising. At the southern summit crater there was no participation in the eruption, but a little white vapor rose at the west edge.

The second outbreak occurred February 10, 1925, at a large crater in the middle of the north slope of the southern peak. This also lasted 20 minutes, with wind in different direction from the first one. There was hissing from the new fumaroles, but the explosion was not so strong as before. On February 22 there was decrease of activity, and a new ash field made a conspicuous white object for 200 meters on the east slope of the summit. A new pit had been formed 50 by 40 meters in size, on the rim of which lay many stones in the midst of the ash, of 50 centimeters diameter. There was further activity at 4 a. m. March 4 and again at 2 p. m., so that a new ashfall occurred, and when the peak was visited March 13 some of the fumaroles had increased their activity. There was wet ash around all the openings, some blocks of rock a meter in diameter were found during the ascent, and trees were broken down. A compass needle showed no disturbance on Acatenango, whereas Fuego at its summit produced great irregularities in magnetic declination. At this time Fuego also was showing increased fumarole activity.

On May 7 a strong outbreak of ash again occurred at Acatenango, and it was found that trees 30 centimeters in diameter were broken off one meter above the ground, only the eastern of the saddle fumaroles were active weakly, while the western ones had caved in to form a large hole where gas was escaping. A small channel had formed connecting different openings. From the mid-slope crater on the north side of the southern peak steam arose feebly, but from the summit rose big steam jets mixed with ash, and a part of the crest had fallen in. All these facts suggested a gradual increase of activity from the beginning of the year 1925.

A later note (Zeitschr. Vulk., Vol. XI, Heft 3, p. 188) states that Acatenango in 1926 after September was in continuous light activity from the same vents, and March 30, 1927 a great rumbling occurred heard in the neighboring towns. Some fine gray ash fell March 31 and April 1 while thick steam clouds rose from the peak. Then the activity died away and nothing more was heard from this peak. Steam was occasionally seen. On the other hand Fuego in August 1927 had increased its activity, 25 irregular fumaroles were in action on the southern peak and about 10 on the east side. There was much sulphur at the peak of Fuego. Out of the crater steam puffs shot up every 10 minutes, and during two hours there were six slides heard in the crater, which is from 300 to 400 meters deep. The east-west diameter is 150 meters and the south-north 75 meters. The northeast rim consists of ash and is higher than the southwest margin, which shows bedrock.

T.A.J.

TILTING OF THE GROUND FOR SEPTEMBER

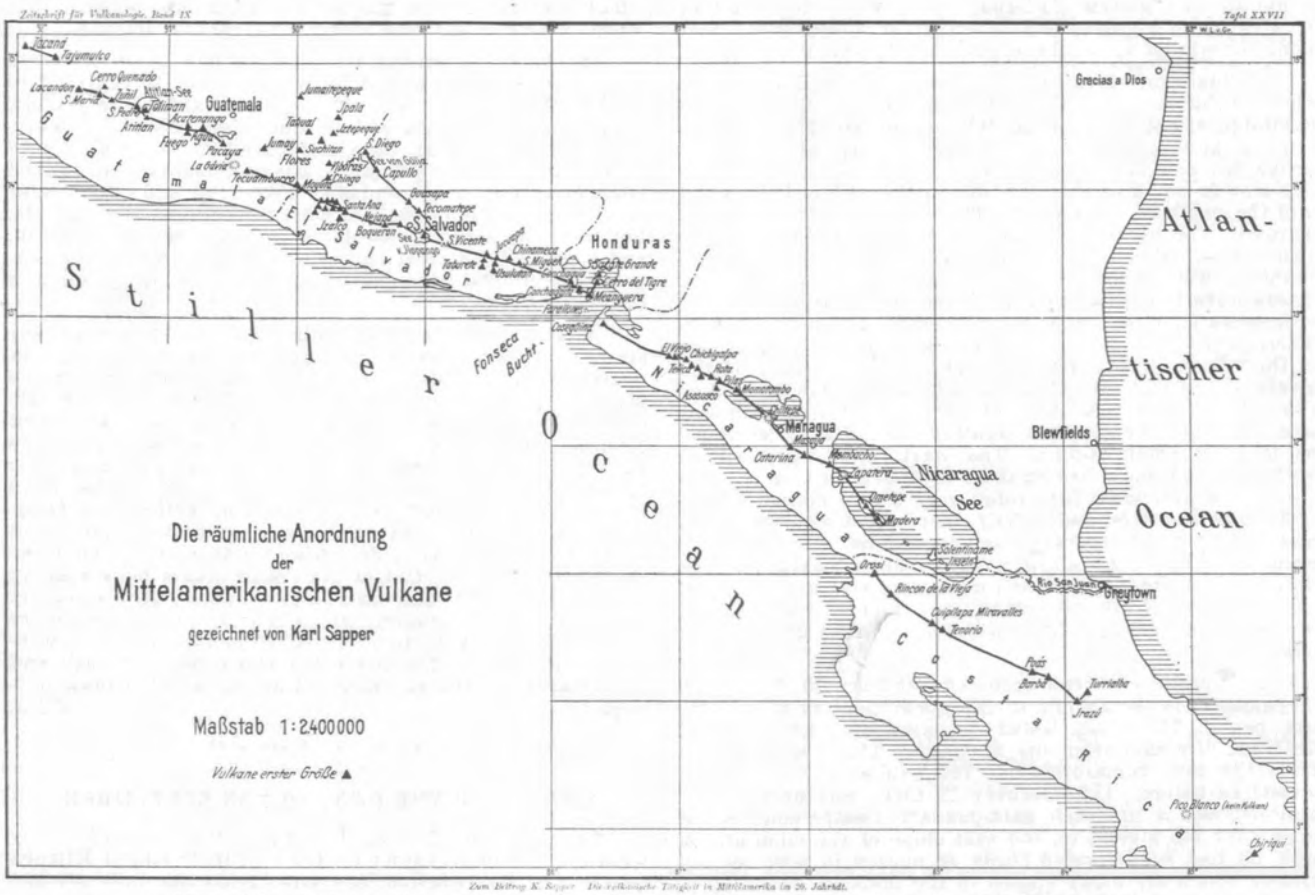
The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

August 31-September 6	1.1 seconds	SW
September 7-13	1.7 seconds	NE
September 14-20	0.5 second	E
September 21-27	1.4 seconds	ENE

E.G.W.



Looking south from Tres Marias at the main peak of Acatenango in 1925. After Sapper.



Map of Central America, showing the belts of active volcanoes, from Costa Rica on the east through Nicaragua, Hondura, Salvador, and Guatemala. After Sapper.

KILAUEA REPORT No. 1029

WEEK ENDING OCTOBER 11, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

At Halemaumau blue fume in the bottom was thin throughout the week. Steam activity also decreased very noticeably. The east rim cracks were measured on October 5 but no changes were found. On the 6th the seismograph at the pit indicated very quiet conditions. On the 8th a few quick-period tremors were recorded. On the 9th a distant earthquake was recorded at 2 p. m.

The seismograps at the Observatory recorded during the week 28 tremors, of which only one gave indication of distance—10 miles. Of a total of eight very feeble local seisms, one showed distance 4 miles, one 6 miles, three 9 miles, one 28 miles, and two 42 miles from the Observatory. One in the third group was felt at Uwekahuna at 3:41 p. m. October 6. There were no stronger shocks.

One teleseism, distance 3500 miles and lasting 1 hour 45 minutes on the record, was registered at about 2 p. m. October 9, the origin not even approximately known as yet. The teleseism of October 3 reported last week was tentatively located by the Honolulu station of the U. S. Coast and Geodetic Survey at 14° S lat., 160° E long., in the Coral Sea near Rennel Island at SE end of the Solomons.

Average tilting of the ground for the week was slight NNW. Microseismic motion was moderately strong.

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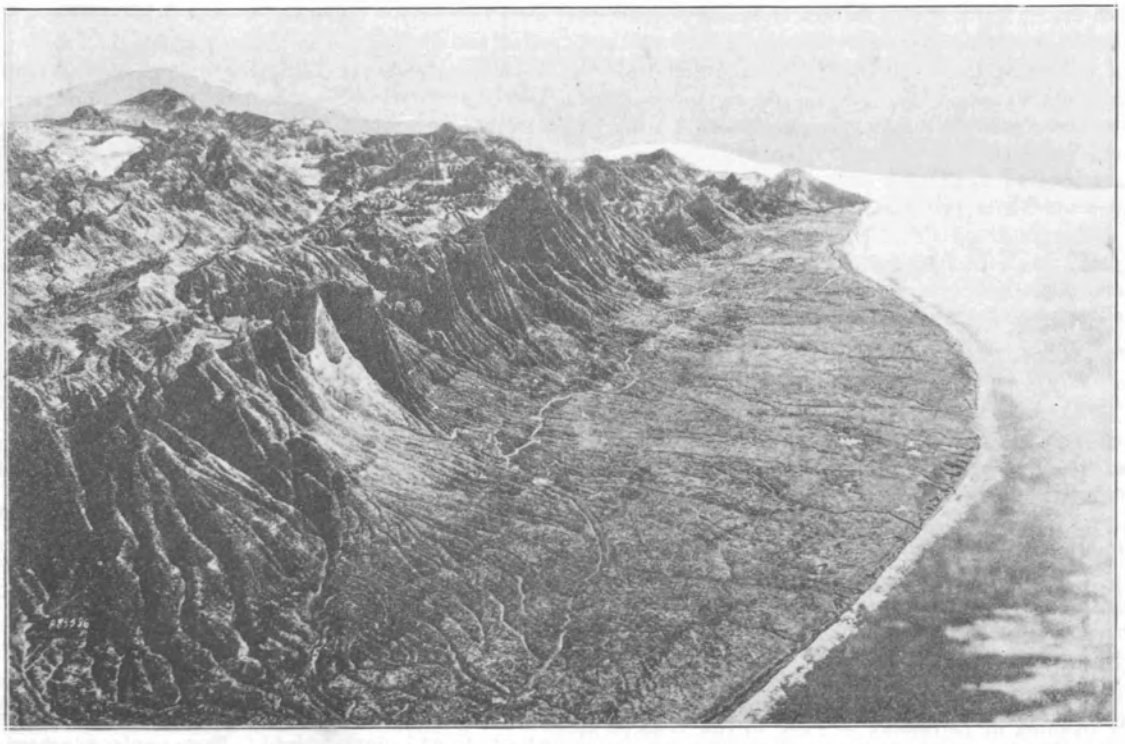
No. 356—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | October 22, 1931



Photograph of a large model of Guatemala, looking southeast along the Pacific coastal plain, which has been uplifted at the base of the line of active volcanoes. Great vertical exaggeration. Santa Maria Volcano with hole in its side from the eruption of 1902. At the left the mountainous plateau of Guatemala. a region of fertility, and one of the coffee belts of the world. Adjacent to this volcanic rift have occurred some of the biggest earthquakes of history.

ERUPTION OF SANTA MARIA NOVEMBER 1929

Santa Maria Volcano in western Guatemala has become a key vent of great importance in connection with the seismic and volcanic activity surrounding the Caribbean Sea. (See Volcano Letters 87 and 262). Heilprin states (The Eruption of Pelée, Lippincott, Philadelphia, 1908) that there was no recorded eruption prior to 1902, and in this apparently Sapper concurs. The 1902 outburst in October split open a great hole in the southwest flank of the mountain (see cut Page One) at about 6,500 feet elevation. the chasm being about the same size as the present Halemaumau, 3,300 feet across. and 800 feet below the rim stood a geyser-like lake of boiling water spouting and making sulphurous fumes until after 1906. Then the volcano became quiet until 1922 when at the end of June new explosive eruptions began and a dome of hornblende-hypersthene andesite lava rose through a fissure in the bottom of the crater and in August of that year had grown until it stood 300 feet above the downhill rim of the cauldron. Thereafter the dome kept growing until in 1925 there was a big castellated heap 1,600 feet high and 4,000 feet across. The growth was replaced by solfataric activity which continued until May 14, 1928, along with the slow development of a second swollen dome on the north and northwest sides of the former dome (Termer, Zeitschr. Vulk. XII Heft 2/3, p.231). About the site of this new plug eruption a short-lived explosive eruption occurred May 14, 1928, throwing ash over the country to the depth of a few millimeters.

Heilprin (l.c. page 71) believed the events of 1902 indicated that in a region like the Caribbean, volcanic and seismic phenomena over distances as great as 2,000 miles are related, that the deep-seated strain of magma might make great earthquakes such as geologists call "tectonic," that the slipping, upheaval and torsion of surface formations in the rock of the earth's crust might be resultants of the jarrings already given to the deeper earth-crust by magma, that the seismo-volcanic condition of the crust is proved to be connected with electro-magnetic phenomena as shown by the magnetic storms all over the earth accompanying the Pelée eruption, and that there is marked synchronism or close following of major disturbances. as has been proved at different periods for eruptions and great earthquakes far removed from each other. The striking illustration of these facts was a destructive earthquake at Quetzaltenango in Guatemala April 17, 1902, synchronous with the first outbreak of Pelée in Martinique at the other end of the Caribbean Sea 2,100 miles away. Two hundred

miles south of Quetzaltenango, Izalco Volcano broke out in Salvador and was in full eruption May 10, two days after Pelée had destroyed St. Pierre. Sourière in St. Vincent had broken out more than 100 miles south of Pelée the day before the St. Pierre catastrophe. Both Soufrière and Pelée continued their eruptions in concert into the autumn of 1902, and during this time Masaya Volcano in Nicaragua started eruptions which continued for two years. And finally Santa Maria in Guatemala developed its unprecedented eruption October 24-November 15 and devastated the coffee lands. If there were any doubt about the sub-crustal sympathy of the magma in these leaps from the volcanic fissure of Guatemala to the great rift of the Caribbee Islands and back, it should be dispelled by the fact that in September 1929 Pelée broke into explosive eruption again just after Santa Maria in 1928 had renewed explosive activity which came to a crisis in November of 1929. It is of interest in comparing Soufrière of St. Vincent with Santa Maria, to note that both these volcanoes in 1902 were left with boiling crater lakes. Now Santa Maria has exterminated this lake and replaced it with a lava dome: will Soufrière eventually do the same?

The photograph on Page Three has much in common with the scenes pictured on the northeast slope of Lassen Peak after its eruption of 1915, and this photograph represents part of a stream bed in the forest below the crater of Santa Maria as it appeared after the new catastrophe of 1929 which destroyed human life and wrecked plantations with an incandescent down-rushing cloud of ash, and torrential floods which transported gigantic bowlders. In both Lassen and Santa Maria volcanoes, as well as at Pelée in 1902, the source of the down-blast was a crater partially filled with a stiff plug of lava.

In the evening of November 2, 1929, in the vicinity of Santa Maria, there had been no forewarning of the coming danger. It was sultry and there was a dry lightning storm, but there had been such electrical phenomena in that vicinity of the lava dome frequently. At Las Animas, close to the volcano on the downhill side, about 9:30 p. m. November 2, persons sleeping on the plantation were suddenly awakened and saw a glowing rain and a flood rushing from the heights of the volcano. Alarming underground noises followed each other in quick succession, then glowing sand and ash fell on the roofs. Those who were so fortunate started to flee finding it difficult to breath the hot air. The bell was rung to awaken the laborers and all hastened toward the Rio Concepcion, where the river bed was found full of boiling mud erroneously called "lava" by the peasants. This was beginning to overflow the adjacent land. They made for another branch of the stream and found it equally in flood so that they were penned on a peninsula between the two torrents and the volcano. They spent the night in the plantation house; when there was a pause in the rumblings shrieks of the sufferers and calls for help could be heard. When they attempted to go to the rescue they found that the cries came from natives who were already engulfed in boiling mud. Nothing could be done. Early the following morning when daylight enabled them to see the devastated land, they improvised a bridge of logs across the stream and about 25 persons were rescued. The wounded were taken to a house on the main road where a relief commission soon began the work of rescue. Bodies were seen protruding from the hardened mud and some persons were trapped in the wreckage of houses. The residence house of one plantation was found totally destroyed and in many places it was necessary to lay down boards in order to cross the excessively hot mud and ash. The manager of this second plantation reported hearing a terrible thundering, and on looking up toward the crater he saw red-hot masses weighing tons being hurled into the air and breaking to pieces when they struck the earth so that glowing fragments and sparks bounced away. Then came subterranean rumblings and fiery streams seemed to pour down from the crater in winding avalanches of incandescence. The illumination was like daytime. Ash and sand fell in a dense rain, the temperature rose, and flight became imperative. Here also the bell was rung for the laborers and at the bank of the Rio Tambor, which had a channel 100 meters deep and 80 meters wide, the river was found in flood and so incandescent with the dry accumulations on its upper surface that they lighted the bank. This is a very remarkable statement, but quite believable, and accounts for phenomena observed in many of the explosive eruptions of Java and elsewhere, when stream floods have been confused with lava flows. It is easy to believe that light pumiceous ash will make a dry bed on top of a mud stream, capable of holding incandescent fragments so as to remain luminous while it flows. Throughout this eruption of Santa Maria the natives thought the contents of the river beds were lavas.

The River Tambor had almost reached the top of the bridge, the under irons were bent, but as yet they had not given way. A smaller stream, the San Jeronimo, was visited and was found to be flowing backwards owing to the fact that this stream pours into the larger river Concepcion, which by reason of its greater height and viscosity due to ash sent a backwater flood up the smaller stream. This was an added danger to the plantation as soon as the backflood poured into the lands and about the buildings.

There was no time to be lost. The laborers were panic stricken and demoralized. Twenty-six of them escaped over the bridge. The man describing the event said his chauffeur wished to go back to the garage to get the automobile and he had to use force to prevent his doing so and snatch the key out of his hand. While he was trying to persuade him to come across the bridge there was a sudden rush of the fiery mud across the slope at the bridge head; this liquid, by its great weight and stickiness, grasped the man's legs and dragged him downstream into the hot torrent. There was only a single heartrending cry and he was gone. Half of the laborers had delayed and were still in the plantation, and now streams of overflow could be seen making their way through the hamlet. The man remaining on the bridge called to them as loudly as possible, but his voice was drowned in the thunder of the cataclysm. He saw his residence collapse, and his automobile torn out and tossed like a toy on the surface of the stiff flood. More thon 25 of those who had remained in the grounds perished. The narrator saw there was nothing for him to do but to save himself, and he ran across the bridge just in time to see it carried away, leaving the plantation cut off. Then the ruins of his house disappeared.

Dr. Sapper concludes that this was a true fiery down-blast of the Pelée type such as destroyed St. Pierre. If this eruption is compared with the first outbreak of Santa Maria October 24, 1902, there are marked differences. The 1902 explosion was enormously bigger in output of material, and while the loss of life was not greatly different, the destruction of property was much less in 1929. The area covered in 1929 was comparatively small, whereas hundreds of square kilometers were buried in 1902. The thickness of ash in 1929 was from 2 to 10 centimeters as against 10 to 20 meters in many places in 1902. Whereas in the earlier eruption earthquakes were numerous and big, in 1929 they were few and unimportant. The noise in 1902 was heard several hundred kilometers away, whereas in

this recent eruption it was confined to the immediate neighborhood.

On the other hand, the devastation in the immediate path of the fiery blast was terrific in 1929, though probably not so great as that which destroyed St. Pierre in Martinique. There was the same deep booming noise, the electrical phenomena in the sky, the hurling out of glowing masses, the carrying of big bowlders on the flood paste of the streams. A notable difference lay in the fact that the Martinique eruption was by daylight at 8 a m., whereas the 1929 eruption at Santa Maria was at night so that light phenomena were conspicuous. The lava dome of Santa Maria glowed with reddish incandescence and glowing masses rolled into the gulches. The force of the blast was much greater at Mount Pelée accompanied with hurricane violence so as to carry big stones like cannon balls. In the Guatemala outbreak the glowing sand and ash masses flowed downwards simply by gravity. There were heat phenomena in both blasts, but the Pelée blast did damage to much greater heights, for there were hills in the path of the hot blast of Santa Maria where vegetation and houses stood uninjured above the level of the destructive cloud. There were at least two distinct blasts in the 1929 eruption. The contents of the ash cloud consisted of hot stones, sand, and dust which retained their heat a long while, and the same was true in 1902 at Soufrière and Pelée. The killing of people in Martinique was due to hot steam mixed with ash, and no case was identified of true asphyxiation. In Guatemala there were more cases apparently due to unbreathable gas, a fact confirmed by many accounts indicating that the people died without any outcry. The breathing of intensely hot air might produce this effect, particularly if it were charged with dust, and the reviewer would point out that incandescent substances driven through vegetation would very quickly generate enough carbon monoxide for instantaneous poisoning. There were cases in both eruptions where the bodies were burned beneath relatively uninjured clothing, owing to death by scalding rather than incineration.

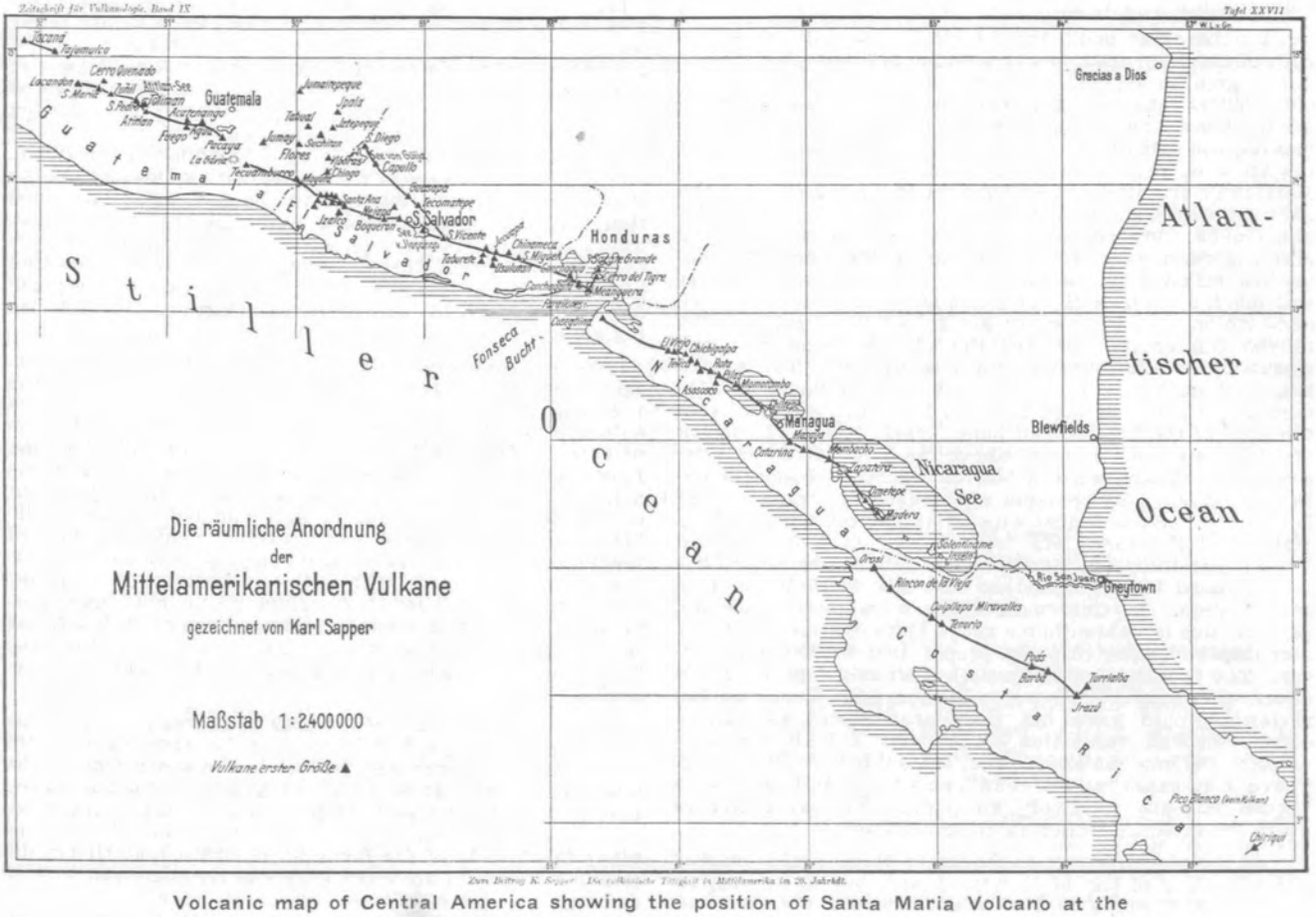
At the place nearest to the Santa Maria crater roaring and whistling of the blast were heard, but in distinction from the Martinique happening an inrushing reverse wind was conspicuous, blowing toward the crater, trees showed scour on the side way from the crater, and in some cases were scorched on the side remote from the volcano. This recalls the indraft at Vesuvius in 1906, when stones broke windows on the sides remote from the volcano. A peculiarity of the Guatemala happening was the wetness of the climate and the occurrence of the eruption at the end of the rainy season. Thus it came about that glowing stones and sand clogged the streams and caused their waters to boil, greatly increasing the volume of the liquid, and in places the valleys were filled with solids so that the flood swept through the intervening lands. It happened that the downblast coincided with the drainage system. There is no reason to suppose that the gigantic bowlders (photograph Page Three) were thrown to the position where they now lie any more than in the case of the flooding of Hat Creek in the Lassen cataclysm of 1915. These big stones were carried with the mud jumble.

Very little pumice fell at the beginning of the eruption. There was much reddish ash. An analysis showed the presence of sodium chloride with three per cent of lime sulphate and traces of silica. Petrographic investigation of a rock sample from the lava dome gulch at elevation 1,800 meters above sea level determined the magma to be a hypersthene-hornblende andesite containing 55 per cent of plagioclase, hypersthene in well bounded crystals, hornblende deeply corroded and showing dense borders of magnetite granules. Three ash somples of various coarseness were examined, with splinter outlines of irregular shape generally showing colorless glass, but sometimes none, and otherwise containing fragments of feldspar, red brown hornblende, and rare rhombric pyroxene. Otherwise there was some augite and a moderate amount of magnetite.

The place of origin of the 1929 blast was the lava dome of 1922. This dome had begun to glow some days before the outbreak. A rift was formed in the south side of the dome where earlier small glowing discharges had taken place. The place was thus prepared for a glowing avalanche along a gash into the valley below. Somewhere along the middle of the dome an elongate crateriform depression was seen after the eruption, its alignment almost due south. (See cut Page Three.) Here after the main eruption a steep-sided bulbous lava mass welled up, the



Looking north after the eruption of November 2, 1929, showing the lava dome in the midst of the crater in the side of Santa Maria Volcano, and in the foreground the flood waste occasioned by the eruption. The ash torrents mingled with flood waters carried the huge bowlders shown. The downblast originated in a rift in the lava dome. There is new lava in the rift. Photo from Sapper and Termer.



Volcanic map of Central America showing the position of Santa Maria Volcano at the west end of Guatemala. From Sapper, Zeitschr. Vulk. IX.

avalanches from the slopes of which produced almost no dust, in contrast to the outer avalanches of the older dome which stirred up great quantities of the dust from the recent eruption. (Zeitschr. Vulk. XIII Heft 2, August 1930. K. Sapper and F. Termer, Outbreak of Santa Maria 2-4 November, 1929. In German.) T.A.J.

KILAUEA REPORT No. 1030

WEEK ENDING OCTOBER 18, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

There is nothing new to report at Halemaumau. During observations throughout the week very little fume and steam were noted, except a slight increase October 12 after heavy rain. On this day at 4 p m. an avalanche north was seen making very little dust because of the wet walls. A few rocks were heard falling at 9:15 a. m. October 16.

The instruments at the Observatory recorded 40 tremors and two very feeble local seisms. There were only two tremors of any length, one lasting five minutes and the other a minute and a half. The latter, judging by the period of its wave, may have been part of an earthquake with a focus near the Island of Hawaii. A seism at 12:32 p. m. October 14 showed distance to origin 6 miles; one at about 5 p. m. October 13 was obscured by the hour mark, but appeared to be less than 30 miles from the Observatory. Spasmodic tremor occurred for more than nine hours October 16 and about six hours October 17. There were no felt shocks.

Tilt was moderate NNE. Microseismic motion was moderate.

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Ropy festoons of pahoehoe basaltic lava, on the Mauna Iki trail southwest of Kilauea Crater. Shows the wrinkling mechanism by which lava flows in the direction of the arching, with twisting of the wrinkles where the middle belt flows the faster. Photo 1931 by Lewis M. Werth.

THE VISCOSITY OF LAVA

By Jean Kinsley

Little experimenting has been done dealing with the viscosity of lava. Viscosity has been defined as the resistance to flow. Where lava is the chief product of a volcano, the shape of the dome may depend on the viscosity of the lava, as well as on its copiousness in different stages of the upbuilding of the dome. The rate of flowing will depend on viscosity, and on change of viscosity as the lava cools. Highly basic lava is more liquid and less viscous that the less fusible acid lava, rich in silica, such as rhyolite or trachyte. Some basic lavas like basalt are fluid enough to run down a one per cent slope, and form flat domes with slopes of from four to ten degrees. Mauna Loa is an example of such a dome, immense in size, yet flat in profile. The andesitic lavas of Japan and Central America are much more viscous, forming cones with slopes of from 25 to 35 degrees, though this production of slope is often complicated with fragmental materials. What effect viscosity actually has, has been little experimented with.

Dr. George F. Becker (Some inquiries into rock differentiation, American Journal of Science, January 1897. page 29) discusses viscosity in connection with theories of diffusivity. Becker estimates the rate of flow of the Kilauea lava stream of 1840 at 22 feet a minute down a two per cent slope. The flow was fed from fissures for a considerable part of its length, thus maintaining a fairly constant temperature. Water according to Becker would flow 24 times as fast. Since lava is 2.5 times as dense as water, it would then be 24 times 2.5, or 60 times as viscous as water.

Becker refutes the possible assertion that lava underground is more fluid before it erupts. Viscosity increases with pressure, and underground magma is under great pressure and close to the melting point. It can not be superheated, according to Becker, or it would melt the surrounding rock and be reduced in temperature. Therefore he concludes that, owing to the pressure, viscosity must be greater before eruption than afterwards. To this statement may be added the heating effects occasioned by gases released from solution, which would diminish viscosity when eruption begins.

Dr. H. S. Palmer (The viscosity of lava, Bulletin Hawaiian Volcano Observatory, January 1927, Vol. XV, No. 1) assumes that Becker based his measurements upon progress of the first front of the flow of 1840, which would be slower than the streaming after a channel has been established. Hence Becker's estimate of the viscosity is too high. That is, he makes the lava too stiff.

No general law connecting temperature with viscosity has been found, though there are several interpolation formulae permitting computation of the variation of vis-

cosity with temperature for any given liquid. In case of water, the decrease of viscosity per degree of rising temperature is greater at the lower temperatures. Becker says that fluid lava need not necessarily be superheated above its melting point, and this agrees with observed facts of measurement in the Kilauea lava lakes which indicates that they are undercooled. Viscosity varies with the molecular weight, and the heavier basic lavas, other things being equal with reference to relation of temperature to fusing point, should be more viscous by reason of their density. But chemical composition and crystallinity play important parts, and the quantity of gas bubbles may act as ball bearings in increasing mobility.

Dr. T. A. Jaggar estimated the Alika flow of 1919 on Mauna Loa in its established channel near the source to be moving 15 miles an hour. Four miles west of the source it was moving three miles an hour. The source lava was pahoehoe, the other aa. The lava feeding the fields moved through the stream forks in the channel about 200 feet an hour, but the field itself moved about two feet an hour. Dr. Palmer thinks that Dr. Jaggar observed a surface thread of lava in the middle of the channel, which would have a velocity 5 to 15 per cent greater than the mean velocity of the inner lava river for its full width. (See photograph of lava festoons Page One.)

The rate of flow of the Alika stream Palmer assumes to have been steady with a force 1.4 times greater driving the lava stream to overcome its viscosity, than would drive a comparable water stream, since the specific gravity of the gas-charged live lava is 1.4. He writes: "If streams of two fluids were alike in all respects except specific gravity, the driving forces would be in the same ratio as the specific gravity. And if the velocities were the same, the viscosities would be proportional to the specific gravities; that is, to the driving forces. Since the velocity of a stream is inversely proportional to the viscosity, we may write the equation

$$\text{Viscosity} = \text{a constant} \times \frac{\text{specific gravity}}{\text{velocity}}.$$

From this formula he concludes that the viscosity of the Alika flow was about 15 times greater than that of water. He conceded the possibility of error in comparing the Alika flow with a similar stream of water, from uncontrolled conditions of the channel and grade.

Jaggar in 1921 (for Alika flow details see Bulletin Hawaiian Volcano Observatory, October 1919, pp. 127, 133-4, 156; also February 1921. pp. 28-9) made an experiment at Halemaumau comparing the viscosity of live lava in a rift cone, and in the lava lake. He attempted to avoid stream errors by measuring the rate of entry of live lava through an aperture in a vessel immersed in it. The apparatus was a metal cylinder 27 inches long of 3 inches inside diameter, on which was a cap with an opening 1.5 inches in diameter. This on the end of a long pipe was immersed about a meter in the molten liquid in the cone and left there for 4 minutes. On withdrawal, the cylinder was found to be about one-third full of pahoehoe lava.

The same experiment was tried in the bubbling lake, with the result that the cylinder was incompletely filled, but in larger volume than before. The current in the molten slag carried the cylinder irrestibly sidewise so as to prevent it from remaining vertical. Large gas vesicles were found in the glassy lava inside the vessel, showing that gas vesiculation had played a part in permitting the lava to enter. A defect in these experiments was the cooling effect of the iron on thrusting it into the lava without preheating to the lava temperature.

In the first experiment, 1180 cubic centimeters of lava weighing 1656 grams had entered the cylinder, filling it 33 per cent. In the second lake experiment, 2500 cubic centimeters entered with a weight of 3500 grams, filling it 83 per cent. The viscosity was thus greater in the spatter cone lava. The density of ordinary Hawaiian lava is from 2.7 to 3.0, but the vesicular lava of the experiment had specific gravity of only 1.4, owing to the large proportion of gas. The radius of the orifice was 2.9 centimeters, and the time of flow 240 seconds. The temperature of the lava in the first experiment was 1100 degrees C., in the second experiment 1200 degrees C., as might be expected from the lower viscosity of the highly effervescent lake lava.

TWO SURFACE FORMATIONS NEAR MAUNA IKI

The photograph on Page One is relevant to what was said above about viscosity of basaltic lava. The ordinary small pahoehoe lava flow has the form of a leaf, with the feeding stream considered as the stem. This stem or feeding thread of molten slag skins over on its upper surface and quickly divides itself into at least three belts of motion, consisting of two drawn-out curtains at the sides, and a belt of festoons in the middle arching downstream. These festoons are at first merely wrinkles, then they cluster together and pile up into folds, then the different speed of flowing of the faster central belt and the two lateral belts tends to twist the contact wrinkles into ropes. Finally the whole structure forms a crust and the incandescent stream inside flows under the bridge of festoons. This stream later escapes at the lower skirts of the flow and leaves the arch of festoons a hollow shell which is apt to cave in and reveal a cavern. The presence of arched festoons is a sure sign of the original direction of flow with the crest of the arches pointing downstream. It often happens that the hardened shells exhibiting such festoons become swollen up in the later history of a flow puddle so that the surface slopes backward in the opposite direction from the slope that made the festoons.

The photograph on Page Three exhibits the detail of a footprint made by a barefooted Hawaiian in the ash mud of 1790 east of Mauna Iki. This is one of the hundreds of footprints which mark the old trail of that time, the material being a pisolitic ash with some small angular pebbles. The pisolites or mud raindrops of the period are the small, round, whitish objects seen at the left of the picture. The footprint shows the five toes and the spread-out effect as the foot squashed down in the mud of that period, which has since hardened like cement so as to preserve the footprints from erosion throughout nearly a century and a half.

T.A.J.

NOTES FROM THE ALEUTIAN ISLANDS

The seismograph observer, Mrs. Wendhab, reports from Dutch Harbor that the trader Mr. Schroder, who owns the store at Chichagof Harbor in Attu, came back from one of his voyages at the end of August and reported that on May 30, 1931, about 12 midnight (following), a very severe earthquake was felt at Attu. He had himself experienced the California earthquake of 1906 and he thought that this one was very nearly as severe. Everything on the shelves was dislodged, dishes were broken, and there was general

havoc. Aftershocks continued every few days accompanied by a distinct roaring noise which preceded the shock and grew in volume as though something was coming closer with great rapidity. Then would come the shake, the roaring accompanying it, followed by a passing on of the movement and a dwindling of both tremor and sound.

Our seismograph records at Kilauea did not show any registration of a large distant earthquake at that time.

Mr. R. H. Finch reports that Aniakchak Volcano on the Alaskan Peninsula was exploding in May 1931 and scattered ashes over a hundred miles from the center. The material that fell at a great distance was very fine and looked like flour under a pocket lens. Some account of this Aniakchak eruption has recently been reported by the explorer Father Hubbard. Katmai Volcano was observed to be smoking early in July. Pavlof was smoking nearly all summer and according to the Reverend D. Hotovitsky of Belkofsky this volcano was in active eruption about May 20, 1931, making a noticeable ashfall, and at times glow was discernible at the crater. Two other volcanoes on the Peninsula were reported fuming.

Gareloi Volcano, a peak 5,334 feet high far to the west in the Aleutian Islands, was very active during the spring and summer of 1930. The appearance of half of the island was said to be changed by lava flows from fissures, and a hut was destroyed belonging to fox farmers. R.H.F.

KILAUEA REPORT No. 1031

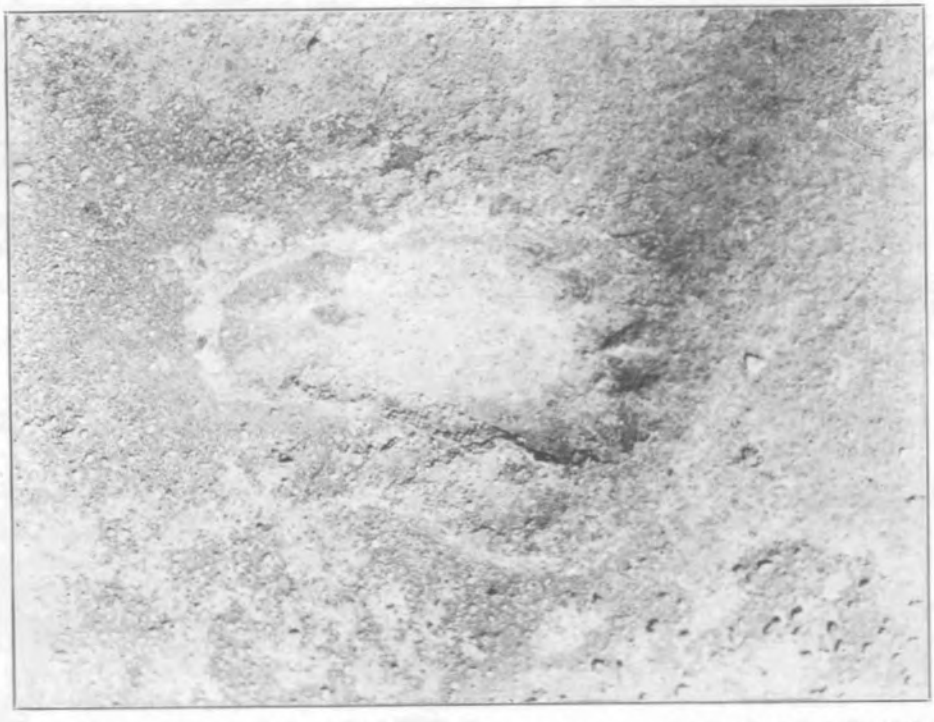
WEEK ENDING OCTOBER 25, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

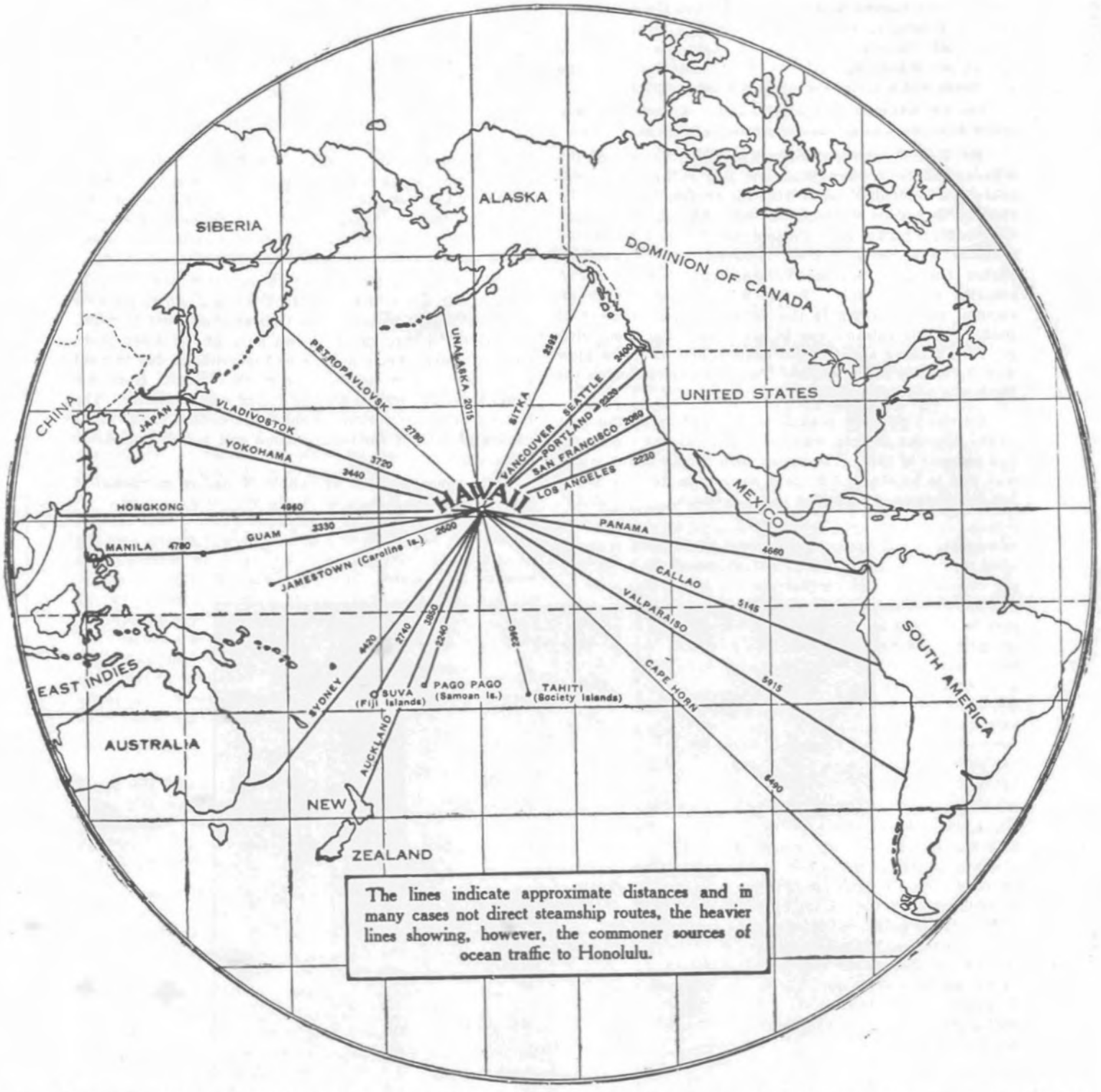
The fume area on the Halemaumau bottom appeared inactive on October 19, and only thin fume and steam were noticeable on the 20th. After light rain on the 21st there was some increase of fume. On the 22d both fume and steam were entirely absent. The seismograph at Halemaumau showed quiet conditions and practically no tilting. There are two new large bowlders on the pit floor between the south and southeast taluses. On October 24 at 8:30 a. m. there was a large avalanche north causing much dust. Crack measurements on October 20 showed no changes.

The seismographs at the Observatory registered 11 tremors, three of which were doubtful, and one very feeble shock, with good phases, from a distance of about 37 miles. In addition during the first two days of the week there were 46 spasmodic tremors, possibly artificial due to road machinery. There has been so much vibration from this cause as to obscure the records during daylight hours. The heavy machinery working in the neighborhood of 100 yards causes periods of one-tenth second and a half millimeter amplitude.

The average of tilt was slight N. and of microseismic motion moderate.



Footprint in ash east of Mauna Iki remnant from the native trails of the eighteenth century. Shows pisolites on the left and small stones on the right.' The natives walked in volcanic mud of the time, which has since hardened. Photo 1931 by Lewis M. Werth.



Map of the Pacific Ocean. Attu Island is the westernmost of the Islands extending towards Kamchatka from Unalaska, and Aniakchak in on the outer part of the Alaskan Peninsula east of Unalaska. Pavlof is still farther west on the Peninsula, and Gareloi is an island midway between Unalaska and Attu.

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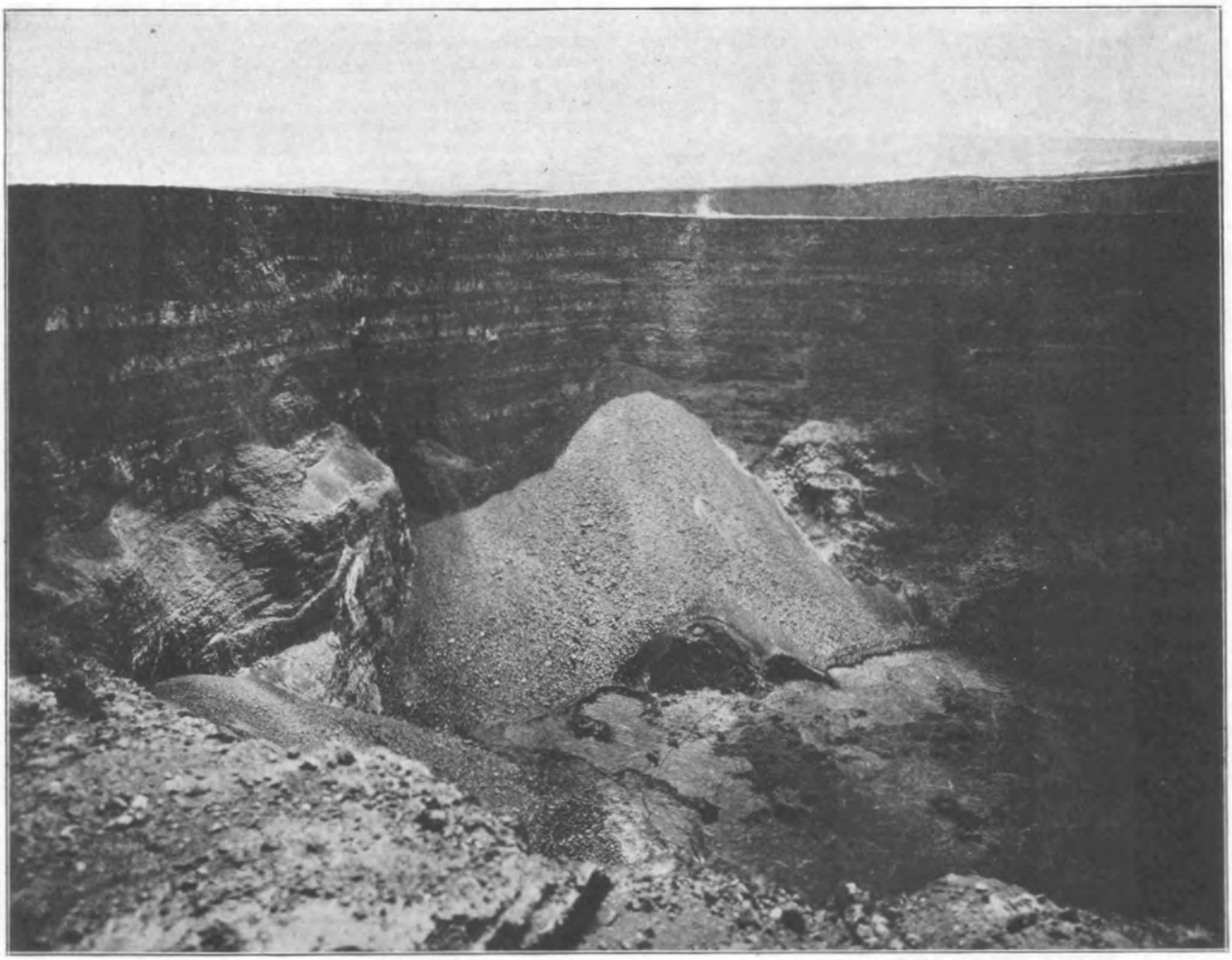


Lava floor of 1929 showing the large half-dome against the west talus left by the fountaining grotto of about July 25, 1929. This half-dome still protrudes at the edge of the floor left by the activity of November-December 1930. Photo Baker.

REVIEW OF HAWAIIAN EARTHQUAKES 1929-1930

The Volcano Letter has recently reviewed the cycles of volcanic activity at Kilauea, showing a tendency to eleven-year periods, and indicating that the present cycle began with the return of lava to Halemaumau pit in July 1924. From time to time we have reviewed the earthquake frequency, showing that recently the Kilauea station registers about 1,000 disturbances per year due to local cause. The following was the record of 1929:

By weeks ending on the dates listed, the following were the frequencies of local earthquakes for 1929:

Date	Number for Week	Notes
Jan. 2, 1929	2 very feeble	
Jan. 9	8 very feeble	Some continuous tremor.
Jan. 16	8 very feeble	
Jan. 23	1 feeble	Several continuous tremors.
	21 very feeble	
Jan. 30	10 very feeble	Less continuous tremor.
Feb. 6	1 moderate	Felt Feb. 5 Hilo and Kohala.
	9 very feeble	
Feb. 13	7 very feeble	Some spasmodic tremor.
Feb. 20	17 very feeble	Continuous harmonic tremor Feb. 20 with outbreak of lava.
Feb. 27	3 slight	
	5 very feeble	Tremor ended when lava stopped Feb. 21.
Mar. 6	1 slight	
	1 feeble	
	4 very feeble	
Mar. 13	4 very feeble	
Mar. 20	17 very feeble	Five prolonged tremor spasms.
Mar. 27	20 very feeble	Seven tremor spasms.
Apr. 3	16 very feeble	Irregular very feeble tremor.
Apr. 10	5 very feeble	Tremor ceased after April 6.
Apr. 17	9 very feeble	
Apr. 24	8 very feeble	
May 1	8 very feeble	Some very faint tremor.
May 8	4 very feeble	

Date	Number for Week	Notes
May 15	1 feeble 6 very feeble	
May 22	3 very feeble	
May 29	7 very feeble	
June 5	8 very feeble	
June 12	16 very feeble	
June 19	2 moderate Several very feeble	One prolonged tremor.
June 26	1 moderate 7 very feeble	One tremor spasm.
July 3	8 very feeble	
July 10	1 feeble 28 very feeble	
July 17	2 feeble 16 very feeble	One tremor spasm.
July 24	19 very feeble	Numerous tremor spasms July 21 and harmonic tremor accompaning lava flow began to be steady the morning of July 25.
July 31	17 very feeble	Harmonic tremor ended July 28 when fountain went out of action.
Aug. 7	2 feeble 27 very feeble	One period of spasmodic tremor.
Aug. 14	28 very feeble	Some continuous tremor.
Aug. 21	1 feeble 19 very feeble	
Aug. 28	1 slight 16 very feeble	
Sept. 4	15 very feeble	
Sept. 11	4 very feeble	
Sept. 18	1 feeble 8 very feeble	
Sept. 25	221 earthquakes and tremors	Violent earthquake disturbances near Hualalai. Some long tremors at seismograph.
Oct. 2	244 earthquakes and tremors	Many more felt in North Kona.
Oct 9	129 earthquakes and tremors	The two strongest shocks were September 25 and October 5.
Oct. 16	97 earthquakes and tremors	North Kona crisis declining.
Oct. 23	3 feeble 9 very feeble	41 prolonged tremors. Total 53 seismic disturbances as compared with 97 for the previous week. The orgin continued to be near Hualalai.
Oct. 30	1 feeble 39 very feeble 56 tremors	Hualalai origins continue active.
Nov. 6	1 feeble 21 very feeble 35 tremors	Hualalai origins continue active.
Nov. 13	2 feeble 28 very feeble 32 tremors	Hualalai origins continue active.
Nov. 20	16 very feeble 12 tremors	Hualalai crisis dwindling.
Nov. 27	2 feeble 12 very feble 18 tremors	Hualalai crisis dwindling.
Dec. 4	2 feeble 13 very feeble 10 tremors	North Kona still feeling shocks.
Dec. 11	8 very feeble 9 tremors	Five indicated North Kona origin.
Dec. 18	9 very feeble 4 tremors	Five indicated North Kona origin.
Dec. 25	3 very feeble 10 tremors	Felt in North Kona.
Jan. 1, 1930	1 feeble 8 very feeble	Five indicated North Kona origin.

The year 1929 as recorded seismically above for Kilauea, was notable volcanically for actual inflow of lava at Halemaumau pit February 20-21 and July 25-28, and for such subterranean disturbance at Hualalai Volcano that intense shaking affected the North Kona District and much of the Island of Hawaii from September 19 to the end of the year. These three events are clearly reflected in the harmonic tremor produced by the Halemaumau eruptions at the Kilauea Observatory, and in the great excess of earthquakes and tremors of all classes which accompanied the Hualalai disturbance beginning with the week which ended September 25. Seismically the frequency and intensity of the Hualalai spasm were both at a maximum during the first fortnight and declined rather evenly thereafter. No lava outflow was determined as occurring under the sea or anywhere during the Hualalai crisis. If we compare the seismic record shown above with the earthquake freqency and intensity that accompanied the explosive eruption of Kilauea in May 1924 (diagram Page Four Volcano Letter No. 328), it is apparent that the seismic maximum at Kilauea was toward the end of the eruptive period, and both frequency and intensity increased as this maximum was approached. There is good reason to think that the Kilauea steam blasts of 1924 were occasioned by an outflow under the sea. Therefore it seems improbable that any submarine outflow occurred at Hualalai in 1929, for the seismic behavior was exactly the opposite of that of Kilauea. It seems more likely that lava flowed in under Hualalai with an upward pressure, splitting open deep rifts, and preparing for eventual outflow somewhere to the north of the Mauna Loa center.

After this gradual dwindling of the Hualalai earthquakes at the end of 1929, it will be of interest to examine the frequencies of local earthquakes at the Kilauea Observatory for 1930, by weeks ending on the dates listed:

Date	Number for Week	Notes
Jan. 5, 1930	8 very feeble	Five indicated North Kona origins.
Jan. 12	7 very feeble 12 tremors	One indicated North Kona origin.
Jan. 19	5 very feeble 5 tremors	One indicated North Kona origin.
Jan. 26	3 very feeble 6 tremors	One indicated North Kona origin.
Feb. 2	1 slight 6 very feeble 7 tremors	North Kona origin. Three indicated North Kona origins.
Feb. 9	4 feeble 2 very feeble 8 tremors	Three probably North Kona origin.
Feb. 16	7 very feeble 16 tremors	One indicating North Kona origin.
Feb. 23	1 slight 9 very feeble 13 tremors	
Mar. 2	3 very feeble 8 tremors	Two indicating North Kona origin.
Mar. 9	1 feeble 7 very feeble 5 tremors	Three indicating North Kona distances.
Mar. 16	1 feeble 5 very feeble 9 tremors	
Mar. 23	5 very feeble 2 tremors	
Mar. 30	4 very feeble 9 tremors	
Apri. 6	5 very feeble 12 tremors	
Apr. 13	1 very feeble 12 tremors	
Apr. 20	3 very feeble 6 tremors	
Apr. 27	3 very feeble 4 tremors	
May 4	5 very feeble 6 tremors	
May 11	3 very feeble 11 tremors	
May 18	8 very feeble 11 tremors	
May 25	1 moderate 2 feeble 3 very feeble 5 tremors	Probably in Puna. Probable origin North Kona.
June 1	1 very feeble 9 tremors	

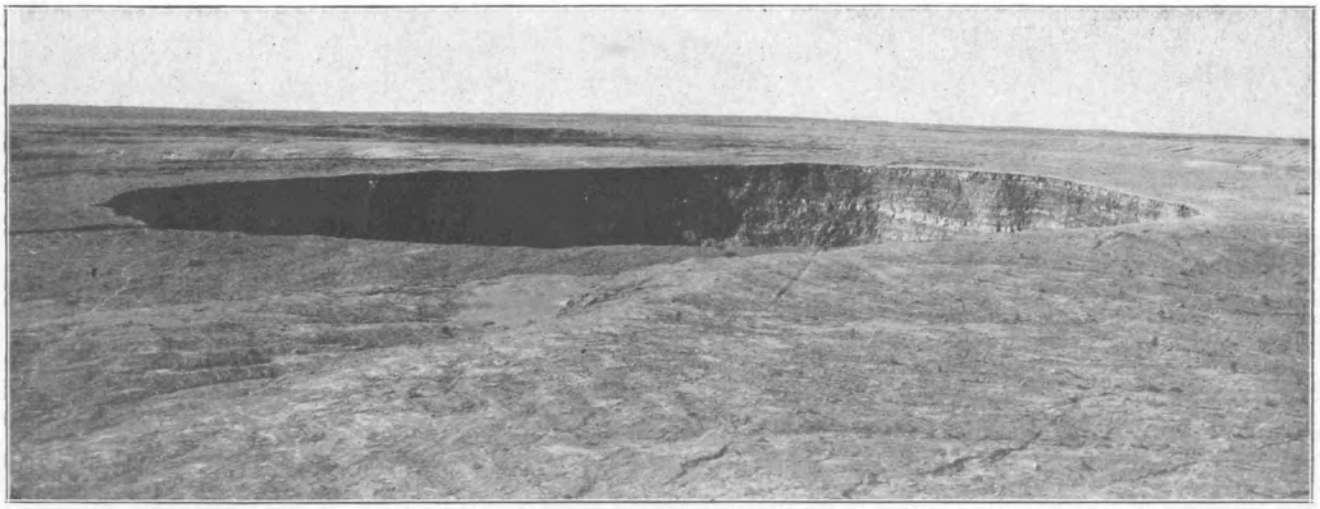
Date	Number for Week	Notes
June 8	3 feeble	One probably Hualalai.
	1 very feeble	
	6 tremors	
June 15	1 slight	
	3 very feeble	
	4 tremors	
June 22	6 very feeble	
	7 tremors	
June 29	1 very feeble	
	5 tremors	
July 6	3 tremors	
July 13	4 very feeble	
	4 tremors	
July 20	6 very feeble	
	6 tremors	
July 27	1 moderate	Strong in North Kona.
	5 very feeble	
	4 tremors	
Aug. 3	3 very feeble	
	10 tremors	
Aug. 10	2 feeble	Several tremors notably at Halemaumau.
	3 very feeble	
	5 tremors	
Aug. 17	3 very feeble	Several tremors.
Aug. 24	1 feeble	
	3 very feeble	
	25 tremors	
Aug. 31	5 very feeble	
	31 tremors	
Sept. 7	6 very feeble	
	26 tremors	
Sept. 14	1 very feeble	
	46 tremors	
Sept. 21	5 very feeble	
	49 tremors	
Sept. 28	1 moderate	
	2 feeble	
	7 very feeble	
	23 tremors	
Oct. 5	1 feeble	
	3 very feeble	
	25 tremors	
Oct. 12	3 very feeble	
	17 tremors	
Oct. 19	1 moderate	
	2 very feeble	
	17 tremors	
Oct. 26	1 moderate	
	1 very feeble	
	57 tremors	
Nov. 2	1 slight	
	3 very feeble	
	42 tremors	
Nov. 9	1 feeble	
	44 tremors	
Nov. 16	10 very feeble	
	48 tremors	
Nov. 23	1 feeble	Harmonic continuous tremor accompanied lava outbreak at Halemaumau November 19.
	8 very feeble	
	24 tremors	
Nov. 30	None	Harmonic volcanic tremor continuous along with lava inflow at Halemaumau.
Dec. 7	2 very feeble	Harmonic tremor and lava action ceased December 7.
	4 tremor spasms	
Dec. 14	3 very feeble	
	33 tremors	
Dec. 21	1 feeble	
	3 very feeble	
	36 tremors	
Dec. 28	1 feeble	
	42 tremors	

The year 1930 as here recorded seismically for Kilauea was notable as retaining traces of the Hualalai seismic spasm in North Kona until March, and thereafter the seismicity may be considered normal as compared with past years. Volcanically there was registered continuous tremor accompanying lava outbreak in Halemaumau from November 19 to December 7 with one week in the middle of this activity showing no local earthquakes at all. It may be said that, except for phenomena of volcanic tremor and tilt, the three lava inflow eruptions of Halemaumau in 1929-30 were notably quiet seismically. and this characteristic was observed in 1927 and at other times. Rising below a sealed vent may make strong preliminary shocks some time before the eruption, but through an open vent like Halemaumau the movement of lava does not make earthquakes.

The totals for the two years were 1,516 local disturbances at the Hawaiian Volcano Observatory for Kilauea seismographs in 1929, and 1070 disturbances for 1930 To show the difference in a distance of 50 miles for a localized seismic spasm, compare the 1929 figure for Kilauea with the 6,211 shocks that were registered in the vicinity of Hualalai between September 21 and October 16, 1929. The Kilauea total for the same period was about 691 shocks, many of them felt.

The totals of seismic disturbances at Kilauea per year since the explosive eruption of 1924 have been:

1925	922
1926	1778
1927	1149
1928	1034
1929	1516
1930	1070



The vast lava pit of Halemaumau taken from the high western bluff of Kilauea Crater. This is the pit the bottom of which has been gradually filling since the tremendous engulfment of 1924. Photo Baker.

The high total of 1926 was due to the Mauna Loa eruption in April, just as that of 1929 was due to the seismic spasm on Hualalai. It is of interest to note that for the 20 days of this Mouna Loa eruption the maximum of both frequency and intensity of earthquakes was reached during the first week in the registration at Kilauea, and in this it was similar to the happenings on Hualalai, and in like manner was contrasted with the seismic record of the Kilauea subsidence and steamblast eruption of 1924. This is further evidence favoring the supposition that the Hualalai disturbance marked an upward lava pressure which suddenly disrupted the mountain by intrusion of lava which has not yet been evacuated.

It will be seen that the average of the last six years at Kilauea is 1278 local disturbances per year, including tremor spasms, whereas the record from 1914 to 1925. inclusive, (Volcano Letter No. 54) showed an average per year of 1022 local earthquakes, wherein all the tremor spasms were not counted, and wherein also the very exceptional total for the year 1924 of 5877 shocks was included In general the figures for the eight years of continuous lava activity in Halemaumau pit between 1914 and 1923. inclusive, omitting 1916 and 1919 when Mauna Loa introduced complications, averaged 410 local shocks per year, which is less than the average at the present time. The figures are not strictly comparable as the listing of tremor spasms greatly increases the totals at present. Nevertheless it appears certain that free lava flow in the pit causes a decrease in numbers of earthquakes. T.A.J.

KILAUEA REPORT No. 1032

WEEK ENDING NOVEMBER 1, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Crack measurements on October 26 found no changes. Two new measuring points were marked on the northeast side of Halemaumau, where freshly broken ground was discovered on October 24. By October 31 one of these points had moved open nearly one-half inch. Fume and steam were absent. On the 27th both fume and steam were fairly thick after rain. Conditions at Halemaumau were quiet seismically. The pit was visited on the 29th after a felt earthquake at 5:45 a. m., and fume appeared strong and steady. There was no apparent avalanching from the shock. The seismograph at the pit showed tilt away from Halemaumau, which would appear to indicate tumescence. A second felt earthquake occurred at 11:34 p. m. October 31.

The records from the instruments at the Observatory were obscured during the daylight hours by artificial tremors caused by road machinery. There were also numbers of disturbances from blasts. Forty known tremors were counted, and 16 that were either artificial or natural. Of three very feeble seisms, one was very local and another was probably from Mauna Loa. Two feeble shocks were felt as noted above. The first showed distance about five miles from the Observatory and the second about 10 miles. Parts of two distant earthquakes were recorded feebly November 1 at 2:12 p. m. and 11:45 p. m.

Tilt for the week was slight WNW. Microseismic motion was moderate to heavy.



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Founded 1911

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It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

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Interior of Soufrière crater, St. Vincent, from southwest rim May 31, 1902, showing boiling pools in the bottom after the great eruption of May 7, 1902, and before the later eruptions, which tended partially to fill the inner bowl with ash surrounding a circular lake at higher level. This filling followed a series of geyser-like gushes in March 1903. Photo Jaggar.

THE CRATER OF SOUFRIERE VOLCANO

A remarkable feature of the volcanic eruptions in the Caribbee Islands made famous by the destruction of St. Pierre by the volcano Pelée in Martinique in 1902, was the fact that a great steam-blast eruption at St. Vincent, 100 miles south of Martinique, occurred at 1:30 p. m. May 7, 1902, and the next morning, about 8 o'clock, occurred the cataclysm at Mont Pelée. There was clearly sympathy along the subterranean rift above which the line of islands has been built. The writer visited both volcanoes in May 1902, and was with the first party that made the ascent of Soufrière Volcano on May 31. He made a sketch map of the crater and a photographic panorama reproduced herewith. We shall here examine the evolution of this crater, which contained a lake before the eruption of May 7, showed boiling water in the bottom immediately afterwards, and refilled to about the former lake level during the following year.

It may be well at the outset to describe the crater as it appeared during our visit of May 31. We ascended the mountain following the spurs which had been swept bare on the southwest side. The mountain is a rugged cone deeply trenched by radial gorges and charted as being 4048 feet high. The old slopes had been steepened by rapid wash and landslides, the luxuriant vegetation was swept away, the slopes were furrowed with feathery patterns of rill drainage cut in the muddy ash covering, and each spur was like a very steep roof with a smooth pathway along the divide and erosion corrugations at the sides. Here and there huge stumps remnant from the former jungle lay prone or jutted upward with limbs charred and sharpened to dagger points by the volcanic sand-blast. At 1610 feet elevation the smooth spurs changed to a steep tumble of mud clots. sometimes knee deep and sticky, with blocks of rock two feet or more in diameter scattered about by the eruption.

After nearly three hours of climbing we came to the crest and looked down into an enormous cauldron, almost circular, showing on the opposite side a wall striped with horizontal bands of columnar intrusive lava, and the peak of the mountain beyond rising high into steam clouds. On the right was a black precipice falling away 2,000 feet almost sheer, and on its face there purled upward from the bottom a long, noise-

less column of steam which broke away in billows. Down at the bottom was a pale green muddy pool sending up a hundred tails of steam and boiling vigorously. On the opposite shore of the pool springs from the wall trickled across a flat making red and sulphurous stains, and uniting into a brook which had built a small delta. The middle bands in the wall were of gray lava, one of these showing a funnel-shaped section as though the slag had filled an upright fissure that spread out above into a drooping mushroom. Farther down there were reddish brown tuffs made of fragments A large dike filled a fissure from bottom to top of the wall on the left, and at the top the northern crater edge was seen to be backed by a higher ridge. Between the two occurs the crater of 1812 which is a subsidiary cup or fiat that was filled with debris by the eruption of 1902. These features may be seen in the photograph on Page One. The bottom of the crater was 2550 feet below the highest distant summit, and 1660 feet below the rim. The upper diameter is 4870 feet, and the western rim where the photograph was taken stood 2735 feet above sea level. The old chart indicated 2013 feet for this elevation. The figures here given were obtained by rough angular measurements from the ends of a base line paced off on the edge of the crater. The eastern rim of the bowl stood over 2000 feet above the boiling pool. This pool was about 1200 feet across from east to west and was incessantly changing. It is probable that the oval of the crater had a greater dimension of more than a mile diameter north and south. The north-northwest corner had been blown away or had collapsed so as to notch the rim outward. The column of steam rose from a point south 18 degrees east from the center of the cauldron and was about 50 feet wide. The base of the steam column marked that part of the lake which was in most violent ebullition, sputtering fiercely and occasionally sending up spurts of black mud and rock fragments a few feet above the bottom of the crater. Jets of steam were seen to come directly from rock fissures on the southern side. The level of the lake was about 1100 feet above the ocean and some 800 feet lower than the lake surface that existed in this crater before the eruption. The pool of boiling water appeared shallow, for the slopes of slide rock shelved off into it at low angles and mud islets rose in the middle.

The crater lake of the Soufrière, before the eruption. was described as a pearly green sheet of water, set in sloping verdant crater walls, smelling of sulphuretted hydrogen, and the water was cold. A native trail crossed the mountain and people had bathed in the lake. The level of the lake surface was 1,930 feet, so that the southern wall over the water had been 1100 feet high, and the northern about 1700 feet. There was no known outlet. Soudings of 43 fathoms near the shore and about 88 fathoms near the center indicated that the bottom of the depression had its deepest part to the north of the center and the bottom must have been over 1600 feet below the southern lip of the crater. In other words, the rock bottom left by earlier eruptions was not very different from what the 1902 eruption produced. The former crater was described as nearly circular, with its northern lip 3623 feet above sea level and about 600 feet higher than the southern lip. The edge of the crater had been an irregular knife edge with inward and outward slopes both of from 30 to 40 degrees, and the crater depression was due to engulfment and erosion. It had not been difficult, with the aid of bushes and small trees, for passers-by to descend to the edge of the lake.

The eruptions of May 1902 disrupted the bottom of this cauldron and somewhat enlarged it, but the small crater under the crescent ridge on the north took no part in them. The phenomena were quite like those of Mont Pelée, gigantic cauliflower clouds, a downblast at the southwest, heavy accumulations of broken rock, sand, and dust 50 to 80 feet deep in the gulches, and this material so hot that the subsequent revival of spring waters made explosions in the valleys where the streams made contact with the banks of hot gravel. These banks were crusted over by a shell of rain mud which tended to retain the heat. Down some of the gulches there were doubtless combinations of flood and blast, similar to those described at Santa Maria in 1929 (Volcano Letter No. 356). Glow appears to have been seen above the crater in certain eruptions, and we may conclude that glowing magma lay under the crater lake, but it never reached the stage of lifting a crater plug as on Mont Pelée.

Just after a notably disastrous explosion of Pelée August 30, 1902, Soufreière followed with a damaging eruption that took no lives. This occurred on September 3 in a series of pulsations with detonations. They reached their climax in 20 hours, sending up a black cloud alive with electric displays and accompanied by some earthquakes. Mud flowed down one of the valleys and there was a heavy fall of ash to leeward. An inspection of the crater September 22 showed newly ejected blocks down to 400 feet below the summit, the great pit was 150 feet deeper than it had been, the lip had been lowered on the west, and banks of ash were piled against the northern and eastern walls. Steam rose from a fissure at the south. At the bottom was a small lake of stone-colored liquid in ebullition and sending up steam clouds.

An intense eruption occurred October 14, 1902, with preliminary clouds of dust-laden steam and the rumbling of avalanches at 8 p. m. followed by violent detonations at midnight. By 12:30 a. m. "a ball of fire" was followed by an incandescent hurricane, or cloud, or blast, down the Larikai valley west-northwest from the crater. At Chateau Belair southwest of the volcano stones began to fall about 2 a. m. October 15 and continued for two hours along with strong electrical displays and the rumbling of thunder. Mud fell at 2 a. m., the detonations died away at 5 a. m., there were several earthquake shocks, and volumes of dust-laden vapor rose from the crater for two days. Dust was carried to Barbados, and coarse debris fell to windward.

An ascent of Soufrière October 28, 1902, was made, and volumes of steam were found rising from the crater. Numerous cones of ashes were being thrown up to a height of 40 feet over a fissure close to the southern wall, and the lake was boiling near the center.

A phenomenon of interest November 26, 1902, was a mud flow down the Rabaka River which leads from under the crescent summit of the mountain to the southeast, as an extension of the Larikai valley on the opposite side of the volcano. This river had been completely blocked by ash avalanches during five months of heavy rainfall. Probably a lake formed in the higher reaches of the river. When the dam broke, two raging steaming torrents descended the valley, destroying the remains of a sugar mill, and blocking up the old stream bed near the sea, so that the river now runs in a new channel to the north of the old one.

An examination of the crater by Sapper February 6, 1903, showed that landslides had deepened the gap at the north, that the diameter of the crater was 1320 meters, that the longer diameter was WNW-ESE, and that the lake had dimensions 540 by 340 meters and its height above sea level was 585 meters or 1919 feet, agreeing with the old chart. In other words, the water had come back to the old level. The lake water was boiling in the center and at the southeast corner.

There was not much saddle left between the northern craterlet and the big pit, this region was deeply covered with ejecta, the smaller crater contained a shallow lake 230 feet in diameter, and fumaroles were found in the main crater rim in two places. It is an interesting and unexplained condition that in both Pelée and Soufrière there are main craters forming profound pits well below the summit on one flank of the mountain, just as at Santa Maria in Guatemala, and minor flat cups containing ephemeral shallow ponds close to the summit. Apparently the great active craters are on a radial fracture line and

the little summit cups are adjacent to an old outlying lip of some former engulfment, as at Monte Somma on Vesuvius.

Lacroix and Hovey visited Soufrière crater March 3, 1903, hot mud ejections upward through the crater lake were happening from time to time, and these as photographed by Lacroix strongly recall the mud geyser explosions of the Waimangu crater in New Zealand. A sudden descent of a torrent of mud was seen in one of the western valleys. The condition of the slopes was unstable and a cloudburst could easily produce phenomena of this kind. Avalanches were falling at the crater, there was an increase in quantities of small stones and large ejected blocks of old rock on the slopes outside the crater, and the water of the lake was quiet and yellow with mud between spells of ebullition. When agitated it became more gray in color. The geyser-like gush which was photographed arose from the center of the lake as a mass of inky mud entangling blocks of rock. One photograph shows it as seen from the south-southeast rim in process of rising, like sheaves of rockets, with upward jetting shreds in the profile and rounded undersurfaces to each sheaf. At this stage it was a thousand meters high above the lake. A photograph made 20 seconds later shows the nodes expanded into steam clouds and the beginning of showers of backfall. The mass of mud, which rose noisily, fell heavily back with a roar, followed from below by a fresh column of vapor. A heavy shower of mud fell at the rim of the crater. These explosions were seen 50 miles away, and were precursors of the last considerable eruption. Hovey, who had seen the crater in 1902, comments on the rapidity of erosion since the first eruption, estimates that 25 million tons had been carried out to sea by the one valley Wallibu at the southwest, and notes many andesite bombs up to three feet in diameter among the ejecta.

On March 21, 1903, Soufrière crater emitted much steam, on March 22 at 7:25 a. m. an explosive black cloud appeared, of cauliflower shape, rising to a tremendous height and then passing away in all directions. Detonations ceased about 10 a m., but there were later noises from the crater and there were several earthquakes during the morning. Dust-laden vapor continued to rise for nine days. A few inches of dust had fallen at the west coast, and 20 feet of new gravel in one of the ravines, with a hot bomb, weighing 75 pounds, on top of an ash layer. Some illumination at the crater was seen on the evening of March 30.

A visitor at the beginning of April 1903 described the inside of Soufrière crater as changed in appearance with the bottom filled up with chocolate-colored ash to about the old water level. In the center of this new deposit was a narrow funnel, which gradually widened in later months. The southern lip of the crater had been built up with new ash, much of the northeastern wall had caved in, and fissures in the new bottom deposit were steaming.

In the spring of 1907 Tempest Anderson revisited



Soufrière Volcano looking northeast, showing the mouth of Wallibu River in foreground and the ruins of the sugar mill, after the eruption of May 7, 1902. The steep sea cliffs were produced by submarine landslip, and Richmond village was buried under 45 feet of hot gravel. This hot gravel shows white under a coating of wet sand, and up the river the stream water produced incessant explosions in contact with it. Photo Taylor May 31, 1902.



Profile section and map of Soufrière crater made by a sketch survey May 31, 1902, by T. A. Jaggar. Vertical and horizontal scales the same, 0.64 mile to the inch. Bottom of crater 2550 feet below summit, 1660 feet below rim. Diameter crater lip 4870 feet. Coast benches east 60 and 200 feet above sea level. Depth of ocean in profile 125 fathoms east, 530 fathoms west. Profile on line north 66 degrees east.

Soufrière (Report on Soufrière, Part I, 1903, Part II, 1908, Phil. Trans. Roy. Soc. Lon., Vols. 200 and 204), and from his review much of the above is taken. He obtained a new and excellent picture of the inner ash terrace of the crater bottom and the enlarged funnel, containing the lake, restored as a circular pool. The topography was as represented on the older chart. The walls are nearly vertical, consisting of alternate layers of tuff and compact rock dipping outwards from the crater. The rock layers are either lava flows or intrusive sheets, and two dikes were seen cutting them. One layer is several hundred feet thick and columnar. The broad bench around the lake, formed by the ejecta of March 1903, is widest on the north and east, and has a talus forming on it by falls from the cliffs above. The lake is something over half a mile in diameter, of uniform light green color, at about the level indicated in the old charts, which is presumably the groundwater level of the mountain. A very little vapor was seen in 1907 from two spots near the foot of the crater walls south and east. There appeared to be more stones on the ground northeast of the crater than elsewhere, and the deposit of new ash a few feet thick on the southern lip was deeply trenched by rain rills and sloped inward evenly at 30 degrees. The upper section of the northern walls shows continuous tuff beds, while the lenses of andesite below interlock, like a pile of flat fish. (See cut Page One.)

T.A.J.

TILTING OF THE GROUND FOR OCTOBER

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

September 28-October 4	0.4 second	N
October 5-11	0.1 second	W
October 12-18	1.9 seconds	NNE
October 19-25	0.5 second	N
October 26-November 1	0.3 second	SSW

E.G.W.

KILAUEA REPORT No. 1033

WEEK ENDING NOVEMBER 8, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Conditions at Kilauea are quiet. Crack point No. 25 on the northeast rim of Halemaumau continues to move open steadily at the rate of about one-half inch per week. Dust from an avalanche was observed from the Observatory at 1:50 p. m. November 3. Fume and steam were absent from Halemaumau except on November 4. On this day in thick fog and mist fume showed steadily at the central sulphur spot, and steam occurred on both the south talus and southeast rock slope.

Road work near the Obseravtory has lessened so that there are fewer artificial disturbances on the records. There were 59 tremors, a few probably of artificial origin. There were no other earthquakes of any class.

Tilt for the week was moderate NE. Microseismic motion was moderate at the beginning of the week, increased to strong on the 3rd, and decreased the following day to moderate for the remainder of the week.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

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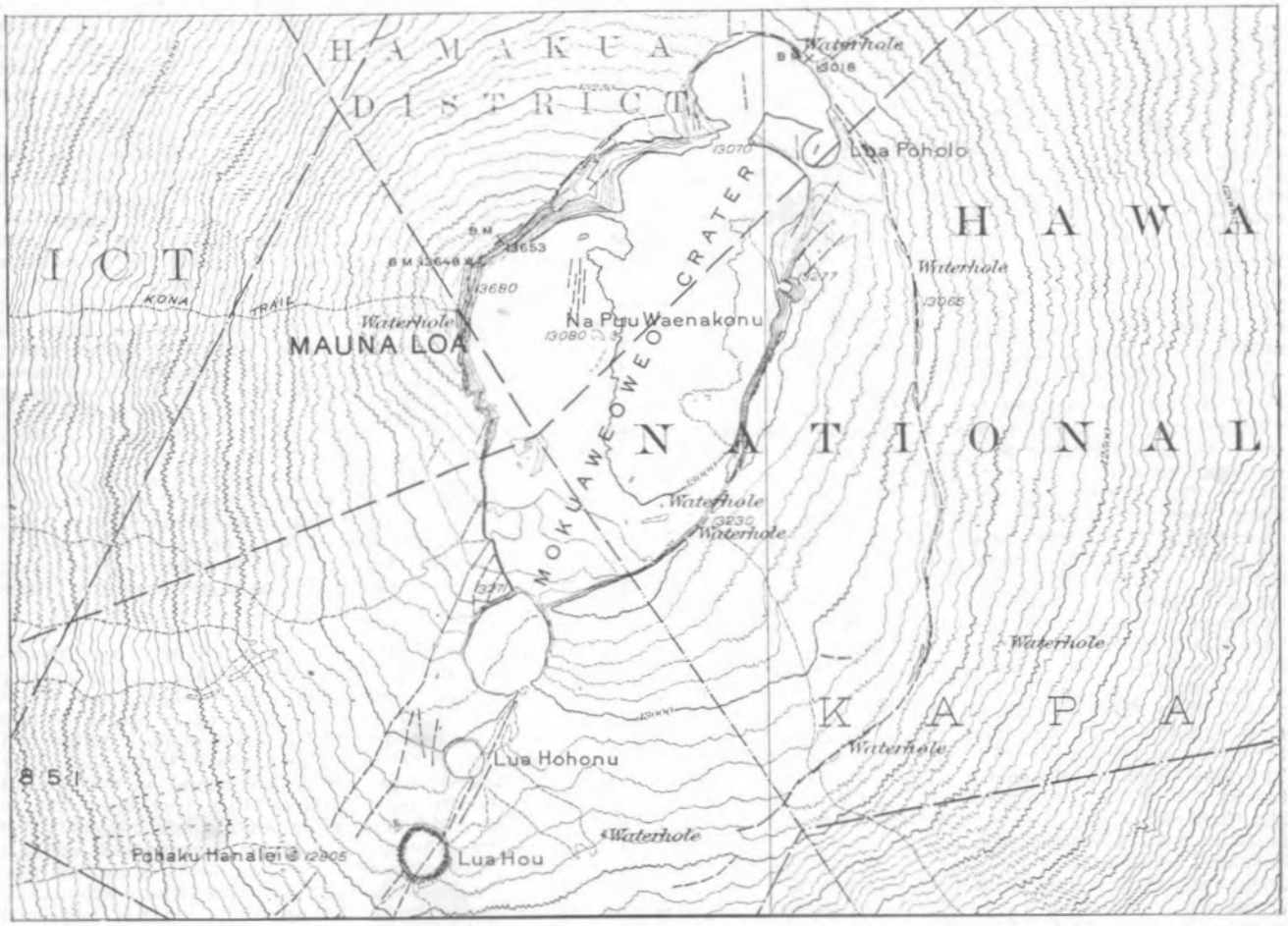


Map of Mokuaweoweo in 1926, topography by E. G. Wingate, scale 1 inch to the mile, contour interval 50 feet outside of the crater, contours largely omitted on the inside. Shows the arrangement by which the crater is a group of coalescing pits in a straight line.

THE CRATER OF MAUNA LOA

The summit crater of Mauna Loa is a sink-like depression or caldera at the meeting point of two fissure belts, the one trending approximately S. 30° W. from the south end of the crater, the other N. 65° E. from the north end of the crater. The crater itself extends these fractures into its western walls, but if the walls were considered extensions of the rifts they would each have to be bent westward, for the west wall of the crater in plan makes an angle of 120° 1.5 kilometers to the northwest of the center of the caldera. The meeting point of the two larger rift systems on the mountain is really at the north embayment of the crater, making an angle as indicated by the above trends of about 145°. The southern rift therefore really extends the whole length of the crater in the direction following the line of pits N. 28° E., thus departing from the northern rift belt 37°. As shown by the modern map on Page One (U. S. G. S. Mokuaweoweo quadrangle) the crater Mokuaweoweo, as the summit crater of Mauna Loa is called by the Hawaiians, really consists of five depressions, of which the second from the north is the large caldera: and this in turn is made up of three parts described as the north and south lunate platforms, and the central more or less circular sink with a group of cones in the middle. It is debatable whether the two lunate platforms were ever themselves separate circular pits in the history of the collapse and merging of the row of pits which has created the crater. It seems likely that they were, for stages of growth of such merging are represented by the order, south pit, north embayment, north lunate, and south lunate, progressively more and more obliterated as distinct circles.

It will be remembered that the Kilauea Crater is at a rather sharp angle between the eastern row of pits and the southwest rift. In like manner on the map of Hawaii the Mauna Loa crater is at a very open angle off to the west of Kilauea, between its northeast and southwest rifts. Both are sinks or subsidence cauldron at the apex of southeastern sectors of the respective domes. The resemblance of both in detail to the craters on the moon, when due allowance is made for scale and gravity differences, will be discussed in another place. In both Mauna Loa and Kilauea the cauldrons lie immediately under the summit points, which in each case stand at an angle of the western wall. The generation of the largest summit pit, therefore, by pulsations of rising and sinking lava, and the overflow of that lava, is directly related to the highest heaping of the lava pile.

In Volcano Letter 325 and 326 the cycle of 132 years in Hawaii after 1792 suggested a building up of increasing lava outflows to 1858, a decline thereafter to 1924, and

throughout the cycle a tendency to big collapses occasionally which may have been produced by submarine outflow. It is of interest to examine the old maps of Mokuaweoweo, the greater center of all this activity, to discover when its floor built up, and when it subsided.

Such imperfect maps as exist have been collated by the writer in four drawings on Pages Three and Four, reduced to a common scale, and drawn with contours of 20 meters interval. The four mappings were by Wilkes in 1841, Lydgate in 1874, J. M. Alexander in 1885, and B. Friedlaender in 1896. To these some details have been added from sketches by other observers. On Page One is reproduced the map abridged from Wingate on the engraved sheet of the U. S. Geological Survey to show without the original details the outline of 1926. In the Wilkes map of 1841 the original summit elevation has been retained on the ground that total subsidence was probable in the half century following, and in any case Wilkes reported a summit point farther north than Alexander, at the main bend of the west wall where there was subsequent caving in. The other maps on Pages Three and Four are drawn to conform to the Alexander summit level. Lydgate's map of 1874 appears disproportionately large, and the size and depth of the south pit is dubious for both Lydgate and Alexander, but it may have been deeper than it is now.

The north embayment in 1841 contained a pit at its western end; in 1874 it was as a whole an elongate pit; after 1885 it contained a pit at its eastern end. The main cauldron contained changing small pits and cones and lava lakes. The conspicuous changes in the crater which the maps show are a breaking back of the western walls to the main fractures originally indicated by Wilkes, and a pronounced deepening by subsidence between 1841 and 1874, followed by filling of the bottom thereafter, and overflowing of the two lunate platforms by this central filling. That the walls cave in was reported by Stearns in August 1924. This was just after the great collapse at Kilauea (U. S. G. S. Water-Supply Paper 616): "During the week at the summit avalanching of rocks from the walls was common, especially on the east side, and made climbing in and out of the great caldera dangerous. At 12:10 a. m. August 23 two smart earthquake shocks were felt in quick succession. The first shock had intensity 4 R. F. and the second intensity 8 R. F. The camp was 40 feet from the rim S. E., and when the earthquakes occurred tons of rock avalanched from the wall in front of the camp, sending up a cloud of dust that was clearly visible in the starlight. Other avalanches were heard thundering to the bottom of the caldera, especially a short distance northeast of the camp. In the morning the pass to the floor, a quarter mile northeast of the camp, was no longer recognizable. A thin section of the rim had fallen down and left a vertical cliff, and a new crack several hundred feet long and over a foot wide had opened a few yards from the brink. Avalanching was frequent all that day, especially at east pit."

Wilkes made the crater a line of four pits and two big platforms. and the circularity of the main cauldron was never afterwards so marked, and it was then the deepest part of the crater. The floor of the cauldron was made of flat sheets of pahoehoe, with ridges 3 to 15 meters high, many fissures trending NNE., and some deep chasms. Wilkes shows a crescent escarpment concentric with the main cauldron in the surface rock of the country separating the south lunate platform from the south pit. This does not appear today, and is of interest in connection with the southeastern plateau shown on the modern map (Page One), bounded by curved fractures on the east and south, which suggests an old greater crater that has been filled up on that side. If these fractures extended around to the southwest, they have been obliterated by later floods of lava, and the crack shown by Wilkes was one of them. In the south pit Wilkes counted 70 horizontal layers, a cascade of frozen lava extended from the lunate platform of the big crater into the south pit, and a great steam crack extended down the mountain southward, and others trended northeast. The only activity was vaporing, especially on the west side of the floor of the main cauldron, and Wilkes mapped 14 cinder cones. one of the inner ones being 61 meters high. Wilkes indicated the cracking, the lava sputter that built cones, the concentric subsidence that built pits, and the sinking fault blocks that connected the pits. He showed that the in-breaking area was a wide isosceles triangle with hinge line at the southeast and apex at the northwest.

Lydgate's survey 33 years after Wilkes, followed five outflows and also the great crisis of 1868 when Mauna Loa had started anew, after an unknown interval, to discharge lava from its low southern slopes. The western wall of the cauldron is a third higher, and the eastern wall twice as high as in 1841. Severance in 1870 had reported the eastern wall still higher (366 meters). Lydgate reported a maximum depth of 320 meters. The southern pit was larger and deeper than that reported by Wilkes. The northern embayment had become a long elliptical pit with two cones on its floor. and Lydgate's report indicated two cones in the main cauldron also. The lunate platforms had sunk deeper and changed proportions. A new southwest extension of the main crater floor contained the active lava pool of June 1874, 153 meters in diameter, and the scene of lava fountains for years after 1872. The floor was rising owing to repeated overflows, and the crisis of 1868 appears to have been a turning point from crateral subsidence to upbuilding of the floor. A subsidence of 27 meters for the summit of the mountain (based on Alexander 1885) is quite conceivable, if there was a sinking of approximately nine square kilometers of crater flooring to a depth of 100 meters between the times of Wilkes and Lydgate. There was 25 years of outflow from 1843 to 1868, implying withdrawal of matter from within the mountain. At least 165 kilometers of lava flow, measured longitudinally as radial ribbons of varying width, was discharged down the mountain slope. Subsiding crest of the dome may follow subsidence of crater floor due to relief by outflow in excess of that balance of pressure of rising lava, which by sill intrusion might keep the crater stationary.

The question of actual height of Mauna Loa is important, for this summit over live lava certainly fluctuates over pressing intrusive magmas which recurrently exude through fissures. Menzies in 1794 made the elevation 13,564 feet (4134 meters); Wilkes 1841 made it 13,750 feet (4194) meters); Alexander 1885 made it 13,675 feet (4168 meters), "obtained with a spherical signal on the summit accurately determined by triangulation from more than 20 stations on Mauna Kea, Hualalai, and in South Kona." The U. S. Geological Survey (U. S. Coast Survey data) made it 13,680 feet (4170 meters) by precise levels from Hilo tide guage in 1926, showing stationary conditions after 1885. Apparently the summit rose between 1794 and 1841, and sank between 1841 and 1885. There may have been some vast outflows of Mauna Loa in the last half of the eighteenth century preceding the great Kilauea eruption of 1790, which accounted for the low level of the summit measured by Menzies.

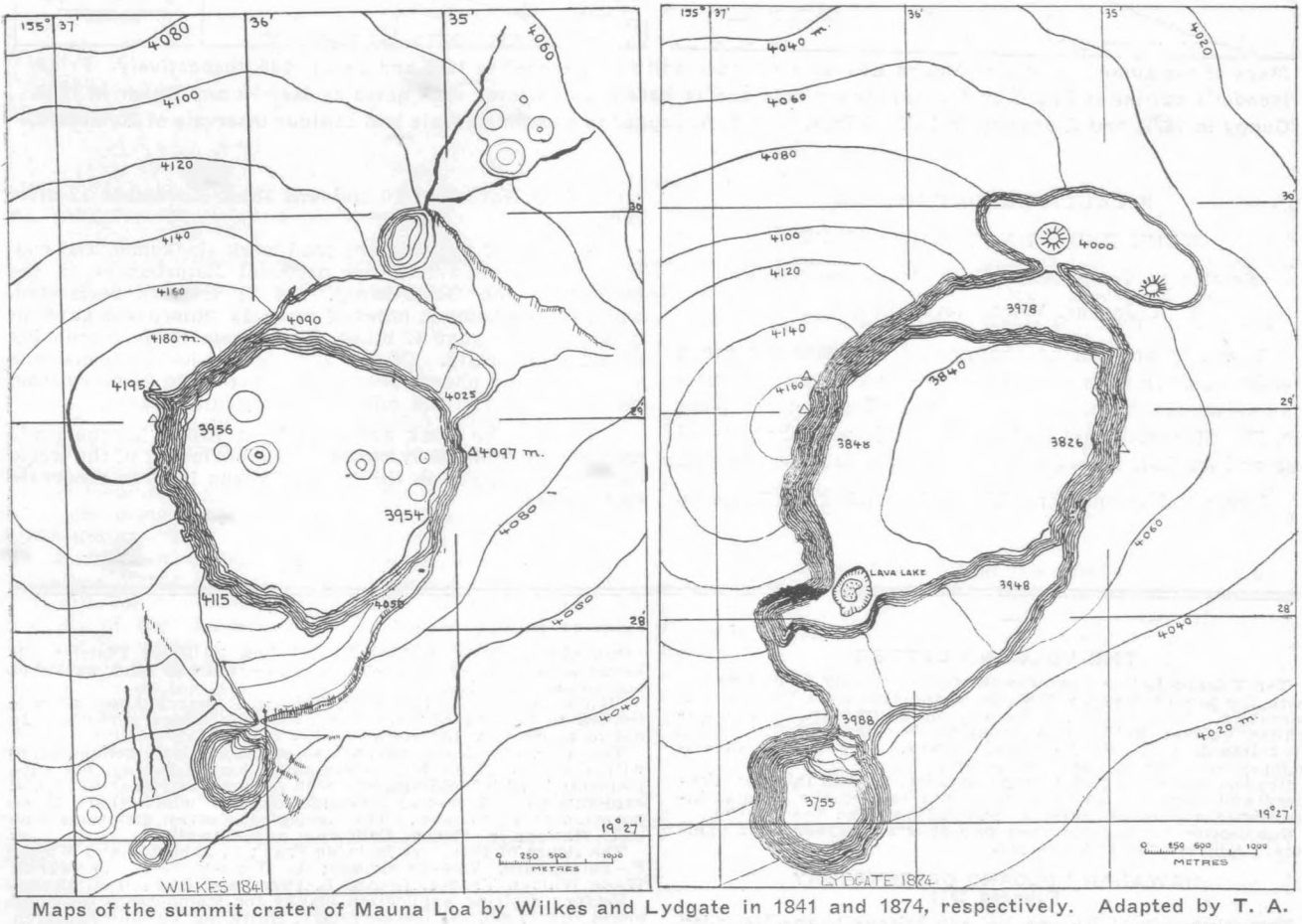
In July 1880 Brigham reported at Mokuaweoweo fresh lava spread over the central floor, obliteration of the inner walls of the lunate platform, talus suggesting recent earthquake, and a lava flow away from the crater on the southwest rim which came from fissures near the brow of the cliff. The flooding of the summit crater with lava from 1872 to 1876 was accompanied by repeated lakings, crater flows, and fountains, and no recorded outflows, except that in 1877 there was a submarine lava flow at Kealakekua Bay. The lava flow of 1881 produced 68 linear kilometers of streaming, starting in November of 1880 after summit effusions in the spring of that year, and taking its origin on the northeast rift 10 km. ENE. from the north embayment of Mokuaweoweo and 3350 meters above sea level. There is a large pit crater where this flow emerged, and the lava divided into two streams, one flowing towards Kilauea. the other towards Mauna Kea, and this latter again divided and its longer arm reached Hilo after nine months of activity.

Alexander in 1885, eleven years after Lydgate, mapped great changes of building up. The south pit was smaller, filled by lateral inflow from wall fissures and from the gateway. The south lunate platform had less relief and was smaller. A fresh lava flow had poured across the platform into the south pit and lava cataracts from cliff-edge fissures had flowed onto the platform. The main floor

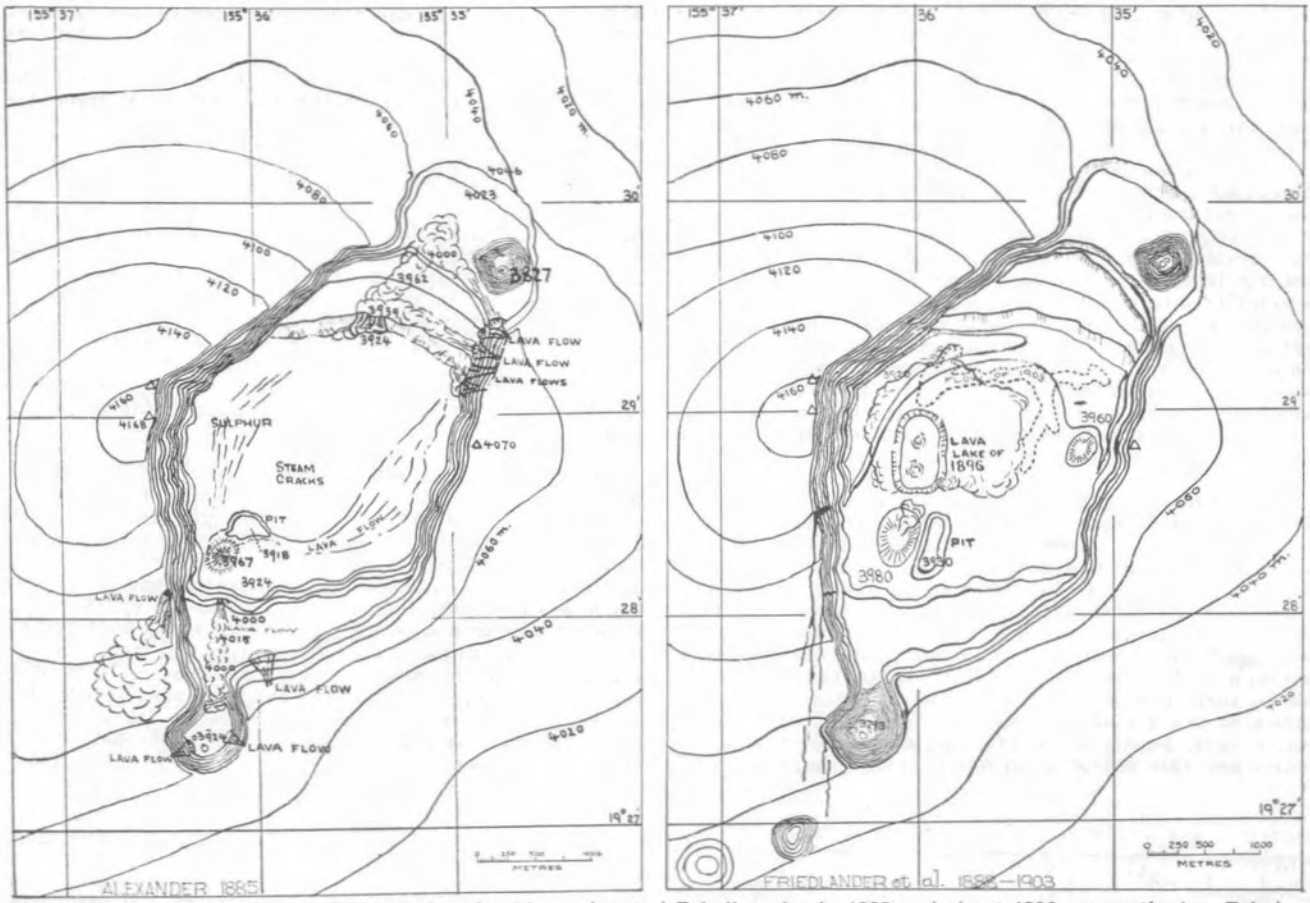
had been built up to new high levels from a vent in the southwest corner. This vent migrated northward 600 meters after 1874; the lava filled 100 meters of depth on the north and east, 80 meters on the west, and 40 meters on the south. The floor apparently sloped away to the northeast from a lava lake at the south just as at Kilauea. The walls had changed, but the northwest angle at the high summit remained the controlling feature of the crater. Alexander saw vaporing from hundreds of cracks in the floor, from the cone at the southwest corner, and from the wall fractures at the heads of the lava cataracts. The floor cracks were streaked with sulphur, the cone was of hot friable lava and pumice 43 meters high, north of it was a solidified lava pool surrounded by a rim six meters high, and the lava of the greater crater floor was pahoehoe. The north lunate platform was overflowed, the promotories had crumbled back. the northern embayment had changed to become a second and higher platform, the western cone was replaced by a lava flow, and the eastern one by a circular pit 183 meters deep and 305 meters across, with a central cone on its floor emitting vapor.

Wood in 1915 (Am. Jour. Sci. May 1916) describes the changes since 1885 as a building up of the floor, submergence under lava of the lunate platforms, and as products of the floor eruption of 1903 a central cone and lava flow, with a NNE rift east of it representing the fresh cones of 1914. The lava flows of 1914 on the floor had covered large portions of the two platforms and the central cauldron. Wood mentions blade lava of extraordinary quality unlike anything in Kilauea, the blades characterizing the texture of the surface of both pahoehoe and aa. Stearns in 1924 indicates the geology of the crater as distributing fresh recent lava, mostly since 1832, all along the line of the crater pits, this widening out into fans of flows at the NNE and SSW slopes of the mountain. He mapped fissures, spatter cones, cinder cones, pit craters, faults. water and ice holes, trails, and fumaroles. The principal scene of eruptions in Mokuaweoweo is a fissure zone about one and one-half miles long extending northeastward from the southwest side of the main crater, and along this zone lie chains of cones. The 1914 cone stands in the southwest part of the floor 100 feet high, is still steaming, and southwest of it is a small crater which contained the lava lake of 1903. Hot yellow pumice lies northwest of it in a field from which dense, blue, sulphur fumes ascend. North of this is a depression 15 or 20 feet deep covered with pahoehoe having islands of aa. Heat radiates from cracks in the floor and rim of this craterlet. Northeast of it is a line of driblet and pumice cones 10 to 75 feet high. The large cone of 1903 near the center of the greater crater, has the remains of another lava lake near it with a hot solfatara west of this lake which is depositing crystalline sulphur. This large 1903 cone lies west of the fissure of 1914.

The fissure zone passes across the south platform up to the rim of the caldera and may be seen in the crater wall. On the rim 200 feet above the platform is a small driblet cone and the lava actually shows as a dike in the cliff below. Southwest from the crater rim is a line of driblet cones which poured out lava that cascaded over the vertical wall of the caldera and spread out on the floor, showing that lava was being extruded on the floor and on the cliff above at two levels different by 300 feet. According to the map by Stearns, which is based on Wingate's topographic map, the country rock east and west of the crater is older basalt showing explosion debris in two marked accumulations northwest and southeast of the central cauldron. T.A.J.



Maps of the summit crater of Mauna Loa by Wilkes and Lydgate in 1841 and 1874, respectively. Adapted by T. A. Jaggar to a common scale and contour intervals of 20 meters. Lydgate's map supplemented by notes of Hall in 1873 and Brigham's discussion of 1880. Lydgate's summit elevation adopted from Alexander in 1875.



Maps of the summit crater of Mauna Loa by Alexander and Friedlaender in 1885 and about 1896, respectively. Friedlaender's outline is based on the Alexander map and is here supplemented with notes by Merritt and Baker in 1888, Guppy in 1879, and Ridgeway in 1903. Adapted by T. A. Jaggar to a common scale and contour intervals of 20 meters.

KILAUEA REPORT No. 1034

WEEK ENDING NOVEMBER 15, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The only noteworthy changes, at Halemaumau are a steady tilt away from the pit, as indicated by the Halemaumau seismograph, and continuous widening at crack point No. 21. Measurements indicate that this point has moved one and one-half inches from October 26 to November 12.

Fume and steam were thin on November 9. Fume increased on November 10 and was thick November 12 after rain.

Because of wet weather road work slackened, and consequently there were fewer artificial disturbances on the records of the Observatory. Of 81 tremors registered, one gave distance 4 miles, 4 gave 15 miles, one gave 18 miles, and one gave 42 miles. Eight tremors were probably of artificial origin. Of six very feeble local seisms, one with indefinite phases showed distance 18 to 28 miles from the Observatory; the others had obscure phases.

Tilt for the week averaged light ESE. Microseismic motion was moderately strong at the beginning of the week, decreased to light on the 14th, and was light to moderate on the 15th.

THE VOLCANO LETTER

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

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The Volcano Letter

Two dollars per year **Ten cents per copy**

No. 361—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | November 26, 1931



Kapele lagoon at east end of Kula fault where a block of land subsided April 21-23, 1924, at the east point of the island of Hawaii. Along with earthquakes and cracking open of the country, this shore line subsided 10 to 12 feet so that these coconut palms, on the date of this photograph, June 9, 1924, and ever since, were submerged with their butts under 8 feet of water. Photo Finch.

PUNA SHORELINE SUBSIDENCE

The Puna District of Hawaii in the vicinity of Kapoho, the east point of the island, was the scene of destructive seismic activity in the spring of 1924. This activity was recorded in Bull. Hawaiian Volcano Observatory April 1924 and in Bull. Seis. Soc. Amer. Dec. 1924. Photographs of the region affected are reproduced in these articles and in the Bulletin of the Observatory for January 1926.

On April 21, 1924, there began a prolonged mild quaking in the Kapoho district, approximately 88 felt earthquakes were counted, and on April 22 and 23 extensive cracks began to open near Kapoho. About 20 pronounced chasms were mapped by an Observatory party. Leveling surveys were run along the railroad by Superintendent Boles of Hawaii National Park, and these indicated a new profile 9 feet lower than before, south of the quarry at Kula, and one foot lower than before at Kapoho station. The block of country between the Kapoho hills and the Kula fault where the greatest downthrow occurred sank in varying amounts from one foot to over 11 feet. At the ocean end of the Kula fault a new lagoon running 200 feet inland was formed, and coconut trees were found standing in 8 feet of water (see cut Page One).

The earthquakes were quite localized and were not felt in Kalapana, about 12 miles to the southwest, nor were any changes in elevation or cracking of the ground noticed in the country south of Kapoho.

Reports, however, have come from time to time during the last few years to members of the Observatory staff of a gradual subsidence of the Puna coast as far south of Kapoho as Kaimu and Kalapana. After a recent conversation with Mr. Henry Lyman of Kapoho, a trip was made through the Puna District for the purpose of verifying, if possible, these reports and gathering further evidence, as well as for locating likely points for future observation and measurement.

The trip was made November 12, 1931, and residents were interviewed at Kapaahu, Kalapana, Kaimu, Opihikao, Pohoiki, and Pahoa; Mr. Richard Lyman of the last place gave information concerning Kapoho and the general conditions of the district. The following was the evidence from different places:

Kapaahu, Kalapana, Kaimu;

Four families were interviewed. None had noticed any change in shore elevation. The washing of waves over the black sand beach and piling back of the sand was thought to be the result of changing currents and unusually high waves. A mark was placed at Punaluu Pond in Kapaahu, and this will be observed from time to time.

Opihikao;

Only one family found at home and these proved to be newcomers.

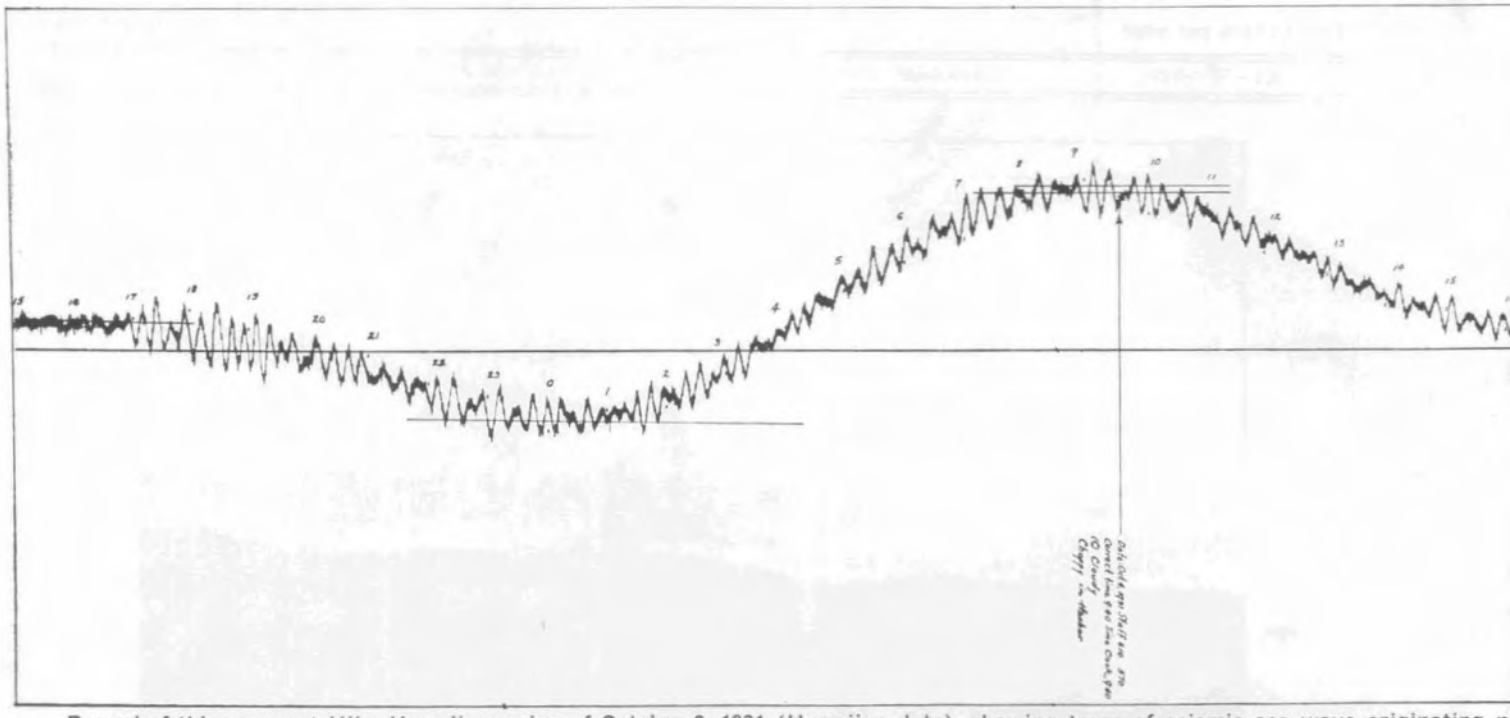
Pohoiki;

One family named Mioi was interviewed. They state as common knowledge in that district that the land has lowered, but are certain that the drop took place during the Kapoho earthquakes of April 1924. They do not connect this tradition with the shore line.

Kapoho;

Mr. Richard Lyman thinks that the sinking occurred entirely at the time of the destructive earthquakes of 1924.

Kapoho crater was visited and it was found that the



Record of tide gauge at Hilo, Hawaii, evening of October 3, 1931 (Hawaiian date), showing trace of seismic sea wave originating n wave something over 8 hours. The range of the wave movement shown at the beginn

middle one of the three pit craters which formerly had a moderate sized pond with water lilies, had gone practically dry. This is due probably to an unusually dry year. Puu Kukii, which in 1922 was covered with growing cane, is now overgrown with guava except where the 1924 disturbance left a bright red scarp. The Kula fault and Koae were also visited, but showed nothing new.

The investigation indicates that probably shore subsidence has extended from Kula as far south as Pohoiki and perhaps Kaimu, and that this subsidence occurred all at once in 1924 and is not a continued slow movement. The down-faulting corresponds on a smaller scale with that of 1868 in this same district (see Memoirs Bernice Pauahi Bishop Museum Volume 2 No. 4 1909). E.G.W.

Erratum

In Volcano Letter No. 359, Page Four, map of Soufrière Crater, the scale is 0.64 inch to the mile, and contour interval 100 feet. In Volcano Letter No. 360, Page Four, line 8, read "crack point No. 25."

EARTHQUAKE AND SEA WAVE OF OCTOBER 3, 1931

On the morning of October 3 the seismographs of the Hawaiian Volcano Observatory showed the record of a big earthquake somewhere, and indicated that possibly a seismic sea wave might arrive at the shores of Hawaii. On October 22 the London Times reported that a severe earthquake occurred on October 4 (the equivalent of October 3 in Hawaii on the western side of the date line) in the central and eastern areas of the British Solomon Islands. The damage was not serious in the central part of the group, but in the island of San Christoval the earthquake was followed by a seismic sea wave which destroyed 18 native villages with a loss of life estimated at 50. The center of the disturbance was believed to have been in the vicinity of Rennell Island, one of the southernmost of the group.

"The British Solomon Islands protectorate consists of the southern islands of the Solomon group, lying to the southeast of New Guinea. The native population is estimated at 150,000, and Europeans and Asiatics between 400 and 500. The principal articles of trade are copra, green snail, and trochus shell, ivory nuts, pearl shell, and tortoise shell.

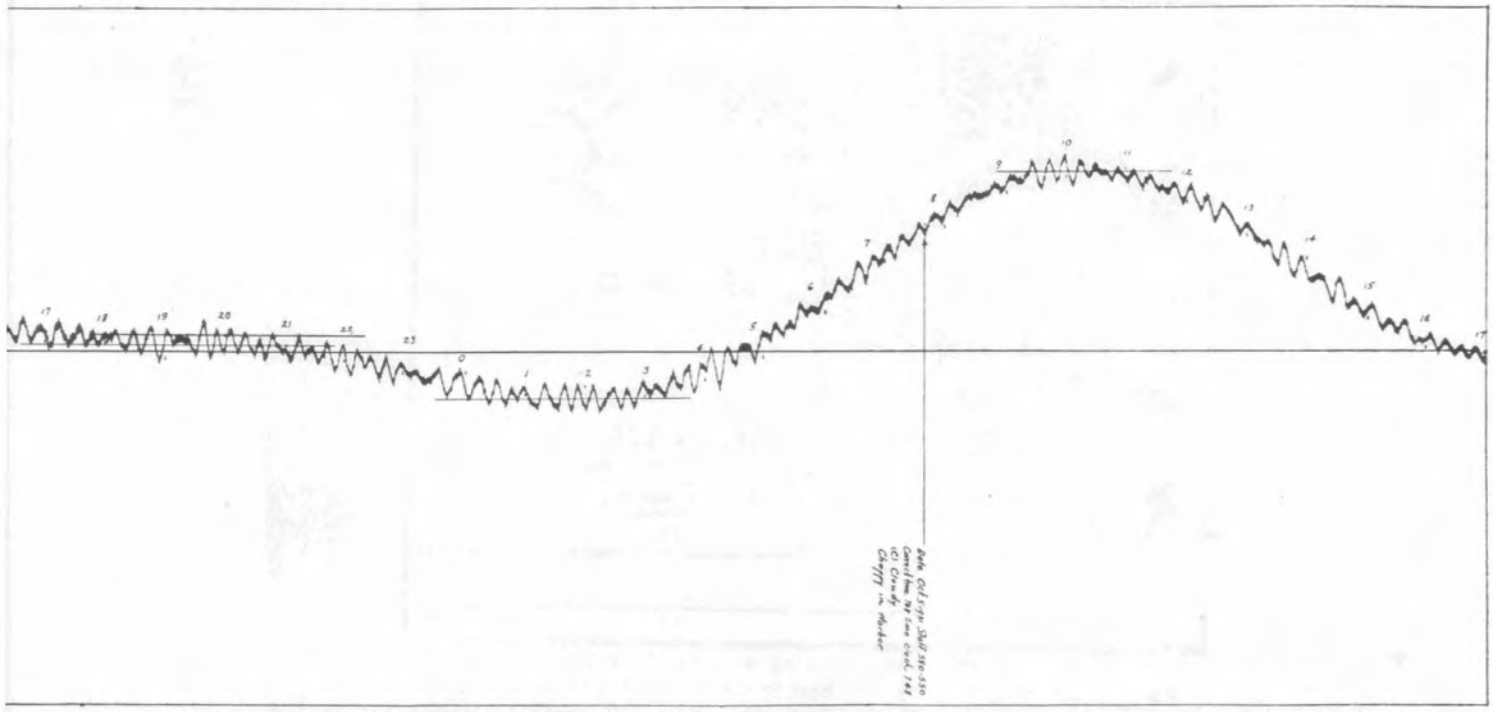
"The earthquake was recorded by instruments in England, Italy, Australia, and New Zealand," and all around the Pacific. It was a world-shaking earthquake of great energy.

The primary or P wave of the earthquake arrived at the Hawaiian Volcano Observatory at 8:52:06 a. m. Hawaiian standard time. The secondary or S wave arrived at 8:59:35 a. m. The interval was 7 minutes 29 seconds which by the tables indicated 3680 miles as the distance to the origin. The indicated time of occurrence was 9 minutes 27 seconds prior to the arrival of the first preliminary wave, which would make the big earthquake at the source region 8:42:39 a. m. by Hawaiian time.

For some little time we expected a sea wave, but nothing arrived sufficient to excite notice without the aid of the tide gauge. As the velocity of such an ocean wave has been found to be about 450 statute miles an hour, it should arrive about 5 p. m. of the same day. It should take a little over 8 hours to travel to the Hilo tide gauge.

By an inspection of the records the direction of the earthquake origin was found by the direction of the first disturbance of the pendulums to be approximately northeast or southwest 3680 miles from the island of Hawaii. To the northeast the origin would be in the center of North America and accordingly there would not be a water wave. To the southwest the origin would be off New Zealand or New Caledonia and there should be a sea wave. As there were a number of shielding island chains in that direction, and from what we know by previous experience here, it was decided that a wave would likely be damped out by their shielding action, and in any case not be dangerous. Accordingly no warning was sent out.

Later findings verified these rough estimates. The Coast and Geodetic Survey announced the first tentative location of the earthquake center as latitude 14°south and longitude 160°east, and the time of occurrence as 8:42:48 a. m. H. S. T. The Jesuit Seismological Association gave a second tentative epicenter as latitude 10° south, longitude



ar the Solomon Islands in a large submarine earthquake. The earth wave took about 9 minutes to reach Hawaii, and the water ng of the disturbance is about 6 inches on the tide staff at Pier One, Kuhio Wharf.

161.4° east, and the time of occurrence as 8:43.10 a. m. H. S T.

These placed the epicenter in or near Solomon Islands. The report above quoted verifies this and announces a big tidal wave.

The tide gauge in Hilo bay on the east side of the island of Hawaii shows that the waves began to arrive within 3 minutes after 5 p. m. October 3 H. S. T. The water in the bay rose and fell every 15 minutes for the next 48 hours. The rise and fall averaged about half a foot total range and the motion was so slow as not to be noticed by the casual observer. The record, however, is plainly shown on the marigram (see cut Pages Two-Three), and the very long duration of it is unusual. There was first a lowering of one-quarter of a foot followed by a rise of three-eighths of a foot, with somewhat irregular seiches thereafter for two days.

These waves are so flat that they can not be seen on the open ocean. Since they travel at the rate of 450 statute miles an hour, and 15 minutes apart, they will measure 112 miles from crest to crest, and being less than half a foot high on the open ocean they are not perceptible.

Such seaquake waves in the water, or tsunamis as they are technically called, have been known to continue even for two or three days with slowly diminishing amplitude (Dutton, Earthquakes, page 280). In R. M. Wilson's account (Bull. H. V. O. XVI June 1928) of a tidal wave arriving at Hawaii from the coast of Mexico, the maximum risings exceeded a foot, and there were several recurrences of the smaller waves at intervals, the whole lasting for 24 hours.

In this sea wave of October 4, 1931, the oscillations lasted for 48 hours. There are several ways to account for this long endurance of water disturbance, for some sea waves last only a few hours. There may be reflections or echoes from the coasts near the origin of the earthquake, which would have the effect of adding to the number of wave trains. In this case the waves, large at the source, may have broken up into numerous small ones by the groups of islands and shallows that they pass through. Again, a large body of water, such as is inclosed in any bay or small sea, if once set in motion is very slow to stop and would vibrate in its natural period for a long time after being disturbed. It is difficult to say in what proportions these possible causes affect the lengthening of the record. (See Bull. H. V. O. March 1928, Monthly Weather Review March 1924, and Volcano Letter No. 274 March 27, 1930.)

A.E.J.

KILAUEA REPORT No. 1035

WEEK ENDING NOVEMBER 22, 1931

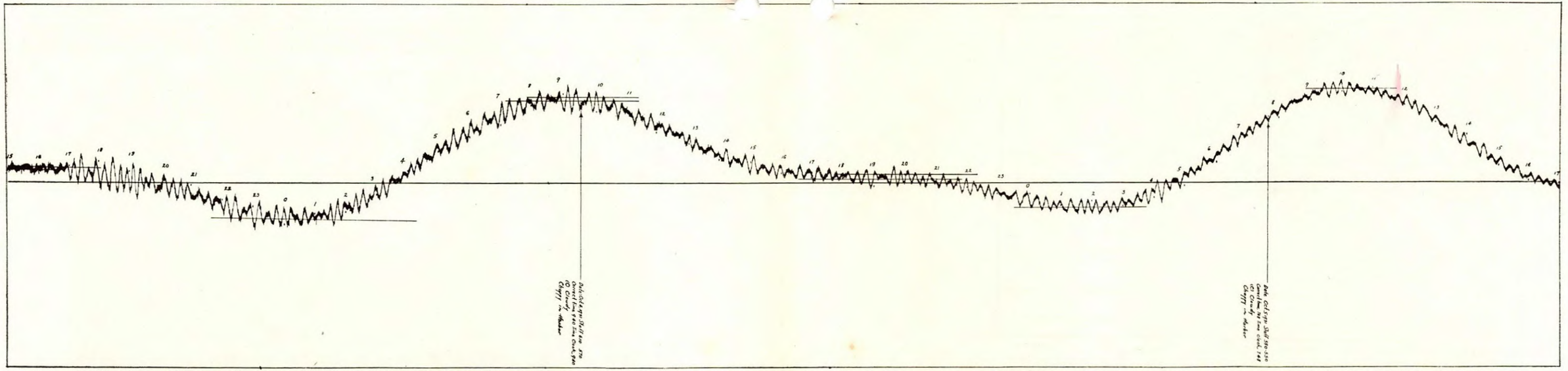
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

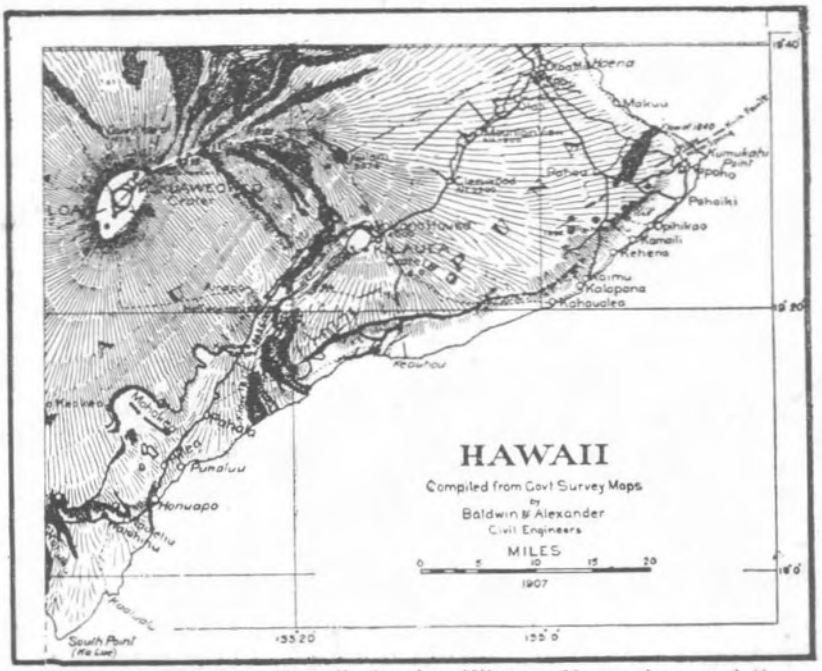
Kilauea continues inactive. Halemaumau pit shows no significant changes, the fume and steam on the floor varying in visibility according to the temperature and the amount of recent rainfall. A few rocks were observed falling from the northeast wall on the forenoon of November 18. Crack point No. 25 shows a widening of the rim fissure here ⅝ inch between November 12 and November 20, 1931. On November 20 new fallen fine debris was seen on one of the northern taluses. The crack above mentioned is where the rim is breaking down at the northeast by adjustment of the pit circle where a year ago there was heavy avalanching and excessive cracking back of a very precipitous part of the wall.

Artificial disturbances were fewer on the records of the Observatory. Fifty-one tremors were recorded, four of which indicated approximate distances of from 40 to 60 miles. On the 19th occurred part of a teleseism without definite phases. A feeble seism at 6:46 p. m. November 22 was felt locally. Its epicenter was 5 miles from the Observatory. At 5:10 p. m. a very feeble seism was registered with a distance of about 12 miles.

Tilt for the week was slight NE. Microseismic motion was moderate, becoming strong at the end of the week. The tilt or ground movement indicates a quiet condition. What slight tilt has occurred can be attributed to seasonal effects. The number of recorded shocks is less than occurred during the preceeding week. The shocks appear to have originated at greater distances than those of last week.



Record of tide gauge at Hilo, Hawaii, evening of October 3, 1931 (Hawaiian date), showing trace of seismic sea wave originating near the Solomon Islands in a large submarine earthquake. The earth wave took about 9 minutes to reach Hawaii, and the water wave something over 8 hours. The range of the wave movement shown at the beginn ing of the disturbance is about 6 inches on the tide staff at Pier One, Kuhio Wharf.



Map of southeastern Hawaii showing Kilauea, Mauna Loa, and the Puna fault cliffs extending northeast to the Kula fault, where the land on the south side subsided in April 1924. The photograph on Page One is looking seaward on the south side of the Kula fault cliff where it enters the ocean.



Black sands of Kaimu beach in November, 1931, showing invasion of the coconut grove and roadway by the sea. The road is being moved back. Photo Powers.

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The Volcano Letter

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No. 362—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | December 3, 1931



New steam vent discovered on south slope of Diamond Peak in southwestern part of Lassen Volcanic National Park. The locality is solfataric but was not known to be steaming prior to the autumn of 1931. Photo taken October 14, 1931, by R. H. Finch, Lassen Volcano Observatory.

CHEMICAL ANALYSES OF KILAUEA LAVAS

One phase of the study of volcanoes which attracts no public attention, but nevertheless is of utmost scientific importance, is the study of the changes which take place in the composition of the lava during the life cycle of a volcano. Geologists may express the composition of a rock either in terms of the kind and amounts of the different minerals which make up the rock, or in terms of the kind and amounts of the different chemical elements contained in the rock. Of course the mineral composition and the chemical composition depend on each other so that a statement of either kind of analysis gives a picture of the composition of the rock. Since an analysis of the chemical composition can be made more accurately and can be expressed in more definite quantitive terms, more attention is paid to determining the chemical composition of different lavas of the important volcanoes which are studied.

Scientists have been studying the chemistry of the lavas of Hawaiian volcanoes for many years. Geologic literature contains first rate analyses of over a hundred different specimens of lava from the several volcanoes of the islands. Part of the work of the Geological Survey is to carry on with this collection of quantitative data. During the past two years, chemical analyses have been made of six different lavas from Kilauea and two from Mauna Loa. These new analyses are given in Table I at the end of this article.

It is obvious that these eight different lavas show very little difference in their chemical composition. Furthermore, the same lavas are decidedly similar in their mineral composition. They all belong to a class of rocks known as basalt. The Hawaiian lavas contain porphyritic crystals of olivine in a groundmass of about equal parts of plagioclase and pyroxene, with glass only in the quickly cooled surface phases (see Volcano Letter No. 348). Not only do the different basalts from Hawaii show a similarity in composition, but they also are remarkably like basalts from other volcanoes in the Pacific islands and basalts from the huge volcanic fields of India, Iceland, and other islands of the north Atlantic, Patagonia. and the Columbia River plateau of North America. This similarity in composition of basalts the world over, together with some other technical reasons, has led many geologists to believe that the whole surface of the earth is underlain by a layer of eruptible basalt of fairly uniform composition. This parent basalt is considered to be the original material of all volcanoes, and the many other kinds of lava with different compositions have all been derived from this basalt by some process of differentiation. The average of 16 analyses of Kilauea basalts, and the average of several other types of this parent basalt, are given in Table II.

The different lavas from Kilauea do not show any great variation from this average basaltic composition. That would mean that no great amount of differentiation has taken place in the lavas during the life of the volcano. This should logically be the case when we consider that Kilauea is a relatively young volcano and probably has lived only part of its normal life cycle. The same is true of Mauna Loa, and the lavas from the present active Mauna Loa do not show very much variation in their composition. It is in the older volcanoes of Hawaii which have completed their life cycle that we would expect to find the greatest change in composition of the lavas, and such is the case. The lava of Puuwaawaa is almost true pumice and obsidian with a chemical composition of trachyte (62 per cent silica, 12 per cent alkalies soda and potash). Also many flows on Kohala and Mauna Kea approach trachyte in their chemical composition.

One of the many problems confronting us is to determine, if possible, how and why this change in composition takes place. The most alluring reason for desiring a solution to this problem is that gold and many other precious metals are associated not with basaltic rocks but with rocks, like the above, which approach a granite in chemical composition. It thus is essential to understand the origin of these ore-bearing rocks in order to learn more of the origin of the valuable ores themselves.

TABLE I

Lavas, Hawaii

1. Olaa. Mauna Loa aa flow, road cut on government road at south boundary of Waiakea Forest Reserve. Analyst J. J. Tahey.
2. Reservoir. Mauna Loa pahoehoe flow, from reservoir at Piihonua. Analyst J. J. Tahey.
3. Quarry. Kilauea pahoehoe flow, National Park quarry, on Hilo road one mile from Observatory. Analyst J. J. Tahey.
4. 1917 Halemaumau. Splash from lava lake. Analyst J. J. Tahey.
5. 1919 Halemaumau. Splash from lava lake during eruption of Alika flow from Mauna Loa. Analyst J. J. Tahey.
6. 1919 Halemaumau. Pahoehoe flow NE edge of floor of Kilauea Crater. Analyist, J. J. Tahey.
7. 1921 Halemaumau. Pahoehoe flow S edge of floor of Kilauea Crater. Analyst L. T. Richardson.
8. 1929 Halemaumau. Scoria from lava fountain. July 1929. Analyst R. E. Stevens.

	1	2	3	4	5	6	7	8
SiO_2	50.41	52.14	51.35	50.14	50.37	50.52	50.85	51.00
Al_2O_3	12.37	13.60	13.36	13.93	14.20	13.85	15.30	13.03
Fe_2O_3	1.94	2.31	1.32	0.57	1.28	0.98	0.28	1.83
FeO	9.56	8.80	9.85	10.07	10.10	9.77	10.42	10.02
MgO	7.68	7.26	7.62	8.25	7.75	7.07	7.80	6.76
CaO	12.56	10.14	10.74	11.17	11.24	11.33	11.45	12.40
Na_2O	1.68	2.02	1.93	1.29	2.20	1.51	.70	2.02
K_2O	0.40	0.48	0.50	0.41	0.56	0.47	.58	0.73
H_2O+110° C.	0.22	0.16	0.29	0.03	0.06	0.04	.18	0.35
H_2O—110° C.	None	0.06	none	none	none	none	trace	none
TiO_2	2.26	2.20	2.50	3.20	2.33	3.63	1.55	2.33
P_2O_5	0.57	0.29	0.28	0.23	0.02	0.22	.22	0.14
Cr_2O_3	0.05	0.02	0.03	0.07	0.05	0.06	.05	0.008*
						less than		
NiO	0.004	0.005	0.025	0.002	0.008	0.001	.002	trace
MnO	0.06	0.07	0.07	0.06	0.14	0.14	.10	0.18
	99.76	99.55	99.86	99.42	100.31	99.59	99.48	100.80

*Quantity of sample insufficient.

TABLE II

	K	D	O	T
SiO_2	49.9	50.6	50.0	47.5
Al_2O_3	12.7	13.6	13.7	13.9
Fe_2O_3	1.45	3.2	2.4	3.6
FeO	10.0	9.9	11.6	9.4
MgO	9.9	5.5	4.7	6.8
CaO	10.5	9.5	8.2	9.8
Na_2O	2.0	2.6	2.9	2.9
K_2O	.45	.7	1.3	1.0
TiO_2	2.7	1.9	2.8	2.7
P_2O_5	.25	.4	.8	.4
MnO	.12	.16	.24	.22

K. Average of 19 analyses Kilauea lavas. 13 from H. S. Washington, Petrology of Hawaiian Lavas. (Amer. Jour. Sci.)

D. Average of 11 analyses Deccan (Western India) lava. H. S. Washington, Deccan Traps and other Plateau Basalts. (Geol. Soc. Amer.)

O. Average of 6 analyses Oregon basalts, H. S. Washington, Deccan Traps, etc. (Geol. Soc. Amer.)

T. Average of 33 Thulean (Iceland-Britain-Greenland) basalts. H. S. Washington, Deccan Traps, etc. (Geol. Soc. Amer.) H.A.P.

LASSEN REPORT No. 30

NEW DIAMOND PEAK STEAM VENT

R. H. Finch, Asociate Volcanologist

A new steam vent was discovered in the Lassen Volcanic National Park during the early autumn of 1931. It is located just below Diamond Peak on the ridge between East and West Sulphur Creeks. This is in the southwestern part of the park near the new road which crosses the mountain mass. The vent was discovered by National Park workmen, and is shown in the photograph on Page One, taken October 14, 1931. As the steam appeared in a clump of trees, the workmen thought at first that they had discovered a forest fire. Adjacent to the new vent, especially on the slope just below, are old solfataric areas. It appears, however, that there has been no activity in this locality for a great many years. Steam escapes from a small vent in the center of an area over which sulphates, chiefly alum, are being deposited. The temperature of the steam is 198 degrees Fahr. The photograph was taken with a view to making later pictures that will show changes in chemical erosion, etc.

The map shown on Page Four is a reduced copy of the topographic map of Lassen Volcanic National Park surveyed by E. P. Davis and R. G. Stevenson of the U. S. Geological Survey in 1925-26. The new road between Upper Meadow and Helen Lake has been completed since the map was made. Mineral, headquarters of the Lassen National Forest, where the volcano observatory is located, is three miles outside of this map to the southwest. Lassen Volcano is in the middle of the west part of the park, the Loomis Museum (where seismograph No. 2 is located) is at Reflection Lake inside the park northwest, and Mount Harkness (where seismograph No. 3 is in the forest ranger station) is just inside the park at the southeast. Cinder Cone and its lava flows lie between Snag Lake and Butte Lake in the northeast corner of the park. The principal hot and boiling spring areas, and the solfataric deposits, and steam jets which accompany them, are in the south-

western part of the park amid the mountains of the northwestern end of the Sierra Nevada above which Lassen Peak stands as an imposing volcanic cone 10,453 feet high.

R.H.F.

KILAUEA REPORT No. 1036

WEEK ENDING NOVEMBER 29, 1931

Section of Volcanology, U. S. Geological Survey

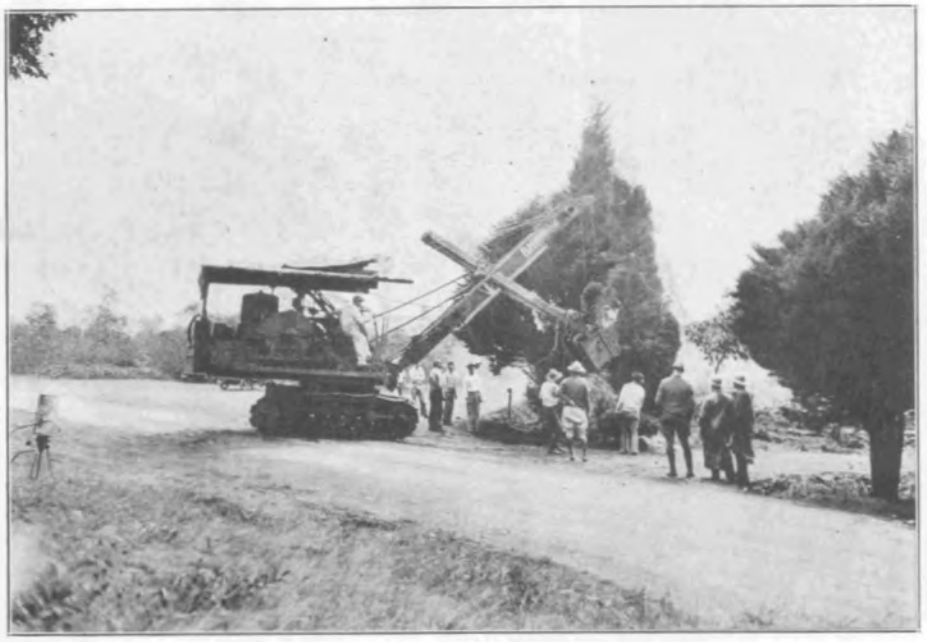
T. A. Jaggar, Volcanologist in Charge

No significant changes in the bottom of Halemaumau pit have occurred. The crack at the northeast edge, No. 25, opened three-quarters of an inch November 20-30. Measurements show a lowering of the rim block adjacent to the crack about one foot between October 26 and November 23. At 10:35 a. m. November 24 an avalanche producing much dust occurred at the northeast wall of the pit under this crack.

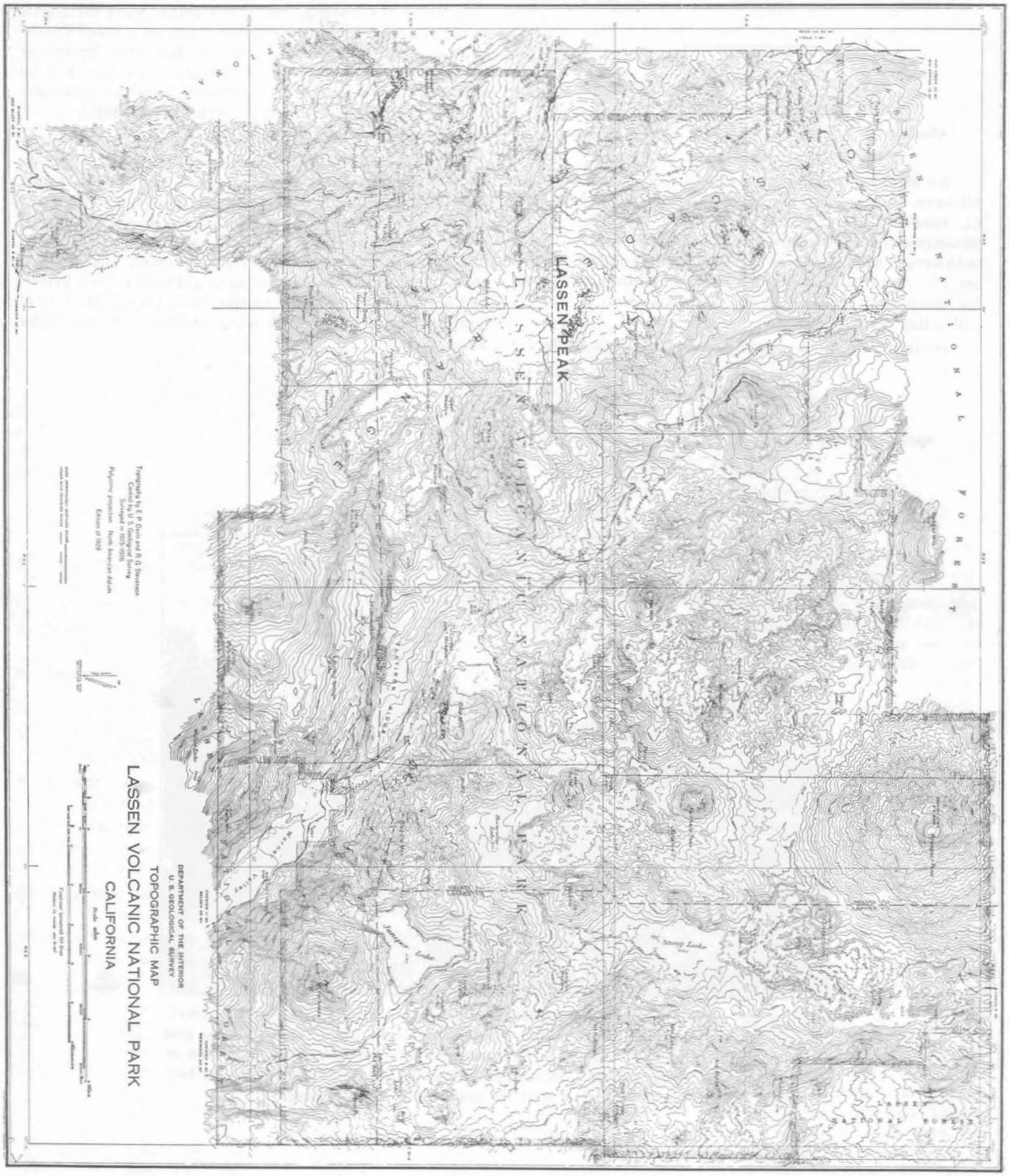
Designs have been drawn and preparations made for rebuilding the seismograph hut at Halemaumau with the cooperation of the National Park Service.

During the week 22 volcanic tremors were registered at the Observatory on the northeast rim of Kilauea Crater as compared to more than 50 of the next preceding weeks. Four gave evidence of distance of origin, one 20 miles, and the others 40 miles. There were two other disturbances possibly of artificial origin, but doubtful.

Two very feeble local seisms were registered, one indicating origin distance about 1 mile, the other about 20 miles. Microseismic motion has been very heavy during the week, probably owing to ocean waves pounding the steep shores of the island, as there has been some strong wind. Tilting of the ground has been very slight NNW. General conditions indicate volcanic quiet, the tremors show about the same distance of origin as the week before, and one of the very feeble shocks indicates origin close at hand, the other far enough away to have occurred under Mauna Loa.



Contractor moving cypress and Japanese cedar trees back from the road front, for purposes of new road construction, Hawaiian Volcano Observatory. Large pits were dug to receive the trees, black fertilizer and loam mixtures were prepared in the pits, and the power shovel with caterpillar treads lifted each trunk with its ball of soil and deposited it at its destination. Photo Jaggar.

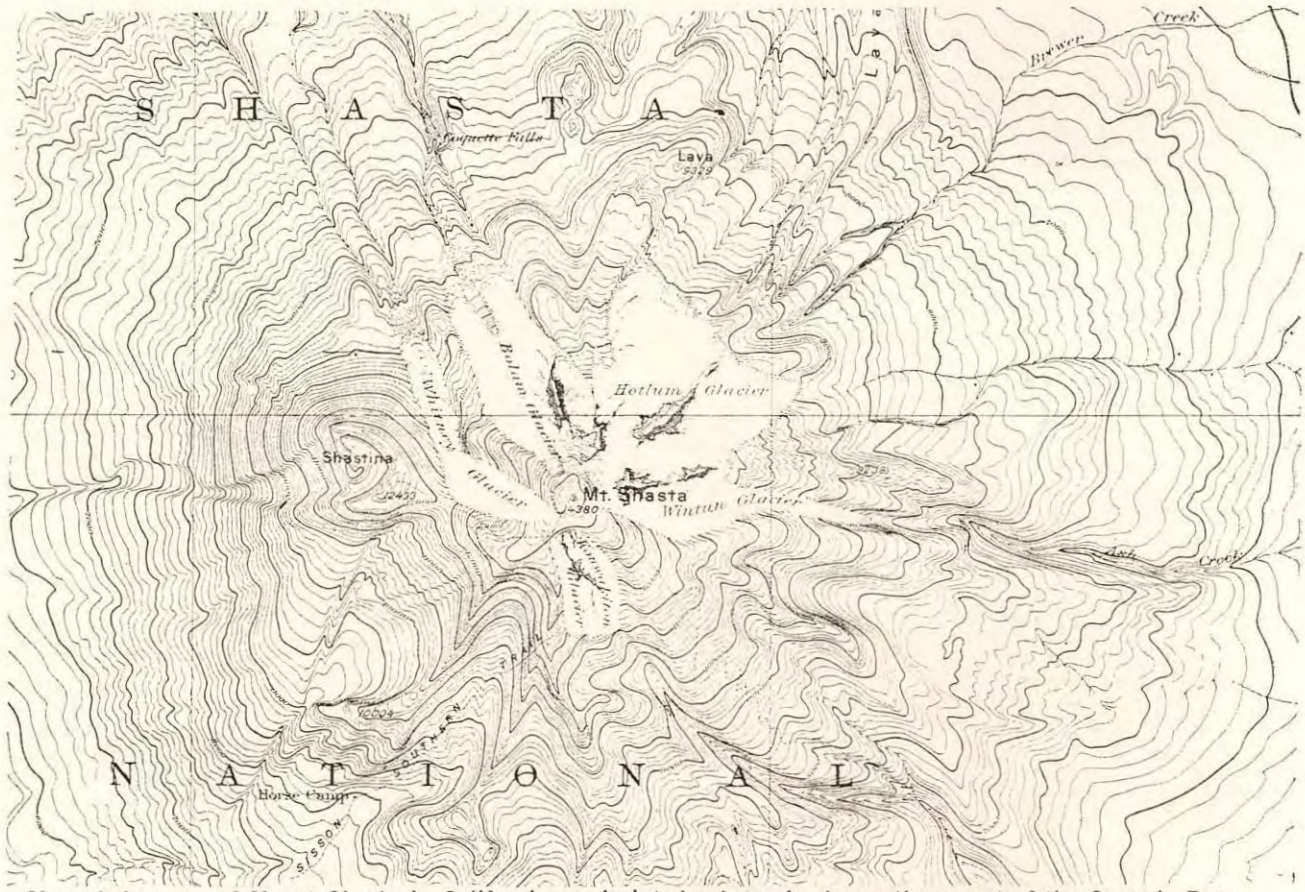


Map of Lassen Volcanic National Park, U. S. Geological Survey 1925-26. Seismographs of the Section of Volcanology are maintained northwest. southwest, and southeast of Lassen Peak, as described in the text.

The Volcano Letter

Two dollars per year **Ten cents per copy**

No. 363—Weekly Hawaiian Volcano Observatory, National Park, Hawaii December 10, 1931



Map of the cone of Mount Shasta in California, an isolated volcano in the southern part of the Cascade Range, with hot springs and steaming vents, and well marked old lava flows about the flanks. Like most of these cones, remnant glaciers surround the summit, which stands 14,380 feet above sea level.

THE ACTIVE AND RECENTLY EXTINCT VOLCANOES OF NORTH AMERICA

Review by G. L. Chang

The most prominent fact brought out by a study of the geographical distribution of volcanoes is that, with but few exceptions, they are mostly situated on the borders of continents or on the ocean's floor.

The volcanoes of North America form a part of a great system of volcanic vents which may be said to surround the Pacific Ocean. This chain of fire beginning in Terra del Fuego extends along the west border of South America, where its course is marked in the Andes by some of the loftiest igneous mountains in the world; it is narrow and well defined on the west border of Central America and far into Mexico, where still steaming craters, some of which are among the highest summits on the continent of North America, define its position. The volcanic belt broadens in the northern part of Mexico and the United States, but is marked by few active craters. Again contracting and approaching close to the ocean's shore, and in several instances marked by island volcanoes, the igneous belt follows the coast of British Columbia and Alaska, and extends westward throughout the length of the Aleutian Islands. Still active craters in Alaska show the positions of earth fractures which unite the volcanic belt of the new world with the still more energetic volcanoes of Kamchatka, Korea, Japan, Formosa, the Philippine Islands, New Guinea, New Caledonia, New Hebrides, and New Zealand. The length of this vast system of active volcanoes, from the southern end of South America about the Northern Pacific to New Zealand, is about 30,000 miles. Within the embrace of the great curve, and rising from the deeply submerged floor of the Pacific, are many volcanic islands and still active craters.

A branch of the western arm of the volcanic system just referred to embraces Java and Sumatra. A corresponding offshoot of the eastern arm is marked by the volcanoes of the West Indies.

It is a matter of observation that the loftiest moun-

tains of a continent face the largest ocean washing its shores. In a similar way it may be remembered from a study of the distribution of volcanoes that the largest volcanic belt in the world embraces the largest ocean. Whether this association indicates an essential or genetic connection between the height of mountains, the prevalence of volcanoes, and the extent of water bodies, remains to be shown.

The volcanic areas of North America form a part of the great Pacific belt, but include an exceptional portion of it, since from central Mexico to southeastern Alaska there are chiefly dormant vents. In this interval of some 4,000 miles, however, there are many recently extinct craters, as well as hot springs and geysers. It is in this break in the chain of steaming craters that the breadth of the volcanic belt is greatest. This coincidence is significant of some subterranean change.

An examination of the map of North America, in which the positions of most of the active and recently extinct volcanoes are indicated, will show that active volcanoes are confined to the western portion of the continent, and for the most part to the immediate border of the Pacific. No volcanoes sufficiently recent to be recognized by their topographic forms occur east of the sharply defined eastern border of the Cordilleran mountain series. The central and eastern portions of the United States, the central, eastern, and northern portions of Canada, and much of Alaska excepting its immediate southern border, are without evidence of recent volcanic activity. No active or recently extinct volcanoes have been discovered in the Greenland region. Iceland, as is well known, is an active volcanic center.

The most recent volcanic rocks in all of the vast region just referred to—east and north of the Cordilleran series and embracing five sixths of North America—are, so far as known, confined to the Atlantic border and occur in the Newark system. They were poured out in part as molten lavas during the mesozoic era, or the middle age of the earth's geological history. Erosion has been so great since the volcanoes from which they came were in activity that scarcely a vestige of the cinder cones or of the mountains they formed now remains. The preservation of such records as still exist is due to the facts that volcanic rocks were buried beneath sedimentary deposits and, for a very long period, so depressed that they were below the ocean's level, and thus escaped removal by erosive agencies.

Still more remote in the earth's history, volcanic eruptions on a grand scale occurred in what is now the Appalachian region and in the Lake Superior basin These ancient volcanoes illustrate the fact that even in the remote past volcanoes were situated on continental borders. When the vents from which the rocks were derived were in activity, the continent had increased but little from its original Archaean nucleus. and the sea occupied the whole of what is now the Mississippi Valley and the northward extension of the same interior basin to the Arctic regions.

The volcanic mountains of the west are nearly all of post-Tertiary age. Some of the lava flows of Idaho, Washington, and California were poured out during the Tertiary and were buried beneath the sediments of great lakes, the date of which is recorded by the fossils they contain.

A portion of the Pacific volcanic belt is only a score of miles wide in Central America, but broadens in the central part of Mexico somewhat abruptly to about 800 miles, and touches both the Gulf and Pacific coasts. A gradual increase in breadth occurs north of Mexico, and in the latitude of San Francisco and Denver it attains its maximum width about 1,000 miles. When followed northward, it again contracts, and in Alaska is as narrow and sharply definied as in Central America. The narrow tapering southern extremity of this volcanic belt curves eastward; its similar northern extremity, which also contracts in breadth towards its extremity, curves westward.

It is in the narrow, curved extremities of this volcanic belt that volcanic eruptions have occurred most recently, and here most of the still active volcanoes of North America are situated. In the broader and less curved central portion chiefly dormant volcanoes occur. (Russell, Volcanoes of North America.)

THE VOLCANOES OF THE CASCADE MOUNTAINS

Review by C. B. Crawford

The Cascade Mountains extend from northern California across Oregon and Washington. Lassen Peak is situated at the extreme southern end of the range; the northern extremity extends past Mount Baker into British Columbia. This range, 500 miles long and 50 miles wide, runs parallel with the Pacific Coast about 120 to 200 miles inland, and its peaks rise 5,000 to 14,000 feet above sea level. The eastern border shows monoclinal structure due to the tilting of fault blocks. Russell suggests that the lava composing the Cascade Mountains, more especially in Washington, is an extension of Columbia lava, which was poured out in successive sheets and afterwards broken, and the blocks thus formed tilted at various angles. However, they are not wholly composed of lava; there are Tertiary rocks of unknown age beneath the lava which have been raised and tilted by the same disturbances. Much of the northern portion of the range is free from lava, the rocks being largely granite and schist, showing that the range as a whole is not of volcanic origin.

The great volcanic peaks hereinafter discussed are of a later date than the uplifting of the main Cascade Range, and owe their origin to the escape of molten material through fractures which were formed at the time of the disturbances. The conclusion that these peaks are of volcanic origin rests in some instances on their general appearance and their occurrence in a volcanic region. None of them is an example of very fresh volcanic activity with the exception of Lassen Peak. Most of these peaks have craters at their summits or on their flanks. They are for the most part the result of Tertiary eruptions and have been modified by erosion, have developed glaciers, and dominate the neighboring mountains.

Mount Shasta is probably typical of the peaks of the Cascade Range. It is a volcanic mountain which has suffered from erosion caused by streams and glaciers. It is 14,380 feet above sea level and its summit is 4,000 feet above the timber line. Small glaciers are still present on its sides. On the west end, 2,000 feet from the summit, is a cone with a crater in its top known as Shastina. On the lower slopes are similar craters, some built of cinders. some of lava. The mountain itself is composed of lava flows with a minor quantity of scoria. On the flanks of Shasta are well defined lava streams which still retain their original rough surface. The longest and most copious of the more recent streams that flowed from Mount Shasta started at an elevation of 5,500 feet. This stream divided into two branches, one of which was 12 miles long. The other entered the canyon of the Sacramento River and reached a distance 50 miles from its source before it cooled. This stream is of ancient date as is shown by the erosion the river has been able to perform in making a new gorge 100 feet deep through the flow. These lava streams, however, show no evidence of having been glaciated, and are considered as being of more recent date than the time when the glaciers starting from the summit reached the plain below; they are subsequent to the glacial epoch. Besides the two principal vents, there are numerous subsidiary ones. There is no history of eruption within memory of man.

Lassen Peak, the most recently active volcano in continental United States, is 10,453 feet above sea level at its summit and marks the terminus of the Cascades. The Lassen Peak district is crossed from northwest to southeast by a belt of volcanic cones about 50 miles long and 25 miles wide. The Cinder Cone is closely connected with Mount Lassen and shows at least two periods of eruption separated by a time sufficiently long to allow 10 feet of infusorial earth to accumulate on the ancient bottom of Lake Bidwell. The first period was one of explosive eruptions which formed the Cinder Cone and ash field; the second of quiet effusion of a large mass of lava. The whole aspect of the Cinder Cone is new, but the evidence demonstrates that the earliest eruption occurred before the beginning of the 19th century. Its age is shown by the relation of the old and new forest trees to the volcanic sand of the first eruption. The living trees grew on the top of the sand but the dead ones were standing at the time of the eruption and grew from the soil beneath the sand. This evidence was thought by Russell to show that the first erup-

tion occurred some 200 years ago and the second more than 75 years ago. The most recent activity occurred 1914-1917 at Lassen Peak in the form of an explosive eruption. Ash was thrown out and large steam clouds were observed. The crater floor was upheaved, rough lava overtopped the rim, and an explosion hole 1,000 feet in diameter was formed. These eruptions were accompanied by blasts from the crater which leveled trees in their path.

The history of Mount Pitt in southern Oregon is similar to that of Shasta. It forms a beautifully regular volcanic cone which shows the remnant of a crater at the summit.

Mount Hood, 11,225 feet above sea level at its summit, is in northwest Oregon. Its summit retains only a portion of the crater walls. In 1888 it was reported that there were still fumaroles on the northeast slope and steaming rifts on the side near what is known as Crater Rock. Sulphurous fumes were very strong. A peculiar phenomenon was noticed in the occurrence of a fumarole in the deeply snow-filled crater. Mount Hood was reported in eruption in 1859 and 1865 (Jillson, Geog. Review, June 1917). A resident reports there was fume from Mount Hood the whole summer about 1886.

Mount Adams, 30 miles north of the Columbia, is deeply truncated at the summit and its slopes are scarred. It is very broad—possibly due to the great size of the original crater, or possibly to the blowing away of the top. Authentic history is unavailable, as it has not been much studied. It has radiating glaciers.

Mount St. Helens (9,671 ft. high) is of regular conical form, which suggests that it may be younger than Mount Adams. Reports of frontiersmen say that it was in activity in 1841-42. There is apparent from a distance the track of a lava flow which cut its way through the forest for miles. There is also discernible a lava flow northward for about 20 miles through the timber. This flow left many interesting tree molds in its path. When the last flow took place the lava appears to have passed over wet places or areas where the steam generated escaped at the surface leaving what are termed "blow-holes."

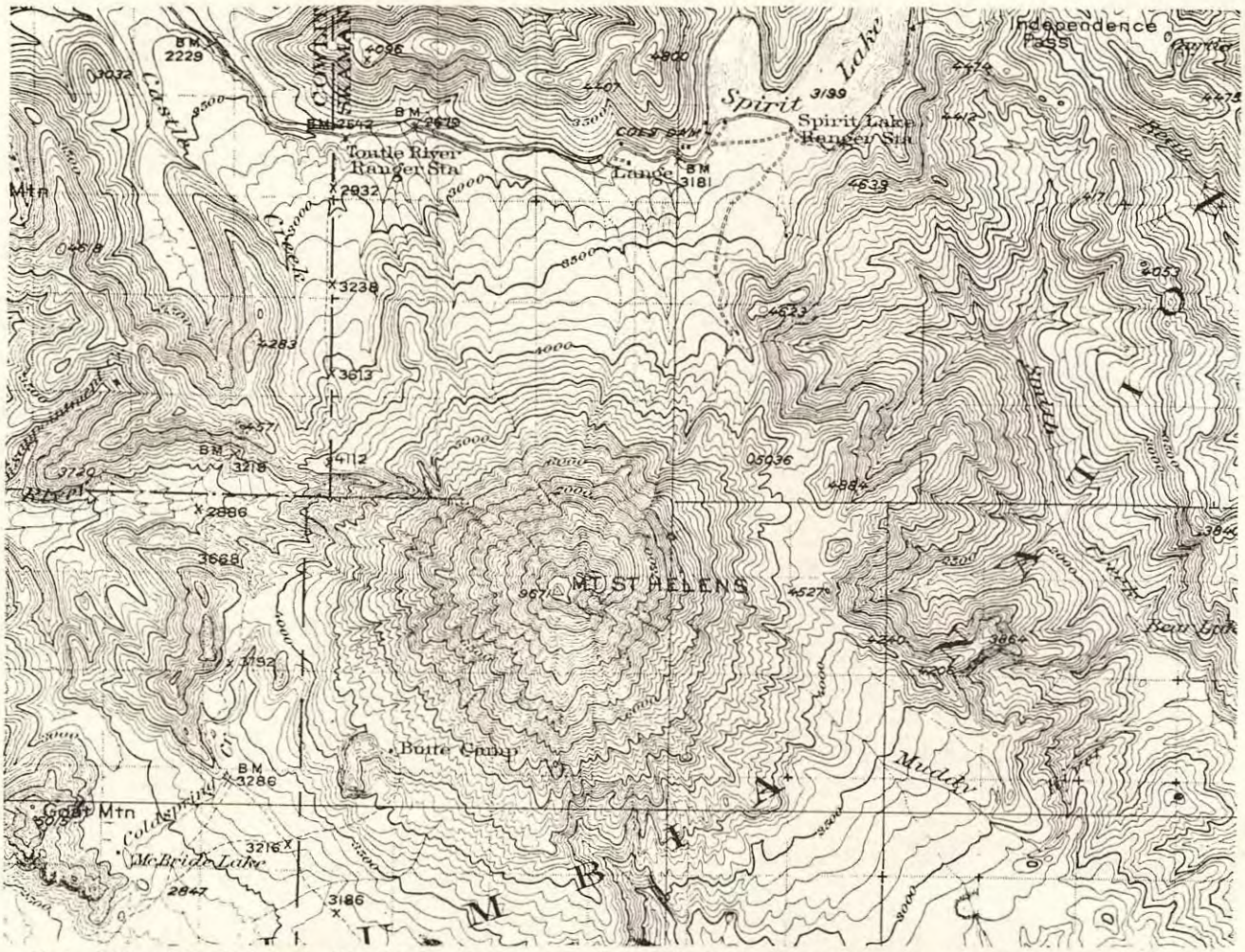
Mount Rainier has a bowl-shaped crater almost circular in form and now filled with snow. Adjoining it are the remains of an earlier crater in the interior of which the more recent one has built itself. There are exposed areas of black lava free from snow which show evidence of internal heat at no great depth below the surface. Countless small jets of steam and gas are present around the interior rim of the crater. No recent eruptions are recorded.

Mount Baker is the most northerly of the volcanic mountains of the Cascade Range south of the Canada line. (See Volcano Letter No. 334 for British Columbia volcanoes.) Little can be said of the history of Mount Baker. The summit is broken, whether due to erosion or volcanic explosions can not be said. Indians state that an eruption occurred about 1843 sympathetic with that of Mount St. Helens, and covered the whole country with ashes, and that the waters of the Skagit River became hot enough to cause the death of all the fish.

Thus the history of the great peaks of the Cascade Range proves to be that of active volcanoes, but now of very slight heat. The history is fragmentary and incomplete. (Largely after Russell.)



Map of the Crater Lake in Mount Mazama at Crater Lake National Park in Oregon, farther north than Mount Shasta. The west rim of this engulfment crater stands 8,156 feet above sea level, and the lake 6,177 feet. The greatest depth of water is 1,996 feet.



Map of Mount St. Helens in Washington State at the Columbia National Forest north of Lewis River. This is a volcano with a record of activity in historic time, elevation 9,671 feet, with radial glaciers, and radial lava flows which have dammed the drainage. Maps U. S. Geological Survey.

KILAUEA REPORT No. 1037

WEEK ENDING DECEMBER 6, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The bottom of Halemaumau remains unchanged, with one fuming sulphur spot and steam on the talus almost absent. Widening continues at a single northeast rim crack where the edge is evidently breaking down. Dust from an avalanche rose at the north rim at 9:08 a. m. December 6.

At the Observatory 24 volcanic tremors occurred, 4 of which indicated origin distances respectively of 2, 4, 46, and 53 miles. Three very feeble local seisms indicated distances of 9 miles for two of them, and 23 miles for the other. Microseismic motion in the middle of the week increased from strong to very strong, and tilting of the ground was moderate ESE.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

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The Volcano Letter

Two dollars per year — Ten cents per copy

No. 364—Weekly — Hawaiian Volcano Observatory. National Park. Hawaii — December 17, 1931



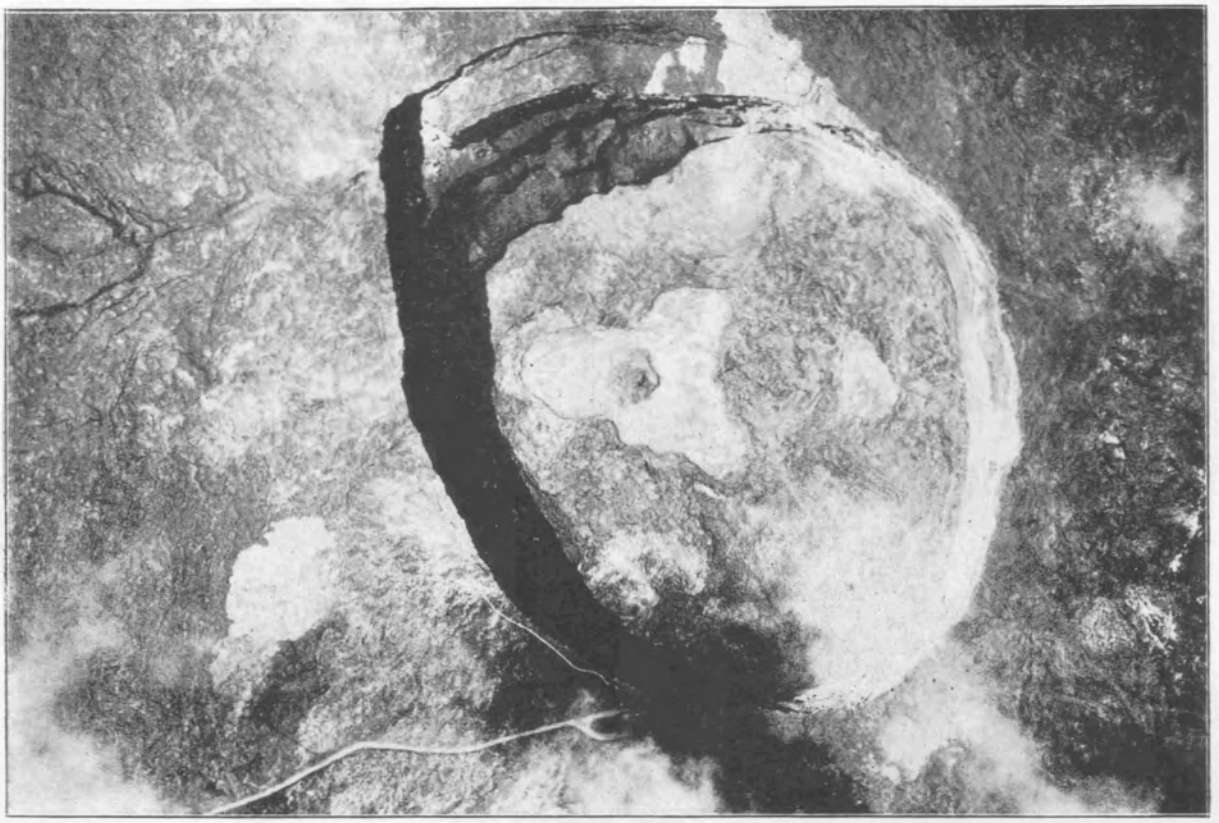
Kilauea Crater 1913 looking north. Showing detail of Halemaumau pit when 1,300 feet in diameter. The outer crack of the Postal Card Rift was the trace of the rim of 1894. There was a subsided shelf at the northeast, and huts were maintained at the north rim by the Hawaiian Volcano Research Association. Photo of Curtis model at Harvard University.

THE CRATER OF KILAUEA

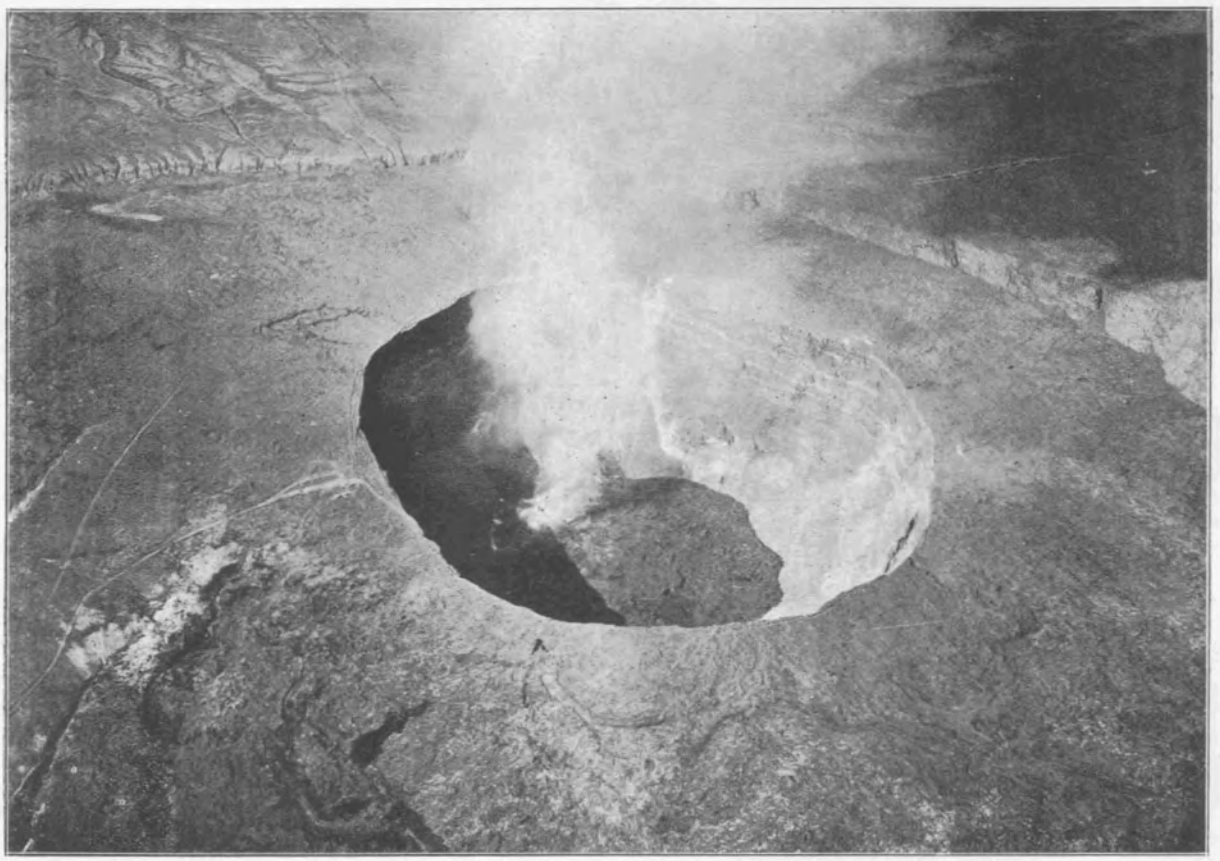
The illustrations of this number are arranged to show the evolution of Kilauea Crater from 1913 to the present time. The cycle 1913-1924 (see Volcano Letters 319, 320, 325, and 326) filled the inner pit, overflowed its rim to build up the floor of the outer crater, and then withdrew the lava, and the inner pit was enlarged by collapse. This 11-year cycle marked for the island of Hawaii the end of a volcanic supercycle of about 132 years, which reached its peak of lava flowing in 1858, and thereafter declined in pulsations of less outflow for both Mauna Loa and Kilauea

Referring to the recently published pictorial review of the evolution of the summit crater of Mauna Loa (Volcano Letter No. 360). it was shown that Mokuaweoweo is the product of merging pits at the angle where two rift lines meet. In like manner the accompanying map indicates that Kilauea Crater has been enlarging by the merging of pits at the angle where two rift lines meet. The rift lines are the southwest Kau Desert cracks that produced the Mauna Iki flows of 1920 far down the mountain flank, and the Chain of Craters fissure that produced flank activities in 1922, 1923, and 1924. The Kilauea angle is almost a right angle shown at the north corner of Kilauea Crater and at the fault cliffs farther north back from the crater's rim. In both Kilauea and Mauna Loa we have to deal with a sector of the mountain flank that has collapsed about its tip at the mountain summit.

The inner pit Halemaumau is the vent that happens to be open near the tip of the sector for the present epoch of activity. Within the last century both Keanakakoi and Kilauea Iki have taken part in this emission and withdrawal of lavas that we call "activity." There were great collapses of Halemaumau in 1840, 1868, and 1886, and in the early part of the 19th century the greater crater of Kilauea was all a large pit with its bottom more than a thousand feet below where it is now. As shown in the contour map, Halemaumau at the peak of the recent cycle was



Airplane photograph of Halemaumau pit November 9, 1923, taken vertically with the sun at the east. The earlier pit had been overflowed in 1919, its rim built up, and then had collapsed to a longer diameter of about 2,000 feet. This diameter is approximately coincident with the Kau Desert rift line trending southwest. Photo 11th Photo Section from elevation 4,000 feet. U. S. Army.



Present pit of Halemaumau 3,500 feet in longer diameter, photographed from the air, looking west, November 25, 1930, during the new activity of that period tending to fill the bottom of the pit. The road terminus is entirely new and 700 feet back of the former one. Compare oval cracked area outside of pit to the south with the same in cut above. Southwestern rim of Kilauea Crater and Kau Desert cracks are shown. Photo Air Corps, U. S. Army, 11th Photo Section.

at the top of a new heap built up since 1886, which had overflowed extensively in 1894, 1919, and 1921. The cut on Page One shows the large outer circle of cracks which had been the pit rim in the early nineties, but was built up by the action of a smaller inner pit in 1894, until the inner heap had overflowed the outer rim, and all that remained of this earlier wall was a scar. The tendency of a building period to make the pit smaller is what may be expected through the congealing of lava on the older walls of collapse. The same thing happened between 1913 and 1919, the rim shown in the first cut became more perfectly circular and smaller, as shown on the map on Page Four, and the lip of the cauldron was built up about 30 feet, so that the pit was replaced by a heap, with lava lakes on top.

It will be observed in Cut 1 that two crescent niches in the rim of Halemaumau northeast and west were filled up and disappeared during the overflows of 1918-21 (compare map Page Four). In the same way there had been extensive niches and outlying small pits extending the Halemaumau of the decades next preceding 1894. These niches are the sites of subordinate pits that are formed by the rise and fall of lava up and down cracks extending from, and close to, a larger pit. The development of an outlying vent which is at first a crack leads to a concentric structure about a vertical shaft, owing to the tendency of lava to freeze in the narrower portions of the crack, and to enlarge the vent circularly in the wider portions. The remarkably perfect circularity of the structure reaches its best development in an active lava slag-pool within a surrounding bench of its own semi-cooled substance. where by pulsations up and down, the central shaft is finally shaped like a paste-tube, and the convectional circulation builds the marginal rampart equally at all points about a center.

We now come to the phenomena of subsidence illustrated by the two airplane photographs on Page Two. It will be remembered that the culmination of constructional overflow was in 1919, and that from 1920 on, the bottom of Halemaumau subsided strongly, while the lava which it had contained flowed out repeatedly from the flank of Kilauea Mountain. Again and again the lava in the pit frothed up to the rim or nearly so, one such rise making the spasmodic and tumultuous overflow of 1921. The overflow or outflow was each time followed by bigger and bigger collapse at the pit. This collapse was dominantly guided by the deep rift in the mountain to the southwest, so that the resultant enlargement of Halemaumau was to an oval in plan extending the pit in that direction. This is illustrated by the first of the two photographs, taken November 9, 1923, and showing the results of the tremendous subsidence accompanied by avalanches which in May 13-27, 1922, enlarged the pit from a maximum diameter of 1,400 feet to 2,000 feet. The floor of Kilauea just outside of Halemaumau to the southwest had been heating, fuming, building cones, and flowing from cracks for four years. It was undermined by tunnels along the line of the Kau Desert rift, and the largest portion of these tunnels, close to the pit, caved in and engulfed a crescent of rim rock, as shown in the picture.

An object of great interest in this picture is the three-armed lake of lava, which was building up the inner floor in the autumn of 1923. An island stands at the meeting point of the three arms. This clover-leaf arrangement of the inner lakes had happened repeatedly during many years prior to this time. It appears to mark a tendency of the inner heap to fracture by tumescence into three sectors, and there is some reason to suspect that the larger domes of Kilauea and Mauna Loa have tendency to a similar breakage. Thus about the Mauna Loa center there are cracks to the northeast, the southwest, and towards Hualalai; about the Kilauea center there are cracks to the southwest, to the east, and towards Kulani north, (a cone in the forest between Kilauea and the northeast rift of Mauna Loa).

The second airplane photograph of Halemaumau, taken November 25, 1930, again during a period of activity of the bottom, exhibits the enormous pit left by the explosive engulfment of 1924. This is also an oval, its greatest length determined underground by the Kau Desert cracks, which appear in the background. It has now become 3,500 feet long, and a very striking feature of this picture is the tendency to concentric rim cracking, shown especially at the left by faint lines of black close to the rim of the pit, these cracks showing clearly the effort of nature to make a perfect circular funnel. This is the more remarkable as the rock which is so breaking is more than 700 feet back from the edge shown in the upper photograph. This enlargement will be realized if the reader will compare the irregular elliptical broken area of the outside lava surface at the south, which in the picture of 1923 lies away from the rim, and in that of 1930 is on the rim. The road terminus of 1930 is entirely different and far to the left of the road loop shown in the 1923 picture. This older loop would now lie far inside the pit, if it were redrawn on the photograph of 1930. The tendency to circularity by collapse, like the tendency to circularity by upbuilding, must be occasioned by a highly centralized shaft.

This picture of 1930 shows the inner dome of the Kilauea floor surrounding Halemaumau pit, and this dome expresses not only the overflows of the peak of the cycle, but also the tendency to swelling which had been characteristic of that time. This tendency to swelling is also a characteristic of the larger volcanic edifice, and its measurement with tilt instruments is one of the most fundamental scientific procedures for interpreting what is going on inside a volcanic mountain.

The history of pulsations of rising and falling lava, as creating a constructional smaller pit of effusion, and then a destructional larger funnel of subsidence, and this within a short cycle of 11 years, is indicative of the larger process that has made the greater craters through larger ages of activity. The crescent niches at the border of Halemaumau, in the pit of 1913 and the pit of 1923, are closely imitated in the lunate platforms of the Mauna Loa crater, and the two similar ones at the northeast (Sulphur Banks flat) and southwest ends of Kilauea Crater. To such extent as the Mauna Loa niches represent outlying lava pits, they are like Keanakakoi and Kilauea Iki outside of Kilauea at the east. There is a tendency for the walls of the Halemaumau funnel to assume at times a rounded pentagonal outline in plan; the same thing is true of the general plan of Kilauea Crater, and of the inner cauldron of Mokuaweoweo. All of these features are also characteristic of many of the craters on the moon, so that to a volcanologist there is no appeal in the impact theory of lunar craters.

T.A.J.

TILTING OF THE GROUND FOR NOVEMBER

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

November 2-8	2.3 seconds	NE
November 9-15	0.7 second	ESE
November 16-22	1.2 seconds	ENE
November 23-29	1.0 second	SE

E.G.W.

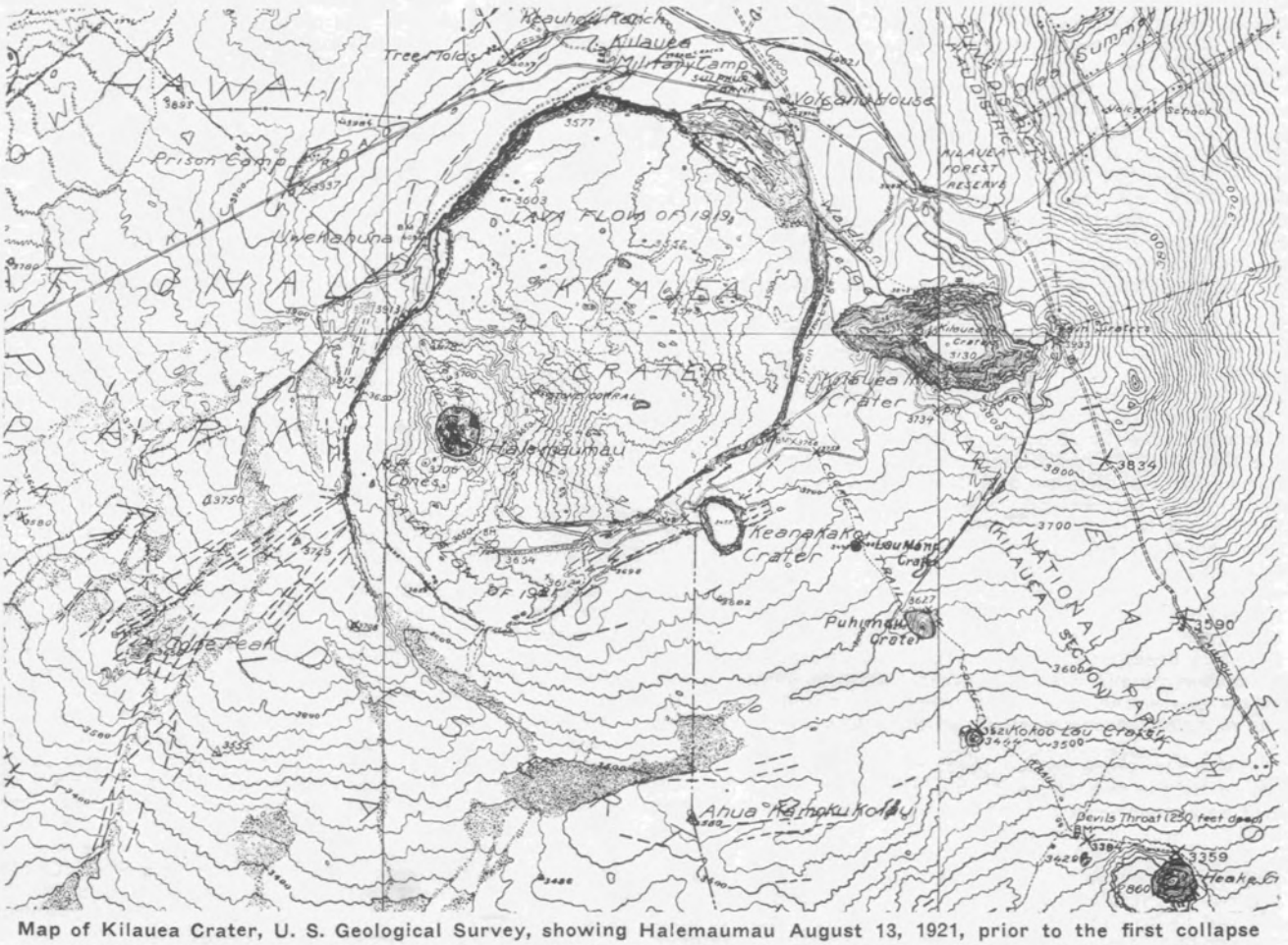
KILAUEA REPORT No. 1038

WEEK ENDING DECEMBER 13, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

On December 7 at 9:50 a. m. there were the usual steaming cracks about Halemaumau pit and on the Kilauea floor which are always seen during damp and cool weather. The fume at the principal sulphur patch on the bottom of the pit appeared denser and rising in puffs. The crack No. 25 at the northeast rim of the pit, which has recently widened. with subsidence of the block on the inner side of it, showed further widening as did other cracks. A small slide fell here at 10:06 a. m. At 3:30 p. m. this rim block fell completely and made an avalanche. A block of the rim fell in from 100 to 150 feet long and from 1 to 20 feet wide. New cracks appeared in the ash for 250 feet



Map of Kilauea Crater, U. S. Geological Survey, showing Halemaumau August 13, 1921, prior to the first collapse and enlargement shown in Cut 2, but after the overflows which had obliterated the conditions of Cut 1. The lava flow of 1919 had filled north corner of Kilauea Crater about 60 feet, and the lava flow of 1921 had filled the south corner and slightly overflowed through a gap as shown by dotted line. From the Postal Card Rift (Cut 1) had arisen flows to the north which created the Postal Caverns. The hot cracks had originally been used by tourists for browning postal cards.

to the north but not to the south. Several small slides were observed after 4 p. m. at the northeast wall, and fresh bowlders lay on the northeast talus. The perceptible earthquake of 10:20 a. m. December 8 dislodged three slides, respectively SW, SE, and NE of the pit, the last the largest. The quake was perceptible at the SE pit rim as a NW-SE swaying. On December 10 in calm weather the fume from the sulphur spot on the bottom of the pit rose in sufficient volume to be seen from a distance rising above rim of pit. This had diminished December 12. After the slides of December 8 the crack widening ceased and some cracks showed a slight closing.

The seismographs at the Observatory recorded 57 disturbances, including twice as many tremors and three times as many small earthquakes as occurred in previous weeks. There were 46 volcanic tremors, 9 very feeble shocks one of which was felt, 1 feeble shock at 12:30 p. m. December 13, and 1 moderate earthquake 10:22 a. m. December 8 that dismantled instruments. This indicated origin 14 miles from the Observatory and persons near Mauna Iki in the Kau Desert reported noise seemingly from Mauna Loa progressing underfoot, and rocks were heard falling down cracks. The tremors indicated origin distances of 6, 9, and 14 miles. the other earthquakes distances of from 9 to 23 miles. Microseismic motion for the week was moderate, and tilting of the ground was light NE.

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The Volcano Letter

Two dollars per year **Ten cents per copy**

No. 365—Weekly Hawaiian Volcano Observatory, National Park, Hawaii December 24, 1931



Mokuaweoweo Crater December 1, 1931, looking southwest from the rim salient between it and the northesat embayment. The smooth lava in the left foreground is the floor of the crater, described in the text, which broke out years ago simultaneously with one on the rim behind the camera. Photo Doerr.

SUMMIT OF MAUNA LOA 1931

Through the courtesy and cooperation of Superintendent Leavitt and Chief Ranger Christ of the Hawaii National Park, two members of the Volcano Observatory staff were enabled to make the ascent and spend two nights at the summit of Mauna Loa observing volcanic conditions and making preliminary geologic investigations. As no Observatory party has been to the summit crater since R. M. Wilson's trip in 1927, and as the close of one of Mauna Loa s four and one-half year cycles has passed (the last activity being in the spring of 1926), and renewed activity may be expected at any time, it was deemed advisable to make an inspection at the present time before the winter snows set in.

The party which left the Park headquarters at 6:10 a. m., November 30, 1931, was composed of Naturalist Doerr of the National Park. in charge, Powers and Wingate of the Observatory staff, and Rangers Brumaghim and Lee of the National Park. The party went by automobile as far as the Ohaikea tanks, where Levi, packer and guide, had the riding horses and pack animals ready for the trip. Chief Ranger Christ was on hand to superintend the start.

The path from Ohaikea leads across country for about a half mile where it joins the new Park trail, from Brown's ranch and the Bird Park, to the summit. The new trail as far as the Rest House at Puu Ulaula is an excellent one. crossing two tongues of the Keaumoku flow and continuing upward through lovely, grassy glades and groves of koa, mamane, and ohia. Ohelo, aalii, and pukeawe are shrubs which are found in abundance. The stone wall marking the upper boundary of the Kapapala grazing lands was passed at 9 a. m., and from that point the vegetation quickly thins out. At the Rest House, elevation 10,000 feet, which was reached at noon, only a little scattered grass and some stunted ohelo and pukeawe are to be found.

Rangers Brumaghim and Lee left the party at this point to make camp at the Rest House for several days while marking the upper part of the trail. The rest of the party, after a short rest for lunch, continued on to the summit which was reached at 5 p. m. Camp was made in the "Hotel de Jaggar," a partly collapsed lava tube on the northeast rim of Mokuaweoweo. The guide returned to the Rest House with the animals which he reached about 8:30 p. m., after a trying trip in the dark.

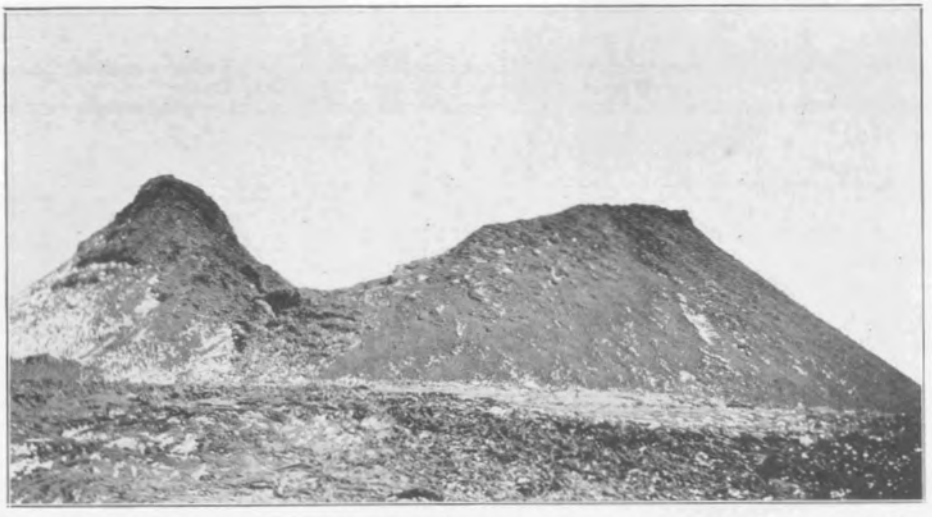
The "Hotel de Jaggar," which has been used for a camp by parties staying overnight at the crater, and by Wingate's topographic party in 1925, was found in rather shabby condition. No attempt at policing the camp apparently had been made for some time.

Due to lack of precipitation on the mountain in the last few years, cracks which held a quantity of ice in 1925 were nearly dried up and such moisture as remained was frozen solid to the bottom. An ample supply, however, was chipped out with a small pick and melted over the fire, for water for the party.

The topographic party in 1926 and 1925 used two small, one piece, kerosene stoves for cooking at the summit camp. On the present trip, charcoal was carried up for fuel and readily proved its superiority, being much easier to pack, and making a more even fire for cooking, as well as being cleaner and less offensive.

December 1 was given to an exploration of the east side of the north embayment. and along the east rim of Mokuaweoweo as far as Wilkes camp ruins, from which point the return to camp was made by following the outlying fault cracks which parallel the east rim of the crater. The party had intended to continue to the south end of the crater, and the head of the upper 1926 flow, but the sky, though clear until noon, had become overcast and threatening, and by 2:30 p. m. snow was falling. During the rest of the afternoon and the evening of December 1 about three-fourths of an inch of snow fell.

The observations made. from a volcanic standpoint, show some changes since 1926, but nothing significant was



Hanalei Peak December 1, 1931, one of the huge cones of frothy lava and slag built up along the northeast rift by the fountains at the source of one of the recent "rift flows." Photo Doerr.

noted. The principal change appeared to be the shifting of the main fuming area from the central part of the crater, in the vicinity of and to the west of the cones of 1903, to the area of the main cone of 1914 in the southwest part of the crater. This cone was steaming strongly and considerable fume was visible at the sunken area west and south of it, and along a few cracks to the east. On the northwest part of the sunken area west of the cone, new patches of sulphur have appeared which are brilliant yellow in color. Steam appeared over this entire area.

Some steam and a little fume were visible in the central part of the crater, which Mr. Doerr said was less than on his visit of November 10 of this year.

Steam along the northeast rift appeared in about the same places and amount as in 1926. Three spots on the floor of the northeast embayment were seen steaming in cloudy weather, and steam appears at one point on the south lunate platform.

As a base for reports by future visitors, a map was prepared showing the locations of the above points with the approximate strength of steam and fume recorded, based on the assumption that very voluminous fume might become visible from the Volcano House, 22 miles away, on a clear day. It is hoped that by this means some check may be kept on visitors' data at the summit crater.

A number of striking geological formations were hurriedly examined. The trail approaches the northeast end of the crater for the last quarter mile over a very shelly pahoehoe flow, which is mantled with khaki-colored pumice and lava froth. The pumice was formed by lava fountains in the northeast rift from which the lava was extruded. This surface flow was formed before the northeast embayment of the crater had reached its present size and shape. It is plainly seen that the walls of the crater are being extended by cracking and slumping of the lava at the edge, and the blocks of wall, which have dropped down most recently, are made up of the same pumice-covered pahoehoe which forms the rim. The floor of the northeast embayment is covered with younger lava which laps up on, and partly buries, some of the huge blocks which have fallen in from the wall. The southwest wall of the northeast embayment slopes rather gradually in its upper part, then is cut off sharply by a cliff down to the lava floor. A small gush of lava has broken out through the loose blocks of the sloping part of the wall and flowed down into the crater. However, this flow is cut off sharply at the cliff. Apparently this small side flow poured out at a time when the crater was filled with lava to the level of the top of the present cliff. Since then, the whole floor of the embayment has sunk many feet, leaving the small feeding flow suspended far above the present floor.

In the southeast side of the northeast embayment is a pit almost circular in shape, much like Halemaumau only a great deal smaller and a little over a hundred feet deep. This pit does not appear on a map of the crater made in 1872, but is shown on one drawn in 1885 (see discussion by T. A. Jaggar in Volcano Letter No. 360). On the east wall of this pit are several patches of cascade lava, remnants of a large lava fall which spilled over the east rim into the pit. This pahoehoe flow came from several large cracks in the outer rim of the main crater about a half mile to the south, and at 200 feet higher elevation. The lava poured out from the cracks, flowed north down the steep slope till it reached the northeast wall of the northeast embayment. Here it piled up high on the wall, then spilled over westward into the small pit. As the lava flowed into the pit, the level of the pond receded about 20 feet, leaving a "high lava mark" of crust and splash along the northeast bank. Part of this same flow tumbled westward over a 200-foot cliff into the main crater. At the same time that the flow was pouring out of cracks on the top of the rim, another flow with its fountains was pouring out from cracks in the sloping floor of the main crater 200 feet below and almost beneath the fountains of the rim flow. The lavas from the two vents, one 200 feet above the other, flowed together on the floor of the main crater. This same strange phenomenon took place in the 1851 eruption from the southwest side of the main crater, only here the difference in elevation, between the floor fountains and the rim fountains was over 300 feet.

While at the summit all of the party suffered from severe headaches and to a slight extent nausea, possibly in part due to charcoal fume.

The lowest temperature recorded on the trip was 22° F at 6 a. m. on December 2.

Very few goats were seen either on the ascent or descent. The descent was made without event, though rain fell over most of the region below the Kapapala stone wall. Park headquarters was reached at 6:30 p. m. December 2.

E.G.W. and H.A.P.

KILAUEA REPORT No. 1039

WEEK ENDING DECEMBER 20, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Halemaumau pit remains stationary and inactive and the increased seismic activity of the previous week proved temporary. At the pit a few rocks were heard falling at the northwest wall at 9:55 a. m. December 14. Crack measurements showed a decrease of width SE, and slight widening E and NE. Crack mark No. 25, which recently showed excessive widening, is now stationary. A noisy avalanche was heard at 4:10 a. m. December 16, and subsequent inspection of Halemaumau showed fresh debris on NE talus. There were other fresh scars on the walls NW, S, and SE. Crack measurements showed no change in the rim.

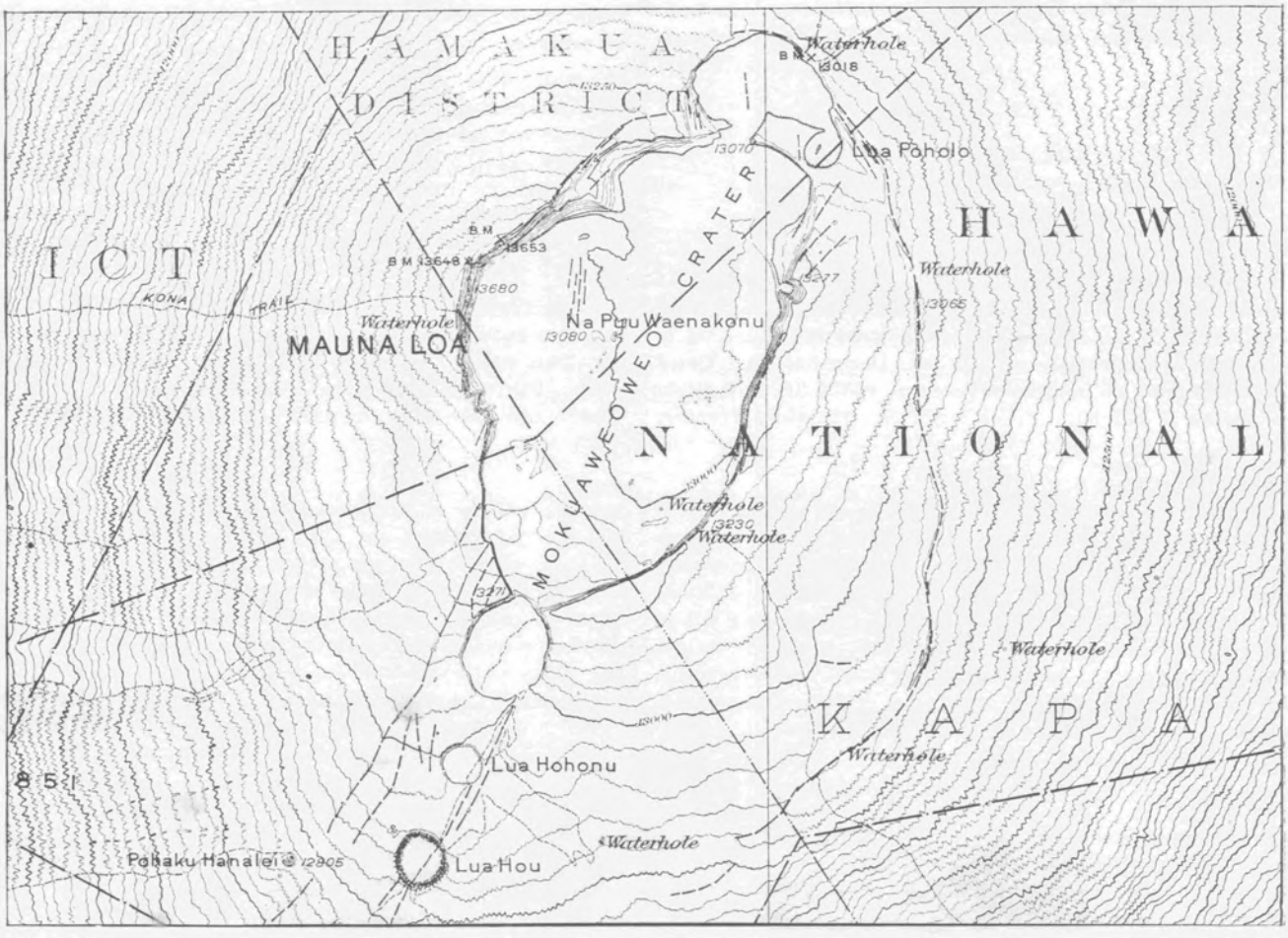
During this week the Park force has excavated a new seismograph cellar near Halemaumau and construction is in progress.

Thirty-four seismic disturbances were registered at the Observatory, of which 28 were tremors, and 6 were very feeble earthquakes, of which four indicated origin distances of 4. 9, 14, and 18 miles. The last at 10 minutes past midnight the morning of December 16 was felt at Kapapala Ranch. Its duration was approximately 15 seconds and its estimated origin distance agrees with the ranch distance within a mile.

Microseismic motion was heavy December 14-16, moderate to heavy December 17-19, and very heavy December 20. This was probably due to heavy seas on the Hamakua cliffs. Tilting of the ground was moderate ENE, with increase and change to the east beginning December 16.



Hotel de Jaggar, the collapsed lava tube which is used as a camp by parties staying at the summit. The "bedroom" extends back about 20 feet behind the men in the "'kitchen." Photo Doerr, Dec. 1, 1931.



Map of Mokuaweoweo, the summit crater of Mauna Loa, by E. G. Wingate, surveyed in 1925-26, U. S. Geological Survey.

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No. 366—Weekly Hawaiian Volcano Observatory, National Park, Hawaii December 31, 1931



The outporing of lava November 19, 1930, which prepared the floor for the eruption of December 23, 1931. The bright fountain at the left built a big cone, and the high half-dome against the talus at the back was the grotto of 1929. The new crack of 1931 extends straight across the middle of the floor between these two, and the new fill covers all of what is here shown by about 100 feet.

JOURNAL OF HALEMAUMAU ERUPTION DECEMBER 23 27, 1931

There is much about this eruption identical in character with those of 1927. 1929, and 1930, each of which tended to add 50 to 60 feet to the bottom of the pit after the lava had shrunk and solidified. and each tended to break out along a crack either diagonally across the former floor or tangentially along the former edge of the floor. The duration of these eruptions varied from a day to three weeks; it is quite in order for such an eruption to develop increased violence of fountaining even when it is dwindling, as the spurting fountains are indicative of clogging vents.

There has been a series of events pointing to the coming of this eruption. The interval average for seismic and volcanic crises in Hawaii during the last 20 years has been one year, and the average of outbreaks of Halemaumau since 1924 has been one a year. The last outbreak ended December 7, 1930. so that now an eruption was expectable. The tilt instrument near the southeast edge of Halemaumau has shown 50 seconds of tipping of the ground away from the center of the pit since the last eruption, suggesting upward pressure. The tilt instrument at the Observatory on the northeast rim of Kilauea Crater has shown tilt away from the crater center of 5.4 seconds to the northeast between November 30 and December 20, 1931, suggesting upward pressure in the mountain. Finally came the rim block avalanche on the northeast edge of Halemaumau December 7 and the excessive number of seismic disturbances for the week ending December 13, 1931, followed on December 23 by the smart local earthquake in the forenoon that left 15 scars of avalanches on the big west bluff of Kilauea Crater, and left the walls of Halemaumau pit con-

tinually sliding for hours. This was undoubtedly the actual rending asunder of the inner heap which constitutes the floor of Kilauea Crater.

December 23.

When the dust cleared after the earthquake of 10:38 a. m., Wingate saw that avalanches had fallen around the northern walls of the pit, scattering debris and dust on the 1930 floor. There were scars on the walls and in some places rim rock had fallen, while 15 whitish scars on the great west wall of the big crater marked places where avalanches had fallen. Before the earthquake the rim cracks measured had shown no opening and the sulphur patches on the 1930 floor shown no fume, this being attributed to dispersal by strong northeast wind. After the earthquake there was no visible increase in fume. Sixteen crack points on the edge of Halemaumau were measured and showed increases in width up to more than an inch in places. A large block on the east rim had moved as a whole, and fresh cracks in the dirt appeared along the north, east, and south rims. Small slides were continuous for hours. After 2:15 p. m. six large slides were counted in 20 minutes. About 2:40, when he was working at surveying stations back of the rim, Wingate heard a low, rumbling noise not like an avalanche. He ran to the edge, where heavy fume clouds had already reached the rim level and were spreading about the interior of the pit. The whole floor was rapidly cracking open along a straight line athwart the middle of the bottom beginning at the southwest under the rift tunnels. Lava fountains there started up and spread to the northeast along the crack. Voluminous fume followed immediately after the first cracking, and the molten lava appeared following the fume. The whole time consumed for the break was probably less than half a minute. It was just at this time, 2:36 to 2:39 p. m., that the seismographs at the Observatory showed sudden development of continuous harmonic tremor from slight to strong.

Wingate reported visibility bad, but the botttom crust appeared rather to be pulled apart than to be heaved up and broken. There was undoubtedly tumescence. He was in imminent danger of asphyxiation, but went to the Park phone and could get no answer. He returned to the rim for a few seconds and saw spatter from the fountains blown high over the rim wall. Some of this from later fountains has been collected, light brown basaltic pumice like the "thread-lace scoria" of the Kilauea Iki region, and like the first ejecta of the Mauna Loa cones. Hasty count showed him 17 large fountains with the two strongest at the northeast end of the crack across the bottom of the pit. Then he ran for his car, badly gassed, and succeeded in escaping to the Keanakakoi sandspit where the air was clear. The sun was obscured for a time, appearing as though viewed through smoked glasses, bluish over the pit against a dark background, and reddish brown in transmitted light where it blew away and was seen against the sky. This was the first time that a scientific observer here watched details of first outbreak inside the pit, and it will be remembered that it was Mr. Wingate's party, engaged in topographic surveys, that was camped nearest to the place of summit outbreak on Mauna Loa in 1926.

The outbreak at the Observatory was observed by the change from rising dust to rising fume, and by the sudden development of harmonic tremor at the instruments. Also there was sudden change at the time of the earthquake in tilting of the ground from northeast to south.

At 4 p. m. the volume of fume rising was greater than in any recent eruption since 1924, and the eddying tornado effects due to convection from the large number of fountains, including the four enormous dome fountains at the north end of the bottom crack, coupled with the high wind from northeast, submerged the road terminals under clouds of sulphur dioxide. The fume and grit were bad on the roadway from Uwekahuna to leeward of the pit. From the north lip of the pit about 30 fountains were counted making a great roar, in a nearly straight line, after darkness began to fall between 5 and 6 p. m., but the seeing was poor. There was already a great lake with bright lines between the skins, spreading out over the whole of the inner mound of 1930 lava. At 4 the glowing froth had been seen flowing away from the fountain line, at 5:30 it was already a flat lake covering the irregularities of the 1930 floor. Therefore the volume of inflow in the first three hours was enormous. The poisonous blue fume tended occasionally to spread in a low layer to the eastward, so that it was necessary to make a wide detour. A fortunate photograph at 7:30 p. m. by Higashida showed four large fountains at the corners of a square under the northeast sill, with a small fountain in the middle, and a grotto fountain against the bank, while the line of smaller fountains extended southwestward across the middle of the lake in the line of the two eastward big gushers of the square. The crack proved to be very slightly offset to the west from the rift tunnels in the southwest Halemaumau wall. The inward convectional draft was from the north and west, and the brown clouds boiled up and rolled off over the desert to the southwest and southeast. Spurts from the big fountains were probably several hundred feet high, but they could not be measured. Pellets of pumice and Pele's hair fell to leeward. The line of smaller fountains were partly merged, and partly isolated, and there were some outlying fountains, with concentric patterns of bright lines clear to the edges of the big lake. where there were outward-pushing toes and some minor grotto fountaining. The illumination at night was so brilliant that every detail of the ground could be seen by pedestrians.

December 24

At 2 a. m. the amplitude of the continuous tremor diminished to about half, and at 5 a. m. increased slightly, and thereafter continued. This was the index of the cessation of the big northeastern fountains. At 3 a. m. Powers reported the fountaining almost stopped except for a few bubbling spots along the rift line. The bright-line pattern of the lake surface extended to the edge of the new fill. The liquid lava had reached the rock cliff, covering the low talus NNW. Both 1929 and 1930 spatter cones appeared to be covered.

At 10 a. m. the botttom appeared to be a continuous leaf-shaped lake with nearly flat floor, the line of fountains making a short belt of big domes southwest of the center. This was extended by small bubble fountains in both directions, ending at the southwest in a small grottto fountain at the bank which was increasing in size. There were traces of crust islands at the southeast about where the 1930 cone had been. The shore line of the lake had made a nearly continuous rampart of congelation and piled crusts, interrupted at one place between the northwest and west taluses where the liquid lava appeared to be nearly against the rock wall. There was a cross line of small fountains, nearly straight and at right angles to the main fountaining line between the central group and the southwest grotto. There was another straight line of fountains parallel with the central line across the northwest part of the lake. The crust nortwestward from the central fountains showed a pattern like a flow or belt of streaming. Small islets were forming in front of the southwest grotto, and the central fountains showed signs of migrating southwestward during the day. There were concentric skins of pahoehoe pattern. The northwest edge showed some cliffs in the rampart facing inward. The southeast edge showed toes of flowing through the rampart. The brightness at night was moderate.

December 25

At noon the nature of the activity was in general as before, but the gas pressure at the fountains was increasing and there was apparent a change in the cross line of small fountains to become the arc of a circle concentric with the lake instead of a straight rectilinear belt. The southwest border fountain was building a higher grotto against the talus, bright lines were radial from this grotto, and there was a clifflet or infacing scarp along the northeast rampart. Rapid moving puffs of blue fume rose up the west wall from the fountains. The liquid lava about the central fountain belt made slow waves outward. The fountaining waxed and waned, some individual spurts going up 200 feet during a time of high pressure, and the noise was like surf on rocks. There was a fine-meshed pattern about the central fountains bounded by a U-shaped curve of contact to the southwest with a broad horseshoe of coarse-meshed bright lines extending from the southwest grotto as a center away to the east and west so as to envelop the central more liquid pool. It was evident that the northeastern region was cracking and solidifying so that the rampart belt was widening inward, and measurements later proved that the southwest was becoming a center of elevation with individual pools about the several fountains. and these tended to stream and make overflows northeastward, over something that was solidifying below. The lake was definitely against the WNW wall of the pit, without any rampart.

December 26

At 9 a. m. a new fountain had developed to the northeast of the elongated central belt, and the southwest grotto was now dominant with a large crescent niche behind it built against the talus. The lake edge was here irregular. At noon it was apparent that the northeastern fountain was sending streams radially outward to the northeast and that the central fountains occupied the most liquid portion of the floor with a fine greenish pattern to the skins. This area was a thick crescent with two horns northward. The big strong fountains of the southwest grotto had built up a high canopy of spatter on the bank, a crescent wall with overhang which broke down from time to time and immediately built up again. A coarse bright-line pattern extended out to the north and east from this grotto with a surface in daylight like black satin. The central fountains were smaller and more separated. There were fresh overflows between the rampart and the talus at the east.

December 27

Measurements by the Observatory engineer on this day showed that lava covered the top of the 1930 cone to a depth of 50 feet, and the depths of the new covering on the irregular relief of the 1930 mound were as follows:

West Bay, 85 feet
North Bay, 96 feet
Northeast Bay, 98 feet
Southwest Bay, 115 feet

As there are shallower places over the big 1930 cone, the average depth of the new fill was about 90 feet, its size 2600 feet long northeast-southwest and 1950 feet wide, covering an area of about 80 acres. Its volume is estimated at 260 million cubic feet, which would amount to some 20 million tons. If this had been distributed over the interval from the beginning it would mean about 45,000 cubic feet per minute from all the vents. The height of lava lake above sea level at southwest grotto was 2773 feet, making the depth of the pit from the southeast rim 971 feet.

At 10 a. m. December 27 fountaining was more violent and the lava from the central group of fountains had encroached on the southwestern crusted belt and on the northeast fountain pool. The later was fountaining steadily but with decreased strength.

At 3 p. m. the northeast margin of the floor for perhaps one-eighth of the area had become bench lava. Marginal overflowing was active SE and N. The southwest horseshoe lake was feeding flows at the edges, and the middle lake was spilling over a bench magma slope at the northeast. At 5:30 p. m. the northeast fountain was making only a sluggish gushing, but the southwest grotto had become a very powerful continuous fountain with a high grotto behind it, and this was beginning to develop the true Mauna Loa type of spraying jet. Detonations now accompanied some of the viscous bursts of the central area.

At 11 p. m. the southwest fountain was sometimes 400 feet high, overflow continued southeast, the lake was shrinking, and gas bubbles burst with loud reports. T.A.J.

KILAUEA REPORT No. 1040

WEEK ENDING DECEMBER 27, 1931

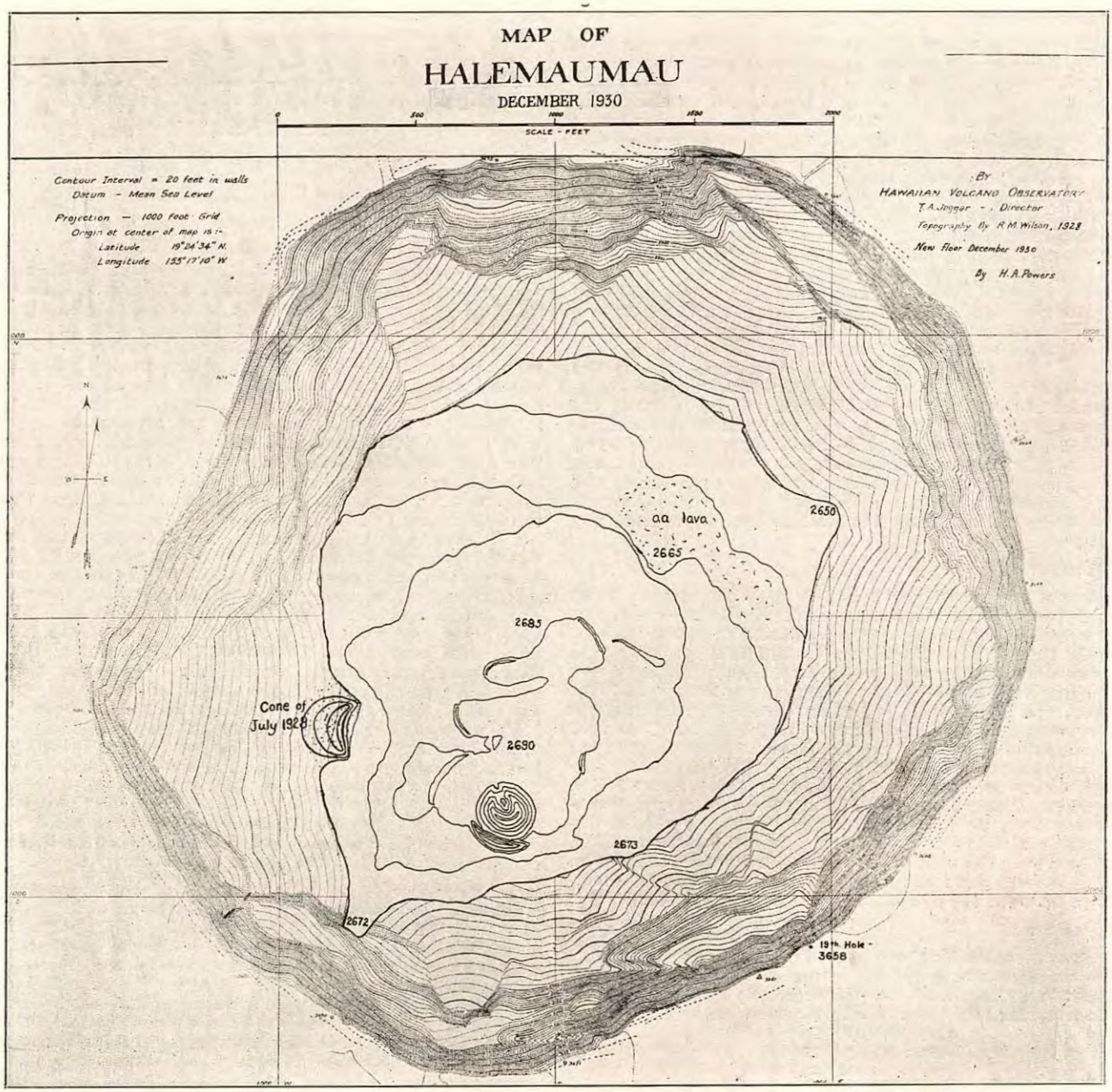
Section of Volcanology, U S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The past week has produced a new outbreak of lava in the bottom of Halemaumau pit about 2:36 p. m. December 23. This was preceded at 10:38 a. m. by a strongish earthquake highly localized and not generally felt at other points on the island. Mr. E. G. Wingate was close to the pit when the outbreak occurred, and heard a low rumbling which led him to look over the edge, where he saw heavy fume clouds filling the interior, and lava fountains starting at the foot of the southwest talus. The floor cracked open from southwest to northeast in less than half a minute. The floor broken appeared to be pulled apart with some tumescence. Spatter from the fountains was blown high over the rim wall, and 17 large fountains were counted with the two largest at the northeast end of the crack. Then a gale of dust, sand, and fume overran the tourist station and it was necessary to retreat to avoid asphyxiation by sulphur dioxide. The sun was obscured by a brownish cloud seen to be blue in reflected light. Lava during the next 11 hours foamed into the pit in enormous volume estimated 6500 cubic feet per second, and the density of the fume cloud was very great for Kilauea. The two or three enormous fountains at the northeast end of the line inside the pit ceased action about 2 a. m. December 24, the fume diminished, and normal conditions were restored whereby the southeast road terminal became accessible. The fountaining continued in a belt of big central gushers and a grotto fountain at the talus at the southwest end of the line. Before the cessation of the big fountains, the brilliancy of the pit at night exceeded anything seen thereafter, and about 30 fountaining points were counted along the straight line of vents that crossed the middle of the bottom of the pit in the direction of the Kau Desert rift.

On December 24 there was a line of small fountains straight across the south end of the lake at right angles to the main rift, and another line parallel to the main rift across the northwest part of the lake. Islets of crust appeared about where the 1930 cone had been. On December 25 a more liquid pool was defined about the central fountain, there had now developed a rampart all about the lake, and the southwest fountain was building a grotto. There were brilliant radial and concentric patterns about the main fountains, and the gas pressure was increasing so as to fling up individual spurts 200 feet into the air. December 27 there were three principal fountaining areas with streaming northeastward in concentric horseshoes. The gas pressure was still stronger and tending to concentrate southwest in spraying jets sometimes 300 feet high, building a huge spatter niche, while the central fountains made detonating puffs of blue fume. Measurements showed the average fill to be 90 feet deep above the 1930 floor and about 260 million cubic feet of new lava had poured in.

Prior to the eruption there were 11 tremors and 7 very feeble earthquakes recorded. Four indicated origin distance four miles. The earthquake of 10:38 a. m. December 23 was strong enough to overturn some objects, especially on Uwekahuna Bluff, and would rank as grade IV R. F. Two very feeble shocks occurred after the eruption. Traces of continuous volcanic tremor appeared after the 10:38 a. m. earthquake, became quite continuous at 2:36 p. m. December 23, reached a maximum at 2:39 p. m., and continued so until 2 a. m. December 24, when the big fountains stopped, and the continuous tremor diminished in amplitude. December 24 at 5 a. m. this tremor increased slightly and has continued ever since. Microseismic motion has been moderate to heavy, and tilt changed suddenly at the time of the strongish earthquake from moderate ENE to strong S. The pit seismograph has for months been indicating tilt away from the center.



Map of the lava floor of December 1930 with 10-foot contours for the bottom area, showing the big 1930 cone and solidified lake at the south, from which the rest of the bottom sloped away as a mound. The cone of July 1929 is shown at the left. All of this is now buried by the new eruption, and the grotto center of 1931 is just south of the 1929 cone.

THE VOLCANO LETTER

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The Volcano Letter

MONTHLY U. S. Geological Survey, Hawaii National Park 1932

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No. 347—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | January 7. 1932



The large northeastern fountains of lava in the bottom of Halemaumau pit, Kilauea Volcano, on the evening of the first day of the eruption, December 23, 1931. from the north-northwest rim, 7:30 p. m. Photo Higashida.

JOURNAL OF HALEMAUMAU ACTIVITY DECEMBER 28-JANUARY 3, 1931-32

It is now evident that the activity of the bottom of Halemaumau in the current eruption is stronger, and the lava fill more voluminous than in any outbreak since 1924. The current week brings to a close the eleventh day of the eruption with the fill at the highest southwestern side of the bottom of the pit at an elevation 110 feet above the corresponding floor of 1930. The progress of the week has determined a concentration of all visible inflow at the big southwestern grotto, where the lava piles up a horseshoe cone with an open cup overflowing to the floor of the pit. The topmost spatter of this cone stands 280 feet above the highest summit of the cone of 1930, and only 650 feet below the tourist station at the southeast rim of the pit. The line of central fountains disappeared after December 29, when it became evident that the southwest border of the floor was to become the top of a new mound from which flows would radiate across a swollen heap of fresh lava in the pit, and these flows have themselves developed a lake at the top of the mound bordered by a rampart of crusts which divides the lake at the southwest from the slope down to the edge of the floor at the northeast. This lake is continually fed by the torrents of lava from the fountaining craterlet, and from time to time the lake breaks through its rampart with overflows that flood the northern slopes of the mound. Seismic activity as usual has dwindled since the magma was released, harmonic tremor from the fountains is continuous, and the change in tilt from northeast to southwest at the Observatory is what would be expected with the lava ejection relieving upward pressure and replacing it by heavy weight of new fill.

December 28

At 11:20 a. m. the concentration of activity at the big southwest fountain was sending frothy jets 350 to 400 feet high and spattering halfway up the west talus. The material appeared to be basaltic froth, and in dimensions and structure the whole cone and fountain were like the Alika source cone of 1919 on Mauna Loa (Volcano Letter 348, Page Three). Heat was strong on the edge of the pit, and this grotto fountain played like a jet from a hose. swinging slowly around a central vertical position, and dropping its light spatter first on one side, then on another. The resemblance to the Mauna Loa source cone was increased by the action of the minor fountains in the central lake and the two explosive vents, at the north, of the fountain line, which are making extraordinary flings of ropy lava to a great height, and detonations accompanied by puffs of blue gas. Just these things happened in the northern cones of the Alika rift, in contrast to the big fountain, with its frothing pool, farther south.

The central fountain was a bubbling pool which occasionally sent up a string of slag even higher than the steady spray of the southwest cone, and this string would loop and bend at the top, and then fall with a slap on the pool below. Both the central fountain and the one farther north made explosive bursts with loud thudding detonations, some of which sounded like a chemical explosion. At the area of the northern fountain there were three definite streams pouring northward on a downhill slope from an edge of crust. indicating that a lake had formed within a slag heap. About 18 fountains of small size extended from the center to the southwest.

The whole area of the northern edges of the floor was cracked and mashed into pressure ridges like the slopes of the mound of 1930. There were four or five jets of blue fume in this slope area. A wide patch of crust made an island about where the big cone of 1930 had been. The lake was leaf-shaped with the southwest fountain at the stem, and the latter was building a high, cracked half circle of its hardened flings on the uphill side against the talus behind it. The inside of its cup would continually cave in revealing red-hot walls. Measurements had shown a gain in height of the built-up bottom of 100 or more feet at the southwest, and only 40 feet to the northwest of the center of the pit, showing that there was development by both overflow and tumescence around the region of maximum fountaining. A cloud of blue fume was always rising from the big fountain, and smaller amounts of it came from the other fountains.

A nationwide broadcast was sent out from the edge of the pit describing the activity for the half hour following 10:45 a. m., by KGU of the Honolulu Advertiser. A microphone attached to the end of a long timber was thrust inside the pit so that listeners might hear the roar of the big fountain and the explosive bursts of the central and north central vents. The arrangement of this apparatus, with wires for relays by radiophone, had been accomplished in less than a day, and was of interest as showing what could be done for securing assistance in case such a volcanic happening were disastrous.

New cracks were discovered in the bottom lava of Ki-



Panorama of the bottom of Halemaumau at 10 a. m. December 24, 1931, looking northwest. This shows the condition when the line of central fountains was in action, the liquid was a continuous lake except for a narrow border rampart, and the southwest grotto at the left was small. Photo Jaggar.

lauea Crater outside of Halemaumau, occasioned by the stresses which produced this eruption at the time of the earthquake of December 23, as follows: Three cracks concentric with the rim to the northeast and seven cracks concentric with the rim to the northwest within 500 feet of distance. Close under Uwekahuna bluff in the same direction appeared nine similar cracks as though the inner heap of Kilauea Crater were broken by motion on the fault of which the Uwekahuna bluff is the trace. The west, southwest. and south outer country of the Kilauea floor showed widening of old cracks and development of some new ones. Large blocks of spatter from the fountains were found to leeward of the pit, and a wounded tropic bird was picked up which had been dashed against the pit wall by the wind and was bleeding. The earthquake of December 23 had dislodged a bowlder three feet in diameter from the Uwekahuna wall and rolled it 200 feet out on the Kilauea floor. Several new steam vents were noted about the inner talus heaps of Halemaumau.

At 4 p. m the southwest grotto fountain had a quiet spell jetting only about 50 feet high, and along the inner belt there were only two sluggish small fountains southwest of the center. Sluggish lava flowed from the grotto. At 9 p. m. for about a half hour the southwest grotto was merely bubbling, but later it renewed activity. The rift fountains in the lake had almost disappeared.

December 29

At 8:30 a. m. the southwest fountain had completely revived, the pit had been bright at night, and the central fountains had gone out of action. Flows were pouring over the floor in two streams from the southwest half-cone, and at this time the northern edges of the floor appeared slumping inward, and the southern edges were being built up and the southern half of the floor was evidently becoming a mound. The flows spreading out on the floor were meandering in leaf-like forms and there was nothing that could be called a lava lake except the pool surrounding the fountain inside the cone, which was hemmed in by an island of half-hardened lava that divided the two streams in front of it. At 8 p. m. the situation remained the same except that only the western of the two torrents from the cone was open.

Elevations above sea level of various points inside Halemaumau were as follows on December 29:

Summit Southwest Grotto	2860 feet
Edge lava in front of grotto	2764 feet
Southwest floor level of pit	2763 feet
Small cone center of pit	2761 feet
West bay of floor	2744 feet
Northwest bay of floor	2743 feet
Northeast bay of floor	2740 feet
Interior floor northwest	2738 feet

It will be seen by these figures that the southwest grotto was 96 feet high, the small central cone was seven feet high by a measurement taken on a point beside it (2754 feet), and the maximum relief of the bottom area between a sagged portion of the northwest floor and the top of the southwest grotto was 122 feet. There had been a slump of from 5 to 10 feet over most of the northern floor and overflows were slowly filling the collapsed area.

December 30

At 8:30 a. m. the fountaining at the southwest grotto continued to fluctuate and as on the previous evening the torrent from the craterlet was pouring to the west of the island in front of it and spreading over the crusts of previous flows. There were some trickling flows at the northwest edge of the new fill, but otherwise the northern floor was now inactive. The last gas puffs from the central vents had been noticed on the afternoon of December 29.

At 3 p. m. the two torrents from the southwest craterlet, cascading on each side of the island in front of the open eruptive amphitheater, had reasserted themselves as glowing streams, the eastern one pouring from under a crust. The puddled flows in front showed the usual bright-line pattern radiating from the two inflows, with numerous islets of accumulation. and enough building around the edges of the big puddle (covering the greater part of the southern half of the floor) to produce the effect of 20 overflow streams out from the edges of the lake of lava. This was to develop into a definite leaf-shaped lake with ramparts about its border, and with the southwest grotto for its source well.

At 8 p. m. the fling of the big fountain was continually falling on the outside of the cone, while the bombardment and overweighting of the inside caused red-hot avalanches into a pool beneath. Two torrents poured east and west of the island in front, but the western one was now arched over with crust at its narrowest part, with a cascade pouring from the froth pool in under the crust.

During these days a single, thin column of blue smoke from the fountain rose high above the west rim of the pit making a cumulus of rain moisture above, thin on a sunny morning, thick and spectacular in the moist evenings. The sun in late afternoon here and in Kona appears like a red ball through the fume. The nights show spectacular glowing cloud effects over the pit, with the glow waxing and waning. No fume obscures the view.

December 31

At 9:30 a. m. it was evident that the area of flows was widening in front of the southwest fountain, and that the cone was growing. Only the west cascade appeared as an open channel. Some jets from the fountain appeared to go up 400 feet. There were frontal streams at the north and northeast edges of the heap. The activity appeared somewhat greater than on the previous evening.

January 1

At 11 a. m. the lake over the southwestern part of the floor continued to enlarge. The floor was now getting to be a mound with concentric ridges and ramparts within the northern half of the area and many cracked areas. The outer edge is like a spoon with some inward slope. The top of the mound is at the southwest and the big fountain is building it up with a lake at the crest. Much pumice has been found in the country outside of Halemaumau to the southwest, some of the pieces two to three inches across. In the night following this day the glow over the pit was very bright, and was added to by the development of electrical storms on the mountains which produced snow on Mauna Loa and Mauna Kea.

January 2

At 9 a. m. the activity appeared to be as strong as ever. At 10:30 a. m. it was evident that the lake in front of the fountain had definite border ramparts where some lava spilled over, the pool covering about one-third of the floor. The spatter rims of the grotto had built out about 150 feet from the large western talus, forming a typical Mauna Loa horseshoe cone with the main channel about 100 feet wide above where it divides about islands into cascades. Apparently the weight of the lake accumulations was causing the sunken northern area to rise. and measurements detected slight rising against the walls of the pit. This is the isostatic effect, frequently noticed a decade ago, when the bench magma is weighted down on one side and the other side rises. At 3 p. m. the fountain was smaller and more like normal Kilauea lava. The lake was scalloped with two big flows through its rampart. At 8 p. m. there was much cracking and foundering of crusts in large fields of half-hardened lava to the north of the lake. The lake overflows were in wide streams on top of these fields.

January 3

At 11 a. m. a single wide cascade was flowing toward the east, the ramparts around the lake were continually pushing out and being overflowed, and the fountain was more sluggish. T.A.J.

KILAUEA REPORT No. 1041

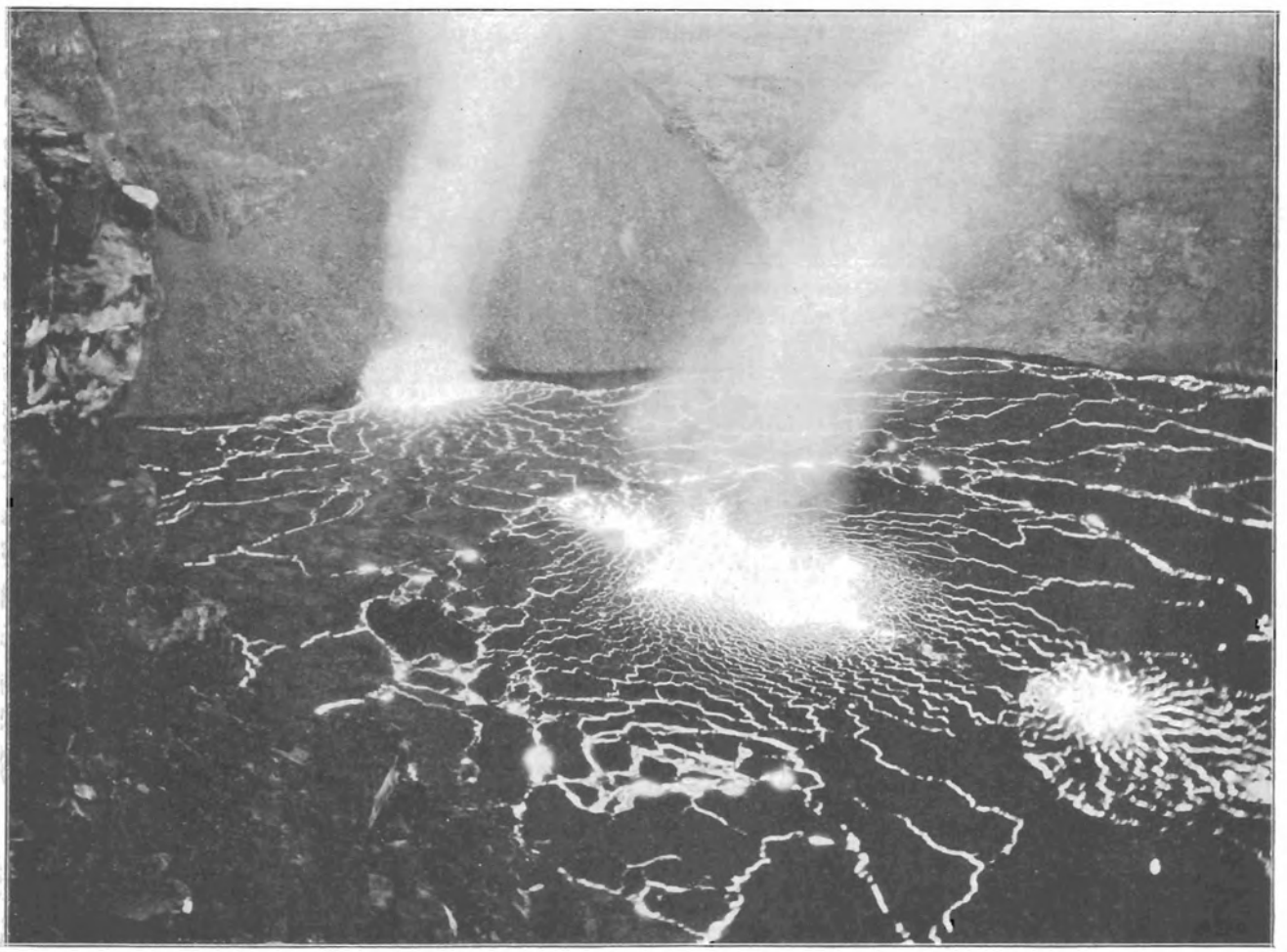
WEEK ENDING JANUARY 3, 1932

Section of Volcanology, U. S. Geological Survey

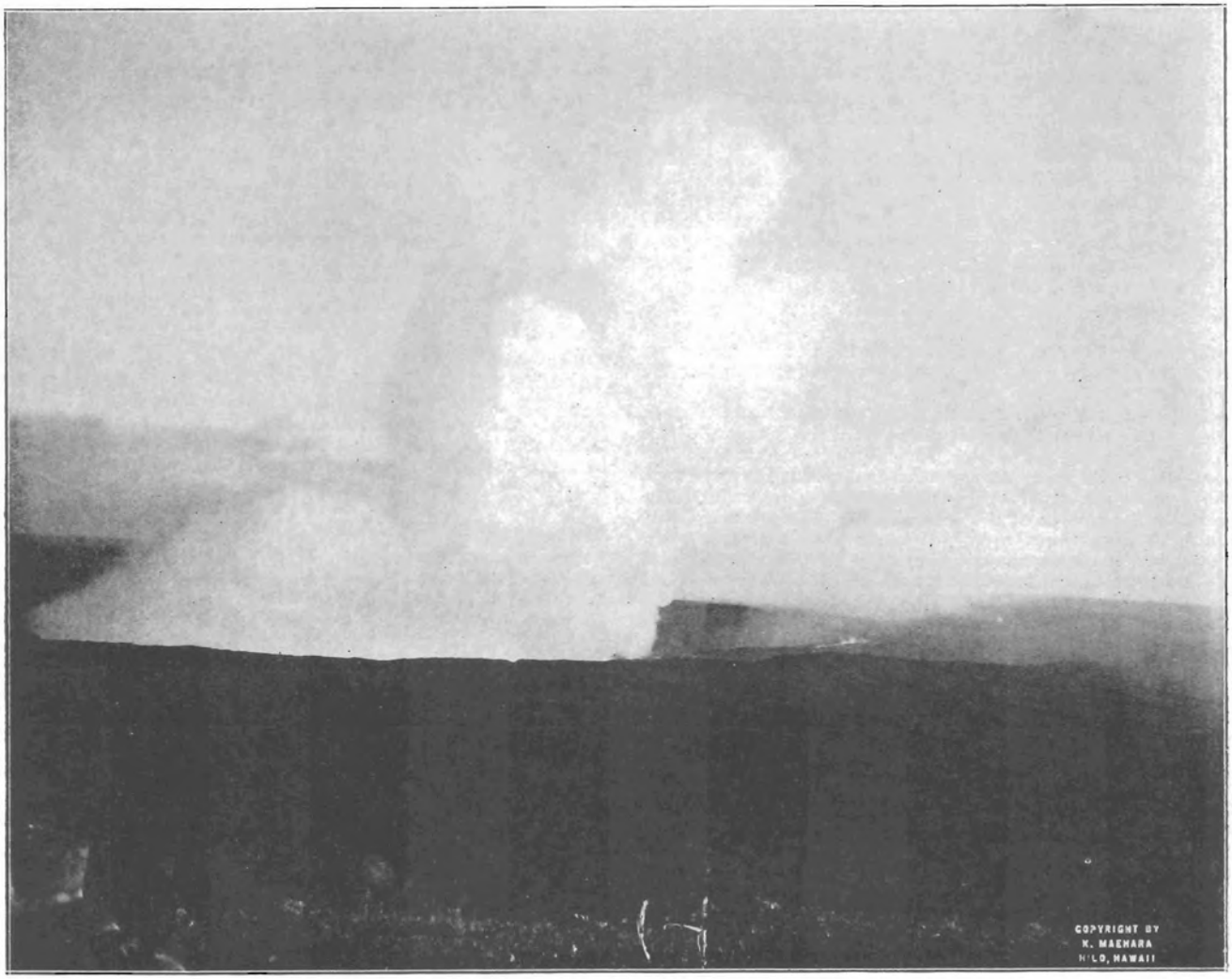
T. A. Jaggar, Volcanologist in Charge

The outbreak of Halemaumau pit in Kilauea Crater which began December 23, 1931, has produced a more voluminous fill than in any outbreak since 1924, and has brought the middle of the floor to an elevation less than 900 feet below the tourist station on the rim of the pit. The fill at the southwest on the eleventh day of the eruption was 110 feet above the corresponding floor of 1930, and the highest spatter on the talus beside the big source cone is about 650 feet below the southeast rim of the pit.

The central fountains disappeared December 29, the southwest grotto became a source cone for flows which built up the floor into a mound, and this activity still continues, with a lake built in front of the cone across the southern half of the bottom of the pit. The cone became an armchair niche 100 feet high with cascades pouring out



Halemaumau by evening light at 5:30 p. m. December 26, 1931, looking west, showing the growth of the southwest grotto at the expense of the central fountains and the co ncentration of the lake in a crescent in front of this grotto. Photo Powers



Halemaumau pit as a whole seen from the highest west bluff of Kilauea Crater on the first evening of the eruption of December 23, 1931, about 5 p. m., when blue-brown fume was puffing up from the big northeastern fountains in intolerable clouds of sulphurous gas. This stopped early the next morning. Photo about two and a quarter hours after the outbreak by Maehara.

of it to make a golden pattern of streaming across the lake. The latter made overflows about its edges, and so weighted down the heap as to cause some swelling up on the opposite side of the bottom area. On December 29 there was difference of elevation across the bottom so that the southwest cone was 122 feet higher than the northern floor. The inflow fountain diminished in size.

Harmonic tremor at the seismographs has been incessant. One feeble local seism December 30 at 11:18 p. m. was felt and indicated origin distance 14 miles. It was felt strongly at Puu Ulaula on northeast slope of Mauna Loa at elevation 10,000 feet. Three very feeble shocks occurred, of which one was felt. time 2:20 a. m. January 3. Microseisms have been heavy, and tilt was moderate SW.

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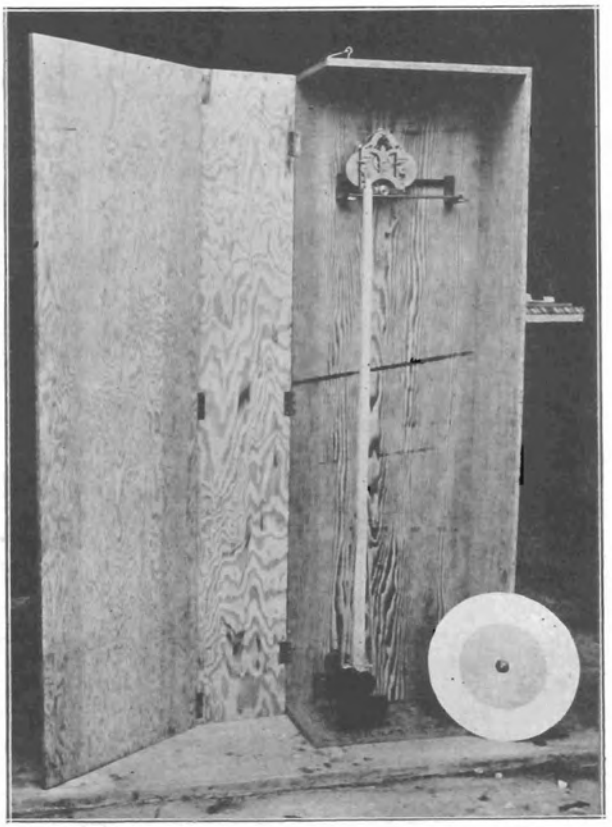
No. 368 Hawaiian Volcano Observatory, National Park, Hawaii January 14, 1932



Case and shock-recorder, with cardboard seismogram and aluminum disc removed, showing the general assembly.

EDITOR'S NOTE

In November 1929 the Scientific American published an article entitled, "Amateur Seismology," describing a simple instrument in the form of a horizontal pendulum consisting of a lead weight hung on a pinched hacksaw blade with an aluminum boom and pen writing on a smoked paper disc, revolved and moved along by a simple clock after the fashion of a gramophone record. A number of experimenters in the United States have made modifications of this instrument, and at the Hawaiian Volcano Observatory we have continued to experiment.

The text herewith is a set of instructions with appropriate illustrations to accompany eight new model shock-recorders which have been sent for service in New Zealand, under the Department of Scientific and Industrial Research. These differ from the original horizontal pendulums in that the mass and boom stand upright from the wall bracket which supports them, so that the entire case may be screwed against a cellar wall in the position of an upright clock. The necessity of having a large tabular surface is avoided and the clock rollers fall into the plane of the spring barrel, which simplifies the mechanism. T.A.J.

JAGGAR SHOCK-RECORDER VERTICAL OR WALL MODEL 1931

Instructions for Assembling

Each shock-recorder should have made for it a case, like a wall clock, a box 48 inches high, 15½ inches wide, 6½ inches deep, inside measure, with sides and cover made of 3-ply wood, the ends and back-board of more substantial planed lumber; and the metal parts are as follows:

2 narrow pieces of channel iron bolted together to form a basal support for the pendulum, and to be screwed against the back-board of the box at the bottom.

A heavy mass with two flat springs, anchored in lead inside a short iron pipe, and protruding from its side. These springs are pinched between the two channel irons about one eighth inch from where they enter the heavy mass. The heavy mass thus stands above the channel iron bracket as an inverted pendulum.

A long balsa-wood boom with a light pen at the upper end and attached at the bottom by aluminum plates and braces screwed into appropriate holes on the face of the heavy mass so that the boom stands upright.

A pair of tracks screwed against the back-board of the box at the top to hold the clockwork which rolls itself along on these tracks.

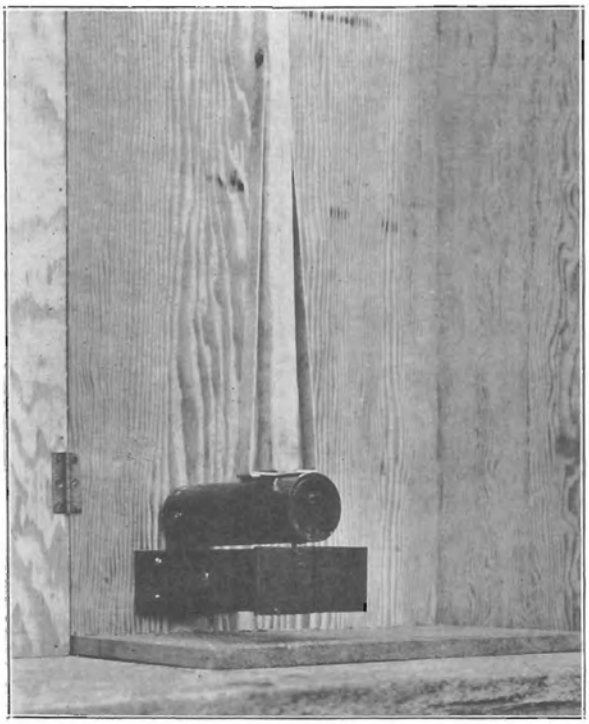
The clockwork equipped with rollers to fit the tracks, the double rollers on the back track and the single roller on the front track. The clock moves from left to right as you face it and is regulated so that its central spindle rotates once an hour when it is working.

Aluminum disc with central sleeve to fit spindle of clock, and central thumbscrew for handling the disc and for clamping to the face of the disc a circular card of white Bristol board 11 inches in diameter, punctured in the center to fit the pin of the thumbscrew cap. A smaller disc 3½ inches in diameter is clamped over the card only for smoking, in order to keep the card clean in the center.

Assemble tracks as shown on drawing, screwing the track rods on the angle bracket and placing at the back the track covered with rubber tubing. As the box is not supplied with the instrument, the placing of the parts on the back-board should be scaled from the drawing.

Clamp the flat springs of the heavy mass in the channel iron support, leaving ⅛ inch of spring between support and mass. Screw the channel irons against the back-board (1 inch round-headed brass wood screws) with the heavy mass uppermost. The lower edge of the channel irons stands ½ inch from the lower extremity of the back-board inside the box, and 4 inches from the left side of the back-board.

Lay out 36¼ inches vertically from the upper side of the channel irons to the angle of the bracket supports on the back-board, and draw a horizontal line as guide for placing these bracket supports. It is understood that the box stands upright against the wall like an old-fashioned clock. The left track bracket stands 2⅝ inches from the left side of the back-board.



Foot of case showing bolted channel iron pinching the two clock springs which are cast into the heavy mass. The boom of balsa wood is screwed to the top of the heavy mass by appropriate braces of aluminum.

Screw the balsa wood boom with its braces onto the mass, so that it stands vertical. The clock is set on the tracks with the small roller in front.

For removing and placing the disc on the spindle, the pen at the top of the boom is laid back, and the clock is simply slid well to the right, where the disc will be clear of the pen. Here the disc may be pressed by friction on the spindle or gently pulled off it by a slight rotation.

The period of the pendulum, set swinging by hand and timed with a watch, should be about ½ second to the right, and ½ second to the left, or a total of 1 second complete period. The longer the spring exposed between the clamp and the heavy mass, the longer the period. Count the number of swings for a full minute.

Needless to say, the adjustment should be such that the boom stands exactly plumb, and the arc of the needle when the point drops over against the carboard disc should bring the point, at about 45 degrees, on a horizontal line passing through the center of the disc, and about 2 inches to the left of the center.

It is possible to bend the supporting springs slightly in order to make the boom vertical, but it is undesirable to do so If these springs break, ordinary clock spring is obtained to replace them, the lead in the pipe which makes the heavy mass is melted and poured off, the springs are straightened and clamped in position, and the melted lead poured back into the pipe.

The weights and channel irons are lettered alike, in pairs. The left side of the shock-recorder box should be hinged against back-board and hooked forward top and bottom, when closed. The cover should be hinged to this side broad. Thus the left side of the instrument may be laid wide open for adjustments.

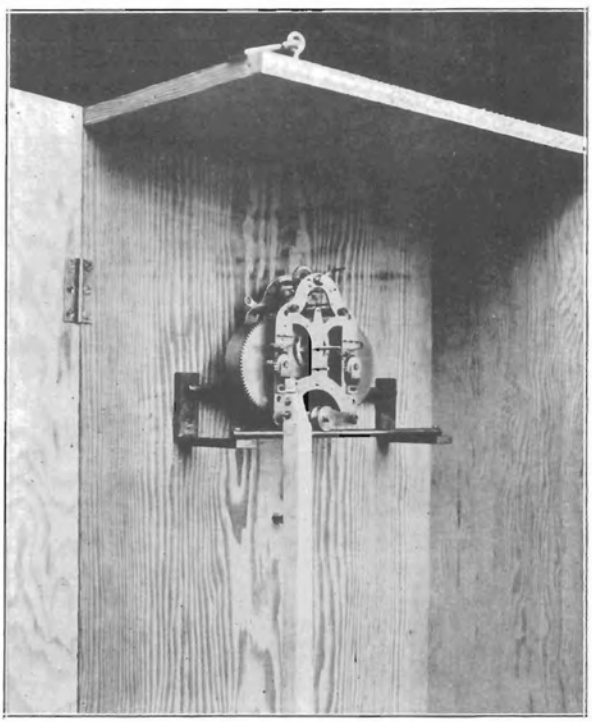
Operation of Shock-Recorder

Wind clock by removing it from tracks and place it back on the tracks. Screw a card disc on front of aluminum disc, by placing over the card the smaller disc, with its handle outward, and clamping with black rubber thumb-screw. Hold this by the back and twirl it slowly over a smoking kerosene flame (a lamp turned up to vigorous smoking of the chimney, kept for this purpose), with the card face downward until the whole card is an even light brown. Do not be afraid of putting card directly in flame provided it is kept twirling. The resulting brown if touched should streak with the finger showing pure white card. It is this brown film on which the shock-recorder pen writes a white line round and round the card during 24 hours. An earthquake interrupts these lines with a zig-zag pattern. The disc is its own clock-hand, as explained below. The smoked card should be handled entirely by the central rod so as not to smudge and disfigure the edges. Let the card, if warped by the flame, straighten itself out by cooling thoroughly.

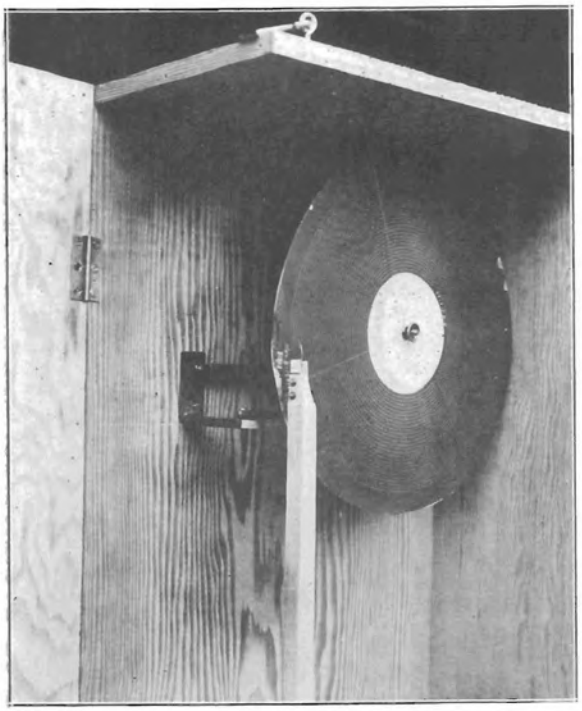
The disc is now pushed on to the clock spindle, with clock at right side of tracks, so that the edge of card is inserted behind the boom. The clock is now slid bodily to the left on the tracks until top of boom is 2 inches to the left of center of card, that is, opposite the inner part of the smoked band. Now tip the pen over, its point resting on the smoked surface. Use a stick like a painter's maul to rest the wrist on, and write with a dry point on the smoke the date, hour, and minute of starting, beside the white line which the pen makes. An ordinary pen without ink is good for this, scraping white figures on the smoke.

The machine is now at work for 24 hours and is left in complete quietness. It is vital that the wall be in a quiet cellar. Any upstairs wall will be affected by opening and shutting doors. The case should be screwed to a cellar wall where nobody goes except the operator once a day. Air currents, carpenters at work, an automobile on the ground close to the building, or a nearby engine, may make an artificial earthquake record. For good seismological work, complete quiet to the location is essential. Also look out for spiders and cockroaches.

Have a regular hour, say 8 a. m., for tending the shock-recorder. When the 24 hours is ended, mark the date and time beside the pen point, tip back the pen, slide the clock to the extreme right, gently remove the disc from the



Top of case showing driving clock on its tracks, impelled by rollers and turning the central spindle once per hour. Lateral movement 3 millimeters per hour.



Top of case with seismogram in place, showing brass pen and lines written on smoked card after 24 hours' work.

spindle by a slight right-hand rotation, and pull on the knob while the left hand holds the clock on the track.

The day's record must now be fixed for permanent keeping. Lay disc on table and carefully remove card from disc, touching card only by the edges. Prepare a flat pan, at least one foot in diameter, containing a solution of one part commercial liquid white shellac and fourteen parts denatured alcohol. This must be kept in a bottle between operations, as it evaporates rapidly. Holding the card by the edges between the two hands, pass it face downwards under the liquid once only, and hang it up to dry with a thumb tack. Data about the record, felt earthquakes, wind or weather, and the names of place and operator, may be written in ink on the white center of the seismogram card. This is now a permanent record of that day's seismical happenings at that place.

To get the time of an earthquake registered on one of the hour lines of the seismogram, it is essential that the disc rotate exactly once an hour. The clockwork may be regulated by the lever at the top in the usual manner, marked S for slower and F for faster. Prepare a tracing-cloth circle to put over the disc for reading time. Divide this circle in ink into 60 parts by tracing an ordinary clock face at the watchmaker's shop. Draw radial lines for each minute and heavier ones for each 5-minute point. Number these 0, 5, 10, etc., backwards as compared with an ordinary clock.

Suppose you started at 8:10 a. m. and the card disc is so marked at the inner first line of the spirals written round the disc by the day's work of the instrument. Set your radius 10 over that point with the tracing cloth centered over the seismogram. Suppose you have an earthquake recorded that was felt at 10:20 that forenoon. The first 0 reading around the line on the inner circle is 9 a. m., the second 0 is 10 a. m., and following on right to left counterclockwise 5, 10, 15, 20 minutes, the earthquake trace will lie under the 20 (10:20 a. m.) at its maximum amplitude; and the unfelt preliminaries will appear a fraction of a minute before the 20. The tail of the earthquake, or the dying away, will appear as a continuing vibration for several minutes.

By regulating the driving clock with some care for a few weeks, the amateur seismologist may get time within a minute by keeping track of the error of the clock as recorded at the end of each day's run. If the error is a constant, it may be best to leave the clock unregulated, and divide the error for 24 hours by the number of minutes in 24 hours. This gives you the error per minute. This applied to the number of minutes from the time of starting to the time of the earthquake corrects the card time for the earthquake.

A good operator should keep a good timepiece by which to mark the seismogram at the beginning and end of each day. Accuracy to the minute is probably near enough for such a rough machine, but persons with physical or astronomical training, receiving time by radio, can use this instrument as a timepiece if they are ingenious. It is customary to set up the shock recorders so that the face of the case is toward the north or south, and the pendulum thus swings east and west.

Erratum. The number of last Volcano Letter (377) should be changed to 367.

KILAUEA REPORT No. 1042

WEEK ENDING JANUARY 10, 1932

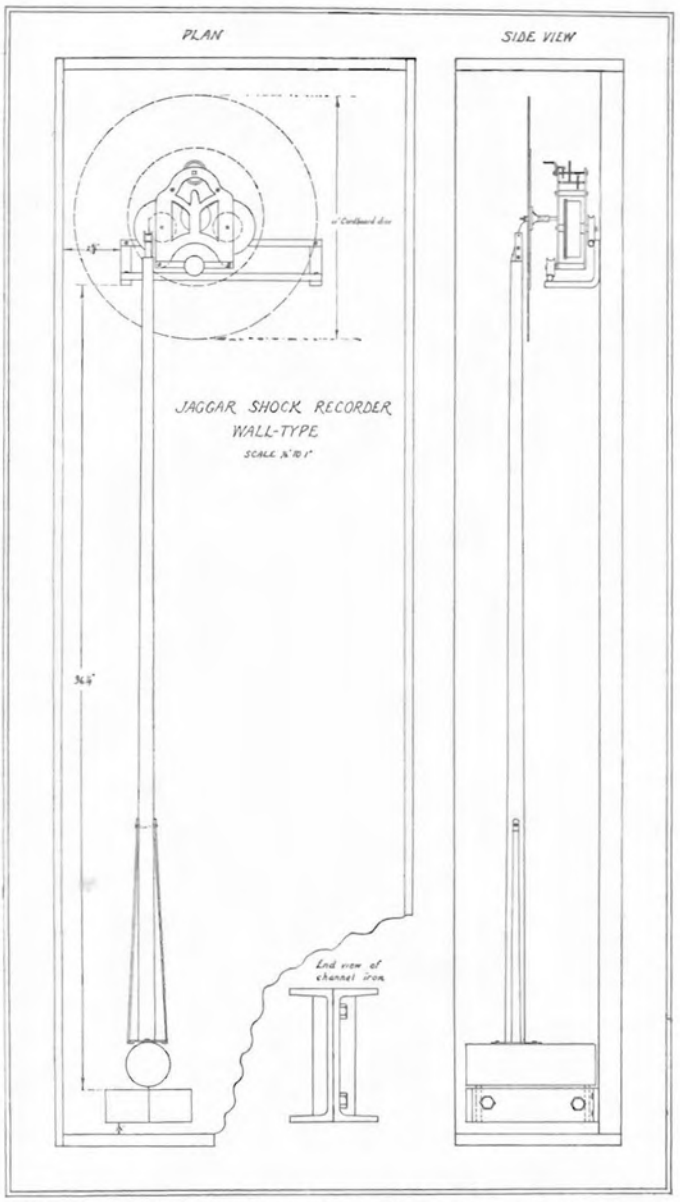
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Activity in Halemaumau continued until January 5, then stopped, leaving a floor with a big cone at one side, as in 1930. January 4 there were three streams from the cone, and an overflowing lake below occupying one third of the floor. January 5 the fountain had spells of stopping in the early morning, though the fume column was brightly lighted. At 10 a. m. there was the usual puffing and splashing, lake ramparts were overflowing east, and 3 rapid cascades poured eastward from the channel. At 2 p. m. the big fountain stopped and a little one formed in front of it: two streams gave place to one. Some booming was heard at 2:20 p m. Tremor on the seismographs at the Observatory was showing spells of increase and decrease. There was some backstreaming from the new fountain over the black lava of the interior of the cone. During the afternoon the cascades narrowed and the fountaining fluctuated, with booming. About 6 p. m. tremor at the Observatory ceased and the fountaining stopped gradually. At 8 p. m. there was very dull red glow, the pattern of lake and cone was outlined in glow cracks, the overflows were dull, and a few glow spots appeared at north edge of floor. The channel fountain made a few spurts of sparks, and a small glow chamber broke open at the central conelet. There were noises of cracking slabs, of small southern slides from the wall, and of hissing with the spurts.

January 6 the lake had slumped leaving hummocks. There were crackling sounds. The inner wall of cone flaked away leaving glow exposed. A little fume came from the east base of cone and other points. Steam rose at southern taluses. January 7 there were two small slides northwest and northeast about 11 a. m. January 9 rain made a hissing on the new floor. There were fume spots around the lake edge and at the cone. Some rocks fell and a small slide occurred at 11:10 a. m. New debris of reddish color had added 40 feet of width to the northwest talus. January 10 a crust ridge at southeast margin of bottom emitted blue fume which showed above the whole pit in afternon light, cumulus cloud still formed above the pit at higher levels due to heat, and a few points of glow still showed at night.

The seismographs registered 24 tremors, one indicated a probable origin distance 18 miles, 4 very feeble local seisms suggested origin distances of 6, 32 and 42 miles, and teleseisms were registered at 3:53 p. m. January 4 and at 46 seconds after midnight the morning of January 9; this last indicated a doubtful origin distance of 880 miles. Microseismic motion was mostly moderate, and tilting of the ground was moderate to the south. The harmonic tremor from the fountaining lava in Halemaumau increased between 1 and 2 p. m. January 5, and then decreased until it disappeared at about 6 p. m. in remarkable coincidence with the cessation of lava inflow.



Front and side elevations of shock-recorder and end view of channel-iron bracket supporting the mass. Cardboard disc 11 inches diameter.

THE VOLCANO LETTER

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Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

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The Volcano Letter

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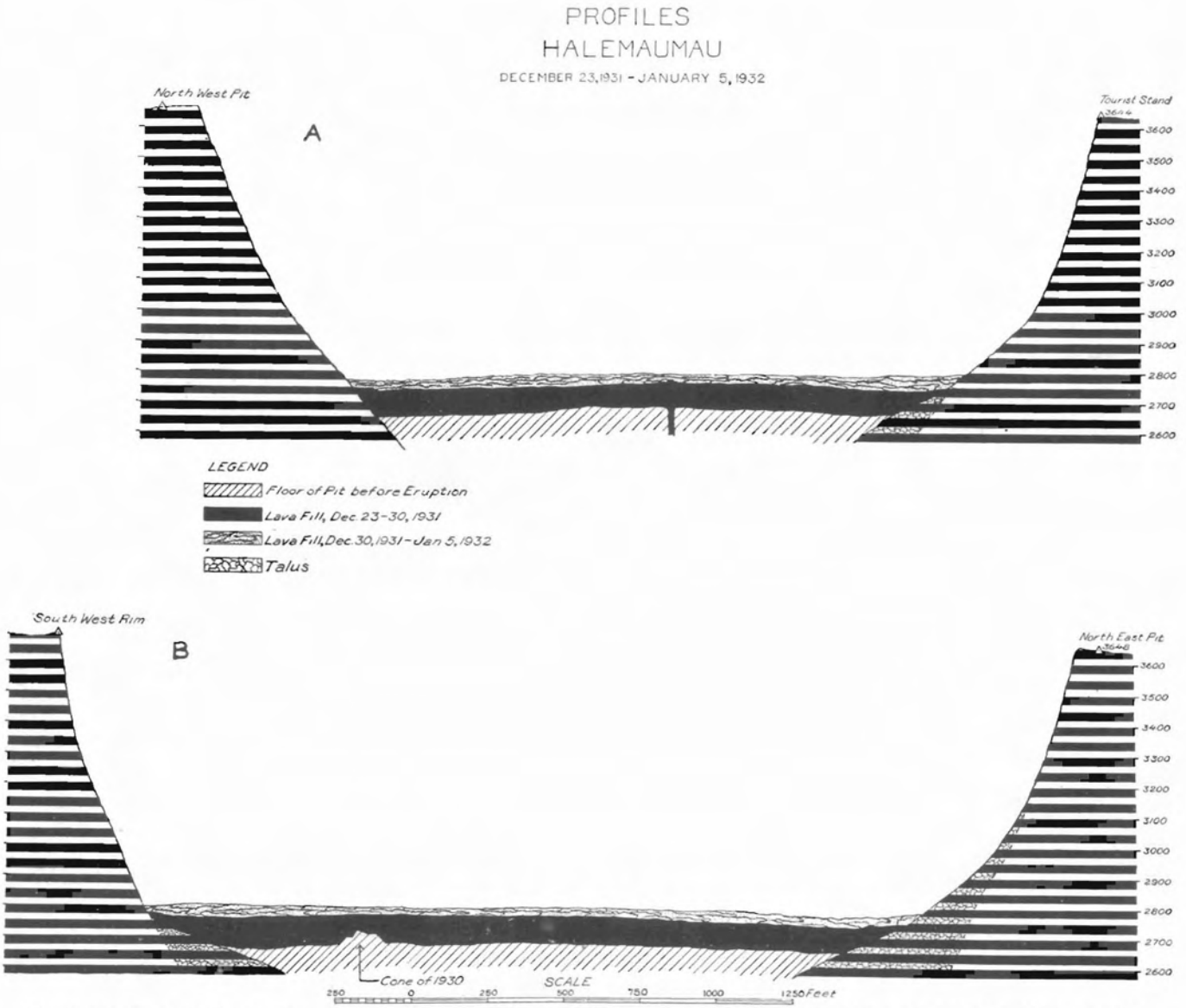
No. 369—Weekly Hawaiian Volcano Observatory, National Park, Hawaii January 21, 1932



Profile sections of Halemaumau pit at the end of the eruptive period December 23, 1931, to January 5, 1932, showing topography of bottom left by the eruption. See discussion in text, and map on Page Four. Drawn by E. G. Wingate.

JOURNAL CONCLUDING HALEMAUMAU ERUPTION JANUARY 4-10, 1932

The eruption which began in Halemaumau pit of Kilauea Volcano December 23, 1931, finished its apparent surface activity the evening of January 5, 1932, after somewhat more than thirteen days of inflowing lava.

Elevations of the parts of the surface of the new bottom when the lava lake was highest, 9:30 to 11:30 a. m. January 5, 1932, reported by E. G. Wingate, were as follows:

Area over 1930 conelet filled 73 feet.....elevation 2793 feet
Southwest bay filled 134 feet.....elevation 2792 feet
Lake under southwest cone filled 125 feet..elevation 2798 feet
Lake southwest of center filled 107 feet..elevation 2777 feet
West bay filled 113 feet.....elevation 2773 feet

The amount of filling over the whole floor was about 115 feet, or some 25 feet more than was shown by the measurements of December 29-30, 1931. The accompanying section profiles show the later fill light colored and the earlier

solid black. December 29 was the day when central fountains stopped. At the end the principal mound was the southwest cone itself, at the edge of the lava floor, not shown in the profile. The average bottom elevation 2789 feet, is 855 feet below the tourist station at the southeast rim of the pit.

The final heaping up of the border cone, with the fountain in its midst sending multiple cascades of lava to spread out on the floor, was quite like the closing stages of the eruption in November-December 1930. The cessation was rapid and quiet, without any marked down-sinking, within a few hours. The flowing simply stopped, the surface solidified, and the tremor at the seismographs stopped simultaneously with the end of fountaining.

January 4

The flow of lava from the southwest cone out over the floor of the pit continued as before, but there was no longer a single lake of lava filling the bottom of the pit as there had been during the first days of the eruption. The line of fountaining vents across the middle of the pit no longer appeared. Everything had been concentrated in an upflow at the big cone at the base of the southwest talus. There were doubtless intrusions going on within the heap covering the bottom of the pit, but their only effect at the surface lay in what was revealed by the surveys with transit showing differences of level of different parts of the bottom. Other effects of piling up, which produced differences of level, were due to the puddled flows from the cone as shown in the accompanying map, which have collectively been called a lake, because of a definite rampart bordering the pool in scallops and numerous islands of clustered crusts. The thickness of the new fill is various, both because of irregular heaping up, with a maximum near the southwest cone, and because of irregular topography of the mound of lava of 1930 which the new fill covered. This variability is shown in the profiles in their relation to the map.

On this morning at 7:30 a. m. there was the usual convection cloud of rain moisture due to the heat rising from the lava fountains and lake. At 8 a. m. three streams were forking from a wide river at the open side of the cone. Rapid cascades carried black crusts past two small islands in the central rivulet. The fountain was variable, as a whole not so high as at the beginning of the previous week, at times somewhat sluggish, and then developing a spurt of high jets with a roar. There were occasional brilliant slides as the red-hot sides of the cone caved in.

At 3 p. m. the fountains were bubbling steadily in the cone and spouting up from 50 to 75 feet. One river of lava poured out from the center of the horseshoe, its course at first northeast, and then deflected to the east by the slaggy slope which had been built up as a mound straight in front of the cone, when the river in earlier days had forked both east and west around an island. The western torrent no longer showed, whatever it may have been doing in tunnels, and the eastern one now divided into three streams surrounding three islands. The whole distributary system radiated out with bright lines and surfaces covered with satiny skins into a lake that covered about a third of the floor and was confined in a well defined rampart. On the west side there was much overflow amid crust islands and one small overflow stream poured from the lake to the east. Back of this was a large island which had been a remarkably persistent feature throughout the eruption, and perhaps marked the site of the cone of 1930. The rest of the floor showed pressure ridges and mounds and irregular hardened flow patterns, with chasms and cracks particularly conspicuous near the borders at the north.

January 5

Surveys were made from 9:30 to 11:30 a. m., and before this at 8 a. m. it was seen that the flow had lessened, but the fountain was still central in the cone, though weaker. The volume of outflow had lessened considerably as shown by the size of the streams, and the lake on the floor was smaller and the overflows through the ramparts had dwindled. Most of the filling appeared to be in the south bay. The river flowing from the cone forked into two streams with rapid cascades, and the islets were tending to become peninsulas. Fume above the pit had increased at 8:40 a. m. At 10 a. m. it was seen that the increased fuming was due to a revival of the fountain, which appeared quite normal with much puffing and splashing. Heat from the lake was strong at the south edge of the pit. The lake had vacated its ramparts on the west, and was overflowing ramparts to the east.

The scarp or heap in front of the main channel appeared brick-red and rusty on its upper surface. Three rapid cascades poured eastward from the channel, and over the pool on the floor of the pit there was streaming with radial zigzag bright lines fanning out to the east and northeast. Three island accumulations divided the cascades. The north floor of the pit showed scallop rampart patterns over its surface, and some pressure ridges. A remarkable feature was a group of four crevasses trending northeast toward the dike in the northeast wall of the pit. These were on the line of the first fountains of December 23, and where the line of fountains had been buried up by subsequent flows. The hardened surface, however, had become cracked on the line of the original rift and was apparently gaping open by tumescence.

The new floor of the pit was now against the rock wall between the taluses at the NE, NNW, WNW, S, and at two places on the E. The old rock wall at the southeast which had extended to the 1930 floor as a triangular ledge parting two taluses was now entirely buried. The cone and crater around the big fountain appeared to be in adjustment, and the noise of the cascades was a steady crackling.

The afternoon of January 5 created a new situation, with reports of avalanches, of a new position of the fountain, spells of excessive harmonic tremor at the seismographs alternating with very weak tremor, and dwindling of the cascades. The details of these changes were as follows, proving important as on this evening the eruption stopped:

At 2 p. m. the big fountain central to the cone went out of action and was replaced by a small fountain in what had been the main stream northeast from the craterlet. Inquiry from bystanders indicated that the large fountain was still erupting at 1 p. m. when the activity during 15 minutes migrated into the channel and about 1:15 the large fountain stopped. At 2 p. m. small streams were pouring down both cascades, but at 2:15 only the southern stream was visible leading from the channel fountain. It was at this time that heavy tremor at the Observatory was replaced by very weak motion.

At 2:20 p. m. booming noise was heard continuing for five minutes, and the northern cascade reasserted itself. It stopped, and the lava in the pot appeared to be rising and flowing back over part of the black lava where the central fountain had been. This action increased. At 2:42 p. m. the channel fountain appeared to be migrating northeast, somewhat smaller than before, and the streams were darker colored. Booming noise was repeated 2:58 to 3 p. m. and again at 3:15, when the cascades were small, duller in color, and flowing more slowly. At 3:24 there was a spell of vigorous fountaining. At 3:30 there was intermittent spurting with some booming. The southern

cascade was very narrow and most of the outflow poured through the northern channel. At 3:55 there was a spell of rather heavy fountaining.

During the course of these changes the crater margins in the cone had caved in, the pool on the lake floor was lowering and becoming dotted with many islands and crusted lumps, and there were some fuming patches about its borders. The dwindling of inflow appears to have been gradual from 4 to 6 p. m., though at the beginning of this time the fountain sent up some spurts 50 feet high. The cessation of the tremor at 6 p. m. probably coincided with actual cessation of inflow.

At 8 p. m. there was very dull red glow over the pit, hardly perceptible on the walls as seen from a distance, and almost none on the cloud above. When the pit was visited, it was found that the pattern of the lake was outlined in bright glow cracks, that of the overflows was less bright, and the cone was clearly outlined by incandescent fissures. There were a few glowing spots at the north edge of the floor. Gas activity still asserted itself in occasional spurts of sparks from the site of the channel fountain. There were hissing noises at these times. A small central cone in the floor which had been the last remnant of the central fountains caved in about 8:15 p. m. revealing a glowing chamber inside and making a noise of cracking slabs. There were some slides heard at the south wall of the pit. It was observable that the glow pattern of the floor showed colors in blue, purple, and red, suggesting the presence of some small flames through the cracks.

January 6

At 6 a. m. there was no visible flowing lava, and cracking sounds were nearly continuous with spells when they were louder. This suggested that cooling and slumping were going on. There were numerous glowing points like a bed of coals. Occasionally a cascade of cinders would fall from the inner walls of the cone showing glow underneath. There were some squeaking noises like rubbing slabs. Where the lake had been there were parts of the outlying rampart and numerous hummocks. A little fume rose at several places in the bottom of the pit, but was not noticed at the cone. There was steam from the talus slope above. Later in the day slight fuming was noticed at the top of the new cone and still more near its eastern base. The lake surface had evidently been slumping. Vapor was noticed on the southeast talus.

January 7

The end of this eruption, as in 1930 and the other short-lived fills within Halemaumau which have occurred since 1924, showed no sinking of the entire lava column. Such sinking was a characteristic of the end of eruptive episodes between 1915 and 1924. The explanation of the difference appears to be a difference in continuity of inflow and volume of material in the upright shaft that remains fluid. These small annual eruptions of the last few years appear to come up a crack in the bottom of the pit, cover the former floor with a layer of paste which more or less congeals with the term of the eruption, the inflow concentrates at one well, and this material also congeals and forms a plug. There may be more or less pastiness and incandescence to the bottom of the temporary fill, and loss of gas from this viscous fluid accounts for some slumping of the surface, also volume is diminished by crystallization. But there is no sign of sudden back-flow into the depths, such as caused lowerings of hundreds of feet in 1916, 1919, etc. The evidence seems rather to favor the supposition that there is a steady upward pressure of magma at present released by an occasional breaking through.

On this day, January 7, the floor of the pit was very irregular and hummocky and all sounds of settling had ceased. Two small wall slides were heard at the northwest and the northeast about 10:50 a. m. Otherwise the bottom was still and motionless just as the congealing lava had left it.

January 9

During rain in the forenoon there was a slight hissing sound from the hot floor. There were fume spots chiefly about the borders of the recent lake and at the south side of the cone. Rocks fell from the walls and a small slide occurred at 11:10 a. m. The rim cracks at the northeast continued to show slight widening such as had been noticed prior to the recent eruption.

January 10

Blue fume was observable over the pit when the sun passed behind the rising vapors, especially at the southeast, and much of this came from a smoking ridge of crust at the southeast margin of the floor. Cumulus was still forming in the high air above the pit, and a few points of glow in the floor were visible at night. T.A.J.

KILAUEA REPORT No. 1043

WEEK ENDING JANUARY 17, 1932

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Volcanic activity at Halemaumau pit remains dormant, and the most interesting development of the week for the Hawaiian Volcano Observatory has been the completion of a new seismograph hut erected for the Geological Survey by the Park force. This hut is close to the southeast rim of Halemaumau, in the same location as the former hut, but capable of housing two or more instruments, for more complete measurement of local earthquakes, tremor, and tilt.

On January 12 new fallen material was observed under the southeast wall and the floor appeared more hummocky. January 13 three slides were reported near the southwest rift crack in the wall during the forenoon, and in the afternoon fume was conspicuous, especially at the southeast hummock, rocks were heard falling, and rim cracks showed slight widening. Sulphur stain appeared in spots. Rather sudden northwest tilt had appeared at the Observatory. At 8:30 p. m. January 17 a glowing crack was seen near the southwest fuming hummock and one spot of glow in front of the new cone. Occasional rocks fell from the walls and a small slide from the north wall occurred at 8:50 p. m.

The seismographs registered 63 spasmodic tremors, two indicating origin distance 18 miles, one 42 miles, and one 46 miles. Five very feeble local seisms indicated distance chiefly 14 to 18 miles. Microseismic motion was moderate, and tilt slight NW.

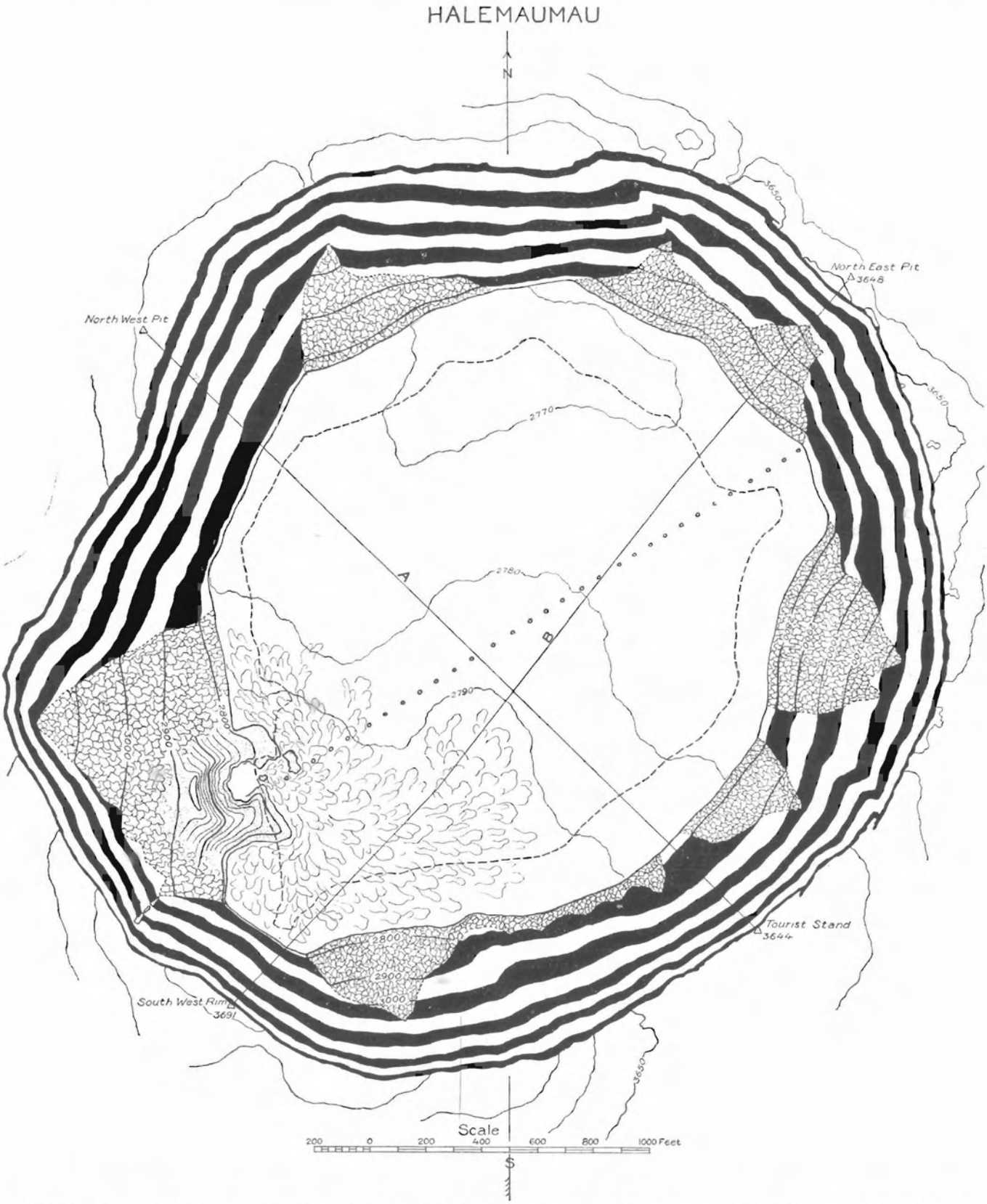
TILTING OF THE GROUND FOR DECEMBER

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction computed from the daily seismograms, by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

November 30-December 6, 1931	1.4 seconds	ENE
December 7-13	0.8 second	NE
December 14-20	3.2 seconds	NE
December 21-28	2.8 seconds	WNW
December 29, 1931-January 4, 1932	2.0 seconds	WSW

Tilt on both N-S and E-W components of the seismograph, as shown by the daily plat, had at the end of the eruption of Halemaumau pit, which occurred December 23 to January 5, indicated a return to a point on the seasonal curves almost identical with the points recorded immediately before the sharp NE tilts, indicated above as occurring just before the outbreak.

This would appear to indicate that these northeast tilts beginning 10 days before the outbreak were due to tumescence that was preparing to split open the lava of the bottom of the pit. These effects were so strong in their northing at the Observatory for the first half of the week December 21-28 indicated above as to make the average tilt show some north, though the actual swing of the pendulums on the day of the outbreak December 23 was strongly south and west. It will be seen that for the time of eruption the averaged tilt of the fortnight was strongly westerly, which is a direction towards Mauna Loa. E.G.W.



Map of January 5, 1932 to accompany profiles A and B, showing new southwest cone. Dotted line was floor of 1930.

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No. 370—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | January 28, 1932



New floor of Halemaumau, looking southwest 11 a. m. January 5, 1932. Lava stream pouring from conelet on southwest talus. In left foreground tension cracks on rift. Note burial of talus slopes as compared with 1927 Page Four. Photo Powers.

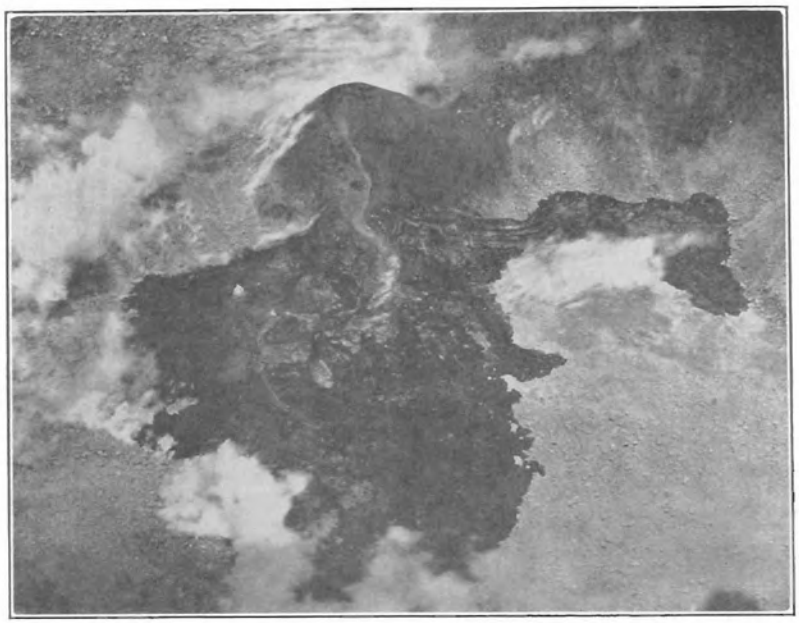
COMPARATIVE DATA ABOUT RECENT ERUPTIONS

The conclusion of the eruption in Halemaumau pit from December 23, 1931, to January 5, 1932, makes it of interest to review the data concerning recent eruptions of Halemaumau in Kilauea Volcano, which have tended to become annual. It was stated in Volcano Letter No. 366 that there had been a series of events tending to forecast the recent outbreak. Besides the expectable interval of about a year, there was accumated tilt away from the center suggesting upward pressure, there was a week of excessive tremors and earthquakes 10 days before the outburst, there was opening of measured cracks by unusual amounts leading to a rim-block avalanche at Halemaumau December 7, there was a strongish earthquake December 13 when Park rangers reported rumbling noises and slabs falling down cracks on the Kau Desert rift southwest of Kilauea, and there was an unusually strong shock on this same rift, within the crater, the forenoon of the day the eruption began. Features accompanying the eruption were the steady harmonic tremor which started and ceased in coincidence with lava inflow, occurrence of the crisis a year and 34 days after the outbreak of 1930, the sudden change of tilt accumulation at the edge of Kilauea Crater, from a tendency away from the center, to an inward tilting as soon as the gas and lava released the upward pressure; the gushing up along a straight crack on the rift line; the concentration to a conelet at one end of this crack; the accumulation of 115 feet of fill; and the duration of only 13 days.

This was all stated to resemble the incidents of former years, and it will now be profitable to compare these incidents systematically, in order to find out what was characteristic of each prelude, in how far these preludes resembled each other, and in what respects the eruptive sequences resembled each other.

Lava Inflow of 1924

The first volcanic event here following the great explo-



First lava eruption in bottom of Halemaumau after explosive crisis of May 1924. Cone and flows under west talus July 22, 1924, with lava flow spreading on bottom of pit. Photo Emerson.

sive engulfment which enlarged Halemaumau pit in May 1924, was the inpouring of lava at the bottom of that pit July 19-31, 1924. The pit was left in a condition of great instability with many avalanches and small earthquakes in June, and red-hot walls far down where intrusive rocks were exposed. A local seismic spasm led to a strong shock June 13 of grade about Rossi-Forel VI, when outside the north rim of Kilauea Crater new cracks were produced in the soil. The seismograph station is on the northeast rim of Kilauea Crater, and showed strong northeast tilts twice during the three weeks preceding the lava outbreak. Blue fume shot up from the pit at noon July 19, this at 1:45 p. m. was a jet spraying up through a vent in the southwest talus, making a small trickle of lava which collected in a puddle in the cup of talus that formed the pit floor. The jet became a fountain 125 feet above the bottom of the pit, the puddle spread about in leaf form with some internal fountaining, the cone became over a hundred feet high around the source, but the floor coating was only 25 feet thick. Harmonic tremor at the seismographs lasted from July 20 to 29.

Mauna Loa Eruption 1926

Mauna Loa broke out near the summit April 10, 1926, at 3 a. m., spread down the southwest rift its splitting action with frothy lava outflow, and sent a torrent to the sea which quickly ceased, but upland flows on the mountain ridge endured until April 30. At Kilauea there were numerous earthquakes indicating origins at Mauna Loa distances during several preceding months, there was a large increase in earthquake frequency during the Mauna Loa eruption, at Halemaumau there were rock slides due to quaking, and new cracks back from the rim broke the surface soil. Harmonic tremor at the Kilauea Observatory sympathized with the maxima of the Mauna Loa eruption April 10 to 22. At the same station there was slight accumulation of east tilt away from Mauna Loa during 1925-26, and very strong east tilt accordant with the Mauna Loa flowing April 11-24, and a reaction to moderate west tilt throughout May after Mauna Loa ceased.

Halemaumau Inflow 1927

After midnight July 7, 1927, a new outbreak of fountains in the bottom of Halemaumau split across the floor of 1924 in a line trending northeast-southwest, with the southernmost fountain some distance up the debris slope as before, and this was the only one which kept working more than a day. The line of four fountains lay but slightly to the west of the rift tunnel line shown by dikes in the wall of Halemaumau. Half the lava of the eruption came in during the first hour. The lake rose around the vents with the exception of the southern cone standing 120 feet above lake level. The area of new lava, shaped like a leaf with the cone at its stem, was 1760 feet long by 1420 feet wide. The new fill was about 110 feet deep when the last gushing ceased July 20, but the cone summit stood much higher.

On March 20 there had been a deep seated strong earthquake felt generally throughout the Territory, and objects were thrown down and broken in Hilo shops. On June 8 a small shock was felt about the island of Hawaii, and a strange light was seen believed to be a meteor. On the day of the outbreak July 7 a moderate earthquake at 3:21 a. m. came about three hours after the lava inflow began.

Cracks on the Halemaumau rim had widened excessively at the northeast side of the pit June 22 and thereafter, so that visitors were warned away from the edge. There was no widening after the eruption began. Tilt was to the north a fortnight before the eruption, and to NW and WNW thereafter. This westing of the tilt after the beginning of Kilauea outbreak has appeared repeatedly. Harmonic tremor at the Observatory appeared in a short spell at 10:55 p. m. July 6 about an hour before the outbreak, then was continuous for 24 hours July 7-8, and showed temporary recurrences July 10-12.

Halemaumau Inflow 1928

This eruption was very small, and its occurrence as lava upflow through cracks across the 1927 floor, in coincidence with a landslip from the northwest which compressed that floor, was explained at the time as a "false eruption' merely due to the squeezing up of 1927 lava still liquid under the crust. There is reason to revise this theory.

What happened on January 11, 1928, about 12:30 a. m. (just after midnight or midday appears to be a favorite time for eruptions), was the appearance of red glow from liquid lava in Halemaumau just after a monstrous

avalanche from the northwest wall which caused a big tremor on the seismograms at 12:26 a. m. It was found that new lava had spouted up at three places on the floor corresponding approximately with the sites of the two northern fountains of 1927. How much the rosy glow seen at first was due to fountaining is not known, but it disappeared in 20 minutes and at 1 a. m. the lava areas were flows glowing through cracked crusts with some blue flame at one vent. The northwest talus cone of the bottom of the pit had been overridden by a big fall of rocks from the wall so that the entire mass of debris slid forward and out on the lava floor in a pointed heap covering a sector of the northwestern surface. Two of the outflows were near the tip of this heap, welling up cracks and flowing away from the heap, and the other was at the north some distance from the debris. If the phenomena had been wholly a squashing down of the crust and a welling up of the liquid around the crushed area, the flowing should have been toward the debris heap. The flows cooled off within a day and the avalanches thereafter ceased, a remarkable fact, for these avalanches from this uneasy wall, and also from other walls of the pit, had been tumbling for a month.

The strongest reason for considering this a true lava outbreak is found in the seismic record of the preceding month December 1927. During this month 243 local earthquakes were registered, the roars from loud avalanches were frequently heard at the Observatory two miles away December 17-28, the slides were from the northern and the southern walls notably in the vicinity of the rift belt, and the eastern cracks at the edge of the pit showed measured widening of 2 to 3 inches increasing toward the north. The July floor became overlapped with debris all around, about 8 seconds of southerly tilt accumulated at the Observatory during the month preceding the outbreak, and the December record suggested a lowering of the pit bottom. However, this may have been an error, for on January 7 the WNW rim of Halemaumau showed new cracks breaking the sod 50 feet back from the rim, and large deep cracks three feet or more wide gave up hot steam. Such widening of cracks, preceding other eruptions, appears to have indicated localized swelling under the pit, whatever may be happening to the outside rim of the greater crater, where the Observatory measures tilt. It was precisely at this WNW rim where the big avalanche occurred at the time of lava outbreak. With the release of the liquid lava the tilt at the Observatory changed from strong southwest to slight northerly. Seventy-eight local earthquakes had occurred December 2 4, more than a month before the outbreak, and the number of general shocks indicating origin distances 15 to 30 miles away, during December and early January, suggests that seismic conditions were affected by a deep-seated cause. The high frequency of local shakings changed to normal abruptly after January 11. All of this evidence goes to show that a change in magmatic pressure under Kilauea Volcano produced extraordinary seismic conditions for six weeks, there was unusual motion on the rift belt along the west side of Halemaumau pit, and the adjustment of a deep-seated block there, both released the eruption and brought the avalanching period to a close.

Halemaumau Inflow February 1929

At 12:46 a. m. February 20 molten lava gushed up in a big fountain at the northwest edge of the bottom along a straight fracture 1370 feet in length. A great lake filled the bottom east of the fracture line, some 60 feet in depth, the southern vents quickly became submerged in the lake, and the northern one built a half-cone of pumice with jets of the Mauna Loa type shooting 225 feet into the air. Pellets of basaltic pumice and Pele's hair fell outside of the pit. The pit seismograph registered tilting, accompanied by small earthquakes, two hours before the eruption was noticed, and straight away from the center. At the same instrument continuous strong volcanic tremor was written during the period of fountaining. This all ceased when the eruption ended about 1 p. m. February 21, and strong tilt was indicated back toward the center of the pit during four hours preceding the cessation of action. The eruption left a net gain of 5 seconds tilt away from the pit.

The prelude to this eruption, as shown by tilt instrument at the Observatory, was strong southerly seasonal tilt throughout the weeks before and after the outbreak, but with a gradual change from east to west. There had been tremor January 5 9 and 16 28, probably occasioned on January 5 by much avalanching, accompanying excessive opening of cracks at the tourist station on the southeast rim of Halemaumau. This necessitated changing the trail and making a new viewpoint. The climax was reached January 10, when slides became fewer. On February 5, 15 days before the outbreak, an earthquake occurred at 2:25 a. m. felt throughout the island of Hawaii.

Halemaumau Inflow July 1929

On July 25 about 4:35 a. m. the seismographs at the Observatory registered a series of very small earthquakes a few minutes apart, each accompanied by tilt to the east. Then strong continuous harmonic tremor developed. Lava again broke out at the west edge of the floor in the bottom of Halemaumau. The center was a fracture through the talus, tangential to the bottom plug, making big fountains at the base of the west talus. The seismograph at the pit showed inward tilt the first day, outward tilt thereafter, and tremor registered continuously while the lava fountains were in action. The eruption ceased the evening of July 28 and the liquid lake reached a depth of 94 feet, followed by settlement of 20 to 30 feet after solidification.

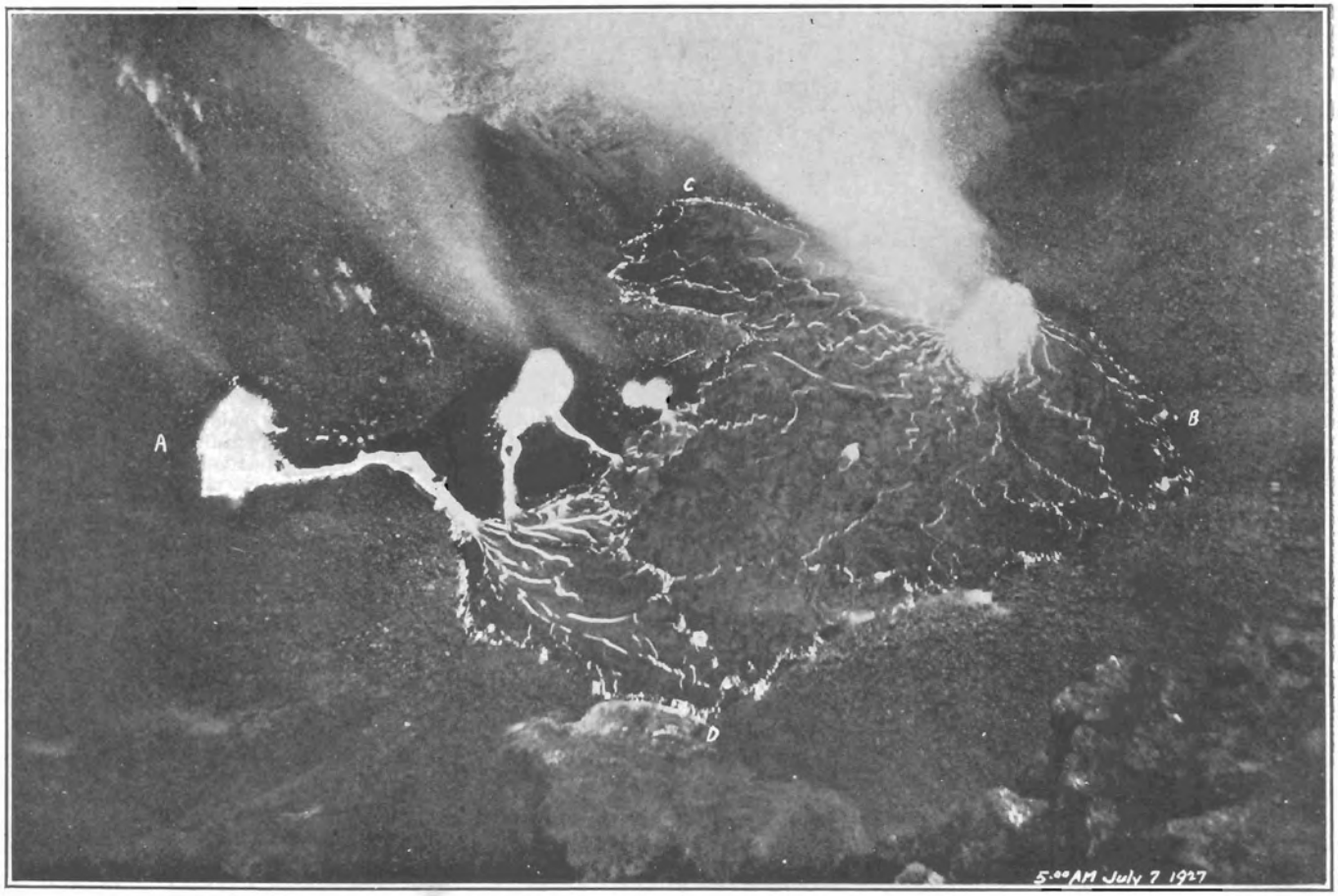
The ground tilted moderately north at the Observatory during the week preceding the eruption, and the tilt changed to southwest on the day of the eruption, becoming moderate south for the week. Cracks at the east edge of the pit had shown by measurement tendency to open since May 15 There had been two strongy felt earthquakes on the morning of June 18, occasioning avalanches on the west bluff of Kilauea Crater as well as in Halemaumau.

Halemaumau Inflow 1930

It should be here recorded that an extraordinary seismic crisis about Hualalai Volcano occurred in October 1929 which appeared to indicate a new shift of magma from under Mauna Loa in the direction of Hualalai. No lava outflow coordinate with this movement has yet appeared.

At 1:29 p. m. November 19, 1930, lava broke through the 1929 floor of Halemaumau in three fountain groups south of the central region, two of these being of small size which disappeared during the first two days, the third continuing to spout vigorously and build up a cone. The lava spread over the 1929 floor, then built a central lake of molten lava surrounded by ramparts, through which overflow on three sides removed the new lava as rapidly as it was supplied, and completely covered the former floor of the pit. After two weeks of action the lake area was 500 by 800 feet, the cone was 75 feet high and 200 feet in diameter at the base, the entire new bottom area was 2300 feet by 1700 feet, and the new mound stood above the former bottom 175 feet at the cone, 100 feet at the lake, and at the north side of the floor about 50 feet. The eruption ended December 7. Tremor accompanied the eruption as before and died away at the end. Tilt change was from moderate northeast November 10-16 to moderate southwest after the outbreak began, with a return to strong north and northeast in December. The pit seismograph had recorded tilting of the ground away from the pit and many small tremors a week before the outbreak. On the day of the outbreak this instrument recorded 18 small shocks culminating in a very feeble earthquake ot 11:06 a. m. with a slight tilt toward the pit. This was followed by a series of 30 small shocks and other earthquakes. Moderate and slight felt earthquakes and avalanches had occurred in September and October.

Reviewing the seven Halemaumau inflows in seven years, a typical eruption may be said to be heralded by one or more strongish earthquakes a few weeks before the outbreak, or by unusual seismic frequency, and 1931 produced a smart earthquake a few hours before inflow. Cracks on the rim of the pit are apt to exhibit distension of the edifice by spreading open, and so loosening the inside walls as to make avalanches. This is likely to occur along with centrifugal tilt just before the eruption. All of these eruptions appear influenced by the northeast-



Eruption in bottom of Halemaumau July 7, 1927, at 5 a. m. Shows the four main vents in line, that on the left being the high cone which persisted. Looking west-northwest. The floor of 1932 is against the wall at the top of the picture. Photo Wilson.

southwest rift belt which crosses Kilauea Crater; the final gushing splits the former floor and rapidly concentrates at one vent. There is temporary inward tilting and continuous tremor while the gas foaming of the fountains is going on. The whole series of eruptions marks an upward pressure accumulating. The eruptions have increased in volume of output and violence of effervescence, but their duration has been variable from 1 hour to 18 days, with the last two outbreaks the most enduring. T.A.J.

KILAUEA REPORT No. 1044

WEEK ENDING JANUARY 24, 1932

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The settling down of the Halemaumau floor, the bottom of the inner pit of Kilauea Crater, is all that has happened during the past week, and the cracks in the new lava of the recent eruption are no longer seen glowing at night. After excessive rainfall for several days, the hot lava fill on January 20 was seen to be steaming from hundreds of small vents all over the surface, the new cone was ringed by steam, there was steam on the taluses and walls, and vertical lines of vapor vents could be followed up the western and southern walls. These are upright cracks in the wall where the east and west fault blocks are marked above by steam cracks parallel with rim of pit. On January 18 at 8:30 a. m. after 4.10 inches of rain in 24 hours a steam cloud rose from Halemaumau and water cascades poured from Uwekahuna. At 2 to 3 p. m. some rocks were heard falling, rim cracks N and NE showed very slight widening, a central vent in the floor showed much blue fume, and eight others showed less, and new debris overlapped the lava floor at the base of the talus slopes. January 22 the pit was absolutely quiet.

One feeble local earthquake occurred 2:06 a. m. January 19, origin distance 32 miles. There were 29 spasdomic tremors, some indicating origins 2, 6, 20, and about 35 miles away. Microseismic motion was moderate, and tilting of the ground moderate ESE.

THE VOLCANO LETTER

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Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

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REVIEW OF EARTHQUAKE RECORD KILAUEA 1931

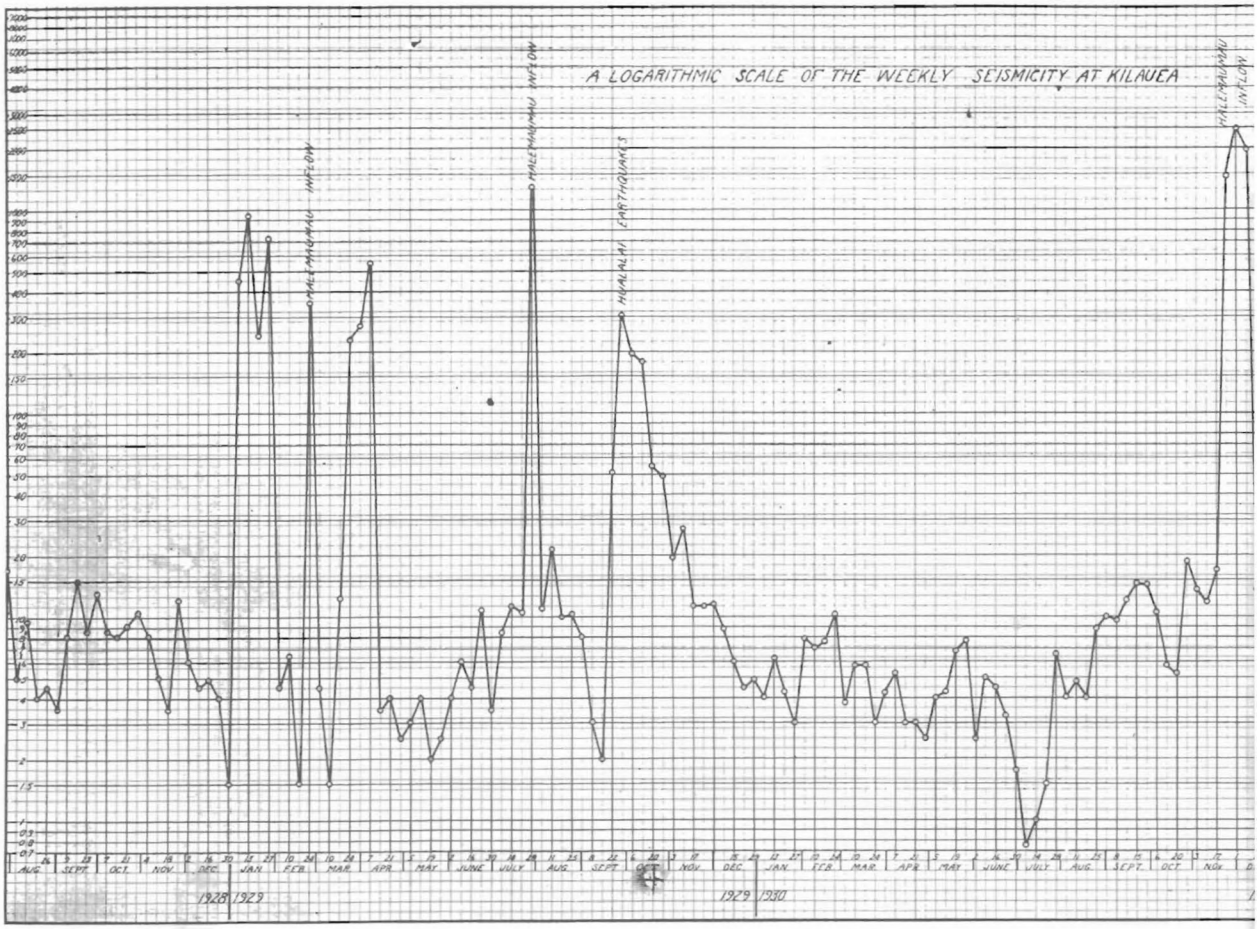
tr —tremor, value ¼ Rossi-Forel
vf —very feeble, ½ Rossi-Forel
f —feeble, 1 Rossi-Forel
SSRF—seismicity summation R.F.
sl —slight, value 2 Rossi-Forel
mod—moderate, 3 Rossi-Forel
tel —teleseism, or distant earthquake, no value for local seismicity.

Week ending 1931	tr	vf	f	sl	mod	tel	SSRF	log
Jan. 5	55	1	1	0	0	1	15.25	1.183
12	27	3	0	0	0	0	8.25	0.917
19	22	5	0	1	0	2	10.00	1.000
26	30	14	0	0	0	0	14.50	1.162
Feb. 2	40	27	1	1	0	0	26.50	1.423
9	11	2	1	0	0	1	4.75	0.677
16	12	2	0	0	0	0	4.00	0.602
23	19	1	0	0	0	0	5.25	0.721
Mar. 2	25	2	1	0	0	0	8.25	0.917
9	16	2	0	1	0	0	7.00	0.845
16	34	3	0	0	0	0	10.00	1.000
23	22	2	0	1	0	3	8.50	0.929
30	29	3	0	0	0	1	9.75	0.989
Apr. 6	55	5	1	0	0	1	17.25	1.237
13	17	0	0	0	0	0	4.25	0.628
20	18	6	1	1	0	0	10.50	1.021
27	23	3	0	0	0	1	7.25	0.861
May 4	33	4	2	0	0	0	12.25	1.088
11	38	0	0	0	0	1	9.50	0.978
18	29	1	0	0	0	0	7.75	0.889
25	25	1	0	0	0	0	6.75	0.829
June 1	33	1	0	0	0	0	8.75	0.942
8	29	1	0	0	0	0	7.75	0.889
15	27	6	0	1	0	0	11.75	1.071
22	26	1	1	0	0	0	8.00	0.903
29	22	0	0	0	0	0	5.50	0.740
July 6	34	2	0	0	0	0	9.00	0.954
13	18	5	0	0	0	0	7.00	0.845
20	18	3	0	0	0	0	6.00	0.778
27	19	2	0	0	0	0	5.75	0.760
Aug. 3	16	1	1	0	0	0	5.50	0.741
10	39	6	0	0	0	1	12.75	1.105
17	22	6	0	0	0	1	8.50	0.929
24	24	3	0	0	0	0	7.50	0.875
31	19	1	2	0	1	0	7.25	0.861
Sep. 7	36	5	0	0	0	0	11.50	1.061
14	56	5	1	0	0	1	17.50	1.243
21	43	1	2	0	0	0	13.25	1.128
28	26	4	1	0	0	1	9.50	0.978
Oct. 5	20	2	0	0	0	1	6.00	0.778
12	28	8	0	0	0	1	11.00	1.042
19	40	2	0	0	0	0	11.00	1.042
26	11	1	0	0	0	0	3.25	0.512
Nov. 2	40	3	2	0	0	0	13.50	1.131
9	59	0	0	0	0	0	14.75	1.169
16	81	6	0	0	0	0	23.25	1.367
23	51	2	0	0	0	0	13.75	1.138
30	22	2	0	0	0	0	6.50	0.810
Dec. 7	24	3	0	0	0	0	7.50	0.875
14	46	9	1	0	1	0	20.00	1.303
21	28	6	0	0	0	0	10.00	1.000
28	6,531	9	1	0	1	0	1641.00	3.215
1932								
Jan. 4	10,080	3	1	0	0	0	2522.00	3.419
11	2,544	4	0	0	0	2	638.00	2.805
18	63	5	0	0	0	0	18.25	1.260
25	29	0	1	0	0	0	8.25	0.915

A CHART OF KILAUEA SEISMICITY

The accompanying diagram exhibiting seismic motion of the ground is a compilation of earthquake activity, representing one of many attempts to show in a single graph a combination of the number and intensity of earthquakes for a given time. What is called seismicity, or the earthquake shakiness of a country, is compounded of tremors and small shakes and big shakes, with many of the smaller phenomena and very few of the big ones. If all are a release of some form of underground energy where magma is moving under a volcano, it is reasonable to think of a single big earthquake as in some way the equivalent of many small ones. (See discussion of Earthquake Intensity Scales, Volcano Lettetr No. 223, April 4, 1929.)

At the Hawaiian Volcano Observatory the weekly descriptions of local seisms or quakes describe them as very feeble, slight. moderate, etc., and these words are not colloquial, but are systematic. The word "slight" means relatively big as compared with "very feeble." By giving a weight or value in terms of the Rossi-Forel scale to each descriptive word, we can add together these values for the number of earthquakes of each grade for each week and secure a figure standing for the combined shakiness of that week. The following is the table of weights:



Curve of rising and falling earthquake and tremor activity, expressing combined weekly frequency and intensity measured at the Observatory on northeast rim of Kilauea Crater from August 1928 to J

Observatory Scale	Weight	Description
Tremor	¼	Can barely be seen on the seismograph records; when continuous the unit is the minute of duration.
Very Feeble	½	A slightly larger shock, not ordinarilly felt by people even when very close to the origin. Rarely reported felt by persons lying down.
Feeble	1	Felt by few or none, an earthquake on the border line between being instrumental and felt. No. I Rossi-Forel scale.
Slight	2	No. II Rossi-Forel scale. Felt slightly.
Moderate	3	No. III Rossi-Forel scale. Felt moderately.
Strong	4	No. IV Rossi-Forel scale. Felt strongly.

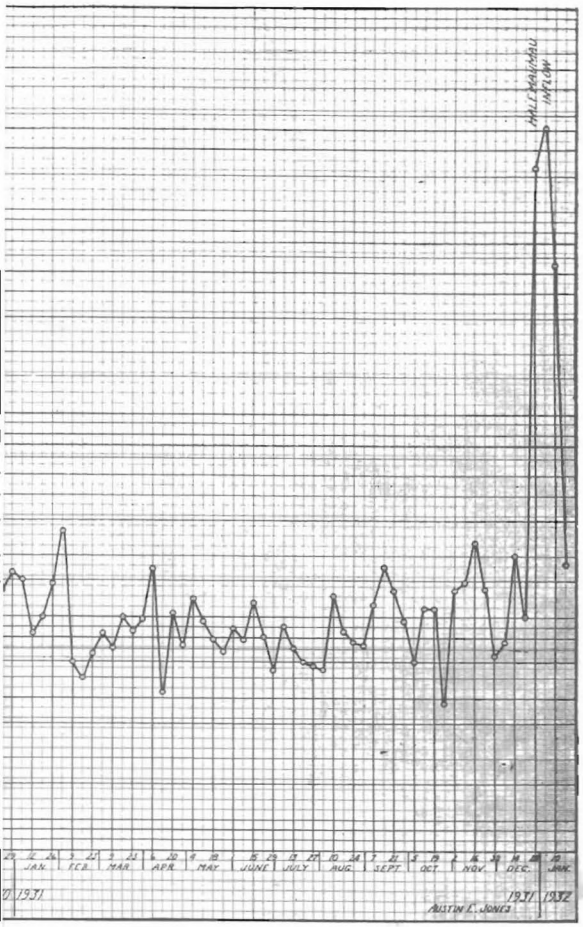
An earthquake felt strongly is still in the weak class, but from the point of view of instrumentalists, operating seismographs that magnify the earth's motion one hundred times, this quake is strong because it always dismantles the connecting bars of a sensitive seismograph. This does not mean that it breaks anything.

These grades are weighted roughly in terms of the Rossi-Forel scale as ¼, ½, 1, 2, 3, 4, and mathematically, in terms of accelerations, the Rossi-Forel scale is logical in that Grade II is twice as big as Grade I, etc., up to Grade IV. Beyond Grade IV the progression is not arithmetical.

If in one week we have 10 tremors or 10 minutes of tremor (value 2½), three very feeble shocks (1½), a slight earthquake (2), and a moderate earthquake (3), the resulting index of that week's seismicity is the summation of these values equal to 9. Thus in the accompanying tabulation the week ending July 6, 1931, had that value because of the very large number of tremors.

If we were to have several days of continuous tremor, each day would produce 1,440 minutes of tremor, or an index of 360. Such an example can be shown for the last eruptive period of Halemaumau beginning in December of 1931. During the week ending December 31, 1931, there were 11 tremors, 9 very feeble shocks, 1 feeble one, and a moderate earthquake preceding the eruption which began on December 23. The summation index to this point is 11.25. This was followed by four days and a half of tremor, the index of which amounted to 1630. The total index of seismicity for the week is obtained by adding together the two figures and amounts to 1641 units.

If this were platted on uniform coordinate paper, the figure 1641 would be about 180 times as great as that for the week mentioned above having the index of 9, so that if inches were used as units on the paper, the line would rise 135 feet. To avoid this difficulty the logarithms of



of local earthquakes, and duration of local tremors.
nuary 1932. By A. E. Jones.

all index numbers have been taken and platted for the number of units involved vertically above each date. In the accompanying table the logarithmic figure is shown in addition to the seismicity figure. On the curve a logarithmic scale has been drawn across the diagram with the seismicity sums R. F. on the left. These read from 0.7 to 9000 and the sheet is thus adequate to contain all the peaks and hollows for the three and a half years from July 1928 to January 1932.

To judge by the height of the peaks, during eruptions of lava flowing into Halemaumau in February and July 1929, November 1930, and December 1931, making a pronounced rise of the curve in each case, determined largely by continuous tremor, evaluated for each minute arbitrarily as one-quarter unit, it seems likely that this arbitrary value is much too great. The method, however, has the advantage of exhibiting an effect of these eruptions on the seismicity curve with much vividness. A.E.J.

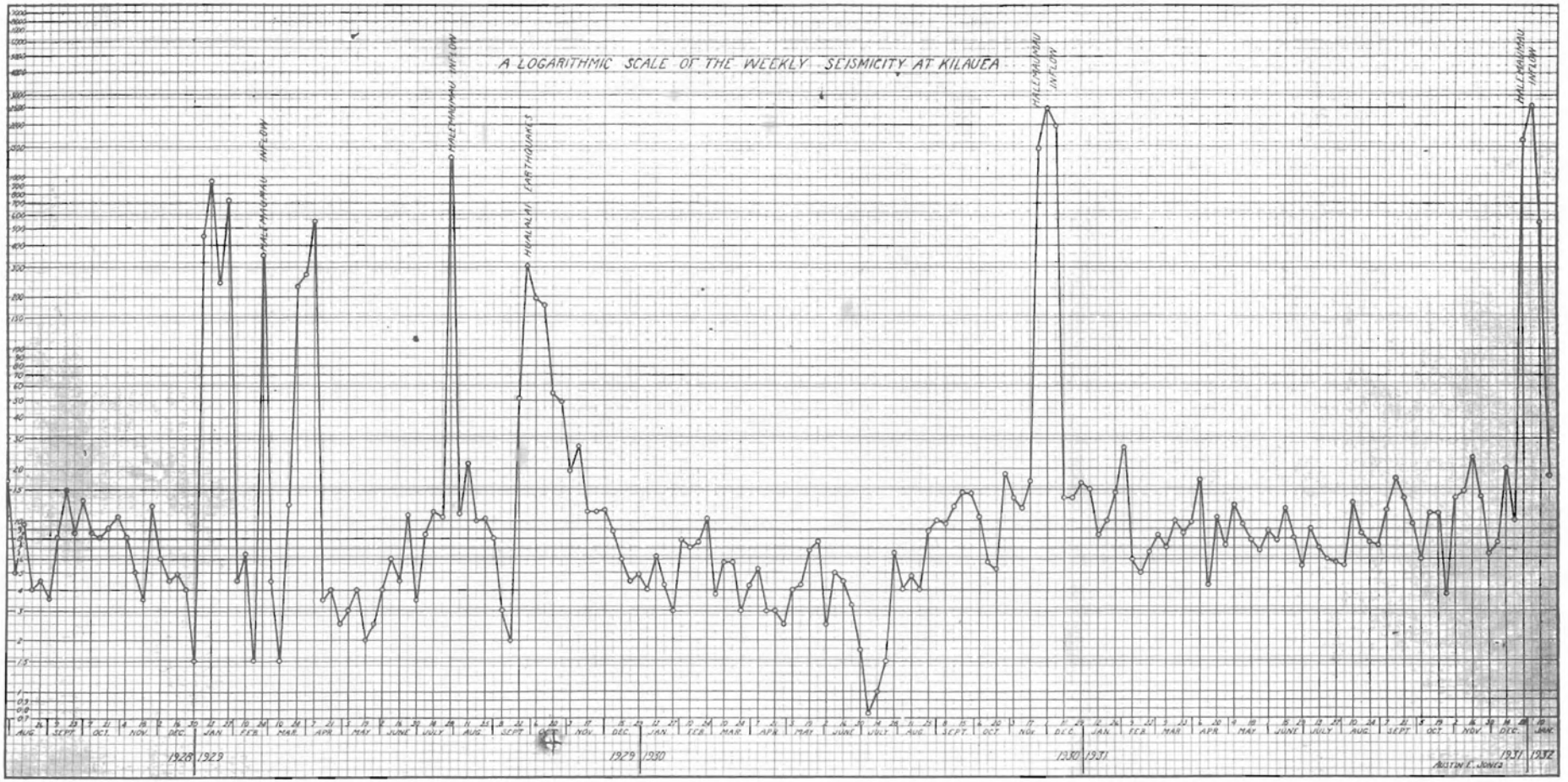
DISCUSSION OF SEISMICITY CURVE 1928-32

The table which was used by Mr. Jones in compiling the curve described above, will be better understood if it is presented in full for this past year 1931 in order to show how the curve was drawn for the right-hand side of the diagram. The table is on Page One.

Curves of earthquake frequency by months and by three-day units have been experimented with at the Hawaiian Volcano Observatory as follows: By Jaggar, monthly local earthquake frequency compared with maximum intensity from 1912 to 1916, in "Seismometric Investigation of the Hawaiian Lava Column," Bull. Seis. Soc. Amer. Dec. 1920, p. 259, when it appeared the peaks were at rythmic intervals of about nine months and increasing along with a series of Mauna Loa events. Next a study by Wilson Bull. Haw'n Volc. Obs. Dec. 1927, fig. 47, wherein the three-day frequency was smoothed by overlapping means, did not include harmonic tremor (nor did the one above), and analogy with the lunar half-month was suggested. Taking frequency alone, there was no peak accompanying the July eruption of Halemaumau 1927, but a comparative symbol indicating intense earthquakes showed a swarm of them not reflected in frequency curve, but occurring at the beginning and the end of the eruption. Thus Wilson's curve, compared with the new method by Jones, would have shot up for the 1927 eruptive period, had it embodied an integration of harmonic tremor and intensity along with frequency, as has been done in the new type of curve. In a diagram compiled by Finch for comparison with tilt (Bull. Seis. Soc. Amer. Mar. 1929, p. 41), marked peaks in monthly earthquake frequency for the years 1913-1925 are shown to accord with drops in the lava of Halemaumau and with Mauna Loa outbreaks, the highest frequency according with the tremendous drop of 1924. In 1916 when there was a sudden drop of the Halemaumau lava immediately following an outbreak of Mauna Loa, there were two peaks of earthquake frequency side by side accompanying these events (Jaggar, Amer. Jour. Sci. Apr. 1917, fig. 2 p. 259).

The outstanding features of the curve for seismicity at Kilauea from 1928 to the beginning of 1932 are the high peaks of suddenly increased seismic activity that accompanied the four outbreaks of Halemaumau. By consulting the last number of the Volcano Letter, January 28, 1932, the reader may learn the details of these eruptions February 28, 1929, July 25, 1929, November 19, 1930, and December 23, 1931. It was there stated that in general these eruptions were progressively more intense and more enduring, and it is clear from the chart that the four peaks of seismicity are progressively higher and wider. Mr. Wilson's curve mentioned above showed a composite peak of earthquake frequency in December 1927 immediately preceding the very mild outbreak of January 1928, and this was made up of much tremor accompanying avalanches in Halemaumau pit and the widening of some cracks on the edge. If that episode were added to the left-hand side of our diagram, we should find a still smaller peak for the actual eruption week of 1928 and a big complex peak preceding it. So for the seven weeks preceding the February eruption of 1929 there is a composite and enduring peak of seismicity which was accompanied by widening of cracks and numerous avalanche tremors, as well as other seismic events distinctly premonitory to the lava inflow of February 20.

Not so clear is the explanation of the third peak between March 10, the time of low tremor following the eruption, and April 14, when general decline began. The only events of note during this time were rather protracted spasms of tremor, a certain number of avalanches, and some rather strong tilting. It seems likely that this peak in seismicity represents a distinct slump in the lava column following the eruption, but its qaulity of gradual rise and sudden fall to a point below normal is unusual.



Curve of rising and falling earthquake and tremor activity, expressing combined weekly frequency and intensity of local earthquakes, and duration of local tremors. measured at the Observatory on northeast rim of Kilauea Crater from August 1928 to January 1932. By A. E. Jones.

If we look at the curves on either side of the other Halemaumau eruptive periods as shown in our diagram, there is nothing analogous to these peaks of preparation and of aftermath.

The Hualalai earthquake crisis of September-October 1929 is developed as a very sudden rise in the seismicity curve, followed by a stepwise decline for 17 weeks, and this curve is quite in accord with the facts of observation, for the strong intensity and the strong frequency showed maxima soon after the beginning. It will be seen that this is a true earthquake curve of sudden intensity, followed by swarms of aftershocks, and quite unlike the steep bilaterial curves that accompanied the Halemaumau outbreaks.

When it comes to the general curve of seismicity in the diagram, disregarding the high peaks, it is evident that this curve as a whole tended to fall below the figure 10 from 1928 to July of 1930, and that then there was a pronounced rise in seismicity, and thereafter the small crests tended to rise above that figure. The minima approached low levels right while the maxima were reaching high ones about February 1929, again in September of that year, and the lowest of all was reached in July of 1930. In the whole diagram there is possibly some suggestion of a wave movement with troughs of minima 16 months apart. When it comes to the small oscillations, there is a marked tendency to troughs from two to six weeks apart, possibly corresponding to the lunar month and half-month. This tidal effect for both seismicity and lava movement has been discussed before. The fact of the diagram are 20 cases of complete periods occupying four to six weeks, 20 occupying three weeks, and 14 occupying two weeks. The mean is 3.4 weeks, which is near enough to the lunar month for such crude results over a short interval of time.

There are many questions raised by this diagram as to the comparability of local seisms, spasmodic tremor, harmonic tremor, and avalanche tremor, and the equivalence of the units used in terms of acceleration, or of whatever product of amplitude and period properly constitutes seismic intensity. It should be noted, however, that this is not an intensity curve, but is rather an intensity-duration curve, and this taking account of frequency is new, and the seismologist of this station is to be congratulated on the experiment. T.A.J.

KILAUEA REPORT No. 1045

WEEK ENDING JANUARY 31, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Nothing remarkable has happened at Halemaumau pit suggestive of movement of lava. The new floor is hot and a high cumulus occasionally forms above the pit. On January 26 in the forenoon no single vents on the floor could be identified as emitting fume, there had been sliding from southerly walls as shown by numerous bowlders and fresh debris on the 1932 floor SE, and red material on floor S. The northeast rim cracks continued to widen slightly by measurement. At 11:18 a. m. a slide from the northeast wall, beginning near the top, made dust.

The seismologist reports 1 very feeble local seism January 28 at 8:18 a. m. with indicated distance 6 miles. Forty-eight local tremors were recorded, 3 suugesting origin distance 9, 18, and 23 miles. A distant earthquake registered January 29 at 3 h 21 m 12 s a.m., indicating approximate origin distance 3100 miles, began too indefinitely to show direction of origin.

Microseismic motion has been moderate, and tilting of the ground moderate to the east.



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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano. also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

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The Volcano Letter

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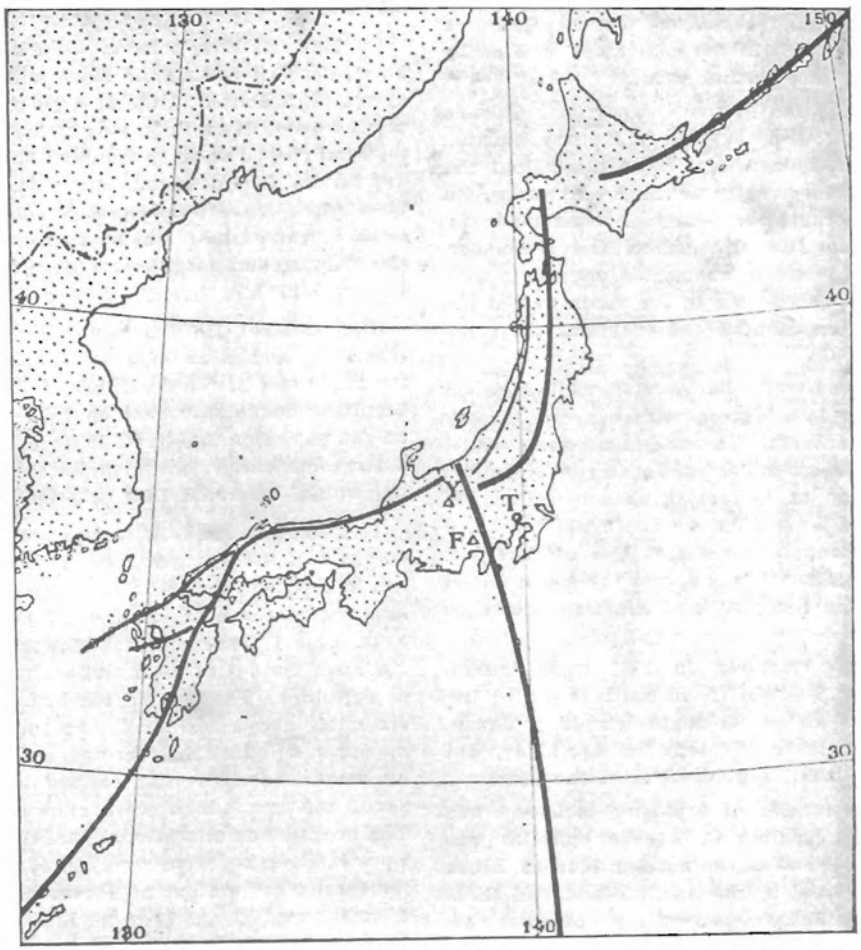

Map of volcanic arcs in Japan, showing the main central Honshu arc, with the Kurile arc at the northeast and the Ryukyu at the southwest. T=Tokyo, F=Fujiyama, Y=Yakedake. The Fujiyama zone extending to the south leads through the Ogasawara Islands. By Omori.

RECENT ERUPTIONS IN JAPAN

An impressive series of arcuate fissures in the crust of the earth, each 1200 to 1500 kilometers long, including the Ryukyu islands, the three mainland islands of Japan, the Kurile Islands at the north, and the Ogasawara line of islands south from Fujiyama, makes up the volcano domain of Japan. In all, this involves 5,000 kilometers or 3100 miles of scattered volcanoes, amid hills and mountains built above the fractures, so that as cracks they are concealed.

The eruptions from 1924 to 1931 have been tabulated by Tanakadate (Japan Jour. Astron. and Geophys. Vol. IX, No. 1, 1931, p. 47).

The activities are divided into smoke explosions, ash explosions, explosive eruptions, pumice flows, mud flows, submarine eruptions, and "increase of normal activity." This normal activity in volcanoes like Aso, Oshima, Tarumai, and Asama involves lava in the crater pit. Lava flows are rare in Japan because the andesites are siliceous and viscous, and the gas or steam of an "eruption" effervesces explosively through the incandescent slag that plugs the crater. "Fire phenomena," or "pumice flows," or "flows of lava blocks," or "glowing lapilli" are frequently described, as seen from a distance. These descriptions means an internal intrusive magma disrupted. (See Tanakadate, "Eruptive Types," Volcano Letter No. 323, March 5, 1931.)

The activity of the seven years speaks volumes for what Japan has to offer to the student of volcanology. Professor Tanakadate has made a very striking compilation of the facts, the upshot of which is that there are only a few months of each year without reported eruptions in some of the volcanic zones.

There are large shiftings from one zone to another.

There was in Japan a striking rise in distributed frequency in 1927-28, and in intensity in 1929, with a lower Japanese volcanicity before and after these three years.

It happens that these were years of sunspot maxima (see Volcano Letter No. 326), and 1928-29 produced extreme volcanicity elsewhere including the Dutch East Indies, Tonga, Chile, Guatemala, Martinique, and Italy.

Reviewing each year for Japan and beginning with September 1924, we get smoke explosions from Asamayama in central Honshu, followed in the next three months by Yakedake a short distance farther west.

In 1925 Yakedake, Asosan in south Japan, and Shirane in central Honshu were all performing in January, blowing fume and dust, and Yakedake kept it up throughout the year. Asama increased activity in May. Suwanose in the Ryukyu Islands erupted in March, Asosan made increasing explosions in July, November, and December. And in the autumn came a submarine eruption, with floating pumice fields, at Hatoma in the south end of the Ryukyu Island line. Kamchatka had eruptions the same year.

In 1926 Yakedake was active but quieter, while Tokachi in the north island made a big explosive eruption in May and continued in the autumn. Tarumai in the same island erupted in October, Asama in central Japan renewed fume explosions preliminary to increasing demonstrations in succeeding years, and Asosan in the south did the same but more violently throughout the last half of the year. The north island, the central island, and the south island were now all in action together, and Aleutian volcanoes also broke out.

This continued and increased in 1927 with Asosan, Yakedake, Asama, and Tokachi (from south to north) the main performers, and all on the main islands of Japan. All four had ash explosions, chiefly in April-May, but Asama reached such maxima at the end of the year.

While in 1928 the number of explosive incidents was less, the diversity of location of intense episodes was greater. Matuwa, an island in the northen Kuriles, broke out in February, Tarumai in the north island had three eruptions, and nearby Tokachi had one; all of these concern the northern area. For central Honshu, Asama was fiercely active the first half of the year, Shirane again blew out crater holes, and Oshima near Tokyo revived in the summer. Yakedake slept. Asosan in Kyushu had four eruptive spasms, of which one was an ash eruption and one was accompanied with mud flow.

The year 1929 produced two major explosive eruptions, Komagadake in the north island in June, and Asama in central Japan in September. Tarumai had another outburst, Yakedake had two, and Asosan had two, of which the last was an ash explosion in October. Komagadake had a revival in September, and Asama had fume explosions four times, in addition to its major eruption. Kamchatka volcanoes were active.

A marked dwindling occurred in 1930, with Asama, however, making ash explosions four times in summer and autumn. Matuwa in the Kurile Islands again exploded in its favored month, February. Yakedake had two explosions in the spring, and Asosan one in the autumn. The Aleutian region reported two eruptions.

The late spring of 1931 produced outbreaks in Asama, Yakedake and Asosan, and the same season was notable for activities in the Aleutian Islands and a major eruption at Aniakchak on the Alaskan Peninsula.

Now let us consider the details of some of the Japanese events. The Tokachi eruption beginning May 7, 1926, was in the center of the north island at a sulphur mine operated at a solfatara on the side of a peak 2,077 meters high. Explosions with fume and sulphur flame increased in violence at a place not historically known to be strongly active. But this is in the Ainu wilderness, and merely shows, as elsewhere in all the solfataric belts of the world, that sulphur and heat may anywhere develop a volcano.

On May 24 three persons were killed in a preliminary burst, debris covering the slope and overwhelming a hot-spring bath house. Then at 4:10 p. m. a tremendous explosion upset five million tons of the mountain flank. This material rushed down in two mud flows devastating forests and farms. The dead numbered 144, the wounded 207, and twenty-five square kilometers of country were devastated. Lava lumps of new magma appeared later as bombs in the debris, and eruptions continued but diminished in 1927 and 1928.

Komagadake, 1140 meters high, is near the city of Hakodate, and is an impressive volcano like Vesuvius at the south end of the north island. It has a record of big eruptions, some as recent as 1905 and 1919. There was an ash explosion in July of 1924. Beginning June 16, 1929, a large destructive eruption began "which ranks next in importance after the 1914 eruption of Sakurajima."

At midnight June 16 a small explosion originated at cracks and fissures extending radially from a small lava hill in the central part of the main crater. Ash fell next morning at the southern foot of the mountain. At 9:30 a. m. June 17 enormous cauliflower clouds arose resembling huge masses of wool and emitting continuous flashes of lightning. The column reached an altitude more than six miles above sea level. At 10 a. m. there were tremendous detonations, roarings, and tremblings, followed by smoke columns that carried blocks of rock, lapilli, sand, and ash which were showered over the country. The ground was almost continuously in vibration, and distinct earthquakes were recorded at the seismograph of the meteorological station at Hakodate, 33 kilometers south from the crater. At 11 a. m. blocks of pumice and small stones were falling at the southeastern foot of the volcano where the forest was devastated, while the village of Sikabe, 13 kilometers to the southeast, had its fields and fishing grounds covered with three or four feet of lapilli.

In the afternoon at frequent intervals glowing masses of pumice blocks ran down the radial valleys in several directions, resembling the glowing blasts (**nuées ardentes**) as described at Mont Pelee in Martinique. These pumice flows traveled in places more than five miles from the crater. At 7 p. m. "fire columns" hung over the crater in the smoke cloud with continuous lightning flashing. The eruptive activity culminated about 10 p. m., after which it gradually declined and towards midnight ceased.

Extraordinary changes took place in the caldera crater of the volcano. The floor was elevated by tumescence, to which relief was added by accumulation of lumps of lava. Three main vents were formed on the domed floor; a round craterlet at the west, a T-shaped fissure at the north, and twin craterlets at the southeast corner, all pouring out white fume. In addition there were numerous minor fissures on the dome.

Quantities of ejectamenta consisting of acidic andesite covered 538 square kilometers of country. Pumice flows in addition, occupying several valleys, covered 27

square kilometers. One person was killed, four were wounded, 65 domestic animals were destroyed, 3500 acres of farm lands were ruined, and about 87,000 acres of pasture and forest were devastated.

There was a renewal of explosive cauliflowers accompanied by tremblings the afternon of September 6.

Asamayama is the Vesuvius of Japan, characterized by explosions with rumbling, quaking, and air shocks, the projectiles consisting of ash, lapilli, bombs, and blocks several tons in weight. Tanakadate says, "Most of the ejecta are considered as not being juvenile" or magmatic, but the reviewer would question this, for the bottom area in the crater which he saw in 1907, appeared to be a typical andesitic aa lava.

After eruptions and earthquakes in 1924, 1927, and 1928 of increasing vehemence at Asama, there came a great eruption on September 18, 1929, at 1 a. m. which began with roarings followed by detonations. The villagers saw glowing smoke clouds ascending from the crater more than a half mile high. Red-hot blocks of lava were hurled up, and atfer three paroxysmal explosions accompanied with such fire phenomena, the energy of the eruption gradually declined, but rumbling continued. Air shocks were unusually strong, ash rain fell to the east, lava blocks were scattered about the crater, the eastern part of the crater wall was destroyed, and new pits were left in the floor of the crater. About 3.4 million cubic meters of material were thrown out.

Other explosions of Asama and earthquakes followed in 1930. On August 20 of that year a sudden explosion accompanied by a heavy downpour of projectiles killed six persons who had ventured too near the crater rim. On September 5 the explosion clouds were accompanied by incandescence, and the ash rain fell in Tokyo 140 kilometers to the south. Some of the earthquakes, centering at Asama, are registered at Tokyo.

The eruptions of Yakedake and Asosan are of the same general character as those described for Asama, with occasional "fire" and much damage to rice fields by showers of ash, and of fine cindery sand called "yona" in the Aso district. In all cases there is more or less trembling and lightning and earthquakes. The flinging out of red-hot breadcrust bombs which make new landmarks on the edges of the craters, and repeated changes in the configuration of the bottoms, are characteristics of Japanese eruptions.

After our experience at the Kilauea Observatory in trying to decide what physical phenomena may be measured all the time near an active crater, and what active craters are most useful for continuous observation, it is of great interest to study these Japanese records. The seven-year table here under discussion shows 26 incidents for Asama, 25 for Yakedake, and 24 for Asosan, with Yakedake dominant 1924-25, Asosan dominant 1926-27, and Asamayama dominant 1928-31. Oshima which fumes all the time in Sagami Bay, and has a red-hot vent in the lava cone of its inner crater, is only mentioned as throwing up ash once August 7-8, 1928, and showing fire at night to the villagers. Yet Oshima with its basaltic lava is for many reasons the ideal volcano for an observatory. It is well placed near the Tokyo center of research, it was near the center of the terrible earthquake of 1923, and it is near the middle of all the volcano belts. A headquarters observatory at Oshima could maintain substations at Asama, Tarumai, Yakedake, and Asosan, and would thereby cover well all the zones. It is a very striking fact that Aso, Yakedake, Asama, and Tarumai all lie at the intersections of two volcanic belts, and it seems likely on this account that the angle between two crustal fissures is the place of most continuous emission. T.A.J.

TILTING OF THE GROUND FOR JANUARY

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction computed from the daily seismograms, by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumb line in seconds of arc, in the direction given.

January 5-11	0.6 second	S
January 12-16	0.4 second	NNE
January 19-25	2.1 seconds	ESE
January 26-February 1	1.6 seconds	S

E.G.W.

KILAUEA REPORT No. 1046

WEEK ENDING FEBRUARY 7, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

Halemaumau continues dormant. In the forenoon February 1 two or three rocks fell from the walls. Cracks on the northeast rim continued slight widening. Five vents emitting slight blue fume were counted on the floor. On February 2 rocks were falling almost continuously and slight widening of rim cracks continued. Surveys showed that the greatest amount of vertical shrinking in the new January lava floor of Halemaumau amounts to between 40 and 50 feet in the southern part. The lava here now stands 30 feet above the top of the former 1930 cone, whereas when it was liquid January 5 the depth was estimated over 70 feet. The edges of the flood have remained stationary, and the average vertical shrinkage out in the middle is between 10 and 20 feet. The average depth of fill is about 110 feet.

The seismographs recorded 1 very feeble shock with indicated origin distance 4 miles. Sixteen tremors were registered, one showing distance 23 miles. There was prolonged tremor for 4 minutes February 3 and for 18 minutes Febraury 6, this latter indicating origin distance 18 miles probably NW. Microseismic motion was moderate, and tilting of the ground moderate SSW.





Map of active and extinct volcanoes in Japan by S. Kozu. Hatoma is at the extreme southwest near Taiwan, and Matuwa is north of the middle of the Chishima zone.

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Big Steamer at Supan's Springs June 13, 1931. Photo from Finch.

LASSEN REPORT No. 31

WORK OF LASSEN VOLCANO OBSERVATORY IN 1931

Mineral, California
R. H. Finch, Associate Volcanologist

Outlying Seismographs

Besides the main station at Mineral, placed in the Forest Reserve three miles outside of Lassen Volcanic National Park to the southwest, seismographs are operated at Viola, seven miles outside the accompanying map at the northwest, and at Mount Harkness in the forest lookout station at the southeast corner of the Park. These seismographs are all of the horizontal pendulum type, those at Mineral and Mount Harkness being Hawaiian type instruments, made in the shop of the Hawaiian Volcano Observatory.

The seismograph at the Loomis Museum near Viola was started in operation for the summer on June 20. 1931, and operated by Mrs. F. J. Hermann, wife of the Park Naturalist. Except during occasional clock trouble, the seismograph registered continuously until September 25.

The seismograph on Mount Harkness was kept in operation from June 30 until October 23 by A. J. Free, Park Service fire lookout. This instrument gave some excellent records of distant earthquakes, and the seismograms were loaned for stuly to the seismographic station of the University of California.

Tilting of the Ground

It will be remembered (Volcano Letter No. 336) that in the report of the Lassen Observatory for 1930 that the accumulation of tilt to the southwest at Mineral, (that is, away from Lassen Peak), was less during 1930 than in former years, and that the Harkness station when first set up indicated southeast tilt, which also is in general away from the Lassen center of volcanism. The correction for accumulated tilt on all seismographs operated by the Lassen Observatory in 1931 was less than during 1930.

Local Earthquakes

Nearly all of the earthquakes, registered on the instruments at Lassen, appear to originate under the big volcano itself. The seismograph at Mineral registered 38 earthquakes during the year 1931. The distribution of these shocks by months was as follows:

January	7 shocks	July	0 shocks
February	2 "	August	9 "
March	1 "	September	2 "
April	3 "	October	4 "
May	2 "	November	4 "
June	3 "	December	1 "

The numbers of shakings recorded during each of the last five years are as follows:

1927	266 shocks
1928	37 "
1929	96 "
1930	74
1931	38 "

Rainfall

The total rainfall and the total snowfall for 1931 compared with previous years were as follows:

Rainfall		Snowfall	
Year	Precipitation	Winter	Snowfall
1927	43.32 inches	1926-27	168 inches
1928	42.10 "	1927-28	106 "
1929	38.65 "	1928 29	130 "
1930	38.94 "	1929 30	138 "
1931	46.30 "	1930-31	64 "
		1931-32	114 "
			to Jan. 1, 1932

It will be seen by these tables that the variation in the rainfall is less than that of the snowfall, and that the latter was extraordinarily different for the season 1930-31. only 64 inches, as compared with 1926-27 when 168 inches accumulated. The winter of 1931-32 is another time of very heavy snows, and Mr. Finch has recently written under date December 30, 1931, "For the past two weeks, it has been about all that I could do to keep up the ordinary routine. We have had over 78 inches of snow during that time. I climb down a flight of stairs, cut in the snow, to get into the office, and to the instrument shelter. So far I have not been able to get any help in removing the snow, but hope to find someone within a few days. It is still snowing and there is considerable possibility of our getting snowed in." The Mineral station is in the midst of big evergreen trees, high in the mountains, and has recently been something of a resort. for winter sports, for people from the Sacramento valley (T.A.J).

In June 1931 some data on slump scarps were obtained. Many examples of this type of cliff can be found in northern California. A note for publication on this subject is being prepared.

Hot Springs Temperatures

Temperature measurements for comparison with the records of former years (as recorded in the 'Bulletin of the Hawaiian Volcano Observatory' and in the 'Volcano Letter' from time to time,), the measurements being made with corrected maximum Fahrenheit thermometers as part of the routine of the station, resulted as follows:

Big Steamer at Supans Springs

(Southwest part of Park west of Diamond Peak)

Date	Temperature
June 13, 1931	190° F.
July 11	195° F.
August 8	196° F.
August 30	199° F.
October 11	194° F.

Bumpass Hell

(Southwest part of Park, south of Bumpass Mountain)

On August 24, 1931, the highest temperature was 198° F. at a mud pot in the center of the area, measured at a depth of 8 feet. The highest temperature of any of the boiling springs was 196° F.

Lassen Crater

(At the summit of Lassen Peak shown in the map above the word "Lassen" in the middle of west end of Park)

On September 1, 1931, the air temperature was 78° F. and there was no snow in the crater The following were the temperatures of the several vents:

Northwest vent	130° F.
North vent	110° F.
Northeast vent	110° F.
South vent	136° F.

Morgan Springs

(Outside the Park, southwest corner of map)

On October 30. 1931, measurements of the several springs were as follows:

No. 3 Larvae Pool	156° F.
No. 14 North	152° F., flowing vigorously
No. 17	200° F.
No. 20	200° F.
Upper Geyser	202° F.

Boiling Lake

(South side of Hot Springs Creek, southern part of Park)

On September 7, with air temperature 66° F., the lake was high within four inches of the outlet. The following measurements were made:

Northwest edge	120° F.
Large mud pot, west	201° F.
Boiler, south end, water	170° F.
Boiler, south end, mud	199° F.

Devil's Kitchen

(Upper Hot Springs Creek. southern part of Park)

The following were measurements of September 7, 1931:

Small pool north side	194° F.
Mud pot north side (thick mud, surface exposure)	144° F.
Small hole at side of pool north side	200° F.
Mud pot northwest	196° F.
Pyrite pool northwest	190° F.

New Steam Vent

(South slope of Diamond Peak southwest part of Park)

The discovery of this vent was described in Volcano Letter No. 362. It is in an ancient solfataric area and had a temperature of 198° F. when it was measured October 14, 1931.

Changes at Supan's Springs

No movement was detected at the line of stakes which had been set up to measure movement, in the landslip area of Supan's Springs, near the bend in the road on Sulphur Creek west of Diamond Park, where for many years there have been fresh cracks across the valley indicating a creep of surface materials. As reported in 1930, the earlier stakes had been broken off, and a new set of iron stakes was installed in that year. New measurement in 1931 showed that no movement could be detected parallel with the valley, nor on the transit line laid out for repeated observations across the valley. There were signs of chemical erosion. The basin at the Big Steamer at Supan's Springs had moved westward a few feet. The volume of the basin had increased by about 50 cubic feet without any surface outflow to account for mechanical loss of eroded material.

On his trip to investigate Akutan Volcano and to inspect seismopragh stations in the Aleutian belt of Alaska, Mr. Finch was absent from the Lassen station from June 25 to September 13. Mr. C. A. Huff operated the station during his absence.

EARTHQUAKE IN THE SOLOMON ISLANDS OCTOBER 1931

We reported registering on seismographs (Volcano Letter No. 355) a large distant earthquake approximately 3750 miles away to the southwest, and another estimated 3500 miles away, the dates being October 3 and October 9, 1931. It has since been reported (Volcano Letter No. 361) that the first of these earthquakes wrought damage in the British Solomon Islands and was followed by a disastrous seismic sea wave, which recorded on the tide gauge at Hilo eight hours after the earthquake occurred in the Coral Sea. Northeast of this Coral Sea lies a line of active volcanoes extending through the New Hebrides, the Santa Cruz Islands, the Solomon Islands, and New Mecklenburg, the whole belt extending northwest in the region between New Guinea and Fiji, and lying between the Micronesian Islands of the western Pacific and the Coral Sea which lies outside of the Great Barrier Reef of northeastern Australia. The inhabitants of this volcanic belt are Melanesians.

The "Church of England Newspaper" January 8, 1932, publishes a report by Dr. Fox, Principal of All Hallows School, Pawa, Solomon Islands, saying the earthquakes lasted more than 15 days. On Sunday October 4 at 5:45 a. m. there was a very big earthquake lasting four and a half minutes. and then a prolonged quiver for two hours,

and then small quakes every half hour or so day and night for 15 days. But there was a second big one, worse than the first, on October 10, at 11 a. m., followed by a succession of big shocks every few minutes, till the worst of all came at 3 p. m., a violent wriggling followed by convulsive waves, when it was hardly possible for a man to keep his feet. Then smaller qaukes occurred every hour gradually getting milder.

All the mission tanks were thrown down, two of the plate timbers of the house were broken, and a wall was torn out. The boys' houses leaned over and another house had a list. The chapel survived the shock best. The tower swayed violently back and forth, and the flag-pole snapped and was thrown down. A Dover stove was smashed anl much small stuff was broken.

The mission staff slept on the shore in a leaf house, but continued to conduct services in the chapel. The boys slept on the shore, as the hill country rocked violently. During the earthquake of 3 p. m. October 10, the ocean suddenly receded from the bay to much beyond the lowest low-tide mark, and in about three minutes swirled back to about four feet above high tide mark. This happened twice, and then the water remained at high-tide level for hours when it should have been low. Dr. Fox, watching it, reported that the wave seemed to come from the east or northeast and judged the origin to be a hundred miles or so away, and wondered whether it was created by a submarine volcano.

A similar report from a station at Aitape in New Guinea (United Empire, London, January 1932) described what is presumably the October 10 quakes of 11 a. m. as occurring at 11:40 a. m. of the local time, when suddenly a rumble came from the sea. Everything heaved and swayed, chairs and other things were overturned, coconuts fell from the trees, cement piles were cracked, and water tanks telescoped and spilt. Cracks opened in the ground. A trestle bridge was thrown out of alignment. The first shock lasted 40 seconds, followed by other severe ones, while small shocks and tremors continued for a fortnight.

Another Solomon Islands earthquake was registered on seismographs November 20, 1931, and one in the New Hebrides January 9, 1932. T.A.J.

KILAUEA REPORT No. 1047

WEEK ENDING FEBRUARY 14, 1932

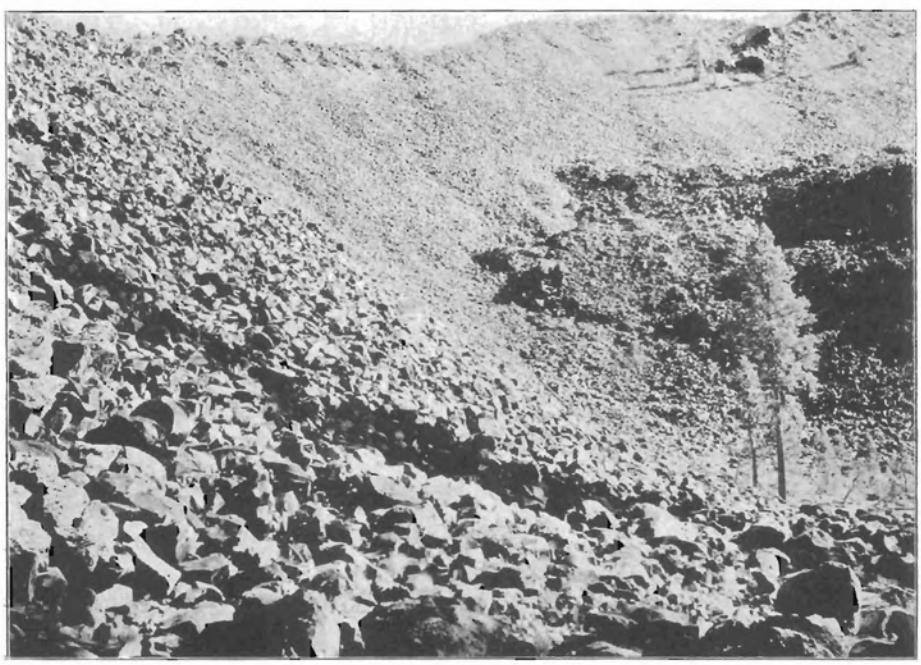
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge.

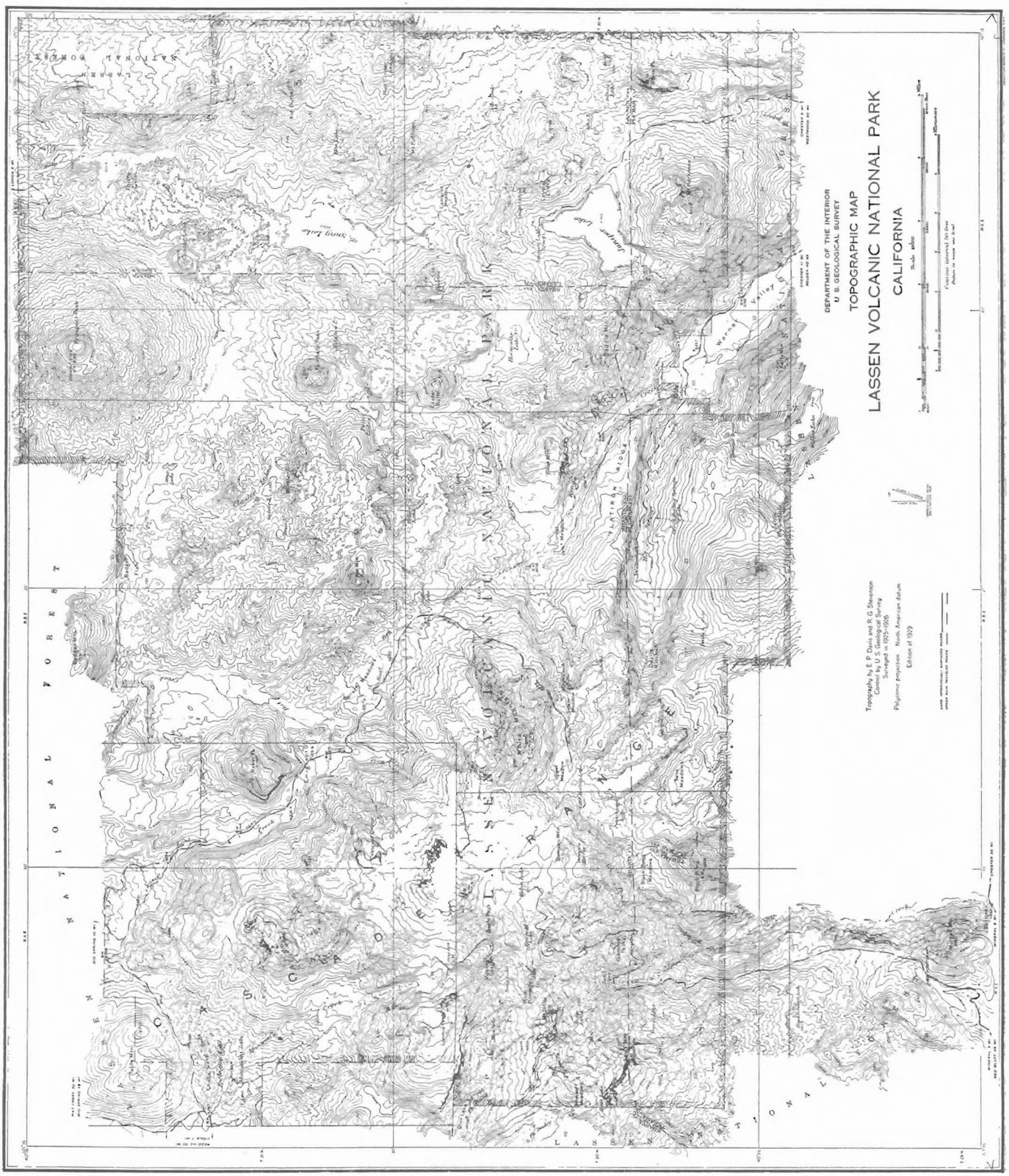
On February 8 fume was noticed at a spot under the west wall of Halemaumau and in a spot in the center of the pit. A small slide fell from the north wall at 9:46 a. m., and rocks fell intermittently. Cracks measured showed slight widening, especially on the northeast rim. On February 12 afternoon a new spot was found fuming in puffs at the west end of the southwest talus on the edge of the talus and floor. Sulphur has been forming there. Moderate fume was noted at the spot under the west wall, and slight fume was issuing from the center of the floor. At 4:10 p. m. a roar of an avalanche was heard at Uwekahuna. Its debris fell from the wall above the southwest bay and appears to be the largest since the recent lava activity. On February 14 there was no change in fuming. At 10:20 a. m. a large avalanche was heard from Uwekahuna by Park rangers. Dust obscured part of one side of the pit.

The seismographs at the Observatory recorded 23 tremors and 3 very feeble local seisms. One of the tremors originated at 14 miles distance, two of the seisms 18 miles, and one seism 14 miles. Two of the latter class were reported felt at Kapapala.

Microseismic motion was moderate throughout the week. The average tilt movement was slight SE.



Edge of glassy lava flow on the west side of Glass Mountain October 19, 1931. These obsidian flows are 80 miles north of Lassen and the rocks are being studied by Dr. C. A. Anderson. Photo from Finch.



Map of Lassen Volcanic National Park, U. S. Geological Survey. Lassen Peak is in the center of the western half with name erased.

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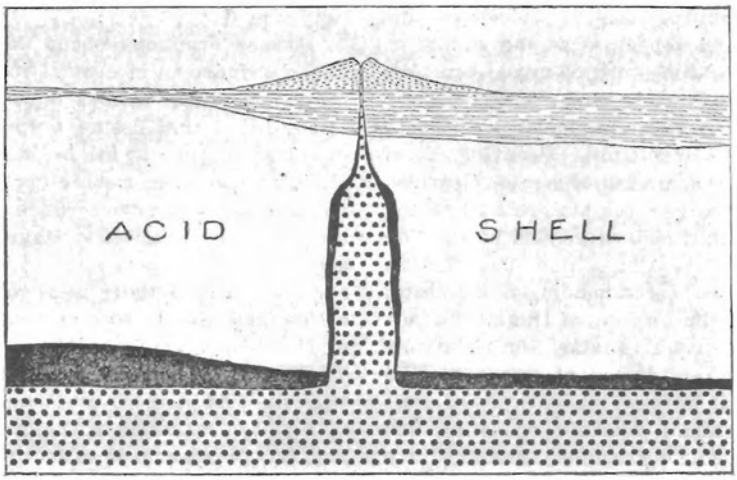
The Volcano Letter

Two dollars per year **Ten cents per copy**

No. 374—Weekly Hawaiian Volcano Observatory, National Park, Hawaii February 25, 1932



Diagramatic section through the earth's crust showing sediments under a volcano, supposed siliceous continental shell, black solidified layer of basalt, and dotted liquid basalt of the substratum extending up into the fissure leading to the volcano. The cone is represented as 5,000 meters high. After Daly.

TYRRELL'S BOOK ON VOLCANOES

Dr. G. W. Tyrrell, lecturer in geology in the University of Glasgow, has recently produced a very readable book entitled, "Volcanoes." (No. 152 in the Home University Library, 1931, Thornton Butterworth, Ltd., London.) This is a small book of 252 pages divided into eight chapters and a bibliography. The introductory chapter describes the general facts about volcanoes. The following is an interesting paragraph:

"The most feasible method of harnessing volcanic energy in the service of man is by utilizing steam jets and hot springs. In Iceland hot springs are used by housewives for cooking and laundry purposes. A beginning has been made in that country on a project for supplying Reykjavik and other towns with a hot water supply from boiling springs. In Tuscany, natural steam power has been used for three-quarters of a century. Over an area of 100 square miles are numerous hot springs and steam jets, which yield boric acid. These natural springs and fumaroles have been largely extended and changed by industrial development. Shallow wells have been bored to tap the steam, which in one of the borings is yielded at the rate of 52,800 lb. per hour at a pressure of one atmosphere (14.7 lb. per square inch), or 28,600 lb. of steam per hour at a pressure of five atmospheres. The steam is often superheated, as its temperature varies between 100° C. and 190° C. A deep boring has now (1928) tapped steam at a pressure of 75 lb. per square inch, which can be directly used to drive turbines. Calculations based on the total production of boric acid in relation to steam, indicates that several million pounds of steam per day are now available in this field.

"Of a somewhat similar nature is the steam-well field which is now being exploited at The Geysers in California. Observations and tests prove that at this locality there is a great store of hot steam, which increases with depth. The first well was drilled in September 1922, and steam from this well furnished the power for boring the second well which was completed in July 1923. From all indications the steam both in Tuscany and California is of deep-seated origin and of practically inexhaustible quantity."

In discussing cycles, Dr. Tyrrell is impressed with the longer geological cycle, as is natural in the viewpoint of a geologist, and he makes the following statement concerning the phases of a long-term cycle:

"If volcanic manifestations are considered in relation to geological time they are found to fall into definite cycles. These cycles seem to have begun with vast floods of basalt lava, with which are usually associated swarms of dikes, and, in proportion to the bulk of lava erupted, were accompanied by an insignificant amount of explosive activity resulting in fragmental products. These enormous lava floods are therefore believed to have been emitted from fissures, and to have rushed up directly from the superheated liquid stratum which at times is formed immediately beneath the crust.

"As the cycle progresses the volcanic activity becomes localized at definite points, which develop into central volcanoes. Lava is still poured out in great bulk, and central volcanoes in this early stage build up enormous flat domes consisting mainly of basalt. At the present day these shield volcanoes occur in Hawaii and Samoa, and also in Iceland. In the earlier stages of the present volcanic cycle, the flows from adjacent shield volcanoes linked

up to form great spreads of lava only inferior in size to those from fissures.

"With the waning of the volcanic cycle, the direct uprise of magma from the depths is checked. It collects in underground chambers, and its contained gases now come into full play in determining the kind of volcanic activity at any center. Hence the volcanoes typical of this stage of the cycle are those in which explosive activity takes a prominent part. The resulting central volcanoes are naturally smaller than shield volcanoes as the supply of magma is now limited. The cones are of mixed composition, partly lava, partly fragmental products of volcanic explosion, and are known as **strato-volcanoes** because of their well-bedded or stratified structure. Vesuvius, Etna, and Fuji-san are well known examples of strato-volcanoes. With the progress of solidification (crystallization) in the magmatic chamber the amount of lava yielded by the volcano gradually lessens, and its composition may change, while the activity of gases correspondingly increases, resulting in an increase in the amount of fragmental material ejected. A purely explosive stage is ultimately reached; and if a new vent is drilled at this stage the resulting volcanic cone will be built up entirely of fragmental materials. Some small volcanic cones of this character (e.g. Monte Nuovo near Naples) are due to a single explosive outburst. The gases which are liberated in this late stage of the volcanic cycle consist chiefly of steam, and the explosions may be of such violence as partly to destroy the cone built up in earlier stages, (Katmai, Alaska; Bandaisan, Japan.)

"As the explosive activity gradually dies away, the final stage of the volcanic cycle is reached with the relatively quiet discharge of steam and other gases from jets or fumaroles (Tuscany, Icleland, California, New Zealand), associated with erupting springs or geysers, boiling or hot springs, and the emanation of carbon dioxide and sulphuretted hydrogen from fissures."

The second chapter deals with the products of volcanism, gaseous, liquid and solid. In this the author follows the usual and regrettable geological dictum that steam is more important than hydrogen as a fundamental volcanic gas. Other chapters deal with the phenomena of volcanic eruption, the shield volcanoes of Hawaii and Iceland, strato-volcanoes such as Etna and Vesuvius, decadent volcanoes such as Katmai and Lassen Peak, the roots of volcanoes and ancient volcanoes, and finally, distribution of volcanoes and origin of igneous rocks. In this last the author follows with interest the theories of Joly and Holmes to the effect that the ultimate causes of igneous activity in general are to be traced to the known facts of storage of heat through the radioactivity of the rocks.

A reading of the book shows that the author has studied carefully some up-to-date volumes on volcanic eruptions such as Perret on Vesuvius, Griggs on Katmai, and Koto on Sakurajima, that he is influenced by the time-honored but trite work of Judd on Krakatoa; and is perhaps without access to the remarkable series of modern monographs of the Dutch East Indies Volcanologic Service; that he is thoroughly acquainted with the work of the petrographers on ancient volcanoes and on the rocks collected from fossil intrusive bodies, but that he is insufficiently acquainted with the seismometric side of the subject as expounded in the big volumes by Omori on Asama, Usu, Oshima, and Sakurajima. The geodetic and engineering side of volcanology is hardly touched. The notion that intrusive volcanism is in progress today, and may be measurable in hot spring districts, does not appear in the book, but there is ample recognition that the study of volcanoes has entered upon a new phase with the establishment of volcanological observatories. The scholarship of the modern German and Italian workers, as recorded in Friedlaender's Zeitschrift and in Sapper's book, is not much quoted. The style is excellent and the author is at his best in the chapter on "The Roots of the Volcanoes." The following is a sample:

"Fissure eruptions occur at the present day only as minor phenomena of central volcanoes, especially those of the shield type. Various lines of evidence, however, lead to the belief that fissure eruptions played a leading part in volcanic action at the beginning of the present volcanic cycle, and in more remote geological periods." (This appears to mean the cycle which has become decadent since the Miocene.) "Basaltic lavas have been poured out on a colossal scale, accompanied by only the most insignificant explosive activity relatively to the effusive mode of action, and usually with swarms of associated dikes, some of which must be regarded as the feeders of the flows. There are no signs of volcanic cones at all commensurable with the size of these eruptions. These stupendous floods of basalt cover areas of the order of 200,000 square miles, and may be thousands of feet thick. Naturally, accumulations of relatively hard rocks such as basalt are extremely durable, and remain in and on the earth's crust as witnesses to volcanic events the magnitude of which has not been approached at the present time.

"The youngest basalt flood is that of the Columbia Plateau in the northwestern United States, which occupies an area of over 200,000 square miles mostly in Washington and Oregon. The Columbia region was formerly mountainous, but in Miocene times it was levelled up by enormous floods of basalt lava, and the former mountains now appear as islands and peninsulas projecting from a monotonous plain of lava. The Columbia and Snake rivers (see Page Four) have cut deep gorges through the plain which expose in places almost the entire thickness of the formation. The plateau is built of a large number of thin, confluent, interlocking flows, between which occur slaggy surfaces, thin sheets of ash, and beds of lacustrine sediments. The supposed feeding dikes are numerous and narrow, seldom reaching 150 feet, and averaging less than 30 feet in width. Igneous activity has continued almost to the present day, especially in Oregon and Idaho, with the production of youthful-looking cones and craters, and fresh, slaggy, lava flows. The average thickness of the plateau is estimated at 3300 feet, and it is known to reach a maximum thickness of at least 5200 feet. Hence the total volume of lava emitted must be of the order of 120,000 cubic miles. Great basaltic plateaux of about the same age as the Columbia plateau occur in Syria and Arabia.

"Another enormous basalt flood is that of the Deccan in Peninsular India, which occupies an area of 250,000 square miles. As this formation is nearly 10,000 feet thick on the Bombay coast, and thins out toward the east and north, it is thought to have had an equally large extension in the adjacent foundered parts of the Indian Ocean. Its total area may therefore have been 500,000 square miles . . . . in one place a boring encountered 29 distinct flows with an average thickness of 40 feet. Large dikes and other intrusive masses are found at a number of places around the margins of the basalt region The eruption appears to have taken place towards the end of the Cretaceous period, or at the beginning of the succeeding Eocene."

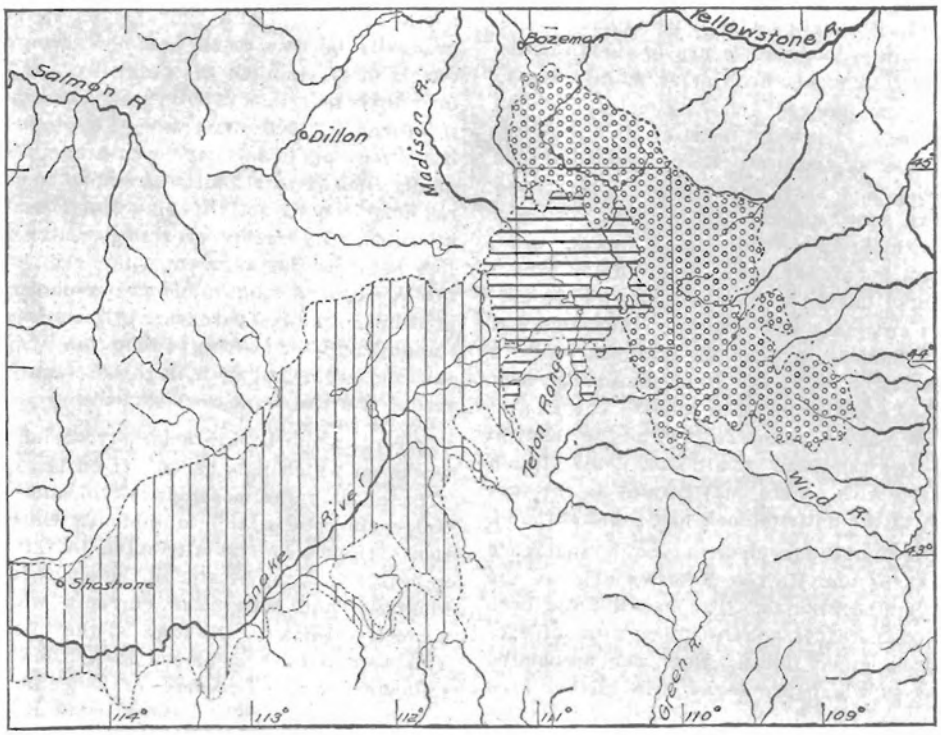
"The Stormberg basalt lavas of South Africa, which occupy an area of 20,000 square miles in Basutoland alone, and there form the great mountain scarp of the Drakensberg, are regarded by Dr. A. L. du Toit as mainly due to fissure eruptions. One hundred and fifty volcanic vents have indeed been found, and many more await discovery; but the greater number of these are filled with pulverized sedimentary material, and have never emitted lava; and the remaining active centers pierce the lowermost basalts only. The average thickness of the plateau appears to be about 3,000 feet, and individual flows are from 100 to 150 feet thick. Correlated basalt extrusions make up the 300-mile-long Lebombo range in the eastern Transvaal, and also a large area of country around the Victoria Falls in Rhodesia. The extrusion of these great masses of lava probably took place in early Jurassic times. The Stormberg lavas are intimately connected with the Karroo dolerite sills; and the relatively small lava fields of this episode, as compared with others, may be due to the fact that a greater part of the activity took place underground.

"In recent years it has become clear that exact analogues to the Stormberg lavas and Karroo dolerites exist in the Parana region of South America. The basalt flows here cover an area of over 300,000 square miles with an estimated bulk of 50,000 cubic miles. They are associated with intrusive masses which are found in a further area of 75,000 square miles. Basaltic lava plateaux of the same age as those of South Africa and South America (mid-Mesozoic) are known also in Tasmania, Antarctica, Peninsular India, and in the eastern United States."

With regard to major cycles in Europe and Asia, Dr. Tyrrell points out that crustal movement (page 228) has worked up to at least four great climaxes during known geological time, and that in the intervals minor disturbances have occurred. The geological cycle begins with the comparatively-sudden emergence of continental land masses, which rapidly become broad and high, with the simultaneous production, especially near their margins, of long ranges of fold-mountains in which the rocks are intensely compressed. The oceans at this stage are relatively small and deep. Igneous and earthquake activity is at a maximum, and on the continents there is extensive glaciation and desert formation. Climatic conditions are thus severe and extreme. At the present day the earth appears to have not long emerged from one such phase of the geological cycle. This revolutionary stage is followed by a protracted period of relative quiet, both as regards earth movement and igneous activity. The continents gradually become small and low owing to the combined effects of erosion and the gradual advance of shallow seas over their margins. The general quiescence is occasionally broken by local disturbances during which igneous activity may again become prominent. Earth movement is finally limited to a gentle up and-down heaving over wide regions, igneous activity dies away completely, and climatic equability ensues over the greater part of the earth. But beneath the apparent quiet the revolutionary earth forces gather strength, and the geological cycle is terminated by a renewed paroxysm of mountain-making and continental uplift. . . . The explanation of igneous activity is thus closely bound up with the explanation of earth movements and the geological cycle."

Errors in the book are largely copied from the original works on which it is based. If on page 55 the statement, "Torrential rains accompany volcanic eruption," means condensing steam, this is dubious. On page 60 the formation of Pele's hair is attributed to "strong winds," when in reality it is the bluster of the gases rushing through the fountains and convection currents which may occur in perfectly still air. On page 93 the "Death Gulch" of the Yellowstone Park is placed in Arizona. On page 67 and following, the discussion of volcanic earthquakes attributed to "explosive subterranean release of magmatic gases" is quite erroneous and inadequate. There is the usual erroneous distinction from tectonic earthquakes, without explanation or discussion of depth or mention of isostasy. The statement on page 84, "Hawaian explosive activity is of a mild type, caused by the rapid emission of gases from the surface of a lava lake," certainly needs modification if the steam blast activity of 1924 is "explosive." On page 87 Pelèe and Soufriére are stated to be characterized by the "intermittent ejection of white-hot clouds composed of an emulsion of glowing gas and solid particles, which, instead of rising into the air were projected downwarls." These were exceptional and not characistic, and the downward-directed cloud in the major explosion in each case was but one component, most of the clouds being directed vertically, and in no case being "white-hot." Down-rushing blasts are common elsewhere. The belief of Penck quoted on page 109 that the 1789 eruption of Kilauea "marked the inception of the volcano" might well have been omitted. T.A.J. and R.H.F.





Region of eastern part of the great Snake River basalt fields as related to the early Tertiary rhyolites (horizontal lines) and andesites (circles) of the Yellowstone Park, itself a place of boiling springs and Tertiary volcanoes. After Daly.

KILAUEA REPORT No. 1048

WEEK ENDING FEBRUARY 21. 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

On February 15 at 9:30 a. m. the slide of the previous day was found to have fallen from the north wall between the north and northwest taluses, causing a fresh scar on the wall and a mound of new debris on the floor. Debris added at 1:20 p. m. February 16, from the same place, built the mound to from 50 to 100 feet high. Fume was strongish at the foot of the southwest talus and under the west wall. The northeast rim cracks continued slight widening. A small scar formed during the night of the 15th from a slide at a point just west of the top of the northwest talus. Fume was quite strong from a spot at the foot of the southwest talus and came from two points about 50 feet apart. Rocks and small slides were heard falling from the north walls more or less continuously about every five minutes from 2 to 4 p. m. On February 17 the district was visited by a southwesterly rain and wind storm which caused some water to enter the seismograph cellar at Halemaumau. The pit during the forenoon was a huge cauldron of steam. Sulphurous fume was blown over the tourist stand. Keanakakoi had seven waterfalls. A lake a thousand feet long and two to three hundred feet wide formed on the southwest Kilauea floor. A little hail fell during the storm, and there was thunder and lightning near. Many trees were uprooted and a garage was blown over.

On February 21 at 10 a. m. the pit had blue fume. The north wall showed a fresh scar from an avalanche and few rocks were heard falling.

The seismographs at the Observatory recorded 11 tremors and two very feeble local seisms. One of the tremors indicated origin distance 25 miles and another about four miles. The two seisms indicated distances of 9 and 32 miles. None was reported felt. High winds during the week caused unusually strong microseismic motion, the Kona storm of the 17th being responsible for vibrations of four seconds' period. The average tilt movement for the week was moderate SW by W.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Arthur L. Dean, President; Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Richard A. Cooke and Wallace R. Farrington.

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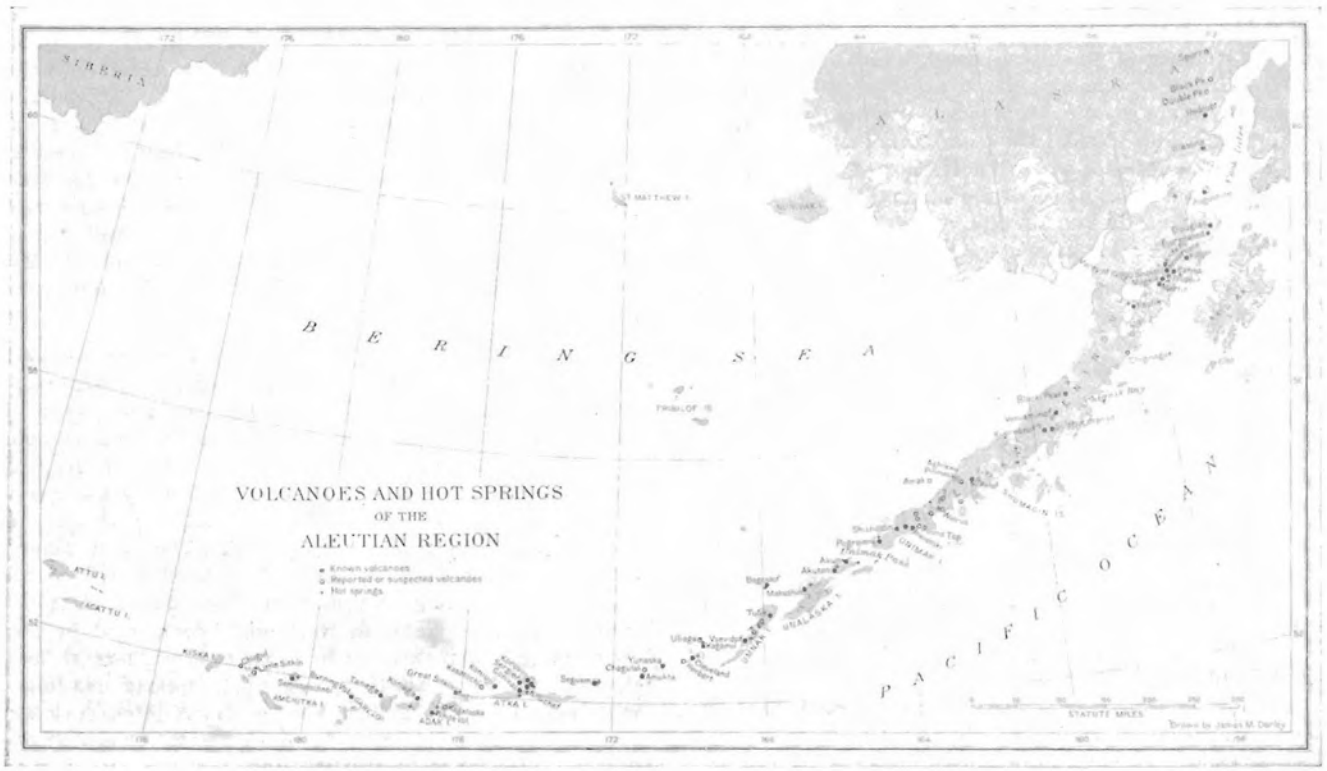
No. 375—Weekly Hawaiian Volcano Observatory, National Park, Hawaii March 3, 1932



Map of volcanoes and hot springs of the Aleutian region, scale 216 miles to the inch. After Griggs, National Geographic Society, 1922. Black Peak is mislocated at Purple Crater, and Aniakchak is northeast of it.

ALEUTIAN ERUPTIONS 1930-32

Notes on activities in the Aleutian Islands and in the volcanoes on the Alaskan Peninsula were published in Volcano Letter Nos. 246 and 357. The year 1931 appears to have brought to a focus the unrest which appeared in several volcanoes in 1929 and 1930 by producing a considerable explosive eruption from Aniakchak Crater on the Peninsula 45 miles NNE from Chignik. But activity of one sort or another appears to be always present in the restless magma which underlies 1700 miles of arched and faulted Tertiary strata from Mount Spurr to Attu, and if one could picture the ridge in its entirety at any one time, some puffing gas would probably be seen.

Our reports have indicated that Akutan was smoking in 1928 and its lower slopes were covered with ash June 18, 1929. "A mountain to the west of Kanatak" was reported fuming in March 1929, and this description might apply to Chiginagak Volcano on the Peninsula east of Aniakchak. Mount Cleveland and a volcano west of it in the Islands of the Four Mountains were fuming in March 1929 and volcanoes of the Katmai group continued fuming. Shishaldin on Unimak Island was "flaming high" May 28, 1929, and glowing matter overwelled the edge of the crater and rolled down the slopes; it was reported fiery again June 23, 1929, opening three new craters low on the north side. Gareloi in the western Aleutians was said to erupt so violently in 1930 as to change its appearance by lava flows from fissures. To a volcanologist the imperfection of these accounts is their chief baffling characteristic, but the observations of mariners confirm the notion of continuous activity somewhere.

We now come to 1931, when on May 1 Aniakchak erupted, on May 20 Pavlof farther west on the Peninsula made explosions and glow and ashfall, two other volcanoes on the Peninsula were reported fuming, ash from Aniakchak fell a great distance away, and on May 30 a severe earthquake was felt in Attu at the extreme western end of the Aleutian chain.

Our observer at Dutch Harbor, Mrs. Wendhab, reports that Captain Nelson of the Alaska Commercial Company

ship "Eunice" passed Tulik Volcano on the east end of Umnak Island March 21, 1931, and its crater was sending up thick black smoke where he has observed only white steam heretofore. He thought its action very unusual and indicative of a coming greater eruption. On March 29 two earthquake shocks of unusual intensity were felt at Dutch Harbor (east end Unalaska). On May 13, 1391, the Umnak eruption was reported by Captain Nelson to be "the volcano on the east end of Umnak Island, fourth peak northwest from Tulik Mountain, pouring out black smoke and heavy clouds of steam," a place that has been dormant until recently. A singular note by Mrs. Wendhab at this time states that Mount Makushin Volcano in the northwest part of Unalaska Island, which has been very active, is now ominously quiet, causing worry." Makushin is usually a crater of quiet steam depositing sulphur. The eruptions of Shishaldin, Pavlof, and Aniakchak are reported by the radio operator at Squaw Harbor on Unga Island in the Shumagin group south of the Alaskan Peninsula to produce a particularly vicious type of static, interfering with radio communication over a wide area.

While not connected with volcanic happenings, it may be of interest to the meteorologists to know that Attu experienced September 30-October 2, 1930, a terrific northwesterly gale for three days, with barometer at 26.40 inches. Two native sod houses and Government buildings were demolished. A still stronger gale in January 1931 was the worst in the history of Attu Island, according to the natives, and drove seas into Chichagof village.

Captain Nelson saw fire issuing from Bogoslof October 31, 1931, and found qauntities of pumice near Umnak Island south of it. This observer believed Bogoslof to be continually smoking, according to his experience, but the "fire" was unusual.

The Eruption of Aniakchak

Aniakchak Crater is one of a chain of remarkable volcanoes spaced out rather evenly about 40 miles apart in the Alaskan Peninsula between Port Heiden on the north and Chignik Bay on the south. Beginning at the southwest end of the series west of Chignik and going northeast, these are Veniaminof (8400 feet), Purple Crater (3020 feet), Aniakchak (4200 feet), Chiginagak (7020 feet), and Mount Peulik (4080 feet). Veniaminof and Chiginagak are covered with glaciers. Aniakchak Crater was mapped by Sargent, described first by W. R. Smith (Professional Paper 132 U. S. Geological Survey, 1925), and mapped geologically by R. S. Knappen (Bulletin 797-F U. S. Geological Survey, 1929). Knappen's colored map is copied in half-tone herewith and shows the even spacing of Veniaminof, Purple Crater, and Aniakchak, and the vast size of the crater bowls, as well as their circularity. Aniakchak Crater has a maximum diameter of six and three-quarter miles, the lowest part of the crater floor is 1100 feet above sea level and contains Surprise Lake, two square miles in area. The walls rise almost vertically 1200 feet to 3000 feet above the bottom of the crater. A large truncated cinder cone rising 2200 feet above Surprise Lake occupies the south central part of the crater floor. Aniakchak River breaks through the east side of the rim of the great crater in a picturesque canyon named "The Gates." The area of the bottom of the crater is 30 square miles. Upper Jurassic sedimentary rocks with fossils occur in the canyon and also quartz diorite, overlaid by layers of lava and agglomerate, while all the valleys of the surrounding country are covered by thick deposits of ash, pumice, and agglomerate. Much of the lava is obsidian.

In the National Georgaphic Magazine for September 1931, Father B. R. Hubbard presents a wonderful series of pictures of the Aniakchak and Veniaminof country made from photographs taken during an exploration in the summer of 1930. Among the most remarkable of these is a picture of curving colunar structure in obsidian, and another of a subordinate crater of crescent shape in the northwestern part of the larger bowl containing an inner cinder cone from which about eight festooned dark-red basaltic lava flows radiated. The festoons were crevassed in concentric arcs. This secondary crater was investigated and hot fumaroles were found, some of which followed a fissure up the sides of a cliff and yielded steam hot enough for cooking. There were multicolored crystals and incrustations surrounding the vents, and solfataric odors of volcanic gases were perceptible. Near Surprise Lake on the west side there is a warm soda and iron bicarbonate spring, and this stains much of the lake shore with orange color. The presence of the warm springs and the hot solfataras indicated that Aniakchak was not dead but sleeping.

Explorations by Father Hubbard in the summer of 1931 (Saturday Evening Post January 2 and 16, 1932) discovered that an observer at Meshik, 20 miles west of Aniakchak, on May 1, 1931, at 10 a. m., saw a dense column of steam shooting up from the volcano. This rose for two hours in billowing clouds, followed by a big blast at noon. A dense black cloud rose over 20,000 feet, spread out like a mushroom, and started to descend. The earth shook, and there was a fiery display of lava bombs making trajectories. Lightning and thunder were added to incessant detonations from the volcano, accompanied by the crash of falling rocks. Then came light cinders at first the size of peas and then larger. Eruptions continued until May 11, when a final blast made it pitch dark for several hours at distances 60 miles away. There was a field of floating pumice with individual blocks 9 or 10 inches across in individual patches five miles in diameter on Bristol Bay, north of the volcano. Dense clouds of gas and smoke continued to rise, and another major eruption May 20 made detonations heard 200 miles away. For several days more the Ugashik cannery, 53 miles NNE from Aniakchak, reported rumbling like distant surf.

At Chignik the fall of ash was reported a pound per hour for each square foot 45 miles SSW from the source. At Ugashik the ashfall was heavier, and in the country between Kodiak and the head of Bristol Bay a mantle of ash a quarter inch deep was formed. Light ash fell in the interior of Alaska at distance of 300 miles. There was much loss of life among wild animals. There were many showers of pisolitic mud balls, and the neighboring snow-covered country and the glaciers were buried under a gray pall.

When the volcano was visited at the end of May, there were clouds of blowing dust and many dust whirlwinds. Everything was covered with ash. The vegetation was gone. Black cinders became coarser at the crater. The water of all streams was muddy. The central inner cone had a crack in its side and gas clouds rising on top. Surprise Lake was choked and muddy. The explosion vent had formed a new crater under the northwest rim, whence rose yellow and brown gas and clouds of steam. A new lava dome was being pushed up above the crater floor,

showing large, tumbled blocks. This was like Novarupta at Katmai. Beside the dome was a deep pit. Hydrogen sulphide was strong. Occasional puffs of brown smoke rose with a rumble from the new vent. The interior of this vent was found to be highly colored with yellow, red, and brown stains, and several pits more than a mile in circumference had formed in the crater floor. Quantities of vapor rose from the new lava dome. The ground was very hot near the vent, more than 200° C., and there were green deposits and signs of hydrochloric acid. There were many impact craters made by falling bowlders. The lava dome lay in the center of a depression three miles in circumference. The lava moved somewhat, there were falls of blocks, and there was much sulphur. In an airplane flight, Hubbard noted that Veniaminof Volcano, with its great circle of glaciers, which he had seen the year before snowy white, was completely mantled with dark colored ash. It may be noted in passing that Hubbard reported in his National Geographic article that an ascent to the edge of Veniaminof Crater was made from the north side, and that this crater, which is known to the natives as Black Peak, and is full of ice, was smoking in unusual fashion in the summer of 1930. The source of this smoke was found to be a cone in the center of the ice, "smoking on two sides of its upbuilt rim from slag heaps of lava, and now and then coughing out black ashes over the surrounding white snow." The ice had impressive chasms where the heat had melted the glacier. There were layers of black volcanic ash and sand a few feet thick alternating with glacial ice more than 20 feet thick. Hubbard suggested that some time-scale of Veniaminof's eruptions might be interpreted from such exposures.

On May 2, 1931, the radio operator at Kanatak, 90 miles NE of Aniakchak, reported ashfall there. On May 13 the ash from Aniakchak was more than a half inch deep and very black, falling continuously at Squaw Harbor in Unga, approximately 140 miles SW of Aniakchak. The Katmai group of volcanoes was reported to be active at this time. The Aniakchak ash that fell at a great distance was fine as flour. On May 12 a freighter at sea off the Aleutian Islands received a fall of sand during a storm (locality not given).

Later Eruptions

Captain Nelson of the "Eunice" brought word on January 18, 1932, that Mount Cleveland on Chuginadak Island, a peak 8156 feet high, approximately 150 English miles west of Dutch Harbor, had again broken into eruption, starting about January 1, 1932. It was reported to him that seven great puffs had occurred in one hour, the volcano sending up very dense smoke. Generally only a little steam had been seen at the crater during previous visits. He passes these Islands of the Four Mountains three or four times a year in his trading trips for the Alaska Commercial Company. He was suprised to see such dense volumes of black fume when he passed the island in early January, the sky being continuously darkened.

On February 10, 1932, a radio from John Gardner in False Pass informed me that Shishaldin erupted February 1, 1932, the outbreak lasting for several days with glowing material flowing down the mountain. A newspaper dispatch of February 4 called this eruption the "most violent and spectacular seen in the past century" for this volcano. The report from Squaw Harbor described "streams of lava flowing down the sides," but this glowing material is quite as likely to be trains of red-hot bowlders for these Aleutian cones. A strong wind carried the ashes many miles northward over the Bering Sea. A dispatch of February 16 said that Shishaldin had again renewed its activity with boomings coming from the creater at two-minute intervals, the volcano hurling hot rocks thousands of feet into the air.

The general map of the Aleutian belt reproduced herewith shows the distribution of volcanoes as compiled by Griggs (Valley of Ten Thousand Smokes, by Robert F. Griggs, National Geographic Society, 1922, page 60). This will give some idea of the great number of active cones along this curved line, and the geological map by Knappen shows how characteristic are the big volcanic heaps lying in a line adjacent to the coastal plain of Bering Sea on the northern side of the Aleutian ridge. This arrangement extends far to the west in the islands, where, for examples, in both Unalaska and Atka the north half of the island is volcanic and the southern half consists of older rocks. Here in the Aniakchak region the belt of mountains southeast of the volcanoes reaches heights rarely exceeding 3000 feet and consists of gently folded Jurassic and Tertiary rocks, which contain fossil plants and shells, and are overlaid by old volcanic rocks which probably date from the Miocene. The slope under the Pacific to the south reaches abysmal depths, the slope to the north, from Unalaska eastward, is very flat to a shallow sea. The line of volcanoes apparently represents a tension crack at the edge of this shallow fill of Bering Sea, through the folded strata, and following in plan a singularly perfect curve for several hundred miles. To the south of the region here considered there is a trough under the ocean parallel with the Pacific shore more than 20,000 feet deep.

T.A.J.

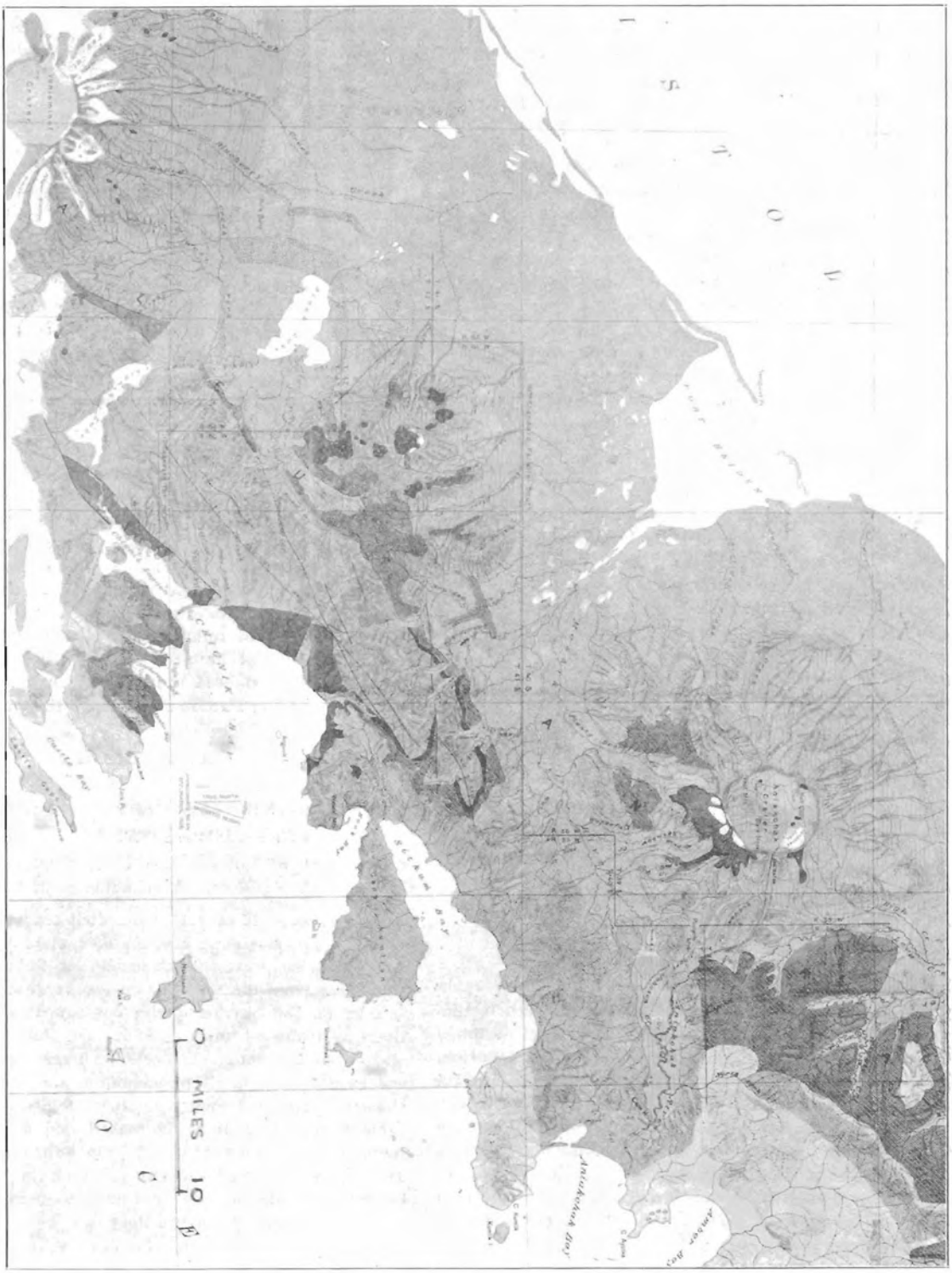
KILAUEA REPORT No. 1049

WEEK ENDING FEBRUARY 28, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

On February 22 at 9:15 a. m. dust from a slide at Halemaumau pit was seen and another slide was reported at the northeast wall the afternoon of February 21. Blue fume rose from the floor at two places west and southwest. Cracks on the northeast rim continued widening, one of them as much as one-half inch. On February 23 a small slide from the rim at the north wall occurred at 9:55 a. m., cracks SW showed slight widening, and cracks NE and N showed slight to strong widening. February 24 at 9 a. m. fume appeared to have increased and a new crack was found back of the north wall. On February 26 crack No. 31 NE had widened one-qaurter inch in four days. On February 28 after much rain, fume was pronounced SW and much steam rose from the floor.

At the Observatory instruments 45 tremors were recorded, one of them indicating distance exceeding 14 miles. Of nine very feeble shocks, three indicated origin distance 2 miles, two 3 miles, three 4 miles, and one 9 miles. Two feeble shocks of the felt class occurred. One of these February 23 at 1:30 a. m. indicated origin distance 2 miles. One during the noon hour February 26 indicated origin distance only 1 mile. Microseisms caused by windy weather were strong except on February 24 and 28, when they were moderate. Tilting of the ground was moderate SW.



Geological map of Aniakchak district copied from a colored sheet. Geology by R. S. Knappen (Bulletin 797-F, U. S. G. S.), topography by R. H. Sargent. Scale 11 miles to the inch. The three circular areas at the northwest are the volcanoes Aniakchak, Purple Crater, and Veniaminof. Surveyed in 1922-23. The faulted belt at the south and the dark area northeast are Jurassic to Tertiary sediments.

THE VOLCANO LETTER

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The Volcano Letter

Two dollars per year **Ten cents per copy**

No. 376—Weekly Hawaiian Volcano Observatory, National Park, Hawaii March 10, 1932



Crater in ice of Makushin Volcano, Unalaska Island, photographed in 1907, and resembling the snow crater on Mount Baker described by Rusk in 1903. Photo Jaggar.

NOTES ON VOLCANOES OF THE CASCADE RANGE

For purposes of the volcanologist, every bit of information concerning craters or heat on mountains known to be volcanoes is of value. In Volcano Letter No. 363 there was published a review with maps concerning some of our northwestern volcanoes other than Lassen Peak. In "Tales of a Western Mountaineer" (Houghton Mifflin 1924) Mr. C. E. Rusk publishes notes made during mountain climbs on some of these volcanoes which are unusual and worthy of quotation.

The crater of Mount Baker or Kulshan is illustrated by a photograph taken about 1900 by the party of John A. Lee. This shows a circular crater opened through snow and ice, with fume rising, and with crevasses extending up a smooth nevé above it. In 1903 Rusk climbed the east side of the main peak of Mount Baker accompanied by George G. Cantwell. They went to Morovits Ranch, and camped at the timber line. The whole east side of the mountain is forbidding and covered with snow and ice. There are two peaks of which the southern is the lower. When well up the slope, on glancing upward, they saw large volumes of smoke rolling from between the two peaks. When they reached the top, it appeared that for several hours the smoke from the crater had been hidden from them by the south shoulder of the main peak. As they emerged from the chimney there burst into view a most thrillingly weird spectacle.

In a bowl-like depression immediately between the two peaks of Mount Baker there was a great orifice in the snow, perhaps 50 feet across. The west side was partly blocked with snow so that the opening was somewhat half-moon shaped. Two hundred feet away a semicircular crevasse swept halfway around the pit. Up from the unknown depths of this abyss black fume boiled out. It drifted away, guided by the shifts in the wind currents, until it dissolved in the upper air. Mr. Rusk speaks of the wild, unearthly loneliness of the scene, which "impressed us profoundly, for its counterpart perhaps does not exist on earth."

This description is astonishingly like that of the ice crater containing sulphur on the summit of Makushin Volcano in Unalaska (Page One). This was photographed and described by the reviewer, and the picture published, in 1908 (Technology Review, Boston, Vol. X, No. 1, Journal of the Technology Expedition to the Aleutian Islands 1907, by T. A. Jaggar, pp. 11-12). "The rim of the greater crater of Makushin was finally reached at 12:45 July 3, 1907. Within was an expanse of snow, probably two miles in diameter, through which three or four steaming vents have maintained openings. We saw a steaming cavity ahead to

the right. Examination proved this to be a new crater opening, a vertical cavity in the snow, 75 feet in diameter, with a 300-foot wall of bedded ice and snow behind it and sulphurous steam incessantly rising through it. A great tumble of snow or ice blocks rested in front of it, and, where the steam drifted across these, their white surfaces were yellowed with sulphur. An inner cone of bowlders and sand was seen beyond this pit and south of it. This was visited and found to contain a crater some 2,000 feet in diameter, with very active solfataras working on its northern side, and sulphurous coatings about the vents."

Rusk's climb was 11 hours from the timber line to the top of Mount Baker, and was presumably early in the season of 1903. When photographed in August 1906 by F. H. Kiser, the crater gave no sign of snow orifice, nor of smoke. There was only a slight depression in the snow and the remnant of a crevasse. Professor George Davidson saw Mount Baker in very active eruption in the early fifties.

Mount Rainier or Tacoma Volcano is described by Rusk as having a great crater from a quarter to a half mile in diameter inclosed by bare cliffs 30 or 40 feet high. The bottom is filled with snow which makes of the interior a comparatively level field. Around the rim are many small vents in the rock, from which jets of steam issue. In places, and at times, this steam melts the snow, leaving cavern-like fissures between the snow and the wall of the crater. The highest point of Mount Rainier is a dome of snow just west of the crater. Mr. Rusk writes: "I crossed the crater alone. On the farther side I was surprised to find lichens clinging to the bare rock surface. I found a jet of steam issuing from a small hole in the sloping face of the rock. I stooped to see if I could detect any odor coming from the place and received a little steam-scald for my pains. The rocks were quite warm, and I have no doubt one could place a frying pan over some of these orifices and there do considerable elementary cooking. I scrambled out of the crater and a short, easy climb brought me to Columbia's Crest, the actual summit."

Glacier Peak is a volcano 10,400 feet high, easy to climb, and Mr. Rusk reached the summit at 11 a. m. The old crater is directly on top, from one-quarter to one-half mile in diameter, broken down in many places, leaving craggy pinnacles around the circumference. One of these on the southern edge is the summit. The crater is filled by a big snow field. On the east the snow feeds into a great ice-fall, the chief branch of Cool Glacier. This peak was climbed by I. C. Russell, and is not described as steaming.

In the case of Mount Hood, the only mention of heat by Mr. Rusk is described from the summit, when, looking far below, near Crater Rock, he saw big jets of steam rising into the air and drifting upward to mingle with the fleecy clouds that were idling across the face of the peak.

During the exploration of Mount Adams, Rusk mentions on the north side a dry stream course that produced a glacial torrent. This started running in the middle of the afternoon, kept flowing part of the night, and was dry the next morning as a daily occurrence which is not explained. This is a part of the Klickitat drainage.

Going up Mount Adams by the southern way, Rusk's party found thousands of dead grasshoppers on a snow-filled saddle south of the first summit. There were also other insects as well as a humming-bird and a duck, each occupying its own little depression in the snow. Rusk states on different occassions, while climbing Mount Adams, he had found numbers of such birds and insects; and once his party found a dead mouse at an elevation of nearly 12,000 feet. One often finds live spiders crawling over the snow at high altitudes, and sometimes, but not often, live butterflies and other insects are seen. Rusk believes that the dead organisms are accounted for by gales of wind, or else during high flights these creatures are blinded by snow, when they fall bewildered and chill to death. It is an interesting question whether there could be any volcanic carbon dioxide or other gas to asphyxiate the insects.

From the pictures reproduced, the Klickitat Glacier must occupy the former crater of Mount Adams, between the summit and the Ridge of Wonders. Professor H. F. Reid, who has climbed among these volcanoes, expressed the opinion that some fused fragments of rock appeared less than 100 years old (Rusk, page 98).

The following are Mr. Rusk's comments on heat in the crater region of Mount Shasta. When he was turning down from the summit, in 1923, he writes: "I had read much of the so-called boiling sulphur spring, and when we were a short distance down the talus slope, a little to the west of where we had come up, we heard a mighty gurgling roar and saw steam rising from farther down the slope. This subterranean cataract appears to start well up the talus slope and only a little below the highest summit of the mountain. It rushes down nearly to the foot of the pinnacle and apparently turns and disappears along a depression between the main summit and another near-by peak just to the south. From the noise it makes, there must be a veritable river of it, and it is certainly forced upward through some internal chimney from a cauldron in the heart of the mountain. The whole thing would doubtless be invisible, had not visitors pricked its outer covering. The underground channel is overlaid by several inches of what seems to be a blue clay. Wherever holes have been gouged in this by the points of alpenstocks or other sharp insturments, the boiling water bubbles through, making animated little springs from which the steam floats away. We saw several of these. The loose rocks on top are so hot that it is hardly possible to hold the hand on some of them, and the whole clay surface is uncomfortably warm."

"I caught some of the boiling water in my cup and the taste was agreeable and rather sour, resembling lemonade. I drank a considerable quantity and suffered no ill effects. On the little flat just below where we sat were several rock inclosures that had been piled up for shelter by men who had spent one or more nights at this place. Even in a severe storm it is possible for a man to survive, as the heat of the rocks on the slope above the boiling spring would keep one from freezing." T.A.J.

TILTING OF THE GROUND FOR FEBRUARY

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction computed from the daily seismograms, by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

February 2-8	1.4 seconds	SE
February 9-15	1.6 seconds	SW
February 16-22	2 0 seconds	SW
February 23-29	1.8 seconds	S

E.G.W.

KILAUEA REPORT No. 1050

WEEK ENDING MARCH 6, 1932

Section of Volcanology, U. S. Geological Survey

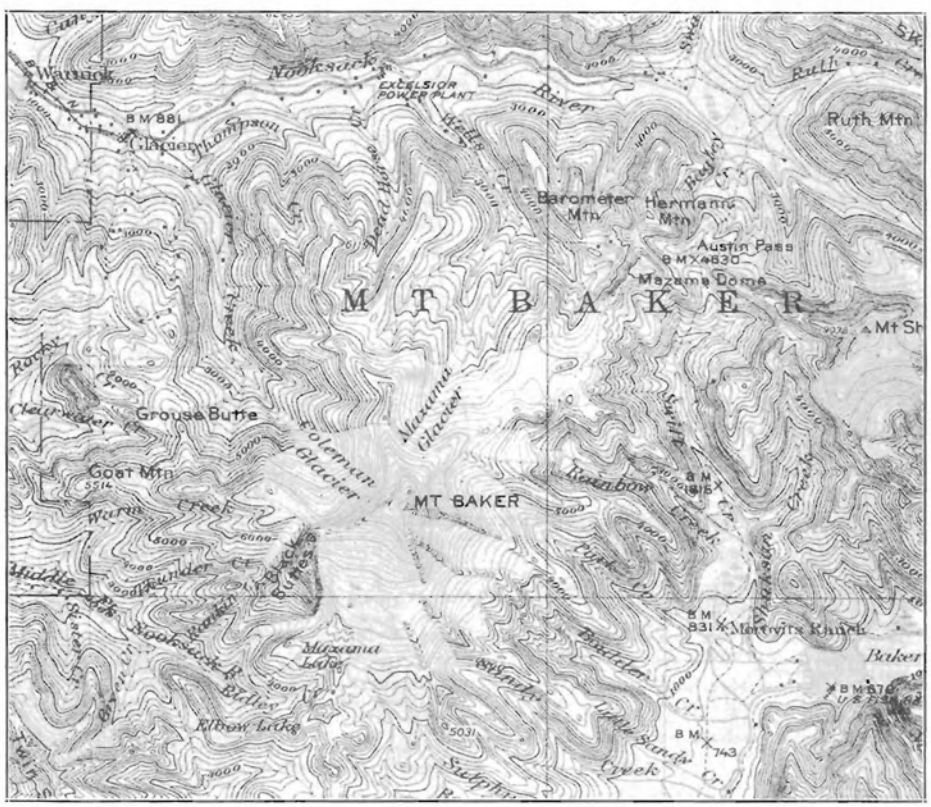
T. A. Jaggar, Volcanologist in Charge.

The widening of crack No 31 NE at the edge of Halemaumau pit has resulted in a crisis of collapse at that portion of the rim. On February 29 there was an avalanche at the northeast wall at 10:17 a. m., and the block in front of crack No. 31 appeared to be instable to judge from the continued widening of the crack. Fume was rather dense under the southwest talus. After a slight earthquake generally felt at 4:43 a. m. March 3, there was seismographic evidence at Halemaumau of strong ESE tilt. The cracks had continued widening and the northeast rim was roped off after an avalanche at 2:10 p. m. There were other avalanches during the day. Fresh debris lay under the northeast wall.

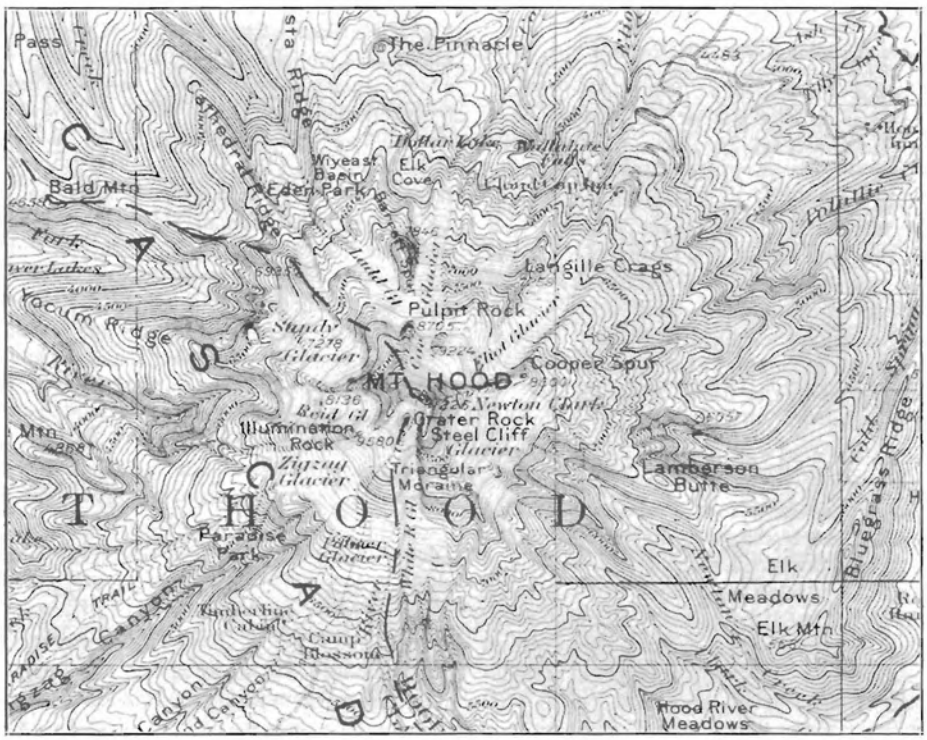
March 4 produced an unusual seismic crisis at Halemaumau and the development of glowing cracks in the January floor. The quaking spasm, which began about 12:53 p. m. and continued for six hours, was strongest for the first hour and a half, and produced eight felt shocks, and much continuous tremor. A visit to the pit showed fresh scars of slides at the west, north, and east walls and small slides were tumbling northeast. Fume was denser than usual, with sulphur odor. There was a large avalanche NE at 2:15 p. m. and others during the afternoon, as well as one NW. Crack No. 31 NE had widened one-half inch in a day. After nightfall two of the deeper cracks in the edge of the lava floor on the east side of the south bay showed distinct glow as though the seismic stress had warped open the thick shell over the still hot January lava.

March 5 produced culmination of the northeastern opening of rim cracks by collapse of the wall. At 11:10 a. m. much new debris was seen under the northeast wall and a small avalanche occurred there. There were numerous fresh cracks, back of the older ones which had been measured. The rim itself had fallen in as far back as the measuring point at crack No. 31. E. G. Wingate ran levels from the sandspit mark in the south end of Kilauea Crater to the northeast rim of Halemaumau and discovered this rim had risen 1.3 feet since the first half of September 1931. This means a swelling upward of the inner dome of the Kilauea floor to accompany the opening of rim cracks. At 3:28 p. m. a section of the northeast rim 500 feet long and 50 feet deep horizontally collapsed in a tremendous avalanche, measuring points Nos. 2, 31, and 35, the danger sign, and the protecting rope were all carried away, and the material overlapped the 1932 lava floor for a length of about 200 feet and a width of 20 feet. Most of this fell after Saturday noon March 5, but the measurements represent the total loss as seen at 9:30 a. m. March 6. The avalanche was accompanied by a small earthquake. Blue fume continued vigorous SW and slight fume rose from the glow cracks which were incandescent as before. A northern slide occurred at 10 p. m. March 6.

The Observatory registered 125 seismic disturbances for the week, including one moderate, 8 slight, 2 feeble, 37 very feeble shocks, and 77 tremors. Of these the spasm of the afternoon of March 4 from 12:53 p. m. to 6:44 p. m. included 1 moderate, 7 slight, 2 feeble, and 31 very feeble earthquakes, and 16 tremors. This spasm indicated mostly



Map of Mount Baker in Washington, scale four miles to the inch, contour interval 200 feet. Surveyed 1907-09, U. S. Geological Survey.



Map of Mount Hood in Oregon, scale two miles to the inch, contour interval 100 feet. Surveyed 1924, U. S. Geological Survey.

a seismometric distance of two miles, corresponding to the distance of Halemaumau. Other indicated distances of the week were 3, 4, 7, and 9 miles, some of which may have been variation in depth under the Halemaumau center. A very feeble shock of 11 p. m. March 1 was felt at Kapapala and the slight shock of 4:43 a. m. March 3, with indicated distance of seven miles from the Observatory, was generally felt on the east side of the island. Microseismic motion was moderate to weak, and tilting of the ground was moderate S to SSE: this tilt was strong for two days prior to March 4, and there were sudden tilts during the earthquake swarm.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Arthur L. Dean, President; Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Richard A. Cooke and Wallace R. Farrington.

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The Volcano Letter

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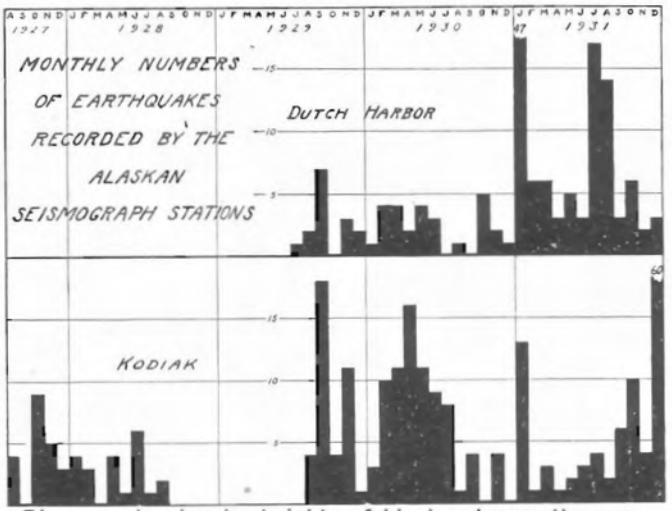


Diagram showing by heights of black columns the comparative frequency of Aleutian earthquakes, by numbers of shocks, per month, at Kodiak and Dutch Harbor (Unalaska) seismograph stations of the Section of Volcanology, U. S. Geological Survey. A. E. Jones.

EARTHQUAKES RECORDED AT THE KODIAK AND DUTCH HARBOR STATIONS

The United States Geological Survey is interested in the seismic activity of the Alaskan volcanoes. Towards that end the Section of Volcanology has placed two seismograph stations at strategic positions. As these places are more than 600 miles apart, neither records the smaller earthquakes local to the other. To facilitate a study of these records, a map of the Alaskan Peninsula and the Aleutian Islands has been prepared which is shown on Pages Two-Three. On this map circles of successive 50-mile distances have been scribed about the two stations. These 50-mile zones aid in the rough location of the earthquakes. With better earthquake reception, or more stations, closer positions could be given. These records are for the purpose of reconnaissance only.

Kodiak Earthquake Registration

The seismograph at Kodiak, Alaska, was put into operation early in August 1927 and was kept in operation until September 1928. It is at the former Agricultural Experiment Station on the hill back of Kodiak village. During this period of 13 months, 35 earthquakes were recorded. The majority of these were local to the Alaskan Peninsula. Fourteen of these quakes originated at distances of 100, 115, and 127 miles and could be attributed to either the nearer active volcanoes of the Aleutian Range or to the steeper part of the ocean bottom. There was one of 520 miles distance, reported from the Yakutat Bay region. Fifteen were teleseisms that were outside the North Pacific area. The remaining 20 shocks were at unassignable distances, but show by the quick period of the long waves that they were local to that area. Probably the 200-mile circle would include them all. Lacking an attendant the station was discontinued for a year.

The next series of records of the Kodiak station begins in the middle of August 1929. During the five months of 1929, six earthquakes were recorded from distances of 20 to 60 miles, two of which were felt by many persons. Thirty-one shocks were recorded that were not teleseisms but show distances of origin otherwise indefinite, but are probably not farther away than 200 miles. There are no teleseisms listed for that period.

During 1930, 25 shocks came from distances of 20 to 70 miles away. One of these was strong enough to be felt generally; it dismantled the seismograph. Fifty-one local shocks of unknown distances of origin were recorded, and only one of 83 miles distance, that could have originated near Kukak Volcano. Six local earthquakes were apparently strong enough to have been felt, but were not so reported. Only one teleseism is listed for the year.

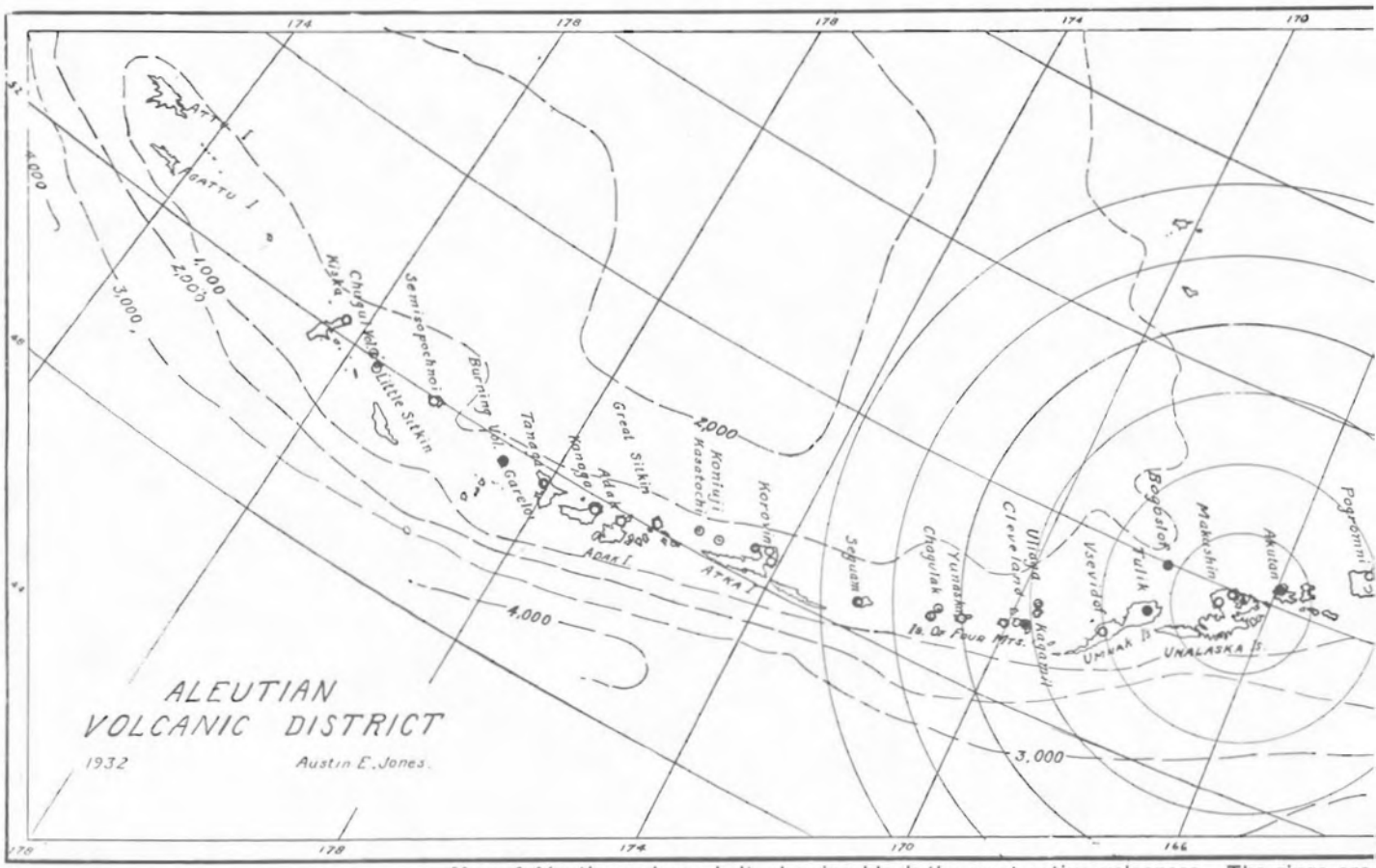
Time used is Kodiak Standard (K.S.T.), 10 hours slower than Greenwich.

Earthquakes recorded at Kodiak, Alaska

Lat. 57° 48′ 40″ N; long. 152° 24′ 20″ W; elev. 300 ft minus

Two Hawaiian-type horizontal pendulums weighing about 70 kg. set up in N-S and E-W directions. Static magnification 135 times with critical oil damping.

1931		Character	K S. T. h.	m.		Distance Miles	Remarks
Jan.	1	Tremor	0	30	a.m.		
	2	Feeble	7	40	p.m.	157	
	4	15 Tremors			p.m.	75-115	Two indicate distance.
	7	Tremor	0	30	a.m.		
	7	Very feeble	3	00	a.m.	20	
	8	Very feeble	11	30	p.m.	83	
	9	Very feeble	1	40	p.m.	20	
	9	Very feeble	8	20	p.m.	143	
	11	Very feeble	3	15	p.m.	50	NE-SW.
	11	Tremor	4	30	p.m.		
	14	Teleseism	5		p.m.		Long waves.
	25	Tremor	6	37	a.m.	110	
	27	Feeble	6	35	a.m.	215	or over. Begins in hour mark. Felt in Seward and Anchorage. Epicenter 61° N 150° W.
	27	Teleseism	11		a.m.		Part of a distant earthquake. Epicenter 31° N 108° E.
Feb.	2	Tremor	6		p.m.	100	



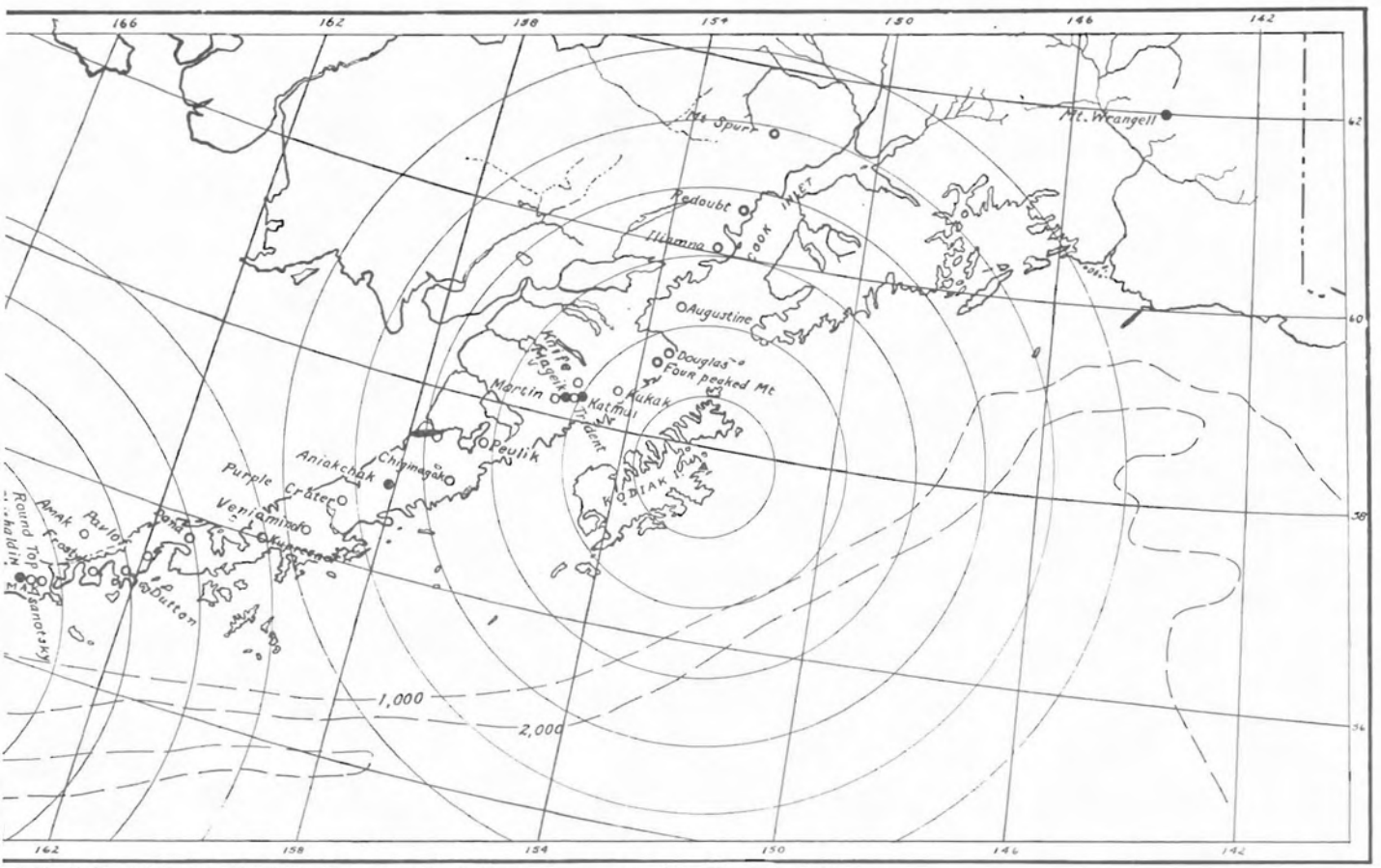
Map of Aleutian volcano belt, showing black the most active volcanoes. The rings aro
Soundings in Bering Sea at the north and Pacific

Mar.	18	Very feeble	5	05 p.m.	100	
	21	Tremor		p.m.	32	or over.
	22	Tremor		a.m.		
Apr.	22	Tremor		p.m.		
May	16	Feeble	10	45 p.m.	147	
	28	Feeble	6?	15 p.m.	320	Epicenter 58° N 158° W.
June	14	Very feeble	7	30 p.m.	32	NW-SE.
	16	Tremor	7	00 p.m.	74	
	27	Very feeble	7	35 p.m.	18	NW-SE.
July	5	Tremor	2	00 a.m.	30	or over.
	26	Tremor	10	17 a.m.	64?	
	26	Tremor	2	15 p.m.	110	
Aug.	1	Tremor	7	15 p.m.		
	22	Tremor	3	00 p.m.		
	27	Teleseism	6	20 a.m.		Long waves, part of earthquake. Epicenter in Baluchistan 30° N 67° E.
Sept.	1	Teleseism	3	50 p.m.	600	or greater—felt locally.
	9	Tremor				
	10	Tremor				
	10	Very feeble	12	00 p.m.	55	NE-SW.
	25	Very feeble	1	30 p.m.	60	
	26	Very feeble	5	00 a.m.	55	NE-SW.
	29	Very feeble	0	55 a.m.	160	or greater.
Oct.	3	Teleseism	10	a.m.		Part of Solomon Islands earthquake, epicenter 10° S 161.°4 E.
	12	Very feeble	3	35 a.m.	46	NE-SW.
	16	Very feeble	3	20 p.m.	64	
	17	Feeble	2	50 a.m.	172	NE-SW.
	18	Feeble	2	15 p.m.	50	NW-SE.
	25	Tremor		p.m.	108	
	25	Tremor		p.m.		
	26	Slight	1	00 a.m.	55	NE-SW.
	29	Feeble	9	45 p.m.	32	NE-SW.
	31	Tremor	2	00 a.m.		
Nov.	17	Tremor	2	40 p.m.		
	20	Very feeble	0	55 a.m.	267	NW-SE.
	20	Tremor	1	25 a.m.		
	25	Feeble	9	50 p.m.	74	NW SE.
Dec.	7	Very feeble	2	50 p.m.	78	
	9	Very feeble	2	30 a.m.	106	Over 30 similar earthquakes having no recognizable P phase between Dec 8 11 p. m. and Dec. 9 7 a. m.
	11	Very feeble	8	30 a.m.	305	20 to 25 tremors during 7:30 to 9:30 a. m.; no distances assignable.

In the above record there were 19 local quakes that originated at distances of 20 to 80 miles. Four of these came from 74 to 78 miles away and could have originated under the near side of the volcanic Aleutian Range. Seventeen occurred at places from 80 to 320 miles away, and it can be estimated that a fair percentage of these were from near volcanoes. There were 13 shocks, mostly graded as tremors, as well as three swarms of 13, 30, and 20, to which there could be assigned no epicentral distance other than that they were not farther away than about 200 miles. Parts of five teleseisms were recorded.

Dutch Harbor Earthquake Registration

The Dutch Harbor seismograph was installed July 1929 and has been run continuously. During the last half of



nd Kodiak and Dutch Harbor seismograph stations are progressive 50 mile distances.
Ocean at the south are in fathoms. A. E. Jones.

that year one shock was recorded from a distance of 37 miles. Akutan Volcano, about 30 miles to the east, was in eruption during the late summer and autumn, and it is more likely that this earthquake occurred there than under the slope of the ocean deep to the south. Eight shocks occurred in the next zone and can be assigned either to the volcanic island Umnak or to the slope of the deep. Six other local quakes of unknown distances were recorded and one teleseism. No earthquakes were reported as felt.

During 1930 four shocks were definitely from within the first zone. One on November 6, 1930, at 3:20 a. m. local time, was felt very strongly at Dutch Harbor and originated 46 miles away. Six more shocks were from the second zone and two occurred at greater distances. There were also 15 local quakes from unknown distances. Only one teleseism was recorded during the year.

Time used is Pacific Standard Time, (P.S.T.) 8 hours slower than Greenwich.

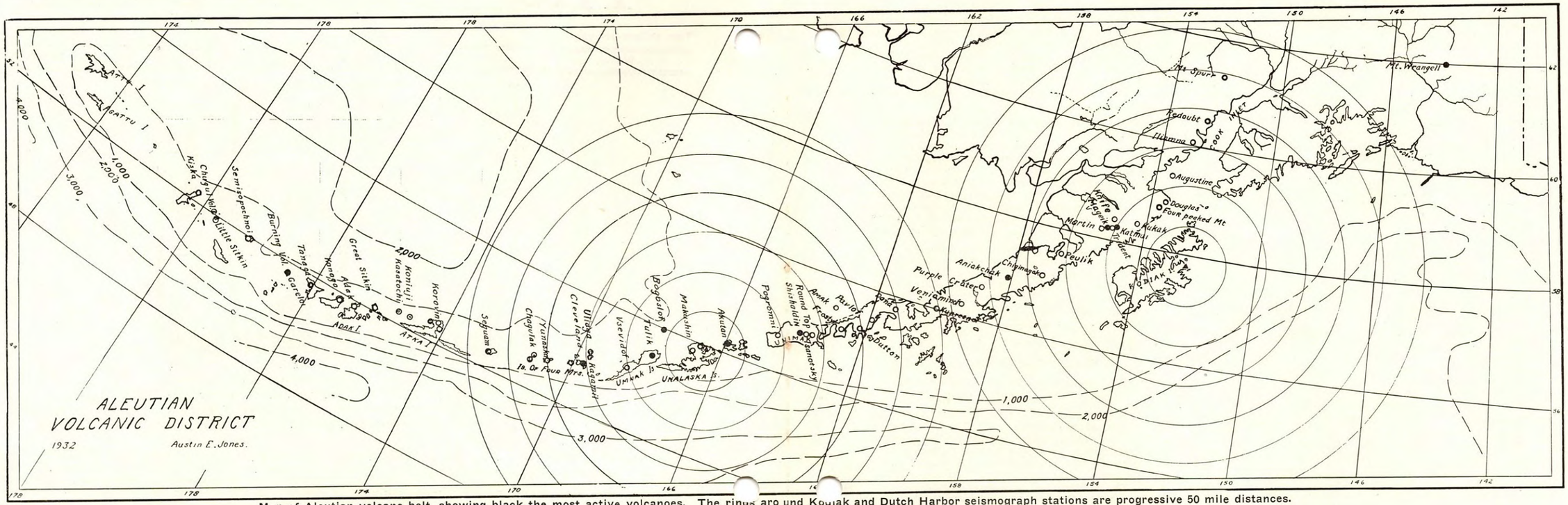
Earthquakes Recorded at Dutch Harbor

Lat. 53° 53′ 09″ N; long. 166° 32′ 05″ W; elev. 15 ft.

Two Hawaiian-type horizontal pendulums weighing about 70 kg., set up in N-S and E-W directions. Static magnification 135 times with critical oil damping.

1931		Character	P. S. T. h. m.		Distance Miles	Remarks
Jan.	2	Tremor	8	25 a.m.	69	
	3	Tremor	11	00 a.m.		
	6	Tremor	8	35 p.m.	60	
	9	Very feeble				
	11	Tremor	6	45 p.m.	42	
	23	Tremor	4	30 p.m.		
	28	5 tremors		p.m.		
	30	35 tremors		p.m.		23-28-32-37-51 59; one at each distance.
	31	Tremor	5	02 p.m.		
Feb.	1	Tremor	5	30 a.m.	57	
	3	Tremor	2	00 p.m.	23	
	10	Tremor	5	30 p.m.	64 or 92;	according to interpretation of phases.
	11	Tremor	9	25 a.m.		
	13	Tremor	4	10 p.m.		
	15	Tremor	7	30 a.m.		
Mar.	2	Very feeble	7	30 a.m.	120	
	2	Tremor	11	35 a.m.	46	
	27	Tremor	5	40 a.m.	147	
	29	Feeble ePEN	9	26 28 a.m.		Felt in Dutch Harbor.
		iSE	9	27 01	106	ESE.
	29	Slight ePN	11	13 36 a.m.		Felt in Dutch Harbor.
		iSE	11	14 08	147	
	29	Tremor	0	52 p.m.	120	or over.
Apr.	3	Tremor	7	25 a.m.	111	
	5	Tremor	4	15 a.m.	64	
	18	Tremor	8	30 p.m.	140	or over.
May	4	Tremor	10	55 a.m.	51	
	5	Tremor	2	15 a.m.	147?	
	9	Tremor	7	00 a.m.		
	20	Tremor		a.m.		
	20	Tremor	0	10 p.m.	23?	
June	19	Tremor		a.m.		
	27	Very feeble	0	50 a.m.	46	NW-SE?
	27	Tremor		p.m.		
July	12	Tremor	5	30 p.m.	46	
	13	Tremor	1	45 p.m.	50?	
	18	*Teleseism	3	20 a.m.		

* The Jesuit Seismological Association lists the following 1931 distant earthquakes from this region: May 27, Lat. 56° N Long. 168° E, Commander Islands off Kamchatka; May 29, 58° N, 158° W, Bristol Bay west of Katmai; May 30, 52° N, 177° E, near Kiska and disastrous at Attu; July 18, 58° N, 169° E, west of Kamchatka. The May 29 shock was registered at Kodiak, and that of July 18 at Dutch Harbor.



Map of Aleutian volcano belt, showing black the most active volcanoes. The rings are und Kodiak and Dutch Harbor seismograph stations are progressive 50 mile distances.
Soundings in Bering Sea at the north and Pacific Ocean at the south are in fathoms. A. E. Jones.

	19	Very feeble	0	05 p.m.	100-200		
	24	6 tremors		p.m.			
	24	Tremor	8	20 p.m.	83		
	29	8 tremors	11	a.m. to			
			12	m.	18	Distance of one only.	
Aug.	2	Tremor	0	10 a.m.	46		
	5	Tremor	2	05 p.m.	500?	Part of a distant quake.	
	8	Very feeble	4	45 a.m.	97		
	8	Tremor	5	15 p.m.		Part of a distant quake.	
	9	3 tremors		p.m.			
	11	Very feeble	6	40 a.m.	88		
	11	Tremor	8	00 a.m.			
	11	14 tremors	4	00 p.m. to			
			8	30 p.m.			
	14	Feeble		a.m.	110		
	14	Tremor	6	00 p.m.	97		
	15	Tremor	4	40 a.m.	120		
	19	Tremor	6	10 a.m.	360?		
	19	Tremor	6	50 p.m.	130		
	24	Tremor	3	30 a.m.	330?		
	31	Tremor	6	00 a.m.	115		
Sept.	2	Very feeble		p.m.	110		
	8	Tremor	8	30 a.m.	42		
	18	Very feeble		a.m.	55		
Oct.	2	Very feeble	4	50 p.m.	100	NE-SW?	
	10	Teleseism					
	10	Tremor					
	10	Tremor	6	40 p.m.	37		
	14	Feeble	2	00 a.m.	115		
	17	Tremor	6	35 a.m.			
	17	Very feeble	8	35 p.m.	55	NE-SW	
Nov.	22	Tremor		a.m.	64?		
	23	Very feeble		a.m.	60	NE-SW.	
Dec.	1	Very feeble		p.m.	125	ENE-WSW.	
	6	Moderate	11	10 p.m.	46	NE-SW. Felt by all. Seismographs dismantled; dishes rattled.	
	14	Feeble		a.m.	125	ENE-WSW.	
	23	Teleseism	9	45 a.m.	900?		

In the above table 13 earthquakes originated in the first zone about Dutch Harbor, while 17 were in the second zone, 11 in the third zone, possibly two in the fourth zone, two outside the zones at 330 and 360 miles, and two more occurred at the probable distances of 500 and 900 miles away. Four teleseisms were recorded completely or in part. One from the Kamchatka region was remarkable for its large single S period. At least 70 local earthquakes were recorded in such small amplitudes that no distance could be determined. During the summer of 1931 there were over 200 artificial disturbances. probably caused by workmen. There were three earthquakes reported felt at Dutch Harbor. The accuracy of the location of earthquakes in these zones is largely dependent on the depth of focus of the earthquake.

During the years 1929-30 the Kodiak station recorded about 2½ times as many earthquakes as the Dutch Harbor station, while in 1931 the Dutch Harbor station recorded 37 per cent more. This would seem for seismicity to parallel Petroff's statement for volcanicity, that when the volcanoes in one part of the Aleutian chain become quiet, others in some other part of the chain become active. This relative localized shift of seismicity also shows in the graph.

Tremors

The numbers of tremors in the tables stand out. Three times as many were recorded by the Dutch Harbor seismograph as were recorded by the Kodiak seismograph, probably because Dutch Harbor is much nearer the subterranean volcanic rift line. They are seismic in character, representing sizable shocks when originating at a distance. They probably could have been felt by any one over, or near, their origin. After having traveled 50 or 100 miles, the earthquake waves have so decreased in size that they are barely registered as tremors on the receiving seismograph. The Kodiak station recorded 36 of these tremors, only 10 being pronounced enough to show distance by the S-P interval. They fall into groups of 30, 70, and 105 miles. The Dutch Harbor station recorded 105 tremors, 35 indicating distance. Most of these originated at distances from 20 to 150 miles away.

The volcanic magma underground on the Alaskan Peninsula near Kodiak may be about as active as that near Dutch Harbor if seismic distance is considered. The latter station is at about 8 and the former at 80 miles distance from part of the Aleutian volcanic rift. If we compare the tremors received at Kodiak from 100 to 115 miles, with those received at Dutch Harbor from approximately the same distance, there are five in each case received on instruments of nearly equal sensitivity. Referring to the map, there are volcanoes at those ranges from each station.

While there are only two indicated 100 miles on each side of Dutch Harbor, there are other smaller craters unlocated, near both Vsevidof and Pogromni, and both Unimak and Umnak islands have produced recent eruptions. The Katmai group is 100 miles from the Kodiak station. (See Volcano Letter No. 375.) A.E.J.

KILAUEA REPORT No. 1051

WEEK ENDING MARCH 13, 1932

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge.

On March 7 fume from near the foot of the southwest talus was as strong as on previous days. The fuming spot under the west wall was inactive. Cracks were measured and showed little change. Two new measuring points were established on the northeast rim back of the area which avalanched last week. A slide occurred from the NE wall at 10:32 a. m. The seismograph at Halemaumau registered sudden tilt in the morning, without tremor, to the east, and a gradual tilt to south. Two glowing cracks reported last week were plainly visible in the evening.

Dust from an avalanche was seen March 8 at 1:13 p. m. from the Observatory. A small quake was felt at Halemaumau at 2:07 p. m. A few rocks were heard falling.

Nothing new was observed during a circuit of the pit on March 9 in the forenoon.

Much dust from big slides was seen about 1 p. m. March 10.

On March 11 much fume was visible from the Volcano House, rising in concentrated puffs during the forenoon. At 10:08 a. m. there was a small slide from the northwest wall. Sulphur stain slowly increases about the fume spots. A slight widening of cracks was noted northeast. The glow from one of the cracks has nearly disappeared. The crack southwest of this continues to be visible at night, but not so bright as formerly.

On the evening of March 12 one glow-crack remained visible. On March 13 fume activity showed no change. A quake at 8:26 a. m. registered stronger on the Halemaumau seismograph than at the Observatory. Moderate tilt to the east was registered during a quake at 1:15 a. m.

The seismographs at the Observatory recorded 41 tremors, 12 very feeble seisms, and one feeble seism at 11:04 p. m. March 8 felt in Hilo. A very feeble seism at 1:15 p. m. March 11 was also reported felt in Hilo. Distance phases of most of the disturbances indicate origins near Kilauea. Microseismic motion was moderate for the first three days of the week, followed by two days of strong microseisms, and decreased to light at the close of the week. Average tilt for the week was strong SSE.

THE VOLCANO LETTER

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The Volcano Letter

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Stucco building damaged by earthquake of August 31, 1926, in Horta, Azores. Photo Agostinho.

FREEMAN'S BOOK ON EARTHQUAKE INSURANCE

This monumental work of 904 pages ("Earthquake Damage and Earthquake Insurance,' by John Ripley Freeman, McGraw-Hill, 1932) includes "studies of a rational basis for earthquake insurance and of engineering data for earthquake-resisting construction."

The twenty-two chapters cover: the present situation; earthquake causes and motion; measure of earthquake violence; frequency and violence in the United States and Canada; the narrow destruction zone; structural lessons from San Francisco and Charleston; structural safety and local ground; structural lessons from other American earthquakes; earthquake-resisting buildings in Japan 1923; lessons from Italian earthquakes; lessons from Nicaragua and New Zealand; prediction of time, place and damage; figures on earthquake loss ratio; insurance rates by stock companies; affiliation of earthquake and fire insurance; municipal building codes; textbooks on earthquake-resisting design; shaking tables; the motion of the ground in an earthquake; design of earthquake-resisting buildings; data from seismograms; suggestions for a program of earthquake research.

This book by a great engineer, President of the Manufacturers Mutual Fire Insurance Company, is something entirely new in the realm of seismological literature. It is a book which should be in the office of every large corporation interested in insurance of its property, and still more in every office interested in writing property insurance. The earthquakes of California, Japan, Central America, Italy, and New Zealand, in recent years accompanied with conflagration, and affecting large cities containing modern expensive structures, have created a new problem. This problem is the economic one of enforcing adequate construction to resist either earthquake or fire or both. Mr. Freeman states in the introduction:

"The following pages are addressed to structural engineers, insurance executives, and property owners. In the beginning the author was by no means so well convinced of the prudence of writing earthquake insurance as he has become by studying the information accumulated. The facts brought together demonstrate that the actual hazard is really extremely small when considered as a mathematical ratio. Earthquake insurance might advantageously be incorporated in every fire insurance policy at remarkably small additional cost. Local building laws should be remodelled. Destructive earthquakes are infrequent, area of destruction is small, successful resistance of many buildings is remarkable, average proportion of damage is small, and earthquake-resisting buildings can be built at small additional cost."

Construction requirements are summed up as follows: "All buildings in a region liable to earthquake violence, equivalent to that of the known seismic regions of Italy, Japan, and of the United States, should be designed to resist a horizontal earthquake force, applied at each floor level, equal to one-tenth of the weight of all of the structure above that level, plus the weight of the actual contents, resting upon the floors, including the roof."

This amounts to provision for the application of a horizontal force of one-tenth of the weight of superincumbent structure and contents, applied at each portion. Requirement in building codes anywhere, of design to withstand one-twentieth of superincumbent weight horizontally applied suddenly, is recommended as a part of the structural

factor of safety against all emergencies of wind or quake. The utmost practicable structural rigidity is desirable. The oscillation period of a building should be as short as possible.

Prediction of time, place, and damage from earthquakes presents a variety of problems. Place and time are wholly generalized with reference to the future. Meteorological, electrical, and astronomical controls are unreliable. Tidal stresses probably have some effect. Earth-tilt as a forerunner of earthquakes is coming to be regarded as important in Japan. Location of concealed slipping planes in motion is the subject of an elaborate instrumental investigation near Los Angeles. An engineering survey in advance is quite capable of predicting expectable damage in any locality, in case a great earthquake should occur, by report on the stability of the ground and the quality of design in structures. With reference to maximum expectable violence, it is improbable that anything bigger than the earthquakes of the past will happen. And it must be remembered that fire did most of the damage in several of these.

The earthquake insurance hazard at Los Angeles is probably a very little smaller than that at San Francisco. A region of greatest earthquake frequency may possibly be the safest. A region of fewest earthquakes may give the greatest loss when an earth-slip does come. Certain belts are liable to recurrent great earthquakes. Such places have immunity periods after the last great shock. Soft fluvial or made land deposits are shaken much more violently than rigid ground. Rigid buildings of good design and faithful workmanship will be found practically earthquake-proof. A rigid massive foundation is important. The expected loss ratios on American experience are 3 per cent for steel-concrete and wood-frame on good foundations, 5 per cent for steel-brick and well designed factories of brick in cement mortar, 10 per cent for brick residences not exceeding 4 stories, 25 per cent on brick-veneered buildings with wood or concrete frames, and 50 per cent for concrete-block and hollow-tile buildings. Stone buildings are not mentioned.

The following is Mr. Freeman's probable loss ratio for the United States. The expected average earthquake damage in cents per year for $100 of structural value is:

California, coast	10 cents
California, great valley	5 cents
California, Sierra	7 cents
Washington and Oregon, coast	6 cents
Washington and Oregon, inland	4 cents
Rocky Mountains	3 cents
Northern mid-continent	1 cent
Mississippi bottom lands	2 cents
Great Lakes region	1 cent
Atlantic region, interior	½ cent
Atlantic coast	1 cent

One cent per $100 per year is equivalent to an average damage of $1 per year on a house worth $10,000.

The discussion of insurance is elaborate, by districts, and types of construction. Roughly the total earthquake damage (excluding fire) in the United States and Canada in a hundred years has been forty million dollars. It must be remembered that San Francisco in numerous earthquakes has lost only $20,000,000, as compared to $414,000,000 by four conflagrations. Premiums differ from probable loss in that overhead must be added.

In San Francisco, if the owner insures for not less than 70 per cent of cash value of property against earthquake, he pays a premium rate, per $100 value per year, of from 15 cents to $2.50 progressively from Class I to Class VIII of buildings, and must himself assume loss from 5 per cent to 15 per cent of the total value in such matters as cracked plastering or minor cracks in walls. This proviso enables the insurance company to avoid payment for earthquake damage on a large proportion of all buildings, where the loss does not exceed this percentage.

East of the Rockes there are four rating zones, the highest risks being places of historical earthquakes such as South Carolina, New England, and the New Madrid region of the Mississippi; the lowest are the central states and the Gulf coast. The lowest rate is 4 cents per $100 per year, or $5 per year on a wooden dwelling valued at $12,500. In Zone 1 of greatest risk, this $5 would purchase earthquake insurance of only $5,000 on a wooden house. As before there are several classes of structure of progressively greater risk and higher premium.

The book is profusely illustrated. There are splendid airplane views of the new city district construction in Los Angeles and San Francisco. There are many isoseismal maps of earthquakes, panoramic photographs of conflagrations such as San Francisco, diagrams of the possible roller joints in a design for the basement supports on an earthquake-proof building, diagrams of the displacement effects of earthquakes on buildings, distribution diagrams for severe earthquakes; a discussion with diagrams of the triangulation displacement in California published in 1924, which contained an error of 24 feet of alleged crustal creep, and the correction of this in 1928; pictures of earthquake effects on all kinds of structures in many lands, and very modern photographs of the ruins in Managua and Napier.

Mr. Freeman has been recently in Japan and has been much impressed by the admirable work of the Japanese engineers in reconstruction. He is equally impressed by the inadequacy of much seismological work, as concerned with the needs of theory rather than the needs of humanity and engineers. Mr. Freeman considers the devotion to "acceleration" in mathematical studies of earthquake damage as "worship of a false god." The assumption of harmonic motion, the formula based on amplitude, period and gravity, and the short time within which the maximum change of motion acts, all render this theoretical acceleration of small value where the relatively prolonged racking of building and ground in several directions is involved. Freeman is greatly interested in the experiments on model buildings, with mechanical shaking machinery, made in Japan and at Stanford University. He is everywhere impressed by the lack of real knowledge of the earthquake **at the place and time** where the damage is done.

He concludes with twenty-two recommendations for a practical program of earthquake research, including systematic study and translation of the Japanese works; study of dominant local oscillations; make research on artificial explosions; extend the shaking-table research; develop a strong-motion seismograph and place it; investigate all factors of public safety in every American earthquake through the U. S. Geological Survey; run levels and straight reference lines in critical places; establish tilt measuring lines; reorganize the Seismological Society of America along the lines of protection of life and property; and get contributions for research from the great power, construction, and insurance corporations. He concludes

with an apt quotation from the late President Branner: "The registration of an earthquake two thousand miles away can hardly be expected to interest a man whose family lies buried beneath the ruins of a house built of improper materials upon ground that any geologist might have told him to keep away from." T.A.J.

KILAUEA REPORT No. 1052

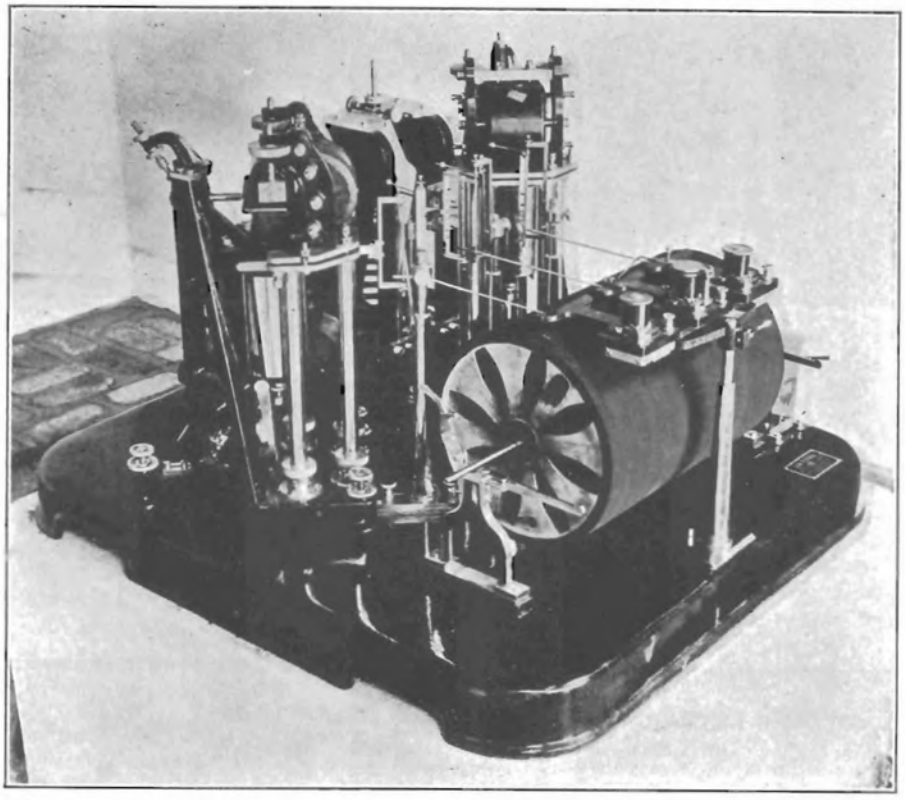
WEEK ENDING MARCH 20, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

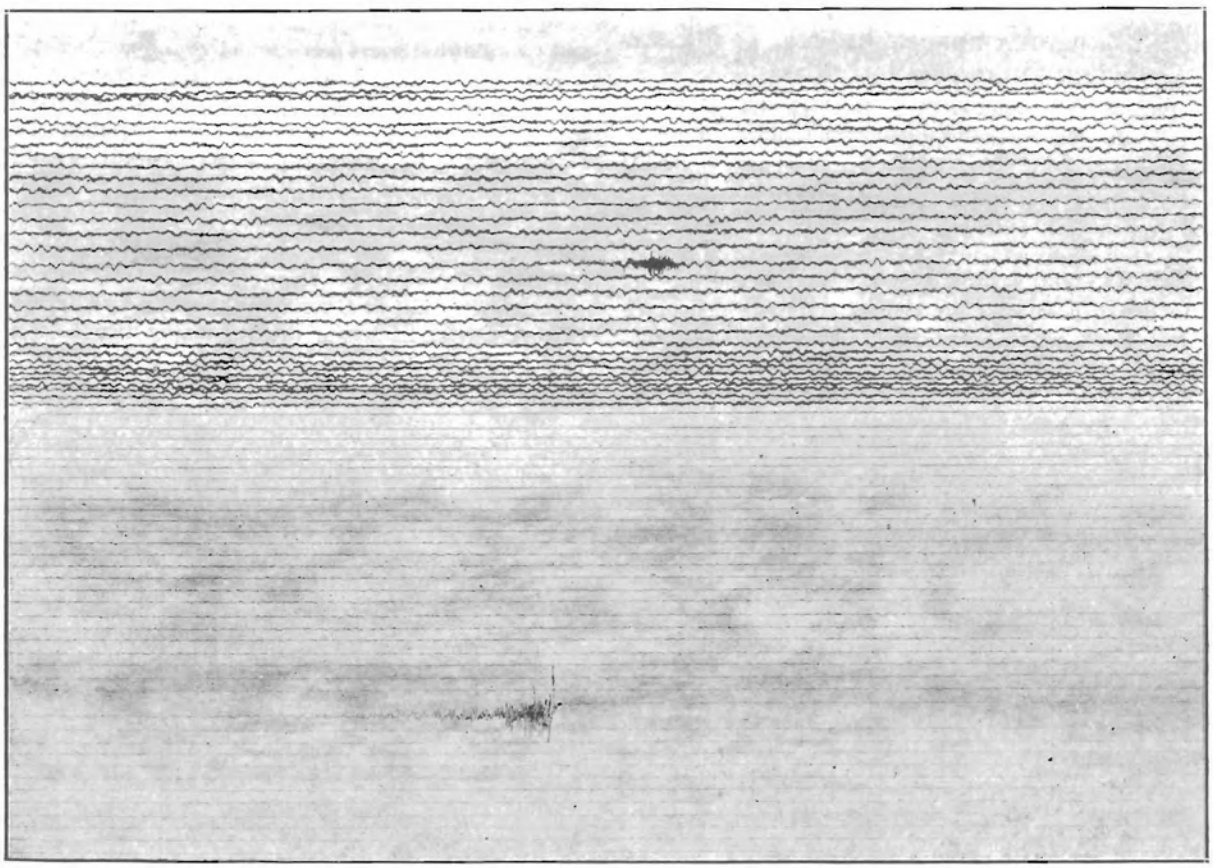
Several slides occurred in Halemaumau during the forenoon of March 14, one larger than the others at 9:37 a. m. over the north wall buttress. Fume appeared about the same. A very slight widening of the northeast rim cracks continued. At night, 8:30 to 9:30, a circuit of the pit was made to locate possible glow spots. Only the one place noted last week, at the southeast, was visible, and this was brighter and larger when viewed from the northeast rim. On March 16 fume showed little change, except that in the forenoon about 11 o'clock none could be seen at the foot of the west wall. At 3:30 p. m. blue fume was plainly visible from the Observatory. On March 17 at 10:15 p. m. fume was again easily visible, and rose from a stained spot by the west talus. At 10:30 a. m. March 18 fume was strong at the same location. On the 19th fume appeared during the forenoon to have decreased slightly. Sulphur stains were quite heavy about the fume spots. Conditions were quiet at Halemaumau. The pit was visited about 7 p. m. and two glowing spots were found at the southeast.

The seismographs at the Observatory recorded 35 tremors, four very feeble seisms, and two feeble seisms. Of the very feeble seisms, one showed origin distance about 4 miles, one about 9 miles, and two about 16 miles. Both feeble quakes showed origin distance about 23 miles. One at 6:31 p. m. March 18 was felt at Kilauea and Hilo; the other at 8:11 p. m. March 19 was felt near Kilauea.

Tilt for the week was strong SW. Microseismic motion was light the first day, moderate the next two days, strong two days, and moderate the remaining two days of the week.



Japanese seismograph designed by Imamura, with three pens writing on a single drum covered with smoked paper. Time marked by lifting pen tips with electromagnets connected with a wall clock. Pendulums record up-down, east-west, north-south motion and are damped with horseshoe magnets.



A seismogram or earthquake autograph written at Kilauea Volcano. The record of crater movement when an eruption stopped. Tremulous upper lines record the eruption. Crowding of lines records tilt. The two groups of crowded oscillations are earthquakes.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Arthur L. Dean, President; Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Richard A. Cooke and Wallace R. Farrington.

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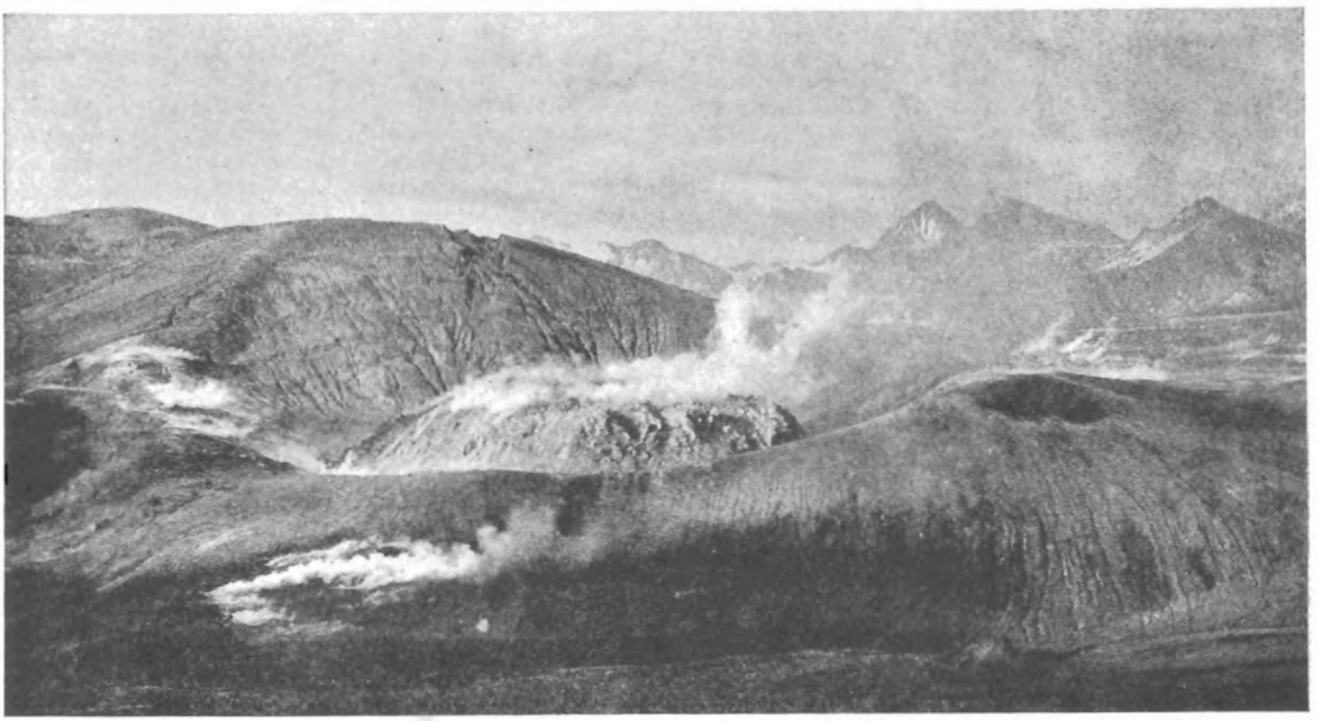


Novarupta dome of siliceous soda rhyolite, near Katmai in Alaska, which rose in 1912 in the bottom of a new explosion crater in a valley, and developed a heap 800 feet across and 200 feet high. Photo National Geographic Society.

WILLIAMS ON LAVA DOMES

An essay of unusual importance for volcanology, with excellent illustrations and a thoughtful, philosophical summary of conclusions has just been published by Dr. Howel Williams (The History and Character of Volcanic Domes, Bull. Dept. Geol. Sci., University of California, Volume 21, No. 5, Berkeley 1932, 95 pages, 37 figures).

Dr. Williams became interested, in the subject of lava flows which arise so stiffly as to build up at once a plug or dome, by his work at Lassen Volcanic National Park where there are 13 such domes within an area of 50 square miles on an even grander scale than the puys of the Auvergne. Massive protrusions are now known to be common manifestations of volcanic activity. There are plug domes which represent upheaved conduit fillings, domes that grow essentially by expansion from within, and domes built by surface effusion. In the last class the large Hawaiian overflow heapings are better described as "shield volcanoes."

The domes described consecutively are those of the Caribbee Islands including notably the dome and spine of Mont Pelée and the dome at the volcano of Guadeloupe. Next come the Central American domes of Santa Maria in Guatemala, Popocatepetl in Mexico, and some minor ones in these countries. South America has numerous lava domes which are imperfectly known, of which the best example is the acid andesite dome, consisting of viscous hardened lava, having an extremely jagged surface, from which steam and fragmental eruptions continually issue, in the crater of Galeras Volcano. In North America, besides the Lassen domes there are those in the chain of craters south of Mono Lake, California. Here at Panum Crater the obsidian lava was so nearly solid that it rose with essentially vertical walls to about 150 feet without exhibiting a tendency to flow in any direction, so that a deep moat separates the dome from the surrounding rim of lapilli. At the Marysville Buttes in California there are banded rhyolites which form intrusive domes among Tertiary sediments along the flanks of an andesitic laccolith, steep-sided and of oval outline from a quarter mile to a mile in length. They were viscous and contained steam, and the rise of the domes was attended by violent steam explosions, some of which blasted a crater, measuring a mile in diameter, through the core of the laccolith. Next come descriptions of Bogoslof in the Aleutian Islands and its numerous domes, and of the remarkable siliceous dome of Novarupta near Katmai on the Alaskan Peninsua. "The rise of this dome, like that of almost all domes, was preceded by strong pyroclastic explosions, whereby a crater almost three quarters of a mile in diameter was opened," and coarse ejecta measuring eight feet in diameter were flung a quarter mile from their source. The explosive phase was followed by the welling up of viscous magma, which as it was slowly thrust upward broke into huge blocks. It was heaped about 800 feet in diameter and 200 feet high. The glassy lava is banded in general parallel to the margins. "Apparently the magma rose to the surface

by the active solution of the country rocks, retaining its heat largely by gas reaction. The original magma was a siliceous soda rhyolite with 75 per cent of silica containing partly fused inclusions of andesite country rock with 62 per cent of silica."

Next come descriptions of Tarumai and Usu domes in Japan, Merapi and Galunggung in Java, and Ruang in the Sangi Islands. A submarine dome during April, 1904, appeared in these islands, and after 1913 three rocks were left emergent above the water. In 1919 a short-lived dome rose above the surface, forming an island 70 meters in diameter and up to 12 meters in height. It consisted of lava blocks of amphibole andesite. There are many other stiff lava domes in the craters of the Dutch East Indies.

Ascension Island in the Atlantic has crater domes of trachyte, and the trachytic eruptions were in all cases preceded by eruptions of basalt. The protrusion of the domes followed long periods of dormancy and was heralded by explosions flinging up obsidian ejecta. The explanation appears to be that after the early outpourings of basalt, the residual magma became differentiated and capped by a siliceous slag. "This sequence of events thus affords another instance of the explosion of a gas-rich, differentiated magma, followed by the quiet upwelling of pasty lava to form" interior heaps in the craters, a sequence apparently common in dome eruptions. The trachytes are poor in vesicles in contrast with the rhyolites and basalts. The diameters of the Ascension Island domes are 400 to 500 meters, and the heights 200 meters more or less. In the Ragged Hill dome, the dome structure is indicated by a pronounced concentric rifting, with plates dipping away 35 degrees, and the platy structure apparently due to thermal contraction. There are inclusions of common basalt in the trachyte. In the case of the Riding School dome, the trachyte flowed over the rim of a basaltic crater after forming a large body in the center of the depression, and then after making a thick flow 700 meters long away from the crater, the surface of the inner dome sank back to form a basin. This withdrawal of magma in the center happened in another dome where the platy structure has an inward dip of from 2 to 5 degrees. At St. Helena there are phonolite domes more deeply eroded than those on Ascension Island, the largest of which, called Great Stone Top, was originally 300 meters high, was fed by a dike only 10 to 15 meters wide, and was accumulated, not in an old crater, but on an almost level floor of basalt. In Samoa there are rhyolite and trachyte domes closely analogous to those of Ascension Island, here also overlying older basalts.

The puys of the Auvergne in France have black basaltic cinder cones with pale-colored craterless domes of trachyte within them, and Scrope in 1825 described them correctly. He observed that basalts tend to yield low, broad cones, because of their high fluidity, whereas lavas of "low specific gravity, especially when combined with a coarse, crystalline texture, will occasion a minimum of fluidity. The trachytic lava seems to have risen upwards from the vent in so pasty or imperfectly liquid a state as to have accumulated above it in the form of a dome or bell, just as would a body of melted wax, or one of moistened clay, if forced outwards through an orifice in the cover of any containing vessel."

The domes of Auvergne are divided into three types, (1) Peléan domes, acid and basic, (2) Peléan domes with craters or with trachyte ejecta, (3) domes with elevated portions of the adjacent rocks. The augite trachyte dome of the Grand Sarcoui has the form of an overturned bowl with a maximum slope of 60 degrees, measures 750 meters across the base, and is 250 meters high. It has a smooth surface and no rock pinnacles, due apparently to the lava having poured uniformly in all directions from a summit vent. On the east flank there are quarries revealing buried talus and the rough structure of an underlying pinnacled dome. This inner heap was of the Pelée type and the overflows at the top were a late phase. In the Puy de Dôme there has been left an irregular truncated pyramid 550 meters high. It is a trachytic protrusion covered by debris from a summit vent. Lacroix explains the sequence by the opening of a fissure in the underlying rocks consisting of granite, gneiss, etc., permitting lava that was partly viscous and partly solid to rise to the surface and build a steep dome. Its crust crumbled, forming great banks of talus cemented by fine dust. Both dome and talus are biotite trachyte. Later eruptions from a new summit crater deposited fragments including pieces of the bedrock pumice, breadcrust bombs, and angular pieces of trachyte. The trachyte ejecta of these final eruptions differed mineralogically from the materials of the dome, and in texture from glassy to coarsely crystalline. The same thing was observed in the dome of Mont Pelée.

The Gulf of Santorini, in the island of Thera of the Grecian Archipelago, produced the first dome eruption well known to European geologists. In February 1866 a new islet appeared in this crater bay composed of lava blocks, pumice, and bottom debris. Steam explosions were frequent. The mass grew without earthquake or visible projection of fragments, silently, but so rapidly that it seemed like the blowing of a soap bubble. It seemed like an expansion movement with the rocks incessantly displaced from the center towards the edge. On the second day the growth was from the edge towards the center. The dome above water measured 70 to 30 meters and was 20 meters high. One could walk on top, although the lava was still glowing beneath. There was no summit crater, but rather a confused heap of big blocks grayish in daytime, fuming, and at night lighted by incandescence, while the lower slopes were covered with cooler debris. There were long crescentic fissures, almost complete circles, on top of the dome. Similar cracks have been observed at Novarupta, Alaska, and at Chaos Crags near Lassen. The first Santorini dome was named Georgios, and on February 15 a second dome, Aphroessa, rose quietly above the sea on its flank. Within two days it grew enormously, and in five days its length had reached 380 meters. Its mode of growth, like the first dome, showed nothing but a progressive displacement of lava blocks. There were, however, occasional eruptions of cinders and lapilli which decapitated and flattened the Georgios dome. On March 8 this measured 350 by 100 meters and stood 50 meters high. The blocks were either scoriaceous or compact glassy andesite. There was an incessant crackling noise and a tinkle like broken porcelain. The fumaroles had temperatures up to 300 degrees C. and the vapor contained hydrochloric and sulphuric acid. On March 10 a third dome, Reka, arose still more quietly without any crackling of blocks breaking asunder in cooling. This heap became joined to Aphroessa. Fouqué called these domes cumulovolcanoes. New hillocks of blocks were piled up and destroyed, the shapes changed, the rates of growth varied, and Georgios developed a pile of blocks on top enclosed

by a circular trench. The end of the activity was on Georgios in October 1870, four years and eight months after the beginning of activity, and the new islet finally stood 120 meters above the sea.

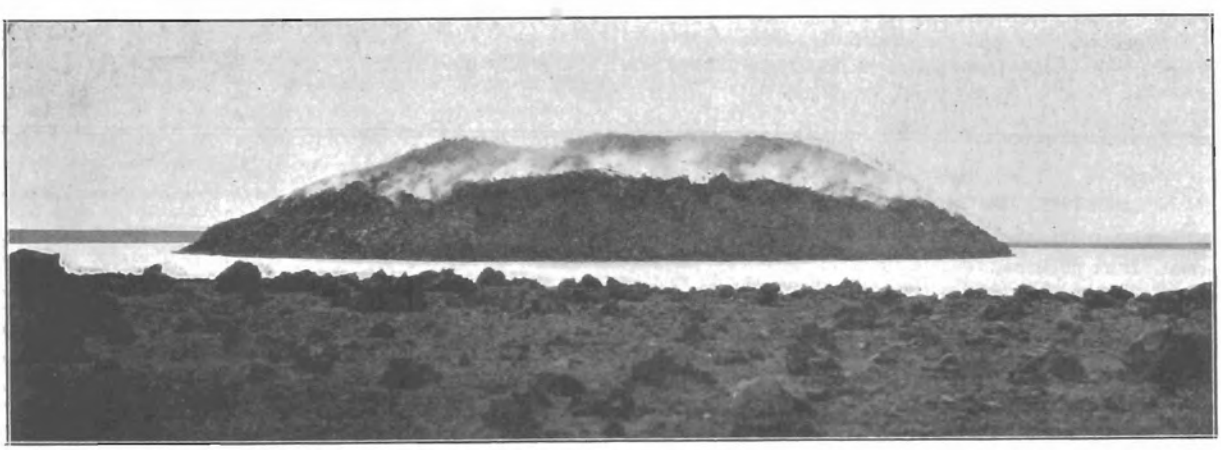
Fifty-five years later in September 1925, the same kind of activity was renewed when Fouqué dome appeared near the earlier island, circular in plan, 150 meters in diameter, and 50 meters high above a plateau of new lava on September 19. The shape of the dome continually changed. There were violent eruptions and a continuous redistribution of the loose blocks. The explosions sent up black cauliflower clouds. The temperature of the upper part of the interior of the dome was 700° to 800° C., there was no definite crater, and small jets of white vapor were emitted all over the surface. The vulcanian explosions took place from different places, mostly near the summit, blowing out loose blocks which fell back, and occasionally decapitating the dome. The blocks were solid and angular, dense, vitreous, and black, and there were no well-defined breadcrust bombs. There were concentric crevices which made a thin ring of bright red incandescence, and in daytime semicircular batteries of narrow jets of gray vapor which formed a crown around the dome. The lava flows associated with the dome had blocky crusts over compact vitreous lava free from vesicles. One small dome on the surface of the flow exhibited concentric banding. In the Georgios dome the lava contained many basic inclusions, very little gas, very little combined water, 65 per cent of silica, and may be called a glassy pyroxene dacite.

In 1831 an island formed by submarine eruption near Pantelleria in the Mediterranean appeared on July 16, had become 65 meters high and 3700 meters in circumference early in August, and was washed away by the end of October. The material was volcanic sand, lapilli, and scoriae arranged in strata around a crater. There appears to have been an upthrust of lava in viscous condition and broken at the top, similar to Bogoslof. There was trachytic pumice, but the island was basaltic. There was much carbon dioxide gas.

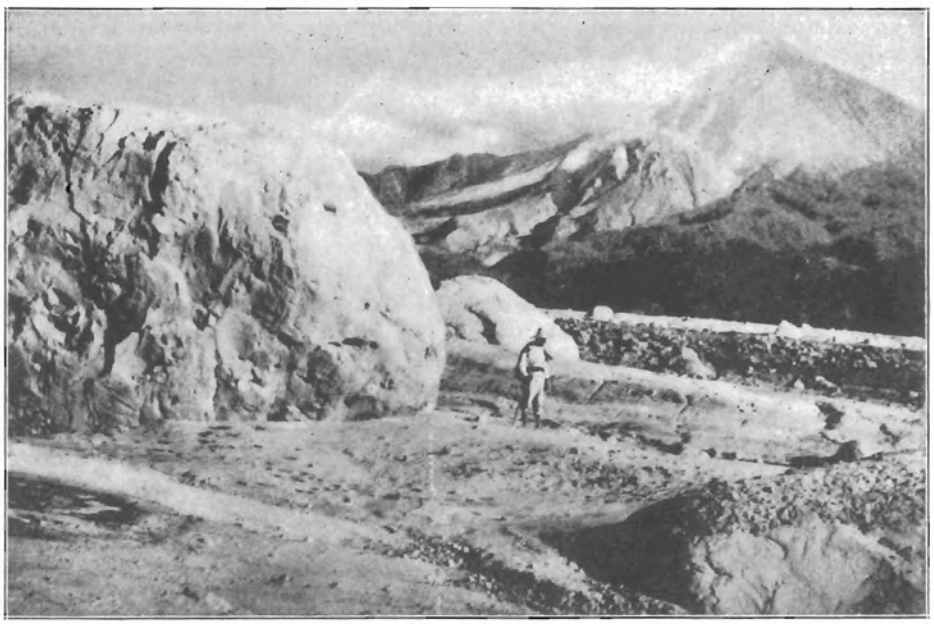
Other domes are described in the Lipari Islands and in the older lavas of Italy, in the Eifel region and elsewhere in Germany, in the Milos Archipelago of Greece, among the Virunga volcanoes of East Africa, in Kamchatka, in the Philippines, in Iceland, in the Azores, and in several places in California including the flanks of Mount Shasta.

Summarizing the characteristics of dome outflow, the largest are one to two miles across and the smallest only a few meters. In shape most of them are truncated domes and pyramids with lower slopes concealed by talus. Breaking up of crusts during upheaval, and the formation of concentric or radial ridges are characteristic features. Slickensides or scrapings are often to be seen along the walls of fissures. Glassiness is very characteristic of the lava of domes, also porphyritic structure, and and the upwelling of the lava is preceded by explosions flinging out pumice and tuff. There are usually many basic inclusions. The rocks are mostly andesties, trachytes, and rhyolites. The temperatures at times of protrusion are estimated to have been less than 850° C. Shepherd and Merwin estimated that the gas pressure inside the Pelée dome was about 100 atmospheres. Intense solfataric action is seldom conspicuous during and after upheaval. The gas content of the lavas is small, 0.15 per cent by weight at Lassen, 0.10 per cent at Santorini. The breadcrust bombs of Pelée contain six times as much gas as the material of the dome. The gases listed as extracted from rock of Pelée, Lassen, and Kilauea show excessive carbon dioxide, sulphur, chlorine, and fluorine for the former and relatively high hydrogen and carbon monoxide for an aa lava of the latter. Lassen Peak andesites have excessive combined water. One is impressed by the great excess in all these analyses of H_2O, 70 to 96 per cent, as compared with H_2, one per cent or less; CO_2, one to 20 per cent, as compared with CO, measuring from less than one to three per cent; and SO_2, on the other hand, always less than one per cent, is in less amount than the sulphur from which it is derived, which approaches one or two per cent. The unoxidized hydrogen reaching its maximum in the Kilauea lava (6.18 per cent), and the fact that one of Day and Shepherd's analyses of the gas from the liquid lava yielded seven per cent, makes it reasonable to suppose that hydrogen is the fundamental volcanic gas, but that it oxidizes during the rise of magma and consolidation, just as do the metallic ingredients in combination with silica.

The rate of growth of domes is rapid. That at Santa Maria rose 100 meters in a week, the dome of Mont Pelée rose 25 meters in a day, that of Tarumai rose 100 meters in four days. The internal structure may have concentric layering, or it may have fan structure, or it may spread



Lava heap of Bogoslof Volcano in the Aleutian Islands, surrounded by warm salt-water lagoon and ring bars of explosion debris. Activity of 1926-28, photo Wheeler.



In distance Santa Maria Volcano in Guatemala after eruption of November 2, 1929, in middle distance the lava dome which had risen in the crater in the flank of the volcano, and in foreground gigantic bowlders carried with floods of the eruption. Photo Sapper and Termer.

with irregular fissuring and sprouting like aa lava. In most cases talus forms around the border. The propelling force Williams considers to be the expansive pressure of internal gas, and generally the dome is the top of a plug forming a seal to the conduit at the close of an active period. T.A.J.

KILAUEA REPORT No. 1053

WEEK ENDING MARCH 27, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

In Halemaumau pit the afternoon of March 21 the fume at the foot of the southwest talus appeared denser than usual. Scars of two small slides had appeared on the south wall; one over the northwest talus at 2:24 p. m. raised a cloud of dust. On March 22 at 10:55 a. m. a sound like floor cracking was heard. Slide dust arose at 12:30 p. m. March 23, and a larger avalanche at 1:40 p. m. dumped fresh debris on NW talus. At 2 p. m. dust continued to rise. The avalanche tremor was registered by the pit seismograph. This avalanche fell directly from the rock of the northwest rim for a length of 150 feet, and left large bowlders below. On March 26 glow was still reported visible in evening in crack at south edge of Halemaumau floor.

Observatory seismographs registered 66 tremors for the week, and two very feeble local seisms, one of which indicated origin 16 miles away. A distant earthquake was recorded beginning at 1:36:32 p. m. Hawaiian time (10 hrs. 30 m. slower than Greenwich) March 25, of probable distance 2980 miles from Hawaii. Tilting of the ground was very slight to the east, and microseismic motion was generally moderate.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

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The Volcano Letter

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No. 380—Weekly Hawaiian Volcano Observatory, National Park, Hawaii April 7, 1932



Construction of Perret's upper station on Mont Pelé proper, November 1930, at Morne Lenard. Photo Perret.

THE NEW DOME OF PELE'E

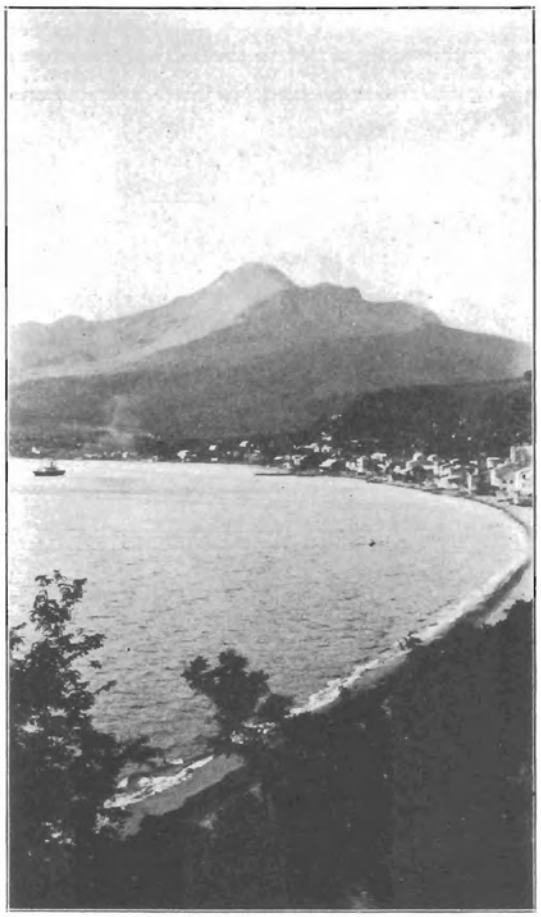
The renewed activity of Mont Pelé was mentioned in Volcano Letter No. 262. Ash eruptions were reported to have begun September 16, 1929. It appears that notes on the evolution of the dome were published in "Comptes rendus" 190-761, 190-623, and 191-1253, 1930-31, by H. Arsandaux. F. A. Perret has added two notes in the same publication, C. R. 193-1342, 193-1439, 1931. These last are reviewed here.

The formation of cone-in-cone structure by dwindling activity of mixed eruption, like Vesuvius in the ring of Monte Somma. is well known. The absence of a chimney in the center of a lava dome makes an interior edifice unexpected. Perret in January, 1930, when he first saw the Peléan dome of 1903, was interested to find it deeply caved in from the explosive process of September 1929. In the center of this cavity was an active eruptive cone.

The new excavation was a depression which widened from southwest to northeast, with a rocky ridge in the wound. The greater part of this was conical, but not the highest part. The explosive phase of eruption which continued in January and February exhibited two sources for steam-blast cauliflower clouds: a large one north, and a smaller and higher one southeast. The undermining produced a horseshoe cup with a medial extension like the latter "E.". With the kernel of the dome surrounded by talus, it was surprising to see the outer shell of weakest material hold itself up in steep walls, while the solid rock of the interior was removed. Evidently eruptive material rose high enough to form a shell whence eruptions diverged before destroying the lateral walls. From the time of the first 1929 eruption, all the explosions were from the inside of the dome of 1902-03.

The inner rocky ridge extended downhill ENE-WSW like a cock's comb, with the lower end a row of needles. Still lower at the ancient opening of the 1902 horseshoe, a series of vents in a line sent up puffs of ash. It could not be determined whether these were in new magma or a rocky remnant of the old dome.

The central ridge was not simple. It was a castellated group of towers. These were round, smooth, and spirally grooved. They appeared tubular. and often lava poured from apertures at the bottom. On the 20th of April, 1930, after an enormous downrush, round columns were left on the dome, black by daylight, but probably incandescent. The towers change rapidly. January 28 they appeared to be destroyed. But the activity appeared rather to be constructive, for on February 3 the towers appeared consolidated into an enlarged mass with the profile of a true dome. On the crest were rudimentary needles. Then came lava activity. that would have been 'Strombolian' if there had been explosive ejection, and this motion never ceased. Such crises were at first rhythmic, and alternating with the cauliflower jets, and they gradually resolved themselves into a regular constructive process, producing numerous needles On all sides of the new dome emerged slender incandescent lava flows. with emission of light transparent vapor. The process was comparable to that of lava cupolas on Vesuvius. The incandescence was dark orange under a thin crust in the darkest places, and elsewhere it was so bright that the illumination reflected on the cloud was visible at Fort-de-France. The flows were liquid a short distance apparently, then presented the well



St. Pierre as it is today, 1932. Photo Perret. Mont Pelé in background.

known "aa" streaming of fragments. The dome grew higher and on February 19 the summit was flat, crowned with small needles, and at the sides were straight talus slopes.

Two mechanisms are involved in the Pelée dome, the spread of lava and the thrusting out of needles. These last tend to rise vertically. This vertical rising is natural enough on the summit, but how about a slope of débris at 35°, where a line of vertical obelisks arises? Why does the internal magma push skyward and through chaotic material? This explanation appears to be the perforating power of rising gas. A fissure holding magma is opened to the surface by gases burrowing upward in a row of aligned chimneys. The magma follows, shells over in contact with the chimney wall, and the pencil so formed is pushed up. The lava flows are similar, but the orifices being more free, the slag remains hot and fluid.

During two months the carapace on the dome was so thin and the mass so fluid that the needles overturned on a pasty base, resembling large pears. The most conspicuous spine began March 25, promptly overturned, and rolled down the slopes. Examination of details at two spines showed one rising a meter per hour, the slope of the dome opening, like a soil clod with a mushroom pushing through. Pasty magma rose in a collar around the needle, then solidified, when the spine was three meters high. In the second case the paste was accompanied by gusts of vapor emerging between the spire and the slope. The needle remained small, but the steam jet continued several weeks. The average height of spines was 12 to 18 meters.

The dome of 1902 grew toward the northwest, overlapping the ridge there (Petit Bonhomme), so that its débris slope extended beyond the ancient crater of the E'tang Sec. The new inner dome has left a gulch on that side, but toward the east and southeast has overtopped the older dome, sent its débris slope down against the wall of the ancient valley on that side, and chilled and ceased activity there, except for fumaroles. In September 1931 the dome was migrating southwest and the long slope of ejecta was overtopping the ridges there so as to threaten the trail to the summit of the mountain. The new dome is 231 meters above Petit Bonhomme, and somewhat higher than was the peak of the old dome.

All the hot blasts (nuées ardentes) emerge from fractures in the dome of 1902 and mostly from the two openings, low north, and high southeast. After the new dome developed, the character of these gushes changed gradually. Four types of downrush are distinguished by Perret. The first is occasioned by an avalanche formed by the squeezing out of a small quantity of magma. It is an imitation of a true hot blast. The magma, not being greatly charged with gas, merely makes a heavy tumble of rocks, which slide down the slope, and excavate a trench. Dense, ashy, light-colored cauliflower clouds arise. The second type is occasioned by heavy rain falling on the dome which seems to penetrate it after a quarter hour or more, so as to start ejections of steam charged with dust which descend the slope rapidly as a gaseous emulsion. After heavy precipitation these down-blasts are certain to come, and they are important, some of them in the spring of 1930 following the gorge of the Riviére Blanche and out to sea for several kilometers. The last two types of gushing are avalanches of incandescent blocks without significant dust clouds, and finally a cooler ash phenomenon where blocks of uniform size roll rapidly and far, carrying imperfectly oxidized carbon gases, and emerging from a part of the dome which has partially congealed.

In the southeast part of the new dome there are fumaroles in a horizontal line, due to water, where the old and new domes are in contact beneath. Where the summit of chilled lava is in contact with active lava, bluish transparent vapor emerges at high temperature.

Mr. Perret has used a microphone for determining the variation in mass of the vibrating active dome. His theory is that an active edifice makes a definite note of lower pitch the greater the mass. The combined roar of slides, blowing of vapor, fall of spines, at any given moment make a musical tone, the timbre of which may be defined in terms of mi, fa, sol, la, si, etc., so the augmentation or diminution of the dome may be followed. His upper station was on the flank of Pelée at Morne Lénard.

At the beginning of November 1930 the tone was si flat. Three months later the dome was bigger and the tone was deeper, exactly la. April 13, 1931, it was sol sharp; June 4, sol; June 25, a little below sol; but on August 10 the pitch had risen to sol sharp, and it continued to become sharper, showing that the mass of the dome was decreasing, and that the arrival of new magma, inside, no longer equalled the loss by slides into the valley, and by erosion.

Establishment of a Research Center at St. Pierre

Mr. Perret has sent the following letter to the Hawaiian Volcano Research Association:

February 2, 1932.

"All the world remembers the destruction of St. Pierre, in 1902, by a terrific eruption of Mont Pelé. St. Pierre was not only the commercial center of Martinique, but the cultural metropolis of the Lesser Antilles. Excavations reveal the exquisite taste of the former inhabitants, and the relics unearthed from time to time are of great beauty, and of interest as showing the effects of the blast of hot gas and ash, which it is useful to study. Those objects—instead of being dispersed as found—should be preserved for all time in a collection, along with photographs of the beautiful ruins, fast disappearing in the rebuilding of the town.

"The recent eruption of Mont Pelé has reawakened scientific interest in this volcano, whose special type of activity is almost unique, and the products of eruption—breadcrust bombs, ash, and lava blocks in new forms—are most interesting. A complete collection of these, placed for comparison with the materials of other volcanoes, and with photographic studies of all their phenomena, is a scientific necessity.

"I may say that my own work here has resulted in a further demonstration of the pratical value of volcanology as an applied science. Eighty million francs of invested capital, depreciated to zero by panic and uncertainty, was restored to par value through diagnosis and prediction based on sound scientific deductions, with the help of apparatus devised for these purposes. For the further development of these methods, the creation of standardized instruments, the bringing together and preserving of the materials, etc., I am now founding at St. Pierre this research center, organized as museum—observing station—laboratory.

"A private institution, out of politics, and not governmental; its continuance, after me, is guaranteed by a Fiduciary Committee, consisting of men of the highest standing in the colony, including honorary memberships of the Mayor and Curé of St. Pierre. Its founding at the present time has been extraordinarily facilitated by the cession to me of a most ideal site for its emplacement, on the beautiful Morne d'Orange, 350 feet above the town, but easily accessible, and commanding a superb view over St. Pierre and of the entire massif of the imposing volcano.

"Construction cost is largely covered by local contributions. This is not to be an American institution, but an American contribution to science in a location where this science can be best developed—a gift to St. Pierre as a continuation of American good will. St. Pierre is visited annually by some thousands of American tourists, whose interest will be quintupled by having a definite goal, where what they most desire to see will be on view.

"The contribution of one thousand dollars, as a minimum, makes the donor a founder of the institution, and the name will be on a marble tablet at the entrance, and upon the stationery of the museum. A few subscriptions are desired, above those already received, when this account will be closed. A total of ten thousand dollars is sought for the foundation.

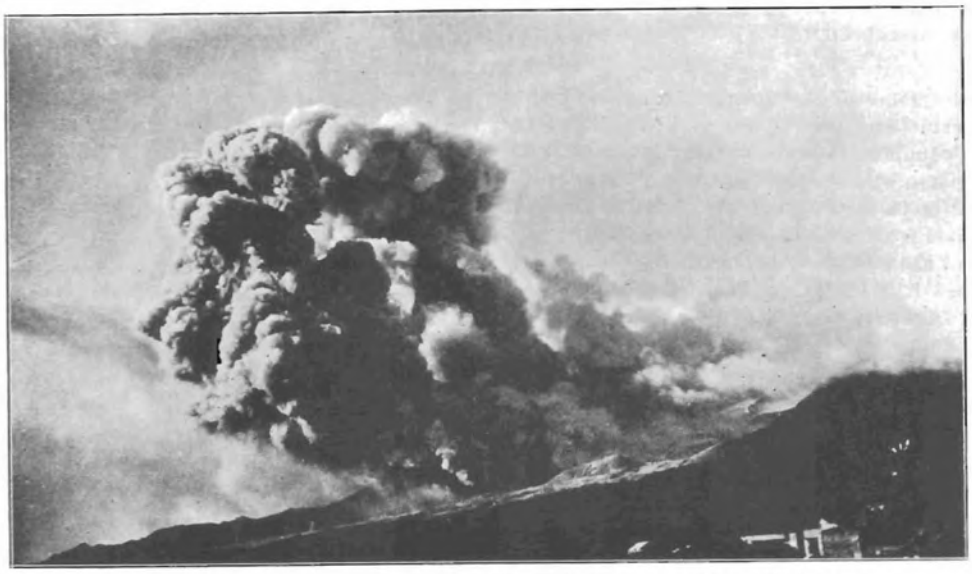
"This work—at once scientific, artistic, and humanitarian—is believed to accomplish more, with a small amount of money. than anything heretofore instituted. It will be selfsupporting through its museum, of direct service by its observation work, and world-contributing in its laboratory research. Contribution involves no obligation of future support.

"You are earnestly invited to become one of its few, distinguished founders."

Mr. Perret has been living at St. Pierre since 1929, and has already started the foundation with contributions from the Carnegie Foundation of Washington, Vincent Astor, and George F. Baker. It is to be hoped that members of the Hawaiian Volcano Research Association will be added to the list of founders, for it was Mr. Perret who camped



The upper station, Mont Pelé, after completion. Photo Perret.



Hot blast from the dome, Mont Pelé, February 9, 1930. Photo Perret.

alone on the edge of Halemaumau pit in 1911, and so started the work which established our Association. T.A.J.

TILTING OF THE GROUND FOR MARCH

The following figures show the net angular tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms, by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

March 1-7	4.6 seconds	SSE
March 8-14	3.3 seconds	SW
March 15-21	1.5 seconds	SW
March 22-28	1.1 seconds	SSW

The accumulation of tilt to March 28 since January 1 is 17.4 seconds south, 0.7 second west. This is greater southerly tilting than whole years have produced usually, with the exception of 1924. E.G.W.

KILAUEA REPORT No. 1054

WEEK ENDING APRIL 3, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

On March 28 at 11 a. m. fume was issuing from a crack at the foot of the south talus in Halemaumau, and steam on this talus was abundant 100 feet south of the fume vent. Fume at the yellow vents at the foot of the southwest talus was unusually prominent. A slide at the north wall made dust at 11:53 a. m. Crack movements at rim of pit have shifted from northeast rim, now quiet, to southeast rim, where slight opening of fissures is now measurable. The rest of the week showed no changes.

The Observatory seismographs registered 5 very feeble local seisms, three registering distances of 14, 25, and 46 miles. There were 25 tremors, one indicating origin 18 miles away. Microseismic motion was strong March 31 and moderate at other times. Tilting of the ground was moderate to the south.

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Two dollars per year — Ten cents per copy

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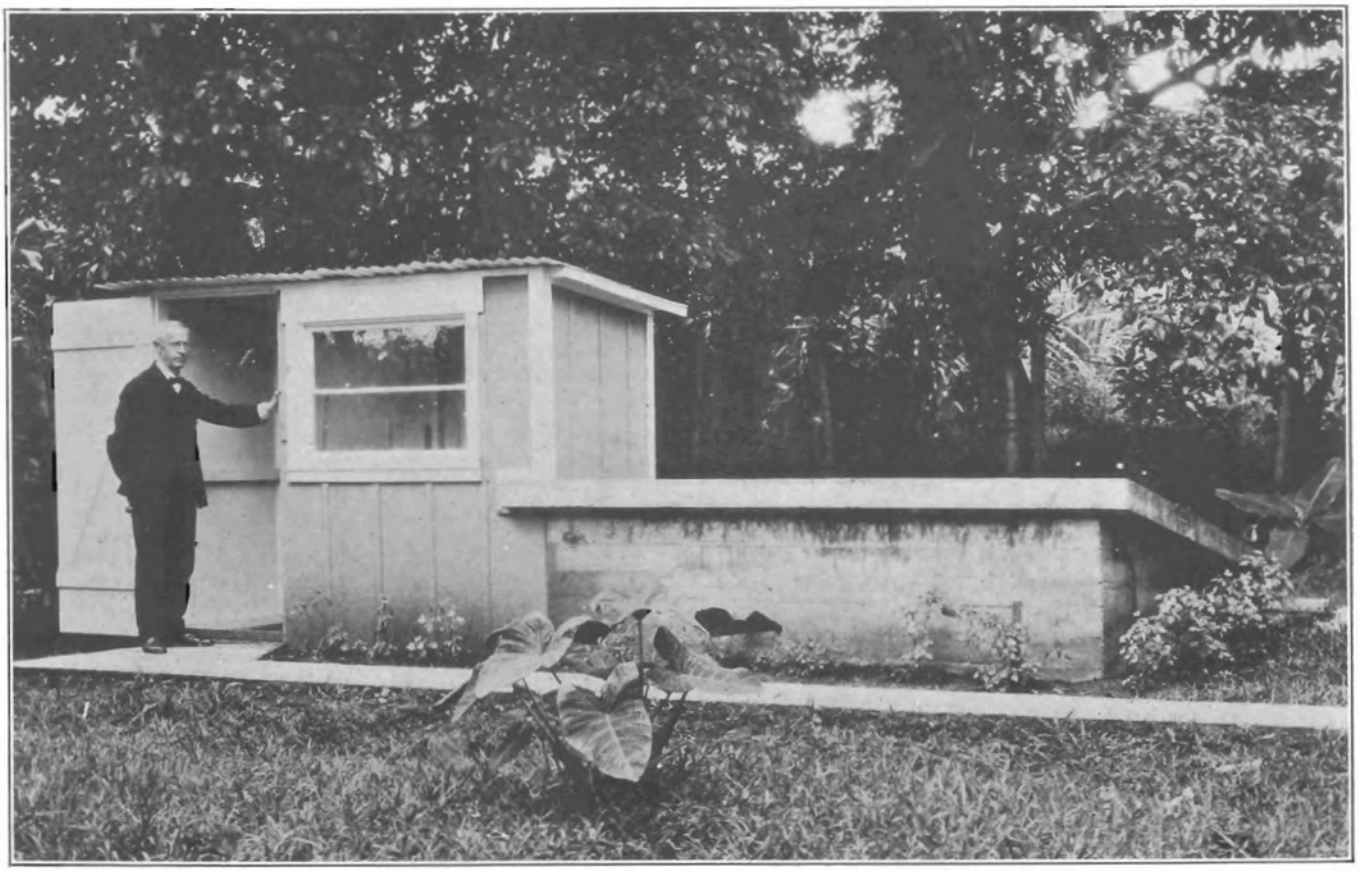


Seismograph cellar of the Hilo station of the Hawaiian Volcano Research Association, built in 1927. Brother J. B. Albert is the observer. The instrument consists of two heavy horizontal pendulums, with clock checked by wireless time signals.

TWENTY YEARS OF VOLCANO STUDY IN HAWAII

Address by T. A. Jaggar at Annual Meeting Hawaiian Volcano Research Association in Honolulu, March 31, 1932.

Administration

The Hawaiian Volcano Observatory was founded by an association formed in Honolulu in 1911 which undertook to finance a geological station on Kilauea Volcano established by the Massachusetts Institute of Technology. Ground was broken for the building on February 15, 1912, when Dr. T. A. Jaggar, who was then Professor of Geology at the Massachusetts Institute, had come to Hawaii for the purpose of establshing permanent volcano research. The Hawaiian society became a chartered corporation named the Hawaiian Volcano Research Association.

In 1919 the work was first assisted by the Government in collaboration with the Hawaiian association, and the governmental supervision was assigned to the United States Weather Bureau. The plant was leased by the Association to the Government at a nominal rental with the understanding that the Weather Bureau would furnish personnel and salaries. Since 1924 this arrangement has been transferred to the United States Geological Survey, which through the interest of the Congress has been enabled to enlarge the work to a Section of Volcanology with small stations in California and Alaska added to the Hawaiian establishment. Routine publication, now carried on through the Volcano Letter, has remained with the original Association.

The objects of the work from the beginning have been: (1) To keep and publish a record of Hawaiian volcanic activity and associated earth movements, (2) to invite specialists to Hawaii or to send them elsewhere for volcanologic studies, and (3) to do everything possible to promote the establishment of permanent volcano stations all over the world.

(1) Recording Hawaiian Volcanic Activity

The preliminary reconnaissance of the Hawaiian field was made by T. A. Jaggar and R. A. Daly in 1909. Mr. Jaggar had been engaged before this time in studies of Mont Pelée and Soufrière in the Caribbee Islands, of

Vesuvius after its eruption in 1906, of the Aleutian Islands in 1907, and through association with F. A. Perret he had been interested in the Messina earthquake. It was evident after the terrible disasters of Messina, Vesuvius, and St. Pierre, along with the earthquake-fire of San Francisco, that more studies of the earth from permanent stations should be made. This had been the subject of a crusade at Harvard and at the Massachusetts Institute of Technology, and a small endowment was obtained at the Institute for geophysical research, having in view the protection of life and property. This is called the Whitney Fund.

With the aid of this fund and through cooperation with the Geophysical Laboratory of the Carnegie Institution of Washington, Dr. E. S. Shepherd of that laboratory along with Mr. Perret, the former a chemist and the latter volcanologist, were induced to spend the summer of 1911 at Kilauea with a view to physical studies of the lava pit. Mr. Perret built a hut at the actual edge of the pit and made weekly reports to the press on measurements of change in the lava column. A cable was stretched across the pit and measurements of temperature of the liquid lava were made with electric thermometers.

The actual foundation of the Research Association was arranged at a luncheon in the University Club of Honolulu, October 5, 1911, when the late L. A. Thurston pointed out that there should be no break in the collection of records at Kilauea, and a subscription list which had been started in 1909 was revived. Mr. Jaggar arrived January 17, 1912, and weekly reports were reestablished. Through special subscriptions raised in Hilo, the present main Observatory building was constructed in February, with the Whitney Laboratory of Seismology in its basement. A topographic map of the proposed Kilauea National Park area was made by the U. S. Geological Survey as a basis for field work. The National Park became a fact in 1916 when Mr. Jaggar went to Washington to draft the final bill. The Volcano Research Association built and gave to the National Park Service the museum on Uwekahuna bluff in 1927.

The keeping of record books at the Observatory has been continuous from 1912 to the present. Mr. H. O. Wood came to the station as seismologist in the summer of 1912, a number of seismographs were set up, and the records were enriched by reports on tremors, earthquakes, and tilting of the ground, which proved to be motions of great interest, when studied in relation to the rising and falling lava.

The year 1912 was a time of vigorous activity in the lava pit, in 1913 the lava column became low and smoky, and thereafter until 1919 there was a steady rise with increasingly good opportunity for making comparative photographs. Mauna Loa broke out in 1914, 1916, and 1919, and these eruptions added to the interest of the work. In the summer of 1912 Doctors Day and Shepherd returned to Kilauea for gas collections at the live lava, and the temperatures proved to be various and somewhat proportionate to the volume of gases discharged by the many fountains. Mr. Jaggar was able to keep up the gas collections in subsequent years and to send the specimens to the Geophysical Laboratory for analysis.

The years from 1912 to 1924, however unfavorable they may have been financially, were fortunate ones from the volcanologic standpoint at Kilauea. in that they represented an eleven-year cycle of extraordinary vehemence for both Kilauea and Mauna Loa, with great variety of action, and a marvelous finale in 1924 when the crater pit of Halemaumau caved in through the recession of the lava, and a steam-blast eruption occupied the month of May 1924 in a fashion not seen here since 1790. The incessant measurements of change in gases, change in temperature, change in elevation of the lava column, and the photographic records accompanied by notes and transit measurements that produced maps of the crater fills and flows, all combined to yield a record of a decade of volcanic activity, in the most primitive volcanoes on earth, such as science had never possessed before. By primitive is meant the quality in a volcano, that exhibits the pure heat and magma, of the material under the primitive earth crust, not complicated with the impure mixtures of sea-bottom sediments and organic life such as occur on the continents. Vesuvius, Lassen Peak, and Katmai are all volcanic heaps made where the blast furnace of the earth crust has discharged through such rocks as limestone, sandstone, and slates. The glowing slag underneath has absorbed unkown amounts of carbon, lime, silica, and alumina.

After 1924 a quiet condition at Kilauea leads people to think the volcano is dead. Instead of this, we are recording some kind of outbreak nearly every year, Mauna Loa had a great eruption and destroyed a village in 1926, and an earthquake crisis on Hualalai in 1929 recalled the wonderful lava flows from that mountain in 1800, a time ten years after the last explosive eruption from Kilauea. The year 1934 will be ten years after the new explosive eruption. Are we to look for more lava flows from Hualalai? The present decade, therefore, is making a record which is a valuable asset, the like of which has not been obtainable since the end of the eighteenth century.

When it comes to earthquakes, the instruments for recording ground movements at Kilauea have been steadily improved, and the experience of 20 years with many ups and downs of the lava column, and outbreaks on Mauna Loa, and big earthquakes on Hualalai, has accumulated thousands of seismograms in the files of the Observatory. These are pieces of smoked paper fixed with shellac, on which automatic pendulums have written a graph of each earthquake or tremor or tilt, and have recorded the clock time. They are all different. Science can interpret from each graph the distance away of the source, the strength of movement, and how the elastic waves passed through the rock. Some of the instruments are in Hilo and Kona, so that when the distances indicated there are compared with the distances from the Observatory, the place underground may be found where the lava split its way upward and made a jolt. As some sets of earthquakes accompanied eruption, on the south flank of Mauna Loa, others on the different flanks of Kilauea, and yet others occurred on Hualalai, it becomes possible to classify Hawaiian earthquakes from their autographs, and the making of this classification promises years of valuable work. Those who think there is nothing to do at a volcano observatory during a quiet time should start studying some of these pieces of smoked paper.

The publishing of results is no small part of the work, and this involves, first, summarizing every week the essential observations at the Kilauea pit, at the seismographs, or on Mauna Loa or elsewhere if activity occurs. These summaries must be published in the papers, and also printed in more permanent form. It is further necessary to assemble observations of like kinds, and coordinate them for understanding the underground processes. An observatory is always a detective, trying to find out what is going on underground, from information the layman does not possess, yielded by a chemical collection, or a measurement with transit, thermometer, level bubble, or pendulum. These assembled observations have been published in scientific journals and it is one of the functions of the Volcano Letter to assemble similar communications from observatories in other lands, in order to make them known to our people here. There is much excellent work in Dutch, Japanese, Italian, French, German, and Spanish from the East Indies, Japan, Europe, and South America, for which a translation institute ought to be endowed, in order to sift out important facts which are now lost to most of the world.

Recording is nothing more than description. It is very hard to use language so as to tell the truth. The reading of any newspaper will prove this. Accurate description is all that is meant by "a theory." Modern physics is not trying to explain the "why," or to explain anything;

it is trying to describe the "how." This is what we are trying to learn about an active volcano, "how" it works. A mere quantitative measurement in figures by itself means nothing. Recording, to be accurate, meaning careful, must be checked all the time by quantitative measurements. These measurements may be put together to make a description, so that the difference between one event and another is dependent on the readings of the measurements, and not on guesswork. When enough of these differences have been collected, it becomes possible to classify events, and then the classifications fall into sequences, and the complete description of a sequence suddenly discovers (or uncovers) what has been going on, in the under-earth, at a place which was invisible. This final description of things unseen is a "theory."

Take in illustration of this the matter of prediction. How can you predict when a volcano is going to erupt? It is first necessary to measure an eruption and to tell the truth as to what an eruption is. If you classify as "eruption" the smoke from an island seen by a mariner, entirely unmeasured, and compare it with the rise of lava for six years measured in Halemaumau pit by scientists, you get nowhere. You do not know whether the mariner's "smoke" happened all the time, or every year, or every six years. You can not describe the "how." In the case of Kilauea, the scientists continue for another five years and find the lava going down and out. Then comes a lull for two or three years. They study the records for a hundred years back and find many measured risings for six years, and sinkings for five years, followed by a lull. Then they find that two volcanoes adjoining took part in this sequence. Perhaps they find in separate years that the biggest risings were in the autumn and the sinkings in the spring. This is a measurement by seasons and years, just as other measurements are by heights and depths. They average all the results. The average shows an eleven-year cycle as a probability for that pair of volcanoes. They may even find that this eleven years corresponds with sunspots, and then that the irregularities in numbers of sunspots which depart from the average, correspond with the irregularities in highest rise of the lava during the century. They know nothing about the "why," but here is a very interesting "how." Knowing all these things, they can "predict" that the next "eruption" will occupy eleven years, will begin by rising and end by sinking, will have its annual rising spasms higher in winter, and if the term is not exactly eleven years, it is likely to depart from that figure in the same way that the sunspots do. Knowing the relation of the two volcanoes, they perhaps can say, that in the course of this eruptive cycle, Mauna Loa is sure to help out Kilauea once or twice during the eleven years.

What is now an eleven-year theory, a seasonal theory, a relationship theory, and a sunspot theory, may eventually advance a step farther so as to describe how all these things are related to some bigger processes in the crust of the earth. They will then all become facts and not theories, but the larger process will remain in the realm of theory. Science is merely piled up descriptions.

(2) Studies by Specialists

In addition to work which has already been mentioned, Dr. E. T. Allen of the Geophysical Laboratory spent a season at Kilauea analyzing the vapor at the sulphur vents, and determined it to contain 96% steam and less than 1% of the sulphurous products. Boring indicated that the temperature, 204° F., is extraordinarily constant.

For two seasons Dr. Arnold Romberg worked at the Observatory on seismograph instruments, and set up optical instruments to determine in what direction the wave movements known as microseisms are propagated through the ground at this place. Also special instruments were designed to measure the tilting of the ground, which was found to have a half-daily and semi-annual change. These changes must be allowed for when measuring what tilts are made by the pressure of the lava underground. Some remarkable changes of tilt have coincided with sudden risings and fallings of lava shown by outbreaks of Kilauea and Mauna Loa. The microseismic waves were found to coincide in direction with the high cliffs of the Hamakua coast bombarded by tradewind waves.

Messrs. J. B. Stone and C. K. Wentworth at different times have studied the geology of Hawaii, and Mr. H. T. Stearns and others have produced a Bulletin of the Geological Survey on the geology of Kau. Dr. Howard Powers is at work on the geology of Kona. All of these studies are providing new knowledge of the soils of the island in relation to the lava flows and the deposits of ash from past eruptions. A basis is being laid for classification of formations and interpretation of the past history of the earlier volcanic vents which preceded the active volcanoes of today. Dr. Wentworth has made a special study of the ash, especially the cinder of the many small cones on the slopes of Mauna Kea, and has greatly enlarged our knowl edge of how those cones were formed and of the differences between the gas eruption there and the liquid lava eruptions on Mauna Loa at the present day.

Mr. Jaggar has been four times in Japan, three times in Alaska, and once each in New Zealand, Costa Rica and the Tonga Islands for studies of earthquakes and volcanoes. These comparative studies are of value not only in showing how different are the volcanoes of different lands, but also the contacts with men of science tend to encourage the last of the three objects above enumerated, namely, promotion of new volcano observatories elsewhere Mr. Finch visited volcanoes in the East Indies in 1929 and Mr. Stone explored and photographed several craters in Chile the same year, both of these men being commissioned by the Hawaiian Volcano Research Association.

Messrs. Wood and Finch have completed a bulletin now in press in Washington listing in technical form all the measured earthquakes registered on the seismographs of the Observatory from 1912 to 1923. This list comprises thousands of shocks and is illuminating in showing the large number of earthquakes which accompany sinkings of the lava, the frequency varying with the rapidity and depth of the sinking. An increase of frequency of earthquakes also accompanies sudden risings of the lava in Halemaumau. In Mauna Loa eruptions the freqnency is greater at the beginning of an outbreak, and as the frequency declines the strength of the shocks becomes greater. In general the comparison of times of fewer earthquakes in Hawaii, with times of high frequency, shows that the greatest intensities of quaking (or the strongest shocks) come when the number of shocks is at a minimum.

(To be continued)

KILAUEA REPORT No. 1055

WEED ENDING APRIL 10. 1932

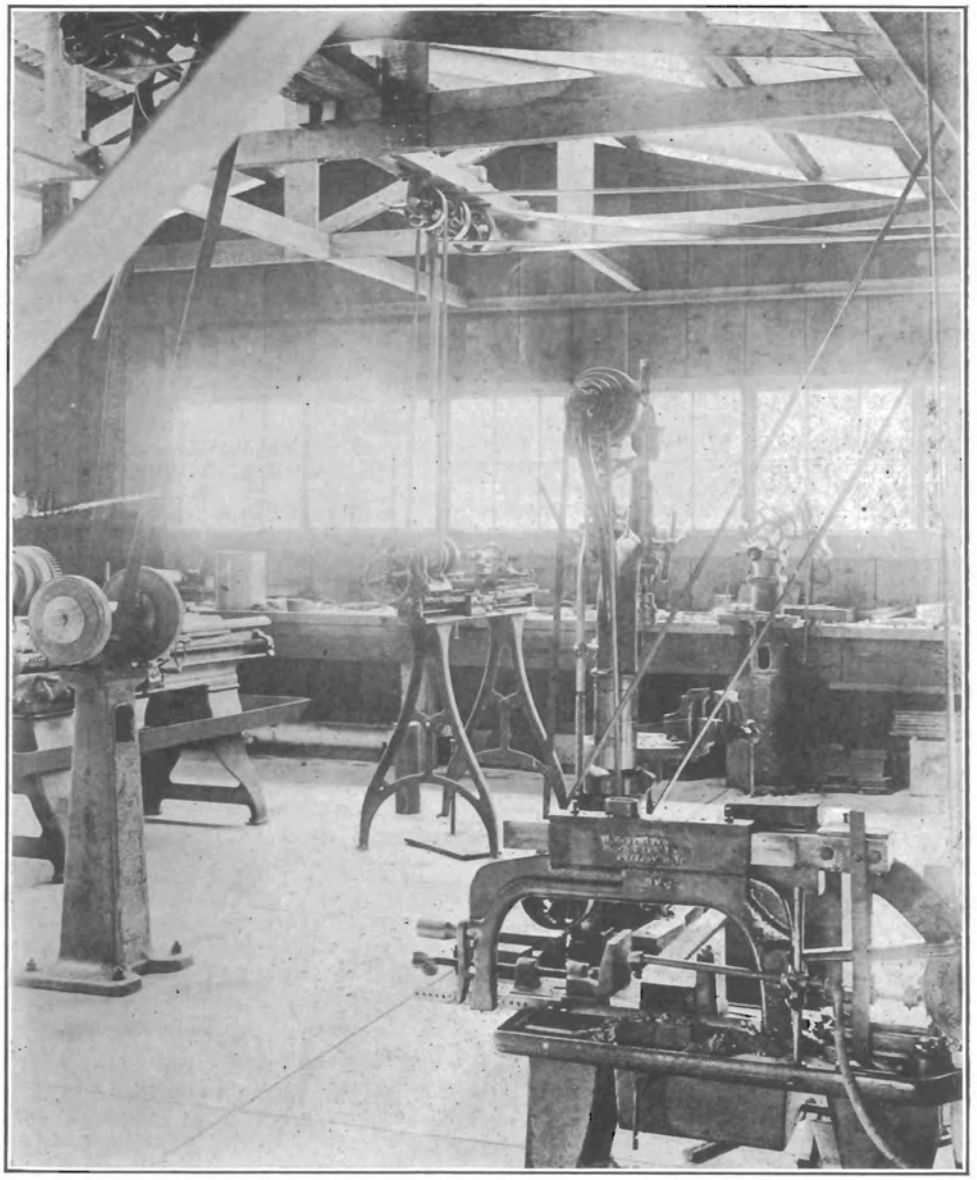
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

Conditions at Halemaumau show little change. The pit was quiet April 4, with slight steam and little variation in fume.

Crack measurements showed very slight changes. On April 6 fume was moderate at the foot of the southwest talus and the spot under the southeast wall and talus still fumed slightly. Brilliant yellow sulphur stain showed at the fume area by the southwest talus. The scar from a small slide was seen on the northeast wall. On April 7 fume at the foot of the southwest talus was dense all day and some fume was visible at the spot under the southeast wall. On April 9 fuming activity had not changed. The seismograph at the pit showed ESE tilt accompanying the earthquake at 5:50 a. m. One tremor showed E tilt

The seismographs at the Observatory recorded 52 tremors, four very feeble seisms, and two feeble seisms. One tremor at 6:25 a. m. April 5 was felt at Waimea and Puuwaawaa and had origin distance 46 miles from the Observatory. One feeble seism at 4:50 a. m. April 9 was felt at the place called "Twenty-nine Miles."

Average tilt for the week was slight NE by N. Microseismic motion was moderate during the first three days of the week, light for the next three days, and moderate on the seventh day.



Machine shop at the Hawaiian Volcano Observatory, installed by the Research Association. There are two lathes, two drill presses, a machine hacksaw, and a grinder, while in the adjacent carpenter shop are power plant, boring machine, and circular saw.

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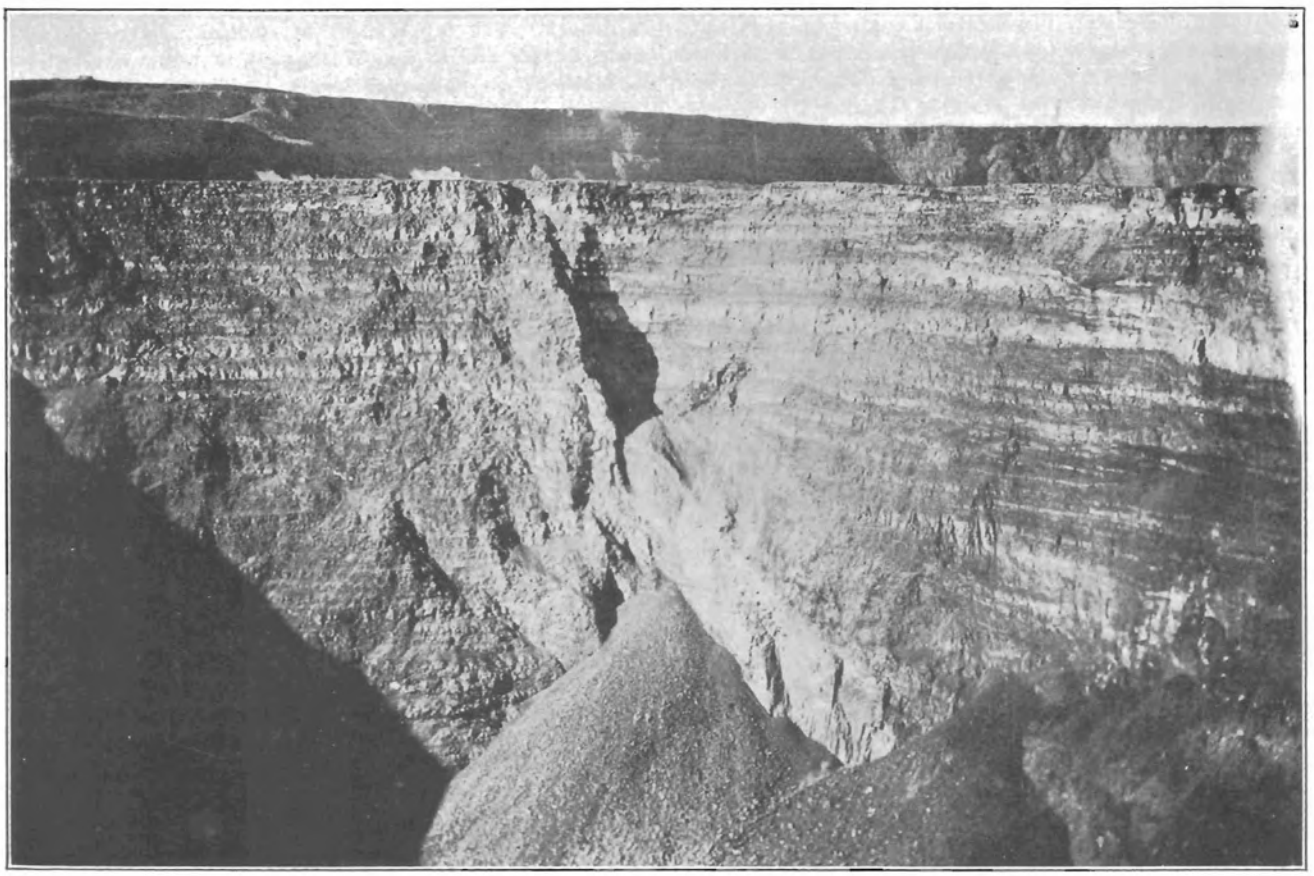
No. 382—Weekly Hawaiian Volcano Observatory, National Park, Hawaii April 21, 1932



Interior of the present Halemaumau pit, showing the north corner, and behind it the cliff bounding the outer Kilauea Crater. The U-curve of white ledge at bottom is the cross section of a former pit. It shows a talus in cross-section above the white ledge. The white ledge was revealed red hot by the engulfment of 1924. The horizontal layers are lava flows, all produced in the nineteenth and twentieth centuries. Photo 1927 by Wilson.

THE RESULTS OF VOLCANO RESEARCH

(Continued from Volcano Letter No. 381)

Second Part of Address by T. A. Jaggar, Annual Meeting Hawaiian Volcano Research Association in Honolulu March 31, 1932.

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(3) World Volcano Stations

In 1926 a seismograph station and observatory were established at Lassen Volcanic National Park in California under Mr. R. H. Finch, who had been in Hawaii. This station has recorded hot spring temperatures and earthquakes, and has served as a base for geological studies in that interesting volcanic region. The work is being extended to other volcanoes of the northwest. Seismograph stations have been placed at two other points in Lassen Park.

In 1927 a seismograph station was established on Kodiak Island, near the Katmai group of volcanoes of the Alaskan Peninsula, and in 1929 a second station was fitted out at Dutch Harbor, on Unalaska Island in the eastern part of the Aleutian chain. In the hands of resident observers these instruments have been operated so that the seismograms are sent for study to the Hawaiian Volcano Observatory. A moderate number of local earthquakes at these stations and at Lassen indicates that some seismic activity accompanies the underground movement of volcanic magma in these places, but there is no such earthquake frequency as exists in Hawaii.

Beginning about 1918 the government of the Netherlands East Indies started a volcanologic service under their Bureau of Mines with headquarters at Bandoeng. This work has steadily grown for 15 years, a small pamphlet each month describes the temperature measurements and earthquakes and volcanic activities at several volcanoes, mostly in Java, and large, beautifully illustrated monographs in the Dutch language, latterly with summaries in English, have been published dealing with important erup-

tions of several of the great volcanoes and the volcanic islands belonging to the group. A number of small observatories are maintained.

The Japanese Empire has maintained a government earthquake investigation service since 1892, in which Professor F. Omori became the dominant figure. The motive of this service from the beginning was to find out everything possible about local earthquakes with a view to alleviation of disaster. To this end engineers. physicists, seismologists, geologists, and other specialists in universities were employed by the government, largely gave their services free, and published a series of important memoirs continuously in both English and Japanese for 30 years. Professor Omori concentrated on volcanoes during the last 15 years of his life, and his serial monographs on Asama, Sakurajima, Usu, Oshima, and other volcanoes, written in English, are among the most important of his productions. Earthquake investigation was reorganized after his death in 1923. and researches directed particularly to tilt and level changes, and to the needs of engineering, have been elaborated since the Tokyo earthquake. Professor H. Tanakadate has studied volcanoes. Seismographs of many kinds are distributed all over Japan, but a permanent volcano service has not yet been organized.

,In Italy, which established an observatory on Vesuvius in the middle of the nineteenth century, the publications about volcanic activity have been largely separate papers in scientific journals from the workers at the observatory and from seismologists and geologists in the universities. In 1924 a new series of volcanologic bulletins was started under Dr. Malladra, Director of the Vesuvian Observatory through the International Geophysical Union. Also some revival has been made of the Annals of the observatory. Mount Etna has also an observatory building on its high slopes, but the workers dwell at the university in Catania. In Naples Dr. I. Friedlaender has established at private expense a Volcanologic Institute and publishes in beautifully illustrated form a long series of volcano researches in several languages by workers all over the world. The first volume was published January 1914.

There have been a number of disasters due to earthquake and volcanoes in New Zealand, and in 1920 the writer as delegate from the Hawaiian Volcano Research Association gave a series of lectures in the universities of New Zealand on the observatory work in Hawaii and on the opportunity for continuous observation which the New Zealand volcanoes offer. The terrible earthquakes of Murchison in the South Island in 1929 and Napier in the North Island in 1931 have served to concentrate governmental attention in New Zealand on alleviation of disaster. Before these earthquakes Mr. L. Grange had been appointed to act as a volcanologic geologist and had done much mapping in the Rotorua volcanic district. Since the earthquakes, the Hawaiian Volcano Research Association has been able to assist somewhat by supplying simple seismographs for distribution in New Zealand under the government Department of Scientific and Industrial Research.

Seismologic services studying local earthquakes exist in Chile, Greece, Austria, Germany, Mexico, India, and Russia, and in some of these places some attempt has been made to begin the study of volcanoes. The Soviet has organized expeditions in Kamchatka, a little work has been done in Salvador and in the Caribbee Islands, some special expeditions have reported on Iceland and on volcanoes near New Guinea. Excellent studies have been made from the university in Athens of the active volcano Santorin and other volcanoes of the Grecian Archipelago. There are enormous volcano belts in the southwest Pacific, in Africa, the whole length of the west side of South America, and of the west side of Central America, which still await a prophet.

Three activities should be mentioned which deal with volcanoes effectively by the statistical method and by expeditions. The universities of Germany have produced Karl Sapper and F. Von Wolff. each of whom has written a textbook on volcano science. Sapper deals with geography and Von Wolff with geology of volcanoes. The Carnegie Institution of Washington through the workers under Dr. A. L. Day has sent out a series of expeditions and published monographs on Katmai, The Geysers in California. Lassen Volcano, Vesuvius, and some other places, and this work sets standards for analyses of gases, sublimates, and rocks, as well as hot waters, in accordance with critical dicta of physical chemistry. The third activity is the publication of the Geographical Society of Geneva, under th Red Cross, which has been issued quarterly since 1924, dealing with the study of calamities. as subjects of scientific prevision and alleviation (Matériaux pour l E'tude des Calamités). This organization has had subcommittees in many countries, and the assemblage of facts has been of great value.

Before leaving world volcano stations, the recent work of the American, Frank A. Perret, a distinguished volcanologist who wrote the great monograph of the Carnegie Institution on "Vesuvius," should be mentioned. He has been living at St. Pierre in Martinique since the end of 1929, and has obtained support for a museum and research center at St. Pierre, which it is planned to make self-supporting through charges to tourists who visit the ruins of the great disaster of 1902 by thousands. This will be a private institution, for which an ideal site has been granted by the French government with construction cost covered by local contribution. The idea is a non-national institution created as a gift to St. Pierre, as a continuation of American good will. Each contributor of $1,000 or more will become a founder, and those who have started the foundation are the Carnegie Institution of Washington, Vincent Astor, and George F. Baker. It is to be hoped that the Hawaiian Volcano Research Association will be added to the list of founders, for it was Mr. Perret who started our work here in 1911, and who published on the eruption of Teneriffe in the first memoir of Friedlaender's Zeitschrift in 1914. In many respects Mr. Perret is thus the founder of modern volcanology from an experimental viewpoint.

(4) Results of Volcano Research

Two principles have been kept in mind, which are unusual in guiding the work in Hawaii: (1) Appeal to people of ordinary education in describing our results; (2) Use people in ordinary life in order to get those results. These mean, first, that the motives should be humane and not highbrow, and the work should be describable as meaning something to business men who want to know why it is done. Secondly, the harnessing of a large piece of country with observations, or instruments, or measurements, can never be done by distributing physicists permanently all over that country. The experts won't go. They prefer the council-chamber of the university. This difficulty may be met only by interesting ordinary people in a method of measuring earthquake or tremors or tiltings, so that they will send us a postcard every week. In order to do this, the method must be simple. The high-brow may sometimes

scorn simple methods. And yet Darwin's and Faraday's greatest works were done by simple methods. So it must be in compelling the earth to tell the story of how its breathings in Alaska are different from its breathings in Hawaii.

Here are a few of the facts suggested by work of the last twenty years:

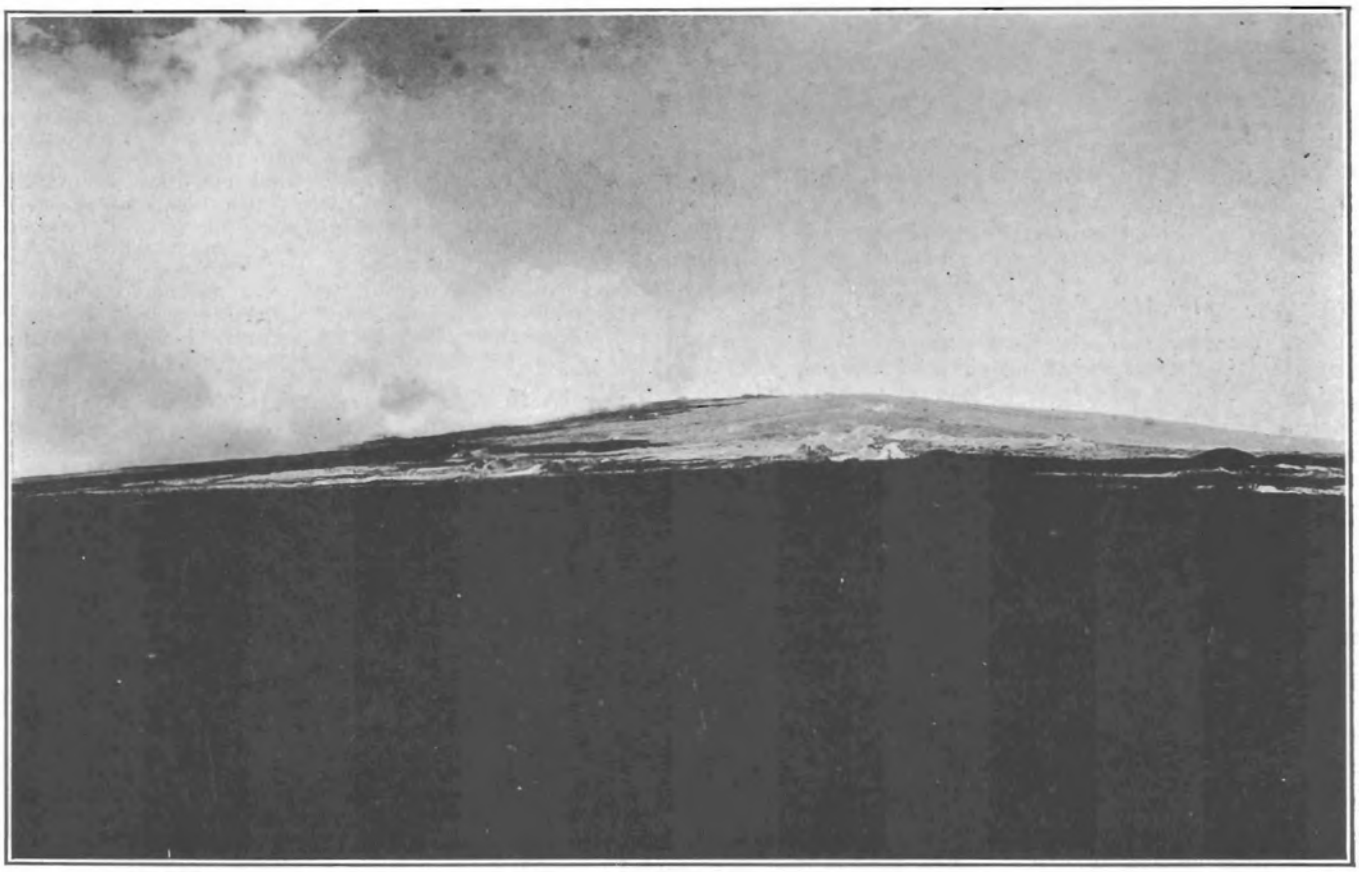
1. That volcanism everywhere has unity.
2. That gas is its prime mover.
3. That hydrogen and olivine basalt are fundamental constitutents.
4. That water is a secondary oxidation product.
5. That sulphur is concentrated at craters.
6. That engulfment is a common process.
7. That explosive eruption is secondary.
8. That major earthquakes may be magmatic in origin.
9. That magma continually presses upward.
10. That cycles are caused by yielding to pressure.
11. That this applies equally to earthquakes and volcanoes.
12. That small crust units involve short cycles.
13. That large crust units involve compound cycles.
14. That these may be of several orders.
15. That a volcanic cycle may exist at intrusions.
16. That intrusions may be studied by tilt and earthquakes.
17. That every volcano has intrusions under it.
18. That submarine outflow of lava is important.
19. That the present is a decadent time in earth volcanism.
20. That from Midway to Hawaii and along the volcanic rift, the crust has thickened and condensed.

We can think of the globe as at some time an incandescent member of the Sun's family. Up cracks as it cooled there piled up lava ridges. Our Hawaiian Territory is one such ridge. Studying the outpouring lava at Kilauea we found it divided into half-hardened, and frothy liquid, portions. We sounded the liquid and found it shallow. The half-hardened stuff was below. We took temperatures and found that the liquid was hottest above, where the most gas was burning. We found that Mauna Loa outbreaks ended with a Kilauea collapse. We found that splitting open the mountain visibly was attended by many earthquakes when lava burst up cracks. It turned out that there was local swelling of the ground. This was greatest at the pit edge. Tilt pendulums showed that it was happening farther away. It proved eventually that there are seasonal and daily tides in the lava and in the swelling of the mountain. The gases rising are mostly hydrogen, carbon monoxide and sulphur. They make flames. Water vapor, carbon dioxide and sulphur dioxide are in the greatest volume, because the burning goes deep. Boring to study ground temperature showed that hot places are due to vapor cracks. In 1924 the steam-blast eruption was preceded by a splitting of the mountain out to seashore, and accompanied by a sinking of lava and engulfment of the walls of the pit. The conviction that the lava escaped under the sea was unavoidable. The groundwater entered the hot hole and exploded. It extended the engulfment and made rhythmic geyser explosions. The last such cataclysm was in 1790. A supercycle of 134 years was indicated, the interval between two lowerings of lava below the groundwater level for Hawaii.

With this outline for working hypothesis, it is easy to see how interesting it is to be the workers to build tilt and tremor instruments, and try to harness the crater and the island in order to interpret what is going on underground. This is what we are working on today with the instrument, designed at the Observatory, called a "clinoscope." It is a heavy horizontal iron ring. hung on wires. with a light vertical magnifying lever pointing upward in the middle. At the top is a dial. The ground tilts and the pointer wanders away from the center of the dial. This wandering each day is to be read in three cellars 400 feet back from the Halemaumau rim. These cellars are to be kept quiet and at constant temperature If the lava is swelling under the botttom of the pit as a center, the three cellars will show tilt away from the center on the clinoscope readings. If the lava is lowering they will show inward tilt. Eventually we expect to have these cellars wired so that each instrument may be called up by automatic telephone, and the pointer position will report itself electrically to the Observatory. This is the latest result of twenty years of work at the Hawaiian Volcano Observatory.



Kapoho, east point of Hawaii, looking northeast at one of the cones of the Kilauea rift zone near the sea. The fresh cracks in the foreground were produced in April 1924, when "the steam-blast eruption was preceded by a splitting of the mountain out to seashore." Photo Maehara.



Just as the Hawaiian islands form a lava ridge, so on Mauna Loa the southwest rift is a flat ridge. Here we are looking up the ridge, formed of source cones of many eruptions, from 8,500 feet elevation. These are true "fissure eruptions" and here is a vast experimental laboratory for the volcanology of the future. Photo Emerson 1923.

KILAUEA REPORT No. 1056

WEEK ENDING APRIL 17, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

Some fume was visible at the foot of the southwest talus on April 12. Cracks within old roped-off area at the southeast rim showed definite but very slight widening. On April 13 at 10:15 a. m. fume could be seen eastward from the southwest talus area, and slight odor of sulphur could be detected. Countless small steam vents were giving out feathery clouds in Halemaumau after rain, and steam at the larger vents was dense. Fume was also visible under the southeast wall in cracks in the new lava fill. Occasionally rocks trickled down the north wall. On the 14th fume was as usual at the foot of the southwest talus, but was not visible southeast. The northeast rim cracks showed no change On the 15th at 10 a. m. Halemaumau remained without changes. On the 17th the sulphur spot at the southwest fuming area showed increase of stain.

The seismographs at the Observatory registered 15 tremors, two very feeble seisms, and one feeble seism. Two of the tremors showed doubtful origin distances of 42 and 56 miles, respectively; the two feeble seisms, 32 miles and 25 miles; and the feeble seism, 10 miles WNW of the Observatorv. This last shock awakened sleepers at the volcano, and in Honomu, Kona and Hilo at 2:55 a. m. April 17.

Microseismic motion was moderate through the week. Tilting of the ground averaged very slight to the east.

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Subcription for non-members two dollars per year of 52 numbers. Address the Observatory.

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The Board of Directors includes Arthur L. Dean, President; Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Walter F. Frear, Richard A. Cooke and Wallace R. Farrington.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

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The Volcano Letter

Two dollars per year **Ten cents per copy**

No. 383—Weekly Hawaiian Volcano Observatory, National Park, Hawaii April 28, 1932



The official party April 19, 1927, at the opening and dedication of Uwekahuna Observatory and Museum on the high western bluff of Kilauea Crater. Presented by the Hawaiian Volcano Research Association to the National Park Service. Right to left, the late Hon. Stephen Tyng Mather, Director of the National Park Service, Hon. Hubert Work, Secretary of the Interior, Volcanologist Jaggar, and Hon. Wallace R. Farrington, Governor of Hawaii.

PROGRESS OF HAWAIIAN VOLCANO RESEARCH

(Continued from Volcano Letter No. 382)

Third part of address of T. A. Jaggar, Annual Meeting of Hawaiian Volcano Research Association in Honolulu, March 31, 1932.

We have seen the growth of twenty years of volcano study in Hawaii by the observatory method, the growth of world volcano stations and some scientific results of volcano research in general. It will now be of interest to the members of this society to review the material progress of the work in Hawaii for the past ten years. The work of the first decade was outlined in the Monthly Bulletin in various annual addresses of 1913, 1915, 1916, 1917, and 1922. The year 1920 had started a new five-year program for the Association, with installation of seismographs at Hilo, Hilea, and Kona, and Dr. Omori, who had visited the Observatory with the Pan-Pacific Science Congress of 1920 had advised us to concentrate on the Mauna Loa center so as to interpret the direction, distance, and depth of the original impulses which make our local earthquakes. A second project was to do core drilling in the vicinity of Kilauea Crater for securing new light on temperatures, volcano power, the relation of volcanism to mining, underground water, and the relation of underground heat to gas. The third project was to secure publication of certain voluminous scientific papers which were ready, but unfinanced.

The Science Congress had recommended a central scientific bureau for dissemination of volcano news about the Pacific. This our Association has somewhat done by publication of the Volcano Letter. A second resolution of the Congress to the effect that the dwellers in volcano lands should be educated on the meaning of volcanoes and earthquakes, and on safeguards and insurance against them, has been promoted by the Volcano Letter, and by such magnificent work in America, Japan, the Dutch East Indies, New Zealand, etc., as is summarized in Sapper's book on Volcano Science, von Wolff's book of Vulcanism, and Freeman's book on "Earthquake Damage and Earthquake Insurance." A third resolution was that ecological studies should be carried out dealing with the rehabilitation of lava and lava soil by organisms, and this was started in Hawaii by Dr. Skottsberg under the Bishop Museum with some assistance from us, by marking ten-meter squares on lava flows of known date, and listing the lichens and other organisms found. These were to be reoccupied at future dates. Another study bearing on this subject has been published by Dr. Howard Powers of the Hawaiian Volcano Observatory in association with Messrs. Ripperton and Goto (Bull. 66 Hawaii Ag. Exper. Sta.), whereby the ash and lava soils of Kona have been specially classified for their adaptability to coffee culture. A last resolution of this Congress recommending that a station be placed on the top of Mauna Loa for combined aerology and volcanology remains still as a goal, but some progress toward it has been made by improvement of trail, and surveys for a road, by the National Park.

The year 1921 produced important material progress at the Observatory in a first shop and electric plant, in a revision of crater surveys for years back, in a beginning of monthly maps of the pit, in new crater experiments, in improved photographic apparatus, in computed curves of the lava tide investigation, in new money for an archives building and for boring, and in the discovery, by the topographers of the United States Geological Survey, of probable elevation of the rim of Kilauea Crater by from two to three feet between 1912 and 1921.

In 1922 the boring experiments were begun, were continued with both churn and core drills until May 1923, and were revived with air drills in 1926 and discontinued in the winter of 1927-28. There resulted 34 drill holes on

the crater floor and the crater rim of Kilauea, which are valuable assets of the Observatory for all time as places for experiment and for measurement of change in temperature and gas chemistry. The iron Archives Building was built in 1922, furniture and garages were improved, a chemical laboratory was started, and Mr. R. M. Wilson produced a first draft of "the Volcano Local System of Levels and Triangulation," which now in 1932 he is finishing in Washington in order to exhibit the important changes by land moment, precisely measured, which have occurred during activities at Kilauea Crater.

This year 1922, beginning the second decade of our work, was one of extraordinary progress for the Research Association in buildings, seismology, drilling for temperatures, and improved equipment. Machinery, tanks, cabinets for seismograms, chemical laboratory, and shop for instruments were added. Seismograms began to appear from Hilo, Hilea, and Kona. Dr. Allen came from the Geophysical Laboratory in Washington to work on the physical chemistry of the bore-hole steam at Sulphur Bank. Here an iron hut had been set up over the hot wells.

In 1923 Dr. O. H. Emerson was employed as chemist and general assistant, Dr. Jaggar was sent to Japan for three months to investigate the Tokyo earthquake, a remarkable motion picture film was obtained there, he made explorations in Tokyo, Yokohama, Kamakura, Boshu, Oshima, and Hakone, he assisted at some committee meetings of Japanese engineers and seismologists, and it was determined by the United States Government after the disaster that a plan for the new embassy should be referred to the Bureau of Standards. It is of interest to note that the earthquake-proof embassy of the United States in Tokyo is now finished. Mr. Jaggar insisted then as now that the volcano Mihara on Oshima Island, in Sagami Bay close to the seismic center of the great earthquake, one of the few volcanoes in Japan which produces lava in its crater most of the time, is a remarkably important place for a permanent observatory.

The scientific staff of the Observatory at this time consisted of Messrs. Jaggar, Finch, and Emerson. The record books were complete to 1923, and these books, typewritten in loose-leaf covers, including photographs and transcriptions of notebook sketches, were duplicated so that one set was kept in Washington. In the winter of 1923-24 the director of the station went to the eastern United States, read three papers at the American Association meeting in Cincinnati, and gave 26 lectures in Cincinnati, Washington, at Maryland University, in New York, New Haven, Cambridge, Boston, Brooklyn, Chicago, Urbana, and Philadelphia. He published articles, setting forth the work of the Association, in the National Geographic Magazine, the American Magazine, Asia, Scribner's, Popular Science Monthly, Bulletin of the Seismological Society, Monthly Weather Review, and the New York Times and Herald-Tribune. The steam-blast eruption of Kilauea occurred in May, 1924, and was admirably cared for by Messrs. Finch and Emerson, the director returning the end of May. The station was transferred to the Geological Survey July 1, 1924. Mr. Boles of the National Park Service ran levels across the disturbed area of Kapoho in Puna, which were of great value in outlining the down-dropped block of country there, which had lowered about 10 feet. It was at this time that numerous papers were published showing that tides, tilts, and cycles affected the lava of Kilauea.

Up to this time the Massachusetts Institute of Technology had continued to be a valued contributor to the Association. In later days the Institute has transferred its experimental work in geophysics to New England fields, but the highest appreciation should be expressed on behalf of the Hawaiian Volcano Research Association to this solid engineering school for bringing about the foundation of the work in 1911 which the Government and the Association have carried forward.

With the entrance of the United States Geological Survey on the work, the Government cooperation had been in progress, since the execution of a lease of the laboratory, from the Association to the Weather Bureau, April 19, 1919. Every assistance and most sympathetic collaboration was given by Chief Charles F. Marvin to volcanology while it was under the U. S. Weather Bureau. Dr. Marvin is himself a seismologist of note. The Research Association has been left entirely independent as a collaborating organization, but at all times the initiative for new methods, new discoveries, new apparatus, outside stations in Hawaii, and for publications and library, has rested with the Association. Also Research Fellows such as Dr. Romberg and Dr. Emerson, called in for studies of physics and chemistry, have been employees of the Association The regular staff is salaried by the Government, but much of the upkeep and nearly all of the improvement in buildings and apparatus has come from the Association.

During the 15 years since the work was started, the Research Association had seen grow the interest of the Congress of the United States in seismology and volcanology; the interest of scientific journals in Italy, Germany, Holland, Great Britain, France, America, and Japan, and of seismological and volcanological establishments in Geneva, Paris, Oxford, and Naples; the interest of the Carnegie Institution, the Pan-Pacific Union, the Weather Bureau, the Coast Survey, the Geological Survey, the National Geographic Society, and the universities and museums in the United States; and the establishment of bureaus and commissions on volcanoes, especially in Japan, the Dutch East Indies, the Philippines, New Guinea, New Zealand, Mexico, and Costa Rica; and it has seen fresh activity in the national and international geophysical unions and congresses.

The Bishop Museum invited Dr. Jaggar to join an expedition, in September 1924, to the Howland and Baker islands in the U. S. S. S. Whippoorwill. This was of geat interest for a volcanologist in view of Darwin's generalizations concerning atolls as representing subsidence. Howland and Baker appear to be the nucleus of an atoll, and as such show no evidence of subsidence, nor of the transition from a previous condition of fringing and barrier reefs. They appear to be accumulations on a submarine bank not significantly related to subsidence, elevation, nor retreat of the sea, but closely related to trade wind and equatorial current.

In 1925 a visit by a Congressional committee headed by Hon. L. C. Cramton of Michigan was destined to advance volcanology immeasurably. Mr. Cramton asked Mr. Jaggar to accompany him in June to Lassen Volcanic National Park and this was the signal for creation in 1926 of enlarged appropriation for a Section of Volcanology to include California and Alaska with Hawaii. Meantime Colonel C. H. Birdseye, in charge of the Topographic Branch of the Geological Survey, undertook to cooperate with volcanology by sending an engineer, Mr. J. C. Beam, for leveling, and for triangulation of the net of proposed bore holes that would determine how the temperature of the crater lava changes horizontally from place to place. In the machine shop we were experimenting with compressed air drills, and have to thank Messrs. W. F. Dillingham and Frank West of the Hawaiian Contracting Company for assistance. Leveling reconnaissance was now indicating that the edge of Halemaumau pit had gone down several feet during the explosions of 1924. Experiments were being tried in the seismological laboratory with earthquakes, with tilt recorders. and with overturning prisms for calibrating strong-motion earthquakes. Mr. E. G. Wingate was surveying Mokuaweoweo Crater, and it is impossible to express all that the Observatory owes to the late Captain A. O. Burkland, in charge of topographic mapping in the Hawaiian Islands.

In 1926 it had become the custom of the Volcanologist, to make a forecast each year, in his report to the Director of the Geological Survey, by way of experimenting with prediction. The report of December 31, 1925, stated that low earthquake frequency and accumulated tilt suggested rising lava and that location of some earthquake centers implied motion in Mauna Loa. This was confirmed by Mauna Loa breaking out April 10, 1926, and producing the Hoopuloa flow. A similar forecast for Halemaumau December 31, 1926, was followed by the outbreak in that pit in July 1927. Forecasting data are growing increasingly accurate.

General reorganization was permitted in 1926. Mr. R. H. Finch in September founding the Lassen Volcano Observatory, Mr. R. M. Wilson becoming engineer and chief assistant at the Hawaiian station, and Mr. R. B. Hodges becoming clerk and disbursing officer. Mr. Beam remained from

December 30, 1925, to May 21, 1926, tested two level lines 1,000 feet long for changes of tilt, releveled old circuits about Kilauea, surveyed the bore-hole net, remapped Halemaumau, and triangulated the Wilson net. Japanese workmen were sent from station to station, on the Kilauea floor, for boring holes 10 feet deep and 1,000 feet apart at the corners of equilateral triangles. There were added to the equipment compressor, truck, and drill, some tested thermometers, one of the modern high-speed cameras, and up-to-date surveying instruments from the Survey.

Meantime the Research Association had met the Congressional increase of funds by a drive for $20,000 for an exhibition room, projection apparatus, and furniture on the top of the great western cliff of Kilauea Crater, which was duly built and turned over to the Secretary of the Interior and the Director of the National Park Service in April 1927. At the same time the Association ordered from Japan an exhibition seismograph, and the best of the mineral collections were placed in the museum. The machine shop of the Observatory was enlarged and a skilled machinist secured for one year. A tide gauge had been installed in Hilo, and the Geological Survey cooperated in securing leveling by the Coast Survey from sea-level to the top of Mauna Loa, and in measuring gravity on the island of Hawaii in the autumn and winter of 1926-27. This work was done by Engineers Simmons, Brown, and Bainbridge. In the summer of 1927 Mr. Jaggar went to Alaska, established a seismograph at Kodiak, sailed to the west end of the Aleutian Islands and back, and inspected the Lassen station. Meantime several new seismographs of a distinctive Hawaiian type, large two-component instruments. were built at Kilauea, one of which was placed in a new cellar constructed for it in Hilo. Engineer Wilson entered on new mapping of Halemaumau, improvement of wireless time service, new leveling and triangulation to determine ground movement, measuring marked fissures at Halemaumau pit, and making artificial earthquakes with an oscillating table.

The year 1928 was thus entered upon with the Hawaiian Volcano Observatory, which had been estabilshed 16 years before by the Hawaiian Volcano Research Association, as the central headquarters in the middle of the Pacific Ocean, for a Section of Volcanology of the United States Geological Survey, maintaining substations in California and Alaska, and so doing its bit, of observing active volcanoes, at the east, north, and center of the Pacific Ocean. The Volcano Letter, issued weekly, was distributing notes about the world on volcano science, particularly with reference to the Pacific. Seismograms were being studied from four places on the Island of Hawaii, and one place each in California and Alaska. The Hawaiian station was equipped with a tide-gauge, a machine shop, a number of permanent bore holes, a chemical laboratory, general laboratory, dark room, fire-proof archives building, library, and vehicles, and the needs of the public had been suitably transferred to the National Park Service by means of a museum and lecture room. Triangulation and leveling had proved elevation and distension of Kilauea Crater before 1924, depression and construction thereafter. Mapping topographically had covered the whole of the Island of Hawaii, and was nearly completed for the Territory. Marked cracks were being systematically measured around Halemaumau pit, and at Lassen by stakes at Supan's Springs. New leveling and gravity measurement had extended to the top of Mauna Loa. A project had been formulated for possible cooperation of several Government bureaus in studying the natural history of the Aleutian Islands.

The National Geographic Society was now taking an active interest, after numerous explorations in volcanic fields, from the time of the Caribbean eruptions of 1902 onward. This Society employed Mr. Jaggar in the summer of 1928 to conduct an expedition to explore and map topographically 2,500 square miles around Pavlof Bay, near an active volcano of the same name, one of the beautiful snowy cones of the Aleutian belt on the south side of the Alaskan Peninsula. This expedition was timely, as Dr. Griggs for the Society had conducted a series of expeditions near Katmai Volcano, and our Section was laying a foundation for expeditions in the Aleutian Islands, two of which has already been made, with studies of Makushin, Bogoslof, Korovin, Gareloi, and Chugul volcanoes. In the Pavlof Expedition the topographic map was made by McKinley and published by the Survey, numerous photographs and motion pictures were taken by Stewart, and the geology and volcanology were studied by Jaggar, and a preliminary report published in the National Geographic Magazine.

It had become evident at the Hawaiian station in 1924 that the tremendous slope, to depths of two or three miles in only a few miles distance east and west of Hawaii under the ocean, is an important basal part of the active volcanic system. An outflow to the west under the sea in 1877, singular waves and submarine noises during lava flows from Mauna Loa into the sea, and a probable submarine flow unperceived off the east point in 1924, all made the study of the volcanic sea bottom by new methods a fundamental part of future volcanology. Accordingly, the development of work from boats is essential. The Pavlof Expedition employed a steel amphibian boat built for the National Geographic Society which was afterwards turned over by the society to the Research Association in Hawaii. The activities of such boats were experimented with in 1927 and 1928 on the east and west sides of Hawaii, as they possess the great advantage, where laboratory work is to be considered at a permanent station, of running up the beach on wheels with all their equipment and collections into a suitable house. Their bottoms may thus be altered or mechanized for any kind of sounding, dredging, probing, or tubular bottom photography with artificial lights in shallow water, and the ordinary disadvantages, of a boat exposed to all weathers, at anchor most of the time, with its bottom fouling, are eliminated. There is very important work to be done close to shore in Hawaii in determining the escape of the groundwater through submarine fresh water springs, by bottom sampling and hydrometer tests. Such submarine springs are known in many places on the active volcanic sides of the island, where no springs whatever emerge above sea level. This is true of many of the volcanic islands of the South Pacific, where the coral reef problem is affected by fresh water, from the ground-water surface beneath the rainfall belt of a lava mountain. As the explosive eruption of 1924 was probably occasioned by lava outflow under the sea, and groundwater inflow to the hot void so created under Halemaumau, it will be seen that critical surveys of the sea-bottom near Hawaii are absolutely necessary for the progress of volcanology. Therefore it is proposed to begin with small vessels close to shore, and to develop apparatus for such volcanologic surveys. It is to be hoped that the Navy and other boating organizations of the Government will give assistance in this work. The Board of Harbor Commissioners of the Territory of Hawaii kindly permitted the Association to use a discarded warehouse at Keauhou in Kona as a shelter for the steel boat "Honukai," where this amphibian is kept for explorations on the west side of Hawaii.

Engineer R. M. Wilson was obliged to return to Washington in November 1928, and was replaced by Engineer E. M. Buckingham, who remained until July 1, 1929. His place was taken by a geologist, Dr. H. A. Powers, who came from Harvard University, and entered upon geologic mapping of the west side of Hawaii, in addition to service as general assistant at the Observatory. Mr. Wilson had completed a contour map of Halemaumau after the bottom changes of 1927. Mr. Buckingham made another after the bottom changes of February 1929. Mr. Powers as petrologist started microscopic studies of rocks from Hawaii and Alaska, and also drafted diagrams of tilt from 1913 to 1930. Mr. A. E. Jones was sent to Alaska in 1929 and established a new seismograph station at Dutch Harbor.

Experiments of 1929 at the Hawaiian station dealt with construction of leverless seismographs tested on the oscillating table, of several models of vertical-component seismographs, wherein it was attempted to make the constants equivalent to the Hawaiian-type horizontal-component instrument, and of several different sizes of shock-recorders designed as simple instruments to put into the hands of amateurs. Also mechanical devices were made the subject of experiment for securing smooth smoking of seismogram paper. For many months a seismograph was operated with a restraining bumper against the pendulum arm having in view the elimination of microseisms and tilt.

and the recording of local earthquakes only. The shock-recorders were successfully used at Puuwaawaa in western Hawaii during the extraordinary and disastrous earthquakes of September-October 1929.

In the Lassen station a new Hawaiian model seismograph was set up and the older instrument was transferred to the Loomis Museum near Viola. Messrs. Howel Willams and C. A. Anderson, in addition to Mr. Finch, were at work on problems of the geology of the vicinity of Lassen Volcano. Dr. Wentworth investigated the geology of Hawaii June-September 1929, Dr. Stone the volcanoes of Chile November-January 1929-30, and Mr. Finch attended the Java Science Congress April-June 1929. On January 12 the Director of the U. S. Geological Survey, Dr. George Otis Smith, called a meeting under the Federal Relations Committee of the National Research Council for conference on scientific cooperation in the Aleutian Islands. This was in line with recommendations of the Pacific Science Congress of 1923. Dr. Jaggar addressed the meeting, and was made chairman of a committee to further Aleutian investigations.

This brings the review of volcanologic activities centering about Hawaii up to 1930-31. The buildings of the Hawaiian station were now enlarged and rehabilitated, tilt studies on a larger scale were prepared for, the Volcano Letter was enlarged and illustrated, a course in volcanology was given annually in the summer session of the University of Hawaii, a journey to the active volcano on the island Niuafoou in Tonga, by Mr. Jaggar, secured valuable photographs and records under the Eclipse Expedition of the U. S. Naval Observatory, shock-recorders were placed there and in New Zealand, Mr. Finch explored Akutan Volcano in Alaska and tested a shock-recorder there, the first clinoscope was constructed, Professor H. S. Palmer joined Dr. Powers in studies of shore-line changes on Hawaii, and finally, beginning July 1, 1931, the Congress of the United States enlarged the funds and activities of the Section of Volcanology by adding two scientific workers.

These are Engineer E. G. Wingate and Seismologist A. E. Jones, and the motive for this enlargement of staff is largely to concentrate measurements on tilting of the ground about an active crater in relation to local earthquakes. These motions have been found significant for prediction. There is certainly such tilting around the Kilauea center, there is presumably such tilting around the Mauna Loa and Hualalai centers, and there should be generalized tilting around the outskirts of the island. The formulation of what the local motions are, in direct relation to the passage of time and the coming of activity at a definite volcanic center, and what such motions show as to location and motion of definite lava underground, is the aim of volcanology. This has led to the placing of clinoscopes, as heretofore described, in three cellars around Halemaumau pit.

The Research Association met the enlargement provided by Congress by supplying new and enlarged buildings and laboratories, and greatly increasing the facilities of the Hawaiian station. We have every reason to express our keen appreciation of the invariable assistance and cordial cooperation of Hawaii National Park. The Research Association owes a debt of gratitude to Delegate Houston, Governor Farrington and to Director Smith of the Geological Survey for bringing about our enlarged opportunities, and equally to his successor, Director W. C. Mendenhall, and to the Chief Geologist of the Survey, Dr. T. W. Stanton.

The Scientific Director of the Association takes this opportunity to express his very keen and heartfelt gratitude to the late honored L. A. Thurston, for many years our President, enthusiastic in support of everything which concerned the study and exploration of Hawaiian volcaones, and skilled as a special pleader and publicist through his extraordinary learning and memory concerning everything Hawaiian. All honor should be paid also by all students of volcanology to the gentlemen of Honolulu who from time to time have served gratuitously and loyally on the Board of Directors of this Association, and especially to the six men in recent years who have served with Mr. Thurston in making for growth of the science through business leadership, public influence, financial judgment, scientific interest, and legal advice, Messrs. Cooke, Atherton, Dillingham, Peck, Dean, and Thayer. Mr. L. W. de Vis-Norton should be especially commended for his long and painstaking service as Secretary and Assistant Treasurer, in attending to the irksome details of the work of recorder, sometime editor, bookkeeper, and correspondent, and in advising with the Scientific Director on all manner of subjects, as well as doing a large amount of literary work which has made volcano research known.

KILAUEA REPORT No. 1057

WEEK ENDING APRIL 24, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

At Halemaumau pit of Kilauea Volcano the week has shown little change. The weather has been normal of the trade-wind type, and at 9 a. m. April 18 the yellow fume patch at the west side of the floor showed thin vapor. Crack measurements about the eastern rim showed but slight widening in the measurements of April 19. The fume emitted continued thin, but is always in evidence as a bluish haze over the western half of the pit in early afternoon light. An avalanche from the northern wall of the pit about 10:05 a. m. April 21 was followed five minutes later by a much larger one which appears to have been registered somewhat as a vibration recorded on the seismographs of the Observatory two miles away. The fallen rocks overlapped the January lava floor, the roar was loud, and a dust cloud arose. There were several other slides on this day and one at 4:38 p. m. was observed April 22 at the northeastern rim.

Seismic activity registered at the Observatory was mild. One very feeble shock indicated origin distance close at hand, something over two miles, and 26 tremors were registered during the week, three of which were sufficiently defined seismically to suggest origin distances of 28, 42, and 46 miles. Microseismic motion for the week changed from moderate to light, and tilting of the ground was strong to the west with slight tendency north.

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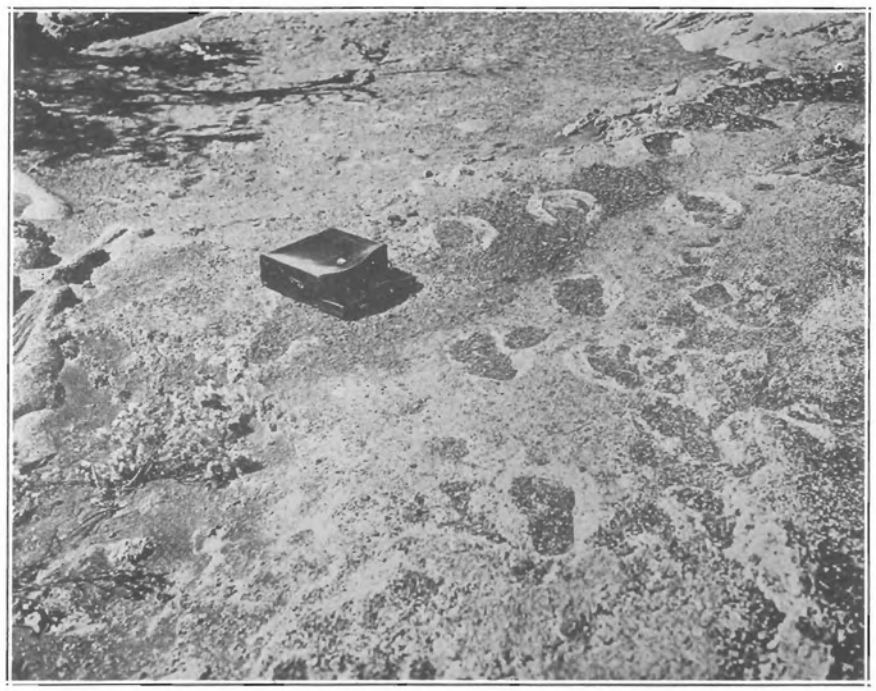
The Volcano Letter

Two dollars per year **Ten cents per copy**

No. 384—Weekly Hawaiian Volcano Observatory, National Park, Hawaii May 5, 1932



Hardened human footprints in the Kilauea ash of 1790, Kau Desert six miles southwest of the crater. The pedestrians were headed north and their bare feet squashed up the mud around the footprints. The mud solidified like cement. The pellets formed by the warm mud rains of the eruption are shown at the right. See Volcano Letter No. 273 and Bulletin Hawaiian Volcano Observatory July 1921.

PROGRESS OF HAWAIIAN VOLCANO RESEARCH

(Continued from Volcano Letter No. 383)

Appendix to Address of T. A. Jaggar, Annual Meeting of Hawaiian Volcano Research Association in Honolulu March 31, 1932.

Publications

In order that the reader of the foregoing review of twenty years of work at the Hawaiian Volcano Observatory may have some references for volcanologic reading, the following list of publications is compiled, first, to show the bulletins of the Hawaiian Volcano Observatory which contain special reviews, lists of publications, and discussions of special subjects, and second, to give references to the scientific papers by the staff which have covered the more important subjects of investigation since 1916. In Bulletin of Hawaiian Volcano Observatory Vol. IV, No. 4, April 1916, was printed a list of publications to that date.

Publications of the Observatory

First Report, Massachusetts Institute of Technology, 1912. Foundation of the Observatory, Kilauea 1909 to April 3, 1912, notes on Mauna Loa.

Second Report, Massachusetts Institute of Technology, 1917. On cyclical variations in eruption at Kilauea, by H. O. Wood.

Special Bulletin Haw'n Volc. Obs'y 1913. Scientific work on Hawaiian volcanoes.

Kilauea and Mauna Loa in 1914 (annual address), Bull. H. V. O. III, No. 4.

Hawaiian earthquake problem, H. O. Wood, III, No. 5, May 1915.

Museum, National Park, publications, etc. (documents), IV, No. 4, April 1916.

Results of six years of work (annual address), V, No. 8, August 1917.

Presidential address by L. A. Thurston (annual meeting), V, No. 10, October 1917.

Index of danger from volcanoes, Jaggar, VI, No. 1, Jan. 1918.

Composition of Hawaiian gases, Shepherd and Allen, VII No. 7, VIII No. 5, IX No. 5, X No. 8, 1919, 1920, 1921, and 1922.

Lava tube at Kilauea, Sidney Powers, VIII No. 3, March 1920.

Fossil human footprints Kau Desert, Jaggar, IX No. 7 anl No. 10, 1921.

Volcano research in Hawaii 1922 (annual address), X No. 4. April 1922.

Progress of boring experiments, X Nos. 5, 6, 7, 9, 10, 1922; XV No. 3, 1927; also Monthly Weather Review March 1924.

Aleutian eruptions December 1922, XI No. 1, Jan. 1923.

Tidal wave at Hilo, XI No. 2, Feb. 1923.

Sulphate stalactites in lava tubes, Finch and Emerson, XII No. 3, Mar. 1924.

Volume relations of explosive eruption of Kilauea, Jaggar, XII No. 12, Dec. 1924.

National standards of volcano and earthquake research (annual address), XIII No. 3, Mar. 1925.

A carbonized tree trunk in New Zealand, Bartrum, XIII No 7, July 1925.

Mauna Kea geology, Jaggar, XIII No. 10, Oct. 1925.

Southwest rift of Mauna Loa, Finch, XIII No. 12, Dec. 1925.

Viscosity of lava, Palmer, XV No. 1, Jan. 1927

Azores earthquake of August 1926, Agostinho, XV No. 2, Feb. 1927.

Opportunity for scientific research in the National Parks of America, Jaggar, address Pan-Pacific Conference, XV No. 4, Apr. 1927.

U. S. Coast Survey cooperation, Wilson, XV No. 6, June 1927.

Gravity anomalies on Hawaii, Wilson, XV No. 10, Oct. 1927 and Goranson, Amer. Jour. Sci. Aug. 1928.

Hilo seismograph station, Wilson, XV No. 11, Nov. 1927.

Review of seismic features for the year, and the Uwekahuna seismograph, Wilson, XV No. 12, Dec. 1927

Lassen Volcano Observatory, Finch, XVI No. 2, Feb. 1928.

A year of tide gauge operation, and Seismic sea waves of 1927. Wilson, XVI No. 3, Mar. 1928.

The amphibian boat "Ohiki," Wilson, XVI No. 4, Apr. 1928.

Seismic sea wave at Hilo June 17, 1928, Wilson, XVI No. 6, June 1928.

Test of Hawaiian-type seismograph, Wilson, XVI No. 8, Aug. 1928.

Magnetism of Lassen lava flows, Jones, XVI No. 9, Sept. 1928.

Aleutian geographic observatory, Jaggar, XVI No. 10, Oct. 1928.

Reviews of progress Hawaiian Volcano Research Association, Volcano Letters Nos. 2, 3, 13, 102, 139, 168, 169, 221, 225, 235.

Publications Outside of the Observatory

Volcanologic investigations at Kilauea, Jaggar, Amer. Jour. of Sci. Vol. 44, Sept. 1927.

Seismometric investigation of the Hawaiian lava column, Jaggar, Bull. Seis. Soc. Amer. Vol. X No. 4, 1920.

The program of experimental volcanology, Jaggar, Proc. First Pan-Pac. Sci. Conf. Part 2, p. 309, 1921, Bishop Museum, Honolulu.

Effects in Mokuaweoweo of the eruption of 1914, Wood, Amer. Jour. Sci. XLI May 1916.

Lava flow from Mauna Loa 1916, Jaggar, Amer. Jour. Sci. XLIII, Apr. 1917.

Notes on the 1916 eruption of Mauna Loa, Wood, Jour. of Geol. XXV, Nos. 4 and 5, 1917.

On the terms Aphrolith and Dermolith. Jaggar, Jour. Wash. Acad. Sci. VII No. 10, May 19, 1917.

Thermal gradient of Kilauea lava lake, Jaggar, Jour. Wash. Acad. Sci. VII No. 13, July 19, 1917.

Results of volcano study in Hawaii, Jaggar, Nature Vol. 101, No. 2525, March 21, 1918, p. 54.

An experiment in teleseismic registration, Jaggar and Romberg, Bull. Seis. Soc. Amer. Vol. VIII Nos. 2-3, 1918.

A New Zealand Department of Volcano Research, Jaggar, New Zeal. Jour. Sci. and Tech. Vol. III, No. 3, 1920, p. 162.

Experiences in a volcano observatory, Jaggar, Natural History, Vol. XXI No. 4, July-Aug. 1921.

The Yokohama-Tokyo earthquake of September 1, 1923, Jaggar, Bull. Seis. Soc. Amer. Vol. XIII, No. 4, Dec. 1923.

A plea for geophysical and geochemical observatories, Jaggar, Jour. Wash. Acad. Sci. Vol. 12, No. 15, Sept. 19, 1922.

Lava tide, seasonal tilt and the volcanic cycle, Jaggar, Finch and Emerson, Monthly Weather Review, March 1924, p. 142.

Seismic sea waves, Finch, Monthly Weather Review, March 1924, p. 147.

Predicting earthquakes, Jaggar, Scribners Magazine, Oct. 1924, p. 370.

Explosive eruption of Kilauea in Hawaii, Jaggar and Finch, Amer. Jour. Sci. VIII Nov. 1924, p. 353.

Tidal oscillations in Halemaumau, Brown, Amer. Jour. Sci. Feb. 1925, p. 95.

National standards of earthquake and volcano research, Jaggar, (annual address) Honolulu Advertiser, Mar. 13. 1925.

Sur le rives du lac de feu, Jaggar, L'Illustration, Paris, No. 4287, May 2, 1925, p. 428.

Aventures at volcanoes, Jaggar, Popular Sci. Mo. Mar. 1925, p. 53.

The lesson of Japan's earthquake, Jaggar, Mid-Pacific Magazine, Mar. 1924, p. 203.

An earthquake prediction at the Hawaiian Volcano Observatory, Finch, Science Jan. 9, 1925.

Seismic sequnces of the explosive eruptions of Kilauea in May 1924, Finch, Bull. Seis. Soc. Amer. Dec. 1924.

The earthquakes at Kapoho. Apr. 1924, Finch, Bull. Seis. Soc. Amer. June 1925.

Earthquake insurance, Jaggar, National Underwriter, Aug. 13, 1925, p. 10.

Earthquake insurance, Jaggar, Materiaux pour l'etude des calamites, Geneva Geog. Soc., Vol. 2, No. 7, 1925 (also Vol. 3, No. 19, 1929).

Plus and minus volcanicity, Jaggar, Jour. Wash. Acad. Sci. Vol. 15, No. 18, Nov. 4, 1925, p. 416.

Chemical significance of engulfment at Kilauea, Shepherd, ditto p. 418.

Progress of volcanology during 1924, Jaggar, ditto, p. 424.

Symposium on scientific cooperation in the Aleutian Islands, Jaggar, Bowie, Sargent, Fenner, Neumann, Ault, and Mitchell, Bull. Nat'l Resear. Counc. No. 56, Washington 1926.

The formation of aa and pahoehoe, Emerson, Amer. Jour. Sci., XII Aug. 1926.

Earthquakes and volcanoes, Jaggar, (chapter in) New Human Interest Library, Midland Press, Chicago, 1927.

Tilting and level changes in Pacific volcanoes, Jaggar and Finch;
Engulfment during Pacific explosive eruptions, Jaggar;
Volcanic relations of great Pacific earthquakes, Jaggar;
Temperature of volcano borings, Jaggar and Finch; all in Proc. Pan-Pac. Sci. Cong., in Tokyo, Nov. 1926, p. 672, etc.

Tilt records for thirteen years at the Hawaiian Volcano Observatory, Jaggar and Finch, Bull. Seis. Soc. Amer. Vol. 19, No. 1, Mar. 1929.

Products and structure of Kilauea, Stone, Bull. 33, B. P. Bishop Museum, Honolulu 1926.

Simple seismic measurements, Kirkpatrick, Science Apr. 15, 1927, p. 379.

Seismic measurements by the overthrow of columns, Kirkpatrick, Bull. Seis. Soc. Amer. June 1927, p. 95.

Sakurajima, Japan's greatest volcanic eruption, Jaggar, Nat'l Geog. Mag. Apr. 1924.

Volcano research of the U. S. Geological Survey, Jaggar, Jour. Wash. Acad. Sci. Vol. XVIII No. 19, p. 512, Nov. 19 1928.

A recent volcanic eruption near Lassen Peak, Williams, Dept. of Geology Pubs. U. of Cal., Vol. XVII No. 7, p. 241, 1928.

Relation of chemical composition to texture of groundmass in siliceous lavas, Powers, Jour. of Geol., Vol. XXVII No. 3, Apr.-May 1929.

Facts about volcanoes, Jaggar, New York Times, Sept. 1, 1929.

Amateur seismology, Jaggar, Sci. Amer. Nov. 1929, p. 411.

Graded swelling and shrinking of volcanoes, Jaggar, Proc. Haw'n Acad. Sci., Spec. Pub. 15 B. P. Bishop Museum Honolulu, p. 10, 1929.

Rainfalls accompanying explosive eruptions of volcanoes, Finch, Amer. Jour. Sci., Feb. 1930, p. 147.

Quartz basalt eruptions of Cinder Cone, Lassen, Finch and Anderson, Bull. Dept. Geol., U. of Cal., Vol. XIX No. 10, p. 245, 1930.

Geology of Kau, Hawaii, Stearns, Clark, and Meinzer, Water-Supply Paper 616, U. S. Geological Survey.

Volcanology, Jaggar, Sci. Amer. Sept. 1930, p. 176.

Hualalai earthquake crisis of 1929, Jaggar, Proc. Haw'n Acad. Sci. Special Pub. 16, B. P. Bishop Museum, Honolulu, p. 89, 1930.

Mechanism of volcanoes, Jaggar, chapter in "Physics of the earth; I, Volcanology," p. 49, Bull. Nat'l Res. Counc. 77, Washington 1931 (with bibliography).

Mapping the home of the great brown bear, Jaggar, Nat'l Geog. Mag., Jan. 1929, p. 109.

The eruption cycles in Hawaii, Jaggar, Thrum's Annual Honolulu, 1932.

Survey of the physical features that affect the agriculture of the Kona District of Hawaii, Powers, Ripperton and Goto, Hawaii Agric. Exper. Sta., Bull. 66, Honolulu, 1932.

Niuafoou Volcano in Tonga; its eruptions and its people, Jaggar, Proc. Haw'n Acad. Sci., Special Pub. 19, B. P. Bishop Museum, p. 9, 1931; also Volcano Letter Nos. 165, 312, and 318.

In addition it should be mentioned that the "Volcano Letter" has been issued weekly since January 1, 1925, and as a four-page leaflet with illustrations, replacing the former "Bulletin" since January 1, 1930. T.A.J.

KILAUEA REPORT No. 1058

WEEK ENDING MAY 1, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge.

No changes were observed in Halemaumau on April 25, except possible increase in sulphur stain on the floor at the foot of the north talus. Crack measurements on the 26th showed no changes. At 8 p. m. no glow was to be seen. On the 27th fume was as usual and nothing new to been seen. At 10:30 a. m. fume rose on the west side of Halemaumau conspicuously in puffs. On the 28th at 8:30 a. m. fume appeared denser at the southwest talus due to damp, cloudy morning. No change in fume observed on the 29th at 9 a. m. There appeared to have been a small slide over west end of the north sill during the night. On the 30th at 8:45 a. m. there was nothing new and fume was as usual at the southwest talus.

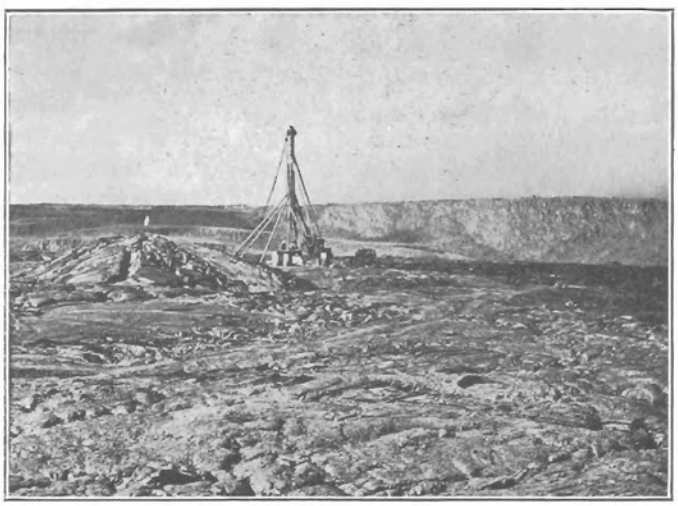
The seismographs at the Observatory recorded 13 tremors, two very feeble shocks, and three feeble earthquakes which were felt. The tremors indicated varying distances, from 23 to 70 miles. The two very feeble shocks showed origin distances 6 and 16 miles. The first of the three feeble earthquakes occurred at 1:59 a. m. April 26. It was felt in Haina, Honomu, Hilo, Kamuela, Kohala, Waikii, and at the Observatory. Its record indicated distance 32 miles from the Observatory, 23 miles from Kealakekua, and 42 miles from Hilo. It is calculated to come from a point five miles below the saddle between Mauna Loa and Hualalai.

The second feeble earthquake was registered at 3:17 a. m. April 28 and was not reported felt by many. The origin was 12 miles from the Observatory. The third feeble earthquake was at 6:24 a. m. May 1, and although probably more generally felt, reports from distant parts of the island have not yet had time to arrive. Reports of perceptibility have come from Honomu, Hilo, and near the Observatory. Records indicate distances 16 miles from the Observatory and 31 miles from Hilo.

Microseismic motion was mainly moderate. Average tilting was slight SE by S.

The Observatory is getting very good cooperation from earthquake observers. Card forms will be furnished anyone willing to report felt shocks.





Churn drill at work on eastern lava field of the floor of Kilauea Crater July 21, 1922. Looking north showing Waldron's Ledge and the Volcano House in the distance. This is one of the numerous temperature wells drilled to shallow depths in the crater floor. These discovered that high temperatures are always on cracks which bring up hot vapor. See Bulletin Hawaiian Volcano Observatory 1922 and 1927.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, on behalf of the section of volcanology. U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

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Founded 1911

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The Volcano Letter

No. 385 Hawaiian Volcano Observatory, National Park, Hawaii May 12, 1932

THE SUSPENSION OF THE VOLCANO LETTER

Among the reductions of governmental appropriation for the fiscal year ending June 30, 1933, is one changing the allotment to volcanology in the U. S. Geological Survey from $35,000 to 15,000. A large proportion of this concerns the Hawaiian Volcano Observatory, which is cooperatively maintained by a personnel chiefly of government employees, and by equipment and expenses, including publication, supplied in large measure by the Hawaiian Volcano Research Association.

The drastic reduction by fifty-seven per cent will permit the continuance of the Hawaiian station and a working staff only by abolishing the weekly Volcano Letter in its present form, as the publication of that periodical has been the largest item of expense from the cooperative fund furnished by the Research Association. This money will be needed to keep alive the work of the Hawaiian Volcano Observatory after July 1, 1932, and therefore it is deemed wise by the Board of Directors of the Association to take action immediately in preparing to reduce the Volcano Letter to a monthly leaflet after the issue of May 26, 1932. As before it will contain reports of the volcano observatories of the U. S. Geological Survey, and volcanologic notes.

As this crisis is a serious one for fundamental research concerning American volcanoes, all friends of volcano research are requested to rally to the support of the Hawaiian Volcano Research Association by subscribing any sum whatever, from one dollar up, and by securing new members and patrons for the Association wherever possible either firms or individuals, and anywhere in the world. The regular annual membership fee of the Association is five dollars, and necessarily the two dollar subscription for the Volcano Letter as a weekly publication is hereby abolished. After July 1, 1932, the monthly Volcano Letter will be sent only to paid up memberships and exchanges.

There will be no suspension of the work done. though the official staffs of the California, Hawaiian, and Alaskan stations will be reduced and some workers eliminated. There will be every effort to enlist new amateur workers who live near volcanoes and in land subject to small earthquakes, and who may be willing to send in official postal cards describing the happenings which come to their notice. The coming year will be an opportunity to bring to publication in scientific journals the material which has accumulated through recording twenty years of varied activities. T.A.J.

NOTICE TO MEMBERS AND SUBSCRIBERS

Honolulu, May 2, 1932.

To Members and Subscribers,
Hawaiian Volcano Research Association.

This communication is ordered by resolution of your Board of Directors on this date, to the following effect:

Resolved:

That the work of the Association shall be carried on, but that every possible avenue of economy shall be followed, including the abolition of the Volcano Letter in its present form. That the Directors approve of the proposed budget as revised for the balance of the current calendar year, with the proviso that further cuts be made, and that every effort be exerted to collect donations not yet received.

Accordingly, this letter is addressed to those who have subscribed two dollars per annum for the Volcano Letter and to regular members and patrons of the Association.

A cut of fifty-seven per cent by the Government, forces us to limit expenses to bare necessities, in order to save the Hawaiian Volcano Observatory.

After May 26, 1932, the Volcano Letter will be reduced to a monthly leaflet, but subscribers will be sent scientific papers from time to time. You are asked to accept this for the good of the cause, but two-dollar subscribers or members who except and require a weekly periodical, and who so notify the Assistant Treasurer, will have their full subscription returned.

Those able to help by enlarging their subscriptions or winning new subscribers, will be benefactors of scientific research in a time of serious crisis.

T. A. JAGGAR,
Scientific Director;
Hawaii National Park, T. H.

L. W. de VIS-NORTON,
Assistant Treasurer,
320 James Campbell Bldg.,
Honolulu, T. H.

KILAUEA REPORT No. 1059

WEEK ENDING MAY 8, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On the forenoon of May 2 Halemaumau pit showed fresh debris which had fallen since the previous day on the floor in the south bay from the wall above. Bluish fume remained constant at the sulphurous cracks at the edge of the floor west. Measurement of southeastern rim cracks showed very slight widening. Inspection at 8 p. m. revealed only a quiet pit and no glow. On May 3 at 9 a. m. the western fume was denser, probably owing to moisture content, as the weather was rainy. At 9 a. m. May 6 some fresh sliding at the south wall of the pit had added to the pile of fragments on the floor.

Progress in construction of the two tilt cellars near Halemaumau west and north shows concrete work in place at the former, and the digging practically complete at the latter

The seismographs recordel three very feeble shocks 23, 28, and 69 miles distant, the last rattling windows at Huehue in North Kona for about 15 seconds May 6 at 5:28 p. m. Twenty-one tremors were registered, one indicating distance 46 miles, and another 9 miles. Tilting of the ground was practically absent, and microseismic motion was moderate.

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Founded 1911

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The Volcano Letter

No. 386 Hawaiian Volcano Observatory, National Park, Hawaii May 19, 1932

KILAUEA REPORT No. 1060

WEEK ENDING MAY 15, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On the forenoon of May 9, with northeasterly squalls and rain, the fume rising from the west edge of the floor of Halemaumau appeared slightly denser than before, and some odor of sulphur was detected at southeast rim of pit. In the afternoon the fume seemed dense and a few wall rocks fell. On May 11, 9 to 10 a. m. the fume was less dense, and some small sliding had taken place at the north. A slide at the south wall in the afternoon agrees in location with a slight opening of the SSE rim cracks recently measured. With damp air May 12 blue fume rose above the rim infrequently.

Experimental runs are now being made with clinoscopes for measuring tilt, in the southeast Halemaumau cellar, by E. G. Wingate.

Observatory seismographs registered one feeble local shock at 10:16 p. m. May 9, felt in Hilo, apparent distance from Kilauea to origin 14 miles. Three very feeble shocks occurred, two indicating distance 18 miles, one a possible distance of 115 miles. Twenty-six tremors were recorded. Microseismic motion was slight to moderate, and tilting of the ground was slight north.

A large distant earthquake May 14 with first preliminary at 2h 52m 57s a. m. H.S.T. (10h 30m slower than Greenwich) indicated distance 5300 miles wsw. This location checks with press report of damage and loss of life at this time in Minahassa, the northern peninsula of Celebes island, a volcanic area of the Netherlands East Indies.

TILTING OF THE GROUND FOR APRIL

The following figures show the net tilt by weeks at the Observatory on the northeast rim of Kilauea crater, and its direction, computed from the daily seismograms, by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

March 29-April 4	1.0 second NE
April 5-11	0.8 second E
April 12-18	0.8 second NW
April 19-25	0.3 second SE
April 26-May 2	0.6 second SSW

E.G.W.

ERUPTION IN LAKE ROTORUA, NEW ZEALAND

A semi-volcanic eruption up through the bottom of the southern cove of Lake Rotorua occurred about 7:45 p. m. January 18, 1932. The place was about one hundred yards away from the shore off the mouth of the Puarenga Stream, the torrent of warm water that pours northward into the lake from the Whakarewarewa Geysers. The place is directly opposite the town of Rotorua. A column of steam, water, mud and stones was hurled up from an aperture in the solfataric shallows from 200 to 400 feet. There was little noise, and a few minutes after it occurred the surface of the lake was again smooth. The Maoris reported it the largest mud-geyser eruption since the explosion of Waimangu in 1917.

The area covered by the falling mud and stones was several acres. For more than one hundred yards along the shores of the lake, and for many yards back from the water, the ground was coated with thick slimy mud, and the point of land which projects in the direction of the vent under the lake was lengthened by 30 yards. People who happened to be on the balcony of the Ward Bathhouse had a splendid view of the outburst.

This explosion here is not the first. It is in the same general locality as two other outbursts a few months earlier, when the Ngapuna pa was startled by a sensational disruption of the flats, a native garden was engulfed and property was threatened. This area is reputed dangerous. The ground is a mass of brittle and steaming solfataric deposits, which crumble underfoot, there are many hot springs, and occasional patches of quicksand. At Whakarewarewa, a mile and a half away to the south, are the famous geysers and paint pots visited by tourists, in a verdant valley filled with boiling springs of varied aspect, and it seems likely that there are volcanic faults extending down the Puarenga valley to the lake. The whole district is highly volcanic, and the hot magma is probably not far from the surface T.A.J.

ASH ERUPTION IN THE ANDES

From the 10th to the 13th of April 1932 there were extensive steam-blast eruptions in the Andes of Argentina near the Chilean border, eight volcanoes being named, and the towns Malargue and San Rafael in Mendoza province received the heaviest ash-fall. Ash fell at Buenos Aires in Argentina 800 miles from the source, at Santiago in Chile and at Montevideo in Uruguay. In the mountain towns two to three feet of ash and sand are said to have fallen. Darkness enveloped much of the country, and earthquakes and fissures were reported, and glow from the craters. The volcanoes mentioned are the Descabezado group, Tinguiririca, Tupungato, Juncal, San Jose, Maipu and Peteroa, and probably a volcano in the Neuquen district of northern Patagonia. The volcano Quizapu in the first group has been the subject of anxious observation by the Chilean Seismological Service since April, 1929. The ash blanket covered thousands of square miles and made the mountains look as though covered with snow (Press reports.) T.A.J.

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The Volcano Letter

No. 387 U. S. Geological Survey, Hawaii National Park May 26, 1932

KILAUEA REPORT No. 1061

WEEK ENDING MAY 22, 1932

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Halemaumau, the inner pit of Kilauea Crater has shown no significant changes during the week. Measurements of cracks May 16 at the rim east and south indicated little movement. A dust cloud at the north wall at 10:55 a. m. May 17 during high wind was accompanied by no visible slide. At 4:45 p. m. the blue fume from the western sulphur spot of the bottom was plainly visible above rim of pit as seen from the Observatory. At 9 a. m. May 18 the scar from a slide was visible above the middle of the "canoe sill" in the lower northeastern wall of the pit.

The building of the tilt cellars west and north of Halemaumau has proceeded so that the western one now has the instrument chamber encased with built-up rubble, and the entrance way has been walled up on either side of the stone stairway at the approach. A heavy slab roof of concrete, separated by an air space from the inner chamber, will be built across the top. The chamber is thus insulated by air spaces, and will have double doors at the entrance.

Seismic activity has been extraordinarily feeble for the week. Only three volcanic tremors were recorded, one indicating a possible origin at 120 miles distance. There has been much artificial tremor from heavy road-working machinery. One very feeble local seism occurred. A distant earthquake indicating origin 4,400 statute miles away, began at 11h 50m 43s p. m. May 20, 1932. reported location Salvador. Microseismic motion for the week was moderate, and tilting of the ground was slight to the north with tendency eastward

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The Volcano Letter will hereafter be monthly.

ERUPTION OF MERAPI IN JAVA

There are two important volcanoes named Merapi, of which one is in Sumatra. The volcano here considered is in central Java, and started a disastrous eruption November 25, 1930. and permitted a stiff, blocky variety of lava to exude from the crater throughout most of 1931. (Der Ausbruch des Merapi, by N. Van Padang, Zeitsch. für Vulk., 1931 page 135, and Bull. Neth. East Ind. Volc. Surv. 1930-1931.)

Except for the volcano on Bali named Batoer, the flowing of lava is rare in the Dutch East Indies, though the slow push upward there of andesitic domes within craters is well known.

There had been an increase of tremors from January to May 1930 at Merapi, and the temperature of the solfataras was about 600° C. in October 1930, but this was not unusual for this place. In November large and small tremors increased, explosions were heard November 23, 1930, and these continued. When the glowing lava in the crater appeared on November 25, 1930, large tremors, which had been caused by crater avalanches, came to an end.

The lava was very tough and irregular in flowing, its glow was variable, with rough blocks falling from the front, which burst and formed small clouds, that mixed with the general cauliflower clouds of the jets from the crater. This lava formed a short, stubby outflow at the crater gulch. Such sluggish flowing, with small gas concentration, continued until December 18, 1930.

The eruption had characters similar to those of Mount Pelé in Martinique, including hot blasts downward and across country, known, in Martinique as "nuées ardentes" or glow clouds. After December 18 big blasts occurred, throwing out old material mixed with fresh lava, and these emerged from a big, deep chasm or gulch in the slope of the mountain opening from the summit crater. Great avalanches, and streams of blocks rushed down, and followed valleys, along with a drifting cloud of sand, ash and gas. While the debris followed the ravines, the whirling hot sand clouds would keep their own direction, with tornado effects, and make fearful destruction.

The largest such glow-cloud blast descended the mountain on December 19, 1930, killed more than 1,300 villagers, devastated 22 square kilometers of country, and spread more than 10 kilometers from the center. The stream of debris in the valleys was 10 to 50 meters thick, and the sand covering beyond was from 1 to 40 centimeters thick.

There had been lava domes which had arisen during eruptions on the summit of Merapi, beginning in 1883, by rise of andesite lava through broken material in the bottom of a crater 100 meters deep There was renewed rise of the lava in 1888. a dome above the top of the mountain had formed in 1909, side by side with this eastern dome there arose a western dome between it and the crater wall in 1911-13, and in 1922 there came out a lava stream at the western wall crack, the source material of which made a triple dome in the crater along with two earlier ones. The sequence is vividly shown in a series of diagrams by Van Padang. In 1930 a new dome and flow were formed beside the others in November-December, and the great eruption of December 18-19 caused collapse of the older domes, but after a succession of hot blasts thick lava rose again which formed a new dome in the chasm, somewhat away from the center of the mountain. The entire description of this eruption coincides strikingly in quality with that of Santa Maria in Guatemala November 2, 1929. (Volcano Letter No. 356)

In January 1931 lava issued from various parts of the new lava dome, blocks fell noisily from the crust as the dome repeatedly burst, and the mud and debris slides in the valleys ("lahars") solidified and cooled. The rains made water explosions against dry, hot debris in the valleys just as at Soufrière and Pelée in the Caribbee Islands in 1902. The rivers carried quantities of sand. Light seen above the lava dome, which showed only fumarolic action in daytime. was indicated at night to be flame from burning gas. The smell of sulphur dioxide was strong, and temperatures of some known fumaroles, formerly 500° C., had lowered to 60° C. On the other hand, solfataric action was spread over a greater area.

On March 25, 1931. there was an older lava stream of 1930 from the gash under the summit, and a younger one emerged March 10, 1931, and increased after March 15, so that on March 19 the lava tongue was 180 meters lower than the week before. There were many small blasts, with much avalanching, and glowing spots on top of the dome marked places where lava was gushing.

Erosion was now etching rill patterns rapidly in the deep, hot, debris fills of the valleys. Mud geysers were thrown up 50 meters high where eroding streams of water made contact with gravel beds almost incandescent. Measured temperatures recorded 280° C. The fumarole activity at the head of Senowo River, where the temperature in October 1930 had been 610° C., had ceased altogether in April 1931.

Lava flowing and hot blasts continued in May and June 1931. A new local observatory was built 4 kilometers from the summit, at elevation 1,279 meters, on the northwest slope of the mountain, with a tunnel to provide safe refuge against hot blasts. In this tunnel a seismograph was placed. In July and August 1931 lava flow and avalanches continued, and at night dark red glow could be seen at the crater, where in day time vapor arose. T.A.J.

The Volcano Letter

No. 388 U. S. Geological Survey, Hawaii National Park JUNE, 1932

KILAUEA REPORT FOR JUNE, 1932

Six weeks period from May 22 midnight to July 3, midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

For the week ending June 5, there were slight falls of rock during an earthquake 1:52 p. m. May 29, and a slide sent up dust at the northeast wall at 12:22 p. m. June 1. On June 6 a slide above the northwest talus at 1:10 p. m. left some new bowlders on the floor.

An event of volcanologic interest from the standpoint of experiment with methods, was the descent about 10 a. m. June 12 to the bottom of Halemaumau of Rikan Konishi, a rigger and contractor of Hilo. This was for the recovery of two dead bodies on the east talus resulting from a local tragedy. Mr. Konishi gave the preceding seven days to setting up an A-frame at the south rim, spanning the east arc with cable, and improvising a trolley. In a wooden cage strongly bound with iron, the task was completed by Mr. Konishi personally going alone to the bottom between 10 a. m. and 5 p. m. He had about fifty helpers and numerous tractors.

The specimens collected of the east edge of the 1932 bottom lava were shred pahoehoe basalt, black with brown stain, highly vesicular, glassy without visible olivine, with reddish brown glaze on inner surfaces. The grade of the talus was 34 degrees. The cage landed on the talus 250 feet above bottom. Time of collection about 3 p. m. June 12, 1932. The lava ledges at the edge of the floor were about 7 feet high, those out in the middle over 40 feet high. Temperature measured at border ledges, 15 minute exposure, 73 degrees Fahr. Temperature up talus 5 minute exposure 85 degrees: at floor edge farther north insufferably hot; at some places on the talus rubber soles were burned. The lava was curled over in shells with cavernous spaces. Mr. Konishi noticed "thin air", a difficulty of breathing, about 600 feet down: this was probably a streak of the fume with sulphuric acid gas from the solfa'ara at the west side of the floor. The Observatory is under obligation to Mr. Konishi for the specimens and the data.

Rim cracks at Halemaumau southeast, measured for the width between opposite sides with calipers, June 13 showed very slight widening at three localities. The pronounced earthquake generally felt on Hawaii about 4:52 a. m. June 14 was apparently accompanied by ESE tilt in the seismograph cellar southeast of Halemaumau. A few rocks were heard falling the forenoon of June 20. The instrument cellars for recording tilt at the pit southwest and north have been completed during the month.

T.A.J.

Earthquakes

During the last six weeks the following teleseisms were recorded on the seismographs of the Observatory. (Hawaiian standard time 10h. 30m. slow G.M.T.)

One May 26 at 5:47:50 a. m., distance 3,250 statute miles.

One June 3 at 0:15:54 a. m., wrote a very large record. It was destructive in Mexico and sea waves originating on that shore were visible in Hilo. These waves arrived in Hilo soon after 7 a. m., were about two and a half feet in height range, and 18 minutes in period, with the maxima between 7:30 and 10:30 a. m. A second series of water waves about a foot high came about 3:30 p. m. These were probably the reflections from the South American shore as the time computation is nearly correct for that path.

Fragments of teleseisms were recorded at 10:59 p. m. June 4 and 10:21:28 p. m. June 6. The latter was slightly destructive in Eureka, California, and only the P and M phases recorded. A teleseism 11:51:22 p. m. June 17 was followed between 7 and 9 a. m. June 18 by a tidal wave two to three inches high in Hilo Bay.

A teleseism June 19 at 11:13 p. m. was fragmentary, consisting of long, sinusoidal waves lasting but a few minutes. June 22 at 2:38:18 a. m. another teleseism began recording from southern Mexico. The P and M phases only were recorded. A slight ocean wave was recorded on the Hilo tide gauge after 9 a. m.

A moderate local earthquake occurred 4:51:45 a. m. June 14. Reports showed that it awakened people generally over the island of Hawaii. It was also reported from Maui. The Bosch-Omori seismograph at Kilauea was dismantled. The approximate center located by distances from two stations and by a direction from a third, was in lat. 19° 28' N., long. 155° 22' W., and about 13 km. deep. It probably occurred on the below-ground projection of the fault between Mauna Loa and Kilauea. This earthquake was estimated to be about III Rossi-Forel.

On May 29 at 1:51:27 p. m. a slight earthquake (about II Rossi-Forel) was felt at both Kilauea and Hilo. Distances from three stations placed it at 19° 21' N., 155° 17' W. and about 12 km. deep.

On June 5 at 6:53 p. m. a feeble shock was felt at Kilauea, about 9 miles away from this station.

A very feeble shock was felt on the Hamakua coast May 25 at 1:42:13 p. m. The epicenter was probably a few miles seaward from that coast.

Twenty other very feeble shocks were recorded at the Kilauea station. Ten of these occurred at distances from 3 to 9 statute miles; eight of the others occurred about 20 miles away, one at 70 and one at 150 miles away from Kilauea.

One hundred fifty-nine tremors were recorded. Due to their small size and inconspicuous phases, very few of these can be located. Some similar tremors have been reported as earthquakes from the north part of the island. In preparing to study these earthquakes a small seismograph hut was completed on June 29. It is located at Waikii telephone station on the northwest slope of Mauna Kea. It is planned that a seismograph, transferred from one of our abandoned Alaskan stations, will be placed there in October 1932.

A.E.J.

Tilting of the Ground

The following figures show the net tilt by weeks at the Observatory on the northeast rim of Kilauea crater, and its direction, computed from the daily seismograms, by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given. The last record was in Volcano Letter No. 386.

May 3-9	0.4 second NNE
May 10-16	1.0 second NNE
May 17 23	1.1 second NW
May 24-30	0.8 second SW
May 31-June 6	0.4 second NNE
June 7-13	0.8 second NE
June 14-20	0.7 second SW
June 21-27	1.0 second N

The accumulated tilt at the Observatory since January 1, 1932 to June 27 is 14.2 seconds S. and 1.4 second W. These records are from the modified two-component Bosch-Omori seismograph which has stood in this cellar for twenty years.

E.G.W.

The Volcano Letter

No. 389—Monthly U. S. Geological Survey, Hawaii National Park JULY, 1932

KILAUEA REPORT FOR JULY, 1932

Including weekly press reports Nos. 1068 to 1071, July 3 to July 31 midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

A slide from the west wall of Halemaumau July 4 left a mound of debris 20 feet high on the floor, and noisy slides raised dust that forenoon. The 1932 conelet southwest had slumped. A northwest wall slide occurred 6:40 a. m. July 13, and another left a scar southeast July 16. The rock above the canoe sill in northeast wall made a slide big enough to make the 1932 lava floor dusty about July 27, and in the night following July 29 a block of the actual rim of the pit south left a wide scar down the wall, visible from the Observatory. Yellow dust and sand was left covering the western half of the floor, while the south bay showed large bowlders and smaller debris. The pit seismograph showed NW or inward tilt accompanying this slide, and two cracks back of the south rim had widened.

Fresh cracks in the ash soil of the northeast rim were occasioned by the slides of July 4. Measured rim cracks northeast on that date showed at 5 p. m. slight general opening compared with June 21. At 7 a. m. July 8 nine out of nineteen eastern rim cracks showed opening compared with July 4, but very slight. At 9:30 a. m July 12 very slight widening apart of eastern cracks continued, and at the end of the month it was found that only the two fissures back of the slide of July 29 showed significant opening, and that less than one sixteenth inch. This work is done carefully at marked and numbered places, with caliper and rule.

At the southeast Halemaumau cellar seismic movements and tilts occur quite different from those registered at the Observatory on the northeast edge of the greater crater of Kilauea. E. G. Wingate is operating this cellar, which contains both clinoscope and Hawaiian type seismograph. The following figures show weekly totals of peculiar pit tremors, sudden small jerking movements of quick period and very slight amplitude, the frequency variable on different days, and generally showing tilt, or widening apart of the seismogram lines, simultaneous with the trembling. This motion is most conspicuous on the east-west pendulum, and as the cellar is to the east of the pit, the dominant tilt which accompanies the tremors is eastward or away from the volcanic center. The action appears to be seismic, and may prove an important index of magma rising below. The new instrument magnifies about 120 times, and is more sensitive than the one in operation prior to the autumn of 1931 at this place. The frequency, or number of tremors counted, was:-

July 3 - 9	343
July 10 - 16	300
July 17 - 23	150
July 24 - 30	137

It happens that there were lower values in May, and an increase in June, so that the maximum was around the solstice (June 20), and the four weeks of July show graded decrease. This tremor frequently at the pit thus is in accord with the seismicity decrease (earthquakes) shown below by Mr. Jones. The idea that these pit tremors are creakings of the inner dome of Kilauea crater floor being pushed up by magma below, is in accord with the opening of the rim cracks, and evidence by topographic surveys which suggest that the ground is rising and that the opposite walls of Kilauea crater are spreading apart The clinoscopes have been placed in the west and north pit cellars, and their operation for a few months should throw new light on the question, is the ground tilting away from Halemaumau in all directions? During very feeble earthquakes July 16 and 17 slight east and south tilt showed on the seismograms, this being inclination away from the pit; whereas during the south avalanche of July 29, the seismographic tilt at the southeast station was northwest or inward toward the pit.

T.A.J.

Earthquakes

The following is a tabulation of the tremors, very feeble and moderate local shocks recorded by the seismographs at the Hawaiian Volcano Observatory during the interval July 4 to 31 inclusive, 1932. Hawaiian Standard Time is 10h. 30m. slower than Greenwich. The seismicity index (seis.) is the summation of weighted numbers given each type of shock, as explained in Volcano Letter No 371.

Date	tr	vf	mod	seis
July 4 to 10	37	5	1	14.75
July 11 to 17	42	2	0	11.50
July 18 to 24	22	0	0	5.50
July 25 to 31	29	2	0	8.25

The seismicity for the preceding two months was;-

Week ending	May 15	seis. 9.00
	May 22	1.25
	May 29	7.25
	June 5	8.75
	June 12	5.25
	June 19	13.00
	June 26	9.75
	July 3	14.25

The moderate shock of July 7, at 10h. 30m. 49s. p. m. was felt generally on the island of Hawaii and was reported from one locality on Oahu. Its focus was about 8 miles south of the Observatory and about 6 miles deep. It was followed on July 8 by two very feeble aftershocks, about 7 miles distant, and by 15 tremors of unknown distance. The change in earth-tilt a few hours before and a few hours after the earthquake was noticeable. Moderate NW tilt preceded and moderate S tilt followed.

The very feeble shocks, other than those mentioned above, occurred at approximate distances of 9, 9, 11, 16 18. 23, and 24 mles. The few tremors for which distances could be estimated occurred at 4, 9, 20, 34, and 40 miles. A fragment of a distant earthquake was recorded beginning 9:13 a. m. July 12, and a second one beginning 10h. 53m. 04s. p. m. July 24, with a secondary wave at 11h. 04m. 59s. p. m. Microseismic motion was light at the beginning and at the end of July, and moderate during the middle fortnight.

A.E.J.

Tilting of the ground

The following figures show the net tilt by weeks at the Observatory on the northeast rim of Kilauea crater, and its direction, computed from the daily seismograms, by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given. The last record was in Volcano Letter 388. The total accumulated tilt from January 1 to August 1, 1932 is 12.6 seconds S., and 2.2 seconds W.

June 28 - July 4	0.6 second	N
July 5 - 11	0.4 second	SSW
July 12 - 18	1.0 second	NNW
July 19 - 25	0.6 second	NE
July 26 - August 1	0.8 second	NW

E.G.W.

Personnel

Mr. Jaggar has been engaged in editing papers for publication and in teaching volcanology to a class of fifty-six at the lecture hall of Hawaii National Park, summer session of the University of Hawaii. Mr. Finch has returned from Shishaldin volcano in Alaska to his duties at Lassen Volcano Observatory. Mr. Wingate has been resurveying the Kilauea triangulation net. Mr. Jones has been computing travel time curves for Hawaiian earthquakes. Mr. Powers has been transferred to geological surveys on Haleakala volcano, Water Resources Branch.

The Volcano Letter

No. 390—Monthly U. S. Geological Survey, Hawaii National Park AUGUST 1932

KILAUEA REPORT FOR AUGUST 1932

Including weekly press reports Nos. 1072 to 1075, July 31 to August 28 midnight.

Section of Volcanology, U. S. Geological Survey

E. G. Wingate temporaily in charge

Volcanology

A visit to the summit of Mauna Loa was made by Park rangers August 9 to 11. They discovered much steam along the upper part of the northeast rift, blue fume and steam about the central cones of Mokuaweoweo, the summit crater of Mauna Loa and the usual steam at the foot of the west wall. Another party led by Messrs. Squire and Corey of Hilo visited the summit on August 17. They reported steam and fume at Mokuaweoweo as usual. The fume over Mokuaweoweo as seen from Kilauea has occasionally been visible in late afternoon as a tenuous volute of definite outline; and several times the northern position of the sunset light has brought out the steam jets of the northeast rift. These things are not unusual in summer time.

Volcanic conditions at Halemaumau in Kilauea have been relatively quiet and inactive during the month. A small slide took place on the sixth. Only four or five rocks falls occurred during the rest of the month. A night observation trip 8 p. m. August 24 showed everything quiet and dark in the pit. The cracks on the rim of the pit of Halemaumau showed no change the first week of August. For the next three weeks six cracks consistently opened for an approximate total of a sixteenth of an inch each. The very local pit tremors have decreased in numbers, the count was 141, 203, 107, and 29 on successive weeks.

A note on Kamchatkan Volcanoes.

A very interesting communication was received from P. T. Novograblenof of the Kamchatka Museum. He describes an eruption at one of their great volcanic cones, Kluchevskaya which is nearly 16,000 feet high. There had been no eruption either in it or its parasitic cones since sometime prior to the Russian invasion of the peninsula in 1696 A. D. For a period of four months preceding the eruption of January 25, 1932 earthquakes were felt almost daily, some being almost destructive in intensity. The eruption started quietly with black fume rising some thousands of feet, above the parasitic cone at the base of the volcano. The explosive phase began two hours later and explosions recurred at intervals of six to seven hours. There were no lava flows. The eruptive products were fume, ash, sand, lapilli and volcanic bombs. Immediately after the culmination of activity on January 29 a party visited the vicinity of the cone. They reported it as growing no less than 12 meters a day. After seven days of explosive activity it quieted and gradually declined. Smoke and glow from the crater could be seen on the day and night of February 12 1932. Karimsky volcano was the only other Kamchatkan volcano in eruption at this time.

Earthquakes

The following is a tabulation of the tremors, very feeble and feeble earthquakes recorded by the Observatory seismograph during the interval August 1 to 29. All of these are of intensity one Rossi-Forel scale. The term tremor is applied to the smallest. For weekly seismicity or seismis index see Volcano Letter No. 371.

date	tremor	v. f.	feeble	seis
Aug. 1 to 7	29	5	0	12.00
Aug. 8 to 14	23	2	1	7.75
Aug. 15 to 21	20	3	1	7.50
Aug. 22 to 28	26	9	1	12.00

One of the very feeble shocks, August 4, was felt by a person sitting on a ledge at Puu Koae in the Kau desert. A partial record of a distance earthquake began 5h; 01m; 12s p. m. H. S. T. August 11. The origin as given by the U. S. C. & G. S. was in the Aleutian Islands near Umnak Island. August 19 a shock was felt in Kona and Kohala. It recorded feebly at Kilauea. Instrumental location placed it two miles at sea near the extension of the Hualalai rift, and about three miles north of Keahole Point on the west side of Hawaii. It was about 12 miles below sea level. A feeble earthquake was felt August 23 by an observer three miles east of the Observatory. The record showed that it was followed in less than two minutes by four very feeble after-shocks, the preliminaries being too weak to indicate distance. A very feeble shock was reported felt in the same neighborhood on August 27. It was nine or ten miles from the Observatory.

The average weekly seismicity at Kilauea for the period of low values since the last lava inflow, ending January 5, 1932, has been about ten. The average for all values during the last four years has been about 80. The values for August are close to the average low for part of this year.

A.E.J.

Ground movement and Tilt

Field work on triangulation of the Kilauea net was completed early in August. Sixteen stations were occupied in the course of the survey and thirty-one triangles closed with and average error of 02".55. A complete report on the ground movements detected by this survey will be made the subject of a separate paper at a later date.

The clinoscope at the seismograph hut at Halemaumau is performing usefully, after several months of various tests. The hut is located 1,800 feet from the center of the pit, in azimuth 325 degrees, and 400 feet back from the rim. The clinoscope is housed in a seperate glass-inclosed room which has a daily range of slightly less than two degrees F. Readings are made once daily. Actual magnification of the clinoscope is about 50 times.

The 'Table of Tilt' shows the net tilt by weeks, as computed from seismograms at the Observatory and from clinoscope readings at Halemaumau. The table represents the movement of the ground, in seconds of arc, in the direction given. The total accumulated tilt at the Observatory from January 1 to September 1, 1932 is 10".5 South and 02".9 West.

TABLE OF TILT

Date	Observatory	Halemaumau
July 31 - Aug. 7	0".5 NNE	0".4 NW
Aug. 8 - Aug. 14	1".0 NW	0".4 WNW
Aug. 15 - Aug. 21	0".4 NW	0".5 NNW
Aug. 22 - Aug. 28	0".6 NNE	0".9 WNW

Clinoscopes of similar design to that above have been installed in the west and north tilt cellars, and are being given experimental runs. The two cellars, together with the seismograph hut, form an equilateral triangle about the center of Halemaumau.

E.G.W.

The Volcano Letter

No. 391—Monthly U. S. Geological Survey, Hawaii National Park SEPTEMBER 1932

KILAUEA REPORT FOR SEPTEMBER 1932

Including weekly press reports Nos. 1076 to 1080, August 29 to October 2 midnight.

Section of Volcanology, U. S. Geological Survey

E. G. Wingate temporarily in charge.

Volcanology

A small slide and a few rocks falls in the pit of Halemaumau in Kilauea crater were noted by observers during the last three days of August. A small slide fell from the east wall soon after daybreak September 8. A second small slide fell from over the Southwest talus slope and a few rocks fell from the east wall during that afternoon. The rim cracks back of the west wall showed widening on this day by fresh looking hair cracks in the overlying ash. Three small slides occurred after the above date and before September 18. Since then no slides large enough to be reported have occurred.

Measurements on the rim cracks under weekly observation have been taken five times, in the period covered by this report. The changes are largely confined to a few cracks that show nearly constant movement. The number of cracks that have opened a slight but measureable amount for each successive week are four, zero, six, ten, and four.

Observations and measurements of tilt at the pit durfng the last month seem to indicate that upward pressure is beginning to be exerted. The tilt changed abruptly from inward tilting to a direction away from the pit following the felt quake of September 7. During the last two weeks of September there began to be noticed a more or less continuous trickling of rocks from the walls, notably from the north and west, with evidences of very small sliding.

A New Map of Halemaumau

During the month of September a complete map of the pit was made by plane-table surveys on a scale of 400 feet to the inch. This is the first map of the entire pit made since the survey by R. M. Wilson in 1928. A comparison of the two maps reveals some interesting changes in the crater.

Halemaumau still retains its general circularity, though the northeast-southeast diameter is greater. The diameters at present are 3504 by 3008 feet. Avalanching from the walls has had the greatest effect on the area extending southward from the tourist lookout. The maximum amount of rim change has taken place in this area, amounting to 130 feet in one place. Other noticeable rim changes occur in the neighborhood of the old 14 ton boulder some 600 feet north of the tourist lookout, where 80 feet of the rim has fallen; along the east rim over the east talus, 80 feet; and 60 feet over the north buttress.

The general floor level has risen 280 feet, at present being 870 feet below the bronze tablet at the lookout. In area the floor has increased from 19 acres in 1928 to 88 acres, while the pit as a whole has enlarged its size only 4 acres. These figures give an approximate volume of fill, by lava extrusion, of 21,000,000 cubic yards, of which the last eruption accounted for almost 13,000,000 cubic yards.

The cone in the southwest corner of the pit is 120 feet above the floor level and the larger hummocks on the floor are from 15 to 20 feet in height.

E.G.W.

Earthquakes

The following is a tabulation of the earthquakes that were recorded during the week preceding the date below.

date	tremor	v. f.	feeble	seis.
September 4	44	8	0	15.00
September 11	19	4	1	6.75
September 18	23	7	1	10.25
September 25	36	5	1	12.50
October 2	10	5	0	5.00

These earthquakes were not larger than No. 1 Rossi-Forel scale.

During the last three days of August a swarm of thirty tremors were recorded on the seismographs of the Hawaiian Volcano Observatory. From measurements on a very few, the seismic disturbances appeared to have occurred from 30 to 60 statute miles away. Since no reports came in from other parts of the island, they probably occurred deep under the island.

A very feeble shock was felt near Kilauea at 2:45 p. m. September 6. It was about five miles away.

A feeble shock awakened people near Kilauea on the seventh at 4:38 a. m. It was also reported from Hilo. Distances and directions from the Hilo and Observatory stations indicated that the focus was under Kilauea crater and nearly under the pit.

A feeble shock, not felt, was recorded September 12 at 5:50 p. m. It was about three miles away from the Observatory. The instruments at the pit showed south and westerly tilt effects for 24 hours following the shock.

A very feeble shock was recorded September 16 at 4:51 p. m. Later, reports came in saying that an earthquake had been felt at Waikii at that time.

A feeble shock was recorded 7:32 a. m. September 24. It occurred about four statute miles from the Observatory and was well recorded on all seismographs at Kilauea. It was not reported felt. It recorded at Hilo as a very feeble shock and at Kona as a tremor.

An earthquake was felt in Kamuela at 9:38 a. m. September 27. It recorded as very feeble at the Hilo and Observatory stations. Distances interpreted from the records placed it about under Kamuela.

The seismic index (seis.), as is shown above, has not been very far from the average low between eruptions.

A.E.J.

Tilting of the ground

The 'Table of Tilt' shows the net tilt by weeks, as computed from seismograms at the Observatory and from clinascope readings at Halemaumau. The table represents the movement of the ground, in seconds of arc, in the direction given. The total accumulated tilt at the Observatory from January 1 to October 2,1932 is 09."6 South and 00."5 West.

TABLE OF TILT

Date	Observatory	Halemaumau
Aug. 29 - Sept. 4	0."7 NE	5."5 NNE
Sept. 5 - Sept. 11	0."4 SSE	6."9 S
Sept. 12 - Sept. 18	1."1 NE	8."2 WNW
Sept. 19 - Sept. 25	0."7 SE	17."0 S
Sept. 26 - Oct. 2	1."0 NNE	14."0 W

That the values for Halemaumau given above are not excessive is shown by spirit levels run on September 27. These levels indicate that the east rim, 400 feet from the B. M. at the clinascope station, has lowered 0.3 feet since March 5 of this year. Between April 5, the date of installation of the clinascope, and September 27, there had accumulated 01' 22."0 of tilt in the direction of the pit, which, at a distance of 400 feet, would amount to 0.12 feet. A much closer actual agreement seems to be indicated, as March 5, the date of latest comparable levels, was the culmination of a minor period of uplift of the Kilauea dome.

E.G.W.

The Volcano Letter

No. 392—Monthly U. S. Geological Survey, Hawaii National Park OCTOBER 1932

KILAUEA REPORT FOR OCTOBER 1932

Including weekly press reports Nos. 1081 to 1084, October 2 to 30 midnight

Section of Volcanology, U. S. Geological Survey

E. G. Wingate temporarily in charge.

Volcanology

Conditions at Halemaumau pit of Kilauea crater remain quiet and inactive. For the first week of the month rock trickling was quite noticeable. From the daily observations and reports of visitors it appeared that there was an almost constant failing of rocks from the walls of the pit. During the next two weeks this was unnoticeable, probably on account of the high winds that may have masked the sound of any falling rocks. For the last week of the month reports showed that there had been a small amount of rock trickling followed by two small slides from the north and northwest walls of the pit. The fume was less noticeable for the greater part of the month. Air conditions on October 26 and 27 apparently increased the visibility of the fume, which appeared in occasional puffs.

Comparison of the October measurements of the rim cracks with the measurements of the past months show that there has been a slight increase in the number opening. Each measuring point on these cracks, consists of two marked copper pins, fixed on either side of the crack. Every week the distance between the marks on the pins is measured to the nearest half millimeter or about one-fiftieth of an inch. The numbers that showed widening for the successive weeks in October were four, eight, eight, and seven, These movements are irregular and scattered among the observation points. In only one case has a crack consistently opened since September 24. Since then it has opened about a sixteenth of an inch each week until at present its total widening is about a quarter of an inch.

Earthquakes

The following is a tabulation of the earthquakes recorded by the seismographs of the Hawaiian Volcano Observatory during the intervals October 3 to 30 inclusive. The instrumental record consists only of tremors and very feeble shocks. The weekly seismicity (seis.) is the summation of weighed numbers given each type of shock as explained in Volcano Letter No. 371.

date	tremor	v. f.	seis.
Oct. 2 to 9	21	1	5.75
Oct. 10 to 16	26	1	9.25
Oct. 17 to 23	41	2	11.25
Oct. 24 to 30	41	1	11.00

Inconsistencies in the above table are due to the duration of tremors.

An earthquake was felt in Kona October 9 at 2:20 p.m. It recorded plainly on the Kealakekua seismograph a few miles away from the epicenter. It recorded as a tremor, not indicating distance, on the Observatory seismograph.

An earthquake was felt at Waikii at 6 a. m. October 27. It was about 60 statute miles from the Observatory but was not recorded. The records of all stations were searched but not a tremor could be found within an hour of that time. As the new instrument at the Waikii station was not in good adjustment it did not record the shock.

Parts of distant earthquakes were recorded on October 16 and 30. Only the long waves of these teleseisms recorded slightly. The microseisms were light on October 7, 8, 9, 28, 29, and 30; and strong on October 19. During the other days of the month the ground vibrations were of moderate intensity.

A.E.J.

The Study of Ground Tilts at the Observatory

At the very beginning of observations at Kilauea in 1913 exceptional tilting of the ground about the volcano became apparent, and with the passing of years became a subject of increasing interest and importance. The accumulation of data, obtained by measuring from a fixed datum line the displacement from day to day, of the writing pens on the seismograph seemed to point to a volcanic origin for a portion of the observed tilts. Certain eruptive periods showing a decided tilt away from the crater preceding the eruption, and the collapse in 1924 showed inward tilting to the amount of 81 seconds of arc between January 1 and July 1 of that year. In Vol. 19, No. 1, March, 1929, Bulletin of the Seismological Society of America, Dr. T. A. Jaggar and R. H. Finch have discussed, "Tilt Records for Thirteen Years at the Hawaiian Volcano Observatory". Their work undertakes the correlation of results from precise levels and triangulation, atmospheric temperature, rainfall, seismicity, and the rise and fall of the Hawaiian lava column with the observed tilts as measured at the Observatory.

The present program of investigation is a continuation and extension of past work. It was felt that a new site for instrumental measurement was necessary as the location of the observatory proper on the outer rim of Kilauea, with earth cracks about it and a much faulted cliff in front as well as the distance (three miles) from the object of study, was not such as to obtain fully reliable records of volcanic tilts. In 1928 a one component seismograph was installed a few hundred feet southeast from Halemaumau. This instrument was in operation until December 1931 when it was dismantled to make way for the building of the first of three tilt cellars centered about the pit. Uplifts and depressions of as much as 15 feet are not uncommon about the rim of Halemaumau, and it was felt that with instrument stations located on the crater floor a short distance from the active pit it would be possible to make a much closer correlation between observed tilts and the rise and fall of the lava column.

Three clinoscopes, for direct measurement of tilt, and one Hawaiian Type seismograph are now in operation on the crater floor and measurements from seismograms at the observatory are being continued. The differential movement of benchmarks is determined by spirit levels from time to time and the horizontal angular value between two points on opposite sides of the pit is measured from the Observatory periodically. The net of triangulation and level stations about Kilauea is resurveyed at five year intervals. This net is to be extended eastward along the Puna rift and an independent net established at its eastern end. This section was the scene of disastrous earthquakes and shore line sinking in 1823, 1868 and 1924. Straight lines of sight, with intervisible marked points, spanning the fault country south of the volcano are contemplated. Records are kept, with daily and smoothed curves platted, of atmospheric temperature, rainfall and atmospheric pressure. Rainfall and temperature are also observed and platted at Halemaumau.

Tilting of the ground

The "Table of Tilt" shows the net tilt by weeks, as computed from seismograms at the Observatory and from clinoscope readings at Halemaumau. The table represents the movement of the ground, in seconds of arc, in the direction given. The total accumulated tilt at the Observatory from January to October 30, 1932 is 6."4 South and 2."1 East.

TABLE OF TILT

Date	Observatory	Halemaumau
Oct. 3 - Oct. 9	1."5 NE	9."7 N
Oct. 10 - Oct. 16	1."9 NNE	27."2 NE
Oct. 17 - Oct. 23	0."7 SE	5."5 ENE
Oct. 24 - Oct. 30	0."6 NE	6."8 SSW

E.G.W.

The Volcano Letter

No. 393—Monthly U. S. Geological Survey, Hawaii National Park NOVEMBER 1932

KILAUEA REPORT FOR NOVEMBER 1932

Including weekly press reports 1085 to 1088, October 30 to November 27 midnight.

Section of Volcanology, U. S. Geological Survey
E. G. Wingate temporarily in charge.

Volcanology

The pit of Halemaumau in Kilauea Crater remains quiet. Fume has been less noticeable than during October. Fume was present during the first three weeks but was not reported during the last week. Rock trickling has died down and there were only a few slides. Slides occurred on November 1, 4, 6, 12, 16 and 21. Puffs of fume were plainly seen November 4, 5, 6. A swarm of 11 tremors was recorded in less than half an hour, about 5 p. m. November 4. No distances could be estimated for these tremors, and as they coincided with fume and sliding at the pit, they were assumed to have occurred deep under Kilauea, rather than under Mauna Loa.

Concentric cracks around the pit have been measured every Saturday. These measurements show that the crack 100 feet north of the tourist stand continues to open. The number of cracks that widened each week were six, eight, four, and ten. The weekly average number of cracks that widened during the past month is slightly larger than the average for October. This increase has been going on ever since July when there was an average of two that widened.

Earthquakes

The following is a tabulation of the frequency of earthquakes recorded by the seismographs of the Hawaiian Volcano Observatory at Kilauea. The weekly seismicity (seis.) is the summation of weighted numbers given each type of shock, as ¼ for a minute of tremor, ½ for a very feeble shock, one for a feeble shock, two for a slight shock, and three for a moderate earthquake. These units follow roughly the numbers of the Rossi-Forel scale. The table gives number of occurrences of each type of shock:—

Date	tr.	v. f.	f.	seis.
Oct. 31 to Nov. 6.	53	2	0	14.25
Nov. 7 to Nov. 13.	30	5	1	11.00
Nov. 14 to Nov. 20.	31	1	1	9.25
Nov. 21 to Nov. 27.	27	5	1	11.25

Hawaiian Standard Time (H. S. T.) is 10h. 30m. slower than Greenwich.

Three feeble earthquakes were recorded at the Observervatory during the past month. The first was felt about two miles east of the Observatory, at 8:35 p. m. November 11. estimated distance from Observatory 30 statute miles. The second was at 2:43 a. m. November 14, distance 20 miles, not reported felt. The third was felt at Hilo and at Hawaii National Park, 4:36 p. m. November 26, distance twelve miles.

Three very-feeble shocks were felt near the volcano. The first was felt at Uwekahuna, at 11:35 a. m. November 9. The other two were felt at a location about two miles east of the Observatory at 2:28 and 2:32 a. m. H. S. T. The first was about 2, and the two later ones about 15 and 16 statute miles distant. Only one of the above six earthquakes was reported felt from more than one place or by more than one person. They were number I Rossi-Forel scale.

The preliminary of a teleseism was recorded at 6:26:43 p. m. H. S. T. November 12 Dispatches place the epicenter in the Sea of Japan.

A.E.J.

Tilting of the ground

The "Table of Tilt" shows the net tilt by weeks, as computed from seismograms at the Observatory and from clinoscope readings at Halemaumau Southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given. The total accumulated tilt at the Observatory since November 27, 1931 is 3."8 South and 7."3 East.

TABLE OF TILT

Date	Observatory	Halemaumau
Oct. 31 - Nov. 6	0."4 SW	13."8 S
Nov. 7 - Nov. 13	0."9 ESE	8."2 WNW
Nov. 14 - Nov. 20	0."8 SE	12."8 SSW
Nov. 21 - Nov. 27	2."9 NE	31."3 NNE

E.G.W.

Results of One Year's Crack Measurements

In the Monthly Bulletin of the Haw. Volc. Obs., Vol. XV, No. 7, on page 54 is the following statement by Mr. R. M. Wilson, then engineer at the Observatory, "Thinking that the steadiness in the widening of the cracks may prove interesting, 15 points for routine measurements were marked and measured along the east rim." These concentric cracks were measured in 1927-28 with some degree of regularity by Mr. Wilson. In 1929-30 the measurements were at irregular intervals.

Topographic Engineer E. G. Wingate on coming to the Observatory in 1931 extended the number of points observed and made some changes in the method of measurement to increase their accuracy. The work is done with special calipers inside of gaping rock fissures marked with paint. Routine observations were begun at weekly intervals for all points and any showing excessive movement are measured once a day or oftener. The points are also measured after any felt quakes of moderate intensity.

In the table are given the results of observations for one year. The last column shows the total accumulated movement through the year for each numbered point observed. And, though it will be noted that all except three points have shown an increase in width, the condensed table cannot show how this took place, wether by a slow gradual opening of the crack or in sudden jerks accompanying earthquakes. Actually both of these movements occurr, and in certain areas where avalanching from the walls and rim has later taken place, the movement has been accelerated up to the time of collapse.

A review of all the observations taken during the year shows two dates when a moderate quake accompanied a sudden opening of cracks. These were Dec. 7, 1931, when the opening was general but slight, and on Dec. 23, between 9:00 a. m. and 11:00 a. m., the shock preceding the last eruption accompanied moderate opening at most of the points, though some were unaffected and three indicated a slight closing of the crack.

Crack point No. 30 illustrates the several kinds of opening described. This crack is on the east side of the pit eighty feet back from the rim. The points were set Nov. 23, 1931 and the original width was 20.05 cm. This width remained unchanged until the avalanche of Dec. 7, 1931 caused increase of 0.15 cm. A slow gradual widening then commenced. amounting to 0.15 cm. at 9:00 a. m. Dec. 23, 1931. When the points were again measured at 11:00 a. m. following the quake at 10:40, the crack had widened 1.°5 cm. During the eruption December 23 to January 5. and for five weeks thereafter an opening of 1 mm per week took place. This became 2mm Feb. 1, 1932 and from that time on until the spasm of quakes and avalanching on Mar. 4. 5, and 6, it exhibited the same acceleration of movement as was noted, more strongly, at several other points: attaining a maximum widening of 1.30 cm. per week and 0.40 cm. per day. From Mar. 7 to the last date

of measurement Nov. 26, 1932 a steady increase of 0.05 cm. every two weeks has been recorded.

Lack of space prohibits a more complete analysis of these observations here. In the appended table the measurements of Dec. 23, 1931 were made three hours before the last eruption commenced, and Mar. 7, 1932 is selected for comparison, as for the preceding several days avalanching had been general, doming up of the crater rim had been observed, and a swarm of earthquakes occurred on March 5. Widths are given in centimeters.

E.G.W.

Table of Crack Measurements, Rim of Halemaumau

Widths in Centimeters.

Point No.	Nov. 23, 1931	Dec. 23, 1931	Mar. 7, 1932	Nov. 26, 1932	Total widening
16	52.95	52.65	53.15	53.75	0.80
17	64.40	64.25	64.75	65.50	1.10
18	62.65	62.65	63.45	63.95	1.30
20	68.35	70.85	71.00	71.05	2.70
5	28.80	28.70	29.00	29.65	0.85
22	20.35	20.80	21.15	21.45	1.10
10	45.00	45.15	45.70	46.10	1.10
9	91.15	91.75	92.85	94.90	3.75
11	74.75	74.65	74.65	74.65	—0.10
24	22.10	23.00	23.25	23.30	1.20
25	37.75	49.35	49.50	Fell in March 6	
25 New	.....	.....	20.05	20.70	0.65
28	17.30	17.80	18.95	18.75*	1.45
30	20.05	21.70	24.20	25.20	5.15
29	46.75	48.65	49.25	49.50	2.75
27	46.90	47.40	47.60	48.00	2.10
26	60.55	61.05	61.75	62.55	2.00
33	.....	46.65	49.30	49.15*	2.50
32	1931 Dec. 9. 16.45	16.80	16.80	16.80	0.35
34	.....	83.70	85.10	86.10	2.40
31	1931 Dec. 9. 20.85	22.60	32.65	Fell in March 6.	
31 New	.....	.....	12.80	12.80	0.00
35	Aug. 23, 1932	.....	86.55	86.65	0.10
36	Sept. 3, 1932	.....	27.30	27.00	0.00
37	Nov. 11, 1932	.....	23.90	24.00	0.10

* Indicates that point was disturbed.

E.G.W.

The Volcano Letter

No. 394—Monthly U. S. Geological Survey, Hawaii National Park DECEMBER 1932

KILAUEA REPORT FOR DECEMBER 1932

Including weekly press reports 1089 to 1093, November 27 to January 1 midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

The pit Halemaumau within Kilauea crater has shown no lava activity. It is floored with lava of January, 1932 at an average depth below Tourist Lookout southeast of 870 feet. (See map on back). There is a sulphurous patch at the west edge of the floor, where most of the blue fume arises. Excessive rain December 1-2 (3.25 inches) penetrated the hot lava, caused hundreds of vapor jets, and dull thuds were heard, becoming infrequent in the course of two days, and more like distant gun shots. Sliding of debris was continuous for a day. Much of the sliding left scars at the east wall. By December 10 the sliding was inconspicuous, and the bottom was clear, but steam through the south talus keeps the rocks wet. A mound near the center of the foor is cracked and sulphur-stained. There were slides north December 14, northeast December 17, and a western slide December 19 covered part of the sulphur patch. There were other small slides toward the end of the month.

For the summit crater of Mauna Loa the National Park Service reports no changes observed about December 12.

Measurements of rim cracks about Halemaumau edge showed 10 out of 23 crack points widened for the week ending December 3, thirteen December 10, four December 17, eight December 24, and six December 31. Crack point No. 9, which had widened 3.75 centimeters during the year ending November 26, 1932, was conspicuous as widening one or two millimeters per week, but this motion ceased December 24-31 for the first time in several months (see table, Volcano Letter No. 393).

Two new crack-measuring points were marked by Engineer Edward G. Wingate December 16, making the total 25 points (see map). The number of the crack is marked on the lava with white paint, and is recorded on the map. The measuring points are upright copper pins, one on either side of the crack, with a slight cut across the head. A steel tape is used to read directly the distance between the cuts to the nearest half millimeter. Closing together of crack walls is rare, opening out is the usual movement, but highly variable. Owing to fragments in the cracks, it is natural that they should fail to close: (see wedge theory of crater fills, Bull. Hawn. Volc. Obsy. Volume XII, No. 12, December 1924, page 120). The opening of a crack is due either to tension in the floor, or to migration of the inner slab toward the pit. If it is tension in the floor. it should correspond to upward arching of the floor of Kilauea crater, that is, upward pressure under Halemaumau pit. The cracks in question are mostly back from and parallel to the line of the pit edge. In some cases several measuring points are marked at different places along the same fissure.

Earthquakes

The following table shows the frequency of local earthquakes recorded by the seismographs of the Hawaiian Volcano Observatory at Kilauea Volcano. The weekly seismicity (seis.. see Volcano Letter 371) is the summation of weighted numbers given each type of shock, as ¼ for a minute of volcanic tremor, ⅛ for a very feeble shock (v. f.), 1 for feeble (f), 2 for slight (sl.). and 3 for moderate (mod.). One, two, and three follow roughly the numbers of the Rossi-Forel Scale. The table shows the weekly number of occurrences of tremors (not by minutes) and of each type of shock . Teleseisms or large distant earthquakes are indicated by (tel.).

Dates 1932 to 1933	tr.	v. f.	f.	tel.	seis.
Nov. 28 to Dec. 4	35	1	1	1	10.25
Dec. 5 to Dec. 11	25	3	0	1	7.75
Dec. 12 to Dec. 18	33	3	0	0	9.75
Dec. 19 to Dec. 25	21	2	0	2	10.25
Dec. 26 to Jan. 1,	19	2	1	0	6.75

The average of weekly seismicity is about 80, so that these numbers stand for weak volcanic tremor and earthquake activity. In what follows the times given are Hawaiian Standard (H. S. T.), 10h 30m slower than Greenwich. Estimate distances are from phases on the seismogram, using travel-time curves modified by local experience.

A feeble local shock at 1:34 p. m. December 3, was reported felt in Puna. The approximate epicenter was placed at sea from 30 to 40 statute miles NE of Hilo.

A feeble shock was felt in Hilo, Glenwood, and at Kilauea crater at 1:21:05 p. m. December 27. It was about four miles SW of the observatory. A field trip was made into the area of the supposed epicenter, no fresh cracks were found, although there were many cracks opened by former eruptions and earth movements.

A very feeble shock was felt in Hawi, Kohala, December 1 at 8:21 p. m. A small record was found only on the Waikii record for that time.

A very feeble shock was reported felt in Pahoehoe and Pahala 7:04 a. m. December 26. Its epicenter was apparently under the SW rift of Mauna Loa.

A very feeble earthquake was felt at Kilauea and Pahoehoe 8:55 p. m. December 27. Its epicenter was probably in the desert 11 miles to the SW of the Observatory.

No other shocks were reported. The tremors were generally less than a minute in duration. December 19 there was a 15 minute period of tremor ending in a very feeble shock about 3 miles distant. December 22 there was one 3 minute period of tremor.

A record of a teleseism was recorded beginning 8:53:44 p. m. December 3. The P and S phases were recorded, the latter being doubtful. An epicenter was given in dispatches for an earthquake in the North Atlantic on this date. The P and L waves of the Nevada earthquake were recorded here, beginning at 7:47:18 p. m. December 20. A teleseism at 3:47:40 p. m. recorded four phases fairly well. The long waves of a teleseism were recorded at 6:15 a. m. December 7.

The seismicity for December has been slightly lower than the November seismicity, however they are both very close to an average of ten, which has been the average since March 1932.

A.E.J.

Tilting of the ground

The "Table of Tilt" shows the net tilt by weeks, as computed from seismograms at the Observatory and from clinoscope readings at Halemaumau Southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given. The total accumulated tilt at the Observatory since January 1, 1932 is 7.5″ South and 3.4″ East.

TABLE OF TILT

Date	Observatory	Halemaumau
Nov. 28 - Dec. 4	1.5″ WSW	20.3″SEE
Dec. 5 - Dec. 11	0.4″ SW	9.7″ SSW
Dec. 12 - Dec. 18	0.9″ ESE	5.2″ WNW
Dec. 19 - Dec. 25	0.8″ NE	16.6″ NNE
Dec 26 - Jan. 1, 1933	2.2″ SW	5.3″ SE

E.G.W.

Postal card earthquake records

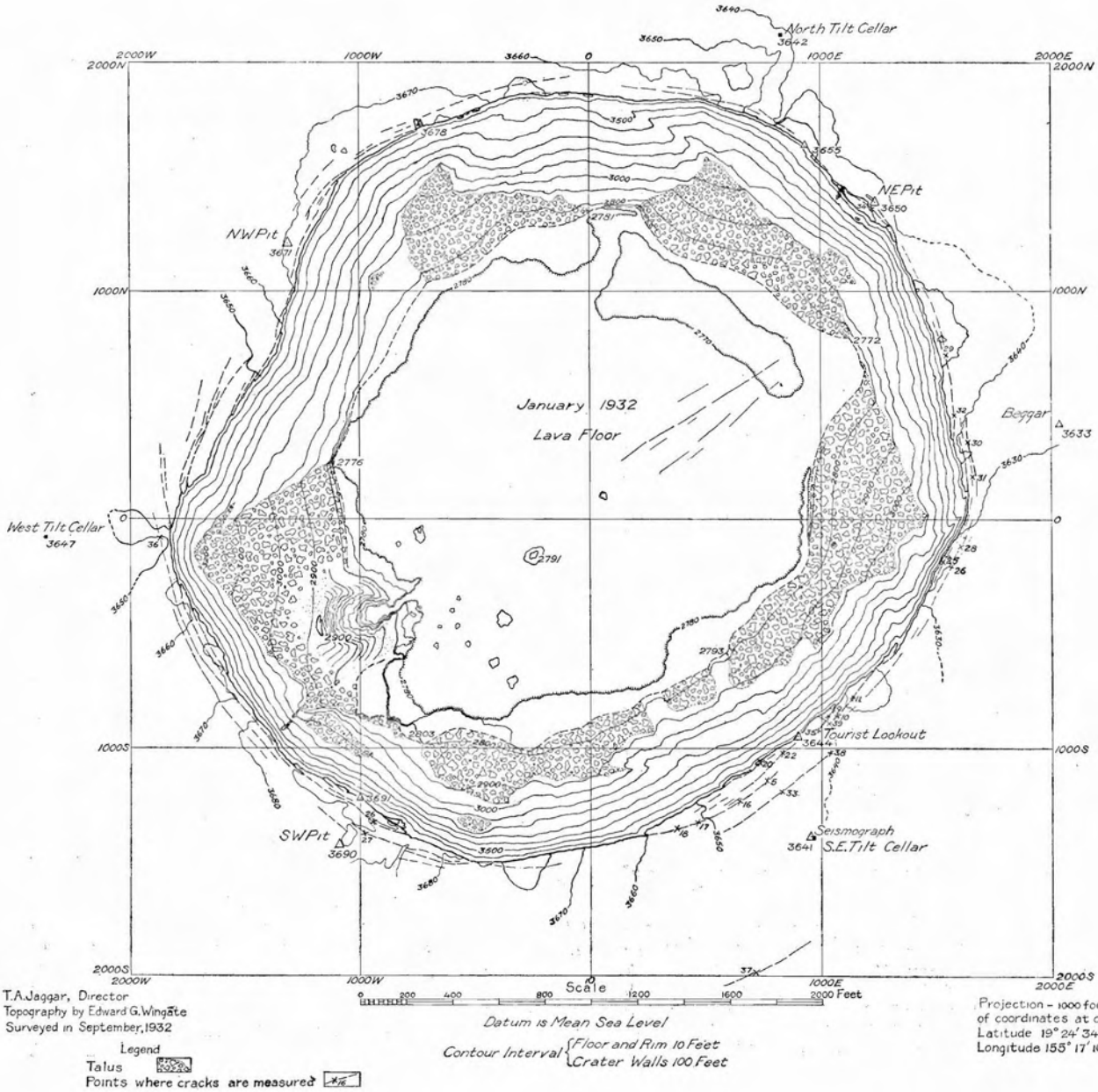
In March, 1932, special postal cards of the U. S. Geological Survey were placed at twenty-five stations on the island Hawaii, to be sent to Kilauea Observatory reporting felt shocks At the present time sixty-one card records of the new series are on file. These are of value in showing what shocks were general, and what ones were localized. A report of the results of these records will be published by A. E. Jones, seismologist. We shall be glad to supply other reporters who are interested. The following have earned the gratitude of the Observatory by sending in postals:—

L. P. Lincolu, Hookena
R. Lyman, Pahoa
J. B. Fordyce, Hawaii National Park
Kohala Sugar Co. Hawi
C. S. Ishii, Kamuela
R. Buzzard, Waikii
R. V. Woods, Kealakekua
J. B. Albert, Hilo
R. B. Hodges, Hawaii National Park
R. E. Baldwin, Hilo
R. L. Hino, Kukuihaele
Honokaa Sugar Co, Haina
Hutchinson Sugar Plantation Co. Naalehu
J. B. Oliver, Honomu
L. Loon Pahala
Hakalau Plantation Co. Hakalau
J. Johnston, Ookala
Kukuihaele Manager, Kukuihaele
E. Brumaghim, Hawaii National Park
Archdeacon Walker, Kohala
R. R. Craik, Hilo
W. Akau, Kawaihae
J. M. Ross, Hakalau
J. M. Ross, Hakalau

DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
HAWAIIAN VOLCANO OBSERVATORY

MAP OF HALEMAUMAU

ISLAND OF HAWAII
KAU DISTRICT
KILAUEA CRATER
HAWAII NATIONAL PARK



T.A.Jaggar, Director
Topography by Edward G.Wingate
Surveyed in September,1932

Legend
Talus
Points where cracks are measured

Datum is Mean Sea Level
Contour Interval {Floor and Rim 10 Feet / Crater Walls 100 Feet

Projection - 1000 foot grid. Origin of coordinates at center of map is:-
Latitude 19° 24' 34" N
Longitude 155° 17' 10" W

The Volcano Letter

No. 395—Monthly U. S. Geological Survey, Hawaii National Park JANUARY 1933

KILAUEA REPORT FOR JANUARY 1933

Including weekly press reports 1094 to 1097, January 1 to January 29 midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

There has been no activity on Kilauea or Mauna Loa. Small slides at Halemaumau were noted January 3, 4, and weakly at other times. Much steam developed on the pit floor due to heavy rains. Of twenty-five rim cracks measured each week about Halemaumau, slight widening was observed of only four January 7, nine January 14 about a sixteenth of an inch each, thirteen January 21, and, seven January 28. It will be observed below that the seismicity was lowest the week when the most cracks opened.

Wingate has started triangulation of the eastern rift belt of Kilauea near Kalapana, Jones made the circuit of the island Hawaii on visitation of seismographs, and Jaggar started a salinity survey of the sea-water at Keauhou Bay, Kona. Hydrometer tests showed freshness conspicuous along shore and in top water near shore, while bottom water out to nine fathoms was highly saline.

Earthquakes at Kilauea

Table (see Volcano Letter December, 1932; for for seismicity index (seis) see Volcano Letter 371)

Date	tr.	v. f.	f.	tel.	seis.
January 2 to 8	24	4	0	1	8.00
January 9 to 15	30	1	1	0	9.00
January 16 to 22	16	1	0	1	4.50
January 23 to 29	32	1	0	1	8.50

No shocks were felt at the observatory and none was reported from other parts of the island. The one feeble shock recorded at 0:45 p. m. January 11 evidently occurred at sea, about 20 to 30 statute miles northeast of Hilo. It was preceded during the noon hour by four foreshocks or tremors at unknown distance. Also a very-feeble shock, about 200 miles west to southwest of Hawaii, preceded it. This very-feeble shock was probably in the vicinity of a large submarine mountain. Following these two shocks were 11 tremors, the swarm ending at 1:54 p. m. January 12. Six of these tremors indicated distances of from 37 to 135 statute miles. A second swarm of 19 tremors was recorded January 28 and 29. It is not known whether or not these earthquakes occurred on one fault line.

The two earlier teleseisms were from New Guinea and the south Indian ocean, respectively: the last is as yet unknown.

A.E.J.

Tilting of the ground

The "Table of Tilt" shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory and from clinoscope readings at Halemaumau Southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given. The total accumulated tilt at the Observatory since January 29, 1932 is 8.1″ South and 1.5″ East.

TABLE OF TILT

Date	Observatory	Halemaumau
Jan. 2 - Jan. 8	0.8″ SSW	13.6″ SW
Jan. 9 - Jan. 15	0.6″ SSE	21.3″ NNE
Jan. 16 - Jan. 22	0.9″ SE	20.1″ NE
Jan. 23 - Jan. 29	1.1″ SSW	4.6″ E

E.G.W.

Waikii Seismograph Station

The Waikii Station on Hawaii island (mentioned in Volcano Letter 388) is in charge of the Radio Engineer of the Mutual Telephone Company in the grounds of the radio telephone establishment on the western slope of Mauna Kea. It is financed by the Hawaiian Volcano Research Association like the stations at Hilo and Kealakekua. We are indebted to Mr. A. W. Carter of the Parker Ranch for permission to install on this land, and to Mr. J. A. Balch of the Telephone Company for cooperation in the work.

The elevation is 4700 feet, the location Lat. 19 degrees, 51 minutes, 57 seconds North, Long. 155 degrees, 39 minutes, 7 seconds West. The seismograph is a two-component Hawaiian type horizontal pendulum apparatus (Bull. Hawn. Volc. Obsy. XVI, No. 8, August 1928) and was set up by A. E. Jones during October 19 and 20, 1932. The observer is Ralph Buzzard. The time service is from a Howard master pendulum clock checked by radio time from U. S. Naval Station, Pearl Harbor, Honolulu.

The piers are still settling and very little performance of earthquake registration has yet been obtained from this station. The seismograms are on smoked paper and are studied and recorded at the Hawaiian Volcano Observatory at Kilauea Volcano, Hawaii National Park.

T.A.J.

LASSEN REPORT No. 32

A report of measurements at the Lassen Volcano Observatory in California during the Calendar year 1932 indicates no crateral activity. C. A. Huff made experiments to synchronize the time markings by wired wireless on three seismographs Mineral, Viola and Harkness, work still awaiting completion. Tilting of the ground appeared to be mostly seasonal and a function of temperature.

The seismographs at Mineral recorded 83 local earthquakes as follows:—

January	3	July	9
February	2	August	15
March	2	September	2
April	0	October	13
May	6	November	5
June	20	December	6

The number of local earthquakes here registered per year has been:—

1927	266
1928	37
1929	96
1930	74
1931	38
1932	83

The indicated distance to origin of most of the local earthquakes of which the seismograms permitted measurement ranged from 12 to 20 kilometers, for the 1932 records.

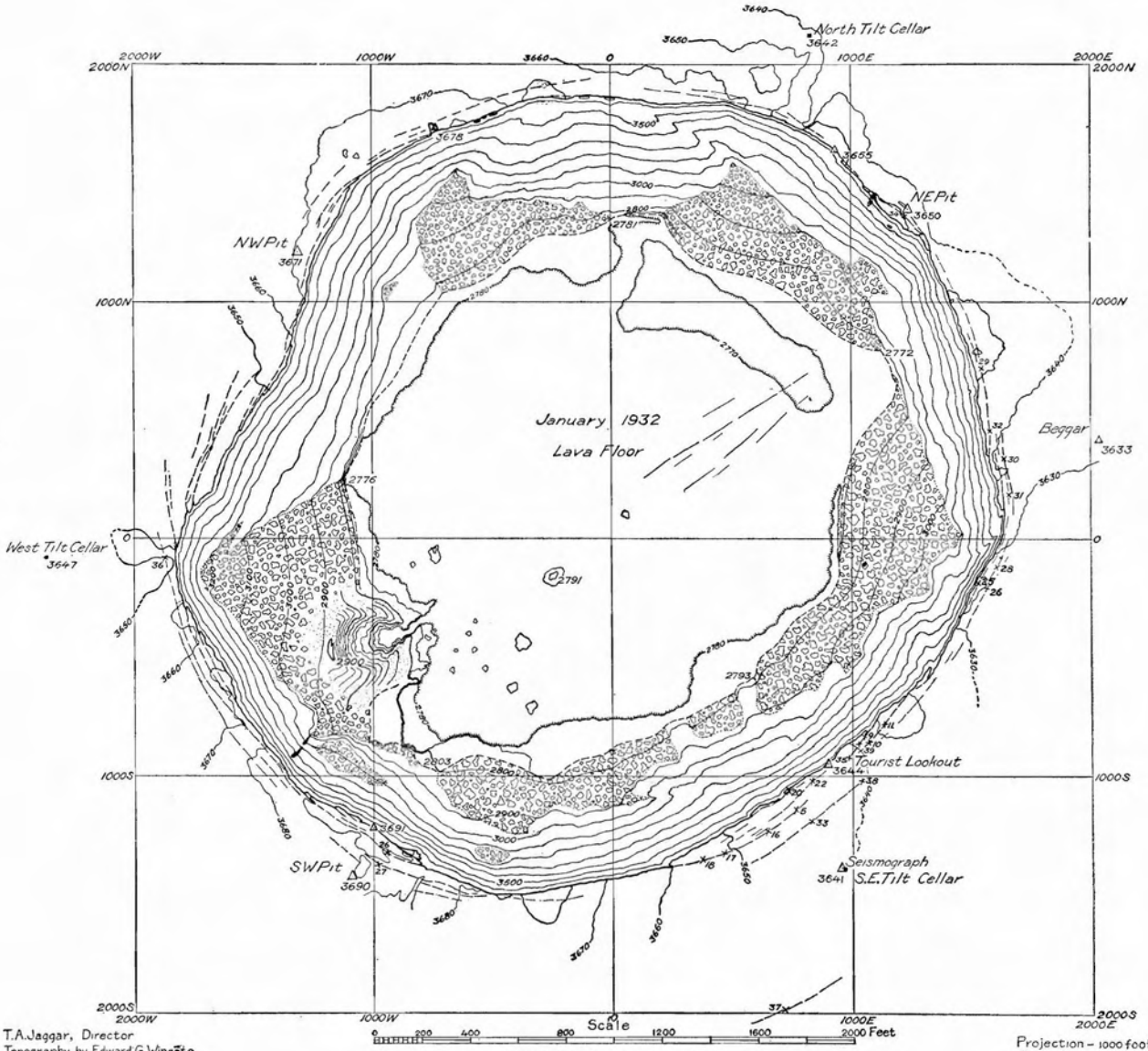
For the hot springs and steam vents, temperatures Fahrenheit measured mostly in August showed Supan's Big Steamer 192-194°, with vent enlarged toward the west, and mud ejected beyond the south rim. The New Vent of Diamond Peak gave 198°. The Lassen Crater vents 120, 142 and 146°. Bumpass Hell registered about 193°. Boiling Lake gave 124 to 148° in the water, 192 to 200° in the mud and steam vents. Terminal Geyser was 198°. Devil's Kitchen gave 196 to 200°, the big steam jet boiling with great vigor and slight overflow. Little Hot Springs Valley October 31 measured 198° imperfectly, the high velocity of escaping steam preventing proper use of thermometer. Morgan Springs gave from 148 to 202°. Supan's line of stakes showed slipping between No. 0 and No. 2 of 1.1 feet, a displacement which was distributed back to 0 between No. 2 and No. 5.

R. H. Finch

DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
HAWAIIAN VOLCANO OBSERVATORY

MAP OF HALEMAUMAU

ISLAND OF HAWAII
KAU DISTRICT
KILAUEA CRATER
HAWAII NATIONAL PARK



T.A. Jaggar, Director
Topography by Edward G. Wingate
Surveyed in September, 1932

Legend
Talus
Points where cracks are measured

Datum is Mean Sea Level

Contour Interval { Floor and Rim 10 Feet
Crater Walls 100 Feet

Projection – 1000 foot grid. Origin of coordinates at center of map is:-
Latitude 19° 24′ 34″ N
Longitude 155° 17′ 10″ W

The Volcano Letter

No. 396—Monthly | U. S. Geological Survey, Hawaii National Park | FEBRUARY 1933

KILAUEA REPORT FOR FEBRUARY 1933

Including weekly press reports 1098 to 1101, January 30 to February 26 midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

There is little to report for the Hawaiian volcanoes which have been apparently entirely quiet during the month of February 1933. There has been much rain which produces visible vapor plumes on the bottom of Halemaumau pit of Kilauea volcano. Rock slides from the pit wall have been rare, and the clinoscopes around the pit have generally shown little tilt, though the southeast station recorded below always shows larger tilts than the Observatory on the northeast rim of the larger Kilauea crater. The record there of 50.2 seconds January 29—February 5 checked with excessive temporary pooling of rain-water close to the hut; the rainfall was 6.16 inches in two days January 30-31.

Crack measurements around Halemaumau rim at 25 points showed five very slightly opened February 4th, eight February 11th, six opened and four closed February 18th, twelve opened and three closed February 25th. The aggregate opening for the twelve was only 1.36 millimeters.

A report of a tidal wave at Kaupoa on the west end of Molokai at night about February 14, with heavy surf flooding inland 100 to 200 feet horizontally, may indicate the aftermath of extraordinary westerly wind which produced unusual wave bombardment accompanied by very heavy microseisms at the seismographs the first part of the month. Thus it will be seen that meteorological conditions of rainfall and wind, as mentioned in this report, may produce seemingly seismic effects.

T.A.J.

Earthquakes at Kilauea

TABLE

(Numbers of tremors, very feeble and feeble local earthquakes: teleseisms or distant earthquakes: and local seismicity index described in Volcano Letter 371)

Week ending	tr.	v. f.	f.	tel.	seis.
February 5	22	1	1	0	6.75
February 12	29	2	0	0	8.25
February 19	22	4	0	0	7.25
February 26	32	2	0	1	9.00

The feeble shock at 6.17 a. m. February 4 was reported felt at Holualoa, Hakalau, Hilo and the Hawaii National Park. The location as found from three stations was about 50 statute miles due south of the observatory.

The following very-feeble shocks have been located.

9:12 p. m. January 31, was placed 15 to 20 miles east of East point. This location is given for the reason that it was not recorded at the Kona seismograph station.

11:56 a. m. February 10 was located 33 miles deep under a point half way between Kilauea and Mokuaweoweo craters.

8:24 p. m. February 13, distances from four stations, placed it in NW Kohala. The depth was possibly less than 5 miles.

Two earthquakes were felt in Honokaa. The first at 0:38 p. m. February 16 was located 23 miles deep under the peak of Mauna Kea. The second at 7:14 p. m. February 18 was located 7 miles deep under Ookala on the Hamakua coast. Both of these shocks were registered at four seismograph stations. The second was recorded as a tremor at the Hawaiian Volcano Observatory.

0:29 p. m. February 18, did not record at the Hilo station but with the aid of the Waikii record it was located 35 miles deep under a point 7 miles NE of Mokuaweoweo crater.

10:30 a. m. February 21 was located 20 miles deep under Mauna Loa.

8:00 a. m. February 22 was located about 12 miles at sea, 1 to 5 miles deep on the probable extension of the Kilauea SW rift.

Two others that could not be located were probably a short distance at sea.

Nine tremors showed some slight evidence of having originated some distance at sea. In one case as much as 500 kilometers or 300 miles away from the observatory.

A.E.J.

Microseisms

This motion of the ground appears to be prevalent throughout the world. Abnormal, large or strong microseisms have been correlated with large ocean waves or seas striking on the steeper coasts of the regions studied. In Europe the correlation has agreed with heavy surf on the coast of Norway. In North America they have been correlated with strong waves pounding the coast of Labrador. The change from light to moderate to strong and reverse is not abrupt. The transition between steps takes place slowly, often taking hours or a day to change from normal to abnormal. They have not been correlated definitely for the Island of Hawaii, but appear to vary with variations in the strength and direction of the sea waves. Ordinarily the time for a complete period, or motion of the ground to and fro, is 4 seconds, rarely it is 3 or 5 seconds.

The following inclusive dates under abnormal and subnormal give the intensity of the microseisms at this station since last published.

Abnormal	1932	Subnormal
Nov. 18, 24, 25.		May 23.
28, 29, 30.		May 28 to June 7.
Dec. 8, 10, 11.		June 11, 13, 14, 17, 18, 21.
22, 23, 24.		June 24 to July 1.
28, 29, 30		July 4 to 9.
		July 17, 18, 24.
		July 26 to 29, and 31.
		Aug 2 to 6, and 9 to 16.
		Aug. 25, 26
		Sept. 1, 2, 5, 6, 8, 15.
		Oct. 8, 9, 28, 29, 30, 31.
		Nov. 22.
		Dec. 3.

Abnormal	1933	Subnormal
Jan. 12.		Jan. 2 to 7
Feb. 4 to 7.		Jan. 19 to 30
Feb. 9 to 11		Feb. 18, 19

A.E.J.

Tilting of the ground

The "Table of Tilt" shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory and from clinoscope readings at Halemaumau Southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given. The total accumulated tilt at the Observatory since February 26 1932 is 7.5″ South and 1.5″ East.

TABLE OF TILT

Date	Observatory	Halemaumau
Jan. 29 - Feb. 5	3.4″ SW	50.2″ SSW
Feb. 6 - Feb. 12	1.8″ S	9.0″ SSW
Feb. 13 - Feb. 19	1.1″ SSE	2.4″ ENE
Feb. 20 - Feb. 26	0.3″ SW	14.6″ NE

E.G.W.

The Volcano Letter

No. 397—Monthly U. S. Geological Survey, Hawaii National Park MARCH 1933

KILAUEA REPORT FOR MARCH 1933

Including weekly press reports 1102 to 1106, February 26 to April 2 midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

March of 1933 was eventful in the seismic world by producing a terrific submarine earthquake east of Japan, and the so-called Long Beach earthquake disaster in the Los Angeles region of California. Hawaii suffered from the former with a tidal wave. But the volcanoes of Hawaii remained at peace.

The first week of the month was rainy, on March 5 in the forenoon rocks were heard falling frequently from the walls of Halemaumau pit at Kilauea after heavy rain March 4, there was moderate blue fume, and numerous small jets made plumes on the lava floor of the pit. Ponds of water had accumulated on the Kilauea crater floor. A small slide fell from the east end of the north buttress at 11 a. m. March 11; there were yellow scars on the east wall and fresh debris south. On March 18 a rim block southwest showed new cracks, a slide had fallen from a shell-shaped pocket in the northeast wall of the pit, and sulphur stain had incresased on top of the inner 1932 cone. During the forenoon March 25, slides occurred at the south 9:35 a. m., west of the north buttress at 10:16 a. m., then a third was heard, and the pit walls showed fresh scars. On April 1 the walls were quiet.

The weekly measurements of rim cracks at Halemaumau gave results as follows; March 4, 7 points opened out of 25, a few slightly closed, maximum motion at a single crack a widening of 1.5 mm., aggregate opening of all 3.5 mm. March 11,15 points out of 25 opened by slight amounts. March 18, 9 points out of 26 opened by slight amounts of 1.5 mm or less. March 25, 12 points out of 26 opened, maximum single opening 2.5 mm. both ends of a rim block southeast showed slight acceleration of opening at the back of the block, and a crack back of a block southwest opened 1.5 mm. April 1, 12 points out of 26 opened 1 mm or less mostly southeast and south.

Volcanologist Jaggar visited Waikii seismograph station March 14, and Honokaa shock-recorder station conducted by Mr. Pritchard March 15, and made tests at Keauhou Kona March 19 with hydrometers and bottom samplers furnished to the Observatory by the U. S. Coast Survey. Engineer Wingate prepared ground near Kapoho and Kalapana in Puna for triangulation towers to be built by the Hawaiian Volcano Research Association, capable of enduring for thirty years of repeated tests for ground movement. An experimental earthquake annunciator was set in operation at the Observatory, capable of releasing a four-point electric indicator in a room above, for grades one, two, three and four of an earthquake intensity scale. Seismologist Jones built a non-tilt attachment for improving the seismograph registration at Waikii, where the nature of the ground has given trouble with tilting effects and other movements which obscure the true seismic motion.

T.A.J.

Earthquakes Recorded.

TABLE

Number of tremors, very feeble, and feeble local earthquakes; teleseisms or distant earthquakes: and local seismicity index described in Volcano Letter 371.

Week ending	tr.	v. f.	f.	tel.	seis.
March. 5	17	2	0	1	5.25
March. 12	24	4	0	1	8.00
March. 19	20	2	0	0	6.00
March. 26	21	4	0	0	7.25
April. 2	31	4	0	0	9.75

An earthquake was felt at Honokaa February 27 at 8:46 p. m. H. S. T. It recorded on the observatory instruments as a tremor, and indicated a distance of 52 statute miles. This would place it under Waipio valley at the greatest possible horizontal distance.

A very feeble shock was recorded at 9:13 p. m. February 28. It has been located at lat. 19° 42.5′ N; long. 156° 05′W near Keahole Point.

A tremor recorded at 5:24 p. m. March 8 was located about 22 miles west of Keauhou Bay on the west side of Hawaii.

A very feeble shock recorded at 5:29 p. m. March 8, was located 7 miles deep under Hilina Pali (a fault scarp cliff). A second very feeble shock at 10:40 p. m. may have occurred on the same fault. It was not so well recorded at Hilo.

A very feeble shock at 10.02 a. m. March 9 was located approximately under Palima Point. It was reported felt in Pahala and in the vicinity of Kilauea crater.

A very feeble shock at 1:08 a. m. March 25 was located 13 miles deep under Napau Crater.

An earthquake felt at Kamuela at 1:55 a. m. March 28 was recorded at the observatory as a tremor. It was not recorded well enough on the other stations to be located. A second shock at 4:26 a. m. was felt as far south as Honomu. It was also reported from Honokaa, Kamuela and Waikii. Distances from two stations placed it 1 to 3 miles deep under central Kohala.

Two very feeble shocks and two tremors occurred less than 3 miles from the observatory, this would place them close to or in the Crater of Kilauea.

The teleseisms listed above were destructive near their epicenters. The location of the first near the coast of Japan was given by the U. S. C. & G. S. as at lat. 39° N long. 142° E. The arrival of the first preliminary was at 7:10:32 a. m. March 2 H. S. T. (10h 30m slower than Greenwich).

The location of the second, March 10 near the California coast was given by the Jesuit Seismological Association as lat. 32° N 118° W. Only the surface waves recorded at H. V. O. This was the Long Beach earthquake.

Microseisms were abnormal or strong March 4 & 5, they were subnormal or light March 12, and from March 21 to April 2.

A.E.J.

Tsunami or earthquake tidal wave March 2, 1933

The distant earthquake on the sea-floor about 7:10 a. m. Hawaiian time as registered at the Kilauea stations, occurred at the western edge of the Tuscarora Deep, 125 miles east of Matsushima, Japan, and near this place the ocean is more than 26,000 feet in depth. The elastic wave through the earth took 10 minutes to reach Hawaii. It registered on the seismograms at Kilauea, Kona and Hilo as a very big movement for several hours, too slow to be felt. The indicated distance was 3950 miles in the azimuth of Japan. The hour and date were 2:31 a. m. March 3 by Japan time.

It was immediately apparent to A. E. Jones, seismologist at Kilauea, and to R. V. Woods, seismograph operator for the Hawaiian Volcano Research Association at Kona on the west side of Hawaii, that a tidal wave in the Pacific ocean might occur. The Radio News Broadcast announced the Japanese earthquake as a disaster about noon March 2 in Hawaii. Radio thus confirmed the notion that the water wave should come from the west, at a time before the water wave had arrived at Hawaii. Travelling 450 miles per hour, such a wave should reach Hawaii 8½ hours after the earthquake occurred.

Mr. Jones notified the Hilo Harbormaster about 10

a. m. to look for a wave about 3:30 p. m. The sampan fleet in the river was moved out to anchorages in the harbor, the waves came at 3:36 p. m., and the range of maximum motion in Hilo was from two to three feet, on the east side of Hawaii; time within six minutes of the expectancy indicated.

Captain Woods on the west side notified American Factors at Kailua and at Napoopoo, and the Captain Cook Coffee Co. that the wave might come about nine hours after 7 a.m. The waves came at the time appointed with great force on the western side of Hawaii, the side towards Japan. They came in a series of swings of the water for hours, beginning with recession. They began about 3:20 p. m. at about ten minute intervals, and the seventh wave was reported the greatest at Napoopoo. There the water receded below mean tide eight feet, rising above mean tide 9½ feet, total vertical range 17½ feet.

The sea-bottom was left bare over wide tracts of the bays at Napoopoo, Kailua, Keauhou and even at Kaalualu at the southeast end of Hawaii. Walls washed down, boats were unmoored and capsized, houses were flooded and moved, lumber was displaced, objects were washed out to sea, damage was done to interior furniture of houses, automobile lorries were flooded so that engines were damaged by sand, and goods were washed off wharves. At Napoopoo the events of 1896 and 1923 were remembered, and cargo was removed from the wharf in expectation of the wave.

At Honolulu the tide gauge made twenty fluctuations in 4 hours, making each complete wave average twelve minutes period. The waves were noted at Kauai, at west Oahu, at Lahaina, and were somewhat damaging at Kawaihae and vicinity on the northwest shore of Hawaii. The train of waves struck Midway Island between 11:05 a. m. and 1 p. m., Honolulu beginning 2:40 p. m., the west side of the island Hawaii 3:20. p. m., and Hilo 3:36 p. m. all progressively farther from the Japanese source.

In Japan there was a great disaster in Iwate province from both earthquake and tidal wave, with reported loss of 1535 lives, 2000 wounded, 7930 houses, 1570 boats, and millions of dollars of property damage at the ports of Kamaishi, Miyako, Yamoto and Omoto.

T.A.J.

Tilting of the ground

The Table of Tilt shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, and from clinoscope readings at Halemaumau southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given; the total accumulated tilt in a year since April 2, 1932 at the Observatory has been 2.2 seconds south, and 2.1 seconds west.

TABLE OF TILT

Date	Observatory	Halemaumau
Feb. 26 - Mar. 5	3.3″ SSW	21.4″ SSW
Mar. 6 - Mar. 12	0.9″ NE	7.5″ North
Mar. 13 - Mar. 19	2.2″ WSW	5.2″ East
Mar. 20 - Mar. 26	0.3″ NW	15.9″ NNE
Mar. 27 - Apr. 2	1.6″ SW	6.5″ NE

E.G.W.

The Volcano Letter

No. 398—Monthly U. S. Geological Survey, Hawaii National Park APRIL, 1933

KILAUEA REPORT FOR APRIL 1933

Including weekly press reports 1107 to 1110, April 2 to April 30, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

The weather at the volcano Kilauea the first week in April was stormy, with thunder, lightning and southerly wind. No crateral changes of importance were observed in the quiet Halemaumau lava pit of Kilauea, nor on the summit of Mauna Loa. There was no sliding of rocks at the Halemaumau walls. A National Park party led by Ranger Fordyce, and accompanied by seismologist Jones, went to Mokuaweoweo, the summit crater of Mauna Loa April 10-12, encountered cold weather with snow, but discovered no new solfataric activity nor steaming.

At Halemaumau April 10 there were falls of rock from the northern walls, and a small avalanche fell from the notch at the east side of the north buttress at 9:35 a. m. During heavy rain there were numerous vapor jets at cracks in the lava floor, and this continued during cessations of the rain. A large pool of water near the southeast tilt cellar did not induce visible tilt at the clinoscope. On April 17 a dusty avalanche scar was discovered, 200 feet wide, extending from top to bottom of east wall of pit. The debris had landed on talus below. The east end of the canoe sill northeast had been breaking away, and rocks fell there from time to time. On April 19 there was similar falling of rocks, while small trickling slides and rock falls continued April 20. There were a few rocks falling April 26, but none during the forenoon of April 29.

Measurement of rim cracks about Halemaumau was recorded weekly as follows:—April 8, 8 points out of 26 opened 1 mm or less, 2 cracks slightly closed. April 16, 9 cracks out of 26 made aggregate opening of 6 mm. April 17 crack point No. 11 just above the new east avalanche scar had closed 2 mm, while four other nearby points had opened each a half millimeter. April 19 a newly moving crack showing broken ground on the southwest rim was found opening a quarter millimeter per day. April 22, 14 points out of 27 opened 2 mm or less, mostly at east side. April 29, 10 points out of 27 opened, 2 slightly closed, aggregate opening with these deducted making 6.5 mm.

T.A.J.

Earthquakes Recorded.

TABLE

Number of minutes of tremors, very feeble and feeble local earthquakes; teleseisms or distant earthquakes; and local seismicity index described in Volcano Letter 371.

Week ending	tr.	v. f.	f.	tel.	seis.
April 9	34	4	0	2	10.50
April 16	65	2	1	0	18.25
April 23	45	2	0	0	12.25
April 30	49	3	1	2	14.75

Hawaiian Standard Time is 10h. 30m. slower than Greenwich.

Spells of 5 and 16 minutes of tremor were recorded the first two weeks of the month. One tremor, recorded at the Kilauea station and at Hilo about 0.28 a. m. April 9, gave larger records as a local earthquake at the Kealakekua and Waikii stations. It was located seismometrically as at the northwestern shore of Hawaii, about 14 miles deep, under Kiholo Bay, Lat. 19° 15′ N.—Long. 155° 54′ W.

A feeble shock, felt in Hilo, at 4:10 a. m. April 16, was located as at sea a short distance WSW from Kalapana, 20 miles deep, Lat. 19° 13′ N, Long. 155° 03′ W.

A very feeble shock was well recorded at four stations at 0:11 a. m. April 30. It was located under a point a short distance out to sea, 12 miles deep, along the extension of the Kilauea SW rift zone, Lat. 19° 13′ N., Long. 155° 18′ W.

A feeble earthquake at 5:24 a m. April 30 was felt at Kilauea and located slightly south of Kilauea crater (3 miles) as 20 miles deep, Lat. 19° 22′ N., Long. 155° 17′ W.

A moderately large record of an Alaskan earthquake from Lat. 61° N, Long. 150° W. was registered on April 26. Only the surface waves of the three other teleseisms were recorded here.

Microseismic motion was abnormally large April 3 to 4; it was subnormally light on April 10, and from 12 to 30.

A.E.J.

Tilting of the ground

The Table of Tilt shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, and from clinoscope readings at Halemaumau southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given; the total accumulated tilt in a year since April 30, 1932 is 4.6 seconds south, and 3.7 seconds west.

TABLE OF TILT

Date	Observatory	Halemaumau
April 3 - 9	2.7″ SW	24.3″ SW
April 10 - 16	0.6″ SSE	5.7″ NNE
April 17 - 23	1.3″ ENE	10.5″ NE
April 24 - 30	1.0″ SW	4.2″ NE

E.G.W.

The Volcano Letter

No. 399—Monthly U. S. Geological Survey, Hawaii National Park MAY, 1933

KILAUEA REPORT FOR MAY, 1933

Including weekly press reports 1111 to 1115, April 30 to June 4, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

No renewed lava outpouring has appeared in Hawaii. The last such activity was in Halemaumau pit in January 1932. At this pit within Kilauea crater at 8 a. m. May 6 there was trickling of rock fragments down the inner walls. On May 10 fresh scars from a slide were found on the east wall. The fall of rocks had occurred during the preceding night, and at the ends of old rim cracks on top, fresh hair cracks had developed in the soil. One rock was heard to fall in the morning. During the third week a slide fell from the west wall, where there had been little motion for several months past. Slight slides continued. June opened with only the promise based on statistics, that activities during this century have averaged once a year, and now a year and a half of quiet have gone by.

Weekly measurement of twenty-seven rim cracks around Halemaumau yielded the following results: May 6, 5 cracks opened slightly, 1 closed a half-millimeter, net aggregate opening 3 mm, mostly southeast; May 13, 10 opened and three closed, aggregate opening 4.5 mm; May 20, 15 opened and 4 closed, aggregate opening 12 mm; May 27, 8 opened and 2 closed, aggregate opening 4 mm; on May 30 a crack on the northeast rim had opened ½ mm in three days; June 3 the weekly measurement showed 15 opened and 3 closed, making net opening 9.5 mm. All this work is directed by Engineer Wingate.

T.A.J.

Earthquakes Recorded.

TABLE

Number of minutes of tremors; very feeble and feeble local earthquakes; teleseisms or distant earthquakes; local seismicity index described in Volcano Letter 371.

Week ending	tr.	v. f.	f.	tel.	seis.
May 7	32	4	0	2	10.00
May 14	39	3	2	0	13.25
May 21	27	5	0	0	9.25
May 28	33	6	1	0	8.00

Hawaiian Standard Time is 10h. 30m. slower than Greenwich.

The following locations of earthquake origins were derived seismometrically from measured seismograms of the four principal stations on Hawaii, Kilauea, Kona, Waikii and Hilo; 3:50 p. m. May 2 under the divide between Mauna Loa and Hualalai; 7:30 p. m. May 9, felt moderately at Puu Ulaula rest house on northeast rift of Mauna Loa, 5 to 12 statute miles deep under that part of the mountain; 6:54 p. m. May 17 a shock felt at Hakalau, on the northeast coast of Hawaii, under a point about 1 mile out to sea from that village, and 15 miles deep. A very feeble shock May 20 was located under the northeast rift of Mauna Loa. A shock 0:21 a. m. May 24, felt at Honokaa, was located on the west shoulder of Mauna Kea, Lat. 19 degrees 49 minutes N., Long. 155 degrees 37 minutes W.

Other local earthquake centers were as follows: 7:31 a. m. May 24, felt at Honokaa, Lat 20 02 N. Long 155 31 W, 3 miles deep, halfway between Mauna Kea and the ocean to the north; 7:48 a. m. May 25, very feeble, Lat 19 55 N, Long 155 35 W, under the northwest shoulder of Mauna Kea, and not over 5 miles deep; 11:38 a. m. May 27, feeble and felt at Kilauea Observatory, Lat 19 27.5 N, Long 155 27.5 W, under a point half way between Kilauea Crater and the Mauna Loa crater, 7 miles deep; 1:47 a. m. May 28, felt at Holualoa in North Kona, approximately at sea off Keauhou Bay.

The distant earthquakes, only partially recorded, beginning 8:37 a.m. May 1, and 6:00 p. m. May 4, were from unknown locations. Microseismic motion was mostly subnormally light for the month, becoming normal at the beginning of the second, and throughout the third week in May.

A.E.J.

Tilting of the ground

The Table of Tilt shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, and from clinoscope readings at Halemaumau southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given; the total accumulated tilt in the year since May 28, 1932 at the Observatory has been 7.8″ south, and 4.0″ west.

TABLE OF TILT

Date	Observatory	Halemaumau
May 1 - May 7	1.0″ WSW	1.3″ NNE
May 8 - May 14	0.3″ SW	0.9″ SSE
May 15 - May 21	1.8″ NE	4.9″ NW
May 22 - May 28	0.8″ WNW	0.0

Halemaumau readings for May show exceptional quiet as compared with other months; the following is a comparison of net tilt by months at Halemaumau southeast, and average rim crack openings by months for the whole 27 marked crack points. If these figures show anything, it is that the crack widening lags behind the tilts. The tilt movements notably alternate between northerly and southerly.

Average crack opening	Halemaumau Tilt by months	
Jan. 0.0160 Cm	8.3 seconds	NNE
Feb. 0.0170	23.2	SW
Mar. 0.0310	18.1	NE
Apr. 0.0260	6.0	SW
May 0.0235	5.0	SW

Spirit Level Changes at Halemaumau

Levelling executed June 12, 1933 for comparison with similar measurements December 31, 1932, giving differences of elevation of points near Halemaumau relative to the datum station Spit southeast of Kilauea Crater resulted as follows; elevation of Spit 3646.93 feet:—

BM Seis June 12	plus (up)	0.02 foot
BM No. 1, Tourist June 12	minus (down)	0.05 "
BM Beggar " "	"	0.03 "
BM NE Pit " "	"	0.08 "
Crack point No. 18 " "	"	0.33 "

The accumulated tilt at the clinoscope of Halemaumau SE (BM Seis above) between December 31 and May 31 was 4.2 seconds of arc SW.

Triangulation in Puna

Field observations over the Puna Triangulation net were completed May 28th. Favorable weather aided the work, and seventeen stations were occupied between May 16 and May 28. Unchecked notes indicate a triangle closure of about 2.1 seconds for 39 triangles. A complete report on the survey will be prepared for June Volcano Letter.

E.G.W.

The Volcano Letter

No. 400—Monthly U. S. Geological Survey, Hawaii National Park JUNE, 1933

KILAUEA REPORT FOR JUNE, 1933

Including weekly press reports 1116 to 1119, June 4 to July 2, midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

Levels run about northeast rim of Halemaumau June 12 showed that the rim had generally lowered, less than one-tenth foot, since December 31, 1932. Weekly measurement of the 27 rim cracks at Halemaumau gave the following:—June 10, 7 points not more than ½ mm each. Two cracks forming a crescent block on the rim south and southwest, about 500 and 800 feet long, showed fresh hair fissures in the soil. June 12 similar cracks were found 100 to 150 feet back from the east and northeast rim. June 17 eleven points showed widening of 1½ mm or less, nine of these being at the east. Aggregate opening for all cracks was 7 mm. June 24 eight cracks had widened 1½ mm or less, mostly southeast, aggregate opening 5 mm. July 1 six points opened only a half millimeter each.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor, very feeble, feeble, and slight earthquakes; teleseisms or distant earthquakes; local seismicity index as described in Volcano Letter 371.

Week ending,	tr.	v. f.	f	sl.	tel.	seis.
June 4	26	3	0	0	0	8.00
June 11	56	4	1	0	0	17.00
June 18	49	3	0	0	1	13.75
June 25	32	3	2	0	1	11.50
July 2	78	2	0	2	1	25.00

Hawaiian Standard Time is 10h. 30m. slower than Greenwich.

The teleseisms were only partly recorded.

Tilting of the ground

The Table of Tilt shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, and from clinoscope readings at Halemaumau southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given; the total accumulated tilt in the year since July 2, 1932 at the Observatory is 4.9″ south and 2.2″ west.

TABLE OF TILT

Date	Observatory	Halemaumau
May 29 - June 4	0.3″ NE	1.4″ N
June 5 - June 11	0.4″ NW	2.7″ S
June 12 - June 18	0.8″ NNE	11.0″ N
June 19 - June 25	1.0″ NNE	10.8″ NNE
June 26 - July 2	0.9″ N	6.4″ NNE

E.G.W.

PUNA TRIANGULATION

Prof. C. Tsuboi, writing in the 'Bulletin of the Earthquake Research Institute, Tokyo Imperial University, Vol. VI, March 1929 an 'Interpretion of the Results of Repeated Precise Levellings in the Tango District', remarks in the beginning, "In the country of Japan, from which a world-shaking earthquake originates not rarely, the scope of seismology naturally goes further beyond the study of propagation of purely elastic seismic waves and is extended to the investigation of those geophysical phenomena that are characteristic to the localities of the earthquake origin."

Similar studies were initiated by Dr. T. A. Jaggar in 1920, here in Hawaii, when he directed the work of Mr. R. M. Wilson in laying out and measuring the net of triangulation and levels about Kilauea Crater. This net was later re-surveyed by Mr. Wilson and the actual ground movements detected by this survey showed the value of applying engineering methods to the study of volcanic and seismic phenomena.

An expansion, by means of similar surveys, into known seismic belts on this island had been long contemplated, only a shortage of funds preventing an earlier beginning. The northeast rift of Kilauea, at its eastern end, was selected for the initial expansion. This section has had volcanic and seismic activity upon four occasons within the last hundred years. On the accompanying map the localities affected are shown by the date of occurrence.

The northeast rift of Kilauea is not a ridge but is a

The following locations are of local earthquakes well recorded at three or more seismograph stations on the Island or Hawaii.

Date	time	lat. N.	long. W.	depth	remarks
June 7	10;38 a.m.	19°;53′	155°;17′.5	10 mi.	not reported felt. S. of Ookala, W. of Hakalau.
June 9	4;55 p.m.	19°;26′.5	155°;42′.5	0 mi.	sharply felt. M. Loa, SW of summit, under 1851 lava flow.
June 15	6;26 p.m.	19°;36′	155°;16′	2 mi.	not reported felt. M. Loa NE rift.
June 19	7:33 p.m.	19°;12′.5	155°;25′	5 mi.	not reported felt. Kilauea SW rift.
June 20	0;32 p.m.	19°;26′	155°;16′.5	2 mi.	not reported felt. under Kilauea.
June 22	8;33 p.m.	20°;03′	155°;33′	7 mi.	felt by several. Mana, SW of Honokaa
June 25	1;15 a.m.	19°;24′	155°;15′	1 mi.	not reported felt. SE of Kilauea.
June 29	0;44 a.m.	19°;40′	155°;48′	0 mi.	moved furniture damaged stone wall. Hualalai shock.
July 2	7;47 a.m.	under Kilauea			not reported felt.

Depths are in statute miles below sea level. The microseismic motion was normal June 30 being subnormal or light during the remainder of the time covered by this report.

series of earthquake cracks, cinder cones, and pit craters, extending along the shoulder of a slope to the south and seaward, which begins at Kapoho and gradually becomes steeper to the west. Faulted cliffs appear to the westward of Kalapana. To inland, or north, there is but little slope away from the rift. The whole area is more or less densely covered with a low-level semitropical forest. At Pahoa, Kapoho, and Kaueleau are cane fields of the Olaa Sugar Co. The lava flow of 1840 followed a course eastward roughly paralleling the rift on the north. North from this flow the country rapidly changes to a grass-covered pahoehoe plain, with a thin growth of Ohia Lehua.

Reconnaissance was begun in January and together with the clearing of trails and lines of sight, the marking of stations, and the erecting of signals, consumed about four-fifths of the working time.

Existing triangulation, in this section of the Puna District, was fragmentary, being confined to four stations on the rift, with some six additional points along the shore, none of which had been determined through figures of any great strength.

The problem in laying out the new net was to get at least two stations, to the north of the rift and the last known cracks, so located as to serve, in a future re-survey, as a probably undisturbed base for computations. All of the stations along the rift, as well as those on the shore, are considered subject to change through volcanic and seismic causes. It was also desirable, with the instruments available, to hold the length of sights to a maximum of ten and a minimum of two miles. Two suitable points were finally found and are represented by the stations 'Makuu' and 'Kokoolau'.

Of the existing stations, listed in U. S. C. & G. S. Special Publication No. 156, only two were found unsuitable for use. The station 'Kamaili' was so located that no sight of sufficient length could be taken to the east, and 'Sand Hill', a cinder cone at the sea end of the 1840 lava flow, is gradually peeling off into the sea.

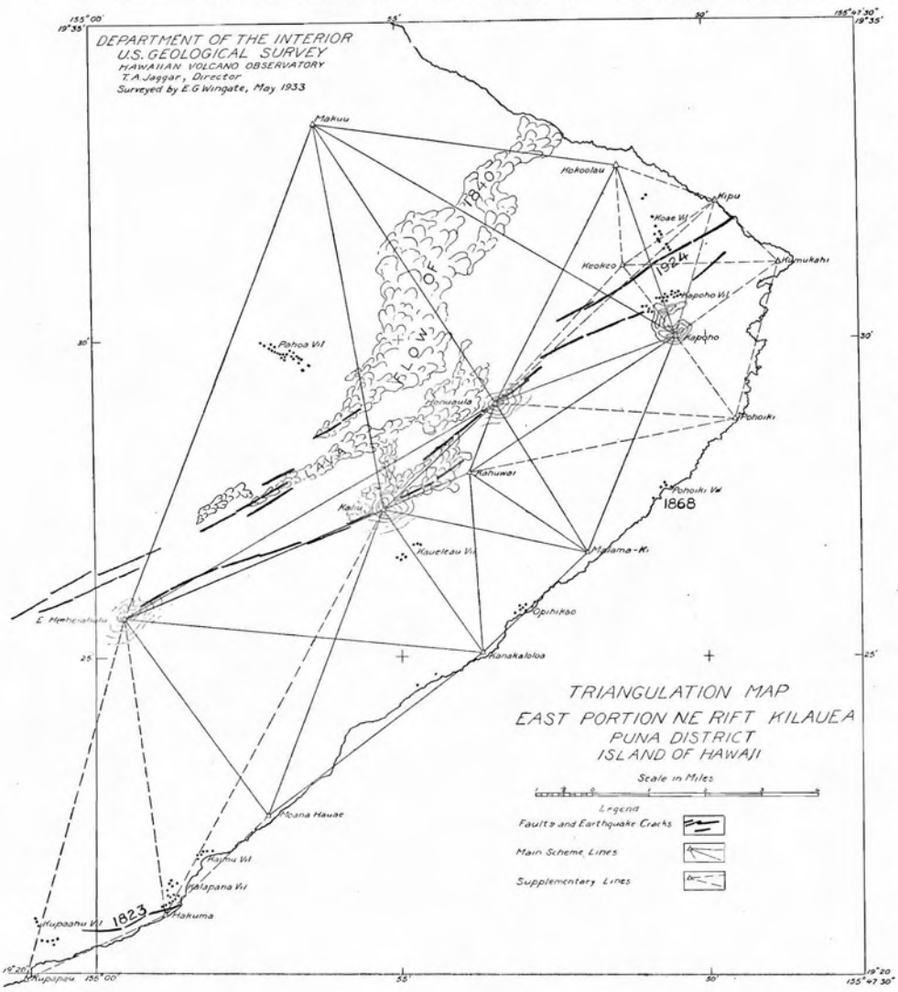
Two towers, of thirty and forty feet in height and of permanent construction, were erected under contract at stations 'Kanakaloloa' and 'Kokoolau' respectively. The observers' platform and scaffold were built around a separate, inner tripod to support the instrument.

The signals at E. Heiheiahulu, Kaliu, and Kapoho were of the new type adopted by the Hawaiian Territorial Survey and are described in 'Special Pub. No. 156' above. All other signals were 2x2 inch poles surmounted by cross targets of light weight galvanized iron, two feet square, painted in two colors, yellow and red. The signals were carefully centered by plumb line and all were erected within five days of the first observations.

The area surveyed was approximately ninety-five sq. miles and due to very favorable weather conditions all observations were completed in eleven days. A 'Berger' direction-transit graduated to 20 seconds, was used and the angles were read by repetition, six repetitions with the telescope direct, and six reversed. The horizon angle was similarly observed.

Twenty triangles in the main scheme had an average closure of 01.8 seconds, plus or minus and eighteen supplementary triangles closed with an error of 02.3 seconds, plus or minus.

The line, of existing triangulation, E. Heiheiahulu-Kaliu was adopted as a base for the present work as it appeared to be the line least subject to disturbance since last measured in 1914.



Computation of the length through the main scheme by two separate chains of triangles adjusted only within themselves gives a closure in in the order of one part in 40,000. Every line, however, in the present survey is subject to the same errors inherent in the line of older triangulation chosen as a base, which was probably of third order accuracy.

Limited funds prohibited the measurement of a base and for the same reason the existing figures about Hakuma and Kupapau were not strengthened. The total field work cost an average of $73.00 a station.

The work was greatly facilitated by the courteous cooperation of officials of The First Trust Co. of Hilo and the Bernice P. Bishop Estate of Honolulu in permitting the erection of permanent towers on their property, and of Mr. Richard Lyman of the Olaa Sugar Co., in allowing the clearing of trees from certain lines of sight. Funds for the erection of the two towers were voted by the Board of Directors, Hawaiian Volcano Research Association, without which the survey as completed would have been impossible.

Complete records of the field observations have been furnished the Hawaiian Territorial Survey and the engineer of the Bernice P. Bishop Estate.

E.G.W.

The Volcano Letter

No. 401—Monthly U. S. Geological Survey, Hawaii National Park JULY, 1933

KILAUEA REPORT FOR JULY, 1933

Including weekly press reports 1120 to 1123, July 2 to July 30, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

The data about the crater of Kilauea, in the absence of lava activity at the inner pit Halemaumau, concern observation of slides from the inner pit wall, other changes if any at the pit, measurement of rim cracks about the upper rim of the pit, measurement of horizontal angle right to left across the pit for pit rim monuments, and tilt of the ground at the pit edge in the clinoscope cellars platted with reference to one component only, the line of direction connecting the center of the pit with each cellar; this is to find out whether the ring of ground around the pit is tilting inward or outward. These measurements are under the direction of topographic engineer E. G. Wingate.

On the outer Kilauea Crater wall (Uwekahuna) about three fourths of a mile south from the summit trig station west of the crater, a small slide left a scar which was detected July 15. There were recent slides on the west wall of the summit crater of Mauna Loa discovered at about the same time. In the early part of the month gales of wind from the northeast blew clouds of dust about the lee side of Kilauea crater into the southwestern country. The age-long persistence of the trade wind is a geologic force to be reckoned with in the transport of loose ash on the island of Hawaii.

In Halemaumau July 9 a few rocks had fallen from the south wall of the pit leaving a small dusty track, and a dark red patch on the northeast wall had appeared. On July 26 there were wall slides at 11:50 a. m., and at 0:50 p. m. The pit seismograph had shown four small quakes July 24, one of them accompanied with NNE tilt, but the walls showed no new scars from avalanches.

Measurement of rim cracks gave the following:— Out of 27 points, 8 showed no movement, 6 opened slightly, and 2 closed a half millimeter each, the area of movement being the rim southeast and south, the date July 8 for the previous week. The following week, date July 15, 12 points out of 27 had widened, 2 of them one half millimeter each, one 1 mm. Five cracks showed slight opening July 22, and 2 points on one crack showed slight closing. On July 29, six crack points showed very slight widening, two showed slight closing, the aggregate opening being 3 mm. One of the opened cracks is far back from the rim, half way between the sand spit south and Halemaumau.

The horizontal angle representing the SE-NW diameter of Halemaumau, as measured from the Observatory on the northeast edge of Kilauea crater, showed on July 28 a closing of 1.2 second since the last measurement on June 20, 1933, a period of 38 days. T.A.J.

LASSEN REPORT NO. 33.

During the first five days of July 1933, 53 earthquakes were recorded on the seismographs at Mineral. The distribution of the earthquakes by days was as follows:

July 1	3	shakes
2	5	"
3	4	"
4	39	"
5	2	"

Things had quieted down by July 8th. Several of the shakes were of sufficient intensity to be perceptible at Mineral, though more were felt in the eastern part of Lassen Park. The indicated distance from Mineral was about 10 miles.

R.H.F.

Earthquakes

TABLE

Number of minutes of tremor; very feeble, feeble and slight earthquakes; teleseisms or distant earthquakes; local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	f	sl.	tel.	seis.
July 9	54	8	0	0	1	17.50
July 16	82	9	1	0	0	26.00
July 23	74	13	2	1	1	29.00
July 30	51	9	0	0	0	17.25

A feeble earthquake was felt at the Volcano House at 0:45 a. m. July 14. It was about one statute mile from the observatory.

A feeble earthquake was felt in Hilo at 3:17 p. m. July 19; as located from the records of three stations it was 25 miles deep under the Kilauea southwest rift zone, near 19° 20'N; 155° 20'W.

A slight earthquake was felt by several near Kilauea crater at 0:39 p. m. July 20. It was less than four miles from the observatory and probably under the crater.

A feeble earthquake was recorded—not reported felt—at 5:59 p. m. July 22. It was about two miles away and under the crater of Kilauea.

During the period covered by this report 25 very feeble shocks and ten tremors have been located at shallow depths, under Kilauea crater. The greater number occurred during the third week when the seismicity figure was the greatest.

The first teleseism was poorly recorded, the second was fair showing several wave arrivals.

The microseisms or ground motion was moderate or normal July 6, 10, 11, 26, 27, 28, and 29, on the other days of the month it was light or subnormal. A.E.J.

Tilting of the ground

The Table of Tilt shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, and from clinoscope readings at Halemaumau southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given; the total accumulated tilt in the year since July 30, 1932 at the Observatory is 2.9" south and 2.1" west.

TABLE OF TILT

Date	Observatory	Halemaumau
July 3 - July 9	1.9" N	2.9" NW
July 10 - July 16	0.8" NNW	9.2" N
July 17 - July 23	0.1" WSW	2.9" WNW
July 24 - July 30	0.7" NNW	3.2" N

E.G.W.

Mauna Loa

For Mauna Loa on July 18 Messrs. Doerr and Wingate report steam seen chiefly in afternoon hours on the northeast rift 3 to 7 miles below Mokuaweoweo; no steam noticed in the north embayment of crater. A moderate amount of fume and steam came from sulphur cracks NNW of the cones of 1903. The 1914 cone was steaming strongly at the top, moderate fume issued from its vicinity, and sulphur patches were visible on the northern slopes of the cone. No fume or steam was observed at the south lunate platform. The west and northwest wall of the crater showed scars of recent rock slides, and at 12:55 p. m. a considerable slide occurred making streams of dust, with the wind blowing lightly from SW. Under clear weather conditions in still air Mr. Doerr notes that such dust might be seen from Kilauea, and it happens that on that same evening at Volcano House the volcanologist saw what looked like a faint fume cloud start above Mokuaweoweo and move slowly north, while the wind below at Volcano House was strong NE. Wingate reports that sulphur stain was seen from the east points of view at the base of, and on, the north wall of Mokuaweoweo about one half mile east of the summit trig station. The water holes examined had much less ice than during 1925-26. There was a small tremor on the Observatory seismogram about the time of the 12:55 avalanche in Mokuaweoweo.

The Volcano Letter

No. 402—Monthly U. S. Geological Survey, Hawaii National Park AUGUST, 1933

KILAUEA REPORT FOR AUGUST, 1933

Including weekly press reports 1124 to 1127, July 30 midnight to August 27 midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

Two slides at Halemaumau were noticed during the first week of the month, and on one occasion some trickling of pebbles. On August 7 a small slide had left a dusty track at the top of the west wall at the big steam crack. One or two rocks were heard falling about 10 a. m. Cracks at the east platform, recently filled in, had shown dribbling in of the sand for some weeks. At 10:24 a. m. August 10 a few rocks fell from the wall at the south corner of the pit, and raised a small cloud of dust. On August 26 a somewhat fresh crack in the ash NE and N of the pit was discovered about 400 feet back from the rim.

Cracks measured at the edge of Halemaumau weekly, showed on August 5 very slight opening at 8 points out of 27, confined to the south and southeast rim area: on August 12 only 3 points had opened and 4 had closed, making the aggregate movement zero, the quietest week by measurement and observation since July, 1931: on August 19 seven rim cracks scattered along the southeast, south and southwest rims of the caldron had widened slightly, the largest amount being 1.5 mm. Two points indicated a very slight closing.

E. G. Wingate, topographic engineer, reports the horizontal angle representing the SE-NW diameter of Halemaumau, July 28—August 21, to have closed 1.7 seconds in 24 days; the angle opened 2.5 seconds August 21—August 29, in 8 days. This angle, measured from the Observatory on the northeast edge of Kilauea crater, is between Stations "NW Pit" and "Seis."

The horizontal angle representing the SSE—NNW diameter of Kilauea crater, measured from "Obsy," between "Uwekahuna" and "Spit," closed 2.5 seconds July 28—August 21, 24 days: and opened in 8 days August 21—29 by 0.3 second.

The combined tilt at Halemaumau, computed for the three clinoscope cellars, and resolved for each cellar into one component to or away from the center of the pit, shows inward tilting of 22.2 seconds July 31—August 27, a period of 27 days. This combined tilt has been computed for each day since October 11, 1932 and on August 27 showed an accumulation of inward tilt amounting to 53 seconds, for this interval 320 days.

It was shown in Volcano Letter 399 that Sta. Seis, the SE clinoscope cellar at Halemaumau had risen by spirit levelling relative to Sta. Spit outside of the Kilauea floor south by 0.02 foot on June 12,1933 relative to December 31, 1932. Levels run August 14, 1933 show that Sta. Tourist east of Halemaumau had lowered 0.13 foot relative to Sta. Seis since September 27, 1932. The distance between these bench marks is 440 feet. "Tourist" is on the rim of the pit, and "Seis" is about 400 feet back. "Tourist" is not greatly off from the line of the computed clinoscope tilt at "Seis" (to and from the center of Halemaumau). An angular depression of 53 seconds as above would at this distance give a change in elevation of minus 0.11 foot. This indicates a close agreement between measured and computed changes in elevation. In approximately this same period the horizontal angle across Halemaumau has closed 3.44 seconds.

The indication from all results is that the pit as a whole is lowering slightly at the present time. This is in agreement with the tilting of the ground for a year past, as recorded in Engineer Wingate's monthly report for the cellar of the Hawaiian Volcano Observatory on the northeast edge of Kilauea crater, the record for the preceding year each month, showing an accumulation of tilt to the southward, or in the general direction of the crater.

Measurement of vapor temperatures at eight vents of the Sulphur Bank near Volcano House with mercurial maximum thermometer, made by Wingate and Jones, on August 16, gave degrees Centigrade as follows:— 85.5, 80.0, 79.0, 77.0, 89.0, 94.5, 94.7, 94.6. These vents were not at the borings, where the maximum temperatures as measured several years ago were rather constant at 96.0 degrees Centigrade, or 204 degrees Fahrenheit. This temperature happens to be the boiling point of water for this elevation.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble, feeble and slight earthquakes; teleseisms or distant earthquakes; local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	f	sl.	tel.	seis.
August 6	45	5	0	1	0	14.50
August 13	28	4	0	0	0	10.00
August 20	22	2	0	0	0	06.50
August 27	37	3	0	0	1	10.75

A slight earthquake was felt by Pritchard in Honokaa, by Sumner in Kapapala, Pahala, by Hutchinson Sugar Co. in Naalehu, by L. P. Lincoln in Hookena, by Fabius Paauilo, and by Hodges and others in Hawaii National Park at 11:56 a. m. July 31. It was located 19° 20′ N 155° 30′ W and 10 miles deep; nearly under Kapapala Ranch where it was felt sharply.

A small shock was felt by Mr. Sumner and others at Ohaikea, August 4.

A shock was felt at Naalehu at 4:08 a. m. Aug. 7. It recorded as very feeble on the Observatory seismographs. It was located from the records of two stations as being 2 miles northwest of Naalehu, 19° 05′ N 155° 39′ W and close to the surface.

The teleseism began recording at 9:33:25 p. m. H.S. T. Aug. 24. The secondary waves arrived at 9:44:07 p. m. The direction was Northwest and the distance 5,965 statute miles. According to press dispatches it was destructive in central China.

Microseismic motion of the ground was moderate or normal on July 31 and August 2, 3, 4, 8, 12, 14, 15, 16; it was light or subnormal on the other days of the month.

A.E.J.

Tilting of the ground

The Table of Tilt shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, and from clinoscope readings at Halemaumau southeast. The table represents the tipping of the ground, in seconds of arc, in the direction given; the total accumulated tilt in the year since August 27, 1932 at the Observatory is 1.5″ south and 1.3″ west.

TABLE OF TILT

Date	Observatory	Halemaumau
July 31 - Aug. 6	1.3″ N	6.5″ NNW
Aug. 7 - Aug. 13	0.4″ NNW	2.6″ NW
Aug. 14 - Aug. 20	1.2″ NNW	1.9″ N
Aug. 21 - Aug. 27	0.7″ NE	6.6″ NW

E.G.W.

The Volcano Letter

No. 403—Monthly U. S. Geological Survey, Hawaii National Park SEPTEMBER, 1933

KILAUEA REPORT FOR SEPTEMBER, 1933

Including weekly press reports 1128 to 1132, August 27 to October 1, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

In Halemaumau September 1 there had been a slide from the east corner. At 10:59 a. m. September 23, rocks fell from the north wall, and the dusty track of a moderate slide southsouthwest was seen. The northeast wall of the greater crater Kilauea showed a yellowish-orange scar from a slide, about a half mile west of the Hawaiian Volcano Observatory. On September 26 all-day inspection of the pit recorded sliding at 10:09 a. m. from the south-southwest wall, making a voluminous dust cloud and much noise. On September 30, sliding was reported as beginning in the pit between 6 and 7 a. m. Dust from slides rising from the pit was noted at the Observatory at 8:12 a. m. and 8:30 a. m. and between 8:37 and 8:45 a. m. the pit as seen from Uwekahuna was full of dusty air.

Weekly rim crack measurements around the Halemaumau border by E. G. Wingate gave:—

September 2. Six crack points out of 29 showed slight widening, two were very slightly closed.

September 9. Six points out of 29 very slightly opened, two points very slightly closed.

September 16. Twelve points widened, out of 29, one point closed. Widening not confined to any one sector.

September 23. Six scattered points widened out of 29, one point closed very slightly.

September 30. Marking nails for crack measurement had been set at three new points on September 26, on the east and northeast rim of Halemaumau.
Measurement for the week showed very slight opening of six scattered points out of 32, and very slight closing occurred at 4 points.

Mr. Wingate reports transit measurement of the horizontal angle from the Hawaiian Volcano Observatory triangulation station, to the two stations representing the southeast-northwest diameter of Halemaumau, as follows, the figures being the change of angle since the last date. Minus is a closing of the angle, or an approaching of the two walls of the pit. Plus is an opening of the angle, or a widening of the pit.

August 29 to September 5, 7 days, 0.6 second minus
September 5 to September 18, 13 days, 1.5 seconds plus
September 18 to September 27, 9 days, 0.4 second minus

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble, feeble, and slight earthquakes; teleseisms or distant earthquakes; and local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	f	sl.	tel.	seis.
September 3	42	3	1	0	1	13.00
September 10	49	1	0	1	2	14.75
September 17	19	6	0	0	0	7.75
September 24	58	5	0	1	1	19.00
October 1	44	3	2	0	1	14.50

Periods of continuous tremor occurred during four weeks out of the five. This vibration has a frequency of about 100 times a minute and is indistinguishable from the tremor found on the seismograph records during the times of lava fountaining in the pit of Halemaumau.

A very feeble shock, on August 31, occurred about 10 statute miles northwest of Hilo. Lat 19 48'N, Long. 155 12'W 24 miles deep.

A feeble shock, September 2, occurred 5 miles under Pali O Mamalu. Lat. 19 2'N, Long. 155 40'W, it was not reported felt.

A slight earthquake, Sepember 7, occurred about 27 miles deep, under Wood Valley. Lat 19 18'N, Long. 155 27'W it was reported felt at Uwekahuna by Doerr, and in Hilo by M. Campbell.

A tremor, 6:13 a. m. September 11, occurred at sea a short distance off of the west coast of Hawaii, and close to the possible extension of the Mauna Loa southwest rift line. Lat. 19 02'N, Long. 155 58'W.

A very feeble shock, 7 a m. September 11, was reported felt by Mair in Pahala. It occurred 7 miles north-northeast of Wood Valley, and about 7 miles deep. Lat 19 23'N, Long. 155 28'W.

A very feeble shock Sept. 14 probably occurred under the sea a short distance of the Puna coast and south west of Kalapana.

A very feeble shock registered September 16, originated 10 miles west of Humuula.

A very feeble shock September 20, originated on the Mauna Loa northeast rift. It may have been one of many reported felt at Kapapala.

A slight earthquake September 21 apparently originated a short distance away from the Observatory, probably under the Kilauea southeast rift. It was not reported felt.

A feeble earthquake was recorded September 26, the location found was 8 miles east of Humuula, Lat. 19 42'N, Long. 155 23'W and 7 miles deep. It was felt in Papaikou, Honomu, Hakalau, Hilo, Olaa and Pahala according to reports sent in by H. Milne; J. B. Oliver; Hakalau Plantation; M. Campbell; and W. Mair.

A feeble shock was reported felt in Pahala by W. Mair September 28. It was located 7 mi. northeast of Kapapala. Lat. 19 22'N, Long. 155 27'W and about 9 miles deep.

A very feeble shock on September 30 was approximately located under the saddle between Mauna Loa and Mauna Kea.

A fair record of a teleseism began at 11:46:11 a. m September 6, and continued for 20 minutes. It was 2,934 statute miles away from he Observatory. The other teleseisms were partial, showing only the maximum or long waves.

The microseisms were moderate September 5, 9, 16, 18, 21 22, 23, 24, and October 1; they were light or subnormal during the remaining days of the month.

A.E.J.

Tilting of the ground

In the Table of Tilt below, the first column shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, which is on the northeast rim of Kilauea crater, 2.2 miles from Halemaumau.

The second column shows the algebraic sum of the readings at three clinoscope cellars around Halemaumau pit, reduced each to its radial direction, outwards from and inwards toward the center of Halemaumau.

The Table represents the tipping of the ground, in seconds of arc, in the direction given.

At the Observatory, a NE reading is outward, a SW reading is inward.

The total accumulated tilt in the year since October 1, 1932 at the Observatory is 1.5" north and 0.7" west.

TABLE OF TILT

Date	Observatory	Halemaumau
Aug. 28 - Sept. 3	0.9" NE	1.3" outward
Sept. 4 - Sept. 10	0.7" NE	2.6" inward
Sept. 11 - Sept. 17	1.3" NNE	0.4" inward
Sept. 18 - Sept. 24	1.1" NNE	2.6" inward
Sept. 25 - Oct. 1	1.0" NNE	0.1" inward

E.G.W.

The Volcano Letter

No. 404—Monthly | U. S. Geological Survey, Hawaii National Park | OCTOBER, 1933

KILAUEA REPORT FOR OCTOBER, 1933

Including weekly press reports 1133 to 1136, October 1 midnight to October 29 midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

Slides from the walls of Halemaumau pit have occurred as follows for the short periods under observation daily in the forenoons, and occasional observation at other times. Slide during day preceding 10 a. m. October 6 left a scar near top of east wall, and fresh dust and small rocks scattered over the east bay of the lava floor. The southeast pit seismograph had registered the vibrations. October 6 at 9:50 a. m. a few rocks were heard falling. October 7 at 8:58 a. m. and 10:07 a. m. small slides at east corner of pit. October 9 forenoon, rocks fell infrequently. October 13 at 3:38 p. m. dust arose at east corner. October 14 new dusty appearances were seen at east talus and south wall. October 24 and 25 in the forenoons, a few rocks were heard falling. October 26 at 10:15 a. m. a small slide fell from the south wall, and one caused dust at 10:35 a. m.

Slides occurred on the west wall of Kilauea crater, about three quarters of a mile south of the museum at 4:38 p. m. October 2, and on October 8 at 10:50 a. m. and at 10:58 a. m. October 23 numerous showers caused vapor to rise from Halemaumau, mixed with some blue fume, and October 26 strong northeast wind raised clouds of dust in Kau desert. A very fresh avalanche scar was located by Wingate October 24 at the north end of the west platform inside of Alealea crater along the Chain of Craters road, with another scar nearby. This was believed related to a shock at 10:32 a. m. October 20, accompanied by a booming noise and a low rumble, felt by a construction crew near Puu Hulahula, and by others heard at 28-miles and at Halemaumau.

Weekly rim crack measurements around the Halemaumau border are reported by E. G. Wingate as follows:—

October 7. Seven crack points out of 32 opened very slightly, two closed very slightly.

October 14. Eleven points out of 32 opened, two points closed, very slightly.

October 21. Three points opened out of 32, one closed, very slightly.

October 28. Out of 32 points, four opened one-half millimeter each. Seven closed one-half millimeter each. One crack northeast showed one-half millimeter lateral movement. The closing cracks were south and southeast, the opening ones were east and northeast. The west rim showed no movement.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble; slight; and moderate earthquakes; teleseisms or distant earthquakes; and local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	sl.	mod.	tel.	seis.
October 8	24	3	0	0	1	10.00
October 15	29	1	0	1	1	11.75
October 22	46	8	1	2	0	25.50
October 29	42	8	0	0	0	15.00

The indicated origin of the moderate earthquake at 3:01 a. m. October 13 was at sea, about 30 statute miles southeast of Cape Kumukahi, in Lat. 19° 15′N; Long. 154° 23′W. It was lightly felt.

The slight earthquake of October 19 at 5:37 a. m. could not be well located. It probably occurred a few miles north of the Mauna Loa northeast rift. It was felt in Hilo and Honomu.

The two earthquakes at 9:10 and 9:11 a. m. October 21 occurred at places about eight miles apart, under the southeast flank of Mauna Loa. The first at Lat. 19° 21′.5N; Long. 155° 31′.5W; and about two miles deep. The second at Lat. 19° 25′N, Long. 155° 30′W and about nine miles deep. The second could not be as accurately located as the first, owing to confusion of its waves with the waves of the first earthquake. Both were reported felt generally on Hawaii.

Six small earthquakes were felt at Kapapala ranch during the month, the observatory records were too small to indicate a distance for any of them. The same was true for an earthquake felt at Pahala and one felt at Kapulani.

The record of the teleseism beginning at 5:11:16 a. m. October 5 was fair, showing a few phases. Only the long waves of the teleseism of October 14 were recorded.

The microseisms were light on October 10, 12, 15, 16, 17, 18, 19, 20, & 29. The microseisms were moderate or normal October 2, 3, 5, 6, 7, 8, 9, 11, 13, 14, & 21. The microseisms were strong or abnormal October 4, 22, 23, 24, 25, 26, 27,& 28.

A.E.J.

Tilting of the ground

In the Table of Tilt below, the first column shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, which is on the northeast rim of Kilauea crater, 2.2 miles from Halemaumau.

The second column shows the algebraic sum of the readings at three clinoscope cellars around Halemaumau pit, reduced each to its radial direction, outwards from and inwards toward the center of Halemaumau.

The Table represents the tipping of the ground, in seconds of arc, in the direction given.

At the Observatory, a NE reading is outward, a SW reading is inward.

The total accumulated tilt in the year since October 29, 1932 at the Observatory is 1.1″ south and 0.8″ west.

TABLE OF TILT

Date	Observatory	Halemaumau
Oct. 2 - Oct. 8	0.7″ E	2.8″ inward
Oct. 9 - Oct. 15	0.3″ NE	11.0″ inward
Oct. 16 - Oct. 22	0.3″ SW	1.3″ outward
Oct. 23 - Oct. 29	2.0″ NE	10.6″ inward

E.G.W.

The Volcano Letter

No. 405—Monthly U. S. Geological Survey, Hawaii National Park NOVEMBER, 1933

KILAUEA REPORT FOR NOVEMBER, 1933

Including weekly press reports 1137 to 1140 October 29 midnight to November 26 midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology:—Kilauea

Halemaumau pit of Kilauea volcano produced a rock slide at the west end of the north sill 9:35 a. m. November 4, and another small one was heard at 10:43 a. m. Fragments of rock dribbled down the south wall 10:44 a. m. November 6. There were very heavy rains November 8-9 amounting to 6.75 inches. Pools of water remained all over the Kilauea crater floor, being lakes at the southwest valley and at the upper bench southwest. November 9 a slide occurred at noon on the south side of the pit. November 11 several hundred tons of rock had fallen from above the lowest part of the canoe sill northeast. The pieces had rolled 150 feet down the talus; at 10:07 a. m. Nov. 11 rocks fell at the northeast. About 10 a. m. Nov. 13 rocks were heard falling from the north, west and south walls; at the same hour November 16 a small slide was heard at the east, and there was fresh debris on the talus. The week ending November 26 was notably quiet.

Weekly rim-crack measurements around the Halemaumau border were as follows:—

November 4. Out of 32 points, 7 opened 1 mm. or less, 4 closed very slightly, 1 northeast crack moved laterally 1 mm.

November 11 Out of 32 points, 10 opened slightly, 4 closed slightly, aggregate result for all, an opening of 3 mm.

November 18. Out of 32 points, 9 opened, 3 closed, aggregate movement an opening of 4 mm.

November 25. Out of 32 points, 11 opened and 3 closed, aggregate opening 5.5 mm.
It will be seen that the aggregate opening gradually increased during the month.

Volcanology:—Mauna Loa

The cluster of earthquakes of October about Mauna Loa, felt especially at Kapapala ranch on the east side of that volcano, led E. G. Wingate and A. E. Jones to visit the summit crater, camping there the night of November 1-2. At Puu Ulaula resthouse the night October 31 the outdoor temperature was 31 degrees Fahrenheit. The northeast end of Mokuaweoweo was reached at 1:30 p. m. November 1.

The main crater showed puffing vapor from the 1914 cone, fume was dense at times from the solfataras of the sunken area adjacent to the 1914 cone, and the central cones of 1903 were about as usual. The summit camp was in a cavern, and ice from cracks was melted for drinking water. The east rim was explored the forenoon of Nov. 2 as far as the Wilkes Camp. The northwest and southwest walls of the crater were dusty showing some fresh scars. There was little blue fume at the central region, and possibly slightly more at the 1914 cone than in July. The Resthouse thermometer recorded 28 degrees F. at 6:10 a. m. Nov. 3. Later events proved that the dense fume and puffing vapor near 1914 cone heralded coming eruption of December 2.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble earthquakes; teleseisms or distant earthquakes; and local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	tel.	seis.
November 5	18	2	00	5.50
November 12	35	5	00	11.25
November 19	30	0	00	7.50
November 26	56	3	1	15.50

This is the only month of the year 1933 to date registering at the Observatory no felt earthquakes of the inntensities "feeble," "slight" or "moderate" for the Kilauea locality.

During the four weeks local shocks that were well recorded on more than one instrument (for location of origin) were rare.

An earthquake reported by Lincoln and Hale in Hookena district, South Kona, was felt at 7:44 p. m. November 10. It was very feeble on the seismograms, and from them appeared to be on the southwest rift of Mauna Loa in Latitude 19 degrees, 16 minutes North; Longitude 155 degrees, 43 minutes West.

A shock reported by Buzzard and registered on his seismogram at Waikii on the west slope of Mauna Kea 9:49 a. m. November 13, appeared to originate deep under that district.

A seismic movement recorded at the Kilauea observatory as a tremor, at 0:52 a. m. November 25, was reported by Archdeacon Walker as felt sharply in Kohala. The distance from the Observatory record would place it in North Kohala.

A very feeble shock registered at 5:15 p. m. November 25 was located under a point northeast of Wood Valley on the east slope of Mauna Loa, about five miles deep. Latitude 19° 22′ North, Longitude 155° 26′ West.

A very feeble shock registered 9:10 a. m. November 26, was located as near the surface of Mauna Loa about five miles north of the 1868 lava source on the southwest rift, Lat. 19° 12′ North, Longitude 155° 41′ West.

Microseisms of the month were light or subnormal October 31 and November, 16 and 21: they were strong or abnormal November 3, 25, 26. The remainder of the month they were normal.

A.E.J.

Tilting of the ground

In the Table of Tilt below, the first column shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, which is on the northeast rim of Kilauea crater, 2.2 miles from Halemaumau.

The second column shows the algebraic sum of the readings at three clinoscope cellars around Halemaumau pit, reduced each to its radial direction, outward away from, and inward in the direction of, the center of Halemaumau.

The Table represents the tipping of the ground, in seconds of arc, in the direction given.

At the Observatory, a northeast reading is away from the crater, a southwest reading is in the direction of the crater.

At the Observatory the total accumulated tilt in the year since November 26, 1932 is 2.2″ West and 2.9″ South, or 3.6″ SW by S.

TABLE OF TILT

Date	Observatory	Halemaumau
Oct. 30 - Nov. 5	0.9″ S by E	4.5″ from
Nov. 6 - Nov. 12	1.3″ S by W	2.5″ from
Nov. 13 - Nov. 19	0.6″ E by S	9.0″ towards
Nov. 20 - Nov. 26	1.9″ NE by E	7.0″ towards

E.G.W. and A.E.J.

The Volcano Letter

No. 406—Monthly U. S. Geological Survey. Hawaii National Park DECEMBER, 1933

KILAUEA REPORT FOR DECEMBER 1933

Including weekly press reports 1141 to 1145, November 26 to December 31, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology:—Kilauea

As Mauna Loa broke out with lava eruption at the summit crater the early morning of December 2, Halemaumau pit in Kilauea crater was watched with special intentness throughout the month. Its bottom being sealed, with the lava plug of December—January 1931-32, this pit showed no sympathy with the Mauna Loa outbreak nor with the Mauna Loa cessation December 18.

In Halemaumau fresh debris lay on NE talus Nov. 27. The color of blue sulphur fume can be seen in sun-shadows. Two large newly fallen rocks were seen at the bottom under E wall December 16.

Weekly rim-crack measurements around the Halemaumau border were as follows:—

Dec. 2, 1933. Out of 32 points measured, 9 opened, 5 closed, aggregate opening 2.5 mm.

Dec. 9, 1933. Seven points opened, 5 closed, aggregate opening 1.5 m.

Dec. 16, 1933. Two points opened, 4 closed, aggregate a closing 1 mm.

Dec. 23, 1933. Eight points opened, 2 closed, aggregate opening 3.5 mm.

Dec. 30, 1933. Seven points opened, 8 closed aggregate opening ½ mm.

During the week ended December 17 levellings repeated on the old line on Kilauea floor near Halemaumau, and the horizontal angle from Observatory, measured twice across the pit, by Jones, revealed no unusual movement of the crater floor.

The minute motion of the ground measured instrumentally around Halemaumau and at the Observatory, by weeks, as shown in Earthquake and Tilt reports herewith, was as follows:—

		Obsy. Tr.	Seis.	Obsy. tilt	Hal. tilt
Week ending Nov. 26		56	15.50	1.9″ ENE	7.0″ inward
Week ending Dec. 3	(Mauna Loa eruption)	1393	360.00	1.5″ NW	15.8″ outward
Week ending Dec. 10	(Mauna Loa eruption)	345	86.00	0.3″ WSW	5.9″ inward
Week ending Dec. 17	(Mauna Loa eruption)	580	170.00	0.7″ SSW	0.0 zero
Week ending Dec. 24		20	6.50	1.1″ WNW	7.9″ inward
Week ending Dec. 31		34	12.50	1.2″ NNE	19.2″ inward

The number of minutes of tremor and accompanying local seismicity rose and fell with the Mauna Loa eruption 22 miles away. The Observatory tilt was strong and northerly or easterly (away from Kilauea crater), before and after the eruption, weaker and westerly during the eruption. The total tilt of the three clinoscope cellars around Halemaumau pit, outward away from the pit, or inward towards the pit, measured on the radial lines from the center of the pit, and disregarding other directions of tilting, yielded very interesting results. The aggregate tilting at the pit had been notably inward for many months. The week of the outbreak it was strongly outward as though the Kilauea floor swelled upward; after the outbreak it was more strongly inward, as though the sinking of the Kilauea floor followed the sinking back of the lava under Mauna Loa. This sequence is just what happened at Kilauea when the live lava in Halemaumau was visible during the Mauna Loa eruptions of 1914, 1916 and 1919.

Volcanology:—Mauna Loa

The summit crater Mokuaweoweo was split along the upper end of the southwest rift and vomited up lava at 5:43 a. m. December 2, 1933. The rift opened along a belt 1.5 miles long in the southwest part of the crater, the gash trending S. 27 W. from the inner basin across the south lunate platform, up the cliff to the outside country next the lava of 1851, on to the south for a half-mile about 500 feet west of the lip of the South Pit No. 1, then for a half-mile more offset 500 feet to the east, emerging from the west corner of this pit and continuing across the upland southwest to pour cascades of lava into both Pit No. 1 and the 2nd. Pit. (Lua Hohonu). The main activity of the eruption was inside the main Mokuaweoweo basin about 500 feet east of the cone of 1914.

The time of outbreak estimated is that shown by the beginning of continuous volcanic tremor at Kilauea seismographs. At 7 a. m. December 2 there were two dense white columns of vapor as seen from Kilauea Observatory about 2 miles apart, the northern one the denser and by angular measure inside Mokuaweoweo. At 9 a. m. there were 3 principal fume jets, the northern the greatest and highest, the two southern ones each double. At 7:30 p. m. the glowing columns were in number, the northern triple and most brilliant, the middle one bright, the southern one faint. The division in three corresponded to the southern-pits gash, the south lunate gash, and the inner basin gash. The southern pits went out of action the first day. After the first two hours the fume column became blue and sulphurous (absinthe red in transmitted light). Pele's hair fell in small amounts at Hookena to leeward. At 11 a. m. December 2 there were lines of moderate fountains, 200 or more feet high, along each gash at its widest part, namely; the upland SW of South Pit No. 1: the lunate at the foot of the cliff NW of this pit, just inside Mokuaweoweo; and the inner basin east of 1924 cone. There were about 35 fountains in the basin and 20 each at the two other localities. The basin fountains concentrated to a smaller number about built-up cones. These basin vents poured lava both east and west. The eastern flows became the great feature, filling the northeastern and lowest part of Mokuaweoweo basin. The western ones obliterated the pit of 1914 which had been adjacent to the cone, and filled against the western cliff of the south lunate platform. The South Pit filled about 70 feet at the base of the new cascade which poured into it from the lunate platform. The main flow area covered about a square mile the second day, and the southern pits had received a square quarter-mile additional. The southernmost rift made big upland fountains the first day, the lava cascading strongly into the south side of South Pit No. 1, and weakly into Lua Hohonu. There was liquid flooding of silvery sheets of lava the first day, but the second day there were crusted floor flows, and flocculent skins on the scarlet torrents from the main line of about 17 conelets. On this day Dec. 3 the big fountain within a horse-shoe cone at the southwest cliff sent a festooned stream in a channel down to the South Pit over the ancient black lava cascade so well known here, and also over fresh streams of the previous day. This fountain was literally in the wall-crack of Mokuaweoweo, on the west side of the South Gap.

December 3 the main fountaining was at two cone centers in Mokuaweoweo basin, and at the southwest wall; the outside southwest cracks were steaming only. The flow lava was pahoehoe of which coin specimens were made. The cones were heaped with basaltic pumice, and Pele's hair lay to leeward. Milky blue fume cirrus lay in belts across the sky, sometimes southeast, sometimes north of Mauna Loa during the next few days. There was glow over the crater at night and fume by day. December 4 the southwest wall fountain stopped. December 5 the two central fountain groups were within throne-like cone heapings 100 to 200 feet high. The steam

at the pit gashes to the southwest of Mokuaweoweo had ceased. The flows within Mokuaweoweo continued to spread north and east, against the east wall, and as far as the north lunate, and one flow had pushed west between the 1903 and 1914 cones. The eastern part of the cliff beneath the north side of the south lunate had been further obliterated by filling. A fan-like rush lava poured east from the throne-cones. This was the scene observed from air-planes day after day, the fountains of the northern cone dwindling to two small ones December 12. December 13 there was only one fountain, with occasional jets from other vents. With change of wind some Pele's hair fell along the northwest trail. The fume and glow as seen from Kilauea continued until December 17, becoming faint. Midnight December 17-18 the fountain was in action. It died down at 2 a. m. December 18, revived slightly after daylight, and thereafter went out of action. The area remained very hot and fuming with jarrings and rumbles.

The first echelon ruptures were at the top of the southwest rift of Mauna Loa, extending the action of that rift as observed in 1926, farther west and farther up, until this year's action centered in the crater itself. The eruption lasted 16 days, with no flank outbreak. Inquiry around the south end of the island December 6 revealed that the early morning earthquakes of the outbreak on December 2, felt in Hilo and Kona, were not felt at the south. The seismographic measurements show that most of the earthquakes originated to the north and east of Mauna Loa during the eruption, becoming deeper and mostly toward Kilauea at the end of the period.

If the splitting of the mountain crosses the crater and opens a flank rupture about 1936 or before, emitting lava flow, it may be along the Hilo rift, or the northwestern 1859 rift, or along the Hualalai rift. It happens that the earthquakes of December 2 this year 1933 were not felt at Puu Waawaa, where the 1929 quakes were strongest.

Toward the end of December, after summit snows about Christmas, there were hot convection puffs of rain cloud over the new lavas of the summit crater. These rose very rapidly and might easily have been mistaken for new eruption. The flows on the Mokuaweoweo floor were about ten feet high near their borders, with some breaking up of the pahoehoe surfaces, where they were pulled after congealing.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble; feeble (I, R. F.); & slight (II, R. F.) earthquakes & local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	f.	sl.	seis.
December 3	1,393	11	3	3	360.00
December 10	345	0	0	0	86.00
December 17	580	4	0	0	170.00
December 24	20	1	1	0	6.50
December 31	34	8	0	0	12.50

The approximate origins of the earthquakes that were well recorded at more than one seismograph station, follows—

Earthquakes Preceding Mauna Loa Eruption.

November 28, a very feeble shock, located under Kilauea crater.

November 30, a very feeble shock, located a mile SW of Kilauea crater.

December 1, a very feeble shock, located on the NE rift, near Mokuaweoweo, the summit crater of Mauna Loa.

Earthquakes correlated with the Mauna Loa outbreak, on December 2.

5:55 a. m. a slight shock, about II on the Rossi-Forel scale of intensity, felt with alarm at the rest house on Mauna Loa, located at the NE end of Mokuaweoweo crater, nine miles deep. The remainder of the group appear to be less deep.

5:56 a. m. a feeble shock, about I on the Rossi-Forel scale, located about seven statute miles NW of Mokuaweoweo crater.

5:58 a. m. a feeble shock, located about one mile NE of the N end of Mokuaweoweo crater.

6:01 a. m. a slight shock, felt with alarm at the rest house, located near west rim of Mokuaweoweo crater.

6:06 a. m. a slight shock, felt with alarm at the rest house, & felt lightly in Hilo by M. E. Campbell, located three miles NE of the N end of Mokuaweoweo crater.

6:08 a. m. a feeble shock, located near the west rim of Mokuaweoweo crater.

Immediately after the first unlocated shock at 5:42 a. m. Dec. 2 harmonic or continuous volcanic tremor began. In the past, eruptions have been accompanied by this type of ground movement. The period of 0.6 seconds (100 vibrations per minute) is fairly constant, while the amplitude is variable with the size of the eruption. The spells of tremor were noted approximately as follows;

date		time	duration minutes
Dec. 2	Beginning	5:43 a. m.	244
" 2	"	9:46 a. m.	590
" 2	"	6:40 p. m.	320
" 3	"	9:00 a. m.	209
" 8	"	8:30 p. m.	80
" 10	"	8 p. m.	240
" 11	"	0 a. m.	300
" 11	"	8 p. m.	100
" 12	"	0 a. m.	150
" 12	"	7 p. m.	90

The amplitude of the waves varied from 0.8 to 0.4 microns, smaller amplitudes become unnoticeable on the records. (1 micron=0.001 m. m.)

Earthquakes During the Eruption.

Dec. 2, 7:28 p. m. a very feeble shock, located under the slope of Mauna Loa about half way between the craters of Kilauea and Mokuaweoweo.

Dec. 3, a very feeble unlocated shock was felt by M. E. Campbell in Hilo. It appeared to be about five miles from the Hilo station.

Dec. 7, a tremor, reported felt in Naalehu by the Hutchinson Sugar Plantation, was located on the Mauna Loa SW rift near the source of the 1887 flow, seven miles up the mountain from the highway.

Dec. 12, a very feeble shock, located three miles west of Kilauea crater, four miles deep under Pali O Kaoiki, a fault between Mauna Loa and Kilauea.

Dec. 14, a very feeble shock, felt in the vicinity of Kilauea crater, located near the Mauna Loa rest house and 17 miles deep.

Earthquakes Following the Eruption.

Dec. 20, a very feeble shock, located half way up the east slope of Mauna Kea from Hakalau.

Dec. 20, a tremor; Dec. 27, 3:44 a. m. a very feeble shock felt lightly at Honomu: 3:56 a. m. a very feeble shock, felt sharply at Honomu, and 4:44 a. m. a very feeble shock felt lightly at Honomu. These four were located in a group under the SE slope of Mauna Kea, half way between Hilo & the summit.

Dec. 27, a very feeble shock, felt near Kilauea, located on the Mauna Loa NE rift half way between Hilo and the summit.

Dec. 30, a very feeble shock felt in Hilo by M. E. Campbell, located six miles SE of Mokuaweoweo and ten miles deep.

Dec. 31, a very feeble shock, located five miles at sea, south of Kilauea crater.

Microseisms. Light or subnormal; Dec. 1, 3, 18, 19, 31.
Moderate or normal; Nov. 27 to 30; Dec. 2, 4, to 13, 17, 20, 21, 27 to 30.
Strong or abnormal; Dec. 13 to 16; 22 to 26.

A.E.J.

Tilting of the ground

The Observatory column shows the net tilt in seconds of arc in the direction given, computed from seismograms. The second column shows the algebraic sum of clinoscope readings for the three cellars around Halemaumau. Each reading is reduced to its radial direction from or towards the pit. As the Observatory is on the northeast rim of the larger Kilauea crater, a southwest reading is towards the crater.

The total accumulated tilt at the Observatory in the year since December 31, 1932 is 1.1" North, and 2.9" West.

TABLE OF TILT

Date	Observatory	Halemaumau
Nov. 27 - Dec. 3	1.5" NW	15.8" from
Dec. 4 - Dec. 10	0.3" W. by S.	5.9" towards
Dec. 11 - Dec. 17	0.7" SSW	0.0
Dec. 18 - Dec. 24	1.1" WNW	7.9" towards
Dec. 25 - Dec. 31	1.2" NE by N	19.2" from

A.E.J.

The Volcano Letter

No. 407—Monthly U. S. Geological Survey, Hawaii National Park JANUARY, 1934

KILAUEA REPORT FOR JANUARY, 1934

Including weekly press reports 1146 to 1149, December 31 to January 28, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology:—Kilauea

The first week in January, 1934 Halemaumau remained quiet as before. The second week the pit showed the effects of heavy rainfall after drought. The rainfall readings for twenty-four hours preceding, at 8 a. m. were 1.37 inch January 10, 0.87 inch on January 11, 1.40 inch on January 12, and 0.29 inch on January 13, measured at Kilauea Observatory on the northeast rim of Kilauea crater. The heavy rains began the night before January 10. As seen from the west bluff of Kilauea, a dense vapor cloud appeared to be rolling out of Halemaumau pit. The actual fact was that the cloud was condensing on top in the air above the pit. The entire lava bottom was perfectly clear with no steam whatever except the usual slight vaporing from cracks under the south talus. The wind blew lightly from the northeast and the condensation of ordinary rain moisture began above the northeast edge of the pit. The big cumulus cloud above was probably assisted by nucleation from sulphur dioxide rising at the bottom solfataras. The heat from the pit made an updraft which drew in the wet air from the sides. The phenomenon showed how deceptive a so-called "steaming crater" might be anywhere on a wet day, where the observer was not in a position to look inside. This is the position of many sea-captains observing an island volcano "steaming". On a sunny day the crater in question would be clear, but the reports of two successive vessels would be for the volcano "active" and "inactive", when in fact there was no difference except the moisture in the air.

On January 11 there was the same cloud, the interior of the pit was clear, it was raining steadily. Now there were tails of steamy vapor in a horseshoe of cracks in the floor of Halemaumau SE, NE and NW where the prolonged rain had penetrated deeply to the hot region. There was clear air for eight hundred feet above the vapor jets, which had no evident relation to the cloud above the pit. The southwest inner cone, of December 1931, was not steaming. The next day January 12, with less rain, the vapor tails on the floor had stopped, and the cloud above the pit as a whole, was thin and stringy. There was drizzle, and a bright clearing sky.

On January 14 some stones were heard dribbling down the northwest inner slopes of Halemaumau. Fresh fallen rocks at the foot of the northeast talus were observed January 18. Small slides occurred later in the day, and fresh sliding occurred the morning of January 24, leaving a piece broken out of the northwestern end of the "Canoe" sill under the north corner of the pit. In the afternoon of the same day while the pit was vaporing from more heavy rains, rocks were heard falling at the north wall. Blue fume was apparent in the darkened corners of the pit in sun-shadow January 26. It is noteworthy at this time, however, that the yellow sulphur patches in Halemaumau do not show fume jets or hot air disturbance detectable with field glass, and they are not the places which steam at times of rainfall.

Weekly rim crack points, 37 in number, around the Halemaumau border, were measured for change in opening of cracks as follows:—

January 6, 1934. 7 points opened, 2 closed, summation 3 millimeters opening.

January 13, 12 points opened, 1 closed, summation 7 millimeters opening.

January 20, 3 points opened, 9 closed, summation 3 millimeters closing.

January 27, 5 points opened, 2 closed, summation 1.5 millimeters opening.

The summation of January 20 was unusual: opening by this amount is common.

Volcanology:—Mauna Loa

There were numerous thunder showers over Mauna Loa the third week in January, with calm weather preceding, and light snow fell on Mauna Loa and Mauna Kea. The recent lava eruptions in Mokuaweoweo crater, it will be remembered, were from December 2 to 17, 1933, followed by marked rain cumulus condensations due to convection on certain days. These upright clouds are still seen occasionally, especially when moisture from melting snow is present.

Ranger R. F. Lueck, National Park Service, and T. Generozza, U. S. Army, spent the night January 6 to 7 in Mokuaweoweo crater at the cone center of the December activity. Arriving at the North Bay 1:30 p. m. January 6, Lueck reports the fume had decreased in ten days 75 percent. They crossed the crater floor southward. Lueck kindly prepared the following report:—"We came to the new floor flow, which had turned west to follow the channel between the 1903 and 1914 cones. The new lava was smooth pahoehoe, broken up at the edges, where it was in contact with the old lava."

"We crossed it, the heat was quite noticeable, and this became more pronounced as we neared the base of the new cones. We finally reached them and there found a place on the fresh lava, where we thought we could spend the night in comfort and safety. Our ideas were suddenly changed, when, at 5:45 p. m. we felt a distinct shock, and at 5:48 another, of less intensity. As there was not much choice of a more suitable location, we stayed where we were."

"After we had crawled into our sleeping bags, we heard a series of rumbles, and occasional sharp cracks, which seemed to originate directly under us. The rumbling was not continuous, but came at intervals of three or four minutes. After about two hours of this, we began to think of a lot of places we would rather be than just here. At 8 p. m. we felt a shock more severe than any we had felt before, so we proceeded to leave that particular spot, as fast as our legs would carry us in the night, across the pumice beds and rough lava. We got to the edge of the new flow to the north of us, and decided to make the best of the situation, making our beds a second time, in a deposit of new warm pumice. During the night we noted several more light shocks, but none was severe enough to cause great alarm. At daylight we packed our belongings, and left for the return trip."

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble, feeble, and slight earthquakes; teleseisms or distant earthquakes; and local seismicity index as described in Volcano Letter 371.

Week ending 1934	tr.	v. f.	f.	sl.	tel.	seis.
January 7	26	4	0	0	0	8.50
January 14	52	1	0	2	1	17.50
January 21	31	0	1	0	0	8.75
January 28	24	5	0	0	0	8.50

The following earthquakes were located:

A very feeble shock was felt 11:22 p. m. January 2, 1934, at Honomu, Waikii, and Kilauea. It was located under the peak of Mauna Kea, 19° 50′ N, 155° 27.5′ W, at a shallow depth, probably being above sea level.

A very feeble shock at 8:06 p. m. January 6, approximate origin 21 miles away, was probably the sharp quake reported by Lueck at Mokuaweoweo.

January 7 two very feeble quakes were recorded 15 minutes apart. The first 3 miles deep under the pit seismograph station; the other was shallow about two miles SW of Kilauea Crater in the SW rift zone.

A slight earthquake was felt 1:59 a. m. January 9 at Hookena, Kapapala, Pahala, and Kilauea. It was located under the Mauna Loa SW rift 19° 12.5′ N, 155° 44.0′ W and shallow in depth.

A slight earthquake was felt generally in Hawaii at 1:35 p. m. January 13. It was located under the sea bottom 19° 11′ N, 155° 11′ W, possibly 10 miles deep.

A tremor originated at a shallow depth about a mile SW of Kilauea crater January 16. It was recorded on the Uwekahuna and Pit seismographs and was in almost the same place as the one located November 30, 1933.

Two shocks felt at Honomu January 17 and 21 were not recorded at Kilauea. The former recorded at the Hilo seismograph station with indicated distance to origin 10 miles.

A feeble shock, not reported felt, was recorded at 9:37 p. m. Jauuary 19. It was located on the Kilauea SW rift, under the 1823 lava flow 19° 14′ N, 155° 25.5′ W.

A very feeble shock was recorded January 25. The best location found for it was four miles deep under the Kamakaia Hills on the Kilauea SW rift, about 10 miles SW of the crater.

The teleseism was one of the destructive Indian earthquakes, near Patna in the Ganges basin. It began on the record 10:31:44 p. m. January 14. In all six groups of waves were recognized, the last group beginning at 11:02:33 p. m. The waves were not large in amplitude.

Microseisms: Subnormal January, 1, 2, 12, 16, 17, 18, 19, 21, 23, 24, 25, 26, 27; normal January 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 20, 22, 28.

A.E.J.

Tilting of the ground

In the Table of Tilt below, the first column shows the net tilt by weeks as computed from seismograms at the Kilauea Observatory, which is on the northeast rim of Kilauea crater, 2.2 miles from Halemaumau.

The second column shows the algebraic sum of the readings at three clinoscope cellars around Halemaumau pit, reduced each to its radial direction, outward away from, and inward in the direction of, the center of Halemaumau.

The Table represents the tipping of the ground, in seconds of arc, in the direction given.

At the Observatory, a northeast reading is away from the crater, a southwest reading is in the direction of the crater.

At the Observatory the total accumulated tilt in the year since January 1, 1933, is 1.9″ west and 1.1″ north, or 2.2″ NW by W.

TABLE OF TILT

Date	Observatory	Halemaumau
Jan. 1 – Jan. 7	1.82″ ESE	15.0″ inwards
Jan. 8 – Jan. 14	1.59″ S by E	11.0″ inwards
Jan. 15 – Jan. 21	0.12″ W	2.0″ outwards
Jan. 22 – Jan. 28	2.38″ SW	15.0″ outwards

A.E.J.

The Volcano Letter

No. 408—Monthly U. S. Geological Survey, Hawaii National Park FEBRUARY 1934

KILAUEA REPORT FOR FEBRUARY, 1934

Including weekly press reports 1150 to 1154, January 29 to March 4, midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

Kilauea and Mauna Loa continue without volcanic outflow of any kind: the last activity was lava gushing in the summit crater of Mauna Loa December 2 to December 18, 1933. The feeble sulphur fuming at yellow patches about the border of the lava floor of Halemaumau pit in Kilauea crater has almost ceased. Small slides in the pit were observed during the casual visits, at the west 2:30 p. m. February 4, at the southwest 10 a. m. February 5, east and northwest about 10 a. m. February 6, northeast the forenoon of February 12.

Thirty-two rim crack points around Halemaumau, showed weekly change in opening of cracks as follows:—
February 3. 11 opened, 1 closed, aggregate opening 6.5 mm.
February 10. 10 opened, 1 closed, aggregate opening 9.5 mm.
February 17. 3 opened, 7 closed, aggregate closing 3 mm.
February 24. 5 opened, 3 closed, aggregate opening 2 mm.
March 3. 7 opened, 5 closed, aggregate opening 1 mm.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble, feeble, and slight earthquakes; teleseisms or distant earthquakes; and local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	f.	sl.	tel.	seis.
February 4	100	4	1	0	1	28.00
February 11	106	2	0	1	0	29.50
February 18	41	2	1	0	1	12.75
February 25	36	3	1	1	1	13.50
March 4	74	3	0	1	0	22.00

The following earthquakes were located.

A feeble earthquake 3:14 a. m. January 30 was not reported felt. It originated 7 mi. SE of Mokuaweoweo, the summit crater of Mauna Loa, lat. 19° 24.5'N long. 155° 32' W. Two very feeble shocks 10:53 and 11:01 a. m. the same day, were close to or in Kilauea crater. A very feeble shock 2:29 p. m. February 1 originated 5 mi. west of Wood Valley, 19 ° 13'N, 155° 34.5'W. A very feeble shock 1:54 a. m. February 2 was in Kilauea crater. The Pit seismograph was disconnected for repairs during the month.

A slight earthquake was felt sharply at Kapapala ranch at 9:59 a. m. February 9. It was reported felt in Hookena, Hawaii National Park and Waikii. It was located 5 mi. SW of Wood Valley 19° 13'N, 155° 33'W. A feeble shock occurred 8:14 a. m. February 15 near or in Kilauea crater. A slight earthquake was felt sharply 3 mi. east of the observatory at 2:20 a. m. February 19. It was located a mile farther east, 19° 25'N, 155° 12.5'W. A feeble shock was felt at Kilauea crater, Hakalau and Honokaa at 5:31 p. m. February 24. The location was half way between Mauna Kea and Hualalai, 19° 46'N, 155° 42'W. and 11 mi. deep.

A very feeble shock occurred close to Kilauea crater 2:45 p. m. February 26. A slight shock was felt generally on the island of Hawaii at 10:22 p. m. March 1. It was reported from Kilauea Navy Camp, Kona, Pahala, Honomu, Hilo and Waikii. It was located 5 mi. north of Mokuaweoweo 19° 33'N, 155° 35'W.

Swarms of tremors, earthquakes barely enough to record, were noted on the following days. A swarm of 47 tremors was recorded between 8 and 11 a. m. Feb. 2. On the forenoons of Feb. 5, 6, 7 and 8 some were recorded together with suggestions of many other very faint tremors too small to be certain of. A swarm of 28 tremors was recorded during the middle of the day of Feb. 28.

A small teleseism began recording at 11:43:01 p. m. Jan. 30. The preliminary waves only were recorded. A small fragmentary record of a teleseism was obtained beginning at 5:41:51 p. m. Feb. 13. A fair record of a teleseism began recording at 8.03:30 p. m. Feb. 23, other waves began at 8:11:19 and 8:20:56. The maximum waves came at 8:22:19 p. m. It appeared to be 3,800 statute miles away.

The microseisms were normal Jan. 29, Feb. 1, 2, 3, 5, 9, 10, 18, 20, 21, 25. Mar. 1 & 4, they were strong or abnormal Feb. 11 and Mar. 2, they were subnormal during the rest of the period under consideration.

A.E.J.

Tilting of the ground

In the Table of Tilt below, the first column shows the net tilt by weeks, as computed from seismograms at the Kilauea Observatory, which is on the northeast rim of Kilauea crater 2.2 miles from Halemaumau.

The second column shows the algebraic sum of the readings at three clinoscope cellars around Halemaumau pit, reduced each to its radial direction, outward away from, and inward in the direction of, the center of Halemaumau.

The Table represents the tipping of the ground, in seconds of arc, in the direction given.

At the Observatory, a northeast reading is away from the crater, a southwest reading is in the direction of the crater.

At the Observatory the total accumulated tilt in the year since March 1, 1933 to March 1, 1934 is 2.7″ west and 3.8″ north.

TABLE OF TILT

Date	Observatory	Halemaumau
Jan. 29 – Feb. 4	1.2″ NE by E	17.0″ from.
Feb. 5 – Feb. 11	2.3″ SW by S	25.0″ from.
Feb. 12 – Feb. 18	2.1″ SW by W	10.0″ from.
Feb. 19 – Feb. 25	0.8″ SW by W	23.0″ towards.
Feb. 26 – Mar. 4	1.0″ S by W	00.0″

The pit tilt figures are somewhat unreliable, for during the period Feb. 2 to 25, a concrete ceiling was put in. The clinoscope was temporarily disconnected and though the connections were not changed, it is unlikely that it was replaced in the same position that it would have reached if undisturbed.

The temporary timbering in the clinoscope chamber must have had a large effect also. The figures are tentative. It is notable that the tilt away from the pit started January 19, 1934 with a net of 17″ at the end of January, so that the net tilt away from the pit of 29″ for the February interval may not be all artificial.

Correction. Tilt Jan. 1–7 should read 4″ inwards, not 15″ inwards.

A.E.J.

The Volcano Letter

No. 409—Monthly U. S. Geological Survey, Hawaii National Park MARCH, 1934

KILAUEA REPORT FOR MARCH, 1934

Including weekly press reports 1155 to 1158, March 4 to April 1, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

There has been no lava activity on the surface of the Mauna Loa—Kilauea volcanic system of the island Hawaii during the month of March. The summit crater of Mauna Loa, Mokuaweoweo, which was spouting basaltic lava December 2 to 18, 1933, has been under observation, as the National Park force are preparing a rest house or camp on the northern r'm of the crater. The rangers report that the blue sulphur fume, at the source cone of December inside the main Mokuaweoweo floor towards the south, has definitely increased, the last visit being noon March 23.

On the Ki'auea east rift, or Chain of Craters, there was a rumor of noises heard by workmen the afternoon of March 24 in the direction of Makaopuhi pit. There were a few tremors recorded on the seismograms of the Kilauea station at about the same time. The field was examined by A. E. Jones March 28. and inspection of the Chain of Craters revealed no sign of recent slides.

Small slides in Halemaumau pit of Kilauea Crater occurred as follows:— At 8:42 a. m March 13, at the northeast wall, started perhaps by strong and gusty northeast wind. At 1:25 p. m. March 19 making dust rise at the west. During the forenoon of March 24, at 10:56 a. m. at the north corner of the pit. On April 1 at 10:24 a. m. at the north corner, and fresh dust lay on the talus at the northeast corner.

The thirty-two rim crack points around the edges of Halemaumau for weekly measurement of opening or closing, yielded the following changes when measured on Saturday forenoons:—

March 10. 5 opened, 2 closed, aggregate opening 1.5 mm.
March 17. 6 opened, 6 closed, aggregate opening 2 mm.
March 24. 3 opened, 1 closed, aggregate opening 1.5 mm.
March 31. 7 opened, 0 closed, aggregate opening 3.5 mm.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; and numbers of very feeble earthquakes; teleseisms or distant earthquakes; and local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	tel.	seis.
March 11	48	2	1	13.00
March 18	35	2	2	9.75
March 25	33	2	1	9.25
April 1	19	5	0	7.25

The following very feeble shocks were located, none was reported felt.

One 0:34 a. m. March 10, 9 miles at sea off Cape Kumukahi. Lat 19° 37.5′ N. Long. 155° 43′ W.

One 1:56 a. m. March 10, under a fault scarp 2 miles SE of Ainahou. Lat 19° 19′ N. Long. 155° 11′ W.

One 5:09 p. m. March 11, 2 miles east of Kalalua crater on the Kilauea east rift. Lat. 19° 25′ N. Long. 155° 03′ W.

One 11:40 a. m March 13, under SE edge of Kilauea Iki crater. Lat. 19° 25′ N. Long. 155° 15′ W.

One 8:09 p. m. March 18 under SE edge of Kilauea crater. Lat. 19° 24.5′ N. Long. 155° 16′ W.

One 3:01 a. m. March 24, between Makaopuhi crater and the cl'ff to the south. Lat 19° 20′ N. Long. 155° 10′ W.

One 4:11 a. m. March 29, on the Mauna Loa SW rift, 10 miles at sea. Lat. 18° 58′ N. Long. 155° 55′ W.

One 1:46 p. m. March 30, north of Pauahi crater on the Kilauea east rift. Lat. 19° 23′N. Long. 155° 13′ W.

The records of the teleseisms were poor, usually preliminary waves followed by L waves.

One began at 1:27:07 a. m. March 5.

One began at 4:43:40 a. m. March 12, reported by press in Utah, Wyoming and Idaho.

One began at 2:51:14 a. m. March 13.

One began at 1:43:47 a. m. March 24 with secondary waves following at 1:51:11 a. m., estimated distance 3600 miles, located in Pacific Ocean near the Solomon Islands.

Microse'sms were subnormal March 5, 6, 7, 8, 10, 11, 13, 14, 17, 18, 19, 20, 21, 22 and April 1.

Microseisms were abnormal March 25, 26, 27, 28, 29, and 30. They were normal or moderate during the rest of the period under consideration.

A.E.J.

Tilting of the Ground.

In the Table of Tilt below, the second column shows the net tilt by weeks, as computed from the seismograms at the Kilauea Observatory, which is on the northeast rim of Kilauea crater 2.2 miles from Halemaumau.

The third column shows the algebraic sum of the readings at three clinoscope cellars around Halemaumau pit, reduced each to its radial direction, outward away from, and inward in the direction of, the center of Halemaumau.

The Table represents the tipping of the ground, in seconds of arc, in the direction given.

At the Observatory, a northeast reading is away from the crater, a southwest reading is in the direction of the crater.

At the Observatory the total accumulated tilt in the year April 1, 1933 to April 1, 1934, is 1.8″ east and 4.0″ north.

TABLE OF TILT

Date	Observatory	Halemaumau
Mar. 5 to Mar 11	0.7″ SSW	3″ towards
Mar. 12 to Mar. 18	0.7″ NE	14″ towards
Mar. 19 to Mar 25	2 1″ SW by S	4″ from
Mar. 26 to Apr. 1	1.2″ NE by E	16″ towards

A.E.J.

The Volcano Letter

No. 410—Monthly | U. S. Geological Survey, Hawaii National Park | APRIL 1934

KILAUEA REPORT FOR APRIL 1934

Including weekly press reports 1159 to 1162, April 1 to April 29, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

No significant changes have been observed, in the craters of Kilauea and Mauna Loa during April, which suggest any immediate activity of lava. In Halemaumau pit of Kilauea volcano, a small fall of rocks at the northwest wall occurred 8:40 a. m. April 11, another at northeast wall 8:30 a. m. April 12, trickle slides moved down the northwest buttress inside the pit at 9:18 a. m. April 21, again at 10:15 a. m. northeast, and at 10:38 a. m. stronger at the top of the northwest buttress; dust arose again at 1:15 p. m. April 25 a northwestern slide again occurred, at 10:12 a. m.

The thirty-two rim crack points marked, around the edges of Halemaumau, for weekly measurement with steel tape, showed the following weekly changes as measured Saturday forenoons:—

April 8. 7 opened, 7 closed, aggregate result zero.
April 15. 5 opened, 6 closed, aggregate closing 1.0 mm.
April 22. 12 opened, 1 closed, aggregate opening 7.5 mm.
April 29. 12 opened, 4 closed, aggregate opening 5.5 mm.

For Mauna Loa, Ranger R. F. Lueck was in Mokuaweoweo crater April 29 for six hours. He visited the cones at the center of eruption of December last. He is familiar with this center from previous visits (Volcano Letter, January, 1934). Where at this center during his January visit he could smell sulphur strongly, there was now in April no more blue fume nor odor at the December vents. The 1914 cone, however, west of the rifts of 1933 in the bottom of the greater crater, was making blue and yellow fumes, as before. Lueck reported that a cone six miles down from the summit along the northeast rift belt of the volcano was steaming from its crater. This cone lies east of the National Park trail below the usual steaming places, and no steam had been noticed there on previous trips.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble, feeble, and slight earthquakes; teleseisms or distant earthquakes; and local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	f.	sl.	tel.	seis.
April 8	15	4	0	0	0	5.75
April 15	25	5	2	1	1	12.75
April 22	18	1	0	0	0	5.00
April 29	18	2	0	0	0	5.50

The following local earthquakes were located.

A very feeble shock at sea on the Kilauea east rift, at 5:46 p. m. April 3. Lat. 19° 40′N. Long. 154° 37′W.

A very feeble shock a short distance north of Kilauea crater at 7:34 p. m. April 6. Lat 19° 28′N. Long. 155° 14′W.

At 2:06 a. m. April 9, a moderate earthquake felt in Kohala, felt lightly in Hilo and in Maui. It recorded as very feeble at the observatory and was located at the north end of the island Lat. 20° 09′N. Long. 155° 53′W.

At 8:21 a. m. April 9, a second shock in central Kohala. It was less widely felt, but recorded as feeble at the observatory; Lat. 20° 06′N. Long. 155° 43′W.

A very feeble shock at 2:38 a. m. April 11, 12 mi. at sea, S by E of Cape Kumukahi, Lat. 19° 16′N. Long. 154° 40′W.

A very feeble shock at 0:01 a. m. April 12 was located in Kilauea crater Lat. 19° 24.8′N. Long. 155° 16.5′W.

A feeble shock at 9:14 a. m. April 14 was located 10 miles north of Mokuaweoweo, Lat. 19° 37.5′N. Long. 155° 37′W.

A slight earthquake at 7:51 p. m. April 14, was felt in Olaa and Hilo. It was located 10 miles at sea on the east rift, Lat. 19° 37.5′N. Long. 154° 43′W.

A very feeble shock was felt in Hawaii National Park at 10:25 p. m. April 15. It was located 3 miles SE of the Volcano House, Lat. 19° 24.5′N. Long. 155° 14′W.

A very feeble shock at 1:06 a. m. April 24 was located near Waiohinu near the south end of the island, Lat. 19° 02′N. Long. 155° 38′W.

The teleseism was partly recorded, the records showing first or P wave only, beginning at 11:57:10 a. m. April 15.

Microseismic ground motion was normal April 4, 9, 11, 12, 13, 14, 15, 18, 20, 21, 26, 27, and 28, and subnormal the remainder of the month.

A.E.J.

Tilting of the Ground.

In the Table of Tilt below, the second column shows the net tilt by weeks, as computed from the seismograms at the Kilauea Observatory, which is on the northeast rim of Kilauea crater 2.2 miles from Halemaumau.

The third column shows the algebraic sum of the readings at three clinoscope cellars around Halemaumau pit, reduced each to its radial direction, outward away from, and inward in the direction of, the center of Halemaumau.

The Table represents the tipping of the ground, in seconds of arc, in the direction given.

At the Observatory, a northeast reading is away from the crater, a southwest reading is in the direction of the crater.

At the Observatory the total accumulated tilt in the year April 29, 1933 to April 29, 1934 is 5.3″ N. and 2.1″ E.

TABLE OF TILT

Date	Observatory	Halemaumau
Apr. 2 to Apr. 8	0.8″ SW by S	3″ towards
Apr. 9 to Apr. 15	0.6″ SW by S	2″ from
Apr. 16 to Apr. 22	0.3″ E by S	8″ from
Apr. 23 to Apr. 29	0.3″ West	1″ towards

A.E.J.

The Volcano Letter

No. 411—Monthly | U. S. Geological Survey, Hawaii National Park | MAY, 1934

KILAUEA REPORT FOR MAY 1934

Including weekly press reports 1163 to 1167 April 29 to June 3, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanology

Slides in Halemaumau pit of Kilauea crater occurred as follows:—a thin dust cloud rose high and straight at northeast side 3:20 p. m. May 3; trickle slides at northeast wall 9:20 a. m. May 8, and thereafter during the day; the strongish earthquake of 10:09 a. m. May 10 left fresh red fragments on lower northwest talus, and there was a break in the wall just above. On May 11 fragments trickled down the northwestern wall as shown by the noise in that region at 9:05 and 9:12 a. m. The earthquakes of 3:23 and 3:25 p. m. May 13 were followed by a slide at Halemaumau at 3:38 p. m. leaving scars at top of west and north wall.

On May 14 at 8:20 a. m. with notably still air and rainy weather, Halemaumau showed vapor rising from the southeast and west walls, from the southwest talus, in voluminous jets up the south talus, at the wall about the southwest rift tunnels, and all along the upper rim cracks, east and west, outside of the pit.

In contrast to this. vapor was notably absent up and down the walls and taluses north and northeast, and no vapor jets whatever rose from the lava floor of the pit, nor from the 1932 cone at the southwest margin of the floor. The walls of the pit were dark red with moisture. This vapor distribution seems to indicate that the release of atmospheric moisture from underground is entirely outside the lava plug.

On May 20 it was noticed, that the tension cracks in the 1932 floor of Halemaumau all radiate from the region of the southwest cone. These include the border cracks, which are notably absent around the northern sides of the floor. The effect is as though strain of uplift were in progress under the 1932 cone. Yet for the last ten months 59% of the tilting at the three tilt cellars around Halemaumau has been inward, measured in seconds, reduced to radii from the center of the pit. The tension cracks are rather a relic of 1932, than anything related to present stress.

Weekly measurement of opening and closing of thirty-two rim crack points around the edges of Halemaumau, showed the following changes Saturday forenoons:—

May 5. 10 opened, 4 closed, aggregate opening 3.5 mm.
May 12. 8 opened, 3 closed, aggregate opening 4.5 mm.
May 19. 5 opened, 13 closed, aggregate closing 4.5 mm.
May 26. 4 opened, 7 closed, aggregate closing 3.0 mm.
June 2, 14 opened, 3 closed, aggregate opening 7.0 mm.

T.A.J.

Earthquakes

TABLE

Number of minutes of tremor; numbers of very feeble, feeble, slight, and moderate earthquakes; teleseisms or distant earthquakes: and local seismicity index as described in Volcano Letter 371.

Week ending	tr.	v. f.	f.	sl.	mod.	tel.	seis
May 6	21	4	0	0	0	1	7.75
May 13	21	3	2	1	1	0	14.75
May 20	11	1	0	0	0	1	3.25
May 27	5	1	0	0	0	0	1.75
June 3	18	1	0	0	0	0	5.00

A tremor at 1:07 p. m. April 30, recorded at both Hilo and Observatory stations, was located about 55 statute miles east of Cape Kumukahi (east point of Hawaii) Lat. 19° 32'N. Long. 153° 59'W.

A very feeble shock at 8 p. m. May 9, was 10 miles deep under Mauna Loa, Lat. 19° 30'N. Long. 155° 30'W.

A moderate to strong quake began at 10:09:05 a. m. May 10 on the Observatory seismograms and was followed by aftershocks at 10:39 a. m. and at 0:34 p. m. The main shock was described at Hakalau as being very strong leading to flight from houses. Honomu and North Kohala reported it as very sharp, and sharp. Hookena and Kapapala reported it moderate, Holualoa and Puuwaawaa as small. Honokaa thought it rather strong. Hilo had objects fall and old paint crack off ceilings, there was some alarm. It was reported felt on the island of Maui. It dismantled some seismographs on Hawaii. The location found was 17 miles deep under the NE section of Mauna Loa. Lat. 19° 38'N. Long. 155° 23'W.

The first aftershock at 10:39 a. m. was felt in Hakalau, it was located 27 miles deep under the SE section of Mauna Loa. Lat. 19° 27"N. Long. 155° 26'W. It registered as very feeble at the Observatory.

The second aftershock at 0:34 p. m. recorded as feeble, was from the shore line of Hawaii to the south of Kilauea, Lat 19° 15'N. Long. 155° 18'W., and probably 4 miles deep. It was reported felt very slightly at Kilauea and Hilo.

Two small quakes were well recorded on the Kona seismograph at 7 p. m. on May 10 and at 11:20 p. m. May 11, but were not well recorded elsewhere.

A slight quake was felt at Kilauea, Hilo and Honokaa at 3:23 p. m. May 13. It was located 14 miles deep on the rift dividing Mauna Loa and Kilauea at Lat. 19° 22.5'N. Long. 155° 22.5'W. It was followed by an aftershock, felt in Kilauea and Hilo, at 3:25 p. m. It was about 2 miles deep under the SW section of Mauna Loa, Lat. 19° 13'N Long. 155° 39'W.

A very feeble shock at 6:30 p. m. May 15 may have occurred under the Mauna Loa SW rift.

Ten very small shocks (tremors and very feeble) occurred under the Kilauea crater during the five weeks covered here.

A small record of a teleseism began at 6:13:56 p. m. May 3, a second began at 11:50:25 a. m. May 14. Both were located by the U. S. Coast and Geodetic Survey. The first Lat. 61°N. Long. 148°W. near Prince William Sound, Alaska; the second Lat. 59°N. 150°W. near Kenai Peninsula, Alaska.

Microseismic motion of the ground was subnormal most of the five weeks, normal intensity was reached only on May 10 and 12.

A.E.J.

Tilting of the Ground.

In the Table of Tilt below, the second column shows the net tilt by weeks, as computed from the seismograms at the Kilauea Observatory, which is on the northeast rim of Kilauea crater 2.2 miles from Halemaumau.

The third column shows the algebraic sum of the readings at three clinoscope cellars around Halemaumau pit, reduced each to its radial direction, outward away from, and inward in the direction of, the center of Halemaumau.

The Table represents the tipping of the ground, in seconds of arc, in the direction given.

At the Observatory, a northeast reading is away from the crater, a southwest reading is in the direction of the crater.

At the Observatory the total accumulated tilt in the year June 3, 1933 to June 3, 1934 is 1.8" E and 4.5" N.

TABLE OF TILT

Date	Observatory	Halemaumau
Apr. 30 to May 6	1.3" NE by N	2" towards
May 7 to May 13	0.4" NW by W	4" towards
May 14 to May 20	1.5" SW	1" towards
May 21 to May 27	0.1" S	4" from
May 28 to June 3	0.5" SE by S	2" towards

A.E.J.

The Volcano Letter

No. 412—Monthly U. S. Geological Survey, Hawaii National Park JUNE, 1934

KILAUEA REPORT FOR JUNE, 1934

Including weekly press reports 1168 to 1171
June 3 to July 1, midnight.

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

At Halemaumau pit of Kilauea Volcano there was no new motion nor sign of lava activity. It is of interest to note how the pressure ridges around the edges of what was the lava lake of 1932 (January), now the floor of the pit, show three stages of shrinkage of the lake. There is the ridge around the edge of the floor, outlining the large lake of December 1931. Then there is a narrow ridge across the floor from the northwest to southeast, marking the first stage of diminution. Lastly there is an innermost rampart with hummocks inside, just in front of the big southwest cone, which contained the last fountaining source of the lava. What liquid lava receded must have finally sucked down the vent under the cone, and so made the slumping of crusts which are now seen in tumbled condition on the floor and at the cone.

Measurements of vapor temperatures by Jaggar, at cracks near Halemaumau, June 1, 2, 3, and 5 gave the following figures in degrees Centigrade (35° C. equals 95° F., and 88° C. equals 190° F.):—

Southwest, over Kau Desert rift line, 54, 57 and 64 degrees C.

West, near big steam crack, 58 and 67 degrees C.

East, north of tourist outlook, 50 and 55 degrees C.

One hundred feet back of this from the pit, 70 to 75 degrees C.

Near road terminus houses, southeast, 35 to 48 degrees C.

Near flag northwest of pit, 51, 53, 56, 58 and 64 degrees C.

Whitened 1919 lava half-mile north of pit, 74, 83, and 88 degrees C.

Whitened 1894 lava southeast of Halemaumau, 82 to 88 degrees C.

These figures show temperatures lower than January 1925 for cracks near the pit (See Volcano Letter 301). The high temperatures in cracks more remote are as usual. The implication is that deeper cracks are found, tapping deeper and hotter vapor, towards the border of the greater Kilauea crater. Probably at the border of the inner fill of Halemaumau, now inaccessible, there are very hot places. These would correspond with the old "postal card crack," which was at the border of a Halemaumau fill of 1894, a "wall-crack," destroyed by overflow in 1919 and by collapse in May, 1922.

Slides in Halemaumau during June were:—

5:30 p. m. June 8, from the notch to the east of the north buttress.

June 14-15, large fresh fall of rocks found, making a broad gray streak on the east talus.

9:42 a. m. June 23, small and continuous slide on north side of lower buttress at the southeast wall, lasting some minutes.

10:57 and 11:21 a. m. June 30 over the middle of the north sill.

Weekly measurement of opening and closing of thirty-two marked rim-crack points, around the edges of Halemaumau, showed the following changes Saturday forenoons:—

June 9. 7 opened, 3 closed, aggregate opening 3.0 mm.
June 16. 6 opened, 5 closed, aggregate opening 0.5 mm.
June 23. 8 opened, 5 closed, aggregate opening 3 mm.
June 30. 9 opened, 7 closed, aggregate opening 1.5 mm.

T.A.J.

EARTHQUAKES

TABLE

Number of minutes of tremor; numbers of very feeble, and moderate local earthquakes as registered at Kilauea; teleseisms or distant large earthquakes; and local seismicity index (see Volcano Letter 371)

Week ending	tr.	v. f.	mod.	tel.	seis.
June 10	15	1	0	0	4.25
June 17	102	3	0	0	27.00
June 24	51	2	0	0	13.75
July 1	32	6	1	1	14.00

The following successive local disturbances began at the times indicated, and the epicenters as shown were located from seismograms; when possible, the depth of the source is indicated. The location of epicenters is based on four main seismograph stations, Kilauea, Hilo, Kona, and Waikii. The intensity is that recorded at Kilauea instruments.

May 16 at 6:29 p. m. very feeble, Lat. 19° 01'N, Long. 155° 38'W.

May 20 at 6:14 p. m. tremor, Lat. 19° 49'N, Long. 156° 13'W on the extension of the Hualalai rift.

June 5 at 8:59 a. m. very feeble on the NE Mauna Loa rift, nearer Hilo than Kilauea.

June 15 at 10:50 p. m. very feeble, Lat. 19° 42'N, Long. 155° 22'W, 6 miles deep under SE slope of Mauna Kea.

June 25 at 2:30 p. m. very feeble, Lat 19° 36'N, Long. 155° 20'W on the northeast Mauna Loa rift.

June 26 at 7:07 p. m. moderate, Lat. 19° 12'N, Long. 155° 05'W, a few miles at sea south from the Puna coast, felt at Honokaa, Hilo, and Kilauea.

June 27 at 7:01 a. m. very feeble, Lat. 20° 02.5'N, Long. 155° 18'W, under Hamakua coast, felt in Honokaa.

Other very feeble local earthquakes at Kilauea crater were two in number June 12, and one each June 19, 23, 26, and 28.

The distant large earthquake was incompletely recorded beginning June 28 at 10h:06m:43s; p. m.

Microseismic motion was subnormal, becoming normal June 4, 19, 24, and 25.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the pit.

At the Observatory the total accumulated tilt in the year ending July 1, 1934 was 3.3″ N and 1.6″ E of the position July 1, 1933.

TABLE OF TILT

Date 1934	Observatory	Halemaumau
June 4 to June 10	0	3.3″ towards
June 11 to June 17	0.9″ NE by E	2.0″ towards
June 18 to June 24	0.9″ NNE	0.6″ towards
June 25 to July 1	0.9″ W by N	72.8″ towards (Earthquake 26th)

A.E.J.

The Volcano Letter

No. 413—Monthly U. S. Geological Survey, Hawaii National Park JULY, 1934

KILAUEA REPORT FOR JULY, 1934

Including weekly press reports 1172 to 1175
July 1 to July 29, midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

Slides in Halemaumau during July were:—

At 1:15 p. m. July 5, north side, making dust cloud, leaving fresh break in wall over west end of Canoe Sill, and leaving fresh debris on the talus.

10:20 a. m. July 7, small slide north.

9:33 a. m. July 19, small slide north.

2:36 p. m. July 20, slides from east and north walls started by an earthquake. The shock was felt by an observer standing on the southwest rim, a swaying motion. This was Mr. Twigg Smith, who immediateiy saw a considerable slide at the east corner of the pit, and a smaller one at the north buttress. Dust rose above the pit. Rocks were still falling at the east at 3:05 p. m. The earthquake origin was probably under the southeast part of Kilauea crater. The pit instruments were partly dismantled, and the cracks used for measurements were somewhat changed.

10:15 a. m. July 21, slide at northwest talus.

Afternoon, July 21, slide made a dust cloud.

8:40 a. m. July 22, a few rocks sliding north.

1:45 p. m. July 24, a few rocks heard sliding.

National Park workers at the summit crater of Mauna Loa reported disagreeable fumes in the west part of the crater, and on July 22 two noises like blasts about twenty seconds apart, to the eastward.

Weekly measurement of opening and closing of thirty-two marked rim-crack points, around the edges of Halemaumau, showed the following changes Saturday forenoons:—

July 7. 8 opened, 3 closed, aggregate opening 5.0 mm.

July 14. 4 opened, 4 closed, aggregate opening 1.5 mm.

July 21. 11 opened, 4 closed, aggregate opening 4.5 mm.

July 28. 6 opened, 8 closed, aggregate closing 1.0 mm.

Crack point No. 37, about 800 feet back from the southeast rim of Halemaumau, and extending northeast along the wall-crack of Kilauea crater against the "Sand Spit" where the Volcano House road emerges on the lava floor, has been opening extensively. It has made marked cracks in the paving of the road, and in the mortared stone coping. This was observed by A. E. Jones June 25. The total opening is 15 mm. (0.6 inch) April 14 to August 4, 1934. This crack had opened slowly during the previous half-year, but it suddenly began rapid weekly movement after April. (For position see map Volcano Letter 395).

T.A.J.

EARTHQUAKES

TABLE

Week ending.	Minutes of tremor.	very feeble earthquakes	Slight earthquakes	Distant earthquakes	Local * Seismicity.
July 8	24	8	0	1	10.00
July 15	12	2	0	0	4.00
July 22	25	1	1	5	9.25
July 29	14	2	0	1	4.50

* For local seismicity see Volcano Letter 371.

The following successive local disturbances began at the times indicated, the epicenters as shown were located from seismograms; when possible, the depth of the source is indicated. The location of epicenters is based on four main seismograph stations, Kilauea, Hilo, Kona, and Waikii. The intensity is that recorded on the Kilauea instruments.

July 5 2 20 a. m. very feeble, Lat. 19° 17'N. Long. 155° 35'W, 22 miles deep under the SE flank of Mauna Loa.

July 5. 3:15 p. m. very feeble, Lat. 19° 33'N, Long. 155° 23'W, 3 miles deep under the Mauna Loa NE rift.

July 20, 2:36 p. m. Slight, felt strongly by visitors near the Pit of Halemaumau, felt slightly at the NE end of Kilauea, occurred under the SE rim of the crater. Dismantled the Pit seismograph, only recorded as a small tremor on both the Hilo and Kona seismographs.

July 20, 1:30 a. m. Felt at Kapapala Ranch. Lat. 19° 24.5'N, Long. 155° 27'W, 4 miles deep.

The teleseisms were recorded as follows;

July 6, 0h:27m:02s. p. m. the secondary waves began at 0:32:45 p. m. It's origin was 41.5° N 124.9° W (Jesuit Seis. Ass.) off the coast of Northern California.

July 17, 3:17:50 p m. secondary waves at 3:27:15 p. m. Its origin was 16° N., 84° W, (USC&GS) in northern Panama.

July 18, 9:19:31 a. m. secondary waves at 9:26:14 a. m. Origin 14° S, 168° E, (USC&GS) near the New Hebrides.

July 18, a fragment of a distant earthquake began recording at 9:30 p. m.

July 20. 7:57:17 p. m. secondary waves at 8:04:48 p. m. Origin 3,700 miles away.

July 21, 0:20:29 a. m. secondary waves at 0:29:52 a. m. 4,900 mi. to origin.

July 27, 11:14:08 a. m. secondary waves at 11:23:36 a. m. 4,985 mi. to origin.

Microseismic ground motion was normal July 6, 18, 19, 21 and 27 and was subnormal the other days of the month.

A.E.J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the pit.

At the Observatory the total accumulated tilt in the year ending July 29 is 3.8″ N and 1.8″ E.

TABLE OF TILT

Date 1934	Observatory	Halemaumau
July 2 to July 8	0.5″ North	3.0″ from
July 9 to July 15	0.8″ N by W	5.4″ towards
July 16 to July 22	1.4″ N by W	64.3″ from * (quake)
July 23 to July 29	1.2″ ENE	4.0″ from

* Local earthquakes have caused the SE clinoscope to change 73″ towards the pit June 26 and 64″ from the pit July 20. What portion of these changes represent actual tilt is uncertain.

A.E.J.

The Volcano Letter

No. 414—Monthly U. S. Geological Survey, Hawaii National Park AUGUST, 1934

KILAUEA REPORT FOR AUGUST, 1934

Including weekly press reports 1176 to 1180

July 29 to September 2, midnight

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

Slides in Halemaumau during August were:—

At 9:10 a. m. August 4, south wall, a small slide.

9:12 a. m. August 4, north wall.

On the previous day August 3 a small slide was reported northwest about 10 a. m.

About 11 a. m. August 12, small slide at the north.

At 9:25 a. m. August 19, an avalanche at the north.

At 1:15 p. m. August 19, another similar slide.

At 10:30 a. m. August 25, slide at the north.

Weekly measurement of opening and closing of thirty-two marked rim-crack points, around the edges of Halemaumau, showed the following changes Saturday forenoons:—

August 4. 6 opened, 4 closed, aggregate opening 2 mm.

August 11. 7 opened, 11 closed, aggregate closing 2.0 mm.

August 18. 9 opened, 7 closed, aggregate opening 2.0 mm.

August 25. 7 opened, 6 closed, aggregate opening 1.0 mm.

September 1. 7 opened, 1 closed, aggregate opening 3.0 mm.

No excessive movement occurred at Crack No. 37, described in July Volcano Letter.

August 30 temperature readings were made on the Kilauea floor north of Halemaumau. A new trail for the purpose has been built by the Hawaii National Park. Heat is at vapor vents. These vents are persistent deep crackings, which assert themselves up through surface flows. Similar temperatures are found over definite areas. Presumably deep cracking has let down rain water and brought up vapor. The mapping of these areas is important, and their changes of temperature may possibly bear on forecast. Hitherto the data of forecast for eruption are elusive, except where based on statistics, or phenomena only a few hours before the event.

In a whitened area north of Halemaumau, in 1919 lava, maximum temperature was 86° Cent; heavy grass and moss grew in the wet vapor. The 1924 ash has assisted vegetation everywhere. Farther north opposite Uwekahuna trail, the temperature was 45° C., also 1919 lava with less vegetation. In 1894 lava near the big lava dome northeast of Halemaumau, a whitened area showing lichens and grass gave 79° C. The whitening is due to insoluble sulphates. On the Volcano House trail farther east, whitened cracks cutting both 1894 and 1921 lava gave 85° C. A big steam hole farther northeast on the line between Halemaumau and the north side of Kilauea Iki gave 89° C (the boiling point of water for this elevation is about 97° C.) This was 1894 lava, the cracks showed blue-green algae in the openings, the rock was rusty and covered with salts, and a reddish belt of these cracks extended east-northeast away toward the outer walls of Kilauea crater, in a sharply marked zone radial to the Halemaumau center. The larger steam-holes that show vapor on a sunny day are very hot. Along the telephone line east of Halemaumau in 1894 lava, the maximum temperature was 63° C., the ground showing some whitened cracks and grass. The temperature of the air was 26°C.

A. E Jones was in charge of a party under Hawaii National Park July 30 to August 3, to map the lava floor of the summit crater of Mauna Loa, as left by the eruption of December 1933. The floor was flagged and a revised topographic map made with plane-table. The helpers were John Mahaiula, Fred Pestana, Louis Braz and Torao Nishimoto. The new summit rest-house was occupied and was found a protection against cold. The four days on the summit were generally clear and comfortable. The temperature was 32° F. at sunset and 20° F. at daylight. The crater was quiet, sounds of falling rocks were heard occasionally, and the 1933 lava was shell pahoehoe. Near the eruption vents the rock was hot enough to be uncomfortable, the shell lava broke easily and in places was dangerous, and sulphurous fume was locally strong. The results of mapping show the new lava field in the eastern half of the main Mokuaweoweo bowl to be two miles long by three-fourths mile wide and 100 feet thick; the source cones at the southwest are 100 feet high. The depression contour basins of the crater are now at the north and southeast. The new lava heap is thus an elongate dome highest at the southwest athwart the crater sink, with its axis northeast-southwest.

T.A.J.

EARTHQUAKES

TABLE

Week ending.	Minutes of tremor.	Very feeble earthquakes	Slight earthquakes	Distant earthquakes	Local * Seismicity.
August 5	11	4	0	0	4.75
August 12	14	3	0	1	5.00
August 19	12	1	1	0	5.50
August 26	18	2	0	0	5.50
September 2	11	4	0	0	4.75

* For local seismicity see Volcano Letter 371.

The following successive local disturbances began at the times indicated, the epicenters as shown were located from seismograms; when possible the depth of the source is indicated. The location of epicenters is based on four main seismograph stations, Kilauea, Hilo, and Kona. Waikii did not return any records for days when earthquakes ocurred. The intensity is that recorded on the Kilauea instruments.

July 30. 0:23 a. m. very feeble, Lat. 19° 40′ N. Long. 155° 45′ W; under Hualalai.

July 30. 4:18 a. m. very feeble, Lat. 19° 20′ N. Long. 155° 14′ W; under Ainahou Ranch.

July 30. 3:28 p. m. very feeble, Lat, 19° 22.5′ N. Long. 155° 17′ W; under the south slope of Kilauea 1 mile from crater.

July 31. 0:06 a. m. very feeble, Lat. 19° 22.5′ N. Long. 155° 13′ W; 1 mile deep under Heake crater, one of the chain of craters.

August 7. 10:19 a. m. very feeble, Lat. 19° 32′ N; Long. 155° 32′ W; 5 miles deep under Mauna Loa NE rift, near summit. Felt in Hilo.

August 11. 2:38 p. m. very feeble, Lat. 19° 18′ N. Long. 155° 28′ W; 1 mile deep under SE flank of Mauna Loa, near Wood valley.

August 16. 2:08 a. m. slight, Lat. 19° 38′ N. Long. 155° 15′ W; 5 miles deep uder Mauna Loa NE rift. It was felt in Hilo and Honomu.

August 25. 2:08 p. m. very feeble, Lat. 19° 25.3′ N. Long. 155° 16 5′ W; 1 mile deep under Kilauea crater.

August 28. 5:51 p. m. very feeble, Felt by several on Kilauea crater rim, probably centered under crater.

The long waves of a teleseism began recording at 5h:30m:40s. p. m. August 6.

USC&GS reports it as occurring near the New Hebrides, Lat. 14° S. Long. 168° E.

Microseismic ground motion was normal (20 to 30 microns) July 30 and 31, and was subnormal (8 to 20 microns) August 1 to September 2.

A.E.J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the pit.

At the Observatory the total accumulated tilt in the year ending September 2, 1934 is 1.9″ N and 2.7″ E.

TABLE OF TILT

Date 1934	Observatory	Halemaumau
July 30 to Aug. 5	0.7″ NNW	0″
Aug. 6 to Aug. 12	0.4″ WNW	1.0″ from
Aug. 13 to Aug. 19	0.8″ ENE	6.9″ towards
Aug. 20 to Aug. 26	1.2″ ENE	5.6″ towards
Aug. 27 to Sept. 2	0.5″ N by E	1.2″ towards

A.E.J.

The Volcano Letter

No. 415—Monthly U. S. Geological Survey, Hawaii National Park SEPTEMBER, 1934

KILAUEA REPORT FOR SEPTEMBER, 1934

Including weekly press reports 1181 to 1184
September 2 to September 30, midnight
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

Halemaumau pit of Kilauea Volcano broke into lava eruption in its bottom about 2:44 a. m. September 6. On the preceding day there were slides before and after noon, and the seismograph SE of Halemaumau registered southwesterly tilt the afternoon of the 5th. This was the first real premonitory symptom.

Sept. 6 tremor spasms began 1:07 a. m. a few minutes apart, and shocks close to the pit accompanied the outbreak, the feeble shock at 2:44 a. m. being followed by the continuous tremor of fountaining, and by the bright glow of inpouring lava and clouds of fume. The fountaining places began at the edge of the 1932 floor north, northwest and west. The first two were at the base of taluses, the third a crack back of the west buttress. Here the lava squirted up in 25 jets along a horizontal line halfway up the wall of the pit. These jets cascaded down the wall in ribbon cataracts. They poured over the large west talus and went out of action by 6 a. m. The northwest fountains were several hundred feet high like jets from hose nozzles, covering up the northwest talus with pumiceous lava. The northern line of fountains trending E-W about 600 feet was quickly submerged under the spreading lake, and became a lake center destined to survive. Between 3 and 4 p. m the northwest fountains went out of action, making a great diminution in fume volume and the eruption adopted stability of action at the northern fountains, followed by gradual dwindling for thirty days.

Sulphurous fume of absinthe red color in transmitted light boiled up several thousand feet the first twelve hours. With it went fragments of basaltic pumice, but nothing resembling ash. The reflected fountain light was yellow-green to orange. The noise was a rumbling and a rushing of gas. Hundreds of whirlwinds swept up clouds of dust west and southwest of Halemaumau, the trade wind being from the northeast. Pumice fragments up to 30 cm. fell on the ground outside of the pit.

At 4 a. m. Sept. 6 there were 30 jet fountains. At 8 a. m. the new bottom pool covered the entire 1932 floor 60 feet deep. Its area was 90 acres and its volume 9 million cubic yards. Only the top of the 1932 border cone was still emergent. Ten main vents persisted until 6 a. m. along the cascade crack, the cascades being 300 to 400 feet high, and there were two or three subordinate cascades, on an extension of the crack which opened on the north side of the west boss.

Northeast and southwest of the pit, the broken ground exhibited new breaks in the ash soil. At noon Sept. 6 the north fountains had dwindled and the northwestern ones were very violent. The lake was covered with a bright-line pattern and black silky skins. There were straight lines of bubble fountains along the meeting belt of surface currents. A bench and rampart of crusts developed around the lake, wider at the taluses, where the submerged slope was flatter. The tremor diminished when the violent northwest fountaining stopped rather suddenly, between 3 and 4 p. m., and only thin blue fume was left arising from the northern interior fountains.

Sept. 7 there were 8 fountains, the larger one making blast-like detonations, flinging up lava 300 feet, and emitting brown puffs. Tremor increase rang the annunciator bell at the Observatory two miles away. The lake diminished to a northern circle around the fountains 1200 feet in diameter. Sept. 9 the floor had shrunk and lowered 10 to 20 feet, and the inner lake was smaller, at the NNE side of the floor. There was a slump scarp all around. A few slides occurred. The lake Sept. 10 measured about 1000 feet east-west by 400 feet north-south, and was defined by a border rampart over which went overflows. The lake became an oval plateau on top of a terraced heap. Spatter banks formed behind the two bigger fountains east and west showing that the lake was shallow as usual Only the fountains were over wells. September 11 overflows poured out of the lake heap on all sides. Sept. 12 islands of crust and spatter began to form near the eastern fountains. Detonations came from the wells from time to time as the vents clogged. Five sulphur patches appeared on the taluses. Sept. 15 there were five principal fountains and a line of islands from NW to SE across the lake. Sept. 16 the western fountain was dominant, with a cone and crater about it. There were ten fountains, six islands and a peninsula.

Sept. 20 the floor measured 2700 by 2200 feet. The lake pool measured 744 by 390 feet. This pool stood 38 feet above the floor, and the highest grotto heap of its banks stood 136 feet above the pre-eruption floor of 1932 immediately under it. The average 1932 floor level was 2796 feet above sea-level, while the average 1934 new floor level is 2874 feet. This makes the average thickness of the new layer 78 feet.

Overflows built up the new lake heap against the north wall of the pit. Ten cracks gradually developed in the outer floor radial to the lake. The overflows appeared to be a stiff viscous pahoehoe Always the streaming was outward from the west fountains as source well, and sometimes the east fountains exhibited a well of inward cascading downward. Evidently a convectional circulation was being established, and the sinkhole well tended to explode with detonations. The lake remained brimming full and the fume remained thin.

Sept. 20 a new feature back of the border slump scarp at the edge of the greater floor of Halemaumau was the welling up of trickle flows glowing red, evidently following the "wall-crack" between the talus and the new cake of 1934 fill. This was the first time after the early days that any glowing lava had appeared from a source away from the lake. These trickle flows at 11 a. m. rose along the base of the east talus, and at 2:30 p. m. they rose along the base of the south taluses. The next day September 21 the west talus developed the same kind of trickle flows along its base. These risings at the floor edge were favored by freedom of percolation of the lava among talus bowlders, but the trickle flows extended to places under the rock walls of the pit. In no case did they cascade over the slump scarp inward, but rose as a dike between the floor cake and the outer funnel. In each case their appearance was marked by extra pressure at the lake, accompanied by overflows. The band of border extrusion was 20 feet wide in places. Sept. 22 during a big overflow from the lake southwest, wall-crack trickle appeared along the small talus heaps west-northwest.

Sept. 22 detonation spells from both east and west wells of the lake recurred from time to time, usually when the east fountain had been transformed into a sinkhole grotto Big bursts of gas and flame came up. The phenomenon of downpouring would last from 10 to 20 minutes. Then the pot would resume ordinary fountaining with outward streaming. Harmonic tremor greatly increased during detonation spells. September 23 the west fountain had become a pool in a raised craterlet, from which a cascade poured southward into the lake.

This craterlet made noisy high explosions emitting brown fume bursts. Four avalanches were observed at the north wall of the pit. About 2 p. m. the lake drained out almost completely through the eastern sinkhole, leaving an empty saucer 20 or more feet deep, with the western source quiet, and explosions at the sinkhole Then the liquid poured in again. The duration of these drainages was from a half-hour to two hours, increasing until October 1 in duration and violence at intervals of about six hours. Eventually the detonations were heard three miles away.

The elevation above sea-level of the lake Sept. 20-21 was 2882 feet. of the floor, 2844 feet, of the floor edge 2860 feet. The spatter heaps stood 26 to 28 feet above the lake. The depth of the pit from the Tourist Stand southeast (B. M. 3644 feet) to the lake plateau was 762 feet, and to the mean level of the bottom 770 feet. The highest spatter heap at the lake stood 71 feet above the lowest part of the floor.

The last week of the month was characterized by the six-hour intervals between explosive drainages of the lake, and by swelling up of the edges of the floor. Probably the whole floor was swelling by intrusion. This accounts for the drainages, and agrees with the earlier wall-crack trickle flows. Apparently the pulsations of lowering the lake basin—all overflows had now ceased—were occasioned by inflow of the liquid under the shell of crust forming the floor of Sept. 7-8. The floor was lifted and the lake went down. The lake heap was thereby abolished. The explosions

were due to clogging of the gases in the increasingly viscous lava of the wells, unable to fountain freely with artesian well action, when by reason of recession the effervescent fluid was trying to fountain at the bottom of a shaft. Failing to overflow, the wells became gun barrels. With each detonation an umbrella-shaped fling of stiff lava would shoot up 400 feet, the roofs of the grottoes would be blown to pieces, and fragments would clatter down all over the surrounding surfaces. Finally the explosive spells would be followed by complete quiet for a half-hour. Then the liquid would quietly recover in the wells, and restore the lake to a period of four or five hours of quiet streaming.

The drainages tended to come after noon and after midnight, and usually once in between. Sept. 25 a band of red glow showed around the floor edge of Halemaumau, indicating that wall-dike intrusion was still in progress. Sept. 26 this disappeared, but a week later it reappeared. The detail of a sinking spell of the lake was as follows. At 9 a. m. the west fountain cone was cascading over its flank; at 11 a. m. the lava had lowered 25 feet from the lake, both east and west fountain wells were cannonading vertically, long squirts of viscous melt were sent up 200 feet, the intervals between detonations or hisses were from five to ten seconds, then the lava pooled in the wells and came back with quiet fountaining at 12:15 p. m. The explosions gradually lessened, a fan-shaped flood from the west fountain met an expanding puddle from the east fountain in mid-lake, the new liquid overriding the foundered crust that formed the floor of the lake.

September 28 there were still some overflows from the lake. An elephant-back ridge 25 feet high was revealed swollen and crevassed in the edge of the new floor at the foot of the east talus. Instead of welling up the wall-crack, the under-lava was now blocked in that direction, and so was lifting the floor instead. The floor which had been 15 feet below the slump-scarp, was now 25 feet above it.

Another survey by T. A. Jaggar September 29 showed the average floor border at elevation 2860 feet as before; the inner floor 2881 feet instead of the former 2844 feet. The lake had lowered slightly from 2882 to 2879 feet elevation. The summits of the lake heap now averaged 2903 feet, where on September 21 they stood at 2909 feet. The length of the lake, now narrower and irregular, had increased from 744 to 812 feet. Its width decreased from 390 to 360 feet. The relative height of the lake heap above the floor remained about 75 feet for its maximum relief above a valley in the floor southeast of the lake basin. The east cone was its highest point, elevation 2910 feet. The relief of the floor is much greater than is apparent as seen from above. The cones about the fountains were 20 to 30 feet above the full lake.

Sept. 29 the lake made small overflows, overhanging grottoes surmounted the two fountains, gradual drainage until noon was followed by intense explosions at both wells, lasting until 1:30 p. m. The explosions demolished the arched grottoes. There was repose until 2:00 p. m. Then the wells quietly filled from below with red puddles covered with gray skin. The lake basin was refilled from both wells by torrents cascading downward over the slag-heaps of the ridge. The lake area was being converted into several ponds. Sept. 30 there was a forenoon drainage; at 8 p. m. the west fountain started lowering and exploding, while the eastern one was giving vent to a voluminous river of lava, which stopped flowing at 8:30 p. m. Then its source the east well gave vent to explosions 400 feet high, the smaller shots coming 20 to the minute. The west pot exploded sending fiery spray 600 feet high, the maximum to date; the detonations were heard 2.2 miles away and rattled iron roofs. The well seemed empty, but the gushes occasionally brought up great sheets of lava; splashes stuck on the pit wall a third of the way to the top. The greater explosions came about every 8 minutes. Cessation followed as usual. By night five glow spots showed along the edge of the floor east.

Weekly measurements of rim cracks around Halemaumau, 32 in number, gave:

Sept. 8. 14 opened, 12 closed, aggregate opening 24 mm.
Sept 15. 11 opened, 6 closed, aggregate opening 6 mm.
Sept. 22. 10 opened, 2 closed, aggregate opening 5.5 mm.
Sept. 29. 8 opened, 6 closed, aggregate opening 2.5 mm.

By measuring the cracks the forenoon of the eruption Sept. 6, a movement of opening of 20 mm. had already taken place, involving 12 opened and 11 closed; 12 mm. of the opening was at Crack No. 37, a deep border fissure of the Kilauea crater floor southeast, which had cracked the road paving. The differential movement was down to the northwest, and up to the southeast. This movement had been in progress for some months (See July Volcano Letter).

The tilt movements at the three clinoscope cellars around Halemaumau accompanying the eruption, were inward towards the pit at the north and southeast cellars, and away from the pit at the west cellar. This amounted to more than 100 seconds at the west and southeast cellars, but the instruments were dismantled, so that the values are indefinite. The north cellar registered 22.5 seconds south since the previous day, (Sept. 5-6).

The tilt at these cellars after the eruption proceeded was recovery at the southeast and west cellars, and continuance in the same direction at the north cellar. The west cellar recovered 21 seconds to the ENE; the southeast cellar 7 seconds to the SE; and the north cellar continued 5 seconds to the SW, between Sept. 6 and Sept. 10. The tilting movements were more normal after September 10. This was the first demonstration of the effect of eruption on these tilt cellars. The instrument pivots are not yet proof against earthquakes. T. A. J.

EARTHQUAKES.

TABLE

Week ending.	Minutes of tremor.	Very feeble earthquakes	Feeble earthquakes	Slight earthquakes	Local * Seismicity.
Sept. 9	4,878	9	1	1	1,725.
Sept. 16	10,080	1	0	0	2,565.
Sept. 23	10,075	3	2	0	2,808.
Sept. 30	9,885	0	0	0	2,763.

* For local seismicity index see Volcano Letter 371.

Note, Some of the tremor was very feeble in amplitude and was weighted accordingly.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indicated. The location of epicenters is based on three main seismograph stations, Kilauea, Hilo, and Kona. No earthquakes were recorded at Waikii. The intensity is that recorded on the Kilauea instruments.

September 6, 1:07 to 2:44 a. m. several very feeble shocks and tremors occurred that were near or in the crater; they preceded the eruption in Halemaumau. At 2:21 a. m. a slight earthquake (2 Rossi-Forel) was felt by several persons living on the rim of the crater. It was located in the creater near Halemaumau. lat. 19° 25′ N long. 155° 17′ W and very near the surface of the crater floor. At 2:44 a. m. a feeble earthquake (1 Rossi-Forel) occurred. It was located near the south rim of Kilauea near the surface, in lat. 19° 23.5′ N long. 155° 16.7′ W. All of the above shocks immediately preceded the out-flow of lava in Halemaumau, and were supposedly caused by the breaking of the crust under the strain of trapped volcanic gas and magma.

September 17, 11:56 a. m. a feeble shock was felt at the Observatory and at Honomu. It was located at 19° 02′ N, 155° 13′ W. 11 miles deep.

Sept. 22. 9:44 a. m. a feeble shock was felt at the Observatory and at Kapapala ranch. It was located 11 miles deep under Hilina Pali, at 19° 15′ N. 155° 20′ W.

September 23. 1:49 a. m. a very feeble shock occurred probably one of seven felt at Kapapala ranch. It was located 9 miles deep under Pa'lima Point on the Kilauea SW rift. 19° 11.5′ N. 155° 27′ W.

No teleseisms were noticed on the seismograph records. Any small records would have been obscured by the large continuous "Harmonic Tremor" generated by flowing lava in Halemaumau.

This tremor had a period of 0.6 seconds and represented a ground movement of from 6 to 48 microns during the early hours of the eruption. Towards the end of the month the fluctuations in amplitude became more marked, dropping at times to less than one micron, at other times becoming as large as 15 microns, all with the same period. These spells were coincident with spells of explosion that recurred at 6 to 7 hour intervals during the last week of the month. (Sept. 24 to 30).

Microseismic motion of the ground was normal on the following days of the month, September 6, 7, 8, 12, 14, 19, 21, 24, 26, and 30, and subnormal the rest of the month. A. E. J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the Pit.

At the Observatory the total accumulated tilt in the year ending September 30, 1934 is 0.4″ S and 1.4″ E.

TABLE OF TILT

Date 1934	Observatory		Halemaumau	
Sept. 3 to Sept. 9	2.0″	SW	120.″ ?	towards
Sept. 10 to Sept. 16	1.4″	ENE	0.4″	towards
Sept. 11 to Sept. 23	1.0″	NNE	2.6″	from
Sept. 24 to Sept. 30	1.2″	NNE	6.0″	from

A. E. J.

The Volcano Letter

No. 416—Monthly U. S. Geological Survey, Hawaii National Park OCTOBER, 1934

KILAUEA REPORT FOR OCTOBER, 1934

Including weekly press reports 1185 to 1188
September 30 to October 28 midnight
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

Oct. 1 at 9 a. m. the west fountain pot started exploding and the lake drained. At 10:46 a. m. the liquid returned by overflow of the east fountain well. Another spell in the evening sent the glowing spray almost up to the pit rim 770 feet high. The noises were heard 3.5 miles away. This ended the detonating phase of activity. Oct. 2 the west fountain was overflowing its cone with seven streams, then the east fountain sent out a torrent 100 feet wide, then a middle fountain sent a stream northward to a new pool, which there overflowed the lake basin and reached the base of the north wall of the pit. After noon the wells lowered to weak bubbling fifty feet down. At seven in the evening heavy fume was rising from the wells.

Oct. 3 three quarters of the lake basin had become a slag-heap, with the north pool a depression in its flank 300 feet long. The middle fountain and the north pool were actively liquid. There were nine smoke holes. At night three pools were outlined by glow. Streaming showed there were tunnels to outlets east and west from the west pot. At the outer edges of the floor there was glow in cracks east, south and southwest. Intrusive lava was welling up along the edges of the floor cake. October 4 the middle fountain noisily jetted up diagonally like a hose, supplied the north pool, and kept the pit luminous at night, but this was the end of illumination. The east pot was a smoke hole, the east pool was dark at night, only a trickle remained at the west pool, and the floor margin glow was less. October 5 the lake area had collapsed, there was fume, streaming continued in the north pool, and blowing noise was audible. Around the edges of the floor there was conspicuous swelling from intrusion, especially northeast. Oct. 6 and 7 the central cone became a whitened fuming heap, the north pool was liquid underneath and showed crusts cracking and foundering in the melt, and the west cone had ceased fuming. Thuddung noise was heard in the western part of the swelling floor, prolonged wall-slides began at the north, and the steaming lessened at the taluses.

The last moving lava in Halemaumau was seen Oct. 7, and the last day of eruption was October 8. On Oct. 8 at 10 a. m. hisses were heard from the middle fume cone. At 11:25 there was prolonged wall-sliding north, and dust arose through a rim crack NNE. About 1 p. m. there were two north slides. Sliding all day occurred at west end of Canoe Sill. At 11:30 a. m. there was a slide east of Southwest Tunnel. At 11:43 a. m. there was a slide at top of West Talus. At 8 p. m. there were 11 glow spots along the east and south wall crack of the floor, and 12 about the lake area.

Oct. 9 at 7:17 a. m. a big avalanche took away the upper edge wall slab NNE of Halemaumau. The lake basin and the northern and eastern taluses were fuming. Out to the edge of the floor from the lake area there are left ten radiating tension cracks. There was a slide N. at 9:06 a. m., a big fall of fresh rock from the lower wall lay on the floor SE, and a few fresh bowlders lay on the floor NE. During the next week the taluses showed dry hot places at the bottom, 11 places on the northeastern half of the floor showed blue fume, and border swellings had cracked into chasms at the edge of the floor east, west and south. The solfatara at the base of the east talus increased its fuming. At the end of the month there was no visible shrinking down of the floor, there was wall-crack heat everywhere, slides were few, snapping was heard, spots of white and yellow staining appeared, especially at the base of the WNW wall cascade and on the NW pumice bank left against the talus by the big fountains of Sept. 6. A curved line of stain on the floor in front of this outlined and buried front of the talus cone.

Weekly measurements of rim cracks around Halemaumau, 32 in number, gave:—

Oct. 6, 11 opened, 3 closed, aggregate opening 5.5 mm
Oct. 13, 7 opened, 4 closed, aggregate opening 3.0 mm
Oct. 20, 9 opened, 5 closed, aggregate opening 3 mm
Oct. 27, 10 opened, 5 closed, aggregate opening 2.5 mm

A levelling circuit from South Sandspit as base by Jones Oct. 17-25, showing changes since July 2, 1934, in elevation of rim of Halemaumau, relative to the south rim of Kilauea Crater, revealed the following facts, presumably correlated with the outbreak of September that was concentrated at the north side of the Halemaumau bottom:—

Elevation to maximum of 1.28 feet within a stretch of the north rim 1800 feet long.

Depression to a maximum of 0.5 foot northwest and northeast of the pit, along a thousand feet of the rim on each side of the elevated tract.

The rest of the rim shows diminishing depression southward to a line of no change 400 feet SSE of the pit.

The north tilt cellar was involved in the elevated area to an elevation of 0.69 foot; its disturbance at the time of the outbreak was much less than that of the other two cellars in the slightly depressed areas. T. A. J.

EARTHQUAKES

TABLE

Week ending	minutes of tremor	very feeble earthquakes	feeble earthquakes	moderate earthquakes	distant earthquakes	local * seismicity
Oct. 7	5,091	5	0	0	0	1,252.
Oct. 14	64	2	0	1	1	20.00
Oct. 21	23	4	1	0	0	8.75
Oct. 28	63	2	1	0	0	17.75

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indicated. The location of epicenters is based on three main seismograph stations, Kilauea, Hilo, and Kona. The intensity is that recorded on the Kilauea instruments.

October 3. 1:50 p. m. very feeble, lat. 19° 18′ N. long. 155° 26′.5 W. 21 miles deep under Kaoiki fault.

October 8 to 9 numerous tremors and very feeble shocks correspond with avalanching of Pit walls.

October 12. 5:45 p. m. a shock was felt at Honokaa, not recorded at Kilauea.

October 13. 7:14 p. m. moderate. Felt generally over the island of Hawaii. 19° 28′ N 155° 30′ W. 44 miles deep under the central part of Mauna Loa.

October 18. 0:20 a. m. feeble, felt generally on Hawaii. 19° 30′ N. 155° 40′ W. 39 miles deep, under central part of Mauna Loa. Followed at 1:41 a. m. by a very feeble shock from near the same place. 19° 30′ N. 155° 42′ W.

October 27. 7:47 a. m. feeble, felt near Kilauea crater. 19° 56′ N. 155° 38′.5 W. 23 miles deep.

The preliminary waves of a teleseism began recording at 5:20:09 a. m. October 10, the secondary waves began at 5:26:34 a. m.

Microseismic motion of the ground was normal October 9, 10, 11, 12, 16, 17, 18, 21, 22, 23, 24, 25, 27, 28, and was abnormal October 15: Other days subnormal.

The 5,091 minutes of tremor in the table represents the closing week of the lava inflow, and has about half the value of other weeks. (See Volcano Letter 415.) The explosive sequence that began in Halemaumau 9:15 a. m. October 1 made at first a record similar to a small earthquake record, later records were obscured by tremor. The last detonation at 9:57 a. m. was felt at Hawaiian Volcano Observatory 2 miles away. The harmonic tremor almost disappeared after October 1, its amplitude always stronger at the stations nearer the pit, and showing direct relation to the visible lava fountaining. A. E. J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the pit.

At the Observatory the total accumulated tilt in the year ending October 28, 1934 is 1.0″ N and 1.7″ E.

TABLE OF TILT

Date 1934	Observatory	Halemaumau
Sept. 30 to Oct. 7	1.2″ NE	9.1″ from
Oct. 8 to Oct. 14	0 6″ N by W	23.3″ toward*
Oct. 15 to Oct. 21	1.4″ ENE	21.3″ from
Oct. 22 to Oct. 28	0.6″ NE by N	2.2″ toward

* Disturbance following quake of October 13.

A. E. J.

The Volcano Letter

No. 417—Monthly U. S. Geological Survey, Hawaii National Park NOVEMBER, 1934

KILAUEA REPORT FOR NOVEMBER, 1934

Including weekly press reports 1189 to 1193
October 28 to December 2, midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

Slides in Halemaumau during the month had the following characters:

At 9:50 a. m. October 29 a block fell noisily southeast. Pebbles fell at the new lava cascades November 1.

Between 8:30 and 10 a. m. November 3, intermittent sliding north.

November 4 this continued.

Week ending November 11, sliding at the west end of the Canoe sill north, notching the wall and making a sandy talus below; the buttress east of the SW tunnels caved away. This made pink dust on the floor.

11 a. m. November 13, a slide northeast sent up dust.

November 20 the sandy top of the north talus, after many slides recently, had changed its shape.

Fume in the pit was noted as follows:—

October 30, 9 fume places and 3 sulphur spots.

November 4, fume from pit as whole rose in thin bluish clouds.

November 11 fume had increased north.

November 12 solfatara at East Talus had lengthened southward. Ten places were fuming.

November 20, a dry day, the central fume patches of the 1934 lava lake area could not be seen; only 7 places counted.

November 22, after more than 1 inch of rainfall, 20 places showed vapor, but none at the lava lake site. On the Kilauea floor southwest over the rift belt, noisy purring at the vapor vents.

December 2, after 3.66 inches rain at Halemaumau gauge, pit was full of vapor, hundreds of steam plumes on the bottom, clockwise whirls indicated small tornadoes.

November 3 fresh hair cracks in soil appeared at pit rim NNE. Cracks of the intrusion ridges around edge of 1934 floor had widened November 11. Stain at the southeast ridge was increasing. Hot dry belts marked the bases of the talus cones, and bright yellow sulphurous stain was increasing at base of WNW wall. The stained area of pumice on top of northwest talus changed from yellow to white under rain washing; it was probably alum. The talus ESE and SSW steams after rainfall.

It is remarkable on the Kilauea floor southwest and northwest of Halemaumau how by condensation the puffing vapor vents have made areas green with tufty grass in the 1924 sand and gravel.

Weekly measurement of opening and closing of 32 marked rim crack points, around the edges of Halemaumau, showed the following changes Saturday forenoons:—

Nov. 3, 9 opened, 3 closed, aggregate opening 4 mm
Nov. 10, 7 opened, 7 closed, aggregate opening 0.5 mm
Nov. 17, 12 opened. 3 closed, aggregate opening 5 mm
Nov. 24, 7 opened, 3 closed, aggregate opening 3 mm
Dec. 1, 5 opened, 4 closed, aggregate opening 0.5 mm

T. A. J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Distant earthquakes	Local * Seismicity
Nov. 4	9	1	0	2.75
Nov. 11	11	0	0	2.75
Nov. 18	29	1	0	7.75
Nov. 25	15	2	0	4.75
Dec. 2	11	2	1	3.75

* For local seismicity index see Volcano Letter 371.

During the five weeks period, only one shock has been approximately located. The Hilo and Kona records of the other shocks were too small to be of value in making a location. The very feeble shock at 5:53 a. m. November 12 was on the Kilauea SW rift. 19° 13′ N. 155° 24′ W.

The preliminary waves of a teleseism began to record about 3:43:54 p. m.; what may have been either secondary or long waves began to record at 3:54:47 p. m. The maximum waves at 3:58 p. m. were very large.

Microseismic motion of the ground was normal November 1, 2, 4, 11, 13, 14, 22, 25, 27, 28, and abnormal October 29, 30, 31, November 3, 5, 6, 12, 21, 23, 29 30, December 1, 2, and subnormal the other days of the month.

A. E. J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the pit.

At the Observatory the total accumulated tilt in the year ending December 2, 1934 is 1.9″ N and 1.1″ E.

TABLE OF TILT

Date 1934	Observatory	Halemaumau
Oct. 28 to Nov. 4	0.5″ N by W	10.9″ toward.
Nov. 5 to Nov. 11	0.4″ N	2.5″ from
Nov. 12 to Nov. 18	0.7″ E	2.0″ from
Nov. 19 to Nov. 25	0.5″ ENE	4.9″ from
Nov. 26 to Dec. 2	0.5″ WSW	18.7″ from.

A. E. J.

The Volcano Letter

No. 418—Monthly U. S. Geological Survey, Hawaii National Park DECEMBER, 1934

KILAUEA REPORT FOR DECEMBER, 1934

Including weekly press reports 1194 to 1197
December 2 to December 30, midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

Slides in Halemaumau were as follows:—

December 16, 9:25 a. m., a fall of rocks at west lava cascade

December 30 about 10 a. m., rocks fell occasionally northeast

Fume in the pit was noted as follows:—

December 10, 9 a. m., 7 places fuming around northern edges of floor. The place of densest fuming was at base of east talus.

December 16, dry sunny day, about 9:30 a. m., vapor visible only at east talus.

Week ending December 23. Fume continues moderately dense at east talus.

Week ending December 30, blue fume from the four northern and eastern talus slopes, where they make contact with the new lava floor. The solfatara making densest steam and fume was at the base of the east talus. where there was in September the largest swelling in the floor due to intrusion. The fume separates itself from the steam and rises to fill the air in the upper part of the pit, while the water vapor dissipates. This fume shows best when the sunlight is behind it; it is thin. December 17 strong northeast wind was blowing clouds of dust over the Kau desert, and making whirls counterclockwise on the western edge of the pit. Thirteen places around the floor showed vapor after rain, but the bases of the taluses showed dryness due to excessive heat below. Vapor rose from high cracks in the western wall.

December 30 six fuming places were counted as visible.

December 10 stain had begun to appear at the wall-crack extrusion against the talus SSE, and the slope showed wet streaks steaming. A snapping noise was heard from the floor. December 16 the base of the WNW cascade had been growing increasingly bright yellow, probably with sulphur stained sulphates, and had extended its stain out on the floor. December 22 new rocks had fallen on the floor east. December 30 during the visit one snap in the floor like a detonation was heard about 9:50 a. m.

Weekly measurements of 32 rim cracks about Halemaumau, for changes of opening and closing as exhibited Saturday forenoons, resulted as follows:—

Dec. 8, 8 opened, 5 closed, aggregate opening 2.5 mm
Dec. 15, 9 opened, 6 closed, aggregate opening 2.5 mm
Dec. 22, 16 opened, none closed, aggregate opening 11.0 mm
Dec. 29, 3 opened, 3 closed, aggregate opening 0.5 mm

The general situation in the Halemaumau bottom is a pause in hot lava deeply crusted since the eruption of September, which had filled in over the 1931-32 floor by something over 90 feet for an average. The yellow sulphates and hot fume around the border, the swollen and cracked floor, the hot dry bases of the talus slopes, and the cracking noises, all indicate that the mobile paste is still there.

T. A. J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Distant earthquakes	Local * Seismicity
Dec. 9	8	2	0	0	4.50
Dec. 16	19	7	0	0	8.25
Dec. 23	12	6	1	0	8.00
Dec. 30	15	2	0	1	4.75

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated; no epicenters could be found. The intensity is that recorded on the Kilauea instruments.

December 22. 1:55 a. m. very feeble, was felt lightly near Kilauea crater.

December 22. 0:46 p. m. feeble, was felt lightly near Kilauea crater. It was reported as stronger at Kapapala Ranch.

December 24. 9:27 a. m. very feeble, was felt at Hakalau.

The long waves of a teleseism began recording at 3:39 a. m. Dec. 30.

Microseisms were subnormal December 14, 29, and 30; they were normal December 13, 15, 22, 24, 25, and 26; and they were abnormal the rest of the period.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the pit.

At the Observatory the total accumulated tilt in the year ending December 30, 1934 is 1.3″ N and 2.8″ E.

TABLE OF TILT

Date 1934	Observatory	Halemaumau
Dec. 3 to Dec. 9	0.7″ NE by N	8.2″ toward
Dec. 10 to Dec. 16	0.6″ NE by E	0.2″ from
Dec. 17 to Dec. 23	1.4″ E	10.1″ from
Dec. 24 to Dec. 30	1.0″ E	6.3″ toward

A. E. J.

The Volcano Letter

No. 419—Monthly U. S. Geological Survey, Hawaii National Park JANUARY, 1935

KILAUEA REPORT FOR JANUARY, 1935

Including weekly press reports 1198 to 1202
December 30, 1934, to February 3, 1935, midnight
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar. Volcanologist in Charge

VOLCANOLOGY

The general situation in the Halemaumau pit bottom for the month of January shows much volcanic motion centering about Kilauea. The lava floor of September, 1934, is hot and uneasy, snapping noises are heard, the tilts about the pit are rather strong and in new places, the hot fume is increasing at the west edge of bottom of pit, and new cracks have appeared near the rim.

Slides at Halemaumau

January 1, forenoon, a few rocks heard falling at the north. January 2, after the strongish earthquake of 6:47 a. m. originating under Kilauea, slides were started, and the pit was watched, but no excessive sliding was reported. January 8, a collapsed rim crack south of Halemaumau indicated recent motion. January 13, at 10 a. m., a slide occurred southwest. January 14, at 9:37 a. m. rocks fell at the east. January 18, at 2:15 p. m., and at 2:30 p. m. lasting a half-minute, slides were reported. January 21, at 9:05 a. m., a fall of rocks occurred near the SW tunnels. January 22, at 9:30 a. m., after a faint booming noise, a few rocks fell, and at 10:09 a. m., a moderate slide occurred south, after other noises. Seven slides occurred in one half hour period. January 26, the excessive sliding on the SSW wall made a streak of dust to the bottom, where fresh debris lay on the south talus and floor; the falls had started 100 feet below the edge. January 27, small slides at the SSW wall occurred twice in the hour 8:40 - 9:40 a. m. January 29, a few rocks fell prior to 10 a. m. January 31, between 9 and 9:20 a. m., a few rocks fell NW and E. A track of a recent slide lay on NW wall through the middle of the 1934 lava cascades. February 3, in the forenoon dust rose from east wall; the slides there were renewed 12:40 p. m., 12:50 p. m., dwindling to 1:05 p. m.; slight sliding occurred continuously 1:30 to 2:30 p. m. The location was above the east talus. There was some sliding at south wall also.

Sounds in Halemaumau

January 1, a clanking noise was heard twice, seeming to come from the 1934 lava lake cup. January 14, at 9:40 a. m. a snap was heard toward the north. January 18, two cracking sounds were heard after 2:30 p. m. January 22, at 9:02 a. m. a loud boom was heard, a faint sound at 9:30, and dull sounds from the east end of the lake cup came at 9:41; at 9:45 a dull sound seemed to come from the bottom of SE wall; again at 9:56 from the SW bay; and from the NW part of the floor at 9:58 a. m.; slides occurred during this half-hour. January 25. One snap was heard NW. January 27, eleven snapping noises were counted between 8:43 and 9:02 a. m., averaging one every 1.7 minutes. The sound is like the blow of an underground hammer. The south wall was sliding slightly. January 31, 9 to 9:20 a. m., some dull thudding noises were noted, and a hissing noise was heard from the SW bay.

Solfataras, at Halemaumau

January 1, five fuming places were noted, at the E, NE, N, and NW taluses, and at the Yellow Solfatara, a vent at the northern base of the west cascades of 1934. January 8, with very heavy rains, there were thousands of steam jets on the hot floor, but not at the lake cup. The heaviest steam jets were at the Yellow Solfatara, and at NW and E taluses. January 10, after more rains, the fume over Halemaumau appeared dense. January 14, after rain, 19 places were steaming or fuming inside the pit. There were hot dry places at the base of talus slopes, which are heaps of broken bowlders extending down under the 1934 lava fill to a depth of 600 feet, and these are porus filters for hot gas. January 17, at noon, with strong southwest wind, the fume from the pit did not show. The vapor jets on the outer floor of Kilauea crater at the north, during such wind, are nucleated by invisible fume from the pit, and show scores of white jets. January 21, the yellow solfatara was strongly fuming. January 25, the heap of sulphur-stained sulphates at the Yellow Solfatara had increased and been washed by rain, and fume was still more voluminous. The solfataric bank on the NW talus showed pink, red, yellow, white and gray salts, with vapors presumably rotting the 1934 pumice, suggesting the Red Solfatara of 1921. January 29, with southwest wind blowing, both fume and vapor were moderate in amount in Halemaumau.

The cracks in the floor of Halemaumau, and elsewhere, were observed as follows:—

January 2, after the earthquake, the cracks and swellings of the floor showed some new features. January 11, new cracks were reported at the tourist stand SE. January 12, cracks were reported newly breaking the curb masonry 450 feet back from the rim of Halemau SE. January 19, this crack in the masonry at the pit measured 3 mm. January 21, the radial cracks on the floor southeast appear widening. One cross-crack has formed in the south floor. The marginal ridge in the floor all around exhibits large gaping cracks. January 25, eleven cracks radial from the cup were counted on the eastern half of the floor, and five or six more are on the western half.

Weekly measurement of 32 marked rim cracks around Halemaumau, resulted as follows:

Week ending forenoon

Jan. 5,	15 opened,	3 closed,	aggregate opening	12 mm.
Jan. 12,	8 opened,	5 closed,	aggregate opening	1.5 mm.
Jan. 19	12 opened,	1 closed,	aggregate opening	7 mm.
Jan. 26,	5 opened,	7 closed,	aggregate closing	0.5 mm.
Feb. 2,	14 opened,	2 closed,	aggregate opening	8 mm.

T. A. J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Moderate earthquakes	Distant earthquakes	Local * Seismicity
Jan. 6	72	10	1	2	26.00
Jan. 13	26	3	0	0	8.00
Jan. 20	14	3	0	0	5.00
Jan. 27	18	5	0	1	7.00
Feb. 3	29	4	0	0	9.25

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indicated. The location of epicenters is based on three main

seismograph stations, Kilauea, Hilo and Kona. The intensity is that recorded on the Kilauea instruments.

Dec. 31, 1934, at 10:40 p. m. very feeble, was SW of Kilauea crater lat. 19° 21′ N long. 155° 19′W 12 mi. deep. It was reported felt near Kilauea crater.

Jan. 2, 1935, at 6:47:17 a. m. moderate, was under the Uwekahuna rim of Kilauea crater. 19° 25.5′ N 155° 17′ W. 2 mi. deep. Reports indicated that it was felt generally over the island of Hawaii, objects fell in Hilo, and a landslip was started in Halemaumau.

Jan. 8 at 2:09 p. m. very feeble, was near Kulani cone 19° 31′ N 155° 17′ W.

Jan. 13 at 1:33 p. m. very feeble, was 3 miles ENE of the Observatory 19° 26′ N 155° 13′ W and 4 mi. deep.

Jan. 17 at 11:35 a. m. very feeble, was probably at sea SE of the island, near 19° 15′ N 155° 0′ W.

Jan. 17 at 10:58 p. m. very feeble, was near Wood Valley, 19° 20′ N 155° 30′ W. It was reported felt at Kapapala Ranch near the epicenter.

Jan. 19 at 5:49 a. m. a tremor, was in Kilauea crater, probably near Byron's Ledge.

Jan. 21 at 0:02 a. m. very feeble, occurred 35 miles deep under the east slope of Mauna Kea, 19° 44′ N 155° 22′ W. It was reported felt along the NE coast of Hawaii.

Jan. 27 at 7:23 p. m. very feeble, was 30 miles deep under Puu Ulaula rest house on the Mauna Loa NE rift zone, 19° 31′ N 155° 29′ W.

Jan. 29 at 4:01 p. m. very feeble, was probably under the summit crater of Mauna Loa.

Jan. 29 at 6:41 p. m. a tremor, was probably near the Kealakekua Bay fault. It was felt and well recorded in Kona.

Jan. 30 at 9:51 p. m. very feeble, was probably on the chain of craters 7 miles SE of Kilauea.

Feb. 3 at 4:21 p. m. very feeble, was 2 miles ENE of Kilauea crater, 19° 26′ N 155° 14′ W, near the epicenter of Jan. 13.

The preliminary waves of a teleseism began recording at 8:16:50 a. m. Dec. 31, 1934. The secondary waves were missing, the long waves were missing, the long waves began to record at 8:32:08 a. m. It was about 3,400 statute miles distant.

The preliminary waves of a teleseism began at 2:58:12 a. m. Jan. 1, 1935. The secondary waves began at 3:03:49 a. m. It was about 2,500 miles distant.

The long waves of a poorly recorded teleseism began at 9:08 p. m. Jan. 22. The distance was unknown.

Microseisms were abnormal Jan. 2, 3, 4, 5, and Jan. 17 to Feb. 3. They were normal Jan. 6, 7, 9, 10, 12. 13, 14, 15, and 16; and subnormal the remainder of the time.

A. E. J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea Crater; at Halemaumau, the readings from each clinoscope, and the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the pit.

At the Observatory the total accumulated tilt in the year ending February 3, 1935 is 2.3″ N and 0.2″ W.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations			
		North	West	Southeast	Pit Resultant
Jan. 6	0.8″ N 28° E	23.6″ S 28° E	28.1″ S 16° W	160.0″ N 20° W	185.0″ toward*
Jan. 13	1.7″ S 66° W	7.3″ S 71° W	7.7″ N 12° W	3.4″ S 4° E	2.9″ toward
Jan. 20	2.2″ S 52° W	2.3″ S 26° W	2.8″ N 25° W	33.6″ S 17° W	20.4″ from
Jan. 27	1.4″ S 55° W	5.1″ N 86° E	1.9″ N 58° W	4.3″ S 3° E	4.4″ from
Feb. 3	1.0″ S 3° W	6.3″ N 25° E	2.2″ N 23° E	9.2″ N 4° E	5.3″ toward

* Southeast station dismantled by earthquake of January 2, 1935.

A. E. J.

The Volcano Letter

No. 420—Monthly U. S. Geological Survey, Hawaii National Park FEBRUARY, 1935

KILAUEA REPORT FOR FEBRUARY, 1935

Including weekly press reports 1203 to 1206

February 3 to March 3, 1935, midnight

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

The month has produced local shakings close to Kilauea, some easterly tilt which suggests tumescence and is abnormal for this season, and small slides from the walls of Halemaumau pit. Many small earthquakes at the Halemaumau seismograph, are mere tremors at the Observatory near Volcano House.

Slides at Halemaumau

February 4, occasional rock falls all day, including one in SW corner of the pit at 5:09 p m. February 5, the scar of this slide was obvious, and rocks were falling there at 9 a. m. Other falls of rock were heard NE, the East wall and talus had been changed. About 7 p. m. a slide was reported. Feb. 6, rocks were heard falling NE and SW. Feb. 9, all the sliding areas appeared freshly disturbed, fallen stones lay on the 1934 floor SE, and the scar of a fresh slide marked the wall halfway up, at the east Feb. 10, at 9:30 a. m. rocks fell at the S wall, and along the swollen monoclinal ridge at the margin of the 1934 lava floor, fallen bowlders lay on the crest of the arched crust in several places. Opposite all the talus slopes there is now fresh fallen debris on the 1934 floor, as result of caving wall matter since the eruption, and at the base of rock walls SE, NE and W NW. Feb. 12, at 9 a. m. a slight rock fall occurred S. After 3:25 p. m. rock slides SE occurred for 30 minutes. At 3:30 a cloud of dust arose from the wall, at 3:40 a larger mass of rock fell from a thin-layered zone near the top, sending a cloud of dust over the floor, and this was followed by rocks slipping for 10 minutes. There were four slides in a half-hour, leaving fresh cracks in the soil back of the edge of the pit, fresh dust on the floor, and a scar on the wall. Feb. 14, about 9 a. m. a tremor and slides were reported, accompanied by the opening of a crack in the floor. Feb. 16, a few rocks fell. Feb. 17, debris had been added to the bases of the east and south taluses, and the eastern floor appeared more swollen and cracked near the east solfatara. Feb. 18, at 9:05 a. m. there was a southern fall of rocks, and at 10:43 a. m. an avalanche fell from half way up the NE wall to the small talus heap. Feb. 25, at 8:52 a m. a fall of rocks occurred NE. Feb. 27, at 11:50 a. m. a small noisy slide fell from the NW buttress. March 1, at 2 a. m. a slide occurred E S E.

Other Phenomena

Feb. 12, there were vaporings at south talus and wall, at west talus and the cascade wall, at the wall west of southwest tunnels; voluminous fume rose from the Yellow Solfatara NW, and there were many small fume jets at the floor edge under the NNW talus. It was a misty forenoon of high humidity after moderate rain, but for no obvious reason the northwest region had suddenly developed excessive vapor and fume, and these had diminished in the east part of the Halemaumau floor. February 17 in cold dry weather hot vapor and fume were very slight, but they had developed at the small NE talus. The vapor and fume certainly fluctuate with the rainfall; during very heavy rains about February 23 deuse clouds of vapor rose from the pit, originating in the symmetrical semi-circle of five fuming talus slopes around the lava-lake oval, or cup, which was the last active pool of lava of October 1934. In the morning light of February 25 the floor cracks around the edges appeared to have increased their gaping, and the crescent of stain in front of the NNW talus—the site of the pumice bank of the largest fountains of September 6, 1934—had definitely become a depression. There is an arc of cracks in front of it, and the floor still farther in front is a plateau; everywhere the floor is a swollen plateau above the wall-valley. The cracks at the edge of the floor plateau are tensional chasms, parallel to the strike of a monoclinal bend which dips down to the floor margin.

Rim Cracks

Weekly measurement of 32 marked rim cracks around the upper edge of Halemaumau resulted as follows:

Week ending forenoon:

Feb. 9, 7 opened, 3 closed, aggregate opening 2.5 mm.
Feb. 16, 10 opened, 2 closed, aggregate opening 5.0 mm.
Feb. 23,* 16 opened, 4 closed, aggregate opening 9.0 mm.
Mar. 2,* 9 opened, 4 closed, aggregate opening 3.5 mm.

* Measured partly Feb. 24, because of heavy rains.

Noises

Thudding noises from the bottom of Halemaumau were heard at 8:58 a. m. and 9:02 a. m. February 12, a clanking was heard at the base of east wall at 10:10 a. m. Feb. 17, and a snapping noise NE at 11:05 a. m. that day, and again Feb. 25 at 8:40 a. m. T. A. J.

EARTHQUAKES

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Slight earthquakes	Distant earthquakes	Local * Seismicity
Feb. 10	28	6	1	0	0	11.00
Feb. 17	15	0	1	0	0	4.50
Feb. 24	46	5	1	0	1	15.00
Mar. 3	67	4	0	1	0	20.75

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indicated The location of epicenters is based on three main seismograph stations, Kilauea, Hilo, and Kona. The intensity is that recorded on the Kilauea instruments.

Feb. 4 at 7:45 p. m feeble, occurred under the west wall of Kilauea crater, under Uwekahuna. Reported felt near Kilauea crater.

Feb. 5 at 0.20 a. m. very feeble, occurred under the NE wall of the crater near the Observatory.

Feb. 11 at 3:59 a. m. very feeble, occurred under Mauna Loa, lat. 19° 26′ N long. 155° 28′ W 16 miles deep.

Feb. 15 at 6:12 p. m. very feeble, occurred 2 miles SE of Kilauea crater.

Feb. 20 at 9:27 a. m. feeble, occurred near the junction of the SW rift and the SW crater wall.

Feb. 21 at 1:21 p. m. very feeble, occurred in the crater, east of the Pit.

Feb. 21 at 8:56 p. m. very feeble, occurred outside of Kilauea crater near Keanakakoi crater.

Feb. 26 at 2:10 a. m. slight, occurred 5 miles deep under N rim of Kilauea.

Feb. 27 at 1:11 p. m. very feeble, near Keanakakoi crater.

Feb. 28 at 5:39 p. m. very feeble, reported felt at Naalehu, located on the Mauna Loa SW rift, near 19° 10′ N 155° 45′ W.

Mar. 3 at 11:11 p. m. tremor, near SW wall of Kilauea crater.

Feb. 22 the preliminary waves of a small teleseism began recording at 6:43:58 a. m. the secondary waves began at 6:50:20 a. m.

Microseismic motion was abnormal Feb. 11, 12, 13, 14, 15, 16, 17. normal Feb. 4, 6, 18, 20, 21, 24, 27, 28, Mar. 1 and 2. and subnormal during the other days of the period.

A. E. J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the readings from each clinoscope and the resultant of radial tilts for the three clinoscopes, towards or from the center of Halemaumau Pit.

At the Observatory the total accumulated tilt for the year ending March 3, 1935 is 3.5″ N and 4.1″ E.

TABLE OF TILT

Week ending	Observatory station	Halemaumau Clinoscope Stations			
		North station	West station	SE station	Resultant
Feb. 10	1.3″ S 38° E	1.7″ S 70° W	2.8″ N 5° E	3.5″ N 43° E	1.7″ toward
Feb. 17	0.9″ S 80° E	3.2″ S 52° W	3.3″ N 81° W	5.9″ N 18° E	9.3″ toward
Feb. 24	0.2″ N 40° E	2.6″ N 68° E	5.1″ N 8° E	19.8″ S 9° E	20.5″ from
March 3	1.8″ S 39° W	2.0″ S 75° E	3.1″ S 86° W	14.7″ S 6° W	8.0″ from

A. E. J.

The Volcano Letter

NO. 421—MONTHLY U. S. Geological Survey, Hawaii National Park MARCH, 1935

KILAUEA REPORT FOR MARCH, 1935

Including weekly press reports 1207 to 1210
March 3 to March 31, 1935 midnight

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

The same processes of fuming, snapping, and avalanching from the walls, have continued in Halemaumau pit.

Slides at Halemaumau

March 4, at 9 a. m.; March 5, at 9:10 a. m.; March 6, a few rock falls after 9 a. m. and a slide at northeast corner 9:28 a. m.; March 7, a few rocks falling between 9:20 and 9:30 a. m.; March 8, rocks heard falling about 9:05 a. m.; March 10 debris on the bottom southeast, was in two new places. These are the incidents observed during a half-hour visit to the pit each forenoon.

March 16, debris at the west showed that a slide had occurred. Another slide scar appeared southeast, and other slides had occurred over the east bay, and at the NNE. March 23, at 9:02 a. m. a noisy avalanche reached the floor and sent up dust, at the south corner of the pit; the disturbance broke the rim, where fresh cracks in the soil were found, parallel to the edge of pit, fifteen feet back from the verge, and extending lengthwise more than a hundred feet. Another slide there at 2:25 p. m. made a similar dust cloud, and the noise was heard at a distance. Two other small slides fell from the west and north walls during the next half-hour.

March 28, slides were heard at 9:40 and 10:20 a. m. March 31, it was evident from the Pit seismograms, and from the dust over the south end of the pit floor, that a large slide had fallen at 8:15 p. m. March 30. The scar was from a point 100 feet below the top of the SSW wall, the same area that had been "working" lately. Cracks were widening in the soil above. The disturbance on the Halemaumau seismogram was much larger than on the Observatory record.

Miscellaneous Phenomena

Rainfall reached 7.5 inches in the four days preceding March 6, at the Halemaumau rain-gauge. Vapor plumes on the hot pit floor occasionally united into a dense cloud. At 9 a. m. March 8, an unexplained hissing noise seemed to be at the SW bay, and lasted about 3 seconds; earlier two dull thuds were heard NW and W. There had been five records of pit shocks on the Halemaumau seismogram, during the preceding 24 hours. The day before this there were one or two little shocks. On March 5, there were 8 small earthquakes on the Halemaumau record, only one of which was recorded at the Observatory two miles to the northeast, and that as a mere tremor.

The heavy rains tended to disturb the tilt instruments. However, there is always more intense volcanic tilting, and seismic activity, at the Halemaumau instruments, than at the northeast edge of Kilauea crater where the Observatory stands. This shows how important it is, in volcanology, to study seismically the innermost focus of a crater, in equipping with seismographs such a place as the summit crater of Mauna Loa. That particular crater must be so equipped very soon.

The radial floor crack at the bottom of Halemaumau, trending east, appeared to have widened March 16. The sulphur at the Yellow Solfatara northwest had so increased March 21 that the stain extended out on the floor, and its fume column was noticed at stations behind buttresses on the west rim of the pit, where it had been invisible before. March 25 about 8:40 a. m. two dull detonations were heard about five minutes apart. Three more were heard to the east of the pit between 9:20 and 9:30 a. m.

Weekly measurement of 32 marked rim cracks around the upper edge of Halemaumau Pit resulted as follows:

Week ending forenoon of

March 9, 7 opened, 4 closed, aggregate opening 2.5 mm.
March 16, 19 opened, 0 closed, aggregate opening 13.5 mm.
March 23, 10 opened, 4 closed, aggregate opening 5.0 mm.
March 30, 11 opened, 5 closed, aggregate opening 3.0 mm.

T. A. J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Distant earthquakes	Local * Seismicity
March 10	22	2	0	6.50
March 17	20	4	0	7.00
March 24	16	2	0	8.00
March 31	20	6	0	8.00

* For local seismicity index see Volcano Letter 371.

The following local very feeble disturances began at the times indicated; the epicenters as shown were located from the seismograms; when possible the depth of the source is indicated. The location of epicenters is based on three main seismograph stations, Kilauea, Hilo, and Kona. For crateral earthquakes, stations at Uwekahuna and Halemaumau are used. The intensity is that recorded on the Kilauea instruments.

March 5 at 5:31 a. m. located one mile deep under the southwest end of Kilauea crater.

March 9 at 1:58 a. m. located half a mile deep under the east side of Halemaumau Pit.

March 20 at 4:48 p. m. felt at Puuwaawaa, but not recorded well enough to be located.

March 24 at 11:29 a. m. felt at Uwekahuna, located 5 miles deep under that wall of Kilauea crater.

March 25 at 0:20 a. m. 3 miles deep under the southwest rift zone, 1 to 2 miles from Kilauea crater.

March 26 at 5:52 p. m. 1 mile deep, 2 miles southwest of Uwekahuna.

March 27 at 0:38 p. m. 1 mile deep under Kaoiki fault, lat. 19° 26′ N, long. 155° 20′ W.

March 28 at 11:48 p. m. 3 miles east of the summit crater of Mauna Loa, lat. 19° 27′ N, long. 155° 34′ W.

March 29 at 2:59 a. m. reported felt in Hilo, not well located.

Microseismic motion of the ground was abnormal March 4, 13, and 16; normal March 7, 14, 15, 18, 19, 20, 22, 24, 25, and 29; and subnormal during the remaining days of the month.

A. E. J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; at Halemaumau the readings from each clinoscope and the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the Pit.

At the Observatory the total accumulated tilt in the year ending March 31, 1935 is 1.1″ N and 0.6″ E.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations			
		North	West	Southeast	Pit Resultant
March 10	1.4″ S 55° W	2.5″ N 67° W	5.1″ N 82° W	8.7″ S 48° W	6.2″ from
March 17	0.7″ N 67° E	3.3″ S 53° E	1.6″ North	12.8″ N 9° W	12.1″ toward
March 24	2.9″ S 50° W	1.3″ S 68° W	0.9″ S 86° W	4.2″ N 6° E	4.9″ toward
March 31	1.5″ S 12° W	1.8″ S 65° W	3.0″ N 11° E	6.4″ N 50° E	4.9″ toward.

A. E. J.

The Volcano Letter

No. 422—Monthly U. S. Geological Survey, Hawaii National Park APRIL, 1935

KILAUEA REPORT FOR APRIL, 1935

Including weekly press reports 1211 to 1214
March 31 to April 28, 1935 midnight
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar. Volcanologist in Charge

VOLCANOLOGY

The month of April at Halemaumau pit was chiefly remarkable for the partial obliteration of the black, solidified lava cascades of September 6, 1934. This was achieved by avalanching, the upper wall NW falling away April 20, and the rim slab was completely removed in front of the West Steamhole. This west steam crack has been a landmark on the edge of Halemaumau since 1924, sending up white clouds of vapor always visible. The enlargement of the pit by engulfment of the rim rock in front of this crack, for a width of 20 feet lengthwise of the margin for 250 feet, leaves the western wall of the former steam crack merely part of the pit wall. The steam is gone. A few small steam cracks extend from here northward, back of the edge of the pit. The thudding noises in the floor have notably decreased since February.

Slides at Halemaumau

April 2 at 5:07 p. m. a noisy slide fell from the north wall, and coursed through the notch to the talus below, some of the bowlders reaching the floor. April 4 at 11:20 a. m. a small slide fell from the south notch which has been recently working. April 5 the pit was quiet between 5:10 and 5:45 p. m., but at 5:46 a moderate slide fell from the southeast wall north of the Tourist Lookout; this was followed by small slides NE and SSW. April 6 at 9 a. m. the rim of Halemaumau above the SSW scar revealed fresh cracking in the surface of the 1924 ash drifts and in the rock below, for 20 feet back from the edge. The length of the fresh breaks was 165 feet. The block of rim appeared ready to fall. April 7 at 9 a. m. there was slight dribbling of stones down the west wall, and there were southern slides later.

April 8 there was small sliding west and south at 9:30 a. m. April 10 at 9:15 a. m. a moderate slide fell from the southeast wall. April 16 a large slide about 1:30 p. m. fell from the NW buttress athwart the lava cascade locality and above the Yellow Solfatara. April 17 at 8:55 a. m. there was a small slide at the east corner of the pit.

Small quakes accompanying slides were recorded April 18. The next day April 19 slides five times made very feeble earthquake records on seismograms, and a still larger number of tremor records at Halemaumau. Seismograph records of slides thereafter became less frequent.

The working of the cascade rift northwest reached a climax of avalanching at 5:50, 5:53 and 5:55 a. m. April 20, largely sweeping away the black ribbons of lava cascade from the wall. What was left was almost covered by fresh dust. The cascade remnants are at the talus south of the scar (West Talus) and at the Yellow Solfatara on the north of it. There were several small earthquakes during the forenoon. A big slide at 9 a. m. fell over the northern end of the cascade, the larger rocks reaching the floor before the finer material. Marked crack No. 36 at the western rim had opened a little. The air in the pit was charged with vapor and fume, and some dust. A slide at 9:02 a. m. fell from three quarters of the way up the wall, over the north end of the lava cascades.

At 9:50 a. m. April 20 there was a small slide WNW. A small quake rang the annunciator at the Observatory at 1:36 p. m., and four minutes later dust arose from the north side of Halemaumau. There was continuous western sliding all day, with avalanches noted at 3:05, 3:15, and after 6:00 p. m. Rock trickling at the west continued all day April 21.

It was this April 20 crisis that destroyed the big west-rim steam crack, as described in the first paragraph above. The new talus below is large, widening the big west talus northward for 250 feet, and piled above the floor 200 feet. The west talus has been widened farther by recent tumbles of rock east of the SW rift caverns in the wall, so that the whole debris slope is now twice as wide as in August 1934 at the elevation now represented by the bottom contour. Two cascades of solidified lava remain on the main talus cone, as produced on September 6th.

Rocks continued to dribble down the western wall, with few intermissions, until April 28. April 22 slides on that scar were noted at 11:13, 11:17, and 11:25 a. m. and later, making dust clouds. April 23 small slides fell from the NW buttress at 8:50, 9:30 and 9:48 a. m. April 24 at 11:05 a. m., rocks fell at the northeast. April 25 rocks were falling on both east and west sides of Halemaumau. At 10:45 a. m. a large block fell, from 75 feet below the rim, at the east. At 12:47 p. m. a large slide was heard at the Observatory, and sent up a cloud of dust. April 26 at 8:50 a. m. there were steady small slides SSW and NW. April 28 rocks were falling more or less continuously at the western scar, making a noisy avalanche at 8:52 a. m. One slide was heard at the east. At 2:25 p. m. a slide at the northeast wall sent up a thick cloud of dust, followed at 2:32 p. m. by two smaller clouds.

Miscellaneous Phenomena

Fumes rose from the Yellow Solfatara in variable amounts. There are four other fuming places at the north and east edges of the floor. April 20 fume was more conspicuous at the NNW talus than at the East talus. During the small WNW slide of 9:50 a. m. that day there was hardly any fume at the East talus; ten minutes later it puffed fume. April 26 white vapor was variable at the three taluses W, S, and SE.

Levelling

Spirit levelling at the Halemaumau rim April 25 by A. E. Jones, using as base the bench-mark at the southern gravel ridge of Kilauea crater (Spit), determined that points on the rim of Halemaumau, since April 3, 1935, had been elevated about 1 cm. or less.

The eruption of September 1934, by this datum, (Volcano Letter 416) had shown elevation 39 cm. of the north rim, and depression each side of the raised area. This April lift is the first movement of elevation since the eruption.

Thus during the week prior to April 3, the levelling of that date had shown lowering of from 1 to 3 cm. since March 27. On March 27 there had been lowering in the 5½ months since October of from 4 to 7 cm. This makes the April 25 elevation a distinct change of habit, probably indicative of renewed lava pressure.

Rim Crack Measurements

Weekly measurement of 32 marked rim cracks around the upper edge of Halemaumau pit, resulted as shown in the tabulation that follows.

This indicates a notable disturbance of the entire pit by the breakdown on April 20 of the western wall, followed by quiet. A similar crack-opening, aggregating 13.5 mm., affecting 19 cracks, occurred on March 16, during the avalanching of that month. There were other maxima January 5, February 2 and February 23. These were the months of snapping noises and of numerous slides. They were also months of lowering rim.

Week ending forenoon of

April 6, 12 opened, 6 closed, aggregate opening 6.5 mm.
April 13, 11 opened, 3 closed, aggregate opening 5.0 mm.
April 20, 16 opened, 1 closed, aggregate opening 12.0 mm.
April 27, 7 opened, 5 closed, aggregate opening 2.0 mm.

T. A. J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Distant earthquakes	Local * Seismicity
April 7	61	2	0	16.25
April 14	44	1	0	11.50
April 21	38	8	0	13.50
April 28	55	1	0	14.25

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indicated. The location of these three very feeble shocks is based on the main station at Kilauea Observatory and two subsidiary stations around the crater. The intensity is that recorded on the Kilauea instruments.

April 3 at 9:34 a. m. 4 miles deep under Kilauea southwest rift zone; lat. 19° 23′ N, long. 155° 19′ W.

April 20 at 1:10 a. m. 2 miles deep under Kaoiki Pali rift, 19° 21′ N, 155° 18′ W.

April 20 at 5:53 p. m. 1 mile deep under Waldron's ledge, part of the east rim of Kilauea crater.

April 22 at 0.18 p. m. an earthquake was felt at Hakalau, it recorded as a tremor at the Observatory.

Microseisms were normal April 10 to 14, and subnormal the remainder of the period. A. E. J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea Crater; at Halemaumau, the readings from each clinoscope, and the algebraic sum of radial tilts for the three clinoscope cellars, towards or away from the center of the Pit.

At the Observatory the total accumulated tilt in the year ending April 28, 1935 is 2.4″ N and 0.7″ E.

TABLE OF TILT

Week ending	Observatory	Halemaumau Clinoscope Stations			
		North	West	Southeast	Pit Resultant
April 7	0.6″ S 60° E	1.1″ N 7° E	0.3″ N 20° W	4.8″ S 71° E	8.9″ from.
April 14	0.8″ N 39° E	5.9″ N 84° E	4.2″ N 36° W	2.6″ N 32° E	0.2″ toward.
April 21	1.1″ S 66° W	7.9″ N 38° E	0.9″ N 66° W	12.2″ S 67° E	17.4″ from.
April 28	0.8″ N 86° W	1.7″ S 12° W	1.9″ S 31° W	1.1″ N 32° E	3.1″ toward.

A. E. J.

The Volcano Letter

No. 423—Monthly U. S. Geological Survey, Hawaii National Park MAY, 1935

KILAUEA REPORT FOR MAY, 1935

Including weekly press reports 1215 to 1219
April 29 to June 2, 1935 midnight
Section of Volcanology. U. S. Geological Survey
T. A. Jaggar. Volcanologist in Charge

The month of May was like April in making critical changes in the wall of Halemaumau by avalanching, but transferring the sliding activity to the south and east corners. The opening of rim cracks also reached a maximum about the middle of the month, followed by immediate diminution.

Slides at Halemaumau

The first week was notable for much sliding from E and S. walls of Halemaumau. April 29, following 8:15 a. m., the SSW scar was sliding, and a stain of dust extended across the floor from it NE. The rim block at the top fell at 9:16 a. m., making a noisy avalanche. This was followed by trickling of small stones NW, and one rock fall NE. At 12:35 p. m. April 29 a small slide fell W, and a large one ESE at 12:45 p. m. On April 30 the SSW scar had extended farther west. May 1, from 1:40 to 3:30 p. m. with snapping sounds at intervals of five to 10 minutes, small slides occurred N, and two larger ones there at 3:15 and 3:20 p. m. After dribbling slides in various places on May 2, a heavy dust cloud arose at 5:10 p. m. from a slide at the NE wall. At 9:30 a. m. May 3, a noisy fall of rocks stripped the east buttress, and this was followed by numerous slides there, north and south of the buttress during the next two days. From such slides a small balanced pinnacle was left on top of the buttress at 11 a. m., May 3, and by the next day this had fallen. On May 4, avalanches occurred here at 9:47, 10:02, and 10:10 a. m., and 6:40 p. m. A large avalanche here May 5, about noon, set up a thick dust cloud.

The following slides were noted during the second week: May 6, 9:15 a. m. NE, 9:36 SW and NW, 9:45 NE; a dust streak extended out on the floor from this place. At 9:58 there were slides W and NW, and again for five minutes after 10:05 a. m., making a continuous dribbling of gravel and much dust. Similar dribbling slides SW and NE occurred 8:45 a. m., May 7. May 10 there was small sliding at the SSW and W scars. May 11 the same thing was going on at 8:45 a. m., and with the strong wind continuous dust arose from these western slopes. At 12:25 p. m., a strong landslip sent up much dust ENE. At 6:00 p. m., a strong slide occurred W. Slides May 12 were at 8:50 a. m. W, 9:38 a. m. E, 9:58 W, and at 12:50 p. m., a large dust cloud rose above the west side of the pit and spread out so as to fill the whole pit.

The avalanching declined during the third week. May 13 rocks were falling SW, W and NE.; at 9:38 a. m. an avalanche fell near the SW trig station, west of the SSW scar, where there have been recent opening of cracks and engulfing of the ash soil. It was obvious that this rim block was about to fall. At 12:45 p. m., May 13 an avalanche sent up dust NE, loud noises were heard in the pit at 1:30 and 2:30 p. m., and that these were the roars of avalanches was verified by one occurring May 15, about 5:40 a. m., so loud that it was heard at Volcano House. At 7:20 a. m., May 15, there was another roar and at 7:54 a. m., a big avalanche fell at the eastern edge of the SSW scar. The stage was now set for the falling of the rim block at the western edge of this scar, and this happened at 12:41 p. m., after minor preliminary slides, the shock shaking the seismographs, sending up thick dust, and making a loud roar heard at a distance. This event brought to a close the active working of that part of the Halemaumau rim.

The fourth week ending May 26 was relatively quiet. The only slides noted occasioned dust clouds seen May 20, at 9:55 a. m., and at 3:25 p. m., and on May 21 at noon and at 4:25 p. m.

The week ending June 2 produced spells of more than 15 minutes at a time when no rocks could be heard falling. May 27 at 10:24 a. m., there was a slide at the SSW scar and at 10:25 a. m. a slide fell NW. May 28 to May 31, the pit was quiet, except for a few rocks heard falling but not seen at 9:50 a. m. on the last date.

Halemaumau Floor Solfataras

On May 7 the fume vents at the edge of the floor were active NW and NE, and at 9 a. m. May 9, though the atmosphere was dry there was much fume from the three solfataras NW, N and E. May 28, about 8:45 a. m., five northern vents were fuming, thudding noises were heard twice, and fume was in greatest volume at the Yellow Solfatara NW where it came up puffing. May 30, at 9:10 a. m., after a rainy night, all five fuming places were puffing. May 31, at 9:50 a. m., after only slight rainfall, the five fuming places were inconspicuous.

Changes In Halemaumau Floor

The May avalanching spells built two new talus cones under the SSW scar, and made a pink stain of dust extending out on the floor. At the lower part of the gulch that extends down the wall along a crevasse at the east, above the large eastern talus cone, vapor rises from the wall itself. Here a buttress of fresh grey rock hangs out toward the pit, in the middle part of a new eastern scar. Big bowlders had extended the eastern talus, but none had been able to surmount the marginal ridge of the floor. The marginal valley here is very deep. The chasms in the top of this ridge lengthwise, and the five eastern radial cracks extending across the floor from the lake basin of 1924, appeared more widely open than ever. It is worthy of note that the talus slopes north and northwest, which were the scene of sliding activity in October, 1934 after the eruption, have not been in motion in 1935.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 32 marked rim cracks around the upper edge of Halemaumau pit, resulted as shown in the tabulation that follows.

Week ending forenoon of

May 4, 11 opened, 3 closed, aggregate opening 6.5 mm.
May 11, 6 opened, 3 closed, aggregate opening 6.5 mm.
May 18, 12 opened, 6 closed, aggregate opening 5.0 mm.
May 25, 5 opened, 3 closed, aggregate opening 2.0 mm.

A large crack in the actual rim of the pit near the southwest trig station opened 23.5 cm in 14 days from April 20 to May 4. T.A.J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Distant earthquakes	Local * Seismicity
May 5	71	9	0	0	22.50
May 12	38	11	0	0	15.00
May 19	41	6	0	0	15.25
May 26	12	1	1	0	4.50
June 2	34	3	0	1	10.00

* For local seismicity index see Volcano Letter 371.

During the first week of May three slides in the Pit were large enough to record on the Observatory seismographs. During the second week five slides made very feeble records, with only one recorded during the third week.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indicated. The location of epicenters is based on the smaller network of seismograph stations, Kilauea, Uwekahuna, and Halemaumau. The intensity is that recorded on the Kilauea instruments.

May 13 at 1:46 p. m. beginning of a series of five very feeble shocks, not reported felt, lasting until 2:01 p. m. Only two could be located. The second of the series was

located about a mile south of Kilauea crater, not over two miles deep, Lat. 19° 23′ N, Long. 155° 17′ W. The third of the series could only be approximately located, two and a half miles west of Kilauea crater, Lat. 19° 25′ N, Long. 155° 20′ W. They were not recorded on the Hilo and Kona instruments.

May 23, at 1:37 a. m. a feeble shock was felt near Kilauea crater. It was located a mile west of Uwekahuna and five miles deep, Lat. 19° 25.5′ N, Long. 155° 18′ W.

The long waves of the destructive earthquake in Baluchistan began recording at 11:57 a. m. H.S.T. May 20.

Microseismic motion of the ground was normal April 29 and subnormal the remainder of the period. A.E.J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea Crater; and at Halemaumau, the readings from each clinoscope, and the resultant of radial tilts for the three clinoscopes, towards or from the center of Halemaumau Pit.

At the Observatory the total accumulated tilt in the year ending June 2 is 3.6″ N., and 0.5″ W.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations			
		North	West	Southeast	Pit Resultant
May 5	1.6″ S 64° W	2.8″ N 54° E	5.0″ N 87° W	7.0″ N 45° W	1.7″ from
May 12	1.0″ N 16° E	2.0″ N 15° E	6.8″ N 36° W	5.8″ S 83° E	9.3″ from
May 19	0.6″ West	3.8″ N 19° E	1.8″ S 62° W	2.4″ N 29° W	2.6″ from
May 26	0.9″ N 30° E	3.8″ N 69° E	1.4″ S 25° E	5.4″ N 28° E	1.1″ toward
June 2	1.0″ S 77° W	1.0″ S 80° W	1.6″ S 83° W	2.8″ S 27° E	2.2″ from.

A. E. J.

ERRATA

Following Sept. 11, 1934, Volcano Letter 415, the resultant tilt at Halemaumau should be as follows;

1934		1935	
Sept. 16	0.8″ from	Jan. 6	165.″- toward
23	1.2″ toward	13	1.1″ toward
30	1.3″ from	20	22.5″ from
Oct. 7	7.9″ from	27	7.1″ from
14	11.0″ toward	Feb. 3	7.7″ toward
21	11.1″ from	10	1.7″ toward
28	8.2″ from	17	3.1″ toward
Nov. 4	2.0″ toward	24	18.2″ from
11	7.1″ from	Mar. 3	14.2″ from
18	12.6″ from	10	4.2″ toward
25	1.4″ toward	17	12.1″ toward
Dec. 2	28.0″ from	24	3.1″ toward
9	0	31	6.7″ toward
16	1.1″ toward	Apr. 7	8.9″ from
23	5.7″ from	14	4.3 from
30	7.8″ from	21	18.9″ from
		28	2.0″ toward.

A.E.J.

The Volcano Letter

No. 424—Monthly U. S. Geological Survey, Hawaii National Park JUNE, 1935

KILAUEA REPORT FOR JUNE, 1935

Including weekly press reports 1220 to 1223
June 2 to June 30, 1935, midnight
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

VOLCANOLOGY

The month of June at Halemaumau pit of Kilauea Volcano was not remarkable for any important events until after the solstice when a very marked increase of earthquake frequency occurred along with notable sharp earthquakes at the end of the month. The press reports Vesuvian activity in Italy and earthquakes in Mexico.

Slides at Halemaumau

At 9:50 a. m. June 3, gravel was falling at the NW scar, and it was evident that some additional pieces of the rim slab had fallen there, and a remnant pinnacle appeared ready to fall. This is equally the case at the middle of the SSW scar, where a column on the rim is hanging out in unstable equilibrium. June 6, at 10:56 a. m. a noisy slide was heard. June 8, at 10:50 a. m. a moderate slide fell E, recording as a tremor on the Halemaumau seismograph. June 9, at 6:36 a. m. an eastern avalanche occurred, and at 9 a. m. the rock wall ENE was scarred and working. There was a fresh wet scar high up, and fresh red debris on the talus. At 12:52 p. m. a slide occurred above the E talus.

The second week produced repeated slides from the east buttress. At 9 a. m., June 14, and again at 9:05, avalanche dust arose. A visit at 9:15 showed that the slide was at the east wall; from the buttress there at 9:25 a large slide fell. At 3:30 p. m., June 15, and at 5:30 p. m., June 16, dust clouds arose.

This eastern sliding was replaced by avalanches on the opposite side of the pit during the third week. The west wall sent up dust June 17, at 4:15 p. m. and 5:00 p. m. This was at the WNW scar which had been quiet of late. Noisy slides were heard 9:50 a. m., 2 p. m., and 2:55 p. m. June 21, while a party was running levels around the pit.

The week ending June 30, stirred the walls considerably owing to large numbers of earthquakes. Slides were almost continuous the afternoon of June 28. and it was evident that the earthquake of 9 a. m. that day had dislodged a slide SSE. At 9:30 a. m. there was a slide NE, at 11:57 a. m., one N. June 29, at 4:35 p. m., a dust cloud arose NNE. June 30, at 11:55 a. m. a slide occurred NE, and dust arose above the pit at 3:10 p. m.

This northeast sliding was accompanied by fresh soil cracks observed 100 feet back of the northeast rim of Halemaumau for a length of 50 feet on June 29; and new breaks in the dirt occurred inside of old cracks NNE; this phenomenon was observed also along the WNW edge of the pit.

Halemaumau Floor Solfataras

June 3, at 9:50 a. m., there was a trace of thin rising fume at the north corner of the 1934 lake cup. Fume was abundant at the Yellow Solfatara NW. June 9, this place was fuming, and fumes were visible at the four other vents north and east. With increasing northeast wind and clear dry weather this fuming from the five vents at the NW, NE, and E edges of the floor continued on June 10. At the west rim of the pit sulphur dioxide could be smelled presumably from the bright yellow solfataras NW and NNW. On days when the relative humidity become lower both the vapor vents and the yellow solfataras produced clouds less dense. The odor of sulphur dioxide along the west rim of the pit was noted by the levelling party June 21. June 22, heavier fume than usual was observed issuing from the NW solfatara at 10:30 a. m.

The earthquake week at the end of the month disturbed the cracks around Halemaumau and increased the odor of sulphur gases from the floor fumeroles. Most of this came from the Yellow Solfatara northwest. The disagreeable odor of hydrogen sulphide was noticed in the early afternoon of June 28 and a little the next day.

Tilt Cellar Effects

The three tilt cellars around Halemaumau showed no unusual tilts after the earthquake of June 25, but their disturbance after the earthquake of June 28 was marked. The boom of the western clinoscope was moved 19 mm. SSW, that of the northern instrument 14 mm E. and at the southeast station the movement was 17 mm NW. Two days later this southeast station had accumulated an additional tilt of 57 mm. before it settled down, always with northwesterly or westerly trend. One millimeter equals approximately two thirds of a second. Northwesterly tilt at the southeast station means a tipping of the ground in the direction of the center of the pit, or in the direction of the northern rift of Mauna Loa. It should always be remembered that these tilting results after earthquakes are only approximate, as a shock disturbs the instrumental adjustments, and also the block of ground may be fractured locally whereon the instrument stands.

Weekly measurement of 32 marked rim cracks around the upper edge of Halemaumau Pit resulted as follows:

Week ending forenoon of

June 8, 8 opened, 7 closed, aggregate opening 0.5 mm.
June 15, 12 opened, 3 closed, aggregate opening 5.5 mm.
June 22, 14 opened, 3 closed, aggregate opening 9.0 mm.
June 29, 11 opened, 4 closed, aggregate opening 9.5 mm.

Levelling

Spirit level determination of elevation changes around the rim of Halemaumau was made by A. E. Jones, June 4, 21, and 28. The base used was the bench mark at the southern gravel ridge of Kilauea Crater ("Spit"). Results showed that the NW trig station on Halemaumau rim had relatively-lowered, or Spit B.M. had raised, between April 25 and June 4, 1 cm. or less; a reverse movement (NW up or Spit down) June 4 to June 21, 0.5 cm.; original movement (NW down or Spit up) June 21 to June 28, 2 cm. In this direction the total NW down or Spit up was 2.5 cm. or less since April 25 (see Volcano Letter 422).

Referring to the movement as NW station lowering, as was done in the Volcano Letter for April, and in other communications, this lowering of the crater floor is a continuation of movement in this direction since the eruption of Kilauea in September 1934, but is in contrast to the elevation of April 1935. The strong earthquake shock of June 28 may have been partly responsible for the sudden lowering of the crater floor between June 21 and 28. Levelling was in progress at the time of the quake, and was stopped by rain before a check could be made. It must be borne in mind that it is quite probable that the change of level of the eruption was a depression of the southern fault block under Spit relative to mean sea-level, and that the change of level since has been an elevation of that fault block relative to the crater floor. T.A.J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Moderate to Strong earthquakes	Distant earthquakes	Local * Seismicity
June 9	40	1	1	0	0	11.50
June 16	53	2	0	0	0	14.25
June 23	134	5	0	0	0	36.00
June 30	143	9	0	2	1	47.25

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indicated. The location of epicenters is based on five stations Kilauea, Hilo, Kona, Halemaumau, and Uwekahuna. The intensity is that recorded on the Kilauea instruments.

June 5, at 6:55 a. m., a feeble earthquake was felt at both Kilauea crater and Honokaa. It was located 15 miles

deep under the Kona side of the island, lat. 19° 28′ N, long. 155° 48′ W.

June 6, at 9:46 a. m., a tremor was recorded, it was larger on the Kona seismogram. It was tentatively located on the seaward extension of the Hualalai rift, in lat. 19° 50′ N, long. 156° 10′ W.

June 16, at 4:35 p. m., a very feeble shock was recorded from the Kaoiki rift about 19° 20′ N, 155° 25′ W.

June 25, at 0:45 a. m., a moderate earthquake dismantled the Observatory seismograph. It awakened people quite generally on south half of the island. The source was two or three miles deep under the north rim of Kilauea crater. 19° 26.5′ N, 155° 16.5′ W.

June 27, at 8:14 a. m., a very feeble shock was felt in north Kona and Puuwaawaa. It appeared to be located near Kailua Bay, 19° 40′ N, 155° 00′ W.

June 28, at 9:00:19 a. m., a moderate to strong earthquake began to record on the Observatory seismographs. The strong motion seismograph was the only instrument on the island not dismantled. The secondary wave did the dismantling. Some damage was caused in Hilo. The selected location was on the Mauna Loa northeast rift, 19° 36′ N, 155° 11′ W and five miles deep. It was felt generally on Hawaaii.

Microseisms were normal 5, 6, 18 and 28, and were subnormal the remainder of the period.

The preliminary waves only, of a teleseism began recording at 1:02:05 p. m., June 24. No location has been reported of it.

A.E.J.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea crater; and at Halemaumau the readings from each clinoscope and the resultant radial tilts for the three clinoscopes, towards or from the center of Halemaumau Pit.

At the Observatory the total accumulated tilt in the year June 30, 1935, is 3.0″ N and 2.7″ E.

TABLE OF TILT

Week ending	Observatory	Halemaumau Clinoscope Stations			
		North	West	Southeast	Pit Resultant
June 9	0.8″ S 20° W	1.4″ N 82° W	2.8″ N 89° W	7.0″ S 34° W	5.6″ From
June 16	1.3″ N 45° E	1.4″ S 70° W	2.4″ S 92° W	9.2″ N 18° E	3.2″ toward
June 23	0.6″ N 65° E	2.2″ N 63° E	6.8″ N 37° W	2.8″ S 70° E	7.6″ from
June 30	2.5″ N 80° E	24.3″ N 75° E	26.8″ S 32° W	118.″ N 60° W	96.″ toward.

A.E.J.

The Volcano Letter

No. 425—Monthly | Department of the Interior, National Park Service | JULY, 1935

KILAUEA REPORT FOR JULY, 1935

Including weekly press reports 1224 to 1227
June 30 to July 28, midnight
HAWAII NATIONAL PARK

E. G. Wingate, Superintendent
T. A. Jaggar, Volcanologist

The month of July at Halemaumau Pit of Kilauea Volcano showed high frequency of earthquake shocks, continued rock slides from the pit walls, and heavy fuming of the solfataras adjacent to the floor of the pit during the first two weeks, but thereafter the pit became very quiet.

Slides at Halemaumau

July 1, slides were reported at 11:55 a. m. and 5:40 p. m. July 2, there were two or three small slides during the day. July 6, the SW wall was making slides at 9:45 a. m. July 7, dust clouds from slides occurred at 11:00 a. m., 1:20 p. m., 3:00 p. m., and 3:25 p. m. There was very large slide at 5:50 p. m. The slide registered as tremors on the Observatory seismograph. Between 8:00 and 9:00 p. m., small slides were noted at intervals of about 9 minutes.

July 8, dust clouds indicated slides at 9:45 a. m., 10:37 a. m., and 10:45 a. m. July 9, at 8:55 a. m., 10:10 a. m. and 1:05 p. m. Small slides were practically continuous the morning of July 9. July 10 dust clouds arose at 1:07 p. m. July 11 there were rock slides at 9:10 a. m.

July 15 and July 20, dust caused by slides covered a large part of the lava floor of Halemaumau, especially NE, W, and N on July 20. Scars have been produced on the N Buttress by slides on July 15. Slides were reported at the following times:

July 16, at 12:53, 1:00, 1:38, 1:43, and 2:05 p. m., mostly E and NE. Very large slides on this day fell from the E wall at 11:00 a. m. and 4:30 p. m. July 17, another slide occurred here at 9:40 a. m. July 20, rocks fell from the N. Buttress at 11:25 a. m., the cloud resembling steam. July 21, there was a slide at 9:45 a. m.

The last week of the month, the pit was quieter, though the numbers of local seismic disturbances were more than 100 weekly throughout July. This was of interest as the numbers greatly decreased during the following month, and had been small before the solstice in June.

As shown by the earthquake report, increased frequency of earthquakes which originate away from Kilauea probably stimulates sliding; on the other hand, the disturbance of the pit occasioned by heavy sliding, itself makes tremors at the instruments. Most tremors are Kilauea phenomena and may be caused not only by slides in the pit, but also by lava movements under the pit. We have not yet devised any method of proving conclusively cause and effect, in the relations between tremors and slides.

Halemaumau Floor Solfataras

Fuming at the NW Solfataras increased slightly with puffs at 12:45 p. m. July 1, and at 2:00 p. m. July 2 fume filled the pit with heavy blue haze. At 12:30 p. m. July 6, sulphurous odor was noted and again the evening of July 7. These phenomena continued July 9, July 11, and July 13, and a small area of yellow sulphur had appeared at the E edge of the floor. By July 20, the fume had decreased. After heavy rainfall July 24, much vapor rose from cracks on the floor.

Tilt Cellar Effects

At the beginning of the month large tilt values continued to be recorded at the SE and W tilt cellars near Halemaumau. Following the earthquake shock of July 4, the W cellar registered about 6 seconds tilt NE, and the SE station about 12 seconds W.

On July 6, the SE cellar again registered a large tilt of 20 seconds W, without the stimulus of any unusual earthquake.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 32 marked rim cracks around the upper edge of Halemaumau Pit resulted as follows:—

Week ending forenoon of

July 6	6	opened,	4	closed,	aggregate opening	2.0 mm.
July 13	9	opened,	7	closed,	aggregate opening	2.5 mm.
Ju'y 20	6	opened	5	closed,	aggregate opening	0.0 mm.
July 27	19	opened,	2	closed,	aggregate opening	11.0 mm.

T.A.J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Distant earthquakes	Local * Seismicity
July 7	105	6	0	0	31.25
July 14	136	8	1	0	42.00
July 21	136	1	1	0	35.50
July 28	119	3	0	1	31.25

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indictated. The location of the earthquakes are based on the main station at the Kilauea Observatory and two subsidiary stations located around the crater. More distant earthquakes were located with the aid of seismograms from stations at Hilo and Kealakekua.

July 4, at 10:02 p. m., slight earthquake under Kilauea southwest rift zone; lat. 19 degree 25′ 54″ N, long. 155 degree 17′ 57″ W, 1.7 miles deep.

July 5, at 9:44 p. m., very feeble earthquake between Keanakakoi and Lua Manu craters; lat. 19 degree 24′ 19″ N, long. 155 degree 15′ 39″ W, .0.9 miles deep.

July 8 at 4:21 p. m., moderate earthquake, some doubt as to the exact location but known to have been centered about 3.6 miles deep in the vicinity of Makaopuhi crater, probably along the southeast rift.

July 10 at 9:49 a. m., very feeble earthquake reported felt in Kona district and 31.4 miles from Kilauea. Thought to be located on S. W. rift of Mauna Loa.

July 10, at 6:47 p. m., very feeble earthquake reported felt in Kona district and 59.5 miles from Kilauea. Thought to be located on sea bottom west of Kealakekua.

July 12, at 4:32 a. m., very feeble earthquake 2.5 miles S. W. of Halemaumau in rift zone; lat. 19 degree 22′ 45″ N, long. 155 degree 18′ 36″ W 2.5 miles deep.

July 12, at 8:30 p. m. feeble earthquake reported felt at Kapapala Ranch where a window pane was broken and a noise like the report of a gun was heard. Located in S. W. rift zone 16.5 miles from Hawaiian Volcano Observatory; lat. 19 degree 15′ N. long. 155 degree 25′ W, 74.0 miles deep.

July 13, at 2:56 p. m., very feeble earthquake reported felt at Summer Camp on S. E. rim of crater. Probably located between Lua Manu crater and Keanakakoi about 1.2 miles deep.

July 16, at 5:10 p. m., a feeble earthquake, beneath ocean, 20 miles S. S. W. of Kilauea, 11.0 miles deep.

July 24, at 6:35 p. m., a very feeble earthquake 0.6 miles north of the north rim of Kilauea crater; lat. 19 degree 26′ 27″ N, long. 155 degree 16′ 9″ W, 5.4 miles deep.

July 26, at 1:51 p. m., very feeble earthquake probably centered in S. W. rift zone about 5 miles from Halemaumau.

The distant earthquake of July 28 which began to record at 9 h: 16 m: 40s p. m. originated 2,775 miles southwest of Hawaii near or in the Tonga Deep.

On July 31 at 9:01 a. m. and 9:35 p. m., 15 and 20 minutes respectively of harmonic tremor began to record.

Microseismic motion was subnormal during July except on the following dates: July 7, 8, 10, 17, 20 and 26 when it was normal and July 14 to 16 inclusive when it was abnormal.

H. H. Waesche.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at Kilauea Observatory, northeast rim of Kilauea Crater; and at Halemaumau, the algebraic sum of radial tilts for the three clinoscope cellars, towards or from the center of the pit.

At the Observatory the total accumulated tilt in the year ending July 28 was 1.1″ N and 4.2″ E.

TABLE OF TILT

Week ending	Observatory	Halemaumau Clinoscope Stations			
		North	West	Southeast	Pit Resultant
July 7	0.7″ N 24° E	2.4″ N 47° W	19.67″ N 18° E	74.5″ N 84° W	51.55″ toward
July 14	0.3″ S 27° E	4.9″ N 37° W	0.75″ S 31° W	51.8″ N 50° W	58.00″ toward
July 21	1.1″ N 45° E	1.2″ S 66° W	1.1″ N 56° W	4.4″ N 69° E	0.94″ from.
July 28	0.8″ N 20° E	0 0	3.96″ N 87° W	4.4″ N 37° W	8.23″ toward.

H.H.W.

The Volcano Letter

No. 426—Monthly | Department of the Interior, National Park Service | AUGUST, 1935

KILAUEA REPORT FOR AUGUST, 1935

Including weekly press reports 1228 to 1232

HAWAII NATIONAL PARK

E. G. Wingate, Superintendent
T. A. Jaggar, Volcanologist

During the month of August at Kilauea Volcano, there was steady decline in local seismicity, but a flurry of local movement occurred in the middle of the month.

Slides at Halemaumau

July 31, 10:50 a. m., a few stones were heard falling near N Buttress, and a similar movement of rocks and dust occurred there August 2, 10:45 a. m. August 7, 5:52 p. m., a slide occurred at the N, and a fresh scar streaked the N Buttress. More N Slides occurred August 8 and August 9 about 10:00 a. m. The N Buttress was again making slides at 2:55 p. m., August 12, and on August 15, a large slide fell at the W at 6:30 a. m. followed by others at the same place at 9:33 and 11:50 a. m.; and at 2:00 p. m., a large slide at the S occurred, another at the N Wall and a small slide occurred SW. August 19, 9:36 a. m. a noisy small slide fell at the N Wall and rocks were slipping at the W Wall. August 20, 9:10 a. m., there was a small slide N and others at the same place, sending up dust. August 21, 9:05 and 10:18 a. m. August 23, fresh talus appeared on the E floor. August 26, new rocks had fallen on the N floor and on August 30, at 12:40 p. m., a slide at the N sent up pinkish dust; gravel was slipping on that wall the next morning. September 1, 9:00 a. m. a snapping noise was heard, and a slight fall of stones occurred at the W five minutes later.

Halemaumau Floor Solfataras

August 3, the sulphur spot E had enlarged and become a brighter yellow. August 7, a new sulphur stain was observed at the foot of the NE talus. During rainy, foggy weather, August 10, there was much fume from the solfataras and vapor from the walls. A fume puff was observed 3:15 p. m. August 12, and on August 13, in the morning, the NW yellow solfatara was puffing vigorously but owing to dry weather fume did not show elsewhere. During afternoons, blue fume became conspicuous at the pit with sunlight in the background, and similarly fume showed over Mokuaweoweo at time of sunset. August 23, the E sulphur spot appeared larger and August 29 calm weather made the fume conspicuous; this continued September 1. as the fume appears heavy and settles. A crack at the NW border of the floor appeared to have widened during the last few months.

Measurement of Halemaumau Rim Cracks

Weekly measurements of 32 marked rim cracks around the upper edge of Halemaumau Pit resulted as follows:

Week ending forenoon of

August 3 10 opened, 3 closed, aggregate opening 2.0 mm.
August 10 6 opened, 9 closed, aggregate closing 2.0 mm.
August 17 8 opened, 6 closed, aggregate opening 1.5 mm.
August 24 10 opened. 4 closed, aggregate opening 2.5 mm.
August 31 14 opened, 3 closed, aggregate opening 7.0 mm.

Levelling

Spirit level determinations were run around the rim of Halemaumau August 15, 1935 by H. H. Waesche. Result shows that crater floor of Halemaumau had lowered 1.2 cm. since July 2. As shown by graphic method, the rate of lowering is about the same as between June 28 and July 2. With the exception of a slight upward movement of the crater floor in April, downward movement has been continuous since the eruption of September 1934. By downward movement is meant the relative lowering with reference to the S gravel ridge of Kilauea Crater (Bench Mark "Spit"). Total lowering has been 8.5 cm. or less since October 1934.

T.A.J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Distant earthquakes	Local * Seismicity
August 4	133	0	0	0	33.25
August 11	123	3	0	1	32.25
August 18	113	1	1	1	30.75
August 25	86	9	0	0	27.00
September 1	49	6	0	0	15.00

* For local seismicity index see Volcano Letter 371.

The fol'owing successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms; when possible the depth of the source is indicated. The locations of the earthquakes are based on the main station at the Kilauea Observatory and two subsidiary stations located at other points around the crater. More distant earthquakes were located with the aid of seismograms from stations at Hilo and Kealakekua.

August 9 at 8:40 a. m. very feeble earthquake under Kilauea S. W. rift zone, 1.5 miles S. W. of Halemaumau; lat. 19 degree 24′ N, long. 155 degree 18.5′ W.

August 11 at 7:12 p. m. very feeble earthquake about 1.2 miles deep and between 2 and 3 miles N. E. of the Volcano Observatory.

August 17, at 12:04 a. m. a slight earthquake felt in Volcano district by many and reported felt in Pahala, Hilo, Hakalau and Hookena. Location on Mauna Loa N. E. rift, 21.7 miles deep; lat. 19 degree 34′ N, long. 155 degree 25.2′ W.

August 20, at 1:23 p. m. a very feeble earthquake thought to have originated in area in S. W. portion of Kilauea Crater.

August 22, at 6:11 a. m. a very feeble earthquake probably located in Kilauea S. W. rift zone, 1.8 miles S. W. of Halemaumau.

August 22, at 8:12 a. m. a very feeble earthquake probably located in Kilauea S. W. rift zone, 0.8 miles S. W. of Halemaumau.

August 23, at 1:28 a. m. a very feeble earthquake probably located 1.7 miles S. W. of Halemaumau in S. W. rift zone.

August 23, at 5:13 a. m. a very feeble earthquake probably located 1.7 miles S. W. of Halemaumau in S. W. rift zone.

August 23, at 6:32 p. m. a very feeble earthquake probably located 2.1 miles S. W. of Halemaumau in S. W. rift zone.

August 24, at 8:20 a. m. a very feeble earthquake located 2.3 miles S. W. of Halemaumau in rift zone 2.5 miles deep; long. 155 degree 18.8′ W.; lat. 19 degree 23′ W.

August 27, at 3:15 a. m. a very feeble earthquake located ½ mile S. E. of Halemaumau near Keanakakoi 3.2 miles deep; lat. 19 degree 24.2′ N, long. 155 degree 16.7′ W.

August 27, at 2:23 p. m. a very feeble earthquake located 1 mile S. E. of Halemaumau about 1 mile deep; lat. 19 degree 24.1′ N, long. 155 degree 16.3′ W.

August 29, at 7:59 a. m. a very feeble earthquake 2.7 miles S. E. of Halemaumau and 3.5 miles deep; lat. 19 degree 22.7′ N, long. 155 degree 15.4′ W.

August 29, at 11:46 p. m. a very feeble earthquake probaly located 3.7 miles S. E. by S. from Halemaumau.

The surface waves of a distant earthquake began recording at the Volcano Observatory at 9 h: 30 m: 05s: p. m., August 10.

The preliminary waves of a distant earthquake began recording at 3h: 23m: 51s: p. m., August 16. It was 3,660 miles from Kilauea and was located at or near New Caledonia.

Microseismic motion was subnormal during the month except on the following dates, August 5, 8, 13, 14, 15, 19, 20 and 24 when it was normal.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at the Volcano Observatory, northeast rim of Kilauea; and at Halemaumau, the algebraic sum of radial tilts for three clinoscope stations towards or from the center of the Pit.

At the Observatory the total accumulated tilt in the year ending September 1, was 0.74″ N and 1.5″ E.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations			
		North	West	Southeast	Pit Resultant
August 4	0.93″ N 24° W	1.19″ S 29° W	1.79″ N 80° W	4.31″ N 82° W	2.37″ toward
August 11	0.55″ S 46° W	4.83″ N 71° W	6.17″ N 50° W	3.40″ N 56° E	4.54″ from.
August 18	0.77″ N 15° W	4.78″ S 78° W	4.41″ N 55° W	19.86″ N 53° W	15.93″ toward
August 25	0.76″ N 3° E	1.48″ S 62° W	3.64″ N 75° W	3.24″ N 48° E	1.92″ from
September 1	0.24″ W	1.00″ N 28° W	7.45″ N 36° W	4.54″ S 5° W	7.93″ from

H.H.W.

The Volcano Letter

No. 427—Monthly | Department of the Interior, National Park Service | SEPTEMBER, 1935

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR SEPTEMBER, 1935

Including weekly press reports 1233 to 1236

September 1 to September 29, 1935, midnight

HAWAII NATIONAL PARK
Edward G. Wingate,
Superintendent

KILAUEA VOLCANO
T. A. Jaggar,
Volcanologist

VOLCANOLOGY

During the month of September, the seismicity declined, this being influenced by the amount of local tremor. At the time of equinox, the week ending September 22, there was distinct increase in seismic frequency and intensity. All but two of the earthquakes of the month were located near Kilauea. The excessive tilt at the SE clinoscope station for the third week is not trustworthy, as earthquakes derange these instruments. Halemaumau pit has been quiet.

Slides At Halemaumau

Slides from the wall of the pit have been noted as follows:—

September 3 at NW wall, 2:40 and 2:55 pm.
September 4, at E bay, 9:37 am.
September 7, large slide NE wall 1:05 pm.
September 7, NE wall, followed by continuous dribbling, 2:09 pm.
September 8, E wall, 1:30 pm.
September 9, NE wall, small slide, 4:45 pm.
September 10, N wall, small slide, 9:45 am.
September 11, E wall, slight slippings, 9:00 am.
September 17, N corner, 11:45 am.
September 17, large dust cloud, 11:55 am.
September 19, small slide E wall, 9:00 am.
September 20, numerous slides N corner, 9:30 am.
September 21, dust cloud and noise, N edge 1:45 pm.
September 21, dribbling on N and W slopes, 2:30 pm.
September 25 light dust cloud E, 10:00 am.

The slides of the first week removed a piece of rim rock NE and made a straight narrow scar down the wall, midway between the E and NE taluses; some fresh debris lay underneath.

Halemaumau Solfataras

In rainy weather, September 2, the walls were wet, and 14 vaporing places were counted. There were dry places on 8 talus slopes. Heavy blue fume arose at the NW Solfataras, and much steam came out of the W wall. On September 9, at 10:00 am, the solfatara at base of E talus was fuming, and fume elsewhere was not seen; at 10:45 am, however, the E fume had disappeared, but the NW Solfatara was smoking variably. For some reason these two places puffed fume interchangeably. September 21, it was apparent that the sulphur patch at edge of floor ESE is growing brighter yellow. September 22 at 8:40 am, with light southerly wind, the blue fume from NW Solfatara rose conspicuously.

Measurement Of Halemaumau Rim Cracks

Weekly measurement of 32 marked places on rim cracks around the upper edge of Halemaumau pit resulted as follows:—

Week ending forenoon of—

Sept. 7, 12 opened, 4 closed, aggregate opening 6.0 mm.
Sept. 14, 7 opened, 2 closed, aggregate opening 4.0 mm.
Sept. 21, 3 opened, 7 closed, aggregate closing 1.5 mm.
Sept. 28, 11 opened, 2 closed, aggregate opening 6.0 mm.

T.A.J.

EARTHQUAKES

TABLE

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Distant earthquakes	Local * Seismicity
Sept. 8	65	4	0	1	22.00
Sept. 15	40	8	0	2	14.00
Sept. 22	50	7	2	3	18.00
Sept. 29	38	8	0	1	13.50

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated; the epicenters as shown were located from seismograms. The depth of focus is indicated whenever determinations were possible. The locations of the earthquakes are based on the main station at the Kilauea Observatory, and the two subsidiary stations at Uwekahuna and Halemaumau respectively. More distant earthquakes were located with the aid of seismograms from stations at Hilo and Kealakekua. The latter net is primarily for locating earthquakes originating on the Island of Hawaii outside of Kilauea area.

September 5 at 10:29 am, very feeble, located under or near Halemaumau.

September 6 at 4:26 pm, very feeble. probably located on SE slope of Hualalai; 19° 36.5′ N; 155° 48.2′ W. Reported felt at Puuwaawaa Ranch.

September 9 at 5:06 am, very feeble, located 0.6 mile deep under SE portion of Halemaumau, 19° 24.5′ N; 155° 17.5′ W.

September 15 at 5:34 pm, very feeble, probably located under NE rift of Mauna Loa near the summit Crater.

September 17 at 10:06 pm, very feeble, located 1.6 miles SSW of Pit seismograph station and 1.7 miles deep. 19° 23.1′ N; 155° 17.7′ W.

September 19 at 9:07 am, very feeble, located 3 miles deep in the Puna rift zone between Lua Manu and Puhimau Craters. 19° 23.9′ N; 155° 15.4′ W.

September 19 at 9:10 am, very feeble, located 4.7 miles deep, 0.2 miles N of Devils Throat in the Puna rift. 19° 23.0′ N; 155° 14.2′ W.

September 20 at 2:31 am, very feeble, located 5.0 miles deep, 1.2 miles east of Halemaumau 19° 24.7′ N; 155° 16.1′ W.

September 20 at 3:59 pm, feeble, located 1.1 miles deep under east rim of Halemaumau. 19° 24.6′ N; 155° 17′ W.

September 21 at 10:31 pm, very feeble, located 5 miles deep, 3.8 miles SSE of Pit seismograph under Kalanaokuaiki Pali. 19° 21.2′ N; 155° 15.9′ W.

September 23 at 8:08 pm, very feeble, located 0.8 mile N of the Pit seismograph. 19° 21.0′ N, 155° 16.9′ W.

September 26 at 2:27 pm, located 0.6 mile deep under SE rim of Halemaumau. 19° 24.5′ N; 155° 17.1′ W.

September 28 at 4:09 am, very feeble, probably located under SE rim of pit.

Distant earthquakes were recorded as follows: September 8 at 7:58 pm, surface waves only, location 58° N; 139° E in the vicinity of Northern New Guinea. September 11 at 3:44 am (preliminary waves); location near Japan; 44° 5′ N; 147° E. September 15, at 4:06 am, long waves only, location, 28° S; 113.3° W, about 2000 miles W of Peru in the Pacific Ocean. September 19 at 3:28 pm; preliminary waves, location 4,510 miles from Kilauea immediately south of Australia and west of Tasmania, 40° S; 140° 5′ E. September 19 at 7:22 pm, surface waves only location in vicinity of the Admiralty Islands, 0° N; 146° E. September 22 at 11:18 pm, surface waves only, location 0.5° N; 141.5° E, in vicinity of Northern New Guinea. September 24, at 11:58 am, location 50° N; 129° W, off Coast of British Columbia.

Microseismic motion was slight during the month except on the following dates, September 12, 14, 16, 17, 23, 25, and 28 when it was normal. It was strong September 29.

H.H.W.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts for three clinoscope locations towards or away from the center of the Pit.

At the Observatory the total accumulated tilt for the year ending September 29, was 0.4″ N and 1.1″ E.

TABLE OF TILT

Week ending	Observatory	Halemaumau Clinoscope Stations			
		North	West	Southeast	Pit Resultant
Sept. 8	0.3″ S 65° E	3.59″ N 45″ W	2.38″ N 55° W	1.45″ S 33° E	4.57″ from.
Sept. 15	0.84″ N	0.90″ S 69° E	2.44″ N 78° W	2.59″ N 64° W	2.22″ toward
Sept. 22	0.15″ N	3.09″ S 35° W	3.58″ N 22° E	32.4″ N 59° W	33.20″ toward
Sept. 29	0.20″ S 45° W	3.51″ N 48″ W	4.62″ N 47° W	1.26″ N 82° W	3.23″ from

NOTE: SE Pit Clinoscope adjusted September 21. Had probably been partially dismantled since earthquake of June 28. rendering results between those dates doubtful.

H.H.W.

The Volcano Letter

No. 428—Monthly | Department of the Interior, National Park Service | OCTOBER, 1935

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR OCTOBER, 1935

Including weekly press reports 1237 to 1240

September 29 to October 27, 1935 midnight

HAWAII NATIONAL PARK
E. G. Wingate
Superintendent

KILAUEA VOLCANO
T. A. Jaggar
Volcanologist

VOLCANOLOGY

A large group of exceptional earthquakes, moderate to strong, occurred on September 30 and October 1, originating under the rift system of Mauna Loa at estimated depths of 17 to 30 miles. In view of the lava flow of Mauna Loa that was to come in November, it is interesting to note that the strongest shock was felt all over Hawaii and its epicenter was located seismometrically under the NE slope of Mauna Loa, near where the Humuula Flow finally came forth. These earthquakes disturbed the Halemaumau walls, made avalanches and opened rim cracks excessively owing to the long swaying movement. Most of the centers were under Mauna Loa. The total number of disturbances for the week ending October 6 was 178. The spasm of 11 shocks the middle of October was quite different and centered at Kilauea. Except for the slides started by earthquakes, Halemaumau pit was quiet. Horizontal angles measured across pit and crater notably opened September 25 to October 30, the Halemaumau rim slightly lowered relative to the southern gravel spit, and tilt of the clinoscope stations around Halemaumau which lately had been away from the center, changed to a tilt towards the center in July and August.

Slides at Halemaumau

Slides from the wall of the pit have been noted as follows:—

September 30, large avalanche cloud, with two smaller ones following it, 9:45 am.

September 30, noisy slides made by the night earthquakes

October 1, smaller slide N wall. 1:20 am.
October 1, W side of pit after 6:00 am.
October 2, NW dribbling slides 10:35 am.
October 3, N wall dribbling slides, 9:30 am.
October 3, NE slide, 5:15 pm.
October 4, NE floor covered with dust, early morning.
October 5, NE slides, 10:32 and 11:00 am.
October 7, NE dust clouds, 4:45 pm.
October 8, dust clouds from slides leaving stones on E floor, 2:55 and 3:50 pm.
Octcober 17, small slides, SW 12:20 and 12:50 pm.
October 18, small slide NW. 12:15 pm.
October 22, rocks heard falling WNW, 9:50 am.

Halemaumau Solfataras

At 10:40 am, September 30, fume rose from yellow spot at E edge of floor. With 5 inches of rain in 2 days, October 12-13, the fuming vapor was dense at the Yellow Solfatara NW. White salts appeared at the vents of the 1934 Lava Cascades, and during heavy rain showers the forenoon of October 12, dense vapor clouds appeared there, and tails of vapor rose all over the floor.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 32 marked places on rim cracks around the upper edge of Halemaumau pit resulted as follows:—

Week ending forenoon of

October 5, 17 opened, 5 closed, aggregate opening 21.0 mm.
October 12, 12 opened, 7 closed, aggregate opening 6.5 mm.
October 19, 8 opened, 5 closed, aggregate opening 2.0 mm.
October 26, 14 opened, 3 closed, aggregate opening 8.0 mm.

After the earthquake spasm of the first week, in some places soil had fallen down the measured cracks and hair cracks in the dirt appeared, showing the effects of disturbance of rim blocks by the earthquakes. T.A.J.

Crater Angles and Levelling

The horizonal angle measured from the Volcano Observatory between SE and NW rims of **Kilauea Crater** showed sharp closing of 4″, July 30 to August 3 and opening 0.8″, August 9 to 29. The angle closed 1″, August 29 to September 21, and opened an equal amount October 9. Opening continued, adding 4″ more October 9 to October 30, the angle on that date reading 38° 30′ 16.2″.

The angle across **Halemaumau** from SE to NW rim stations, changed similarly to the one across Kilauea Crater. It closed 3.0″ to a record dow value of 16° 14′ 27″, August 29 from its reading of July 30. From that date, there was steady opening 2.4″ to October 30.

Spirit levelling between Spit B. M. in the southern rim region of Kilauea Crater, and the NW station B. M. of Halemaumau, shows relative lowering of NW station. The amounts of lowering are as follows:

July 2 to August 13, 12.0 mm; August 13 to September 18, 1.0 mm; September 18 to October 18, 4.0 mm.

H.H.W.

EARTHQUAKES

TABLE

Week ending	Tremors	Very feeble earthquakes	Feeble earthquakes	Slight earthquakes	Moderate earthquakes	Local * Seismicity
Oct. 6	142	27	3	2	4	69,00
Oct. 13	36	2	0	0	0	10.00
Oct. 20	33	10	1	3	0	20.25
Oct. 27	30	3	0	0	0	9.00

* For local seismicity index see Volcano Letter 371.

The following successive local disturbances began at the times indicated and the epicenters were located from seismograms. The depth of focus is indicated wherever such determinations were possible. The locations of these earthquakes are based on the main station at the Kilauea Observatory, and the two subsidiary stations at Uwekahuna and Halemaumau respectively. More distant earthquakes were located with the aid of seismograms from stations at Hilo and Kealakekua. The latter net is primarily for locating shocks originating on the Island of Hawaii outside of the Kilauea Area.

September 30 at 8:28 am, very feeble, located 0.8 miles deep under SE rim of Halemaumau, 155° 17.1′ W; 19° 24.5′ N.

September 30, at 10:35 pm, very feeble, located 25 miles deep on NE rift near Summit Crater of Mauna Loa, 155° 31.6′ W; 19° 31.4′ N.

September 30, at 10:36 pm, moderate, felt generally on the Island of Hawaii. It was located 30 miles deep under the SW rift of Mauna Loa 155° 39.5′ W; 19° 22′ N.

September 30, at 11:58 pm, moderate to strong, felt over entire Island of Hawaii, located under NE slope of Mauna Loa about midway between Puu Ulaula and Humuula Sheep Station and 17.4 miles deep, 155° 26.3′ W; 19° 38.7′ N.

October 1, at 12:02 am, moderate, generally felt as a continuation of the preceding one, location undertermined, but focus was probably under the Mauna Loa rift system.

October 1, at 12:10 am, feeble, felt slightly in NE sections of the Island of Hawaii, location undetermined but probably under Mauna Loa, like preceding quake.

October 1, at 12:34 am, slight, associated with this same series of Mauna Loa disturbances.

October 1, at 12:54 am, slight, felt in Kilauea Area and NE section of Island of Hawaii, located half way between Mokuaweoweo and Hilo about 25 miles deep under the Mauna Loa NE rift zone; 22 miles NE of the summit Crater 155° 24.5′ W; 19° 34.4′ N.

October 1, at 10:22 am, moderate, reported felt in Hilo and in the Kilauea district, located under the NE rift

zone of Mauna Loa 15 miles SW of Hilo 155° 19.2′ W; 19° 38.3′ N.

Between 10:30 pm, September 30 and midnight October 1, there were 23 very feeble earthquakes associated with the disturbance centered under the SW and NE rift zones of Mauna Loa.

October 4, at 5:33 am, feeble, located 30 miles deep under SW rift of Mauna Loa about 6 miles SW of Summit Crater, 155° 38.2′ W; 19° 23.5′ N.

October 5, at 1:49 am, feeble, reported felt strongly at summit rest house of Mauna Loa. Also felt at Waiohinu, Naalehu and Honuapo, located approximately under NE edge of Mokuaweoweo.

October 11, at 7:37 am, very feeble, located 1.3 miles deep under Halemaumau 155° 17.1′ W; 19° 24.5′ N.

Octcober 15, at 4:53 pm, very feeble, located 2.8 miles deep near the Devils Throat in Kilauea SE rift zone 155° 14.4′ W; 19° 22.9′ N.

October 15, at 6:35 pm, feeble, located 3.7 miles deep 3.2 miles S of Halemaumau 155° 17.′ W; 19° 21.5′ N.

Octcober 15, at 7:20 pm, slight, located 1.8 miles deep near Cone Crater, Pit Craters and Puu Koae in Kau rift zone of Kilauea 155° 19.0′ W; 19° 21.5′ N.

October 15, at 8:09 pm, very feeble, located 4 miles deep and 3.3 miles SW of Halemaumau in Kau rift zone 155° 18.8′ W; 19° 22.1 N.

October 15, at 8:09 pm, slight, located 3.8 miles deep and 3.4 miles SW by W from Halemaumau 155° 19.7′ W; 19° 22.8′ N.

October 16, at 12:07 am, slight 1.3 miles deep and 0.5 mile NW of Puu Ohale 155° 17.3′ W; 19° 21.6′ N.

October 20, at 5:01 pm, very feeble, located 1.2 miles under east rim of Halemaumau 155° 17.0′ W; 19° 24.5′ N.

October 25, at 11:45 pm, very feeble, located 0.7 mile deep under Crater of Kilauea 0.2 mile NE of Pit seismograph station 155° 16.9′ W; 19° 24.4′ N.

No distant earthquakes were recorded during the month.

Microseismic motion was normal October, 1, 2, 5, 6, 7, 10, 11, 14 to 17 inclusive, 20 and 24; light 8, 9 and 21 to 23 inclusive; and strong September 30, October 3, 4, 12, 13, 18, 19 and 25 to 27 inclusive. H.H.W.

TILTING OF THE GROUND

The table shows tilt by weeks from seismograms at the Volcano Observatory, NE rim of Kilauea Crater; and at Halemaumau, the algebraic sum of radial tilts for two* clinoscope locations towards or away from the center of the Pit.

At the Observatory the total accumulated tilt for the year ending October 27, was 1.12″ S and 1.25″ E.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations		
		West	Southeast	Pit Resultant
October 6	1.87″ N 32° E	14.75″ N 27° W	41.80″ N 8° W	27.69″ toward
October 13	0.9″ S 77° E	3.28″ S 79° W	8.42″ N 19° E	1.42″ toward
October 20	0.17″ S 44° E	6.57″ S 27° W	4.21″ S 39° W	4.56″ from
October 27	0.64″ S 82° E	2.98″ N 59° W	2.43″ S 51° E	4.80″ from

* N Clinoscope dismantled September 30. Discontinued until changes made in design. H.H.W.

THE VOLCANO LETTER

No. 429—Monthly, Department of the Interior, National Park Service, November, 1935

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaii Volcano Observatory
T. A. Jaggar, Volcanologist

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR NOVEMBER, 1935

Including weekly press reports 1241 to 1245
October 27 to December 1, 1935 Midnight

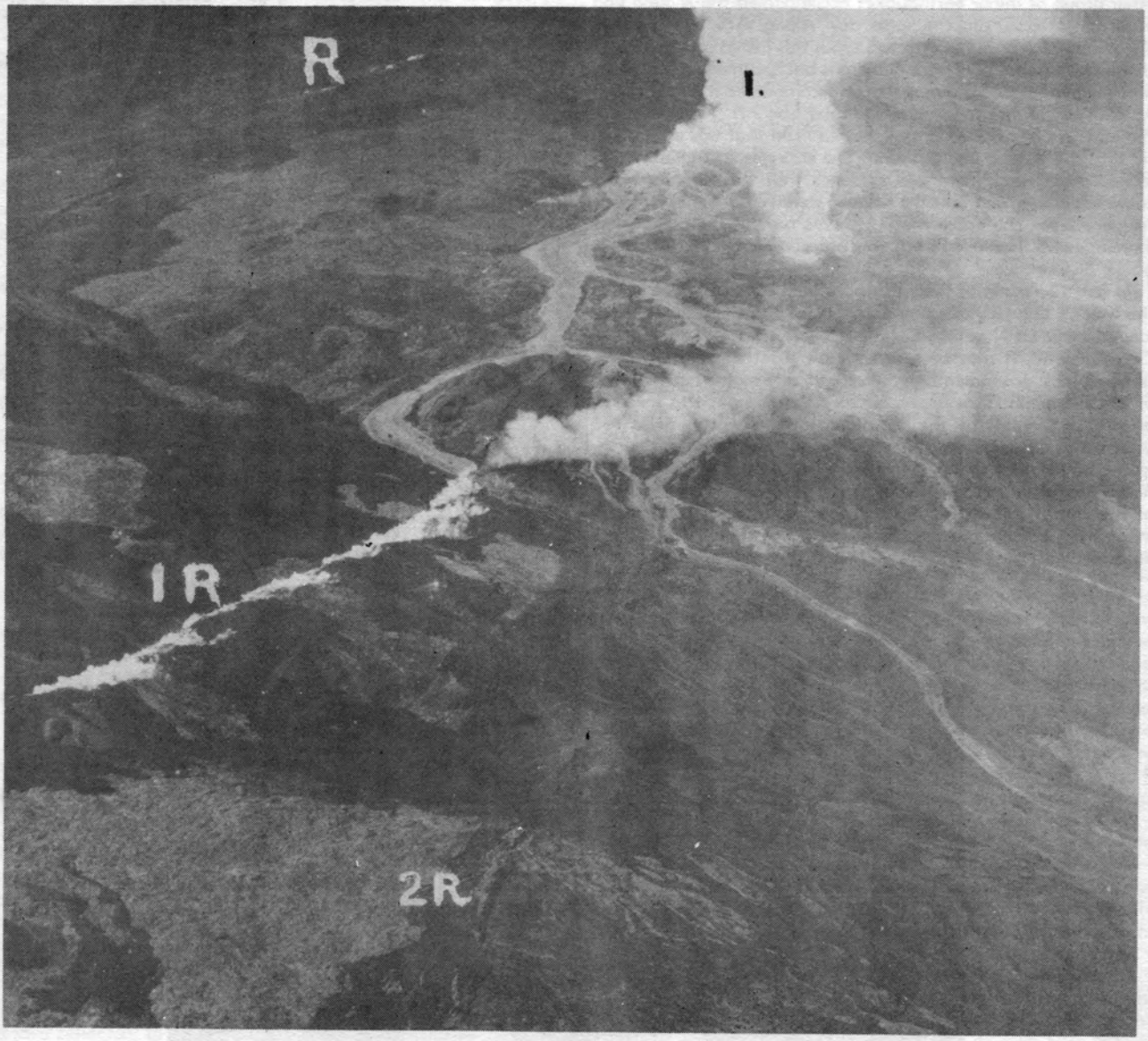


FIGURE 1. Airplane view November 22, 1935. Mauna Loa looking south. Showing northeast rift R; new rift fountaining and sending lava streams of aa north; (1) is a fountain; (1R) is the steaming lower end of new rift. (2R) is branch rift receiving a cascade of lava at a smoking pit below and to the right of (1). Probably (2R) developed into the flow outlet 2, Figure 6, about November 27.—By permission Fleet Air Base, Pearl Harbor, U.S. Navy.

VOLCANOLOGY

There were three reasons for expecting in 1935, an outbreak from Kilauea or Mauna Loa; and the preponderant evidence of recent years indicated it was likely to be Mauna Loa. The first is that the average interval between Hawaiian eruptions since 1924 has been 1.26 years, and the last oubreak was in 1933. The second is that the average cycle is 11 years, and the last cycle culminated in 1924. The third is that Mauna Loa had a summit crater eruption in 1933, which pointed to a coming lava flow on the north side in about two years.* Therefore it was not unexpected that Mauna Loa lava erupted from a north rift on November 21.

*The Coming Lava Flow, by T. A. Jaggar, March, 1934, Honolulu. (Published by Hawaiian Volc. Res. Ass'n.)

The Observatory headquarters at Kilauea had shown exceptional Mauna Loa earthquakes October 1, with an echo of Kilauea earthquakes, October 15. The month of November showed about 50 local seismic disturbances per week for the first three weeks. Then an earthquake strongly felt occurred at 1:11 am November 21 under the NE rift of Mauna Loa, slightly felt even in Honolulu. This was followed by minor shocks, and another group of minor earthquakes accompanied the Mauna Loa outbreak at 6:20 pm the same day. Along with this, tremors appeared which became continuous, but this lasted only two days; thereafter, the tremors were numerous but spasmodic. It is probable the period of continuous tremor accompanied the continuous rush of gas fountaining at the Mauna Loa rift. Halemaumau, the inner pit of Kilauea Crater showed little that was sympathetic with the Mauna Loa outburst. The stronger earthquakes dislodged slides, and there was evidence that the fumaroles became less active, and that the Kilauea steam cracks showed lower temperatures. The crack measurements around the pit showed more opening than usual, but this is a common effect of earthquake disturbance.

Fresh filaments of basaltic spun glass, or Pele's hair, from the Mauna Loa fountains nineteen miles away, fell all over Kilauea Crater on November 22.

In general, it may be said that the location of the Mauna Loa outbreak was indicated seismometrically by the earthquakes of October 1, and November 21; that the approach to the outbreak was forecast by the seismic conditions within these two intervals of 51 days and of 19 hours; and that the larger earthquake of the first group indicated a depth of seventeen and a half miles, while that of the day of the outbreak showed a depth of five miles or less, this difference implying a splitting movement from below upward, which the seismological travel-time data located at the point of outbreak.

Kilauea Observations

Slides at Halemaumau

Slides from the wall of the pit have been noted as follows:—

October 31, dust on NE floor, and gravel slipping from NE wall, 9:00 am.
November 1, rocks fall at NE and W scars, 8:38 am.
November 2, slides at NW wall, 10:45 am.
November 4, noisy slide at E wall, introduced by a small one, 10:00 am.
November 8, NE slide sent up dust, 2:20 pm.
November 16, small rock fall at NE talus, 9:30 am.
November 20, new scar of slide 150 feet below NW edge.
November 21, rocks dribbling down W wall, and N wall showing disturbance owing to earthquake of 1:11 am, observed 10:00 am.
November 22, rocks dribbling N wall 9:54 am.
November 22, noisy slide falling from point 200 feet below SE edge, 2:15 pm.
November 23, dust from slide at N wall, and trickles of debris moving down N talus, 10:00 am.
November 24, rocks dribbling continuously W wall, and small slide there 9:25 am.
November 24, slide W wall, 9:55 am.
November 25, slide making dense dust cloud, W wall 10:55 am.
November 27, slide made dust, 8:40 am.
November 28, two slides made dust clouds W, 1:35 pm.
November 30, slide W, 10:36 am.
November 30, noisy slide with thick dust NW, 11:09 am.

Halemaumau Solfataras

Observations of the sulphurous fumaroles around the edges of the Halemaumau floor, cnd of the vapor cracks, have been as follows:—

November 16, heavy fume at sulphurous spot E, in rainy weather, 9:30 am.
November 17, after heavy rain, vapor at all the solfataras, at other places on floor and walls, and at N side of 1934 lava lake basin. Cumulus over W side of Halemaumau, due to heat convection or nucleation from sulphur fume.
November 18, no fume detected, an unusual condition; some vapor places, 9:00 am.
November 23, no fume visible, 10:00 am.
November 23, faint puff of fume started at Yellow Solfatara NW, 10:57 am, and became normal 11:30 am.
November 25 to December 1, fume NW solfatara very slight.

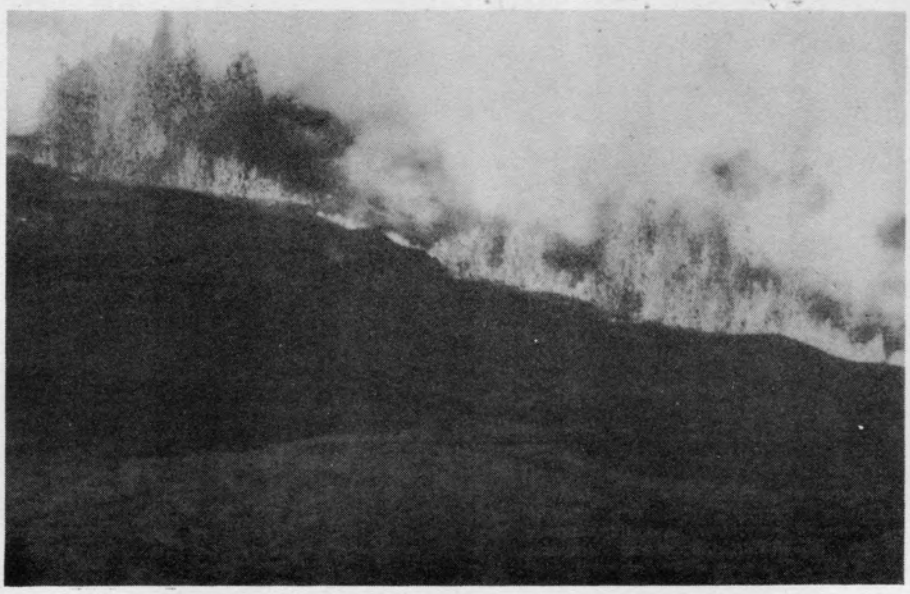


FIGURE 2. Rift fountains in sheets. Maximum 500 feet high. November 22, looking southwest, 2 pm., elevation 12,000 feet, airplane view. After 19 hours of eruption, northeast rift of Mauna Loa. Liquidity high, continuous scarlet froth jets.—By permission 11th Photo. Section, U.S. Army.



FIGURE 3. Lowest series source fountains northeast rift, 250 feet away, 150 feet high. Mauna Kea in background. November 23, 1:30 pm. Liquidity dwindling after 43 hours of eruption. Cones building, fountain jets spasmodic. —Photo by Wingate.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 32 marked places on rim cracks around the upper edge of Halemaumau pit resulted as follows:—

Week ending forenoon of

Nov. 2,	12 opened,	1 closed,	aggregate opening,	8.0 mm
Nov. 9,	9 opened,	5 closed,	aggregate opening,	3.5 mm
Nov. 16,	7 opened,	6 closed,	aggregate opening,	2.0 mm
Nov. 23,	20 opened,	1 closed,	aggregate opening,	20.0 mm
Nov. 30,	15 opened,	3 closed,	aggregate opening,	11.5 mm

The unusual opening of cracks noted November 23, followed the numerous unusual earthquakes of November 21, occasioned by the Mauna Loa eruption, which produced swaying disturbance of upright slices of the Halemaumau rim. This caused rocks to settle in the cracks, and so is different from gradual warping movement. —T. A. J.

Crater Angles and Levelling

Measurement with precision transit from the Observatory on NE rim of Kilauea across the crater between the SE and NW trig stations, on the edge of Kilauea Crater, showed a closing of 0.8" between October 30, and November 8. This angle measured again comparing November 8 with November 21 showed a closing of 3.3". Measured again, comparing November 21 with December 9, the angle opened by 2.4".

Measuring from the Observatory across Halemaumau pit from its SE rim station, to its NW rim station, showed similar changes. This angle closed 1.3" between October 30 and November 8. It closed 1.2" between November 8 and November 21. It opened 1.4" November 21 to December 9.

Spirit levelling, using Spit B.M. on the southern rim region of Kilauea Crater as a base, showed the NW station B.M. on the rim of Halemaumau to have been relatively stationary, comparing October 18 to November 26. This last date was the fifth day of the Mauna Loa eruption. —H. H. W.

MAUNA LOA OBSERVATIONS

Earthquakes

A moderate earthquake at 1:11 a.m. November 21 was felt generally from Hawaii to Honolulu, and strongly at Kapapala on the east side of Mauna Loa. Seismographic evidence located the origin less than five miles deep under the NE rift of Mauna Loa about 5 miles from Mokuaweoweo Crater. A felt earthquake of less intensity, followed by feeble ones, and tremors, occurred at 6:35 p.m. November 21, marking the visible beginning of a lava eruption on the NW side of this rift.

Rift Gushing

Light, gas-charged foaming incandescent lava opened cracks, extending from the north bay of Mokuaweoweo, where a pool of lava collected, to an old red cone 4 miles from Mokuaweoweo at elevation 11,453 feet above sea level. This line of cracking is on the NW side of the Mokuaweoweo Trail, which was invaded by the spill of the new lava only at one or two places along the upper stretches, relatively close to the summit crater. The upper two miles of the spurting cracks quickly became sealed the first night of the eruption leaving a line of small conelets, and small flows of pahoehoe lava. The next two miles NE by E became a place of large fountains, playing up in sheets along the crack, and sending floods of lava, pahoehoe above turning into aa below, down the Mauna Loa slope, in a direction nearly north towards Puu Koli.

These floods originated all along the two miles of opened crack, made braided streams, which distributed about islands of old lava on the slope to the north, changed from the smooth glassy pahoehoe to rough aa a mile or so from the vents, and united below into two main elongate torrents. Approximately the east flow travelled about 8 miles, and the west one about 7 miles in the course of the next two days, but their exact locations will not be known until this wild area of very rough ancient lavas is surveyed. The west flow went well below the treeline, as seen from airplanes the forenoon of February 22. Roughly the eastern flow was towards Mauna Kea and the western one was towards Kohala (Figure 9).

There were seven principal vents that made lava jets along the rift, each jet surmounted by gushing sulphurous fume that rose into the upper atmosphere, ginger brown in transmitted light, milky bluish in reflected light. The streamers made high cirrus, which lingered all day in the upper air. The drift of the upper wind the first day strewed Pele's hair over Kilauea. The first night there were high clouds, the glow was brilliant, and was seen from many NW localities, all the way to Honolulu.

Inspection 9:30 to 11:00 a.m. November 22 by airplane, was made by Mr. Jaggar and Mr. Waesche, flying at 11,500 feet elevation over the new flows and along the SE side of the belt of rift fountains. The field of activity was photographed from the air by Army and Navy photographers (Figures 1 & 2). Five main ribbons of liquid lava flowed in rather straight streams from the two miles of open rift, and these diverged from a wide river of lava that poured along the rift northeastward. This river divided around the old red cone, the northern branch pouring away down the slope, the southern one, after half encircling the cone, cascading into a newly opened crack on the NE side of the cone which was an extension of the rift. Beyond this point to the NE the crack was marked by many jets of white steam for perhaps a half-mile.

About a half mile west of this red cone (11,453 feet) there are some old cinder heaps on the map, and a profound pit. A branch of the rift river flowed northward about 2,000 feet to this pit and made a large cascade into it, disappearing into the depths of the mountain. Very hot fume puffed up from the pit where the bright orange melt disappeared into the void, and there was a similar gush of fume at the other cascade, by the cone.

The biggest fountains, guided by the upright planes of the gaping rift, squirted up as sheets, very narrow NE-SW, semicircular and scalloped in plan and profile, as seen from the SE. They shot up 200 to 300 feet, in about 10 main jets of scarlet molten slag, for a length of several thousand feet along the crack between elevation 11,600 feet and 11,900 feet. This region produced the effect of a flat, scalloped wall of fire with the jets continuous, like the squirting of water from a hose, (Figure 2). The detail of the rift that had opened at the base of the fountains

indicated a wall, higher on the SE side of the crack than on the NW side, where the torrents poured away down the mountain slope. Great quantities of fume rose from the fountains and the crack, and the splitting of the mountain was not confined to a single crack. With the wind blowing from the eastward, the sharp definition of the larger crack that gave vent to the fountains was very marked, the wall in plan taking the form of a series of cusps between the fountains, and of crescent bays where each larger fountain group stood. On the SE side of the line there was almost no outlying breakage or steaming. On the NW side, however, the new fractures forked in places, and the photographs show that an important secondary rift extended to the NE from the big cascade pit, with a tendency to curve northward, farther down the mountain. This crack distinctly diverges from the steam crack below the red cone. It seems likely that this fissure leads toward the lower flow vent, that later became important, (Figure 1).

The intensity of the fountaining along the open part of the crack was greatest at the NE when seen the forenoon of November 22, but angular measurement had indicated the brightest fountains farther SW the previous night. Toward the end of fountaining about November 28, the vent on the rift which persisted longest was at the SW end of the active belt, at about the 12,000 foot contour. This was destined to become a smoke hole over a concealed lava pit beneath, that acted as reservoir, within the mountain, for the Humuula lava flow of December. The increasing viscosity of the fountaining lava was very marked November 23-24, (Figures 3-4).

Upper Rift Lava Flows

The lava flows of the upper rift during the week from November 21 to November 25 were so rapidly and violently stirred into crystallization, at first, that the lava turned to aa clinker a short distance from the rift. The fountains as usual built up enclosing cones of spatter, and from breaches in the cones, pahoehoe flows poured in places along the rift belt on the SE side. The earlier photographs of November 22 show the torrents on the NW with dark clinker on each side, and with the peculiar surface pattern, of a dark line of lagging crusts up the middle of each stream; and more rapid flow along the bright glowing overhang of the stream margins. The result is a pattern of bright line crescents with the horns pointed downstream. This is exactly the opposite of the pahoehoe stream pattern, where in plan the horseshoe toe of the festoons points downstream, and the greatest drag, or restraint of the surface skin, is at the stream margin.

The fume column above the fountains was more than 5,000 feet high and above this stood a mushroom of rain cumulus. Along the crack uphill were fiery fuming vents of declining fountains, remnant from the first outbreak. Probably the first of these was the vent in the NW corner of the north bay of Mokuaweoweo. It is of interest to note that this eruption, breaking out in that bay, continued the splitting of the mountain northeastward, from where the crater outbreak left off, in December 1933.

The pattern of the flows which developed on this mountain slope to the north, appeared like that of the earlier ones which are numerous on this declivity. The braided torrents of glowing liquid were from 30 to 50 feet wide, near their sources, and these became narrower farther down the mountain and the rapidity of their forward motion became less. The front of each flow several miles down the mountain exhibited a widening into delta-shape, with dark cherry-red stream in the middle, covered with ragged sprouts and bowlders, and the actual front a glowing wall tumbling forward very slowly. Strong heat rose from the flows, and caused the airplanes to lurch violently. The odor was the usual foundry smell. The middle ribbon of liquid lava was bright orange near the source, the flow in the stream appeared liquid and rapid, within banks of its own clinker which formed fringes and tongues, of varying widths, on either side. These border fields appeared granular with many bowlders. All the torrents united into one about two miles from the source. Below this, the flow divided into two streams with one branch headed toward Mauna Kea, and the other toward Puu Koli. It is probable that these forked above the source heap of the 1843 Flow.

During the following week the pahoehoe lava of the fountains extended itself over the aa lava of the earlier flows, and also built up heaps along the rift line, the source fountaining becoming concentrated to a single cone. Probably there was flowing under the crust of the stream along the rift, and of some of the streams down the northern slope.

Detail of Upper Rift Fountains

H. H. Waesche and S. H. Lamb obtained night views of the upper fountains along with C. K. Wentworth, November 24. Fountaining activity extended for three-quarters of a mile along the fissure, with conspicuous fountain-built cones at each end. The large lower fountain had eight active centers, throwing spatter upward 100 to 300 feet. The cone was about 750 feet long, with a lava river at its base southeast, taking its origin in other cones southwest of it; this was pahoehoe flowing rapidly within a field of aa. At the upper limit of the active belt, there were three fountaining vents, the largest a truncated cone vomiting a very fluid lava from its northeast side which fed the flow pouring along the rift. The action was violent, sometimes flinging up material 400 feet, and the cone was 200 feet across and 75 feet high. A

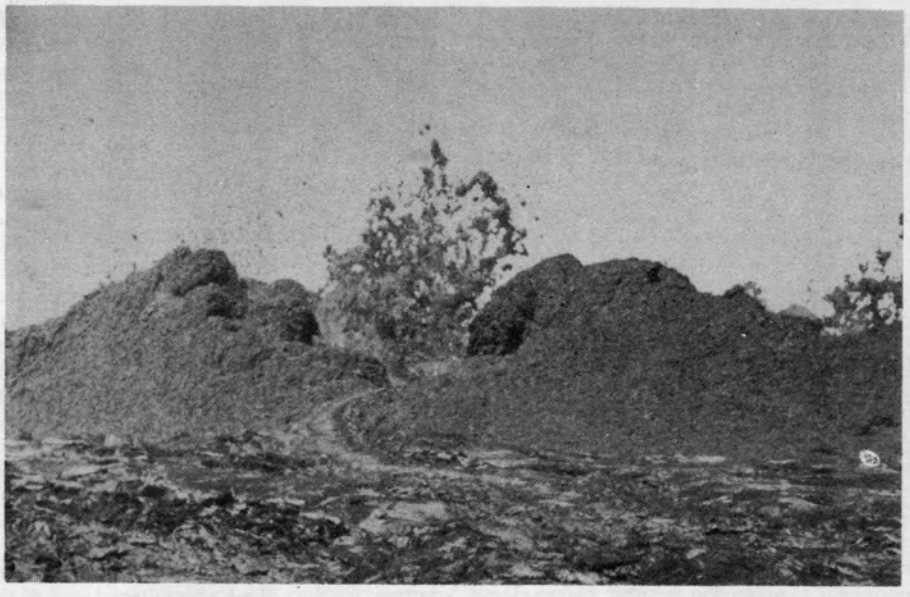


FIGURE 4. Detail of northeast rift fountains November 24, 7 am., showing overflow of pahoehoe lava from the cones. Liquidity low, viscous heavy slag after 60 hours of eruption. Looking northwest.—Photo by C. W. Carlsmith.



FIGURE 5. Mauna Loa from the north at Humuula evening November 24. To be compared with Figure 6. (1) is the rift fountain area, and long aa flows to the right. (2) later developed a flow source elevation about 9,000 feet. (3) was the flow front November 29. The glow spot between 2 and 3 lights a cloud behind Huluhulu hill. Its meaning is not clear.
—Photo by Hilo Photo Supply.

vent 75 feet NNE of this one emitted gas burning with a blue flame, occasionally jetting up in blasts with yellowish flames, at intervals of from three to five minutes. Seventy-five feet farther NE a spatter cone flung out filaments and gushes of viscous lava, building up the cone rapidly to the size of the larger ones within three hours. There were many vents farther NE flinging out incandescent cinders and showing blue flames or gas blasts. One large vent erupted with a roar at intervals of twenty minutes. Along the course of the flow there was a lava cascade. Crust on the flow would lift like a trap-door and emit rapidly cooling aa. The noise of the fountains was like surf on a rocky coast-line, and the gas vents made prolonged coughing exhausts. This entire history closely resembles that of the 1919 fountains. (See Bulletin Hawaiian Volcano Observatory, October, 1919, pages 131 and 155).

Development of Humuula Flow

As is usual with Mauna Loa outbreaks, the chief characteristic of the first week at the line of fountains, impelled up through the rift by gas-effervescence, was the rapid decline of heat and gas pressure, and the concentration of all activity to one vent (Figures 2, 3, 4). Apparently the rift opened quietly on the west side of the Dewey Crater of 1899, and a flow more than a mile long was reported there the morning of November 24. Then on November 27 there came the report of a light-colored flow originating at elevation 9,000 feet, at a fuming channel in the north side of the mountain midway between the 1899 Flow and the 1843 Flow. The area of this slope of the mountain is vast, and what really happened is obscure. Certain it is that a flow appeared, with a line of smoke at its source, about elevation 8,500 feet, Longitude 155°, 29.5′ west, Latitude 19°, 35.5′ north. Seen from the air, this place had two north-flowing pahoehoe lava channels emerging directly from under the skirt of an old flow. The larger channel had sulphur-stained fume vents along its bank, and inspection at night from Humuula sheep station, 8 miles away, showed bright spots here suggesting small standing fountains. The pahoehoe poured down these channels, spread out and changed into delta-shaped aa fronts, and as the flow progressed, these tended to force each new front farther westward than its predecessor.

The net effect of this, between November 27 and mid-December, was to make great fields of aa lava widening from above downward in the direction of Humuula station, and gradually overlapping the lava flow of 1843, the source being above elevation 8,500 feet, and the wide-spread frontal region in the vicinity of the 6,800 foot contour.

Decline of Upper Rift Fountains

H. S. Palmer and W. O. Clark spent the night November 27-28 at the rift cone, elevation 12,000 feet. There were three most active vents, behind a rampart 500 feet long and about 100 feet high, the NE one being the most energetic, and discharging great quantities of gas-carrying incandescent clots up into the air. The biggest of these were six inches across, sometimes falling outside the rampart and rolling down. Spindle and ribbon bombs were flung up, and others shaped like a dumbbell. The bombs generally followed parabolic trajectories but sometimes they took irregular, wavy paths. At the east end of the heap stood a beehive cone 50 feet high, surmounted by a glowing hole 25 feet in diameter, which discharged tremendous clouds of fume, believed to be steam and sulphur dioxide. The general level of activity was fairly constant with some increasing force about once an hour. There were pulsatory discharges at intervals of from one to five seconds with surf-like noise. The odor was of sulphur-dioxide when the gas came toward the observers, and there were some light drizzles.

This clotted activity reduced to a single vent, with the new pahoehoe lava flow stationary but hot, adjacent to the active cone, was succeeded on November 28 by a sinking away of the fountains so that the surf-like noise was replaced by explosive detonations at intervals, this process flinging out lava spatter and bombs. No glow or flinging out of material was seen at the upper rift source after December 1, but the fume continued to rise there charged with much white vapor. It was evident from the lowering of the lava in this craterlet, and from the explosions during the closing phases of its activities, that the rift underneath communicated directly with the 9,000 foot source of the Humuula flow farther down the mountain; and it did not seem likely that that source was a tunnel leading from the upper cone through new surface flows, as no glow whatever remained in the upper region. This makes it probable that the rift makes a long bend for six miles NE, and then north, under the shell of old lavas, and opens at the lower locality to give rise to the flow. The lower source is more than 3,000 feet below the base of the rift cone, and may be an old tunnel.

It is of interest to note that Ranger Kenneth Williams who was stationed at the upper rift and described the explosive recession of the lava in spells between November 28 and December 1, compared the action to the sinking spells of the lava in Halemaumau, described as "explosive drainages" in September and October 1934. (See Volcano Letter, of those months.)

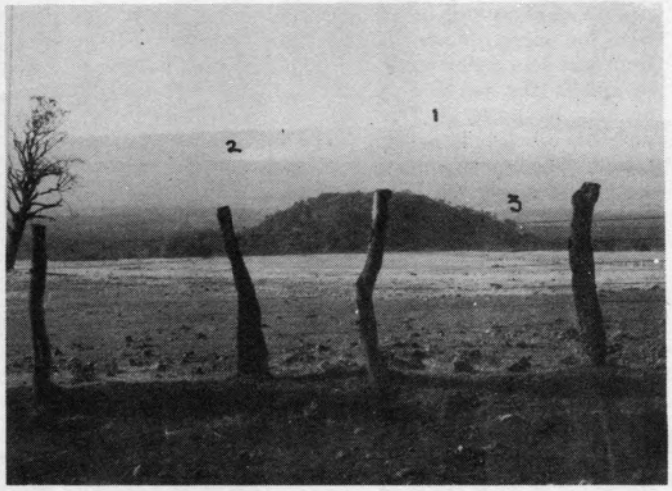


FIGURE 6. Mauna Loa looking south from Humuula, November 30, 7 am. (1) rift cones: (2) flow source: (3) flow front of aa lava. Sheep pasture and Huluhulu hill in foreground. The glow spot of Figure 5 corresponds to the middle flow region of Figure 6. The upper flows of Figure 5 had now ceased action.
—Photo by Jaggar.

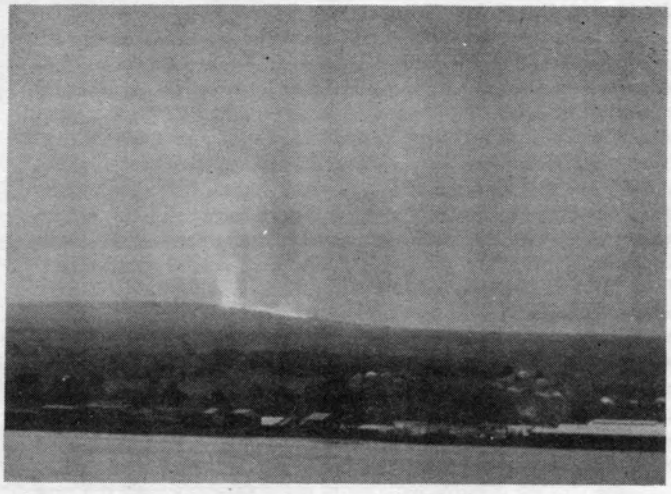


FIGURE 7. Hilo and Mauna Loa eruption, November 22, early morning light. Shows the high fume cloud, the fountains on northeast rift, and the upper flows of the first day sweeping northward. These flows stopped after five days. —Photo by Maehara.

Progress of Humuula Flow

The phases of this eruption had now been (1) Earthquakes of November 21. (2) Summit rift gushing November 21-26, producing short-lived lava flows. (3) Development of Humuula Flow, November 27-December 1, along with subsidence of upper rift lava.

From the hills east of Humuula, November 23, could be seen at night a meandering aa stream headed northwest, and joining a branch headed farther west between Puu Koli and the 1843 Flow, (Figure 5.) November 25, the west branch was visited by Naturalist Doerr, and Park Architect Sager and the live aa of 1935 was found on the west side of the 1843 Flow. The front, of the rough broken lava was 15 to 25 feet high, the end of a lobe moving only a few feet per hour, on top of ancient bushy country where falling incandescent bowlders occasionally set fire to shrubs. The main flow showed glowing areas 10 or 12 feet across. The cooler solidified rocks on top kept rolling down, to be over-ridden by the advancing paste, with a continual cracking noise. An eastern flow some miles away showed heat waves in the air rising above it. That night this east flow was dull and the extreme front of the west flow glowed. The latter came from the 12,000-foot rift.

November 28 the east or Humuula Flow developed a bright new phase of gushing at the 9,000-foot vents, and the west flow from the upper rift went out of action November 29. The new front was four miles north of Humuula on old pahoehoe lava; its middle lobe, fed by a medial stream, pushed ahead 120 feet per hour, November 29. The front as a whole was variable, making probably a half-mile per day. Sometimes the progress would increase, the glowing bank would increase in height, huge bowlders would topple over the front impelled forward on the upper surface of the delta-shaped plateau, and there was steady tinkle of falling debris down the 18-foot wall. Red hot blocks fell out with a musical ringing noise. The pasty swelling forward of the mass was distinctly visible. The behavior was like a caterpillar tractor. When a spell of increased thrust arrived, the front glowed more brightly, the tinkling noises were more continuous, the top of the bank piled up to heights of 20 to 25 feet, and larger fragments fell more frequently.

The flow as seen from Humuula was now like a snake in four meanders, and it had stopped to fan out at the bends. The front visited was 2,000 feet across, and a stream 50 feet wide and dark cherry-red in color occupied a canyon of its own making in the background, to spread in lobes as it fed the delta. The canyon appeared to have cascades of lava as one looked up the mountain, all the other bright places vanishing around bends in a shimmer of heat, and a dark line up the middle of the river marked the characteristic choked zone of rafts and crusts, which come tumbling along on the surface of aa liquid, and occasionally hit bottom.

The front of the flow produced flames, and smoke of the burning sparse vegetation; there were very large bowlders of lava on top of the delta plateau, sometimes 10 feet across and made of pahoehoe lava, where the stream had brought down rafts and thrust them into the lobes. The brightness of glow at the front was a direct measure of the activity of motion. Dust was made by the incessant flow of coarse and fine material down the frontal wall, and there were explosions in old caverns of lava under the flow, where the gases of burnt vegetation mixed up with air and ignited. Such explosions were not conspicuous outside of the front. The progress in 6 days was 0.4 mile per day.

On November 30, the aa front was widening eastward and was less bright and active than on the previous day. As one looked up Mauna Loa from Humuula, the source of the flow was seen to be at the tip of an inverted V of new lava, which meandered back and forth within the V, the swings of the meanders becoming wider towards the front (north). This V-pattern is of the same quality as that of the 1843 Flow, and of most of the flows which originate at a single vent and then widen out in a flat region below. The source of the 1935 flow showed two sulphurous smoking spots sending up a quantity of blue fume, and at night these places were very bright as though they were standing fountains of lava. In a straight line with them just below were several white steam jets, which suggested a crack, producing water vapor from its downhill extension, as in the case of the summit rift, (See figure 6). All this time the summit rift cone sent up dense fume clouds and at night the glow there was growing fainter. This was the time of the lowering lava in the shaft, and of the explosions.

—T. A. J.

EARTHQUAKES **TABLE**

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Slight earthquakes	Moderate earthquakes	*Local Seismicity
Nov. 3	41	7	1	0	0	14.75
Nov. 10	37	4	0	0	0	11.25
Nov. 17	44	4	0	0	0	13.00
Nov. 24	3281	8	2	2	1	835.75
Dec. 1	157	5	0	0	0	41.75

*For local seismicity index see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations located at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant of these quakes were located with the aid of seismograms from stations at Hilo and Kealakekua. All the disturbances began at the time indicated and whenever determinations were possible, the depth of focus is given.

November 1, at 6:23 pm, very feeble, located in vicinity of the S rim of the Crater of Kilauea.

November 1, at 6:34 pm, feeble, located 0.8 mile under N rim of Halemaumau. 19° 24.7′ N; 155° 17.2′ W.

November 1, at 7:40 pm, very feeble earthquakes in the same location as the one preceding.

November 7, at 5:36 am, very feeble, located 4.6 miles deep and 3.2 miles west of the Volcano Observatory. 19° 25.9′ N; 155° 18.6′ W.

November 17, at 1:52 am, very feeble, located 12 miles deep and 8 miles NW of Humuula Sheep Station. 19° 48′ N; 155° 32.5′ W.

November 18, at 3:04 pm, very feeble, located approximately under NE edge of Mokuaweoweo.

November 20, at 5:57 am, very feeble, located 4.5 miles deep and 1.8 miles W of Halemaumau. 19° 24.9′ N; 155° 18.8′ W.

November 20, at 11:52 am, very feeble. Probable location on NE rift of Mauna Loa halfway between Hilo and the summit crater, Mokuaweoweo.

November 21 at 1:11 am, a moderate earthquake was gen-

erally felt on the Island of Hawaii and was reported felt at Waikiki on the island of Oahu, and at Hana on the island of Maui. It was most strongly felt at Kapapala Ranch where the shock lasted one and a half minutes, made a noise like an explosion, knocked objects from shelves, broke one window, knocked over bottles and cause a tube of tooth paste to fall into a wash basin. In the Kilauea area, people were generally awakened, pheasants called, and in one case books were reported knocked from shelves. The seismographs at all stations were dismantled. Location in NE rift of Mauna Loa five miles SW by W from the rest house at Puu Ulaula and an equal distance NE by E from the center of Mokuaweoweo Crater. This quake was evidently caused by the opening of the NE rift in this vicinity resulting in the Mauna Loa eruption which started seventeen hours later. The depth of the quake is uncertain but is estimated to be not more than five miles and was probably less. 19° 31′ N; 155° 31.5′ W.

November 21, at 6:35 pm., there was a slight earthquake which probably marked the visible beginning of the Mauna Loa eruption. Preceding this shock, there were fourteen minutes of harmonic tremor, interrupted by a very feeble quake at 6:33 pm. Following this there were 3 more minutes of harmonic tremor. The tremor was interrupted by another slight earthquake at 6:42 pm. At 6:45 pm there was a feeble earthquake with its origin indicated as being at the NE edge of Mokuaweoweo Crater. Another feeble quake followed at 6:49 pm, located approximately 6 miles W of Puu Ulaula on Mauna Loa NE rift. A very feeble earthquake occurred at 6:58 pm. Harmonic tremor continued until midnight November 24. Tremors continued with a decreasing rate of frequency until the end of the month. The locations of these disturbances were approximately along the NE rift of Mauna Loa from the NE edge of Mokuaweoweo to a point approximately four miles SW by W from the rest house at Puu Ulaula. None of the shocks associated with the Mauna Loa outbreak was reported felt.

The harmonic tremor had a period of 0.6 second. The amplitude varied but indicated a ground movement at the Observatory of between 1 and 10 microns the first three days of the fountaining activity. Afterwards the tremors became intermittent with a decrease of both frequency and intensity.

November 24, at 2:46 pm, very feeble, 0.6 mile deep and 0.5 mile east of Tourist Stand on SE rim of Halemaumau. 19° 24.5′ N; 155° 16.6 W.

November 27, at 12:30 am, very feeble, 9.5 miles deep and 4.8 miles NW of Puu Ulaula on N slope of Mauna Loa. 19° 33.7′ N; 155° 32.0′ W.

November 27, at 6:15 pm, very feeble, located 1.1 miles deep 0.4 mile SW of Pit seismograph station. 19° 24.2′ N; 155° 17.2′ W.

November 29, at 1:48 pm, very feeble, located 0.5 mile SW of Pit seismograph. 19° 24.0′ N; 155° 20.6′ W.

No distant earthquakes were recorded.

Microseismic motion was normal, November 1, 2, 8, 11 to 13, 16 to 22, 25 to 27, 29 to December 1, inclusive. It was strong the remainder of the month except November 14, 15, 23 and 24, when it was light. —H. H. W.

Tilting of the Ground

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope locations towards or away from the crater of the Pit.

At the Observatory the total accumulated tilt for the year ending December 1, was 1.3″ S and 3.85″ E.

TABLE OF TILT

Week ending	Observatory	Halemaumau Clinoscope Stations		
		West	Southeast	Pit resultant
Nov. 3	0.15″ E	1.04″ E	7.78″ N 11° E	6.22″ toward
Nov. 10	0.32″ S 41° E	5.13″ N 5° W	2.30″ S 55° E	2.12″ from
Nov. 17	0.83″ S 45° E	5.36″ N 5° W	12.96″ S 78° W	5.51″ toward
Nov. 24	1.83″ N 45° E	3.28″ N 75° W	14.90″ N 47° E	1.20″ from
Dec. 1	0.91″ N 70° E	1.88″ N 59° W	8.26″ N 30° E	1.75″ toward

H. H. W.

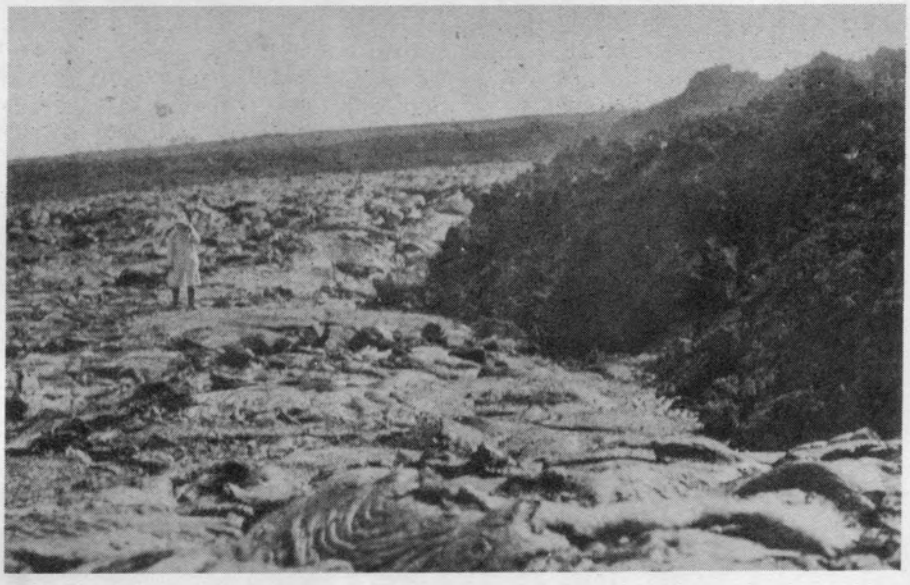
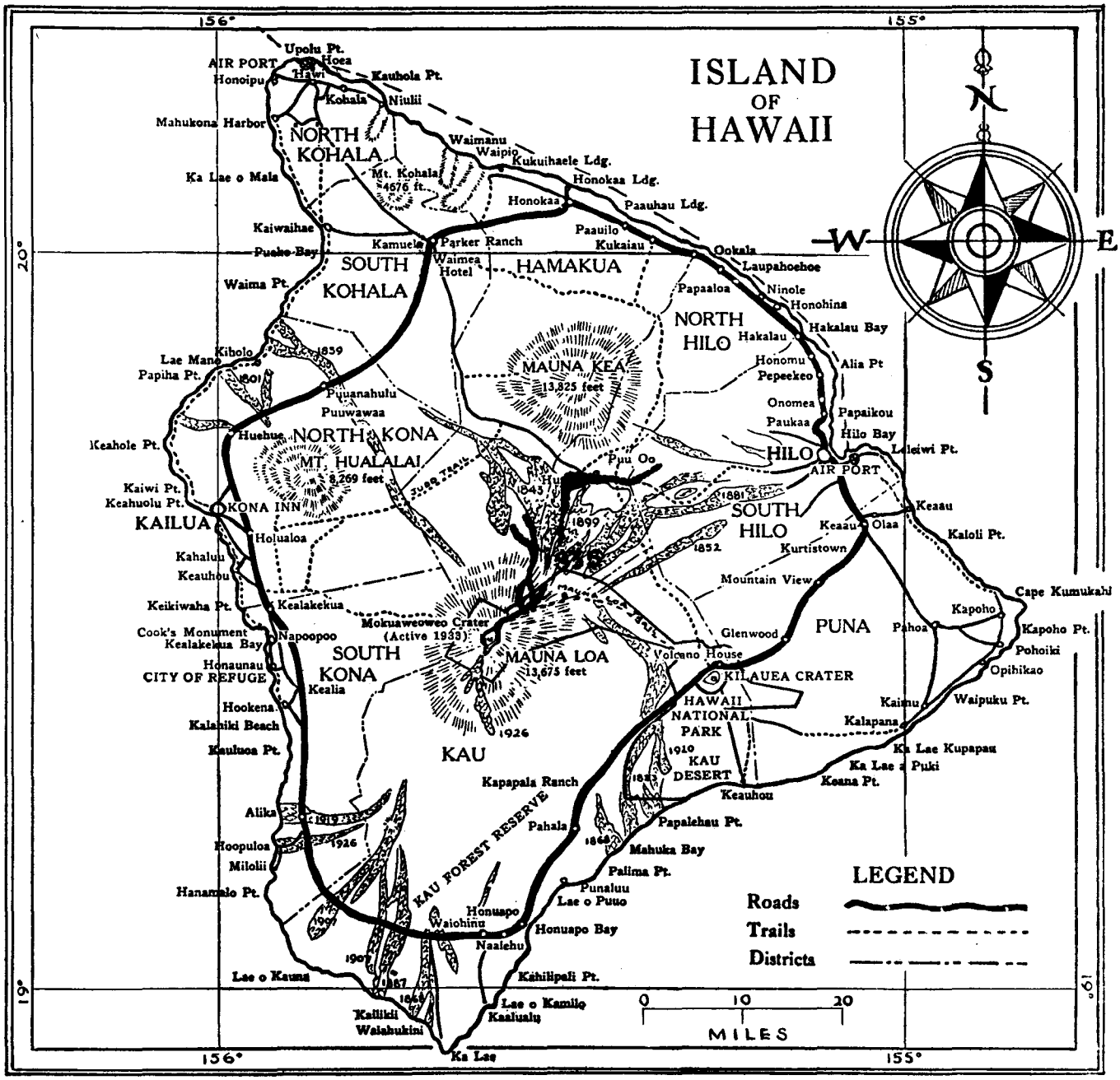


FIGURE 8. Front of glowing aa lava, 18 feet high, moving over old pahoehoe, right to left, at a rate 120 feet per hour. Looking east, 3.3 miles southwest by south from Humuula Station, 11 am., November 29. This was one of a succession of lobate fronts that moved north northwest from the 9,000-foot source, down the north slope of Mauna Loa—Photo by Jaggar.


ISLAND OF HAWAII
156°
155°
20°
19°
N
S
E
W
Upolu Pt.
AIR PORT
Hoea
Honoipu
Hawi
Kauhola Pt.
Kohala
Niulii
Mahukona Harbor
NORTH KOHALA
Waimanu
Waipio
Kukuihaele Ldg.
Ka Lae o Mala
Mt. Kohala 4676 ft.
Honokaa Ldg.
Honokaa
Paauhau Ldg.
Kaiwaihae
Paauilo
Kukaiau
Kamuela
Parker Ranch
Pueko Bay
Waimea Hotel
Ookala
SOUTH KOHALA
HAMAKUA
Laupahoehoe
Waima Pt.
Papaaloa
Ninole
Honohina
NORTH HILO
Hakalau
Hakalau Bay
Kiholo
1859
Lae Mano
Papiha Pt.
1801
MAUNA KEA 13,825 feet
Honomu
Pepeekeo
Alia Pt
Puuanahulu
Puuwawaa
Onomea
Papaikou
Paukaa
Huehue
NORTH KONA
Keahole Pt.
MT. HUALALAI 8,269 feet
Hilo Bay
HILO
Leleiwi Pt.
AIR PORT
Puu Oo
Kaiwi Pt.
Keahuolu Pt.
KONA INN
1843
1881
SOUTH HILO
Keaau
KAILUA
1899
Keaau
Olaa
Kaloli Pt.
Holualoa
1852
Kurtistown
Kahaluu
Keauhou
Mountain View
Cape Kumukahi
Keikiwaha Pt.
Kealakekua
Kapoho
Mokuaweoweo Crater (Active 1933)
Kapoho Pt.
Cook's Monument
Kealakekua Bay
Napoopoo
Glenwood
PUNA
Pahoa
Pohoiki
Honaunau
CITY OF REFUGE
SOUTH KONA
MAUNA LOA 13,675 feet
Volcano House
Opihikao
Kealia
KILAUEA CRATER
Hookena
HAWAII NATIONAL PARK
Kaimu
Waipuku Pt.
Kalahiki Beach
Kalapana
1926
Kauluoa Pt.
KAU
1910
KAU DESERT
Ka Lae Kupapau
Ka Lae a Puki
Kapapala Ranch
1823
Keana Pt.
Keauhou
Alika
1919
Papalehau Pt.
Pahala
1926
1868
Hoopuloa
Mahuka Bay
Milolii
KAU FOREST RESERVE
Palima Pt.
Hanamalo Pt.
Punaluu
Lae o Puuo
Honuapo
Waiohinu
Honuapo Bay
1907
Naalehu
1907
Lae o Kauna
Kahilipali Pt.
1887
1868
Lae o Kamilo
Kailikii
Kaalualu
Waiahukini
Ka Lae
LEGEND
Roads
Trails
Districts
0
10
20
MILES

THE VOLCANO LETTER

No. 430—Monthly, Department of the Interior, National Park Service, December, 1935

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR DECEMBER, 1935

Including weekly press reports 1246 to 1249
December 1 to December 29, 1935 Midnight



FIGURE 1. December 21. Pahoehoe flow at Humuula, advancing towards Hilo. Bronze in general color with glowing, cherry-red "toes."

VOLCANOLOGY

The release of gas, of molten lava, and of heat achieved in great quantities by the outflows of the Mauna Loa eruption in December, which continued throughout the month, reacted at Kilauea in a pronounced decrease in numbers and intensity of tremors and earthquakes. The weekly local seismicity declined from 30.50 to 4.25. This did not mean a decline in the volume of Mauna Loa outpouring, for seventy per-cent of the earthquakes located were Kilauea shocks. It appears rather to mean that a free release of thermal energy for the whole volcanic system, if continued through open vents, reduces the local seismicity. Thus we find the average weekly seismicity for October 27, for November 20, (disregarding the excessive figure for the week of outbreak, due to continuous tremor) and December 14. This tendency has been observed in other eruptions and suggests that abortive eruption or intrusion accounts for times of high seismicity.

A correspondence between the release of heat at Mauna Loa and an observed lowering of temperature at Kilauea was noted. The time when blue fume disappeared at the northwestern Yellow Solfatara in Halemaumau, November 18, three days before the Mauna Loa outbreak, was characterized by cooling of the bath steam in the Observatory ground. By December 18, sulphur fume reappeared at the pit and the vapor temperatures became hot again at the Observatory.

An observation worth recording reported by A. M. Brown of Keahou Ranch is the following:—

On July 22, 1935 at 4:30 am, along the Puu Oo trail, on the east slope of Mauna Loa about elevation 5,000 feet, between Keahou Ranch house and Keawewai Camp, in old pahoehoe lava, five persons noted hot places in the ground.

Kilauea Observations

Slides of Halemaumau

Slides from the wall of the pit have been noted as follows:—

December 5, continuous small sliding from W, NW, and N walls, 10:05 am
December 13, slides occasioned by slight earthquakes 9:31 am
December 13, dust rose from NW side at 12:49 and 12:55 pm
December 19, rocks were dribbling at E wall, 9:50 am
December 21, fresh scar observed on NE wall 10:00 am
December 22, avalanche dust arose NE, 12:55 pm
December 26, small slide E wall 9:58 am
December 26, noisy slide and dribbling of rocks at N wall, 10:03 am
December 27, small slide NE wall, 9:45 am
December 28, small slide N wall, 10:23 am

Such slides during the inspection hour indicate the average conditions.

For the last two weeks of the month, volcanic conditions at Kilauea were unusually and increasingly quiet.

Halemaumau Solfataras

Observations of the sulphurous fumaroles around the edges of the Halemaumau floor, and of the vapor cracks, have been as follows:—

December 3, almost no fume visible at NW Solfatara, fumes strong, from new sulphur spot SE, 10:20 am
December 5, fume normal at all vents, 10:05 am
December 13, new sulphur spots noticed SE 9:30 am
December 19, abundant fume in pit, apparently increasing at border crack SE 9:50 am

Measurement of Halemaumau Rim Cracks

Weekly measurement of 32 marked places on rim cracks around the upper edge of Halemaumau pit resulted as follows:—

Week ending forenoon of

Dec. 7,	6 opened,	3 closed,	aggregate opening	4.0 mm
Dec. 14,	17 opened,	1 closed,	aggregate opening	14.0 mm
Dec. 21,	8 opened,	3 closed,	aggregate opening	5.5 mm
Dec. 28,	6 opened,	7 closed,	aggregate opening	1.0 mm

—T. A. J.

Crater Angles

The horizontal angle measurement from Observatory showed a closing of the angle between SE and NW rims of Kilauea Crater, 1.0" comparing December 9, to December 19, and showed no change comparing December 19 to January 9, 1936.

The same kind of measurement across Halemaumau pit from the Observatory showed a closing of 2.2" between December 9, and December 19, and an opening of 1.2" between December 19 and January 9, 1936.

HAWAIIAN VOLCANO OBSERVATORY REPORT
Week Ending December 8, 1935

The northern flow of the current Mauna Loa eruption continued its advance during the week. The front of the flow moving to the north and west has reached a point within two miles of the Humuula Sheep station. All forward motion of the main flow had apparently stopped however, by December 7. The glow from the aa river feeding the flow was reported to be quite bright on the evening of December 7, showing that fresh lava was still being fed to the stream. At several localities the channel was probably being blocked by cooling lava as small flows issued from the stream and flowed for short distances from the side of the main flow. The upper source fountains have ceased all visible activity although a glow was still noticeable at that point from the north side of the Island, December 7. No glow at that point has been visible from the Observatory this week although heavy fume columns were visible during the day until December 6. Cloudy weather has prevented observation since that date but the fume was greatly diminished when last observed.

Little or no fume was visible at the N.W. solfatara of Halemaumau December 3, at 10:20 am; at the same time the fume from the comparatively new sulphur spot at the S.E. edge of the floor of Halemaumau was rather strong. The weather was rainy and the wind was moderate from the Northeast. Fume was apparently normal from all vents in Halemaumau at 10:05 December 5. Small slides occured from the west, northwest and north walls at this same time.

116 local seismic disturbances were registered on the Observatory seismograph of which 112 were tremors, one was a feeble earthquake and three were very feeble earthquakes. The feeble earthquake occurred at 9:13 pm, December 4 and was 2.4 miles from the Observatory probably under Halemaumau. It was reported felt at the C.C.C. Camp. The very feeble earthquakes were, December 2, at 7:55 am at a distance of 17.8 miles; December 3, at 6:30 am at a distance of 19.4 miles; and December 7, at 12:31 am at a distance of 2.4 miles. Those of December 2 and 3 were probably associated with the Mauna Loa eruption. Seismic index for the week was 30.50. Microseismic motion was normal but increased to strong on December 8. Tilting of the ground at the Observatory was slight S by E.

Measurement for the week of 32 crack localities around Halemaumau, December 7, showed that 6 had opened and 3 had closed for a resulting aggregate of 4.0 millimeters opening.

One hundred and sixteen local seismic disturbances were recorded at the Volcano Observatory during the week.

At 9:13 pm, December 4, a feeble earthquake was registered. The shock was apparently centered 2.4 from the Observatory under Halemaumau. The Pit seismograph was dismantled and the quake was reported felt at the C.C.C. Camp.

The following very feeble earthquakes registered.

December 2, at 7:55 am, at a distance of 17.8 miles
" 3, at 6:30 am, " " " " 19.4 "
" 7, at 12:31 am, " " " " 2.4 "

A total of 112 tremors were recorded for the week.

Seismic indices (0 to 12 miles: :1.50) (0 to 66 miles: : 1.00) Weekly 30.50.

Tilt—Dec.	2	61	184	M
"	3	62	185	M
"	4	62	182	M
"	5	62	182	M
"	6	65	180	M
"	7	68	174	M
"	8	64	168	St

	63	179	63	179
	59	178	-17	000
	4 S	1 E	Slight S by E tilt	46 179

To compare with next week.

Of 32 crack points measured December 7, 6 opened, 3 closed for an aggregate opening of 4.0 millimeters.

HAWAIIAN VOLCANO OBSERVATORY REPORT
Week Ending December 15, 1935

The Mauna Loa eruption continued, with the front of the flow changing to pahoehoe, or glassy liquid lava, a half mile from the cones immediately west of Humuula. The pahoehoe has come down the lava channel overriding the aa fields. December 9 the aa front was three quarters of a mile from the foot of Mauna Kea and at 8 p.m. the pahoehoe began spilling out the west side of the front. The upper lava rivers were voluminous and

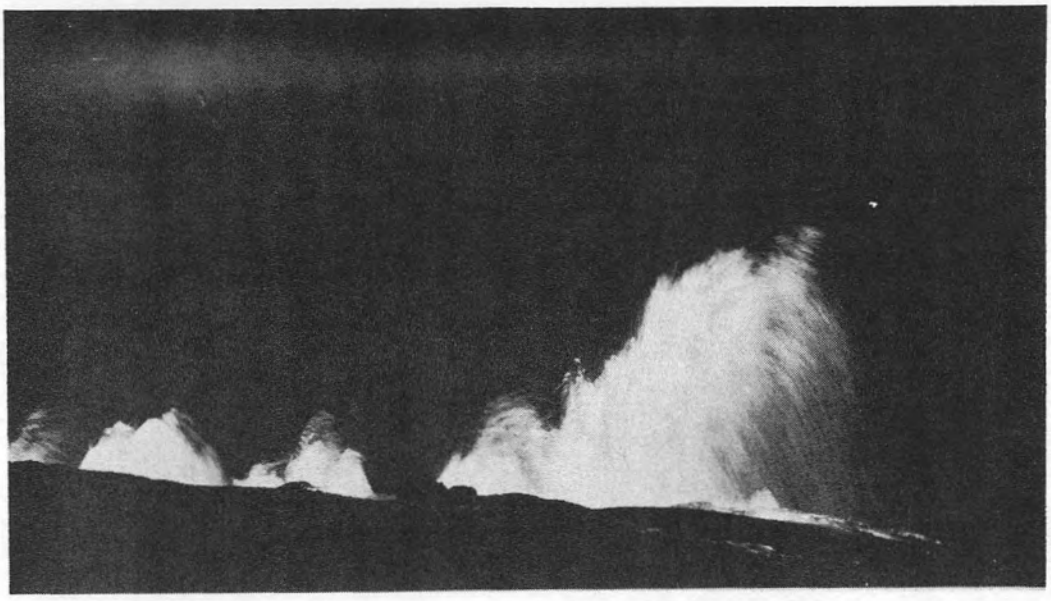


FIGURE 2. November 23, 7:00 p.m. Great fountains over rift-line. Right-hand fountain is approximately 400 feet high. —Photo by Wingate.

brilliant. The rift cones smoked, and the 9000-foot source made a line of smoke holes. December 10 the front slowed, but above there was dusty aa in motion. December 11 the front stopped. From Kilauea and Hilo there was smoke seen at the rift cones and glow above the lava flows. December 12 there was slight revival of the pahoehoe front which stopped the next day. December 14 the piling heaps of pahoehoe at the 9000-foot source appeared to make scattered flows westward. December 15 new aa fronts moving west from the heap and the big lava rivers of the middle slopes of the mountain increased in size.

Halemaumau has shown nothing of importance. A slight earthquake there December 13 at 9:30 am made some sliding. New sulphur spots were noticed southeast. Measurement December 14 of the 32 marked places on cracks around Halemaumau indicated that 17 had opened, 1 had closed, result in aggregate opening of 14 mm.

Assistant Naturalist H. H. Waesche reports 55 local seismic disturbances and one distant earthquake. The distant large earthquakes indicated origin 3780 miles away and began at 8:47 pm December 14.

A slight earthquake of 9:31 am December 13 was felt strongly at Halemaumau and a feeble shock 2:33 pm December 14 indicated origin 18 miles away from Kilauea, the distance of the Mauna Loa rift source of the present eruption. Very feeble earthquakes were registered December 10 at 6:09 am and 6:19 pm, distances 19 and 20 miles, December 11 at 1:36 pm distance 32 miles and December 13 at 9:31 am, distance 2 miles. Forty-nine tremors were recorded. Seismis index for the week was 17.25. Miscroseismic motion was strong. Tilting of the ground at the Observatory was slight NE.

Fifty-five local seismic disturbances were recorded at the Volcano Observatory during the week.

At 9:31 a.m., December 13, a slight earthquake was registered. The shock was centered under Halemaumau, 2.4 miles from the Observatory. It was felt by a few around the National Park Headquarters area and strongly by several on the rim of Halemaumau. The E.W. component of the Pit seismograph was dismantled.

A feeble earthquake registered at 2:33 pm, December 14. Its distance was 18.3 miles and was probably associated with the Mauna Loa eruption.

The following very feeble earthquakes were recorded.

December 10, at 6:09 am, at a distance of 18.9 miles
" 10, at 6:19 pm, " " " " 20.2 "
" 11, at 1:36 pm, " " " " 31.9 "
" 13, at 9:31 am, " " " " 2.4 "

There were a total of 49 tremors. The preliminary waves of a teleseism began recording at 8:47 pm, December 14. Distance 3,780 miles.

Seismic indices (0 to 12 miles: :1.50) (0 to 66 miles: : 3.50) Weekly 17.25.

Tilt—Dec.	9	47	164	St		
"	10	49	169	St		
"	11	49	175	St		
"	12	46	180	St		
"	13	41	182	St		
"	14	37	184	St		
"	15	36	186	St		
	44	177	Tilt this week		44	177
	46	179	Tilt last week		0	-13
	2N	2W	Slight NE tilt		44	164

To compare with next week.

Of 32 crack points measured December 14, 17 opened, 1 closed for an aggregate opening of 14 millimeters.

HAWAIIAN VOLCANO OBSERVATORY REPORT
Week Ending December 22, 1935

The Mauna Loa lava flow bent eastward toward Hilo December 22, creating a crisis. December 16 the brown fume arose densely at the rift sources, and glow of the pahoehoe streams was visible at Hilo and at Kilauea. These streams December 17 revived the front opposite Humuula. December 19 this pahoehoe lava moved northeast 1800 feet, and spread out in a sheet east of the 1843 flow, one-half mile south of the stone wall extending west from Puu Huluhulu at Humuula.

December 20, just on the solstice, with a spurt forward, the liquid overflowed the wall for one-half mile, fronting Puu Huluhulu within one-quarter mile. December 21 the forest and grass lands were burning on the flat south of Humuula sheep station. December 22 the pahoehoe lava passed Puu Huluhulu, between that hill and Mauna Kea, flowed eastward more than a mile, with a front 200 feet wide, and tended by reason of slope and stirring to change to aa lava. The progress had been one-quarter mile per day; it suddenly changed to one mile or more a day, draining the large lake which had accummulated in the saddle between Mauna Loa and Mauna Kea. The source heaps on the north flank of Mauna Loa were now brilliant with a meandering pahoehoe stream of liquid fiery lava, and soon the lava field closed around the Huluhulu hill, and sent a second stream on its south

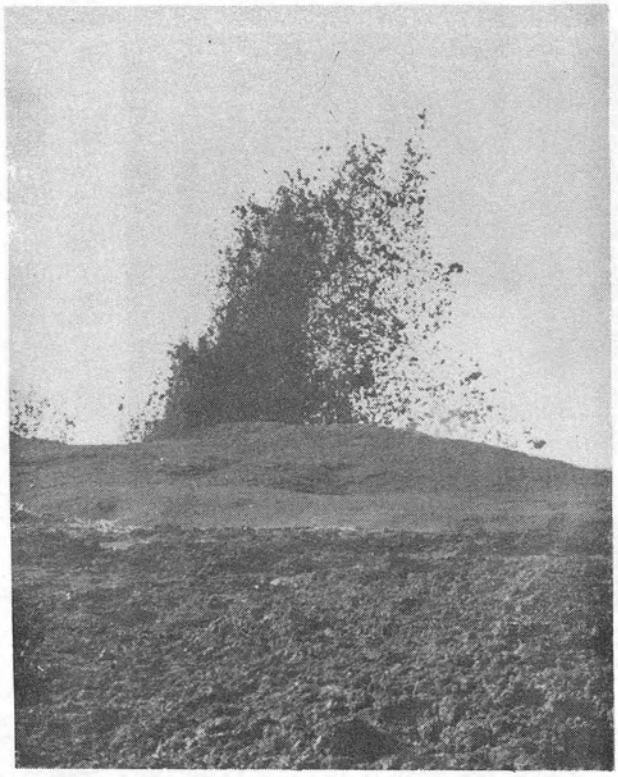


FIGURE 3. November 23, 2:00 p.m. 250-foot fountain over vent in lowest series. —Photo by Wingate.

side to join the main east-flowing river of slag. The flow-source about 9000 feet elevation, exhibits, from the air, a channel 40 feet wide emerging from under dead flows above, with smoking grottoes or vents, and silvery splashes of distributary pahoehoe make a widening feather-pattern down the mountain north, into which the glowing river disappears under gleaming crust. This flow source led into the rift belt southward, toward Mokuaweoweo at 13,000 feet where the eruption began on November 21. At elevation 11,000 to 12,000 feet, the 1935 cones and chasms of the rift belt sent up brown fumes in seven columns, densest at the big new cone. The cone lies at the southern end of the active cracks, which form a zone 3 miles long.

The eruption thus has three centers: The main summit crater shaft, the secondary smoke shaft within which the lava has lowered and the flow vent which siphons the liquid out at a single point. The liquid crusts and pours in tunnels down the mountain under its crust, distributing to numerous fronts. It is necessary to keep the upper smoke shaft and the lava vent separately in mind—they are six miles apart—in order to understand future developments.

At Halemaumau pit of Kilauea volcano trivial slides were observed December 21 and December 22. The reduction of blue fume at the Yellow Solfatara noted November 18 just before the Mauna Loa outbreak, was accompanied by cooling of the bath steam in the Observatory grounds. Both visible sulphur fume at the pit and steam temperatures at the Observatory, had returned to normal December 18.

Measurement of 32 marked crack localities, around Halemaumau pit, for the week ending December 21, showed that 8 opened and 3 closed, making aggregate opening of 5.5 mm.

The seismographs show approximately 31 disturbances, of which 29 were very feeble shocks and tremors. Feeble earthquakes occurred about 12:54 pm December 17, and 5:23 am December 20. Formal seismometric report will be made in January.

HAWAIIAN VOLCANO OBSERVATORY REPORT
Week Ending December 29, 1935

The Mauna Loa eruption continued to eject dense vapor and fume from the sulphur-stained rift cone at elevation 1,200 feet. December 23, the lava flow was 2 miles east of Humuula, about 200 feet wide, changing from pahoehoe lava to aa lava The stone wall drowned under a lake of lava, south of Humuula, tended to reappear as the lake level sank. Explosions were common in old cavities along the lava fronts. This had occurred from the time vegetation made carbon monoxide gas, and the liquid lava penetrated cracks and pockets under the soil, where mixtures of gas and air were ignited. In some places hundreds of feet from the lava front, bluish flaming gases of charred grass roots, shot up through sandy hollows. The explosions disrupted old rock surfaces, and made cannon-like detonations. December 24, smoke and glow at the saddle between Mauna Loa and Mauna Kea were plainly visible from Hilo. The aa flowed more slowly. December 25, a tongue of the front reached Puu Oo ranch, reaching the wall at 11 am; it had been wholly within the Parker Ranch. December 26, the front increased its speed locally to 800 feet per hour. The average progress was one mile per day on a grade 157 feet to the mile, steeper to the east. At this rate, the flow would have been in the Kaumana road of Hilo on January 9. The widest parts of the flow reached a breadth of 2000 feet, where there was a spreading out on flat places.

The volcanologist recommended bombing the source at elevation 8500 feet on Mauna Loa, to break up the stability of the flow tunnels, and to divert the flowing at the source region. This was done by U. S. Army bombing planes December 27, after the officers were shown the target, from the air. Six tons of T.N.T. explosive were detonated about the vent and channel. Fresh incandescent streaming there was seen December 28, and dusty aa flows in motion immediately below on the mountain slope were detected December 29 and later. At the front fifteen miles away down the lava stream, 33 hours after the bombing, the front stopped moving for a half-day in Puu Oo ranch. Apparently the violent release of lava, of gas and of hydrostatic pressure, at the source, robbed the lower flow of its substance, and of its heat.

At the lower front there was only side and frontal spilling of viscous channel lava thereafter. The total forward motion December 28 was approximately 1000 feet, and December 29, 500 feet. In the pooled pahoehoe lava of the divide at Humuula, fresh puddles of glistening slag welled up through cracks. The night following the bombing, the glow of the middle lava channels had been very brilliant, probably occasioned by drainage of the tunnels and over flowing of clogged canals.

At Halemaumau pit of Kilauea volcano conditions have been unusually and increasingly quiet. There were small slides at the east and north walls of the pit 9:58 am and 10:03 am December 26, at the northeast wall 9:45 am December 27, and at the north wall 10:23 am December 28, during inspections.

Measurement of the 32 rim crack localities around Halemaumau, for the week ended December 28, showed that 6 had opened and 7 had closed, resulting in aggregate opening of 1.0 mm.

H. H. Waesche, Assistant Geologist, reports as follows for the seismographs at Kilauea crater:—

For the week ending December 22, there were 21 local seismic disturbances, of which 18 were tremors, and 3 were very feeble earthquakes. The latter were at 12:13 am December 18, distance of origin 11 miles, 2:52 pm December 22, distance undetermined, and 6:35 pm December 22, distance 1.6 miles, Seismic Index was 6:00, microseismic motion was strong, and tilting of the ground at the Observatory was moderate SW by W.

For the week ending December 29, there were 17 local seismic disturbances, all tremors. At 4:31 pm December 27, a distant earthquake began recording, distance not evident. Weekly local seismic index was 4.25. Microseismic motion was strong. Tilting was moderate W by N.

JOURNAL MAUNA LOA ERUPTION DECEMBER, 1935

December 1

At 4:30 pm Mauna Loa showed three very slight puffs at rift source as seen from Observatory; Humuula reports glow of flow and aa progress still strong, but only smoke was seen at rift cone where glow has ceased. The flow was pushing its front NNW about a half-mile per day toward the 1843 pahoehoe.



FIGURE 4. December 21. Pahoehoe advancing through forest land and forming tree-molds by solidifying around the tree-trunks which are then burned away—leaving perfect casts of themselves in the rock.
—Photo by Maehara.

December 2

Strong white cauliflowers of fume rose at the rift source, and rumbling was heard there. The front of the Humuula Flow and its medial river were very bright and reported moving 150 feet per hour with the front migrating westward from its position of November 29.

December 3

At the resthouse on Puu Ulaula, elevation 10,000 feet NE side of Mauna Loa, a rushing noise could be heard underground along with rumbling in the direction of the 1935 fissure. The flow was reported to be overlapping the eastern belt of 1843 pahoehoe. It was said to be two miles nearer Humuula than on November 29. From eastern parts of the island, the bright glow had shifted from the source region to the flow region, so that from Kilauea and Hilo it stood as a broad band of light on the clouds, back of the lower northeastern Mauna Loa slope.

December 5

Two or three new lobes were moving west from the flow and the front progressed rapidly along the 1843 Flow overlapping the middle aa of that year. Seen from the air, the smoking source region of the flow, at elevation 8500 feet, appeared to be streams emerging from under the crust of an older flow.

December 6

The conspicuous feature of this day was the bright glow at night over the flow region, while the fume at the upper rift cone rose in great volume with ginger-red color and dense volutes.

December 7

The brightness of the Humuula Flow was occasioned in part by the development of floods of pahoehoe lava moving down the medial river channels of the main aa stream. When this happened, the front of the aa moving north, had spread into a wide delta about 2 miles south of the Omaokoili Hills, and its lateral spreading had checked its forward motion. It is probable that at this time side streams were making out from the source heap. The glow from the aa river was bright this evening, showing that fresh lava was still coming down, but small flows were issuing from the sides of the main aa flow. Glow was still seen occasionally at the upper rift conelet.

December 8

The source heap of the Humuula Flow was now developing pahoehoe lava veneering over its upper slopes and spreading down the big aa channel that led to the front.

December 9

The upper rift cone had now settled down to steady ejection of sulphurous fume clouds. The aa front of the Humuula Flow was three-quarters of a mile from the foot of Mauna Kea. From Humuula, the big flow was seen to be fed by a bright meandering river zig-zagging down the mountain, with its wide front west of the position of November 29, and 1.9 miles farther north. The front lay in the 1843 aa. About 8:00 pm the main feeding river began spilling pahoehoe lava at a position on the west side of the front; this was very brilliant, in contrast to the somber red of the aa river.

December 10

A visit to the front this day discovered a field of shallow slabby pahoehoe of thick porridge-like consistency, moving along the aa front eastward to within 200 yards of where that front lay on the eastern marginal strip of 1843 pahoehoe. The 1935 aa made occasional cavings along its front and showed red glow in cracks. Its wall was 20 feet high. The pahoehoe was spreading out vigorously on the 1843 aa, but it did not quite reach the eastern band of 1843 pahoehoe. Many pasty toes of lava were progressing, perhaps one-quarter mile per day as a whole, and the entire front was about one-half mile wide in an EW direction. The surface of the aa fields sloped down to where the river of pahoehoe swept in a curve from the west side of the front. This river then spread out eastward at the base of the aa wall. There was thus a narrow pahoehoe delta about 5 feet high, in front of the much higher and wider aa delta. The feeding river af pahoehoe coursed down the west side of the upper aa fields.

Looking from the summit of Puu Huluhulu at 3:00 pm the summit rift conelets of 1935 were seen to have their greatest development at the upper end where heavy fume rose in four jets. Farther to the left (NE) were three other faint vapor jets among small cones. On the mountain slope below were the floods of lava of November, with islands of old light-colored lavas amid the new dark streams. At the source of the active flow, in the direction of Pukauahi two-thirds of the way up the mountain, could be seen a line of blue smokes from separate vents trending apparently NNW, and the belt of aa streams meandered from that point, towards Humuula in three stretches, respectively, NNW, NNE, and NNW with bends between. The whole field at this time was mostly aa except for some silvery gleam of pahoehoe in the source region, and below, where a narrow band of the frontal pahoehoe made a fourth meander stretched eastward. Portions of the dull red river that occupied the main channel were visible in places where the bends of the channel made the gorge visible to an observer at the north. There were several places where aa was

in motion at tumbling fronts, which may be described as moving lobes at the meander elbows, particularly on the east side of the flow as seen from this position. These places sent up dust and also made some smoke, probably due to burning vegetation. They represented the eastern corners of successive deltas of aa which overlap in plan from SE to NW from about elevation 7,200 feet on the mountain. The second of these aa fronts made a huge wall more than 50 feet high and this was caving and making dust.

The process of the interior progress of an aa delta is exhibited by some of the vertical airplane photographs. These show wide medial streams and frontal outlines in plan like a feather to which the stream is the quill. On flat ground, these streams thicken, pile up, show transverse wrinkling and distinct marginal lobes are formed in plan, and slump terraces are developed at the front of the lobes. A large lobate feather of this kind may have a plexus of streams down the middle with wrinkled surfaces and a large number of delta lobes, like separate leaves. These recall the miniature deltas formed on low tide flats by rills. The pahoehoe pattern is altogether different, a delicate tracery like frost on a windowpane, with a tendency to overlapping "lobster claws" from uphill downward.

As a whole, it appeared that the pahoehoe was pushing its way down the mountain on the west side of the series of aa deltas. It was clear that at this time a very critical change had occurred, just as in 1843 the pahoehoe lava had come later than the aa, and poured down the mountain over the middle of it on the upper steep slope, and at the sides of the aa field below.

December 11

The new pahoehoe front of the Humuula Flow became quiet and relatively stationary. There was much river action in the upper parts of the flow and dusty aa was seen in motion. A series of panchromatic photographs was taken with color filters, of the flow, from the lower Omaokoili Hills. These pictures show how inconspicuous the pahoehoe was at this time in comparison to what it became later.

From Kilauea and Hilo smoke was seen at the rift cones and glow above the lava flow area.

An investigation of the location of the first two 1935 lava flows of November 21-24, obtained by questioning observers living at Humuula station makes it seem probable that this pair of flows lay on the west side of the present Humuula Flow. The easternmost of the two is overlapped by the western meanders of the present flow. On November 23, this eastern aa of the first pair may have come down the general line of the 1843 source well to the west of the smoking source streams of November 27-28. Numerous photographs taken from Humuula at this time suggest this arrangement. The observer at Humuula noted a very definite development at this last place on November 27 and sketched it as making new smoke where smoke had not been seen before. This new smoke was noted by both Mr. Wingate and Mr. Jaggar, on their arrival at Humuula November 28, after previous visits.

December 12

From Kilauea four fume columns appeared above the upper rift and no glow was seen at night. At Humuula there was revival of the pahoehoe front.

December 13

The glow and fume continued at the Humuula source and lava channel, the progress of the pahoehoe front was comparatively quiet, and an earthquake was felt at Kilauea.

December 14

The upper slopes along the course of the Humuula Flow showed glowing areas more scattered than before, suggesting pahoehoe flow over the western side of the heap. The pahoehoe front was glowing but not progressing. Smoke continued at both the rift source and the flow source and glow was reported but doubtful at the rift source. Another earthquake was felt, originating at the Mauna Loa sources. Seen from Kilauea, dense fume arose at the upper rift source in the afternoon.

December 15

The glowing stream of the channel of the Humuula Flow appeared bigger to observers at the ranch and the pahoehoe front was motionless. A new aa flow or branch in the middle of the flow region was reported to be moving on top of earlier aa flows in the direction of the upper 1843 aa westward from the middle stream of the Humuula Flow.

This may have meant that some of the new pahoehoe developing in the upper reaches of the flow had spilled over sideways and speeded up so as to be stirred into making aa. This would account for the lack of progress at the extreme front.

December 16

At this time, glow as seen from Kilauea appeared back of the lower part of the northern Mauna Loa profile. Wingate at Humuula reported revival of the pahoehoe front from the eastern side of the front of December 10 and progressing over the old aa between the 1843 Flow and Humuula station.

December 17

The pahoehoe front was reported to be 200 feet wide, proceeding toward the high stone wall of the sheep pasture, which extends west from Puu Huluhulu. The source of the flow was reported to be smoking, fiery, and the stream channels active. Wingate estimated the smoke source of the Humuula Flow to be at elevation 8,500 feet. From Kilauea at 5:00 pm the rift source showed a dense ginger-colored cloud rising with seven stems, a mushroom shape above and standing 2,000 feet above the rift.

December 18

On this day rangers Murray and Waesche explored the region immediately NW of Puu Ulaula resthouse for about 3 miles. From the large cone there at elevation 10,126 feet which is in line of the curved rift believed to extend northward to the flank outlet, which forms the source of the Humuula Flow, Waesche reported that the lava flows of November 21-22 were a considerable distance to the west. From that cone the smoking flank source heap of the Humuula Flow appeared very far away to the north over interminable fields of old aa. This observation is of great interest, in that it indicates the upper lava flows chose a path mostly west of the 1843 source.

One mile west of this old red cone, Waesche reports reaching the east side of an aa flow, probably 1935. From the top of it a ridge cut off his view westward. The only pahoehoe seen was up the mountain. The aa on December 19 was cold and quite accessible.

Comparing these facts with the data in the Army and Navy airplane photographs of November 22, it appears certain that the smoking source on the mountain flank, elevation 8,500 feet, of the Humuula Flow, was not in the track of the floods of lava of November 21-22 which made the two long streams in the direction of Puu Koli.

On the night of December 17-18, the glow over the Mauna Loa profile seen from the east appeared farther up the mountain than before and dense brown fume rose high in calm air from the upper rift source.

December 19

The flow was brilliant, the upper rift source fume was dense, and there was strong pahoehoe advance NE 1,800 feet over the old aa in the saddle between Mauna Loa and Mauna Kea to within a half-mile of the stone wall. The pahoehoe front was about a quarter-mile wide, spreading out in a sheet east of the 1843 Flow. The progress of the front changed for a time from spreading eastward to spreading westward. The wall of aa behind the pahoehoe and around the front of which the pahoehoe had executed an encircling movement from west to east between December 13 and December 19, was in motion, dropping rocks over its front with clinking noises. New appearance of pahoehoe lava was reported higher up the aa flow near the front of November 29 on the east side of the flow belt. A heavy pall of smoke 2 to 3 miles wide was rising in the evening at the upper rift cones. Soldiers visiting that region reported that they could not approach the cones because of irrespirable sulphur fume. The fume in the upper atmosphere made milky cirrus clouds. This intense development of sulphurous fume from the pit where the summit fountains had been, was entirely different from December 1914, and from December 1933, when the fountaining persisted at the upper vents until the end of the eruption. In 1935, the fountaining was far down inside the shaft and this concealed pit was acting as a

reservoir to the flank flow, just as Halemaumau had acted as a reservoir to the Kau Desert flow of 1920.

An unconfirmed report from one observer in Hilo mentioned two glow points seen from there at the upper rift the evening of December 18, which were called "fountains."

December 20

It was now evident that an extremely critical advance of the flow was in progress. The topographic map showed that the ground of the saddle under Humuula station slopes eastward towards Hilo. The solstice was producing sudden and rapid increase of lava pressure.

At markers placed at the front 8:00 pm December 19, the flow had moved northward 400 feet at 6:30 am December 20. On this day with a spurt forward, the liquid lava overflowed a half-mile of the stone wall, and the eastern side of the front was within one-quarter mile of Puu Huluhulu.

At 4:00 pm a visit was made to the pahoehoe front of the flow at the stone wall. The lava was pouring over it and into the hollows of old aa. It appeared to be a normal heavy pahoehoe, progressing toward the trees and grassy land at the base of Mauna Kea, and at this time approximately a third of the stone wall was being overwhelmed at elevation 6,575 feet above sea level. This stone wall extends 1.8 miles between Puu Huluhulu and the southernmost of the Omaokoili Hills. The middle and eastern portions of the wall were gradually covered. The wall was a massive structure of carefully piled lava slabs, about 3 feet thick and 6 feet high. The flow piled against it on the southern side, usually without knocking it down, until cascades of lava overtopped the wall and filled the space on the northern side. These cascades then fed flows which united in a pool on the northern side. All these pools merged and advanced toward the vegetation in the saddle. This vegetation was at the edge of a former flow from Mauna Loa consisting of both aa and pahoehoe, with large craggy domes, gorges, and forest trees north of the wall in the western part of the area, while towards Puu Huluhulu at the edge of the old lava there were open fields. All of this tract was destined to be invaded by the new pahoehoe, which cascaded into the chasms and burnt the forest at the west, and spread over the grassy lands at the east.

December 21

The development of pahoehoe had been very rapid over the source heap and the upper parts of the flow during the preceding week. The flow as seen from the Mauna Kea slope was now silvery pahoehoe on top in four large meanders, which sent out two tongues to the west over the 1843 aa. This silvery surface, reflecting the light from the sky, was in marked contrast to the earlier condition when the Mauna Loa slope was photographed December 11 and all the aa fields were dead and lusterless, of dark reddish-brown color, the only glossy pahoehoe being at the source, and on the crust of the main stream.

There was now a liquid sea of this silvery lava which had spread over a large area of the ancient aa fields immediately below Humuula station. This big lake on this day expended its energies of forward progress by penetrating the fields and low rocky hills and burning the vegetation WNW of Puu Huluhulu for a width of front of three-quarters of a mile, with its eastern limit about one-quarter of a mile from Puu Huluhulu. Estimates of progress at different lobes of the front showed the glowing paste progressing in one place 10 feet in 10 minutes, in another place 20 feet in 15 minutes, these meaning forward movement of from 60 to 80 feet per hour. The flow as a whole moved more slowly, but in detail there were places that were swift cascades, where the new fill overtopped ancient obstructions and rushed forward.

Some of the energy of the flood at this time was being expended in spreading out a mile or so south of the saddle in the region SSW of Puu Huluhulu among ancient flows which were almost horizontal. Individual tongues actually flowed backward or to the south in this country, at the southern edges of the lake of lava, and there was backing up of the lake also to the west as far as the slope would permit. The 1843 Flow, however, obstructed the new lava in that direction, where the older flow had partially encircled the wooded hill there which is 6,823 feet above sea level. Th backing of the lake soon reached its limit, and the greater stream which was pressing forward around the earlier aa front from the west pushed eastward into the saddle between Puu Huluhulu Mauna Kea where it found a pronounced valley leading down in the Hilo direction. Another stream from the SE tongues of the lake area found a similar grade eventually on the south side of Puu Huluhulu, that led it cascading NE into the same valley.

On this day another photographic panorama was made to show the contrast in the gleaming smooth-topped flow up to the source from the conditions of December 11.

A development which always accompanies the invasion of vegetation by pahoehoe lava, where the old ground under the root system is cavernous, was the exploding and flaming of carbon gases, supplied with oxygen of the air in the region adjacent to the front. The explosions became numerous and noisy, and in many places blocks of rock were flung up in heaps where mixtures of carbon monoxide and air were ignited in ancient lava caverns by flames or by penetrating tongues of melt. Another phenomenon, more unusual, was the presence of burning gases making wandering blue flames, or banners of yellow flames, in sand pockets sometimes 50 to 100 feet away from the lava front, in a grassy pasture. Apparently the carbon gas was generated by charring of the deep sod. This penetrated cavernous spaces or cracks under the field, and remained sufficiently free from contamination by air to escape and burn without explosion. Such flames were later seen burning in the hollows of the new lava, where it overlay masses of carbonized vegetation.

The lake area of the flow had a depth of 7 to 10 feet, was moderately flat on top, and the stretch of stone wall left its mark as a straight line through these portions of the flow where the wall was covered. This was due to some molding effect where the cascades over the wall left a scar on the final lava field.

December 22

The flow passed between Puu Huluhulu and Mauna Kea, found a steeper slope and progressed eastward more than a mile with a front 200 feet wide and tended by reason of slope and stirring to develop internal crystallization and so to change to aa or clinker lava. The progress, which had been of the order of one-quarter mile per day on the flat land, now suddenly changed to more than one mile a day, and this started draining the large lake which had accummulated in the Humuula saddle. The speed of progress was augmented when the second stream on the south side of the Huluhulu Hill joined the main east-flowing river of slag.

The Mechanism of Aa and Pahoehoe Lavas

There were now three distinct centers of activity requiring attention, in order to understand the Mauna Loa Flow. There was the smoking rift crack about elevation 11,500 feet, beneath which the internal lava was boiling in a pit. There was the source vent on the north flank of Mauna Loa, whence the Humuula Lava Flow poured down to the saddle between Mauna Loa and Mauna Kea. This flow source was 6 miles north of the upper rift and its smoke shaft. The third active area was the new drainage from Huluhulu Hill to the front of the lava flow, a steadily progressing mass of clinkery paste covered with huge bowlders, and fed by glowing torrents of slaggy melt which tended to crust itself over from the source downward to the broken dam at the Humuula lava lake. This melt was essentially a foam impelled both by gravity and by hot gas expanding within it. The tunnel system created by its crust made a pipe leading from elevation 8,500 feet down the slope of Mauna Loa to elevation 6,500 feet. Here the pipe bent sharply eastward at a right angle, and vomited out its content in an open river. Down to this point, the froth stream secreted a glassy skin over itself as a roof; this is pahoehoe lava.

Such a torrent in a tunnel, makes an adjusted pressure system connected with the foam column in the shaft, inside the mountain. The open pit at the top of this shaft sends up sulphur smoke and other gases, from the summit rift craterlet, which had been fountaining with the hot froth at the beginning of the eruption. The froth had lowered in the vent, and was now fountaining internally.

This statement exhibits the relationship of the upper vent to the lower flow vent. When the pahoehoe stage is reached, the adjusted pressure system above referred to, means an equilibrium of gas-heated foam holding a certain level in the shaft, and flowing foam in the pipe system which pours down the crusted-over river under both hydrostatic pressure and gas-pressure. A man with hob-nailed boots might possibly have walked eight

miles on top of the pahoehoe stream from the flow vent to Humuula and avoided any liquid. The main lava river was flowing in a tunnel.

This arrangement is closely similar to the overflow of an uncorked champagne bottle if one imagines a small pipe leading from the neck of the bottle and the uncorking controlled by a stop-cock instead of a cork. The foam might then be allowed to rise in the neck and overflow through the pipe, while the liquid being converted into foam always remained below the neck. So the magma in the mountain is the liquid below the foam with gases escaping from solution. The foam we call lava is frothing molten glass. It differs from champagne in that the gases react chemically to release heat and make the foam more fluent than the mother-liquid below, and in that it solidifies in cold air.

When the flow gathered speed down the valley east of Humuula station, by reason of suddenly breaking the dam beside Huluhulu Hill, the liquid under the crust, of the lake area, rushed out into the open and down the slope with a rapidity which stirred it into the "sugaring" condition, known as aa lava. There was at this point a sudden quasi-new eruption; a quasi-new vent broke out so to speak, from under a sensitively adjusted cover to a steeper slope beyond. The flow down this slope towards Hilo was thus a third repetition, on a small scale of the breaking out of November 21 from under the heavy ancient cover we call Mauna Loa Volcano, and of the second on November 27 from the flow source crack in the mountain flank. As in that case, the new gushing made skins over itself (pahoehoe) just below its point of escape at Huluhulu Hill, but below that it crystallized into clinker, with a dark-red river in the middle, and would make no more glassy skin over itself, until a new adjustment was reached by pooling in some hollow below, when the Huluhulu pahoehoe would push down the river and overtake the aa with a skin.

The process by which such an adjusted skinning over of a lava with a glassy crust comes about is as follows:—

The gas-charged melt of a vent is stirred and rapidly crystallized both by boiling or effervescing and by rapid flowing. If it rapidly flows with gases rising from within it, it is heated on top by the gases, it is heated within by crystallization, and it is cooled and solidified, chiefly on the bottom, by contact. The hot gases incessantly escape without forming bubbles, and the solidification proceeds from the bottom upward. This solidification is free to take forms of sprouting determined by crystal groupings, and no time is allowed for the separating out on top of a glassy foam. Such glassy foam is formed in enormous quantities near the vent, and makes the basaltic pumices, Pele's hair, Pele's tears, and heavy ropy folds of coarse pahoehoe which is always characteristic of the source region of any flow. A short distance away, the highly stirred crystallizing material pours out from under this tangle of glassy membranes, and the solidifying from there to the lower end of the first streams proceeds by the aa process.

When the gas stirring becomes less, and the rate of flowing becomes slower, whatever may be the causes of the change, glassy bubbles are free to form and rise to the top. These make a layer of many membranes of glass which stretch themselves over the expanding and advancing liquid. When this happens, there is no longer a heating on top by reacting, escaping, and oxidizing gas, and a cooling only at the bottom, with an eternal sprouting upward in a clinker, such as is characteristic of aa; but the cooling proceeds from above downward, and a glassy crust confines the melted stuff within. In this condition we have exactly the same liquid melt inside tending to crystallize, but it fills a pipe. This pipe itself imposes a continuous restraint by pressure, on the escape of gas from solution; and the eternal formation of new glassy membrane over the liquid, pushing out as toes under the skirt of crust at the front, imposes a restraint by pressure on the speed of flow of the liquid. These two restraints enforce a relatively constant adjusted pressure and the vesicular crust now has the effect of a heat and gas insulator and keeps the melt inside from losing too much gas—and gas is its main heating agent—and from radiating heat and so losing its liquidity. By keeping the gas in, it keeps the source of its auto thermic action. All these adjustments bring about the formation of a tunnel system, with liquid lava running through the pipe, and the pipe continually strengthened by layers of glaze added as interior coatings. As the gas does not escape, except through flaming cupolas near the vent, which have fountains inside, the whole system preserves the heat of reaction between the gases, and so a lava tunnel may be at brilliant yellow heat, even when the liquid river inside has lowered somewhat, and through windows is sucking in oxygen to unite with the gases, and also with the glazes, to keep the temperature high.

To return to the Humuula Flow: the transition from the aa stage of the first week of December, to the silvery pahoehoe crust covering the whole course of the flow the third week of December marked a gradual change in these adjustments of internal heating to external cooling. A highly critical point is reached whereby clinker sprouting and solidifying from below, is replaced by vesicular glassy crusting and solidifying from above. In general, the conquest of a flow by pahoehoe crust proceeds from uphill downward along the course of the river channel. In like manner, if the aa lava flow toward Hilo from Humuula station were to reach another pahoehoe adjustment, it would be by the pahoehoe skins and crusts spreading down the channels and mastering the front of the flow as had happened when the Humuula lake was the front.

There are three important corollaries to this heat argument, namely (1) pahoehoe and aa lavas are exactly the same substance. (2) The internal liquid or paste under any pahoehoe crust is quite competent to become aa lava if allowed to flow in the open. (3) The only mechanism which could carry a lava flow 30 to 50 miles on a flat grade is pahoehoe tunnel-making, for that insures retention of heat and liquidity.

A fourth experimental corollary of the pahoehoe argument is this:—

If an artificial disturbance like blasting is applied to the outside of the tunnel system near the vent, after pahoehoe adjustment had been attained, the stream inside under pressure would flow out into the open, without restraint of gas, and without restraint of flow. There would be immediate cooling and solidifying of the remnant material within the tunnel, after what remained liquid in the downhill system of tubes had poured out, and there would be nothing to keep up the supply.

A second possible result of such blasting might be this:—

If the stream suddenly released near the source vent were a foam torrent close to the hydrostatic level of the foam inside the shaft reservoir of the mountain, the gushing might drain the reservoir below that level, the flow would stop, cool, stiffen, back up, and seal the cracks from which it came, and the "small tube in the side of the neck of the bottle" would thereby be shut off. Rising of the foam thereafter in the shaft might pass this level, but newly solidified hot lava is an unbreakable plug. The reservoir shaft would continue its internal fountaining and external puffing of gas, until the gas release and heat radiation which determines the duration of an eruption were ended. Eruption would end, as all eruptions probably end, by an act of viscous intrusion somewhere inside the mountain. The blasting would have accomplished an interruption of the frontal progress of the flow, and also plugging of the flow vent.

December 23

The revived flow east of Humuula station travelled more than a mile turning into an aa stream with aa fields in front and at the sides. There was some slumping of the lava lake around the stone wall. In the evening a brilliant torrent was cascading around the south side of Puu Huluhulu, this joined the main river farther east, the front of which was some 2 miles from this hill. Flames burst through the marginal lava, there were big explosions in old caverns, and the large lake in the saddle was nearly black as seen at night.

The actual time when the flow passed Puu Huluhulu was the morning of December 22. There are now many explosions in old pahoehoe caverns not only at the borders of the pahoehoe near Humuula, but also at the lower aa front as the flow approached the wall which separates the Puu Oo lands, from the Parker Ranch, to which Humuula sheep station belongs.

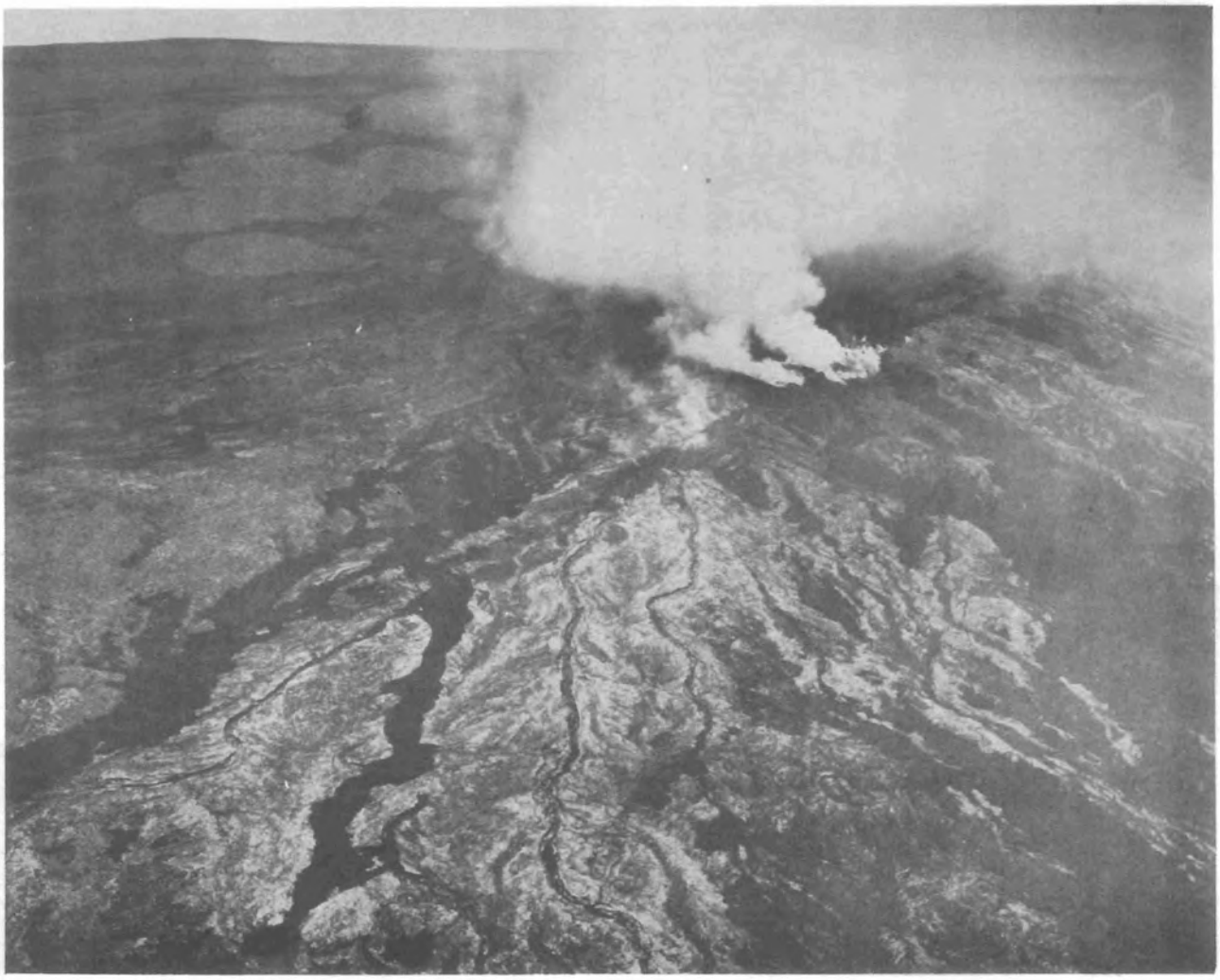
THE VOLCANO LETTER

No. 431—Monthly, Department of the Interior, National Park Service, January, 1936

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JANUARY, 1936



The top crater and well smoking at 12,000 feet.—December 27, 1935.

VOLCANOLOGY

As was anticipated, the operations carried out during the last week of December, 1935, by the bombing of certain selected localities upon the mountain-flank, thus venting the heavily gas-charged lava flowing within roofed tunnels, hastened the conclusion of the Mauna Loa eruption. While the actual bombing took place on December 27 with immediately recognizable results in the form of gushing of aa lava from the channel in the lower flow December 30 to January 2—the forward movement entirely ceased upon the latter date. The most marked features of the period subsequent to the bombing—in addition to the gushing referred to—comprised lateral overflow to northward of the main stream at an elevation of 5,750 feet: and sudden spillings from the medial channel at the front itself. These ranged in width from 50 to 200 feet—and pushed forward at speeds varying between 75 and 1400 feet per hour. The last forward movement ceased during the early morning of January 2 at Long. 155° 21′ west: Lat. 19° 42′ north, at a point 600 feet inside the Forest Reservation Fence. At this spot, a finger of pahoehoe, 50 feet wide, pushed slowly forward and then ceased to move. The great Mauna Loa lava flow had definitely ended.

It cannot be claimed, however, that the eruption has come to a close. During the entire month there has been continued emission of smoke and fume at the rift cone northeast of the summit crater at the 12,000 foot level. As long as this continues there is, undoubtedly, moving lava within deep cracks and the mountain is still in actual eruption.

Routine observation reports of this section during the month were as follows:

January 3 to 5. Fume with vapor at the cone which was heavily encrusted with sulphur. Fume and smoke rising from the cooling flows in various places.

January 10 to 11. A wide band of brown fume-changing on January 11 to a thin, upright column.

January 14. Faint fume visible from Observatory, and again on January 17, rising in a thin dark column in definite puffs, brown in color. Marked increase in fume density on January 18.

January 19. A report from a party of five observers visiting the cone on this date, stated: "Glassy black Pele's tears (droplets of lava spatter) were found on the ground near the trail. The conelet was climbed at the S end of the new crater in the large lava hill. Dark smoke puffed up from the shaft at the bottom of the crater with a purring noise, and spells of greatly increased pressure occurred, when it came with a roar. When the wind veered, the sulphur gas was unbearable. Within the cone there was yellow sulphur and greenish coatings. On the outer flanks the sulphur was brilliantly yellow, especially at the S. The outer lava was warm and brittle."

January 26. Fume from the upper rift continues unabated, making a brown cloud—and hangs in the upper atmosphere in thin wisps of bluish-white color.

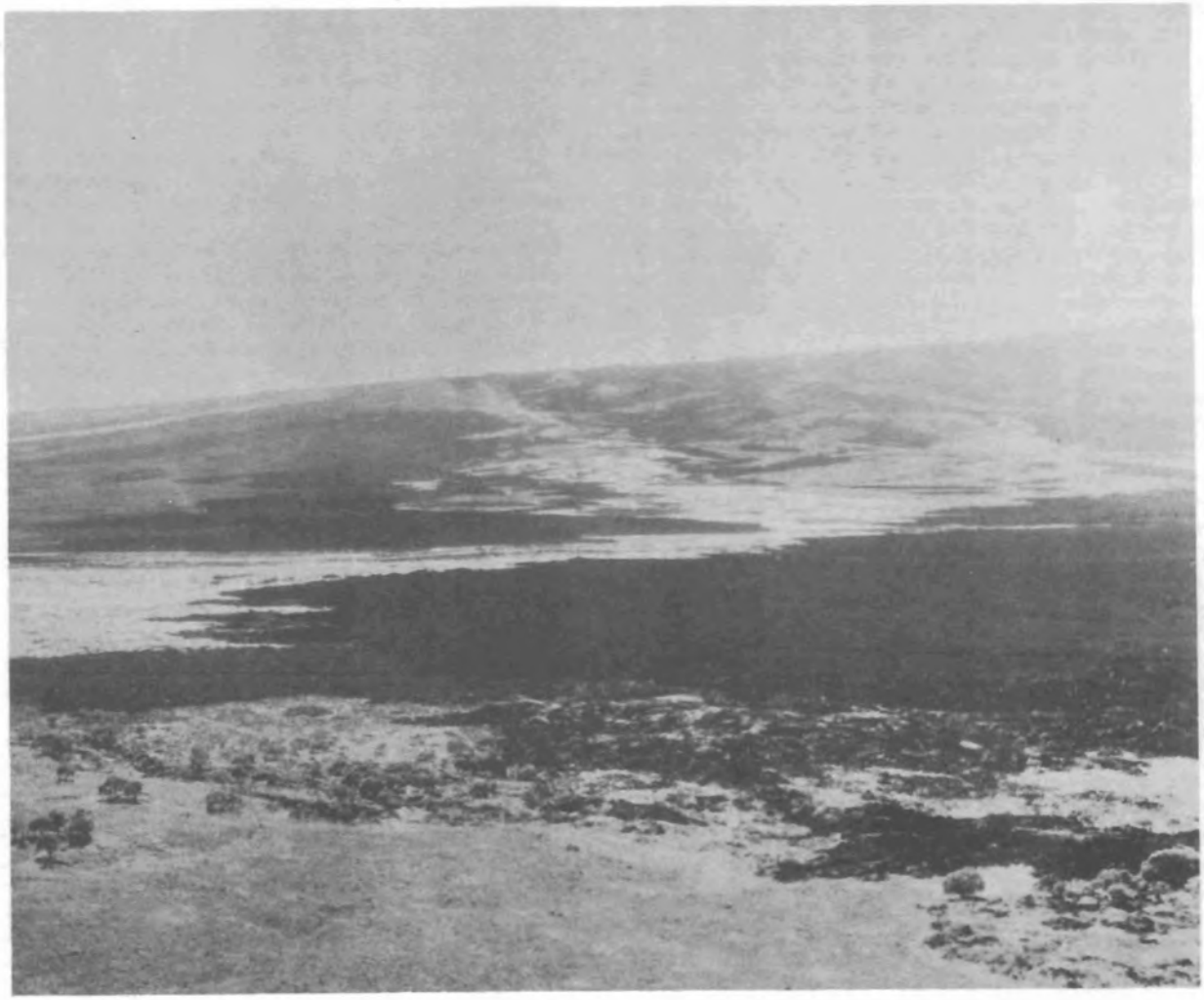
January 30. The Mauna Loa activity is not yet finished. The rift cone continues to send up jets of sulphur fume showing bluish under overhanging clouds. The mountain above 9,700 feet is heavily covered with snow.

KILAUEA OBSERVATIONS

Halemaumau on January 1 showed no sign of fresh slides. Blue fume rose at the yellow solfatara NW. On January 2 and 4 slope gravel was in motion WNW and at the north wall. Unusually dense fume was rising on January 7 at 3:30 pm and avalanche dust was observed on January 9. A slide occurred at the west wall at 9:32 am January 16 and fume from the SE edge of the floor was rising on January 18. In calm weather on January 21, blue fume, mostly from the yellow solfatara NW, filled the pit, producing an odor of spicy sulphur. With a moderate NE wind on January 24-25 the fume was inconspicuous. Earlier west wall sliding, 10 am January 30, developed into a large slide at 11:05 am—followed by another at 11:25 am between the northwest talus and the yellow solfatara. At noon on this date there was an eastern slide and freshly fallen rocks thereafter lay upon the southeast floor.



The lava stream is seen flowing diagonally at upper right.—Dec. 28, 1935.



The target source on the mountain slope.—December 29, 1935

Crack Measurements

Measurements of the 32 places marked on concentric cracks around Halemaumau, resulted as follows:

Week ending January 4. 11 opened. 3 closed. Aggregate opening for the week 9.5 mm.

Week ending January 11. 15 opened. None closed. Aggregate opening for week, 13.5 mm.

Week ending January 18. 7 opened. 6 closed. Aggregate opening for week 6.0 mm.

Week ending January 25. 11 opened. 1 closed. Aggregate opening for week 11.5 mm.

Week ending February 1. 7 opened. 4 closed. Aggregate opening for week 6.0 mm.

Seismic Observations

During the month of December, there was a total of 196 minutes of tremor and 15 earthquakes were recorded. Of these latter, ten were very feeble, two were feeble, one was slight and two were distant. Local seismicity was 14.5.

The epicenters of local earthquakes were determined as follows:

December 2, at 7:55 am, very feeble, located 13 miles W of the Volcano Observatory and 6 miles S of Puu Ulaula, 19° 26.8′ N; 155° 28.0′ W.

December 4, at 9:14 pm, feeble, located 1.1 miles deep under Kilauea Crater 0.4 mile E of Pit seismograph station, 19° 24.4′ N; 155° 16.7′ W.

December 10, at 6:19 pm, very feeble, probable location under Kilauea SW rift 14 miles SW of Pit seismograph station.

December 13, at 9:31 am, very feeble, located 1.6 miles deep and 0.4 mile E of Pit seismograph station. 19° 24.3′N; 155° 16.7′ W.

Seismic Observations

During the month of January, 138 seisms were recorded of which, 111 were tremors and 27 were very feeble earthquakes.

The very feeble shocks were:

Dec. 30	1.04 am	Estimated distance	12	miles
Jan. 2	2.47 pm	" S	25	"
Jan. 3	7.34 am	" "	Uncertain	
Jan. 3	9.41 am	" "	20	miles
Jan. 4	11.44 am	" "	14	"
Jan. 5	10.27 am	" "	2	"
Jan. 6	6.00 am	" "	2	"
Jan. 7	8.06 am	" "	2	"
Jan. 7	11.08 am	" "	2	"
Jan. 8	4.32 am	" "	25	"
Jan. 11	2.14 pm	" "	2	"
Jan. 12	7.54 pm	" "	20	"
Jan. 15	9.59 pm	" "	2	"
Jan. 16	10.15 am	" "	6	"
Jan. 16	1.14 pm	" "	3.5	"
Jan. 16	11.43 pm	" "	2.4	"
Jan. 17	1.11 pm	" "	49	"
Jan. 18	1.45 am	" "	62	"
Jan. 19	11.31 pm	" "	24	"
Jan. 22	5.27 pm	" "	20	"
Jan. 23	5.15 pm	" "	2.7	"

An analysis of these distances shows that shocks recorded at distances up to six miles from the Observatory were under— or adjacent to Kilauea Crater. All others, with the exception of those on January 17-18, being Mauna Loa earthquakes. The increase in recorded shocks from Mauna Loa during the week ending January 5 is indicative of increased friction within the mountain as the internal lava became blocked. Mauna Loa distances for the 1935 vents approximate 19 miles. It is noteworthy that no larger shocks occurred during the month to point to the sealing of the rift and the end of the eruption. Local seismic indices (1), microseismic motion (2), and tilting of the ground at the Observatory for the month (3) were

Week ending	(1)	(2)	(3)
Jan. 5	7.75	Strong	Slight SW
Jan. 12	8.75	Moderate	Moderate E
Jan. 19	7.50	Strong to Moderate	Slight SE
Jan. 26	10.00	Moderate to Light	Slight SW
Feb. 2	7.25	Light to Strong	Slight WNW

The increase of microseismic motion during the week ending February 2 was coincident with marked barometric depression and unusual cyclonic storm.

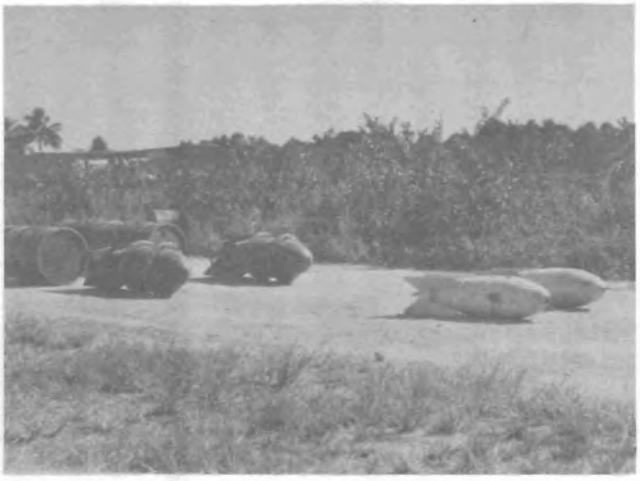
THE BOMBING OPERATION AT MAUNA LOA

A brief account of the actual bombing operation—an event that has aroused widespread interest in many parts of the world, will be of interest here. As was stated in the December issue of the Volcano Letter, there was nothing in the earlier phases of the flowing of Mauna Loa lavas to cause apprehension of damage other than to certain sections of pasture lands belonging to ranches situated at relatively high altitudes. Much of the elevated terrain at the junction of the slopes of Mauna Loa and Mauna Kea consists of lava covered land, rocky and sterile, intermingled with grassy pasture areas, not of particularly great agricultural value. As long as the flows were confined—in the main—to this area, they would spread slowly across it and would be harmless. This condition was maintained until the solstice on December 21 when a sudden change took place with the commencement of the draining of a large lake which had accumulated in the saddle between the two mountains. Upon the following day, the pahoehoe lava passed Puu Huluhulu and flowed eastward for more than a mile with a front 200 feet wide, tending to change to aa. The front of this flow almost immediately commenced to pour into a pronounced valley leading directly towards Hilo on the sea coast—and it was speedily apparent that a serious crisis might be developing.

It is of value at this point to recall the three distinct centers of activity: (1) the smoking rift crack at elevation 11,500 feet, beneath which the internal lava was boiling in a pit; (2) the source vent on the north flank of the mountain (some 6 miles north of the upper rift crack) from which the Humuula flow was being fed, and (3) the new activity caused by the draining of the Huluhulu lake. This presented an onward moving mass of clinkery paste carrying huge bowlders upon its surface—consistently fed by glowing torrents that tended to crust over and form roofs—thus creating tunnels from the source downwards and forming a pipe leading down the side of the mountain. Through this tunnel, the slaggy melt was moving—impelled both by gravity and by hot gases expanding within it. Even though there might be breaks, or windows in the roofs of such tunnel



Bomb dropped into flowing channel, throwing molten lava high into the air. The picture shows the wide expanse of Pahoehoe lava in foreground.
—Photo by Maehara, December 27, 1935.



TNT bombs, bomb pointers, gasoline for planes.—Photo by Maehara

systems—these would merely act as flues through which oxygen would be sucked—to unite with the gases and maintain the temperature of the flowing mass. It was through such a tunnel as this that the main stream was now advancing at the rate of more than a mile a day travelling upon a down grade of 157 feet to the mile.

It was abundantly obvious that a continuance of this flow would constitute a danger, not only to the sources of Hilo's water supply—but also the city itself. Even discounting the probability of an acceleration of the rate of travel as the flow reached a steeper grade to the eastward, the front would be in the Kaumana road of Hilo by January 9th, and would have an almost unobstructed path down towards the city upon the seashore. When it is remembered that the flow was spreading out upon flat places to a breadth of 2000 feet it will be seen that the situation had become serious and presented a marked change from the conditions prevailing prior to December 21. It must be remembered also that there were other indications of danger other than those more apparent upon the surface. The structure of the mountain itself beneath the upper layer of surface rock, particularly under the lower levels, is honeycombed with tunnels and tubes of earlier lava flows. That the lava was making its way under the ground through such passages, was evident from the cannon-like detonations that were constantly occurring—hundreds of feet in advance of the main flow. These were due to the penetration of live lava into such tunnels, igniting mixtures of gas and air and shattering the old rock surface.

Under such conditions therefore, it had become imperative to take action, and the volcanologist sought assistance from the United States Army with a view to bombing the source at the 8500 foot level, and by thus breaking up the stability of the flow tunnels to spread and divert the flowing throughout this region.

On December 23, the matter was taken up through Major Hugh Gilchrist, Commander of the Kilauea Military Camp—and an urgent appeal was forwarded by airplane to Colonel Daniel Van Voorhis, Department Chief of Staff at Fort Shafter in Honolulu. The response was immediate. Upon the same day, an army amphibian, carrying a pilot, an engineering officer and a bombing officer was dispatched from headquarters under orders to fly over the area and to report upon return to Colonel Delos C. Emmons, Department Air Officer, upon December 24. Colonel Emmons accompanied by Lieut. Col. Virgil L. Peterson, Commander of the 3rd Engineers flew over the lava flows—and the U.S.A.T. Royal C. Frank was ordered to proceed immediately to Hilo with a supply of 600 lb. TNT high-explosive bombs. It had been decided that the occasion was of considerable urgency and that all possible cooperation should be accorded by the Army. Several reconnaissance flights were made upon this day—accompanied by the volcanologist—the course of the various flows was carefully mapped and a large number of vertical photographs taken in order that the targets might be indicated in the precise localities where bombing would be likely to be of the greatest value. The general situation at this time was that the main easterly flow was twenty miles in length with its front within five miles of the Hilo water supply—and only fifteen miles from the city itself. If it followed the natural contour of the ground it would undoubtedly reach Hilo.

Fourteen army planes arrived from Honolulu during the day and all arrangements were made for the operation, twenty officers and twenty-seven enlisted men being detailed to carry out the details involved. The ships were ten bombardment aircraft, two amphibians and two observation planes. Officer personnel comprised Lt. Col. Duncan, Maj. Lucas V. Bean, Maj. Roscoe C. Winston; Capts. Maurice C. Bisson, Joseph J. Ladd, Lewis R. Parker, Clarence P. Kane, Ford J. Lauer, Charles F. Born, Walter A. Fernander; 1st. Lieuts. Byram A. Bunch, William C. Beard, Charles E. Fisher, William C. Capp, David N. Crickette, Dale E. Altman, N. F. Coddington, Christian H. Clark; 2nd Lieuts. John C. Armstrong and Travis Hatherington. To these gentlemen fell the honor of being participants in the first experiment of its kind in the history of science.

It was decided by Col. Emmons that, owing to their dangerous cargo, the planes would not fly over Hilo, but would head out to sea until the proper altitude had been reached—and then circle in towards the mountain, passing over the sparsely populated Puna section on their way to the saddle land. Arrived over their targets and from a position at least three thousand feet above them—the bombs would be dropped. Arrangements were made for the posting of guards to divert traffic and spectators were warned to keep away from the vicinity. All was now in readiness and, favored by magnificently clear weather, the planes took off early on the morning of December 27. Taking off from the Hilo airport at intervals of ten minutes, seven Keystone bombers were employed, each carrying a pair of 600 lb. TNT bombs and two 300 lb. sighting bombs. The volcanologist, from his chosen post of observation upon Puu Oo Hill, had an uninterrupted view of the entire operation which was spectacular and impressive. Amid the thunder of shattering explosions, masses of rock and sheets of glowing lava were hurled in all directions, many of the great bombs, dropped from planes travelling at high speed, plunging directly into open channels through which molten lava was flowing, while others crashed upon the roofs of tunnels, blowing them open and releasing the melt imprisoned within, causing it to gush upwards and commence spreading immediately.



The Puu Oo flow moving 800 feet an hour.
—Photo by H. Shipman, December 25, 1935.

From the airport, at which interested crowds had gathered, the roar of the explosions could not be heard, but gigantic columns of black smoke, rising one after the other, were clearly seen, the great plumes drifting steadily off upon the prevailing trade-wind. The undertaking was continued until six tons of bombs had been dropped—and was entirely successful, the violent release of gas, of lava, and of hydrostatic pressure at the source, robbing the lower flow of its substance and heat. During the following night, there was greatly increased glare as seen from Hilo—this being occasioned by the draining of the tunnels and overflowing of clogged canals.

On December 28, fresh incandescent streaming was observed about the vent and channel. Thirty-three hours after the conclusion of the bombing, the front of the flow, fifteen miles away down the lava stream in Puu Oo ranch, stopped moving entirely for a half-day. At the lower front there was only side and frontal spilling of viscous channel lava and the total forward motion was approximately 1000 feet, dwindling to 500 feet on December 29. In the pooled pahoehoe lava of the divide at Humuula—fresh puddles of glistening slag were observed welling up through cracks. During the next two days there was slight gushing of aa lava from the channel in the lower flow, but by early morning of January 2 all motion at the front had definitely come to an end and the former crisis had ceased to exist.

Thus, terminated the first experiment of its kind in attempting to curb one of the most destructive forces of nature—and thus also was afforded a happy exemplification of the results that may be obtained by the cooperation of one branch of science with another. It is entirely permissible through the medium of this publication, publicly to acknowledge the high appreciation of the extremely courteous and valuable help rendered by the Army Air Service upon this occasion and to express profound admiration of the almost miraculous accuracy with which the task was performed. That it has aroused world-wide interest is gratifying, for it is obvious that further research along similar lines may prove of incalculable value to those who live in active volcano lands and are at all times under the shadow of possible menace.

NATIVE SUPERSTITION

It may not be out of place as a matter of general interest, to comment upon the reaction of the older generation of native Hawaiians to the bombing of Mauna Loa. For countless generations, belief in Pele—the Polynesian goddess of fire, played an important part in the lives of the Hawaiian people.

Legendary lore is filled with stories of the doings of this mythical deity who lived in turn within the craters of the various islands, forsaking them in succession until she finally established her habitat in the depths of Halemaumau, the firepit of Kilauea—and under Mauna Loa. Indubitably, very many of the older natives still cling to their belief that the fiery floods pouring down the mountain are the visible effect of some insult offered to the dangerous goddess, and many are the efforts made upon such occasions to propitiate her in order that her anger may be stayed. The island of Hawaii, upon which these two great active volcanoes are situated, abounds in legends of Pele, and it cannot be gainsaid that many startling rumors of her appearance in human form in various places upon the mountain sides have been closely followed by lava outbreaks, although this has by no means been a natural corollary.

It was certain that many objections would be raised by older Hawaiians to any project of bombing Mauna Loa lava flows. They maintained that the goddess had her own reasons for being out on the mountain in the midst of her fiery torrents, and predicted dire catastrophe if her plans should be hampered by the unbelieving white man. They recalled an ancient legend of Pele and her bitter enemy, Kamapuaa—who, after many centuries of warfare during which the latter fought Pele's fires with water, endeavoring to drown her—came to an agreement under whose terms the goddess agreed never to destroy lands upon the northern side of the Wailuku river which runs through Hilo—if her enemy would undertake to protect the lands on the southern side from floods. Confident that this agreement would be kept—the Hawaiians predicted that any attempt to bomb the flows would anger the goddess who would immediately vent her wrath upon the city and cause widespread destruction. This feeling was widely shared and considerable strength was given to it by the fact



Illustrating the thick, pasty consistency of the Pahoehoe lava flowing through the forest.—Photo by Maehara, December 21, 1935.



The front dead —January 4, 1936.

that the flows did not immediately stop after the bombing operations. On the morning of December 28—considerable native excitement was caused by an aged Hawaiian who declared that he had seen an immense image of the goddess, with bulging eyes and streaming hair hovering over the flow region.

Perhaps the most interesting, and amusing, reaction was the declaration of an aged native, Keala Nuionaahienaena Kaha Kanianikaipo, more familiarly known as Ben Amina, who described how he, personally, had stopped the flow by direct supplication to the goddess. This gentleman claims direct descent from the goddess herself and his story—as told to the Hilo Tribune-Herald on January 8, six days after all movement of the flows had ceased, is well worth quoting.

"It was like this," he said. "I heard from my friends that the Army planes were going to throw bombs on Mauna Loa on December 27th to stop the flow. I shook my head because I knew Pele's life would be endangered by these bombs. I knew she would become angry and seek vengeance upon us. I was ready to do anything to stop this mad experiment, but my family prevented me. The bombing took place but the lava flow still continued. I was feeling desperate because I knew Pele too well. So, on December 31 at 4:30 p.m. I went up the road with four witnesses, Joe Pacheco, John Medeiros, Tony Reach, and William Rocha, all of Hilo, and gave the Hawaiian prayer which would melt Pele's heart. They were with me all the time I prayed to the fire-goddess.

"I faced the mountain and the huge column of smoke, raising my hand and beseeching Pele to hear my prayer. Then I called to her that I was her descendant who wanted to save my friends and the people of the island from this awful fate. I told her she had had a wonderful Christmas on Mauna Loa and that she was now celebrating New Year's Eve in her home of fire. I begged her to stop the flow on New Year's morning—beseeching her 'Pau, pau, pau (stop, stop, stop.) ' "

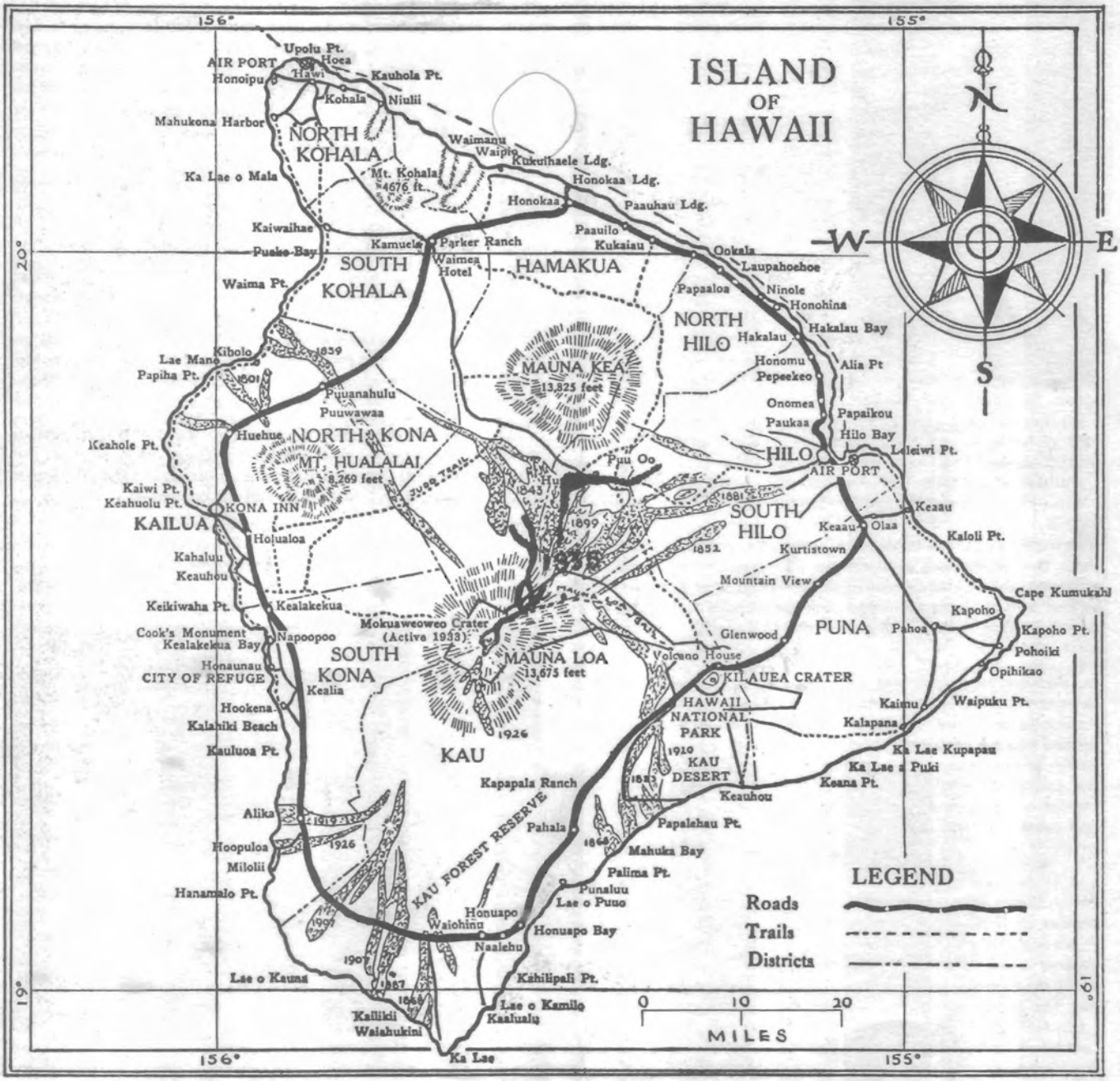
He stated that he sat in front of his home all night, keeping a close watch upon the mountain, and praying to Pele throughout the vigil. "At one o'clock in the morning," he said, "just an hour after the New Year was heralded, the mountain grew dark and no light could be seen. Pele had answered my prayer and I am grateful."

Hilo at large heard the news that the flow had stopped, on New Year's Day. Amid the general feeling of relieved tension, old Ben sat and chuckled, convinced that he was the one who stopped it.

Such beliefs may appear strange to those who are familiar with the development and progressiveness of these islands. But they are founded upon centuries of faith in a vast assemblage of gods and goddesses and they do not die out easily.



The man in foreground points with his stick to a place where an explosion from beneath the ground has disrupted the surface. Such explosions were frequent in advance of the flows; were violent and dangerous.
—Photo by Jaggar, January 4, 1936.


ISLAND
OF
HAWAII
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156°
155°
20°
19°
Upolu Pt.
AIR PORT
Hoea
Honoipu
Hawi
Kauhola Pt.
Kohala
Niulii
Mahukona Harbor
NORTH
KOHALA
Waimanu
Waipio
Kukuihaele Ldg.
Ka Lae o Mala
Mt. Kohala
4676 ft.
Honokaa Ldg.
Honokaa
Paauhau Ldg.
Kaiwaihae
Puako Bay
Kamuela
Parker Ranch
Waimea
Hotel
SOUTH
KOHALA
HAMAKUA
Paauilo
Kukaiau
Ookala
Laupahoehoe
Waima Pt.
Papaaloa
Ninole
Honohina
NORTH
HILO
Hakalau
Hakalau Bay
Kiholo
1859
Lae Mane
Papiha Pt.
1801
MAUNA KEA
13,825 feet
Honomu
Pepeekeo
Alia Pt
Puuanahulu
Puuwawaa
Onomea
Paukaa
Papaikou
Hilo Bay
Keahole Pt.
Huehue
NORTH KONA
MT. HUALALAI
8,269 feet
HILO
Leleiwi Pt.
AIR PORT
Puu Oo
1843
1881
Kaiwi Pt.
Keahuolu Pt.
KONA INN
KAILUA
1899
SOUTH
HILO
Keaau
Olaa
Kaloli Pt.
Holualoa
1852
Kurtistown
Kahaluu
Keauhou
Mountain View
Cape Kumukahi
Keikiwaha Pt.
Kealakekua
Kapoho
Mokuaweoweo Crater
(Active 1933)
Cook's Monument
Kealakekua Bay
Napoopoo
Glenwood
PUNA
Pahoa
Kapoho Pt.
Volcano House
Honaunau
CITY OF REFUGE
SOUTH
KONA
Kealia
MAUNA LOA
13,675 feet
KILAUEA CRATER
Pohoiki
Opihikao
Hookena
Kalahiki Beach
HAWAII
NATIONAL
PARK
Kaimu
Waipuku Pt.
Kalapana
1926
Kauluoa Pt.
KAU
1910
KAU
DESERT
Ka Lae Kupapau
Ka Lae a Puki
Kapapala Ranch
1823
Keana Pt.
Keauhou
Alika
1919
Pahala
Papalehau Pt.
Hoopuloa
1926
1868
Mahuka Bay
Milolii
KAU FOREST RESERVE
Palima Pt.
Hanamalo Pt.
Punaluu
Lae o Puuo
Honuapo
Waiohinu
1907
Honuapo Bay
Naalehu
1907
Lae o Kauna
1887
Kahilipali Pt.
1868
Lae o Kamilo
Kaalualu
Kailiki
Waiahukini
Ka Lae
LEGEND
Roads
Trails
Districts
0
10
20
MILES

THE VOLCANO LETTER

No. 432—Monthly, Dept. of the Interior, National Park Service, February, 1936

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR FEBRUARY, 1936

VOLCANOLOGY

Conditions at Kilauea

The month at the Halemaumau Pit of Kilauea produced no notable changes. Conditions were extremely quiet. A moderately heavy slide occurred about February 13, piling fresh debris upon the floor and leaving a scar upon the NE wall. On February 16, the SE wall showed the mark of a slide and rocks were dribbling from the West and NE walls. Some cracks on the floor appeared to be widening. On February 18, rocks were falling from the N wall which appeared dry. Small slides from this wall and the NE wall occurred upon the following day.

Mauna Loa Observations

Fume was still rising in puffs from the rift source at 12,000 feet as the month of February drew to a close. As long as this puffing continues it cannot be said that the eruption has ended since it is obviously due to continuance of lava action within the pit from which it comes. From the eastward, or Hilo side, this fume is not often now discernible as it is blown southwestward by the prevalent tradewind. Occasionally however—in still air—more particularly about the time of sundown it may be seen rising as a thin column by observers near the city.

The Observatory upon the rim of the Kilauea Crater, being situated many miles to the south-south-east, is more favorably located and, provided the mountain is unobscured by cloud, the fume may generally be seen. On February 6, it was visible at noon, and on the 9th, it stood as a large yellowish milky cloud about 900 feet above its base. At the base, it was more dense and appeared to be puffing steadily. The mountain was covered with snow at this time and the cold would have condensed water vapor—but there was more sulphur smoke than steam in this cloud. At 5 pm on February 6, an opalescent fume cirrus was left by this cloud in the upper atmosphere: it lay in a sheet to the west of the zenith, bluish in color and with rainbow hues on its edges. On February 10, light fume was visible in the morning, both from Kilauea and from Hilo. A southerly wind on February 14 made brown fume visible all day: a tall, slender brown column was seen at 7 am on February 15, and milky fume against the western sun was reported by a Hilo observer on the following day.

On February 18 the smoking rift cone was visited by Seismologist H. H. Waesche of the Kilauea Station. He reported that, accompanied by D. McClellan he reached the NE cinder cone after crossing lava of the present eruption. "This was found to be black shelly pahoehoe with aa on its outer edges and gave off almost no heat when crossing over it. In fact, in many places, unmelted snow was lying upon its surface. The cone itself was from 50 to 75 feet in height—composed of black cinders and ash—and was about 750 feet in length—with a width, at its base, of approximately 150 feet. No fuming or steaming areas were found in or upon it—but considerable heat, accompanied by the familiar foundry-like odor emanated from the interior. Upon the SE slope and towards the SW end of the cone were areas of sulphur deposits associated with white salts. Two openings in the NW flank—one about the center of the cone's length—and the other towards the SW end had served as outlets for lava flows which had streamed away northwards.

"The SW cone was next visited from its northern side—more of the 1935 lava being crossed in order to reach it. This lava also was black and more or less shelly pahoehoe with occasional patches of aa. It was warm in places but for the main part was cool enough for snow to remain unmelted. Immediately to the NW of both cones there was much pumice and fine cinders—mixed with the rounded glassy droplets known as Pele's Tears and with pieces of irregularly shaped lava glass from one-half to three-quarters of an inch in diameter.

"Immediately adjacent to the SW cone and to the northeast of it was a large spatter cone some 75 feet in height and 100 feet in diameter at its base. From an orifice at its summit a large volume of fume was steadily pouring. With a moderate NE wind it was possible to approach from the northern side. No pulsation in the fuming process was observed—neither was there any marked force in the volume either from the spatter cone or from a cinder cone further to the SW which also fumed steadily. It was possible to reach the brink of the throat of the cinder cone by use of a handkerchief held over the nose. This cone was between 75 and 100 feet high and about 250 in diameter in the direction of the rift. Although in climbing the



Looking NE along former lava stream which originally flowed from SW cone along base of NE cone, February 18, 1936.

cone progress was made over a large snowbank, the cinders underfoot were distinctly warm. The fume clouds were bluish-white in color and the strong odor of H^2SO^3 was strong and unpleasant even through the folds of the protecting handkerchief upon which yellow sulphur stains were left where they had been deposited by fume associated with air breathed through the material.



Opening in NW rim of NE cone through which lava stream flowed during activity, February 18, 1936.

"Along the base of the cone and more particularly to the SW, large areas of sulphur were forming and fume was rising from these places and from numerous spots of a similar nature though of smaller size along the flanks of the cone. Where new lava lay beneath such areas it had become soft and of a rotten texture. The largest sulphur deposit was at the SW end of the cone where the latter was superimposed upon the rift, which lay open towards the SW and was emitting steam. There was no sound of internal noises and no vibrations were felt. We crossed the rift to the SW of the cone and made our way back to the trail, passing through moderate fume strongly impregnated with sulphur."

SEISMOLOGY

During the month of February there were 12 seisms of which two were feeble earthquakes, nine were classified as very feeble, and one was a record of a distant shock. These produced a total of 89 minutes of tremor. Their distribution was as follows:

Feb. 4. 2 miles deep: 0.7 miles S of pit seismograph: feeble. A Kilauea earthquake.

Feb. 5. 21 miles deep: 5.0 miles NW of Puukoli. North slope of Mauna Loa: feeble, but reported felt in Hilo and at Kilauea Military camp.

Feb. 12. 4.6 miles deep: 1.5 miles SW of pit seismograph: SW rift zone of Kilauea: very feeble.

Feb. 12. 5.0 miles deep: 0.8 miles WNW of pit seismograph: vicinity of Kilauea Rift Cones: very feeble.

Feb. 13. 1.9 miles deep: 0.2 miles N by E of KoKoolau Crater: very feeble.

Feb. 21. 3.5 miles deep: 3.5 miles E of Kilauea Iki Crater: very feeble.

Feb. 27. 2.8 miles deep: 0.5 mile N of Pauahi Crater in Kilauea SE rift zone: very feeble.

Mar. 1. Very feeble—located probably in Kilauea SW rift zone about 1.0 mile SW of Halemaumau.

The epicenters of the above local disturbances were determined from the seismograms of instruments operated at stations of the Hawaiian Volcano Observatory. Kilauea earthquakes were located by means of the main station located at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant earthquakes were determined with aid of seismograms from stations at Hilo and Kealakekua. The depth of focus is given wherever possible.

16 minutes of harmonic tremor began recording at 10:19 am on February 13. On February 26, two spells of harmonic tremor were recorded. The first commenced at 2:41 pm and lasted 6 minutes, and the second, lasting 13 minutes, began at 3:08 pm.

The preliminary waves of a distant earthquake began recording at 2:29 am on February 15. Its estimated distance from the Volcano Observatory was 5735 miles.

Microseismic motion was strong February 3 to 9 and on February 29. It was normal February 10 to 12, 15, 19 to 28, and March 1, and light on February 13, 14 and 16 to 18, all dates inclusive.

TILTING OF THE GROUND

The following table shows tilt by weeks from seismograms at the Volcano Observatory, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope locations towards or away from the Pit.

				Stations
Week Ending	Observatory	Halemaumau West	Clinoscope Southeast	Pit Resultant
Feb. 9	1.31"S.44°W	8.20"N.34°E	8.62"S. 7°W	8.56" *
Feb. 16	1.46"S.57°W	2.09"S. 76°W	5.38"N.57°E	2.41" *
Feb. 23	0.87"S.29°W	3.87"N.43°W	3.01"S. 81°E	4.29" *
Mar. 1	0.80"S.45°E	3.58"S. 70°W	7.94"N.	2.89" †

*—from. †—toward.

The total accumulated tilt at the Observatory for the year ending March 1, was 0.37"S and 0.40"W.

RETROSPECT

Now that the outbreak of Mauna Loa is ended, it may be interesting to look back a few years and compare the precise predictions then made, with what actually happened in 1935. Such retrospection will, at least, show the value of consistent study and uninterrupted compilation and maintenance of record, since—in just the same way as a small



View of Spatter cone and SW cinder cone as seen looking to SW from the NE cone, February 18, 1936.

acorn may develop into a mighty oak, so the true picture of what is likely to occur in connection with individual volcanoes—can only be gained by taking most careful note, through many years, not only of major happenings, but of even the most infinitesimal and, to the layman, seemingly unimportant movements far below the surface of the ground. It is a truism that the most important part of the work of volcanology is the correct interpretation, not of the outward manifestations of an eruption—but of the calm periods when the earth seems to be in a complaisant mood. For it is during such periods that vigilance is most necessary in order that no least movement may be overlooked. The faintest stirring of the calm evening air may be the precursor of the cyclone: the most minute tremor beneath the ground may be the forerunner of increasingly greater movements that may end in a disastrous earthquake, or an eruption with accompanying lava flow.



Spatter cone and SW cone as seen from N, February 18, 1936.

Inhabitants of volcanic lands may be subjected to four different classes of disaster. These are: 1. Explosion and volcanic blast: (2) Lava flow: (3) Earthquake, and (4) Tidal wave. All of these four have happened in Hawaii. There was a great explosive eruption of Kilauea in 1924: Lava flows from Mauna Loa in 1881 threatening Hilo, in 1926, destroying Hoopuloa—and a large number of other flows in very recent years: earthquakes, notably in Kau in 1868, in Puna in 1923 and at Puuwaawaa in 1929: tidal waves in Puna in 1868, and at Hilo in 1877 and again in 1923. As each of these is represented by damage in this century—the topic is a live one.

Speaking before the Hilo Chamber of Commerce on June 9, 1931, Dr. T. A. Jaggar, Director of the Hawaiian Volcano Observatory, called attention to the possibility of disaster to Hilo and urged that precautionary action and organization be taken and established. He said, in part:

"Hilo is peculiar among cities in the world in that it is squarely in a volcanic belt, but happens to have been largely spared until now. So far as strong earthquake is concerned this is equally true of Honolulu, for both of these places are liable to a terrific earthquake, when everybody will be surprised just as the living generation was surprised at Charleston, Santa Barbara and San Francisco. They will be surprised in Hawaii, because the earthquake interval overlaps several generations, and in Hawaii in the 18th century, before the coming of the white man, earthquakes made no impression upon grass houses.

"Hilo is definitely committed to future lava flows. The years 1801, 1843, and 1859 sent flows northwest, two of them building new land in the sea, from Hualalai and Mauna Loa. The years 1852, 1855, 1881, and 1899 sent flows towards Hilo. The flow of 1881 reached Waiakea, and that of 1855 reached Kaumana. The years 1868, 1887, 1907, 1919 and 1926 have sent flows at short intervals to the southwest from Mauna Loa, always in different places, three of them reaching the shoreline, and all of them destructive of ranches, or roads, or villages, or all three. Earthquakes, destructive and dangerous, came in a swarm in October, 1929, shifting the area of underground activity of the enemy from Kahuku to Hualalai, and **suggesting that the north side of Mauna Loa as the center of it all, will probably be the sector where he will concentrate his artillery for the next attack.**

"Apart from these dates, history indicates that Mauna Loa will average activity about every four and a half years, so that we are now on the verge of a new outbreak. There are pros and cons that argue for long intervals in some parts of the century, but we know too little to apply them here. **The fact is inevitable that Hilo will look up some evening and see what resembles a bright star on the northeast rift line of Mauna Loa, and a flow will start, following the hollows among the flows of 1852, 1855, and 1881 in the direction of the valley of the Wailuku River.** After it has been going for a month, we shall know whether it is likely to keep going for a year. It begins with rapid aa flows, the source cones make pahoehoe, the aa ceases, then the pahoehoe slowly tongues out from above, past the earlier aa extremities, and, pushing through tunnels to spreading leaf-like fronts, the pahoehoe may creep through the forest downwards for many months. This would invade and dry up the Hilo water supply. **The lava would be fed through a source tunnel up around the nine thousand foot level, forking out into many tubes down below.** If a flow once got started between the 1855 and the 1881 flows, or on the north side of the 1855 flow, it would pour down the line of the waterfalls of the main valley of the Wailuku, as it has done in prehistoric times in

the past, and as it did in 1881. The waterfalls were made by many lava dams. The visible tributaries are mostly from the north, those from the south being buried under lava and flowing underground. On this course, the lava would pour straight down through Piihonua, and the fate of Hilo would depend upon how long the tunnel supply of pahoehoe kept on flooding at the source.

"Just at this point could be applied the project to stop a lava flow advocated by the late honored L. A. Thurston, **and only at this point.**

"No aa flow in its early and rapid stages could be arrested. **A pahoehoe flow in the later stages of an eruption, by reason of the tunnel mechanism, could be blown up at the source tunnel about the nine thousand foot level, or just below the source cone so as to dam the lava stream with rock and force it to start afresh.** The eruption would continue as before, with the lava starting to flow anew out of the blocked channel over the surface of the country by a slightly changed course. If the previous pahoehoe flow took five months to get down near the Hilo level, the renewed flow 30 miles up the mountain would require as much or more, and the city would be given five months respite. The main source would go out of action in that time, and Hilo would be saved.

"If **the 1855 or the 1881 situations were exactly repeated, this diversion of the flow at the source could be done.** It could not possibly have been done for Hoopuloa or Alika. The 1855 flow lasted 15 months, the 1859 flow ten months, and the flow of 1881, nine months. Such durations are quite possible now—for the tunnel flows on the Kilauea floor in 1919, lasted seven months, and so did the Kau Desert flow in 1920. Contemplation of these possibilities is thoroughly sound economics for this community."

The foregoing predictions were made in 1931. Let us, in the light of them, look at what happened in 1935.

On October 1st of that year exceptional Mauna Loa earthquakes were recorded—followed by smaller ones, and by 50 seismic disturbances per week for the first three weeks of November. Warnings were issued by the Observatory that an outbreak along the northeast rift line of Mauna Loa was imminent. At 1:11 am on November 21, a heavy earthquake occurred under this rift line. The quake of October 1 was located at 17½ miles below the surface: that of November 21 was less than 5 miles down—clearly implying a splitting movement from below upward. At 6:25 pm on November 21, another earthquake—followed immediately by smaller ones, occurred, and the people of Hilo looked up and saw the bright light on the northeast rift line. The great lava flow had commenced.

By mid December, the main flow had definitely swung in the direction of Hilo and was headed for the valley of the Wailuku River. It was being fed through a source tunnel at an elevation of 8,500 feet, forking out into many tubes below around the 6,500 foot level, and the danger not only to the water supply of Hilo but to the city itself, was clearly apparent. It was therefore necessary to blow up the source tunnel in order to secure the result whose possibility had been outlined in the speech of 1931. This was done on December 27, with entire success. The details have been fully covered in the January issue of the Volcano Letter.

It was during the same speech in which these predictions, later so accurately borne out, were made, that Dr. Jaggar touched upon the topic of organization for preparedness, in order that, should disaster occur, suffering might be reduced to a minimum. Alluding to the terrific earthquake in the North Island of New Zealand in February of that year, he said:

"Let us look at what has happened at Napier. Wherever you were, in your car, on the road, standing indoors, standing outdoors, suddenly there comes a tremendous crash like an explosion and down you go. Everything goes down, houses,



Rift looking SW from SW cone February 18, 1936.

bridges, gulches, cliffs, fires start, road fills crack open, automobiles fall into the cracks, wharves are all down, some of the shipping is grounded, the breakwater has settled out of sight in places. In other words, the enemy has hit Hilo with a Big Bertha. The railway is out of commission, emergency telepones are called for as the wires are all down, the water mains have burst, the sewage is interrupted, the fire engines are pinned in their houses, the roads are interrupted by landslides. More than all, the people are struck dumb with shock, and until a warship arrives, to which this sort of thing is all in the day's work, the population is dependent on whatever leaders happen to be soldiers.

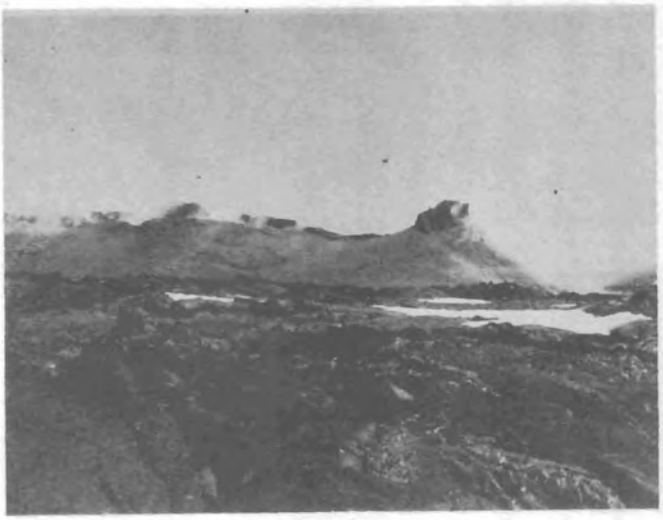
"Rescue parties are organized to dig out the wounded, portable cranes are in demand. Explosives must be used to demolish tottering masonry, which is likely to kill more people with the thousands of aftershocks that are coming along. Temporary wireless is one of the first requirements as the radio masts are down. Airplanes are summoned to rush anaesthetics and medical supplies, for these things have given out. They have to be carried by air. A large number of tents are needed for temporary hospitals, and the roads interrupted by slides and cracks are not immediately available for carrying

people to towns which suffered less. Sea transportation is organized as fast as possible by wireless, but that takes some time. The water supply being cut off, it is necessary to get in a chlorinating plant, organize a road survey immediately, and start work on pipes for an auxiliary water supply from a place where fresh water is available. The contents of the banks are laid wide open as well as many other valuable safes and cash drawers, and martial law is immediately organized by soldiers and constables who understand such things, a ring of pickets is run around the city, looters are shot on sight by marine guards. The jail prisoners are called out for digging, and do heroic work of rescue. Many motorists are caught in gorges and gulches and search parties have to be organized to seek them. The post office department is entirely disrupted and a quick reorganization is called for, as inquiries begin to pour in by mail as soon as any partial organization has been made; people inquire for the safety of their relatives. All lights go out at the very beginning and the organization of a temporary lighting plant and the cleaning up of wires is of first importance when the darkness of night settles over ruins, where work has to continue with the aid of flares, and where valuables have to be guarded.

"Necessarily the Navy and shipping are of great use, and there were three ships which reached Napier. A small, compact, efficient, relief committee was found to be the first requirement at Napier and the organization of an information bureau to answer inquiries. Within a week when outsiders arrive to bring relief, there is need of quarters to correspond with the destroyed hotel, and there is need of increased wharf facility. Free meals have to be organized with the relief funds. Now there is need for a card record of hospital cases, of which there were 2,200 at Napier. The stoppage of the sewers and the bad water supply made it necessary to get together as many trucks as possible as soon as the road gangs had opened a way to get out of the district, and 5,000 people evacuated from Napier and Hastings to a neighboring town which had not suffered, Palmerston. Palmerston organized itself to receive the transport of refugees. There was an acute clothing shortage, and notices had to be placed in newspapers of other towns instructing the public what to send, for they sent too many groceries and too little clothing. The loss at the central towns was of the order of $15,000,000. Fire insurance was simply not paid, for the situation was just the same as at San Francisco and Tokyo, and companies when they do write



View of fuming SW cone taken from South. Distance about ¼ mile, February, 18, 1936.



SW Cinder cone Mauna Loa eruption of November 1935, as seen from N. February 18, 1936.

risks involving conflagration always reinsure with other companies. Only when earthquake is specified, and fire resulting from earthquake, and when these risks are paid for, can there be any expectation of restoration by insurance. **After the event** in all these cases, San Francisco, Tokyo, and Napier, insurance companies wrote earthquake risks. This is always done without any logic, on the part of the owners seeking insurance, who try to save the horses after the barn is burned down. Then after 45 or 50 years when there is real danger, everybody has forgotten it, insurance has been withdrawn, the building code has been relaxed, and it all happens over again. Such is human nature."

Dealing with the important subject of organization for preparedness Dr. Jaggar said:

"Every city should have a small committee of far-seeing men accustomed to administer discipline, representing commerce, public health, police and national guard, transport, and statistics. These people should have a clean-cut war problem with map of the city, just as war problems are worked out by General Staffs. The needs in time of disaster may be small or big, local or general, but the big possibilities should be looked at so that nobody will be surprised. The needs are:

(1) Organization of discipline and communication.
(2) Organization of rescue.
(3) Organization of relief.
(4) Organization of relief funds.
(5) Organization of camp for refugees.
(6) Organization of rebuilding.

(1) Discipline and Communication

"This in Hilo would naturally fall to the Police service and the National Guard, and the communication side of it would call for the assistance and representation of the Naval and commercial wireless. Public Health agencies would be needed right away, and a representative of everybody possessing motor trucks.

(2) Rescue

"This calls for large forces of laborers and truckmen, the National Guard to protect property, Boy and Girl Scouts to act as messengers, all the auxiliary police available, and all the resources of the Red Cross, including everybody who has had any nurse training.

(3) Relief



SW end of cone showing major sulphur forming area, February 18, 1936.

"The prompt selection of camp grounds, creation of sanitation, and finding of auxiliary water, light if the main sources are destroyed, and assembling of food supplies have to be governed by circumstances. This sort of thing is best directed by some one familiar with organizing a camp on military lines and capable of enforcing martial law. There are needed food supplies, tents, surgical supplies, washing appliances, utensils, fuel, stoves, and competent cooks. Don't say 'get them at the hospital.'

"The natural reaction of a committee is to say, 'We have camp supplies in the armory, surgical things at the hospital, and trucks in the county stables.' Remember that for the extreme crisis contemplated, all three may be toppled over and burning, or under a laval flow, with 500 people dead, 1500 needing hospital treatment, and 5,000 homeless. The thing to face is the extreme possibility, the resources in water and supplies of Olaa and Hamakua, evacuation by sea to Maui or Kona, the place for a sanitary refugee concentration camp.

(4) Relief Funds

"There have been cases of disaster where relief funds have been misapplied. One of the first things to happen when a catastrophe is announced is for subscriptions from elsewhere to pour in. The Red Cross is the proper center, with reputable financiers to act as custodians of money.

(5) Refugee Camp

"Supposing Hilo partially destroyed under some great calamity, it is a matter of debate where to put a relief camp. The requirements are access to transportation, good water, supplies of food and clothing, policing, and communication by telephone and radio. If the wharves at Hilo were not destroyed or buried under lava, the place might be Waiakea or the airport. If a lava flow came through that side, the place would have to be in Hamakua."

WHAT MAY BE LEARNED FROM TILT

Tilting of the ground as recorded by the slow and persistent wandering of the recording pens of the seismograph bears an important relation to the whole problem of the movement of lava columns underground and therefore to the problem of forecasting of possible surface outbreaks.

Study of the records made at the Hawaiian Volcano Observatory during many years has shown that tilting away from the pit of Halemaumau has, as a whole, been correlated with rising of the lava column, while tilting towards the pit has usually marked retirement of the lava or has been pronounced at times of general collapse. The tilt at the Observatory appears to have a normal annual range of about 10 seconds of arc towards the pit (southwest) during the first half of the year, and a recovery during the second half. This, however, may not be strictly due to volcanic causes. Changes of temperature in the instrument room itself: of the ground upon which the Observatory stands, or of the face of the cliff near the buildings may produce tilting effect and so account in part for this annual change, though experiments have shown that it certainly is not a purely local movement. Volcanic conditions undoubtedly produce tilt, and these volcanic tilt effects are superimposed upon the tilts produced by other causes.

Quantitative measurements of the uplift and depression of the Kilauea dome have been made upon many occasions by means of precise spirit levels, and horizontal movement detected by a careful retriangulation of a network of stations about the pit also connected by precise levels. Such levels run in 1912, 1920, and 1927 have amply demonstrated the value of spirit levels as a means of detecting even small amounts of vertical displacement. The net of triangulation stations about Kilauea was first established in 1920 and connecting levels were run during the same period. Final adjustment of both surveys by the method of least squares was made by the computing section of the Geological Survey in Washington. D.C.

The resurvey of this net in 1927 and 1928 correlated most satisfactorily in its results with the general breakdown and depression of the Kilauea dome during the seven year period from 1920. Horizontal movement was shown to be a general pull-in of all points towards Halemaumau as a center.

Similar repetitions of surveys have been made upon an extensive scale by the Japanese government in earthquake-stricken provinces, and the area along the San Andreas rift in California has been retriangulated by the U.S. Coast and Geodetic Survey. The results of these measurements, as of those in Hawaii—clearly demonstrate the amount of displacements of the earth's crust which took place during periods of disturbance. Some of these displacements were extremely small and required the most accurate of modern engineering methods to detect: also, the surveys were made after the greatest movement had occurred. But the lesson to be learned is that by applying the same methods at regular intervals it may be possible to predict the likelihood of earthquake—or what more closely concerns us in Hawaii, the rise of the Kilauea or Mauna Loa lava columns.



Rift looking toward SW base of SW cone, February 18, 1936.

The measurements in California or Japan have been concerned partly with earthquakes of tectonic origin, and as these are caused by continued long strain and warping of the earth's crust over a number of years until the breaking point is reached, it follows that periodic surveys of known active fault areas may be of the utmost value, in the prediction of approaching disturbances. Here in Hawaii it would be necessary to correlate such measurements with data from the seismograph or tilt-meter and to continue it through two or more active phases since the actual tilt of the ground from day to day is small and not perceptible except by magnification. However, cumulative tilt is undoubtedly a measurable quantity, and since accumulated tilt away from the Halemaumau pit has been shown generally to precede an active period, it is logical to assume that measurements of the relative change in elevation of established bench-marks together with the measurement of the horizontal angular change between such points would give a more firm basis for prediction.

With this end in view, new stations were established about the rim of Halemaumau. One of these adjoins the pit seismograph cellar—the others forming a rough square spanning the crater, and being triangulated for any immediate emergency. Horizontal angles were observed by a repetition with a Berger transit graduated to 20 seconds. Each angle is observed 12 times, six times in a clockwise direction, three settings made with telescope direct, and three reversed, both verniers being read. The angle is then measured in a similar manner but in a counter-clockwise direction, the mean of the 12 readings giving the correct angular value free from instrumental errors. Horizon closures are made the same way. Particular care must be given to the centering of the instruments over their respective marks.



View of SE cone Mauna Loa, February 18, 1936, as seen from S.

The measurement of rim cracks around Halemaumau has in the past proved of scientific interest, as well as of value to the public in marking off weak or dangerous sections about the pit. This precaution is highly necessary as Halemaumau is the main attraction to all visitors to the Hawaii National Park and is reached directly by automobile from Hilo—the seaport city on the coast at the foot of Kilauea mountain. As one of the world's most stupendous windows into the molten heart of the globe, it attracts thousands of visitors throughout the year, any unusual activity causing an influx of tourists and island people whose safety must be carefully considered.

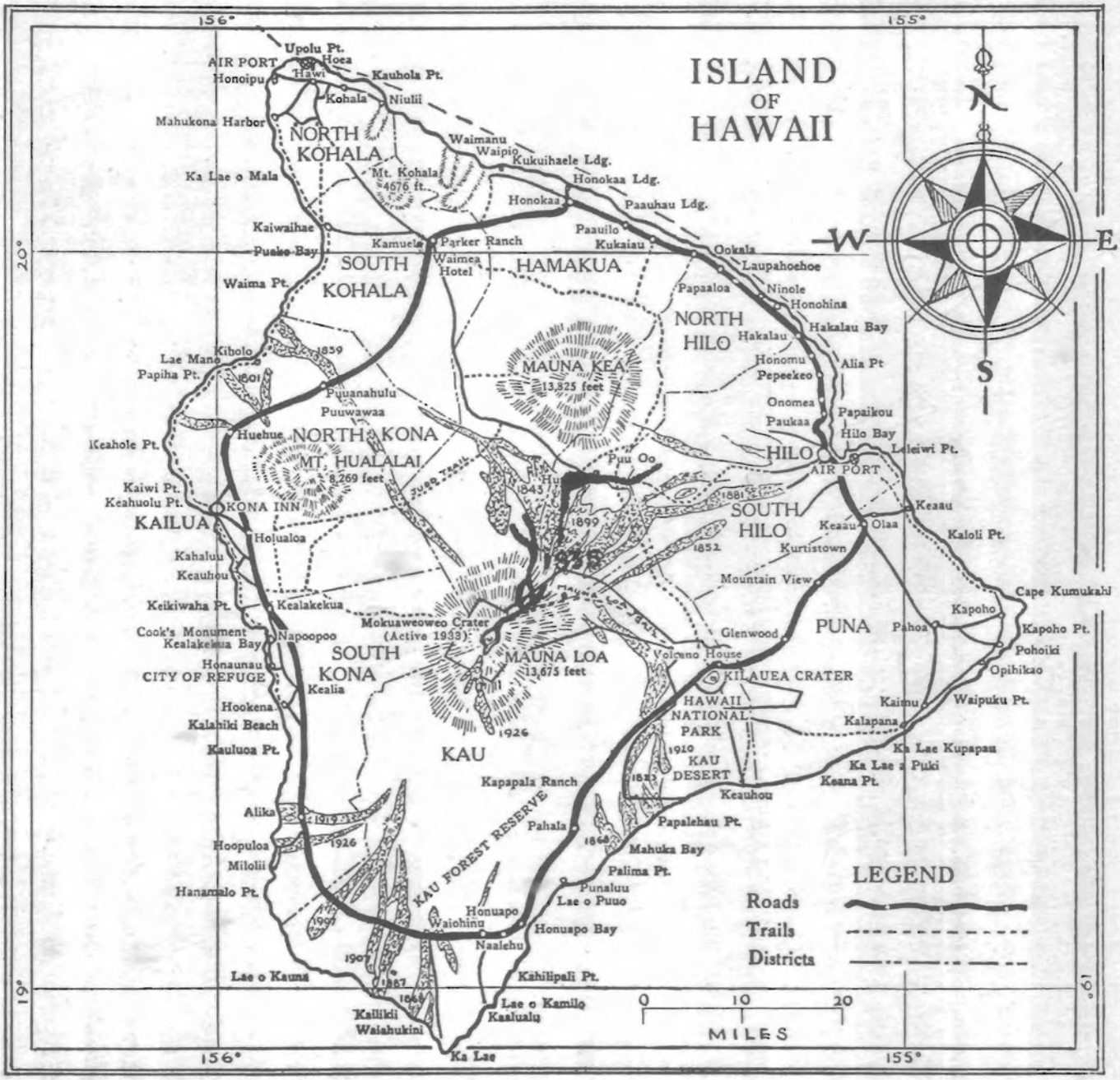
Measurements of rim cracks however, are not always meticulously accurate, instrumental errors amounting to as much as two or three millimeters having occurred, owing to the uncertainty of exact points of measurement as well as to the inaccessibility of some of these points. Measurements must be made from new points as may become necessary and new methods of measuring must also be devised. Tumescence of the Kilauea dome as the result of rising lava has its effect upon the more deep-seated fractures, the lifting of the lava column upon various occasions causing a widening of the superficial rim cracks with sections breaking off and avalanching into the pit.

But as a part of the complicated, process of volcano study, observation of the tilting of the ground is a highly important factor.

E.G.W.



General view from SE of fountain area of Mauna Loa eruption, February 18, 1936. SW cone is to left and NE cone to right.


ISLAND
OF
HAWAII
N
S
E
W
156°
155°
20°
19°
Upolu Pt.
AIR PORT
Hoea
Honoipu
Hawi
Kauhola Pt.
Kohala
Niulii
Mahukona Harbor
NORTH KOHALA
Waimanu
Waipio
Kukuihaele Ldg.
Ka Lae o Mala
Mt. Kohala 4676 ft.
Honokaa Ldg.
Honokaa
Paauhau Ldg.
Kaiwaihae
Puako Bay
Kamuela
Parker Ranch
Paauilo
Kukaiau
Ookala
SOUTH KOHALA
Waimea
Hotel
HAMAKUA
Laupahoehoe
Waima Pt.
Papaaloa
Ninole
Honohina
NORTH HILO
Hakalau
Hakalau Bay
Kiholo
1859
Lae Mano
Papiha Pt.
1801
MAUNA KEA
13,825 feet
Honomu
Alia Pt
Pepeekeo
Puuanahulu
Puuwawaa
Onomea
Papaikou
Paukaa
Hilo Bay
Keahole Pt.
Huehue
NORTH KONA
MT. HUALALAI
8,269 feet
HILO
Leleiwi Pt.
AIR PORT
Puu Oo
1843
1881
Kaiwi Pt.
Keahuolu Pt.
KONA INN
KAILUA
1899
SOUTH HILO
Keaau
Olaa
Kaloli Pt.
Holualoa
1852
Kurtistown
Kahaluu
Keauhou
1955
Mountain View
Cape Kumukahi
Keikiwaha Pt.
Kealakekua
Kapoho
Mokuaweoweo Crater
(Active 1933)
Cook's Monument
Kealakekua Bay
Napoopoo
Glenwood
PUNA
Pahoa
Kapoho Pt.
Volcano House
Honaunau
CITY OF REFUGE
SOUTH KONA
MAUNA LOA
13,675 feet
KILAUEA CRATER
Pohoiki
Opihikao
Kealia
Hookena
HAWAII NATIONAL PARK
Kaimu
Waipuku Pt.
Kalapana
Kalahiki Beach
1926
Kauluoa Pt.
KAU
1910
KAU DESERT
Ka Lae Kupapau
Ka Lae o Puki
1823
Kapapala Ranch
Keauhou
Keana Pt.
Alika
1919
Pahala
Papalehau Pt.
1926
Hoopuloa
1868
Mahuka Bay
Milolii
KAU FOREST RESERVE
Palima Pt.
Hanamalo Pt.
Punaluu
Lae o Puuo
Honuapo
1907
Waiohinu
Honuapo Bay
Naalehu
1907
Lae o Kauna
1887
Kahilipali Pt.
1868
Lae o Kamilo
Kaalualu
Kailikii
Waiahukini
Ka Lae
LEGEND
Roads
Trails
Districts
0 10 20
MILES

THE VOLCANO LETTER

NO. 433—Monthly, Dept. of the Interior, National Park Service, March, 1936

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR MARCH, 1936

VOLCANOLOGY

Activity at Halemaumau during March was marked by increased seismic activity the middle of the month followed by a sudden decrease the latter part. Numbers of slides from rim walls increased as did the size of individual slides. The peak of seismic activity was reached the afternoon of March 12, when three feeble earthquakes within one hour's time shook the Kilauea District. Their location was apparently under the East Rim of the Crater S of Kilauea Iki. The significance of the shocks of the second and third weeks of March and the quiet of the fourth week is probably a sinking of the deep lava under Kilauea as a reaction from similar sinking under Mauna Loa. This period of activity was closed with a feeble earthquake, March 21. Much of the seismic activity of the third week was the result of unusually heavy sliding of Halemaumau walls thus producing a large number of tremors on the Observatory record. Large sections of the NE rim fell into the Pit greatly increasing NE talus accumulations on the edge of the lava floor. A section of the rim bounded on the NE by one of the regularly measured cracks disappeared between March 15 and 22. This was discovered March 22, when making the regular rounds of crack measurements and the SW side of the crack was found to be missing. The distance from the former crack to the previous edge of the Pit was about thirty-five feet. The length of this section may have been two hundred feet. It is interesting to note that this excessive rim sliding is at the NE side of the Pit which is thought to be in the vicinity of the emergence of Crater rifts from the NE. The receding lava column suggested in the review of the earthquakes, may have caused movement in the rift region thus precipitating sections of the Pit walls in this weakened zone. Nearby Crack No. 46 opened considerably. Excepting these two cracks, it was noticed that an abnormal number of other concentric cracks had closed. An analysis of this condition further tends to confirm the supposition that lava was receding below Kilauea and Mauna Loa. Reference to records of 1935, show that heavy sliding occurred during the latter part of March and continued into April and May. At that time the SSW wall of the Pit was in the active center of avalanching. As was true of the same



Fig. 1. Section of Rim of Halemaumau showing bay largely formed by the falling of masses of wall rock. Note figure of man for comparison with Fig. 2.

phenomena this past month, last year seismic activity increased in a manner similar to this year because of tremors resulting from heavy rock falls. The 1935 series of slides were to the west of the point of emergence of the Kilauea SW rift at the Pit. The points of greatest avalanching were at opposite ends of the Pit but both were associated by proximity to the main crater rift system. The occurrence of each at approximately the same time of year may be of significance demonstrating possible annual lava movements or pulsations of like nature.

Fume from the yellow solfataras around the edge of the floor of Halemaumau continued emitting bluish fumes with apparently little change throughout the month. Fuming was reported as very light at 9:50 am, March 29. The day was clear and a moderate wind was blowing from the NE.

Fuming of the source cones of the 1935 eruption at 12,000 feet on Mauna Loa has died down considerably as no fume was observed from the Observatory after the first week in March.

The summary of these events in each case tends to show a lowering of the lava column and or pressures under Mauna Loa because of:—

1. Earthquake shocks and high seismicity followed by a sudden drop in seismicity;
2. Slides in Halemaumau from probable lowering of Crater floor;
3. Closing of more than the usual number of cracks and,
4. The disappearance of fume on Mauna Loa as seen from the Observatory.

KILAUEA OBSERVATIONS

Slides at Halemaumau

Slides at Halemaumau have been noted as follows:—

March 7, small slides from N wall at 9:58 and 10:35 am.

March 4, at 9:46 am, small slide from N wall and from fresh dust on floor probable slides from SE and NE wall within last 24 hours.

March 13, fresh scar about 500 feet below NE rim, fresh talus at foot of wall and fresh dust on floor seen at 9:48 am, indicate large slide during preceding night.

March 17, at 10:13 am, slide from NE wall about 200 feet below rim.

March 18, sliding from NE wall noted as follows: loud noise of falling rocks indicating large slide heard at Pit seismograph station at 9:56 am; 10:06 am, small slide; 10:10 am, heavy slide followed by another small one at 10:14 am. A very heavy slide occurred about two-thirds of the way up Pit wall at 3:20 pm. This was followed by a larger one at 3:32 pm, leaving a large apse like embayment at same point as 3:20 slide. Continuous trickle of small rocks interrupted by large sliding bowlders from time to time was observed between 3 and 3:45 pm.

March 19, continuous trickling of rocks from NE wall about 9:30 am.

March 20, much noise and trickling of rocks from NE wall at 9:58 am.

March 22, small slide from NE wall at 9:48 am. Dust cloud over Halemaumau as seen from Observatory at 4:36 pm indicated sliding.

March 23, rocks trickling from NE wall at 9:57 am; noise and trickling of rocks from NW wall 10:05 am; dust clouds at 12:40 pm and 12:51 pm seen from the Observatory indicate moderate slides in the Pit.

March 25, slide from NE wall at 9:40 am.

March 29, small slide from NE wall at 9:50 am.

Halemaumau Solfataras

Observations of the sulphurous fumaroles around the edges of the Halemaumau floor, and of the vapor cracks have been as follows:—

March 17, fume very slight, 10:13 am. Weather: light NE wind with rain and high humidity.

March 20, strong fume from yellow solfatara below Tourist Lookout 9:58 am. Lt. SE wind, heavy fog and mist, and high humidity.

March 29, fume very slight at 9:50 am from all solfataras. Weather clear, moderate humidity and wind was moderate NE.

Note:—Weather is an important factor in observations of fume as all the variable factors may influence its appearance so that the same amount of fume may appear different depending upon immediate meteorological conditions. That is to say, that for a given amount of fume, it appears to increase with an increase of humidity which of course increases directly with fog and rainfall. Thus, the greater the percent of moisture in the air, the greater the volume of fume seems to be. The lower the temperature, the greater the fume, and temperature also affects humidity. The lower the temperature the greater the relative humidity. Wind direction and strength will affect air currents in the Pit, thus at times disseminating the fume more or less rapidly as the case might be so that the location of the vent may be protected from the wind one day and not the next. There is always more fume visible on a quiet day than on a windy day. From this it can readily be understood that for comparative results on fume visibility care must be taken to consider weather conditions at the time of observation.

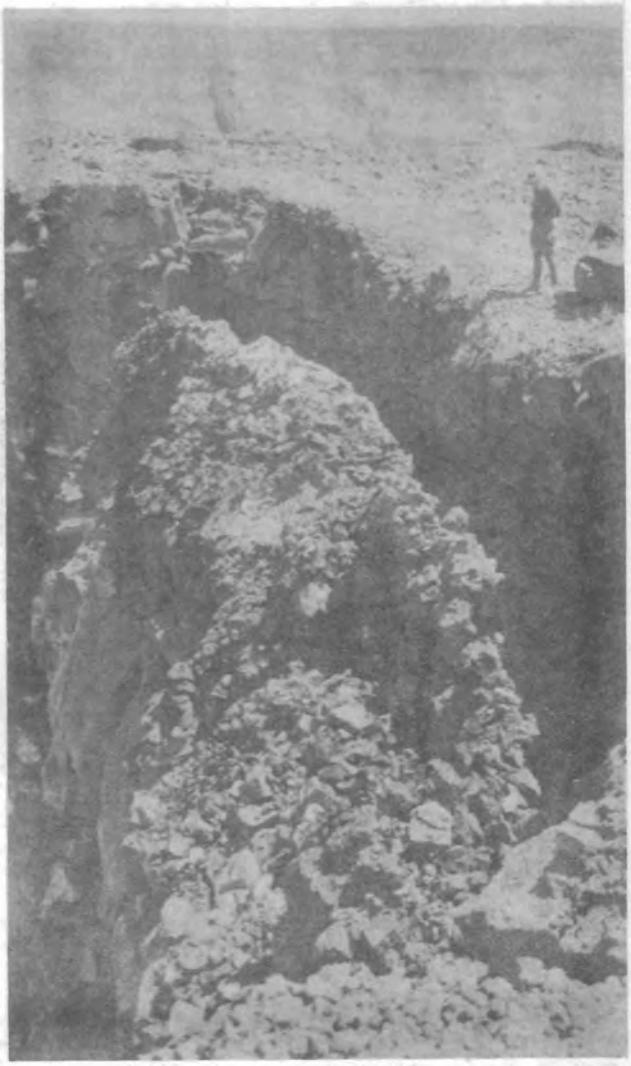


Fig. 2. Detail of condition of rim as shown in Fig. 1, in front of observer illustrating probability of further collapse.

Measurements of Halemaumau Rim Cracks

Weekly measurement of 32 marked places on rim cracks around the upper edge of Halemaumau pit resulted as follows:—

	Opened	Closed	Aggregate Opening
March 7	16	0	21.0 mm.
March 14	14	0	54.5 mm.
March 22	4	8	6.5 mm.
	(31 cracks as No. 34 had disappeared)		
March 28	13	2	14.0 mm.
	(31 cracks)		

Cracks No. 46 and No. 34 combined, contributed 10.5 mm. of the total amount for March 7, and 47.5 mm. of the total for March 14. As previously stated Crack No. 34 was eliminated by sliding during week preceding March 22.

Crater Angles

The horizontal angle measurement across Kilauea Crater and Halemaumau for March 16, taken from the Observatory, compared with similar measurements for February 20, showed closing of the angles in all cases. Between SE and NW Rims of Kilauea there was closing of 4.2". Between the SE and NW Rims of Halemaumau there was closing of 0.8". Accompanying this marked closing of the Crater angles there was much sliding of rock from the walls of Halemaumau.



Fig. 3. Rim Crack #46 at point where weekly measurements are made. This crack has continued opening of 4.5 millimeters per week for the past two months.

SEISMOLOGY

Earthquakes

Table

Week ending	Minutes of tremor	Very feeble earthquakes	Feeble earthquakes	Slight earthquakes	Distant earthquakes	Local * Seismicity
Mar. 8	31	4	0	0	1	9.75
" 15	22	5	0	3	0	14.00
" 22	52	7	1	0	0	17.50
" 29	26	4	0	0	0	8.50

*—For local seismicity see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station located at the Observatory and the two subsidiary stations located at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant quakes were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and, whenever such determinations were possible, the depth of focus is given.

March 3, at 1:36 am, very feeble, probable location under N rim of Halemaumau, Kilauea Crater.

March 5, at 7:31 am, very feeble, located 1.6 miles deep and 1.8 miles E of Pit Seismograph Station. 19° 24'.4N; 155° 15'.4W.

March 6, at 5:33 pm, very feeble, probable location under SW rim of Halemaumau.

March 9, at 2:15 pm, very feeble, probable location under SE portion of Kilauea Crater.

March 10, at 12:59 pm, very feeble, probable location under E slope of Hualalai volcano.

On the afternoon of March 11, there were three slight earthquakes all of which were sharply felt in the Volcano District by many people. The first one of the series began at 4:15 pm; it was located 1.1 miles deep on the East rim of Kilauea Crater and 0.6 mile S of Kilauea Iki; 19° 24'.5N; 155° 15'.1W. The second shock followed at 4:54 pm, and was located 1.5 miles deep and 0.7 mile S of Kilauea Iki, 0.6 mile E of the E rim of Kilauea Crater; 19° 24'.4N; 155° 15'.0 W. The third shock at 4:55 indicated the same location as the preceding. Very feeble shocks registered on the Observatory seismograph at 4:19 pm and 4:49 pm. They were apparently associated with the disturbances which caused the heavier shocks.

March 21, at 3:50 pm, a feeble earthquake began to record. The probable location was deep under the west slope of Hualalai Volcano.

March 22, 5:44 am, very feeble, located 35 miles under Mokuaweoweo Crater of Mauna Loa. 19° 26'.5N; 155° 35'.8W.

March 23, at 8:19 am, very feeble, probable location, deep under Kilauea Crater.

March 25, at 2:34 am, very feeble, located 3.0 miles deep and 1.2 miles E of Puhimau Crater in SE Kilauea Rift zone. 19° 23'.8N; 155° 14'.0W.

Several spells of harmonic tremor occurred during the month. Sixteen minutes of such continuous tremor began recording on the seismograph at 7:05 am, March 8. Four minutes were recorded beginning at 5:04 am, March 17, and on March 24 at 11:58 pm, an eleven minute spell began, lasting until 12:09 am, March 25. These tremors were similar in every way to those accompanying volcanic outbreaks of Mauna Loa and possibly are caused by lava movements underground.

The surface waves of a distant earthquake began to record at 8:06 pm, March 4.

Microseismic motion of the ground at the Observatory was light March 9 to 11, and 26 to 29, inclusive. It was normal March 2, 4 to 8, 12 to 15, 17 to 19, inclusive and was strong the remaining days of the month. —H.H.W.

Tilting of the Ground

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE Rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope locations, towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending March 29, was 3.37″N and 2.88″E.

Table of Tilt

Week ending	Observatory	Halemaumau West	Clinoscope Stations Southeast	Pit resultant
Mar. 8	2.12″N 77°E	10.79″N 60°E	3.58″N 29°W	2.63″†
Mar. 15	0.76″N 13°E	3.73″N 33°E	1.64″S 64°W	0.19″†
Mar. 22	2.84″S 54°W	24.95″S 37°W	2.09″S 75°W	9.35″†
Mar. 29	0.12″W	8.75″N 16°W	7.36″S 89°W	0.80″§

† from. § toward.

—H.H.W.



Fig. 4. Cascade of 1934 flow showing conditions prior to the heavy avalanching of 1935.

A TRIP UP THE 1935 MAUNA LOA FLOW

On the morning of March 1, 1936, Dr. T. A. Jaggar and H. H. Waesche of the Volcano Observatory left Kilauea for an exploration of the Mauna Loa flow of November-December 1935. The objective was to be the source vent at about 8,500 feet elevation on the N slope of Mauna Loa. This locality was of added interest because it was the scene of the bombing operations of December 27. The night was spent in the Forest Reservation west of Puu Huluhulu.

At 8:00 am, March 2, approach to the edge of the flow was made as nearly as possible by car. The weather appeared unfavorable for the expedition as it was raining heavily and there were no signs of a change. To attempt the trip over still warm lava flows would have been dangerous as steam or fog would be created, lowering visibility to a point where travelling would be slow and directions uncertain. This situation caused abandonment of the trip for the day. However, exploration of the pahoehoe in the vicinity about one mile west of Puu Huluhulu was made. From this area, a tongue of pahoehoe, hitherto unnoticed was seen extending about a mile to the west. It had stopped about two miles southwest of Puu Huluhulu and immediately S of the Omaokoili Hills. It was of interest in that this lobe had evidently been stopped by 1843 aa and thus dammed, was prevented from moving farther to the west and consequently caused a filling in of all the low areas of the Humuula Ranch land before finally extending itself eastward and then advancing rapidly toward the upper source of the Hilo water supply. The new pahoehoe, although formed in the third week of December was still warm and in some places quite hot. The hotter spots may have been localities of greater thickness of lava or may have been caused by chemical reactions still progressing, particularly within the remains of buried vegetation. Cooling had contracted the lava so that many cracks had been formed and some were emitting fume or vapor or both which was depositing sulphur and white salts along their surfaces. In some cases the red color indicating selenium was seen. The fuming hot spots seemed to be more common near the edge of the lava bordering the grass lands thus supporting the idea that some of the heat was possibly the result of chemical activity between the lava and covered vegetation. The trace of a former stone wall was crossed. The location of the wall could readily be followed along its former line. In some places this wall had been pushed over by the force of the advancing lava but more often the pahoehoe had frozen on the S side of the wall thus strengthening it so that the lava was either locally diverted or forced to build up to the height of the wall and then cascade over. Where this latter had happened the wall was completely invisible but was marked by a change in the character of the lava along its course. Where the lava had been diverted, the wall was visible on the N but usually buried on the S side. The exploration was continued until the main river channel of the flow was reached about two miles SW of Humuula. It was decided that the frozen surface of this river would make the best path of travel in reaching the source vents and would be so used when the weather permitted. At this point, the river channel was about thirty feet in width and its surface was more or less corrugated as seen in the photograph with the corrugations running in the direction of flowage. As the weather still showed no signs of change, the party returned to the car and back to Waimea Hotel.

The weather seemed very unfavorable again on March 3, so that continuation of the trip was postponed until March 4. On this date however, it was decided to make the hike up the flow even though the weather still was not too favorable. The start was made from an edge of the flow near Puu Huluhulu. The pahoehoe here was the typical billowy type and was comparatively dense so that at no time did it give way under foot as is so often the case with shelly pahoehoe usually encountered near source vents. After walking about a mile the



Fig 5. Talus slopes in Spring of 1935 covering cascade shown in Fig 4.

frozen surface of the former meandering lava river was encountered. The river varied in width from a few feet in some places to as much as one hundred and fifty in others. As is true of rivers of water, the lava river was narrower and straighter on steeper grades whereas it meandered and was wider on the more level portions. It had built up more or less natural levees at each side, 5 to 25 feet high, making the flow higher than its surroundings. The pahoehoe on each side of the river was much broken and contorted and in some places the location of the actual river was not identifiable because of the broken condition of the surface of the entire flow. Hiking was comparatively easy. Along the river course there were to be seen interesting peculiarities such as cascades

and as shown in accompanying photograph, the frozen design of a former cascade with a whirlpool at its base. The boundary to the east was either 1935 aa, pahoehoe of the 1899 flow or very old light brown pahoehoe. To the west the river boundary was either 1935 aa or aa of 1843, mostly the latter. The 1935 pahoehoe as seen along the river was either black or bronze in color and billowy as it had been at the start of the hike.

After climbing up grade for about five miles, the slope became steeper. From this point on, the river's course was marked by frequent yawning holes of various shapes and sizes from a few feet to thirty. They connected with a lava tube below. The lava tube was apparently the location of the former very active liquid stream which had fed the front of the flow far below during the height of the activity. Its floor was five to possibly fifteen feet below the surface of the river. Intense heat poured from practically all, making exploration either very difficult or impossible. The holes were the result of the caving-in of weak portions of the tube roof. After hiking about seven miles from the starting point, a place was found where the roof of the tunnel had caved in leaving a pit about fifty feet long and about thirty feet wide. At each end the openings of the tube were seen. The one to the north was too hot to be approached but the one to the south was cool. Camp was made in this cooled portion of the tube. The floor was covered with slabs of material which had fallen from the ceiling. In many places slabby portions of the roof seemed most precariously perched and ready to fall at any minute. Lunch was partaken of and then the hike continued about two miles farther up the flow. A point was reached where the going was difficult as the lava became broken and slabby with many patches of aa. The main source vent was still to be seen between one and two miles farther along. To the SW could be seen fume and steam rising from a distant portion of the 1935 flow. In the immediate vicinity and on up to the main source vent, bluish fume made the air somewhat hazy. It was at this locality that depressions and craterlets showed an interesting variety, showing characteristics of eruptive activity, such as might be caused by bombing and in other cases, collapse seemed to be the cause. In all cases there had been fresh outpourings of smooth pahoehoe as seen in photos No. 1 and 2. No. 2 shows a typical depression and No. 1 shows the downstream flow of pahoehoe which had welled out of the depression. It was at first thought that these might be bomb craters. Later determinations showed this to be incorrect as the locality was not one of those bombed. After abandoning attempted continuation of the exploration for that day because of rain, camp was made in the tunnel at the place previously mentioned. During the night booming sounds with a slight jarring motion of the lava issued from the flow. These were apparently caused by more rapid cooling of the lava at night with consequent shrinkage.

On the morning of March 5, the main lava river was left in favor of a small more easterly arm of pahoehoe which led directly to the lower bombing locality. This locality consisted of a large heap of lava both pahoehoe and aa through which ran a channel, the former path of the main lava stream and the target of the army bombers. The floor of the channel was about thirty feet below the surface and was about fifteen to twenty-five feet in width. Observation of the channel could be made through much elongated openings or windows along its course. Wherever one of these windows was discovered, large amounts of pahoehoe and lava veneer surrounded it apparently having flowed from the vent at a very late period of the eruption. As this region was a part of the bombed area further discussion of its nature will be left to future articles concerning the results and other data related to the unique experiment of bombing a lava flow.

The uneventful hike back to Puu Huluhulu ended a most interesting and profitable trip up the still hot course of the river which fed the main Mauna Loa flow of 1935.



Pahoehoe which had flowed from craterlet of picture below.

LASSEN VOLCANO — CALIFORNIA

Attention has been drawn to Lassen Park at this season by the large number of earthquakes recorded in this area. Many of the newspaper reports have been exaggerated and without scientific foundation. Speculation and prediction have been rife and those not familiar with the situation may be led to believe that the volcano is about to burst forth into cataclysmic activity. Under those conditions, an impartial description of the present status of Lassen Peak as a volcano, so far as can be determined from its features and activities, may be of value.

Since the 1917 activity of Lassen Peak, more than thirty constantly active fumaroles have been present on or near the summit. These fumaroles are located in and around the 1915 and 1917 craters and consist of steam issuing from fissures in the dacite. Some H_2S and SO_2 gas is present but is usually just barely noticeable. Sulphur deposits are present around some of the vents but there are no evidences of recent sulphur deposition. There are no hot springs, mud pots, or other solfataric features present, and the steam vents may not be noticed by the casual observer, especially on a warm, dry day when the steam is quickly evaporated and dissipated.

Observers in the vicinity of the base of the peak have noticed an unusually large amount of steam coming from these fumaroles this spring. Jets of steam, probably two or three hundred feet high are observed frequently from Manzanita Lake, four miles from the summit. On several occasions clouds, perhaps partly composed of steam, have been seen hovering over the craters on quiet, moonlit evenings. These phenomena have not been unknown in the past, but they are much more frequent this spring.

In an effort to ascertain the cause of this seemingly unusual activity, Park Naturalist Swartzlow and the writer recently climbed to the summit of Lassen Peak. The craters were carefully inspected and special attention was given the fumaroles. So far as could be determined, there are no new steam vents present and the known fumaroles are not emitting excessive amounts of steam. Having inspected the area under various conditions more than 100 times during the past three summers, the writer feels qualified to state that there are no obvious reasons for believing that Lassen Peak or its fumaroles are more than usually active. In fact, on several damp, cold days last season, there was much more steam visible than on the occasion now referred to.

The writer also inspected the hot springs at Bumpa's Hell to see if they were unusually active. They were reported to be excessively violent this year and it was thought that there might be some connection between the recent earthquakes



Showing one of the craterlets.



Cascade and whirlpool in lava river of 1935. Mauna Loa Flow.

and their activity, since they are probably located on a fault which may be active. However, the hot springs, mud pots and fumaroles seemed to be normal in action. Since features of this kind are probably dependent upon surface water, they are naturally more active when the snow is melting rapidly in the spring and early summer than later when the supply of water is small.

The appearance of an unusual amount of steam from the fumaroles this year is probably due to atmospheric conditions. During the past six weeks, the weather has been unusually cold and damp and there has been little wind. Such conditions prevent the rapid evaporation and dissipation of steam and increase its visibility so that the normal quantity appears much greater.

One cannot say that Lassen Peak will not erupt tomorrow because no one can see what is transpiring below the surface and our seismographs are poor indicators of subterranean activity. However, there have been no surface indications that any unusual activity is present or is about to begin.

—By Russell Farmer, Ranger Naturalist.

HOW TO MAKE A SIMPLE SEISMOGRAPH

From time to time the Hawaiian Volcano Observatory receives inquiries from students and other interested persons upon the method of construction of a simple earthquake-recording instrument that—while not possessing the refinements and high magnification common to costly apparatus, shall, nevertheless, show practical results for ordinary purposes of daily observation.

Since such inquiries have become increasingly frequent during the past few months and it has been impossible to reply to all of them in full detail—we here present a brief working plan from which, with a little patience and ingenuity, a satisfactory seismograph may be constructed, using only the most simple of materials and avoiding the necessity of outlay upon expensive equipment.

The seismograph in most common use is a horizontal pendulum. Figure 1 shows the hanging part of such a pendulum which anyone can make for himself. There is here shown a clock on the wall which is a good timepiece made by the Howard Company in Boston, Mass. This is fitted with electrical contacts closing the circuit of a four-cell dry battery for about



Lava river of 1935. Mauna Loa Flow.



Looking upstream. 1935 Mauna Loa Flow.

two seconds every minute and about six seconds every hour. It is a weight-driven pendulum regulator with eight-day movement. The electrical contacts on the minute and hour are for marking the time continuously on the smoked paper which covers the drum of the seismograph, so that any hour or minute may be identified on the paper for discovering the time when an earthquake has marked the paper.

On the left is shown a concrete post in a basement room with an upright hollow or groove cast at the bottom where the post rises from a concrete table or pier. It is better to have the cylinder as shown hanging from an isolated post than to hang it from the wall. We have tried both plans for

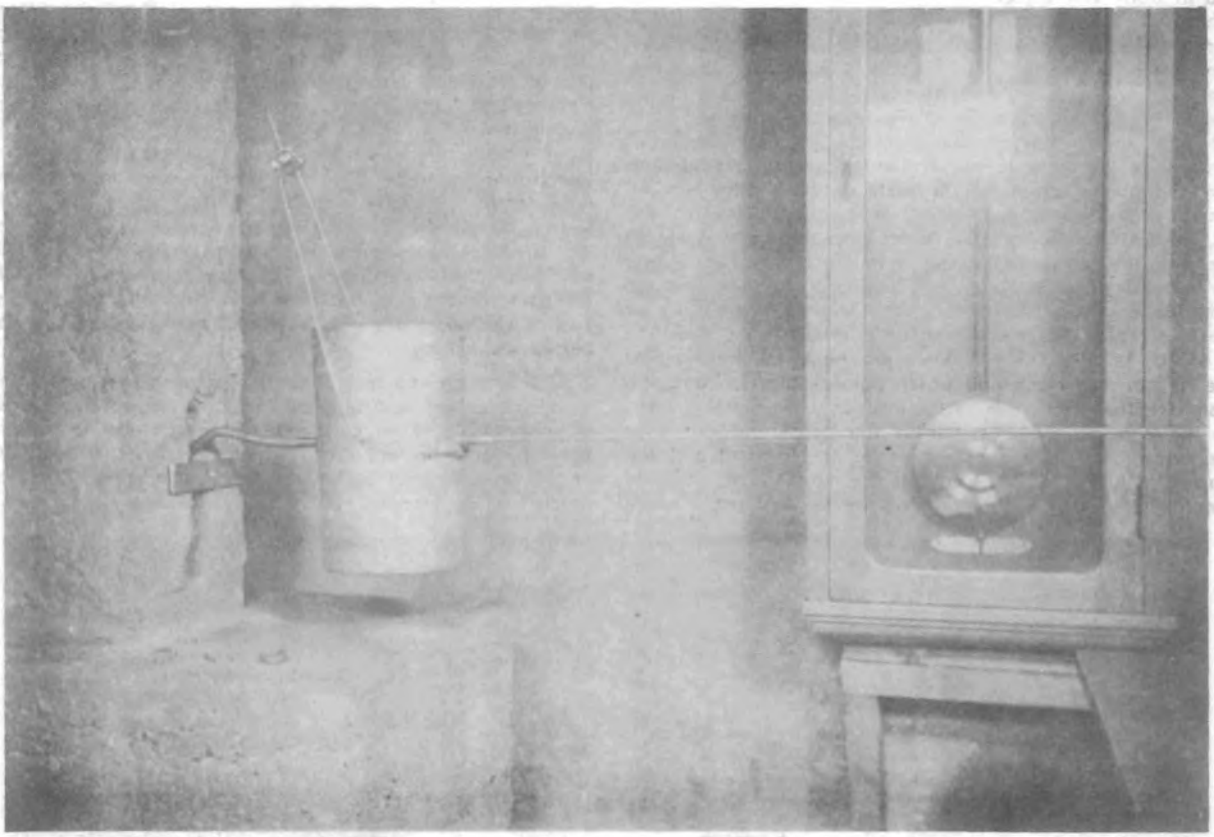


Fig. 1. Showing concrete pier and post—heavy mass suspension and boom and the Howard Clock.

different instruments at the Hawaiian Volcano Observatory. As the hanging cylinder is very sensitive to the slightest tilt given to its supports, walls are not desirable. The upper part of the concrete wall of a cellar on the outside of the building is heated by the sun for some parts of each day. The heating expands the wall and it cools at night, thereby contracting. The seismograph is so sensitive, magnifying earth motion some two hundred times in case of a horizontal displacement, that the distortion of the wall under expansion and contraction will cause the writing pen to swing sidewise an inch or more in the course of a day. This causes the lines to interfere and interlace with each other. A certain amount of normal tilting of the ground is to be expected in the course of each day anywhere, and it is likely to be exceptionally big at an active volcano. Therefore we do not want any tilting due to solar heating of the house. What tilting we get, measured by the swinging apart or the close approach of the lines, should be indicative of what the actual ground is doing under the whole country, and therefore is measurable for the particular two directions in which a single horizontal pendulum swings.

The dimensions of the cellar shown in the picture are ten by ten feet, and the general plan of the instruments followed the lines of the Omori seismograph. The concrete post, ten by ten inches square, stands 27 inches high above the pier which is 18 inches high above the floor and two feet square. The cylinder consists of a cast-iron container holding nine circular lead discs, which make the whole weigh 225 pounds. The lead discs are each bored and threaded in the center to take a large screw-eye, so that the container can be handled by one man by lifting the discs out or putting them in separately.

An iron rod, bigger near the post, and smaller at its outer end, passes horizontally through the middle of the heavy mass or cylinder. This protrudes 52 inches from the center of the cylinder. The bit end of the rod is bent and lies in the niche at the base of the post, supported by a short hinge of spring-steel wire. This wire hinge is terminated by metal balls in two slots cut with a hack-saw. One of these slots is in the flat iron strap shown pinned across the niche, the other in the bent end of the rod. The heavy cylinder is supported by a stirrup hanging from a piano wire which is made fast to a simple adjustable bolt in two angle irons pinned to the top of the concrete post. For these attachments to the post it is convenient to use expansion bolts, which are readily put in holes drilled in the concrete. The adjustments of the upper attachment of the piano wire permit of winding it up to lift the mass, and of moving it right and left to bring the outer end

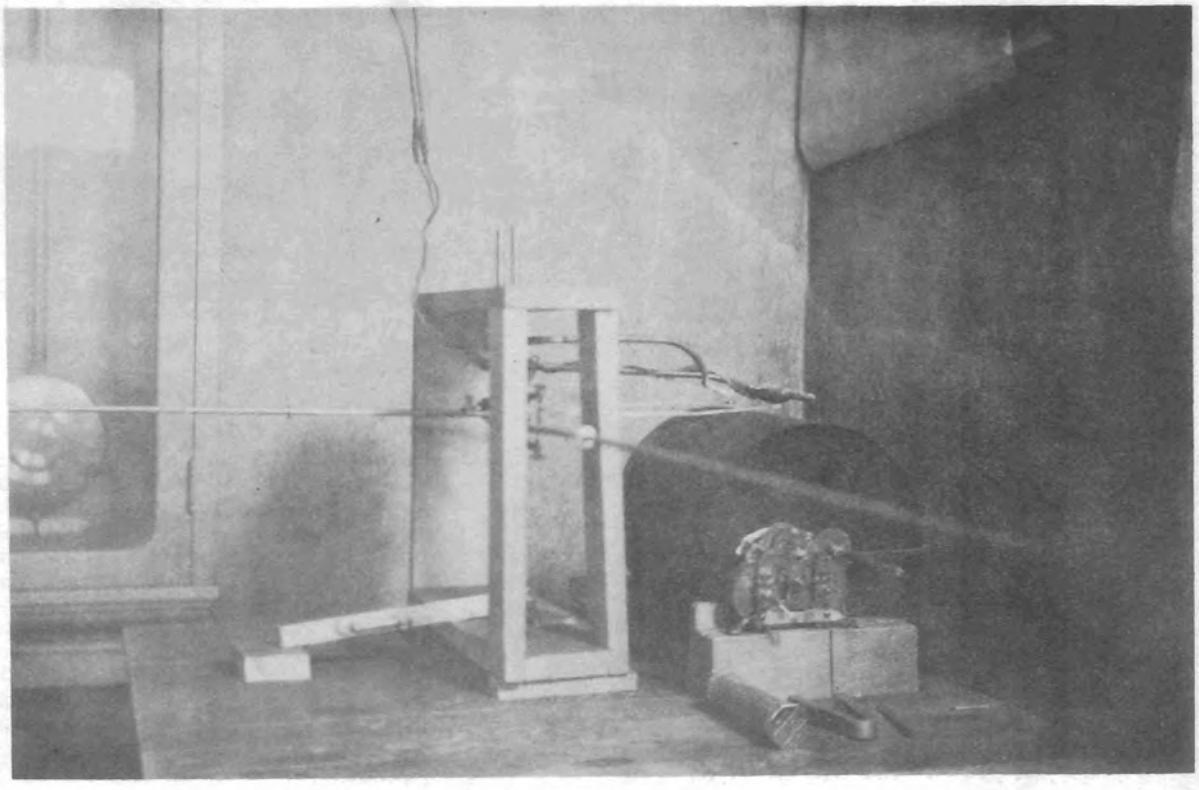
of the rod or boom to a medial position.

From all this there results a mass hung like a door with a boom protruding out from it, designed to record those oscillations or tilts of the earth at right angles to the plane of the suspension. The boom is braced by fine steel wires extending from its outer end to the cylinder. If the boom points to the east, the inertia of the mass registers the north-south earthquakes. Another similar pendulum is hung north-south to record the east-west components of the motion. Under each pendulum the system is damped, or prevented from free swaying on its own account, by sheet-aluminum vanes attached to the boom, protruding downward into a metal tank of automobile oil, so that with swinging of the pendulum, the vanes move edgeways in the oil. The little oil tanks, four or five inches square, not shown in the illustration, are supported by a removable stand in front of the pier.

The registering mechanism is shown in Figure 2. The recording drum is built on a steel spindle threaded with ¼-inch worm at the end away from the drive clock. This moves the drum lengthways in a sleeve at the driving end. The drive-clock is a Seth Thomas two-barrel power movement with rotation of spindle once in 30 minutes. The inner sleeve of the drum is set by a screw on the clockwork spindle. The worm end of the drum spindle rests on knife-edge wheels. Glassine paper is wrapped around the drum, pasted at the ends, smoked over a kerosene lamp, and the drum is set in place with the set-screw locking it to the clock. The writing lever-pen from the pendulum has a hinged stainless steel tip which rests on the smoke surface. The lever pens are made of aluminum. They are pivotted about a vertical axis near the end of the booms. The pen tips and the levers have pivots made of standard clock and watch balance staffs. Motion is transmitted from the boom to the lever by light metal T-bars, with the ends of the cross-bar in the boom and the lever respectively. The drum ends are made of ply-wood and the surface of pasteboard. The pen tips are magnetized, lifted to make a gap in the written line on the smoked paper every minute by an electro-magnet connected with the time-piece on the wall. The drum surface moves 30 mm. to the minute. The static magnification of the boom is five and of the writing lever forty, making the total 200. A marker pen attached to the plate supporting the drum and lever system, is made to write a line for a few minutes once a day on the side of the smoked paper, to be used as a datum line for measurement of wandering of the pendulums under tilting of the ground.

The free period of the pendulums is adjusted to seven seconds by moving the upper support of the piano wire in and out from the posts. The pen tips are laid back with a horseshoe magnet when the drum is changed. The change of paper is made once a day and the seismogram removed is passed through a bath of very dilute shellac and denatured alcohol, which fixes the smoke image of the line written by the pens. In the second photograph there is shown the second boom vanishing into the foreground, connected with the second pen by its T-bar impinging on an angle piece in the lever at right angles to the lever. In this way both pens, north-south and east-west, write during the day bands of lines side by side on the same paper. The paper is 12½ by 38 inches. Each line is interrupted by its minute and hour marks, the operator indicates the time of the starting mark by scratching it in the smoke, and simple counting for the succeeding hour marks on the smoke is all that is needed for timing an earthquake autograph that may appear. The light pasting of the ends of the paper on the drum is easily separated by a slender paper-cutter. The seismogram is dated and marked with its location before shellacking.

It will readily be seen from this account that any amateur with mechanical aptitude can build for himself a sensitive seismograph, and he can learn all about the technique of the science if he will consult the back files of the Bulletin of the Seismological Society of America, the headquarters of which are at Stanford University, California.



Feb. 2. Recording end of simple seismograph, showing booms of both north-south and east-west pendulums, pivot connections with writing levers, straight-wound electric magnet for marking time and the driving clock and drum, the latter with smoked paper.

THE VOLCANO LETTER

No. 434---Monthly, Department of the Interior, National Park Service, April, 1936

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

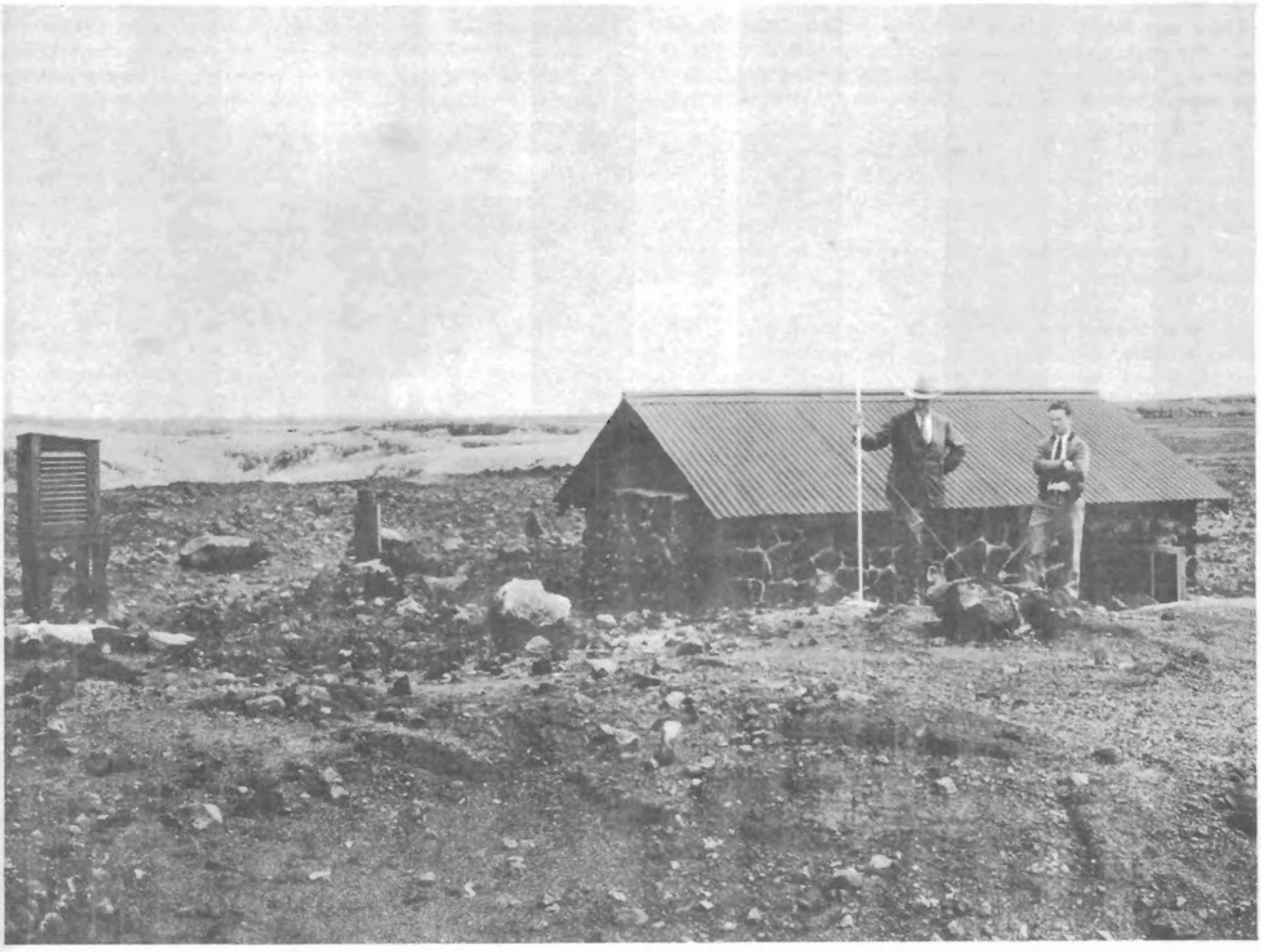
HAWAIIAN VOLCANO OBSERVATORY REPORT FOR APRIL, 1936

HAWAIIAN VOLCANO OBSERVATORY

A signal honor was conferred upon Director T. A. Jaggar early in the month in the form of an invitation from the Royal Society of London, England, to assist a scientific party it was sending to the island of Montserrat in the British West Indies to study an alarming earthquake crisis in progress there and to make necessary preparations for the protection of the population in the event of a possible volcanic eruption upon that island.

Permission was secured from the Secretary of the Interior and Dr. Jaggar sailed from Hilo on April 11 to connect with a vessel from Honolulu a week later, expecting to be away for at least two months. A complete report of this expedition will be published in a later issue of the Volcano Letter.

While in Honolulu, Dr. Jaggar delivered an illustrated lecture upon the recent eruption of Mauna Loa and the successful bombing experiment. The attendance was so overwhelming that many hundreds of people were unable to obtain admission and



Seismograph Hut southeast of Halemaumau. Thermometer shelter, rain gauge, bench mark, trig station, and in the hut both tilt-meter and two-component seismograph. Shows T. A. Jaggar, volcanologist, and H. H. Waesche, seismologist.

the lecture was accordingly repeated a few days later—also to a capacity crowd.

With Assistant Geologist Waesche absent on annual leave to the Orient, the Observatory was reduced to a skeleton staff and no more than usual routine operations could be carried out. These consisted, in the main, of the care of the seismographs with changing of the records: measurement of rim cracks and tabulation of all changes—and the usual compilation of meteorological data. The weekly reports, reading and study of the seismograms, preparation of other data and all correspondence were handled by Superintendent E. G. Wingate.

Repair and boxing of seismograph parts for transmission to Lassen National Park and the University of Hawaii was attended to during the month.

MAUNA LOA OBSERVATIONS

With Kilauea remaining quiet, attention was concentrated upon Mauna Loa throughout April. Blue fume rising from the source region of the recent eruption was plainly visible under favorable atmospheric conditions. Towards the latter part of the month, fume was observed in increased volume and density. A Navy aviator reported the source cones as smoking profusely and covered with brilliant sulphur deposits.

On the night of April 28 there were many unconfirmed reports of activity at the source cones—but since the seismographs indicated no activity at this time, it is probable that the reports owed their origin to the reflection of a brush or cane fire upon an overhanging blanket of cloud.

There was, however, some indication of increased activity during the week ending April 26th. This consisted largely of tremors—of which several were noticeable for their duration. Three spells, occurring on April 20, were of 12, 18 and 25 minutes duration respectively.

On April 15, a slight to moderate earthquake occurred at 8:28 a.m. It was felt more or less strongly in the Kilauea section —also at Olaa Village near Hilo, and at Hookena in South Kona on the west side of the island. It was sufficiently strong at the Kilauea Observatory to dismantle the east-west component of the Bosch-Omori seismograph—but no reports of damage were received.

Review of the seismograms from the Hilo, Kona and Kilauea stations indicated the epicenter as east of the summit crater of Mauna Loa and south of the recent eruption source about 15 miles from the Observatory. All other earthquakes occurring during the month were classed as very feeble or feeble.—E.G.W.

TABLE

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Moderate Earthquakes	Distant Earthquakes	Local* Seismicity
April 5	41	5	0	0	2	12.75
" 12	28	3	0	0	0	8.50
" 19	18	7	1	1	1	12.00
" 26	86	6	0	0	1	24.50
May 3	20	3	0	0	0	6.50

Epicenters of the following local disturbances were determined by means of seismograms from the station operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant quakes were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and, whenever such determinations were possible, the depth of focus is given.

April 1 at 11:13 am, very feeble, probable focus in vicinity of Cone Peak, about 1.6 miles SW of Pit seismograph.

April 4, at 4:24 am, very feeble, located 2.5 miles deep under SE rim of Kilauea Crater and 0.8 mile SW of Keanakakoi Crater. 19° 23.9' N; 155° 16.4' W.

April 5, 9:31 pm, very feeble, located 1.1 miles deep and 2.0 miles SE of the Volcano Observatory under S edge of Kilauea Iki. 19° 24.6' N; 155° 18.4' W.

April 9, 10:40 am, very feeble, located about 8.0 miles deep off the Hamakua Coast in the vicinity of Pepeekeo. 19° 49.5' N; 155° 5.5' W.

April 10, 7:21 am, very feeble, probable location under Kilauea Crater.

April 11, 9:50 pm, very feeble, thought to be located in vicinity of Pahala.

April 13, 6:46 am, very feeble, located 1.6 miles deep and 1.8 miles S of the Observatory under SE rim of Kilauea. 19° 24.4' N; 155° 15.8' W.

April 13, 6:59 pm, very feeble, probable location 1.5 miles SW of Pit seismograph in Kilauea SW Rift zone.

April 14, 2:13 am, very feeble, located 1.8 miles deep and 1.0 mile NE of Pit seismograph. 19° 24.8' N; 155° 16.3' W.

April 15, 6:03 am, very feeble, located 0.6 mile under Kilauea Crater and 1.4 miles SW of the Observatory. 19° 25.2' N; 155° 18.7' W.

At 8:27 am, April 15, a moderate earthquake occurred which was generally felt on the Island of Hawaii. Definite reports were received from Olaa, Hookena and the Hamakua district. It was felt rather strongly in the Volcano district. The east-west component of the Observatory seismograph was dismantled. Its origin was determined to be 18 miles under the SE portion of Kilauea Crater. 19° 24.0' N; 155° 15' W.

A feeble earthquake which occurred at 12:30 pm, April 15, was located 8.0 miles deep and 3.8 miles SSE of the Pit seismograph under Pali Kalanaokuaiki.

April 15, 6:47 pm, very feeble, located near the surface of Kilauea Crater floor and 0.7 mile ENE Pit seismograph. 19° 24.6' N; 155° 16.4' W.

April 16, 3:38 pm, very feeble, probable location under NE section of Kilauea Crater.

April 17, 7:44 pm, very feeble, located 0.9 mile deep under Kilauea Crater and 0.4 mile N of Keanakakoi Crater. 19° 24.6 N; 155° 16.0' W.

April 20, 1:24 pm, very feeble, probable location about 1.0 mile SW of Volcano Observatory in Kilauea Crater.

April 23, 1:08 pm, very feeble, probable location 0.9 mile W of Pit seismograph in Kilauea SW Rift zone.

April 25, 3:11 pm, very feeble, located 1.1 miles deep and 2.0 miles SE Pit seismograph in the vicinity of Ahua Kamokukolau. 19° 22.0' N; 155° 15.7' W.

April 26, 9:22 am, very feeble, located 8.5 miles deep and 1 mile SE of Makaopuhi in Kilauea SE Rift zone. 19° 21.5' N; 155° 10' W.

April 27, 3:47 am, very feeble 8.0 miles deep under ocean floor 5 miles NW of Hoopuloa. Reported felt at Hoopuloa. 19° 15.5' N; 155° 57.4' W.

April 29, 8:29 am, very feeble, probably located 2.0 miles SW Pit seismograph in Kilauea SW Rift zone.

May 2, 7:09 am, very feeble, probable origin under Mauna Loa SW Rift about 8.0 miles from summit.

Spells of harmonic tremor began recording at the Observatory as follows: March 30, 4:46 am, for a duration of 17 minutes; April 5, 11:22 pm, 4 minutes, and on April 20, at 5:00 am, 9:30 am, 1:21 pm, 1:26 pm and 6:24 pm for 25, 5, 3, 14, and 11 minutes respectively. This represents the greatest amount of harmonic tremor within the same time limits since the first three days of the Mauna Loa eruption in November, 1935.

Microseismic motion of the ground at the Observatory was

* For local seismicity see Volcano Letter 371.

strong April 6 and 7, it was moderate March 30, April 5, 8, 9, 14, 15, 17, 18 and April 27 to May 3, inclusive. The remainder of the month it was light.

Four teleseisms, or distant earthquakes, were recorded during the month. Preliminary waves began to register at 3:51 pm, March 31, for the first of the series. The origin was 5380 miles from Kilauea. The reported location was 46 miles below the ocean floor, N of the Celebes Island. 2.5° N; 123.5° E. The secondary waves of the second teleseism began recording at about 8:30 pm, April 1. Its location was undetermined. The preliminary tremors of a teleseism began recording at 6:47 pm, April 18. The estimated distance from the Volcano Observatory was 3745 miles. The reported location was in the vicinity of the Solomon Islands. 9° S; 15.6° E. The secondary waves of the last recorded teleseism of the month began at 1:01 pm, April 23. The reported location was in the vicinity of the Aleutian Islands. 50.5° N; 17.8' E, 62 miles deep. H.H.W.

Tilting of the Ground

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Hale-



Measuring a crack locality on Halemaumau rim with steel tape over permanent metal studs in the rock.

maumau the algebraic sum of radial tilts for two clinoscope locations towards or away from the Pit.

At the Obseravtory the total accumulated for the year ending May 3 was 4.13" N and 2.66" E.

TABLE OF TILT

		HALEMAUMAU CLINOSCOPE STATIONS		
Week Ending	Observatory	West	Southeast	Pit Resultant
April 5	0.76"S 70°W	2.62"N 42°W	2.66"S 5°E	3.59" from
April 12	0.60"S 47°W	3.87"S 85°W	9.72"N 2°E	3.58" toward
April 19	1.50"N 14°E	1.49"N 48°W	6.16"N 24°E	2.04" toward
April 26	2.48"S 66°W	6.38"N 20°W	5.22"S 55°W	1.49" from
May 3	1.10" N 66°E	4.41"N 74°W	6.54"N 9°W	1.66" toward

H.H.W.

UNIVERSITY OF HAWAII SUMMER SESSION

The Summer Session of the University of Hawaii this year changes its Volcano School to a program of research only. This is in charge of Dr. Thomas A. Jaggar, Professor of Volcanology in the Graduate Division. As volcanologist in the national park Dr. Jaggar has developed a number of experimental problems during the last twenty-five years. One is the location underground of earthquake centers, produced by some kind of impact or jolt. Another is the possible gradual change, or sudden change, from time to time, in such gases as those at the Volcano House sulphur bank. Both of these things, if measured and interpreted promptly, and more accurately, may indicate the coming of eruptions. The foretelling of eruptions is one important result of volcano study.

Accordingly in August, two investigators from the Physics Department of the University will start using new instruments at Kilauea. The shops of the Volcano Observatory have been renovated for their use. A University Laboratory has been arranged in a special building. The workers are Assistant Professor Stanley S. Ballard, specialist in spectroscopic work, and Instructor Iwao Miyake, skilled in electrical instruments.

Dr. Ballard will collect the Sulphur Bank gases, and also the gaseous products in Kilauea Crater at certain localities. The collection will be with pumps and tubes specially designed to exclude outside air, which tends to be sucked in when steam condenses in ordinary vacuum tubes. The object is to design field apparatus which will be effective in retaining pure volcanic gas, after collecting such gas not only at solfataras, but even at flame vents in lava where gas is burning. There is no such lava available now, but many experiments may be made in preparation for such active periods as last December. The tubes of gas will be carried back to Honolulu laboratories. There the gas will be carefully subdivided into numerous samples for use in discharge tubes, in partial vacuum, illumined by an electric discharge. These will be photographed for the spectrum of rare gases. This work is done with a large quartz prism spectrograph.

It is planned to make negatives of numerous gases, and if results are satisfactory, to establish a new routine at the Observatory. This will consist in collecting the gases at regular intervals and sending them to Honolulu to see if there is any change. It is also hoped to obtain for the Observatory a small model spectrograph which may perhaps be used in the field for direct recording of gases. The object of all the work is to start a movement for more precise use of the spectroscope in volcanology.

The work of Mr. Miyake is based on experiments started more than a year ago under the direction of Assistant Professor Willard H. Eller at the University of Hawaii. His experiments were designed to record the exact time in fractions of a second of blasting explosions at Moiliili quarry. Then an electrically equipped seismograph was set up at the Physics Laboratory some distance away recording the exact time that the earthquake shock from the explosion reached the University. According to the difference in times of the quarry measurement and the university measurement, the rate of travel of the earth wave could be discovered. Mr. Miyake has been improving the apparatus for doing this kind of exact work electrically.

It is now proposed that he bring his apparatus to the Volcano Observatory where thirty or forty actual seismic disturbances occur every week. The seismologic work of the earthquake investigators at the Observatory has taught how to locate earthquake centers approximately. We need to know exactly how fast and in which direction the earth waves travel for a Mauna Loa earthquake, a Kilauea earthquake and others. It may be possible with simple apparatus buried in the ground to compel an earthquake wave passing a place five miles away to send a wireless message to the Observatory and record its time on an Observatory chronograph. If the same earthquake when it reaches the Observatory makes another record on the same chronograph, the time of travel for the five miles will be known. It is hoped by electrical work of high precision to discover the travel times of different kinds of earthquake waves. The Volcano Observatory is a natural laboratory for this work, because it has many movements of tilting and trembling all the time.

These investigations will continue until the end of September, and Dr. Jaggar and Mr. Waesche will bring to bear the resources of the Observatory records on the two kinds of work. The University of Hawaii has recently published four papers from the Volcano Observatory by Wilson, Jones, Powers and Wentworth on ground movement, seismology, soils and geography of Hawaii. The appointment of Professor Jaggar brings the resources of the Kilauea laboratories and their large accumulation of unstudied records within the orbit of a research university graduate school. This contact of National Park and University to make available the natural resources of the nation to scholarship and education, is along the lines of what other national parks are doing.

THE INFLUENCE OF VOLCANIC RESEARCH IN HAWAII

The by-products of the popularity of our volcanoes have been the National Park and its improved roads; the Mauna Loa road and camps; the military recreation camp; the Chain of Craters road; the Haleakala road and Park; the Hilo-Volcano road; the Uwekahuna Museum; the projected Hilo-Kona road; increased tourist visitation effects of this on Island business; the coming expansion of the National Park and its road system; the pleasure visitation of Mauna Loa and Kilauea by airplanes; the gradual opening of Mauna Loa to visitation and science; the completion of topographic maps of the whole island; science guiding the police, the ranchers to safety, and the public to sight-seeing, through ten lava crises. All of these things we have seen grow up during the last twenty-five years.

What Did the Science Do?

It measured continuously the materials and the movements coming forth out of the three active volcanoes Kilauea, Mauna Loa and Hualalai. Having this experience led in part to the **social** benefits enumerated. The latest of these is the **social** contract with a British presidency, another volcanic island, seven thousand miles away.

Larger Meaning of Measuring the Earth

The following are results of measuring the earth's powers: Boulder Dam, the Panama Canal, the Tennessee Valley Authority, the Mississippi Flood Control, the Great Lakes Drainage Project, the Golden Gate Bridge, Earthquake Insurance, Earthquake-proof construction. Geophysical prospecting for oil. Finding radium, caesium, selenium, tungsten, vanadium, uranium, rhodium, fluorine, helium and nitrogen. Prospecting the soil for its real meanings, a far cry from the days of guano and Chilean nitrate. Developing the air drill, the Diesel tractor, the new explosives for moving mountains. Tying up the earth in roads, pipe lines, telefer wires and aqueducts such as the world never

dreamed of. Penetrating fogs. Steering by sea-bottoms. Mapping by airplanes And traversing Antartica by the tools of modern science.

All of this is the work of that man of science called the engineer. He has become utterly **Social.** He has a fine ethics like the physician. This is because his responsibility is for public safety, and for justifying a **measurement** of the earth that he has made for service. It makes him sober, to know that he has the responsibility of serving **socially** a million people in the future.

There is a still larger social aspect to the sciences of the Earth. We hear much of extravagance, of colossal expenditure, and the question "Who is going to pay for it all?" But pay for it in what? If the labor of the nation is doing it, and the result is doing the nation good, why not look back and say "Who has ever paid for the free franchises, free farms, free rights of way, and free public utilities of the American people? Who has ever paid science for improving the earth for man's occupancy? What modern men of science ever work for profit?

Is anyone now asking who will ever pay the great inventors for the extravagance, the colossal expenditure in blood and brain and spirit, of Jesus, Lincoln, Goethals, Walter Reed, Gorgas, Darwin, Faraday, Pasteur or Curie?

Do we realize that one man or woman somewhere and somewhen, produced a future billion dollars, in prospecting the Earth with his brain, for each great engineering and social achievement, among such constructive discoveries as those I have enumerated, like the Boulder Dam or the rare metals? For the Boulder Dam is just as much a discovery as the North Pole, and requires a hundred times more courage and brains.

The bonded debts of the world can never be repaid in coins. Money is the blood of youth and the labor of men. The earth furnishes some raw material and power for blood and labor to use. There is no other wealth than the good-will of men, and the self-sacrificing measurements of progressive learning, in economizing happily the energies of men. The energies of men are banded together to discover moral power and earth power. By moral we mean "MORES," improved human habits. This is the whole of education.

The Earth is yielding much to the chemist. It is not being made to yield enough of its resources to the engineer. Our sea-bottoms are not mapped, our deserts and mountains are almost untouched, our oceans are not working for us, our sunlight is not yet running our cars and planes. We live too much in city laboratories. There is here a gigantic field for the employer of labor.

Science is not yet extricating Society from its foolish city congestions: and sending MEN out in vast employments, to discover THE EARTH, with the new **social** tools of modern physics and engineering. Here is a chance for the benefactors of mankind to rethink social science. T. A. J.

THE VOLCANIC AREA OF BUFUMBIRA, UGANDA

The following excerpts and paraphrasings from "The Volcanic Area of Bufumbira" by A. D. Combe and W. C. Simmons,



The west tilt cellar on Kilauea crater floor, housing clinoscope pendulum for daily readings.

published in 1933 by the Geological Survey of Uganda, shows many striking similarities to descriptions of Kilauea at various times.

The volcano Nyamlagira is in about 1° 25' south latitude and about 29° 12' longitude east of Greenwich in Belgian territory. The summit is 10,026 feet above sea level. It rises gently to a height of about 5,000 feet above its base. The mountain has been built by the piling up of successive lava flows apparently of large volume and in a very fluid state.

The caldera or crater depression is over a mile in diameter and it is surrounded by a vertical wall from 200 to 300 feet high, which is breached on the northwest side by a gap between 500 and 600 yards wide. The main part of the floor of the depression is formed by a flat terrace with a general crescentic outline and possibly 800 yards in width over its widest part. The breach in the caldera wall is on a level with this terrace, and thus one can walk onto it from the slopes of the mountain without climbing down. This terrace is in part bordered by a narrower one from 100 to 150 yards in width and about 100 feet lower. From the lower terrace there is a descent of perhaps 100 feet to an irregular elliptical depression which occupies the greater part of the southern portion of the caldera, the floor of which is covered with ropy and pahoehoe lava. It is on this that the pools of liquid lava are situated. On the south-east side of this depression there is a direct drop from the upper terrace and on the southern side a direct descent into it from the high wall surrounding the caldera as a whole. In the southwest corner of the depression there is a pit from 150 to 200 feet lower with an irregular elliptical outline, vertical sides, and perhaps from 250 to 300 yards across. The floor of this pit is the lowest part of the caldera. The southwest side of the pit is formed by the main wall of the caldera which is there from 400 to 450 feet high, while the west side descends directly from the upper terrace.

At the time of Combe's visit nine centers of activity could be seen. The largest was a pool of boiling lava, perhaps 70 yards in width, from the surface of which jets of lava, probably caused by the escape of juvenile gases, issue at frequent intervals. The rim of the pool has been built up above the level of the adjacent floor. The others have built up small cones from which large volumes of steam and sulphurous gases are given off. Liquid lava was seen in several of these cones. In many places jets of gas and steam issue through the surface of the ropy lava. At the time of his visit small intermittent streams of liquid lava issued from under the solid ropy rock and dropped over the steep wall into the lowest part of the caldera. These did not reach the bottom in a liquid state, but became partly solidified and dropped as lumps of scoria which have formed a large pile along the base of the wall resembling the ash heap of a power plant.

A striking feature of the structure of the volcano is that the wall surrounding the caldera, the terraces and the sides of the lowest depression are formed by a homogeneous lava in horizontal layers. The edges of the layers present a generally jagged surface cut off vertically, which suggests that they have been broken off by subsidence within the caldera. In many places large strips and blocks have broken away from the edges of the terraces. Over the floor of the terraces lines of fumaroles issue from fissures, the gases of which appear to be mainly of steam and sulphurous types, but in one place there was a strong smell of sulphuretted hydrogen. Native sulphur has been deposited adjacent to some of the fumaroles.

It is quite clear that the present-day caldera has been formed by the direct subsidence of the upper part of the volcano. The mode of origin of the flat layers of homogeneous rock, none of which exhibits columnar structure, is not so clear.

No recent flows have been derived from Nyamlagira itself that reach any considerable distance down the mountain side, for the lower slopes are clothed with dense forests.

On the whole the activity of Nyamlagira appears to have been rather quiet, but that violent explosions have taken place is indicated by the large number of bombs and ejected blocks, some of which are as much as two feet in diameter, scattered over the slopes of the mountain and over the upper terrace.

The lavas of Nyamlagira are mainly medium-grained leucite-basanites in which porphyritic crystals of plagioclase, augite, and a brownish olivine are set in a holocrystalline groundmass.

One of the fundamental tenets of science is that like causes produce like results. Nyamlagira is a volcano which, like Kilauea and Mauna Loa, yields chiefly basic, fluid lavas. Consequently the resulting volcano and volcanic structures and topography are much alike.

The matter abstracted above regarding Nyamlagira reads very much like various descriptions of Kilauea written during the nineteenth century.—H. S. Palmer.

EARTHQUAKES IN UNITED STATES

It is not generally realized how wide has been the range of seismic disturbances in what now comprises the United States of America. Practically every state in the Union has recorded earthquakes within the last hundred and sixty years and Indian tradition constantly refers to such occurrences in earlier times. Students of the geology of the North American continent can point to abundant evidence of many great upheavals that have occurred within comparatively recent geologic time.

Probably the greatest earthquake of modern times in North Amrica was the catastrophic series of shocks that commenced early on the morning of December 16, 1811, and affected an area extending from Cairo, Missouri, along both banks of the Mississippi River through Arkansas to the vicinity of Vicksburg in the south. While the greatest destruction occurred within these limits, the effects were felt over an area of 50,000 square miles while the vibrations were clearly perceived by persons in upper Canada as well as in Detroit, Washington, and Boston. This actually means that the shocks of this great earthquake were felt over a million square miles, half of the area which became the United States of today.

We take the liberty of reviewing a most interesting account of this great disaster by Thomas Ewing Dabney, appearing in a recent issue of the magazine section of the New Orleans Times-Picayune. The gifted pen of the author has conjured up a vivid picture of the occurrence.

"Trees," he says, "began to move on a windless day, then clashed together like flailing clubs. High bluffs leaned forward, poised in fearful dignity, bowed into the river with enormous splashes. Waves of earth rolled over the land; rose higher and higher and burst. Back flowed the Mississippi; waterfalls raced above its surface, cast their roarings into the chaos.

"The shocks began soon after 2:00 a.m. on December 16. The crash of falling chimneys, the groaning and creaking of house timbers and the noise of overthrown furniture drove the inhabitants of New Madrid outdoors. A horrible darkness pressed down from the sky; strange odors released by the breaking earth filled the air. Daybreak came with dreadful rumblings; the ground rose and fell so that one could not stand erect. Forests fought and fell; a welter of sound rose from the tortured rivers."

Throughout that day and the next, the shocks were incessant but steadily decreasing in intensity. There was a savage renewal on January 23, 1812, followed by two weeks that were almost normal. But there was a renewal of the upheaval on February 7 and for many days after that the earth was shaking constantly. The shocks gradually ceased, but for more than twelve months afterwards recurrences kept the people in a state of alarm.

"One observer who attempted a systematic record counted 1,874 shocks between December 16, 1811, and March 15, 1812. This count was made in Louisville, far away from the main disturbance. Unfortunately no record was kept in New Madrid where, as one man said, 'the world seemed to be blowing up with loud explosions.'

"Passengers on the river steamer New Orleans which visited the devastated areas, described the enormous changes which had taken place.

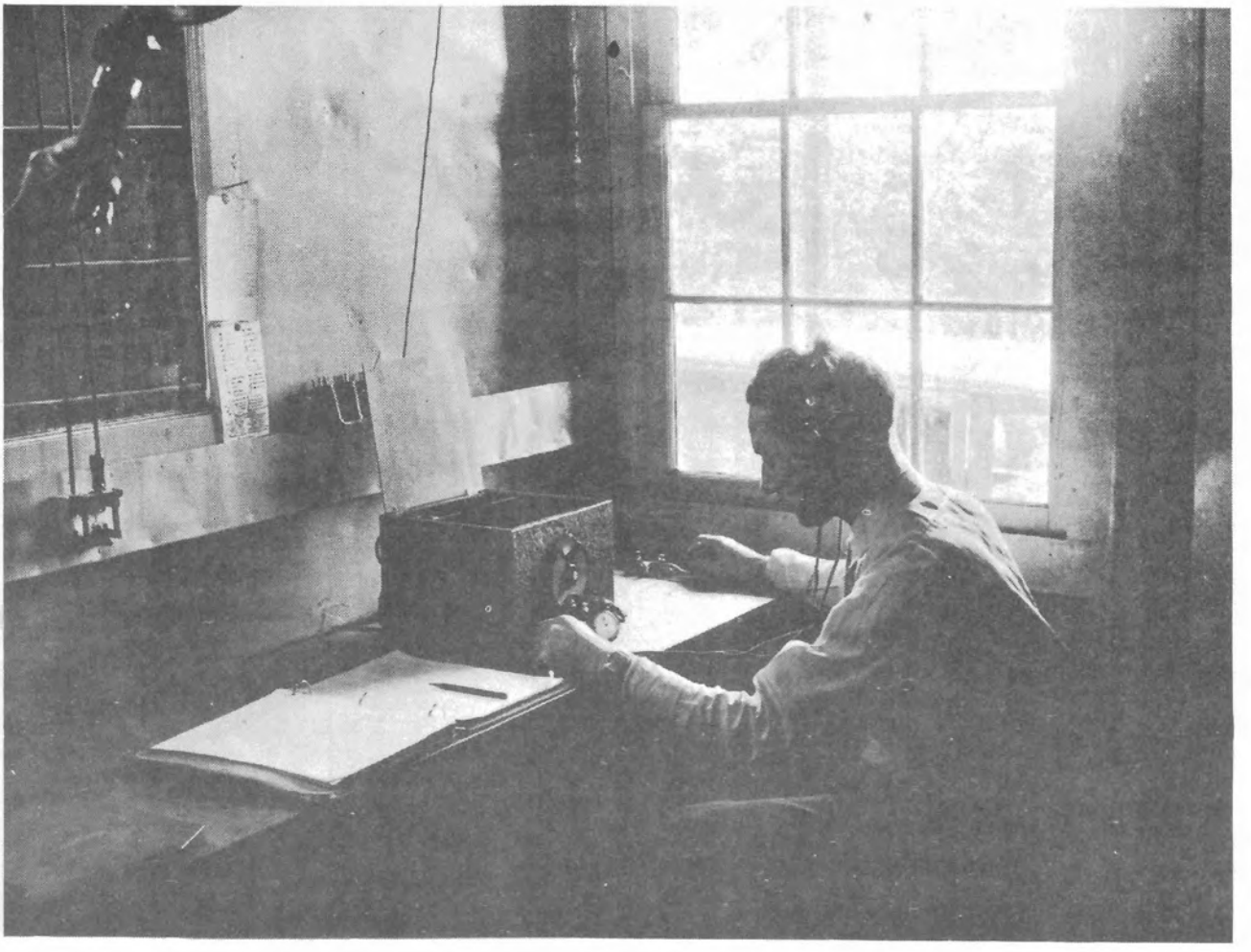
"New Madrid itself, they found, was practically destroyed. Much of the town had been swallowed by the river and the houses on higher ground had collapsed. Further down the river, the prosperous agricultural community of Little Prairie (the Caruthersville of today) had become a desolate waste of sand and water spewed up from the splitting earth. The whole channel of the Mississippi River appeared to be up-tilted so that the water ran backward towards its sources for more than an hour and until the current broke its way through the upthrust material, the river was a crazy thing. One account speaks of a great waterfall six feet high and half a mile wide, apparently formed by the water being violently sucked into some chasm in the river's bottom. The same narrator speaks of another fall of the same character eight miles below New Madrid.

What are now called the "sunken lands' 'of western Tennessee, southwestern Missouri, and northwestern Arkansas covering hundreds of square miles were made in this subsidence to which Reelfoot Lake also owes its origin.

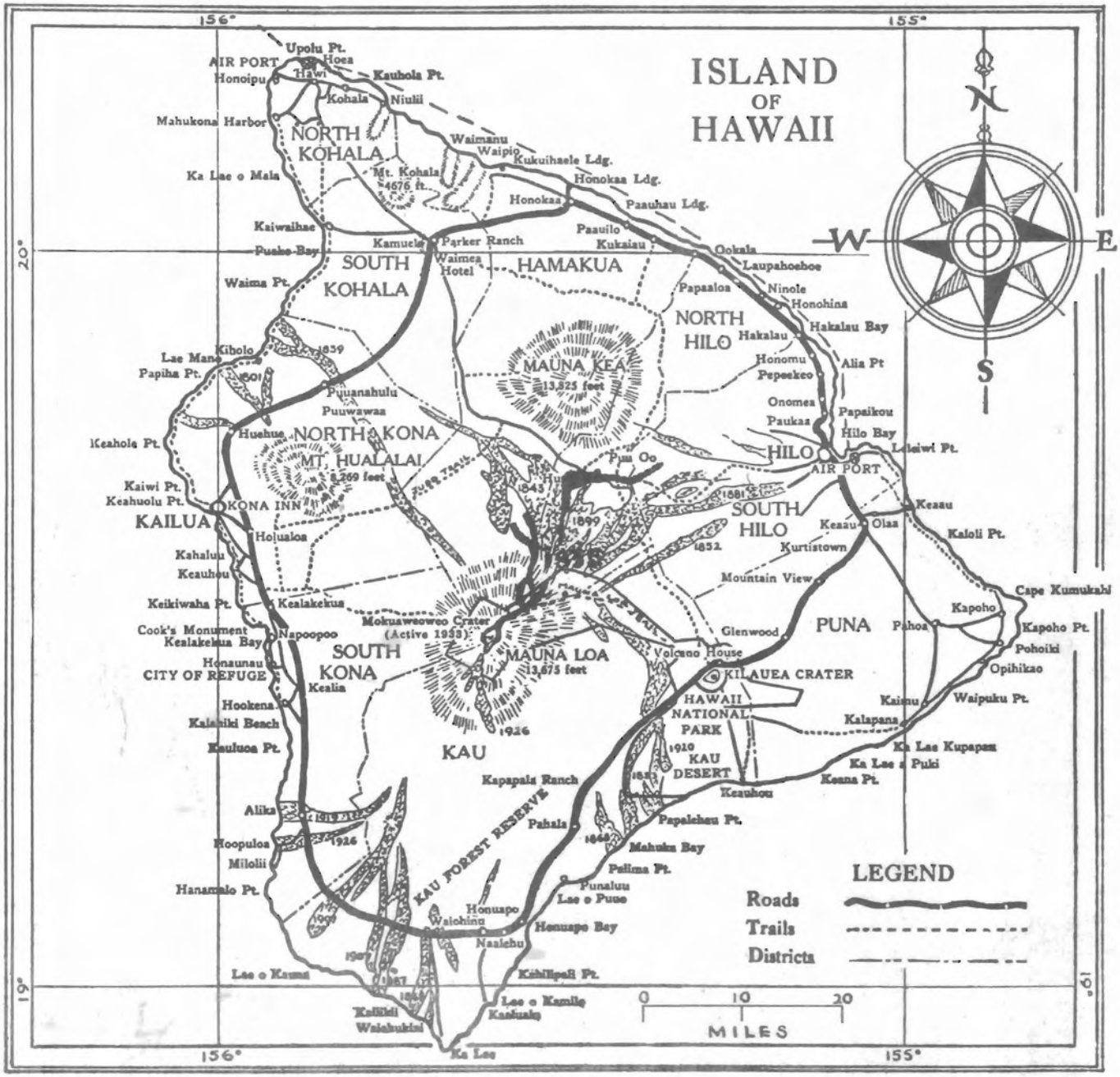
In other sections, land was raised and navigable streams went dry. A fifteen-mile stretch or territory in southeast Missouri, once a part of the flood plain, was raised nearly twenty feet. There was widespread fissuring, due to the opening of the earth after the main wave-motion had swept through the surface strata. Mr. Dabney tells us that some of these openings were several hundred feet long and were so numerous that in some sections men felled trees against the direction of the movement and clung to them to prevent being engulfed. It is worthy of note that while many of these fissures were twenty feet in width, their depth was shallow and reached only to the quicksands underlying the surface alluvium. Through many of these fissures tremendous ejections of sand, water and carbonaceous material took place, burying the fertile land. At one place the skull of the long extinct musk ox was thrown out on the surface and was later placed in the Museum of Natural History in New York.

The loss of life, owing of course, to the scanty population, was astonishingly small. Should such a shock occur in these present days of closely crowded people and tall buildings, most of which are anything but earthquake proof, the loss of life would be almost too appalling to contemplate. Congress passed an act allowing the sufferers from the disaster to locate on an equivalent amount of land in any other part of the public domain open to entry. But after a year of frequent earthquake shocks, the survivors had become so accustomed to them that of the five hundred certificates issued only twenty were located by the original claimants in person.

Mr. Dabney, in his able article, has made a valuable contribution to American literature on this important subject.—deV-N.



Short wave radio set in Volcano Observatory for receiving time signals from Washington and imprinting them on seismograms through a telegraph key.


ISLAND
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Mahukona Harbor
NORTH
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Kamuela
Parker Ranch
Waimea
Hotel
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Paauilo
Kukaiau
Ookala
Laupahoehoe
Waima Pt.
Papaaloa
Ninole
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NORTH
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Hakalau
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Lae Mano
Papiha Pt.
1801
MAUNA KEA
13,825 feet
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Pepeekeo
Alia Pt
Puuanahulu
Puuwawaa
Onomea
Paukaa
Papaikou
Hilo Bay
Keahole Pt.
Huehue
NORTH KONA
MT. HUALALAI
8,269 feet
HILO
AIR PORT
Leleiwi Pt.
Kaiwi Pt.
Keahuolu Pt.
KONA INN
KAILUA
1843
1881
SOUTH
HILO
Keaau
Olaa
Kaloli Pt.
Holualoa
1899
1852
Kurtistown
Kahaluu
Keauhou
Mountain View
Cape Kumukahi
Keikiwaha Pt.
Kealakekua
Kapoho
Mokuaweoweo Crater
(Active 1933)
Cook's Monument
Napoopoo
Glenwood
PUNA
Pahoa
Kapoho Pt.
Kealakekua Bay
SOUTH
KONA
MAUNA LOA
13,675 feet
Volcano House
Pohoiki
Honaunau
CITY OF REFUGE
Kealia
KILAUEA CRATER
Opihikao
Hookena
HAWAII
NATIONAL
PARK
Kaimu
Waipuku Pt.
Kalaniki Beach
1926
Kalapana
Kauluoa Pt.
KAU
1920
KAU
DESERT
Ka Lae Kupapau
Ka Lae a Puki
Kapapala Ranch
1823
Keauhou
Keana Pt.
Alika
KAU FOREST RESERVE
Pahala
Papalekau Pt.
Hoopuloa
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1868
Mahuka Bay
Milolii
Pelima Pt.
Hanamalo Pt.
Punaluu
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Honuapo
Waiohinu
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MILES

THE VOLCANO LETTER

No. 435 — Monthly, Department of the Interior, National Park Service, May, 1936

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

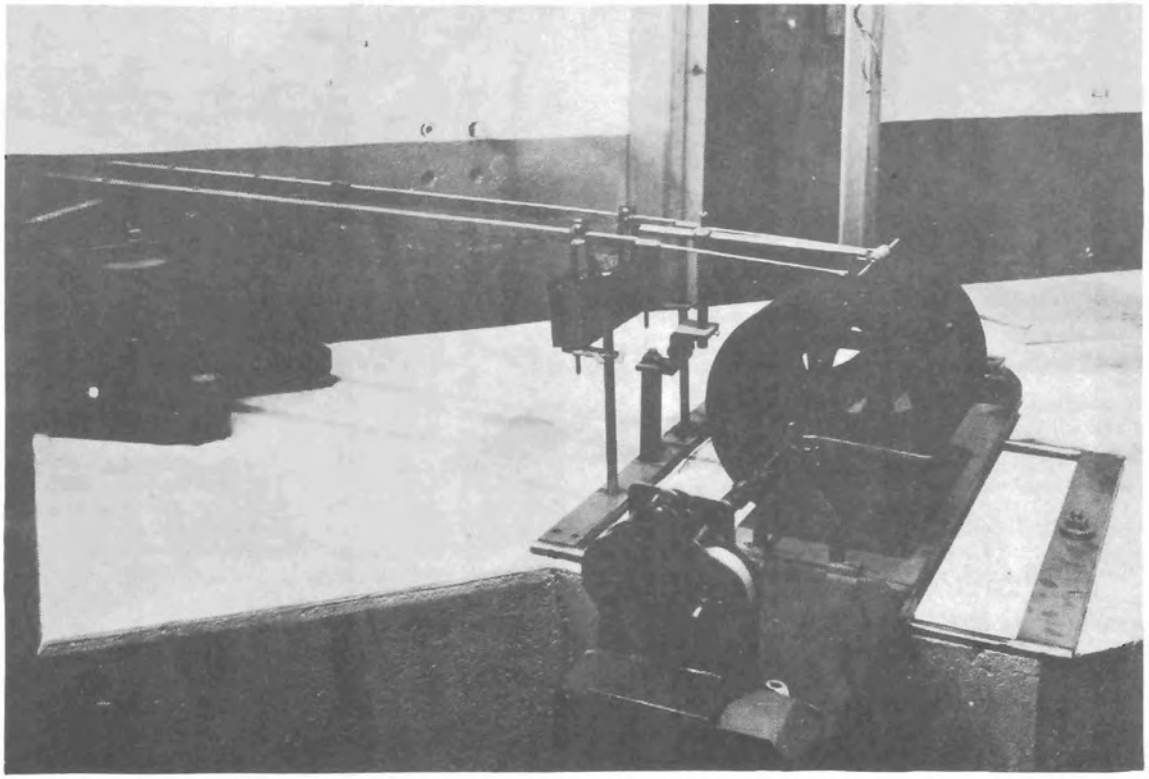
HAWAIIAN VOLCANO OBSERVATORY REPORT FOR MAY 1936

HAWAIIAN VOLCANO OBSERVATORY

Routine work at the Volcano Observatory was ably carried on during the month by H. Yasunaka, who at times was assisted by Asao Okuda, carpenter and mechanic, both Volcano Research Association employees. This work consisted of caring for seismographs, changing of records, recording meteorological data, recording tilt at clinescope stations and caring for the Observatory grounds, buildings and equipment.

In the absence of both Volcanologist T. A. Jaggar and Assistant Geologist Waesche, weekly reports were written by Superintendent Wingate. Dr. Jaggar is on an expedition to the island of Montserrat in the West Indies by invitation of the Royal Society of London. He is studying a volcano on that island which has given indications of a possible eruption at an early date. H. H. Waesche was absent on annual leave from the park on a trip to the Orient, but returned to resume his regular duties at the Observatory May 23.

M. S. Seger, Associate Landscape Architect of the National Park Service, accompanied Mr. Waesche on the trip to the Orient. An inspection of Japanese national parks was made, including visits to the volcanic parks of Aso, Unsen and Fuji.



Strong-motion seismograph with low magnification to record those earthquakes that are too big for the other instruments.

Other parks visited were Inland Sea and Nikko. A visit was made to the national park headquarters in the Home Office Building in Tokyo, where members of the administrative staff were met. Dr. Tamura of the Japanese National Parks presented Mr. Waesche with a bomb from the summit of Mt. Fuji. This is a "sister rock" to the one presented to Ambassador Grew, in ceremonies in Tokyo, as a present from the Japanese national parks to those of the United States. The Mt. Rainier rock was part of the exchange of courtesies of this nature between Mt. Rainier National Park and the Japanese National Parks. Sakarajima Volcano was visited. Inspection was made of the seismological institute of Tokyo Imperial University as well as the seismological research department of the same institution. In addition to Japan, China, Manchukuo and Korea were visited.



SEISMOGRAPH ROUTINE 1
Checking the clock time against a stop-watch, Uwekahuna Seismograph.

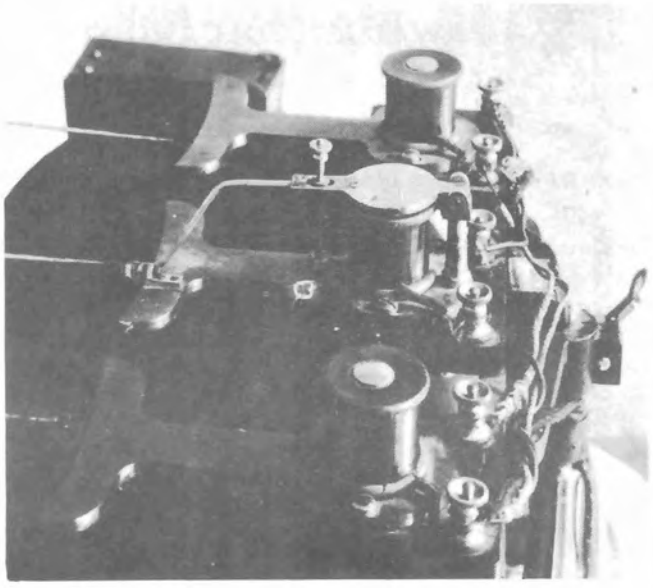
KILAUEA AND MAUNA LOA OBSERVATIONS

Kilauea and Mauna Loa have both been quiet throughout the month. As late as May 16 fume was reported seen at the rift cones of the 1935 eruption of Mauna Loa. Sulphur deposits around the cones were said to be increasing. No fume has been noticed the latter part of the month. Fuming at the sulphur spots in Halemaumau continues about the same. Slides have been few and small.

Seismic activity has been comparatively moderate. There were feeble earthquakes May 2, 7 and 26, none of which was reported felt. All other disturbances were classed as very feeble or as tremors. Spells of continuous tremor of 5 minutes duration were reported for May 8 and 9. Most of the disturbances for the month originated in the Kilauea area.

Crack measurements showed abnormal opening of No. 46 on the NE rim of Halemaumau near the point where a large section of the rim disappeared into the pit in March.

Addition was made to the Observatory equipment of a Leitz precise level.



SEISMOGRAPH ROUTINE 1a:
The pens for east-west, north-south, and up-down, pendulums. The spools are electro-magnets lifting the pen-tips every minute.

TABLE

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant Earthquakes	Local* Seismicity
May 10	19	4	1	0	7.75
" 17	22	3	0	0	7.00
" 24	41	3	0	1	11.75
" 31	39	9	1	1	15.25

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at the Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant quakes were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and whenever such determinations were possible, the depth of focus is given.

* For local seismicity, see Volcano Letter 371.

May 6, 8:55 pm, very feeble, located 0.6 mile deep in Kilauea Crater, 1.0 mile SW of the Observatory. 19° 25' 2N; 155° 16' 2W.

May 7, 6:51 am, very feeble, located 1.9 miles deep in Kilauea Crater near SE rim. 19° 24' 7N; 155° 15' 9W.

May 7, 8:07 am, feeble, located 0.4 mile deep in approximate center of Kilauea Crater 1.5 miles SW of the Observatory. 19° 24' 9N; 155° 16' 5W.

May 10, 6:57 pm, very feeble, located 1.2 miles deep under W portion of Kilauea Iki. 19° 25' 0N; 155° 15' 1W.

May 14, 4:42 pm, very feeble, located 1.6 miles deep under SE rim of Kilauea Crater and 0.4 mile W of Keanakakoi Crater. 19° 24' 2N; 155° 16' 3W.

May 14, 9:04 pm, very feeble, located 1.2 miles deep and 0.6 mile S of the Twin Craters and 1.2 miles E of Kilauea Crater rim. 19° 25' 4N; 155° 14' 6W.

May 16, 6:35 am, very feeble, probably located under S rim of Kilauea Crater.

May 21, 2:31 pm, very feeble, probably located in Kilauea Crater.

May 21, 2:46 pm, very feeble, located 1.7 miles deep and 0.4 mile N of Keauhou Ranch House. 19° 26' 6N; 155° 16' 9W.

May 25, 10:46 am, very feeble, located 1.1 miles under Waldron Ledge, NE rim of Kilauea Crater. 19° 25' 5N; 155° 15' 5W.

May 26, 11:48 am, feeble, located 1.4 miles deep under Waldron Ledge. Same as preceding quake.

May 28, 3:09 am, very feeble, located 9.0 miles deep in the Hilina-Kapukapu Fault system, 3 miles N of Keauhou Point. 19° 19' 3N; 155° 14' 8W.

May 30, at 6:19 am, very feeble, probably located in NE rift of Mauna Loa.

The preliminary waves of a teleseism began recording at 4:45 pm, May 19, and the indicated distance from the Observatory was 3630 miles. The reported location was in the vicinity of the Solomon Islands 7° 7S; 159° 6E. On May 28, at 8:35 am, the secondary waves of a distant earthquake began to register. The reported location was about 900 miles off the SW coast of Honduras. 9°N; 103° 5W.

Microseismic motion was moderate, May 10, 11, 15, 19; the remainder of the month it was light.



SEISMOGRAPH ROUTINE 2
Removing the drum covered with smoked paper.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations West	Southeast	Pit Resultant
May 10	0" 83 N 27°E	4" 77 N75°W	4" 47 N 36° E	2" 87 from
" 17	0" 57 N 54°W	5" 19 S 78° W	2" 27 N 30°E	4" 25 from
" 24	0" 85 N 4°W	1" 01 S 23°W	2" 27 N 5°W	1" 33 toward
" 31	1" 24 S 82°W	2" 21 N 58°W	5" 57 S60°W	1" 14 from H.H.W.



SEISMOGRAPH ROUTINE 3
Installing a fresh drum and pulling over the pen points with a horseshoe magnet.

Tilting of the Ground

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending May 31, was 4" 20N and 1" 9E.

THE METHODS OF THE HAWAIIAN VOLCANO OBSERVATORY

From trying everything experimentally, in 1912, to a routine of measurement in 1936, there was growth of method at Kilauea in the effort to discern what a volcano is doing underground. One of the impressive results of the Observatory approach to volcanoes, is the failure of underground lava to announce its intentions. Newcomers to volcano science always think a hot crack at the edge of a live crater will get hotter when an eruption is impending. They solemnly measure with a thermometer. The eruption comes and goes, and nothing whatever happens to their hot crack.

Or it may be earthquakes. The lava gushes up in the bottom of the pit, and immediately the tremors may become fewer than before. Or the shakes temporarily flare up, if measured very close to the crater, and then die away before the eruption ends.

The idea that a beautiful fever chart would show everything, before the disease breaks out, is a dream doomed to disappointment. Lava is there all the time. It is a substance which suddenly releases thermal and kinetic energy, apparently from great depths. But **how,** chemically and physically, this release proceeds, is still a mystery.

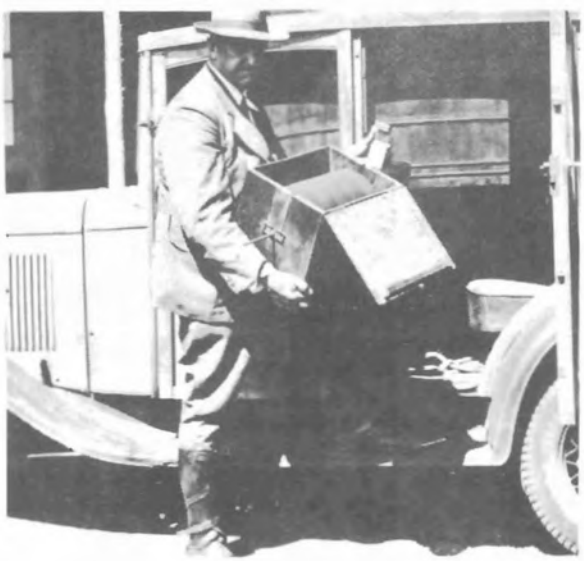
The mere finding out that the lava is there all the time is a real discovery. It is proved by the sudden geysering of gas and red hot froth at the edge of a plug in the pit bottom, when a new eruption begins. By experimental drilling into Kilauea crater we found places growing hotter downward. By watching the walls of the pit when a big cave-in occurred, we found red hot avalanches 600 feet down. And when a thick new flow cools off, we find the under parts stay hot for years.

Comparing the dull times when the lava in the pit was sluggish but liquid, and the dull time now when it is crusted and hard, there is no essential difference in behavior: sulphurous hot gas always rises, the rim cracks move, the earth tremors increase and decrease, and the top of the mountain is a flexible shell that tips inward, or tips outward. Always the ground is **alive,** and very different from the terra firma of Honolulu.

Four things, weather, earthquakes, slow movement, and gas emission are the things we set ourselves to measure after twenty-five years of Observatory work. First, the measured changes of the weather. We must know what weight of rainwater loads the mountain, what pressure and temperature of the air may make changes in the rock, and how wind and storm and sunshine may deceive us in viewing steam or vapor from cracks.

Second comes the locating of earthquakes. This looked like a delightful prospect in 1912. We would find out who felt the quakes most. We would make a nice little instrument for everybody. Then Kona would tell us the December quake there was of Grade 2, Kohala would have Grade 1, Hilo would show Grade 6, and Kilauea would be Grade 8. Ergo, Kilauea was strongest, and Kilauea lava made the shake.

But nothing like that happened. When it came to **feeling,** people in one end of Hilo town felt quakes that nobody noticed in the other end. With a magnifying seismograph in Hilo and at Kilauea, Kilauea got many tremors that did not show at all in Hilo. When a nice little earthquake was felt in Kohala, Kona, Hilo and at Kilauea, all at the same hour, and surely the same shock, nobody felt it more strongly than anybody



SEISMOGRAPH ROUTINE 4
Carrying case for drum, transported by car to be changed, and the record varnished.

else: it seemed to have been felt equally all over the island. This was most disconcerting. It raised such baffling questions as "What is an earthquake, anyway?" And so we were led to phases, and compression, and angle of emergence, and vertical component, and depth of origin. And to the question, what is an origin? Is it a snapping open, or a scraping slip, or a closing bump?

The entire science of seismology was painfully reviewed and investigated and experimented with; complicated seismographs were set up and discarded and tried anew; at Kilauea, Hilea, Kona, Puu Waawaa, Waikii, Honokaa, and Hilo. Trials of simplified shock recorders were made. The telephone was used to send the same time-keeping to different stations. Wireless was installed to get the same time-signal to each station. Some instruments were made to write with a beam of light on photographic film. And all of this had a **geographical** motive, to



SEISMOGRAPH ROUTINE 5
Fixing the smoked seismogram with varnish bath.

cover the whole island. The result was a deadlock, for the whole island had to be covered with skilled physicists, an obvious impossibility. The workers were faithful amateurs, but a seismograph properly requires a highly trained scientist.

So the Observatory muddled through, getting a result here and a result there, and an improving list of earth movements. The dream of 1912 faded away. The harnessing of an island with amateurs is still awaiting a suitable instrument. Three stations have been maintained at corners of a triangle. Theoretical seismology has improved, and the routine is shown in the accompanying photographs. The horizontal pendulum three-component seismograph, with smoked-paper records, is still used, and the earth has written thousands of autographs. The locating of a place underground, where an outbreak appeared above ground, was done on Mauna Loa in 1935. This was the result of careful studies for two decades by faithful seismologists. But we are still far from knowing exactly what an earthquake is.

The third quest of the Observatory concerns finding out what is the secular strain under which a volcano is laboring. Not only does the ground shake, but it rises and tilts. This involves a long engineering program, again harnessing an island. Kilauea Crater has been proved to move more, through a period of twenty years, than Hilo. The movements up and down were big, before and after the pit exploded in 1924. They were up before, down afterward. The mountain swelled for ten years, then its top was let down suddenly. At the same time the lava was withdrawn, water must have rushed in below, and steam gushed out. Probably the lava flowed out under the ocean.

All of this story from 1912 to 1926 was told by R. M. Wilson in engineering language, "Ground Surface Movements at Kilauea Volcano," (University of Hawaii Research Publications No. 10, 1935, 56 pp. with maps and charts). The work has been done repeatedly by levelling, tide gauge reading, triangulation, setting up nets of flags, bench marks and towers across the volcano, and by comparing the results of 1897, 1912, 1922, 1927 and other times.

This has been supplemented by the pendulums of the Observatory, writing on smoked paper, from day to day, many years. This writing showed tilting of the ground away from Kilauea very strongly after 1918. And there was strong tilting back again towards the crater in 1924. The Volcano House rose bodily about two feet during the years before 1924. It

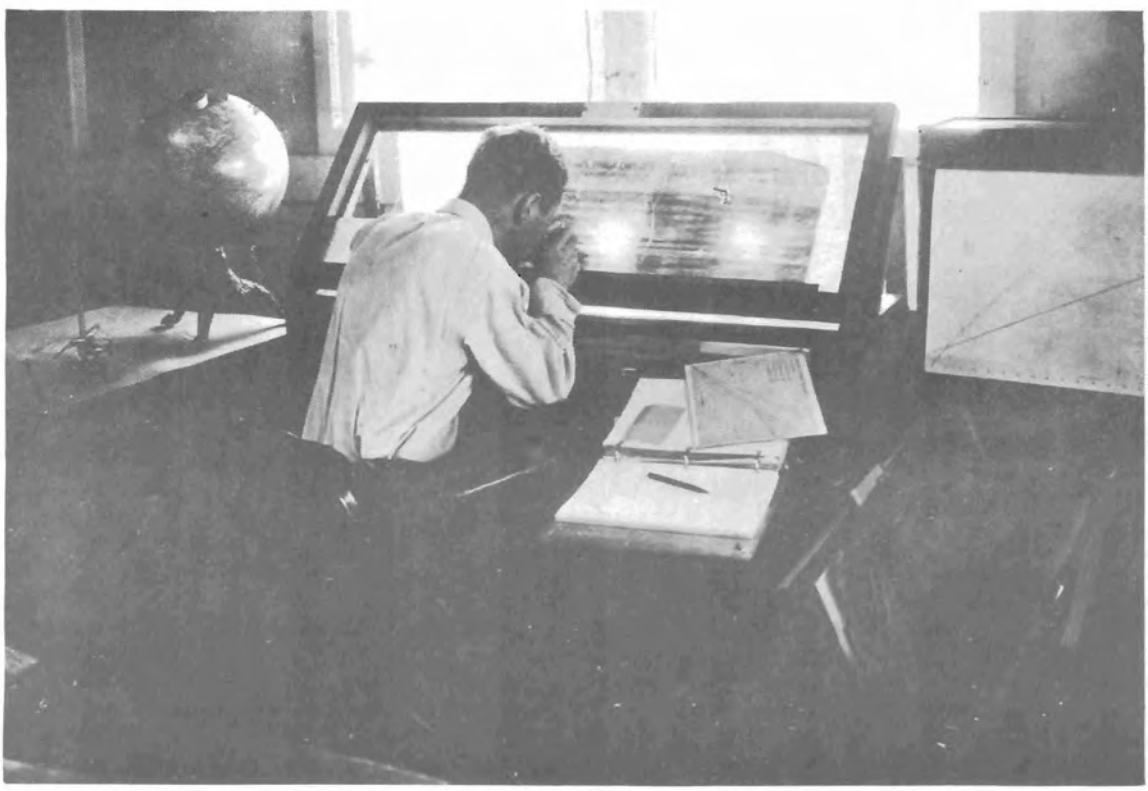
sank as much after the lava collapsed in 1924. And the edge of the inner pit Halemaumau sank **thirteen feet,** and the walls on opposite sides of the crater **approached each other.** This was proved by measuring horizontal angles with a transit, in the triangulation.

All of these laborious discoveries might have applied equally to the great crater on the summit of Mauna Loa, if men and means had been available, before and after the eruptions of Mauna Loa in 1914, 1916, 1919, 1926, 1933 and 1935. What Wilson began at Kilauea has gradually been added to by the weekly and monthly measurements at the Observatory, with level and transit. This was set in motion by E. G. Wingate, who succeeded Wilson as topographic engineer. Some of our illustrations show the surveying instruments used to line up the changing geometry of the crater.

The fourth and most elusive high ambition of the Hawaiian Volcano Observatory, in its methods of studying the chemistry and physics of the inner earth, deals with the emission of gases, especially hydrogen. To collect new or "juvenile" gas from live lava, to trap and analyze it, to develop a technique that can be applied at any sulphurous volcanic vent or actual flame, is the volcano student's dream. Whenever the mighty fountains play above a gushing rift on Mauna Loa, there are flames. When the gushing stops, there are steam jets and sulphur and selenium and alum. The so-called "solfataric" mild activity (Sulphur Bank) of quiescent volcanoes, is still **in communication by gas ducts** with potentially live lava below. We see such gases on the sun, and both volcano and sun yield free hydrogen. Free hydrogen at high temperature is not to be trapped. No laboratory container will restrain it. At lower temperature it has been trapped at Kilauea, in small percentages. Its oxide, water vapor, appears in large percentages. The lower the water vapor, the higher the hydrogen. This ratio leads to the suspicion that if spectroscopic or other method could find out, what is the Hawaiian gas before it vanishes in flame, we might discover hydrogen to be the prime mover of all volcanism. It is certainly a primary element in all chemistry, and in astro-physics: and water vapor is nothing more than burned hydrogen.

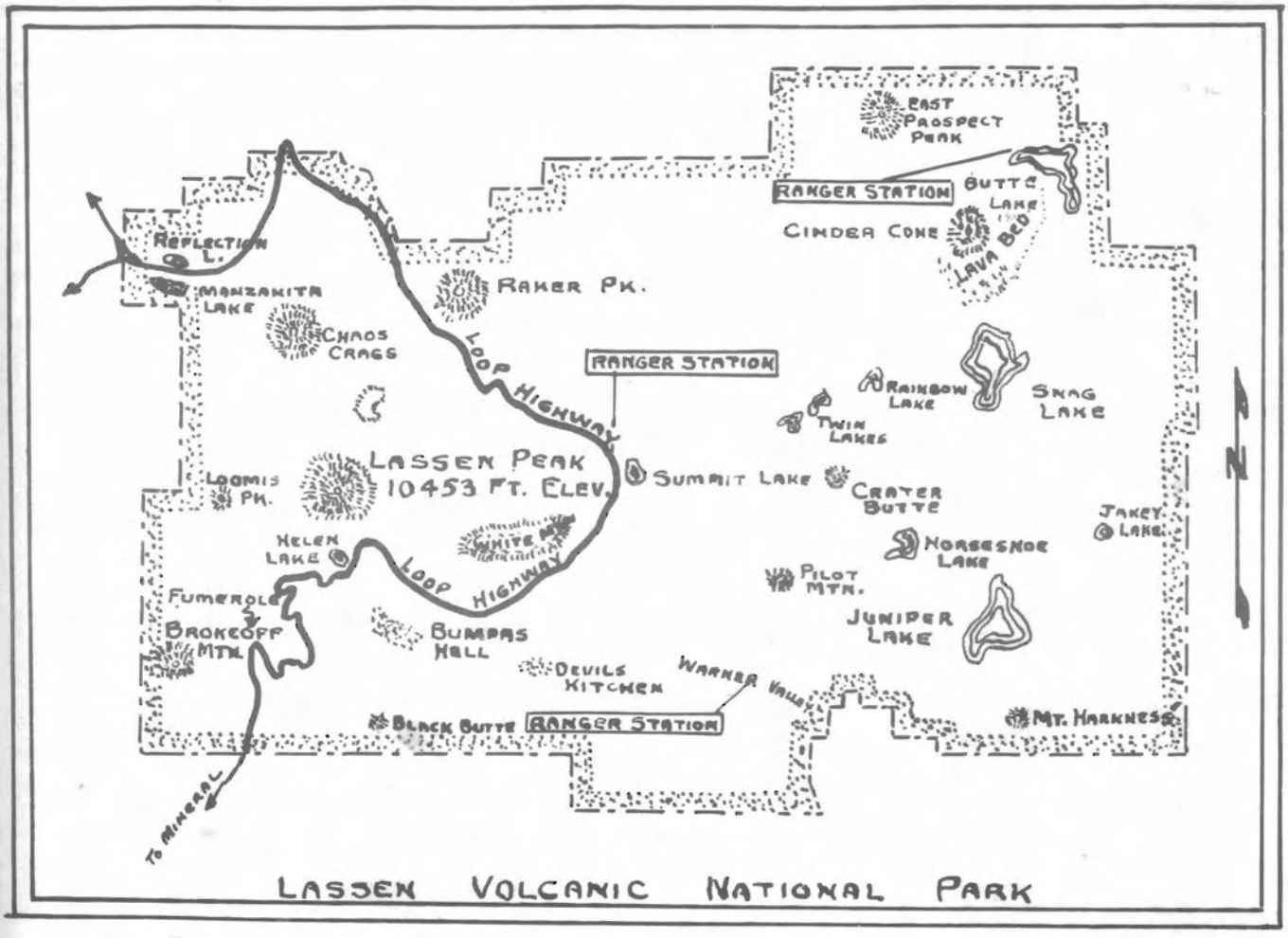
The methods of attacking the gas problem are illustrated in some of the photographs. Vacuum tubes are thrust behind a flame, or into a sulphurous crack, and the tip is melted or broken deliberately. The glass is sealed and the contained gas carried to a laboratory for analysis. This work is now being improved by special researches by the Physics Department of the University of Hawaii; in which the spectroscope will play a part.

The illustrations appearing in this issue of the Volcano Letter show the seismograph routine; other apparatus in regular daily use will be shown in succeeding issues. T. A. J.



SEISMOGRAPH ROUTINE 6

Studying and measuring the seismogram, calculating the epicentral location, and entering in record book.



EARTHQUAKES IN LASSEN VOLCANIC NATIONAL PARK DURING MAY, 1936

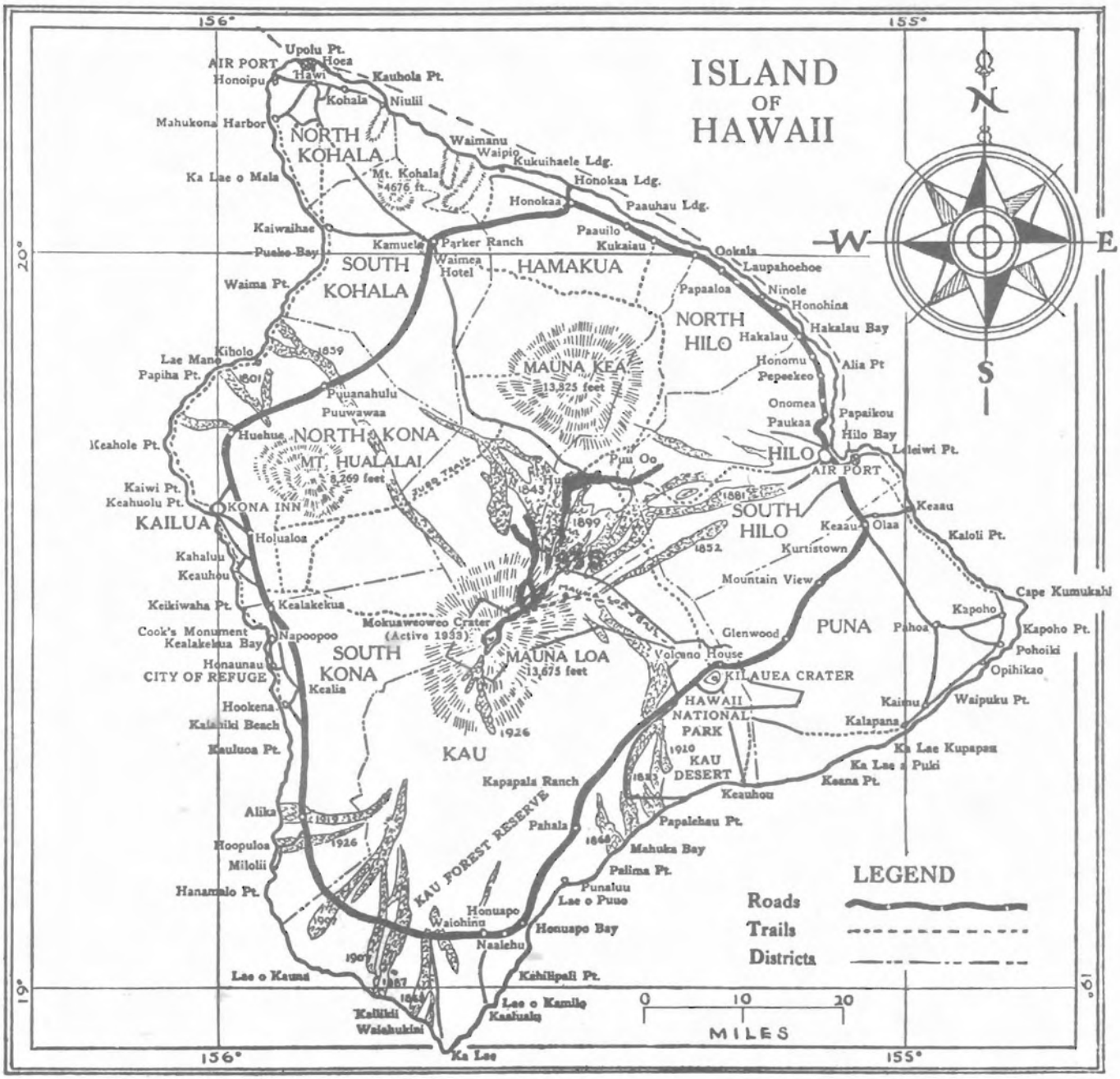
Carl R. Swartzlow
Park Naturalist

More earthquakes occurred in May, 1936, than in any previous month. The shocks were all of low intensity. Only four were of No. 5 intensity, according to the McAdie Scale, and the rest were less severe.

The earthquakes were accompanied by considerable tilt during the periods of greatest activity.

With a few exceptions the epicenters were located within the park boundaries. Most of the shocks did not center under Lassen Peak as many people believed but were located along fault zones in the eastern part of the park. The Warner Valley fault zone was the center of greatest activity, with some minor shocks felt in the Butte Lake District.

The hot spring activity has remained practically normal throughout the month. On April 30, four columns of steam rose from the crater of Lassen Peak to a height of between 200 and 300 feet, but activity on the peak has been normal since that day, although a little abnormal activity was noted in Bumpas' Hell early in the season. Conditions in the Devil's Kitchen in Warner Valley have been normal during the period of observation.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Cape Kumukahi
Keikiwaha Pt.
Kealakekua
Kapoho
Cook's Monument
Kealakekua Bay
Napoopoo
Mokuaweoweo Crater
(Active 1933)
Glenwood
PUNA
Pahoa
Kapoho Pt.
Honaunau
CITY OF REFUGE
SOUTH
KONA
MAUNA LOA
13,675 feet
Volcano House
Pohoiki
KILAUEA CRATER
Opihikao
Kealia
Hookena
HAWAII
NATIONAL
PARK
Kaimu
Waipuku Pt.
Kalahiki Beach
Kalapana
1926
Kauluoa Pt.
1920
KAU
DESERT
Ka Lae Kupapau
Ka Lae o Puki
Kapapala Ranch
1823
Keana Pt.
Keauhou
Alika
KAU FOREST RESERVE
Pahala
Papalehau Pt.
Hoopuloa
1926
1868
Mahuka Bay
Mililii
Palima Pt.
Hanamalo Pt.
Punaluu
Lae o Puue
Honuapo
Waiohinu
Honuapo Bay
1907
Naalehu
1907
Lae o Kauna
1887
Kehilipali Pt.
1868
Lae o Kamilo
Kaalualu
Kalilikli
Waiahukini
Ka Lae
LEGEND
Roads
Trails
Districts
0
10
20
MILES

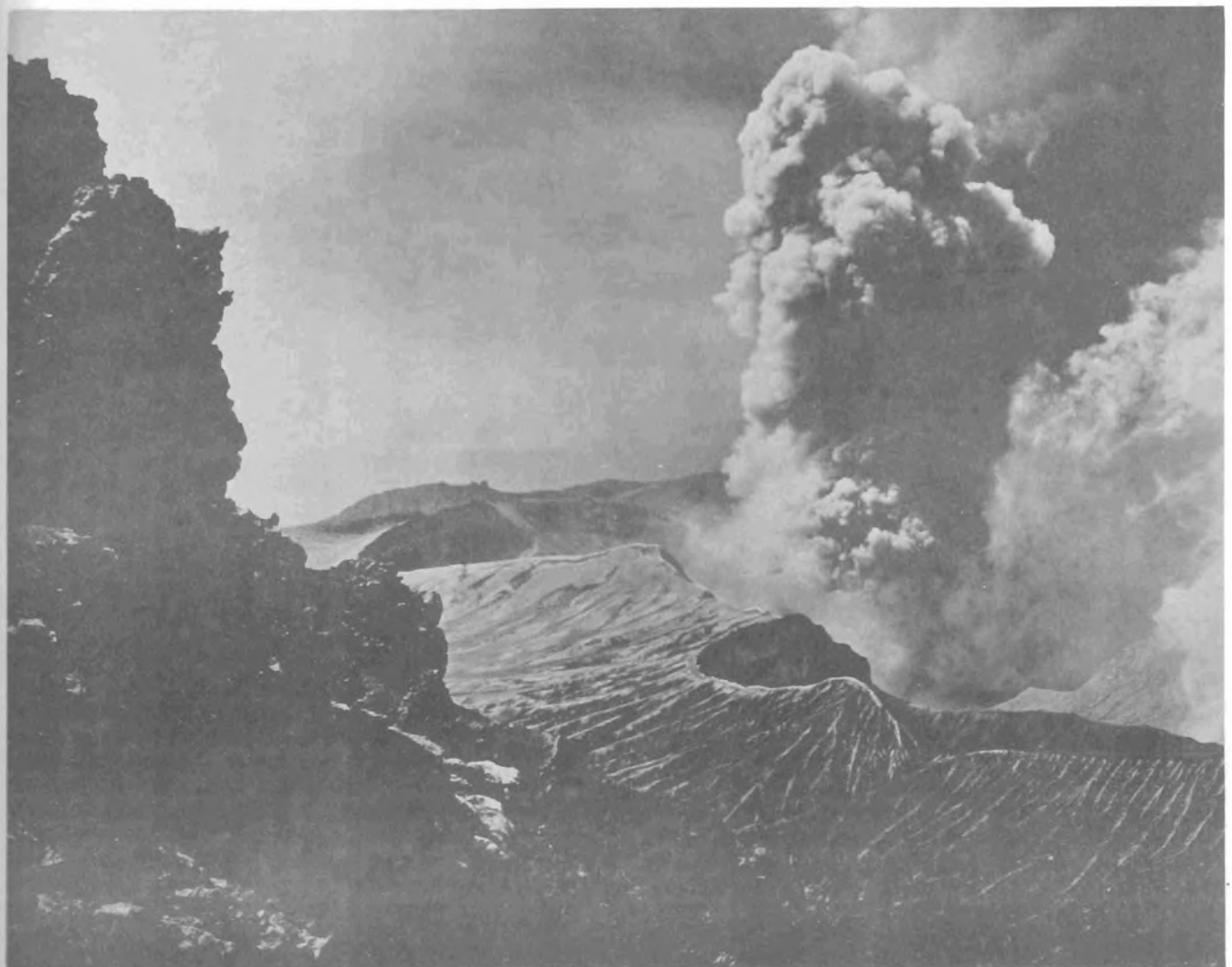
THE VOLCANO LETTER

No. 436—Monthly, Department of the Interior, National Park Service, June, 1936

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JUNE, 1936



Naka-dake Crater, Pit No. 2, of Mount Aso Volcano, Japan

REPORT OF VOLCANO OBSERVATORY FOR JUNE, 1936

The normal schedule of routine activities has been carried on at the Volcano Observatory during the month. Regular records have been kept of daily activities and of observations of Mauna Loa and Kilauea. The usual daily trips to the seismograph stations and tilt stations for observations have been made. Daily meteorological records have been kept.

The Volcanologist, Dr. Jaggar, is still absent on a scientific expedition studying conditions at Montserrat for the Royal Society of London.

Mauna Loa and Kilauea have been quiet throughout the month. June 14 ended a week of exceptional quiet at Kilauea, during which no rock slides from the walls of Halemaumau were reported. This is the first time that such has been the case for over a year. Active sliding was again resumed the

week of June 28. A party accompanied by Ranger Murray made a trip to the summit of Mauna Loa June 13 to 16. They report that there had been considerable activity in the NE section of Mokuaweoweo, the summit crater, during the November, 1935, eruption. The trail, one-half mile below the crater, was covered by a new lava flow. Fuming, though greatly diminished, was continuing at the source cones at the 1200-foot elevation and deposits of sulphur were reported large around their base. All trails and markers in the NE portion of Mokuaweoweo have been obliterated. The summit rest house was unharmed.

Seismic activity has been moderate and fairly consistent as shown by the numbers of disturbances for the successive weeks of 32, 32, 21 and 32. Of these one was a feeble quake on June 4, 26 were very feeble shocks and the remainder was made up of tremors. Three minutes of continuous tremor began at 11:26 P.M. June 2. On the morning of June 30 at 3:59 twenty-eight minutes of continuous tremors began recording. Most of the disturbances are of Kilauea origin.

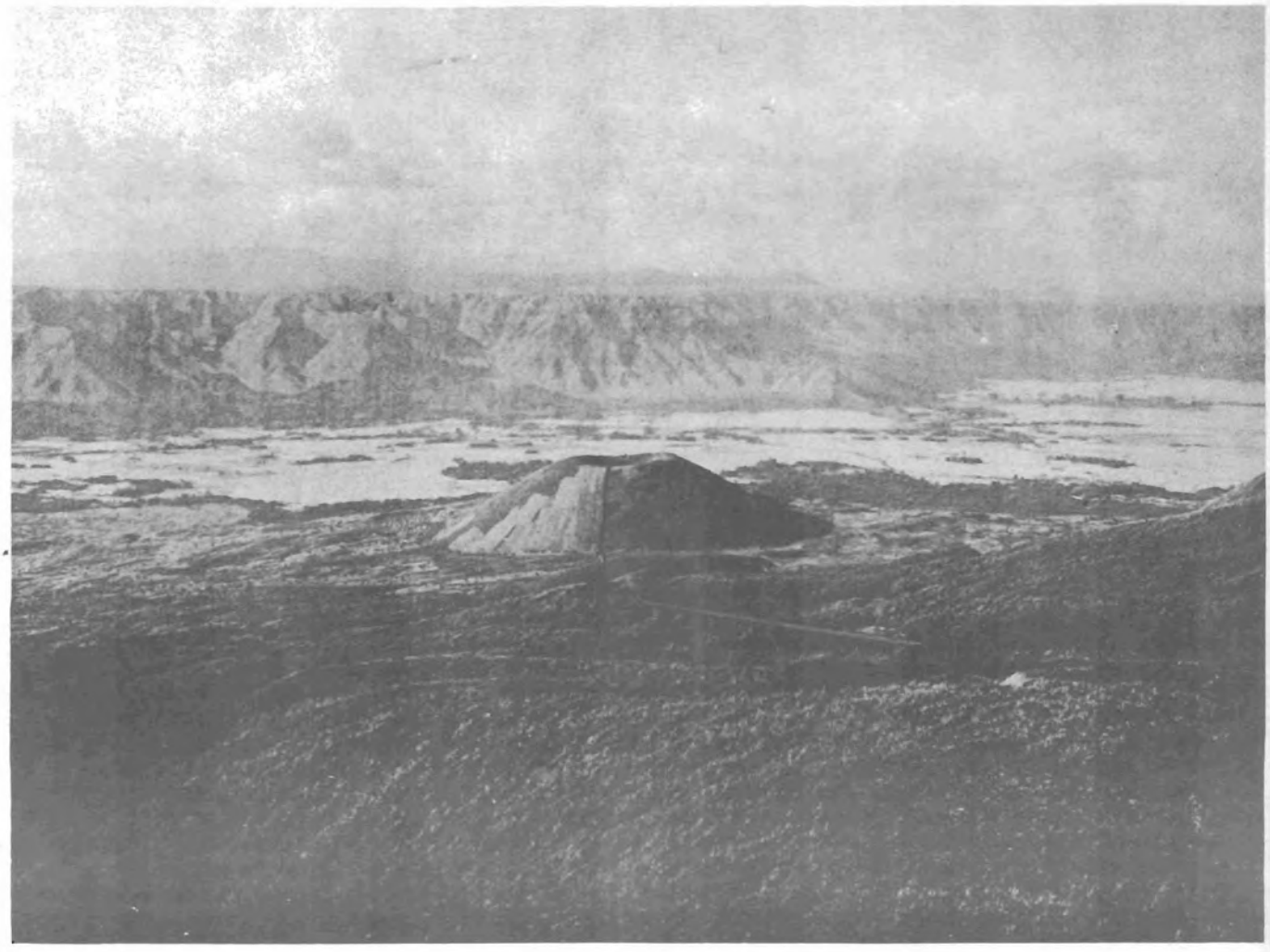
Crack measurements around Halemaumau for the month showed very little change except number 46, located on the NE rim, which has consistently opened at an abnormal rate of 4.5 millimeters per week.

Mr. F. Chase of the Department of Geology, Harvard University, visited the Park on June 10-17. He spent considerable time studying at the Observatory and made a trip to the summit of Mauna Loa. He had been two years in Australian gold mining work and was returning to Cambridge to resume his duties there.

TABLE

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant Earthquakes	Local* Seismicity
June 7	25	8	1	1	11.25
" 14	28	4	0	0	9.00
" 21	17	4	0	0	6.25
" 28	23	9	0	0	10.25



View of Mount Aso Crater, Japan

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant quakes were located with the aid of the seismograms from stations at Hilo and Kealake-



Boiling Mud at Hot Springs, near Beppu, Japan

kua. The disturbances began at the times indicated and whenever possible determinations of depth of focus have been made.

June 1, 6:33 pm, very feeble, probable location in Kilauea Crater.

June 1, 7:53 pm, very feeble, located 2.5 miles SSW of Pit seismograph station in Kau Desert. 19° 22' 3N; 155° 18' 0W.

June 3, 8:13 pm, very feeble, located 1.5 miles deep in Kilauea Crater 1:0 mile SW of the Volcano Observatory. 19° 25' 2N; 155° 16' 1W.

June 4, 1:21 pm, very feeble, located 2.5 miles under SE rim of Kilauea Crater 19° 24' 7N; 155° 15' 8W.

June 4, 3:18 pm, very feeble, located 1.8 miles deep in Kilauea Crater, 1.0 mile SW of the Volcano Observatory. 19° 25' 2N; 155° 16' 1W.

June 4, 3:21 pm, feeble, located 3.0 miles deep in Kilauea SW Rift zone 0.4 mile west of Halemaumau in vicinity of the Rift Cones. 19° 24' 6N; 155° 22' 8W.

June 5, 4:09 pm, very feeble, located 1.2 miles under Pit Seismograph in Kilauea Crater. 19° 24' 3N; 155° 17' 0W.

June 7, 9:53 pm, very feeble, located 0.8 mile deep under SE rim of Kilauea Crater. 19° 24' 5N; 155° 15' 9W.

June 7, 11:28 pm, very feeble, located 1.2 miles under N rim of Kilauea in vicinity of Kilauea Military Camp. 19° 26' 3N; 155° 16' 8W.

June 11, 5:05 pm, very feeble, located 1.4 miles deep in Kilauea Crater 5.0 miles SW of the Volcano Observatory. 19° 25' 6N; 155° 16' 0W.

June 14, 8:31 am, very feeble, probably located in Kilauea SW Rift zone 8 to 9 miles SW of Halemaumau.

June 17, 12:55 am, very feeble, located 1.4 miles S of Pit seismograph and 1.9 miles deep. 19° 23' 2N; 155° 18' 0W.

June 18, 12:03 am, very feeble, located 2.5 miles under W rim of Kilauea Crater 0.7 mile SW of Uwekahuna. 19° 25' 1N; 155° 18' 0W.

June 22, 2:37 am, very feeble, probable location in vicinity of Hilina Pali.

June 23, 7:19 am, very febele, probable location in Kilauea Crater.

June 25, 8:34 pm, very feeble, located 3.7 miles deep and 1.1 miles SW of Puu Ohale. 19° 20' 9N; 155° 17' 7W.

June 25, 8:37 pm, very feeble, located 3.1 miles under NW rim of Kilauea. 19° 25' 9N; 155° 17' 4W.

June 26, 6:57 am, very feeble, located 1.6 miles deep and 0.3 mile S of S rim of Kilauea Iki. 19° 24' 6N; 155° 15' 1W.

June 26, 9:25 am, very feeble, probable location in NE portion of Kilauea Crater.

June 26, 2:54 pm, located 1.6 miles deep and 0.8 mile S of Twin Craters. 19° 24' 4N; 155° 14' 2W.

The surface (L) waves of a distant earthquake began recording at the Observatory at 11:02 pm, June 2. The reported location was off the Coast of British Columbia. 40° 7N; 125° 5W.

Three minutes of continuous tremor registered, starting at 11:26 pm, June 2.

Microseismic motion was moderate, June 2, the remainder of the month it was light.

Tilting of the Ground

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending June 28 was 5".08 N and 0".74 W.

H.H.W.

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory June 9, compared with similar measurements March 16 and April 15, showed little change across Halemaumau but indicated opening across the crater from rim to rim in a NW-SE direction. March 16, to April 15, Halemaumau showed opening of 0".11 and April 15, to June 9, it closed 0".52. Across the Crater there was an opening of 0".75, and April 15 to June 9, an opening of 2".18.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations West	Southeast	Pit Resultant
June 7	1".00 S 40°W	6".59 S 65°W	7".52 N 10°W	0".34 toward
" 14	0".29 N 59°E	3".10 N 38°W	6".19 S 9°E	7".11 from
" 21	0".75 N 33°E	4".26 S 40°W	6".71 N 2°E	2".22 toward
" 28	0".92 N 19°E	5".96 N 79°W	1".94 S 83°W	4".69 from



View of Sakurajima, Kagoshima in Foreground, 1914 Eruption

NOTES ON JAPANESE VOLCANOLOGY, AND ON SEISMOLOGICAL RESEARCH

H. H. Waesche

Cherry blossoms, temples, and volcanoes are three things that every visitor to Japan becomes conscious of as soon as his ship docks at one of the Empire's many ports. He may not see the cherry blossoms as they are a seasonal exhibit only, and a visit could be made without seeing any of the shrines or temples, but evidence of volcanic activity, either past or present, cannot be overlooked. Volcanoes are a part of the everyday life of all the Japanese. Volcanism is a major motif in their art, it enters into religion, and even in their play at various hot-spring resorts or "spas," as they are called. Fujiyama is known the world over for its grace and symmetry of form. This dormant volcano is exhibited in practically all Japanese arts and being sacred it influences the thought of the entire country. It is probably the typical volcano. Volcanic eruptions, destructive and otherwise, have been a part of the history of Japan from its very beginning. There are many volcanoes which are periodically active, such as Asama, Mihara (Oshima), Aso, and Sakurajima among the more famous, and others at scattered localities from Hokkaido in the North to Kyushu in the South. Anyone interested in volcanology and its related subject, seismology, will find both well represented in their many phases in the "Land of the Rising Sun."

H. Waesche, Assistant Geologist at the Hawaiian Volcano Observatory, and Merel S. Sager, Associate Landscape Architect of the U. S. National Park Service, visited Japan during April and May, 1936. Trips to the volcanic areas of Mt. Fuji, Beppu, Sakurajima, Mt. Aso and Unzen were made during their stay. They also visited the Department of Geology, and the Research Institute of the Tokyo Imperial University. Acknowledgment is made of the many courtesies extended and helpful information given by Dr. S. Tsuboi of the Department of Geology, Dr. M. Ishimoto of the Research Institute, and Drs. Imamura and Matuzawa of the Seismological Institute. The trips to the National Park Areas were made most enjoyable and profitable through the very kind assistance of Dr. T. Tamura, of the Japanese National Park Association, his assist-

ant Mr. Kato, and the local directors of the several parks, as well as local prefectural officers. All contributed toward making the trip one of outstanding value.

The morning of April 17 was spent inspecting Hot Springs in the vicinity of Beppu. This city is one of the most famous of Japan's 1200 spas. It is located on the east coast of the Island of Kyushu bordering the famous Inland Sea. Here in a volcanic area of about twenty square miles are found over a hundred thermal springs and fumaroles exhibiting a variety of characteristics. They are known as "Big Hells" or to the Japanese as jigoku. Associated with many of the hot springs are smaller areas several feet in diameter of boiling mud similar to the "paint pots" seen in Yellowstone. These latter are noisily and continuously agitated by escaping steam. The largest of the hot springs is known as Umijigoku and is thought to be over 400 feet in depth and has a temperature of 195° F. at the surface. The water of one spring visited possessed a bright red color which appeared to be caused by the presence of iron, evidently in the form of ferric oxide. Articles of clothing and other materials dipped in the red water and stained were valued souvenirs by many visitors. The name of this spring was Chinoikejigoku or "blood pond." Most of the fumaroles produced sulphurous odors. No native sulphur deposits were observed, however. A popular novelty along the seacoast at Beppu is the so-called "sand bathing." Hot springs bubble up through the sand beaches where the bathers bury themselves in the sand and take a modified turkish bath.

The next stop after leaving Beppu was made at the city of Kagoshima in the southern part of the Island of Kyushu. This city is located on the shores of Kagoshima Bay. In the Bay and two miles east of the city, towering 3,500 feet above the water, is Sakurajima, one of Japan's mightiest volcanoes. This cone marks the scene of the greatest eruption in the annals of the Island Empire which took place beginning in January, 1914. It is of interest that this eruption was expected, and the local residents being thus warned were prepared, with a consequent loss of life of only 35 people and some millions of dollars in property damage. Warnings concerning the possibility of an explosive eruption were made as early as 1909 following rather violent earthquakes in the vicinity. In 1913 violent eruptions began at Kirishima Volcano some thirty miles to the north of Sakurajima. The last two eruptions there occurred on November 8 and December 9, consequently expectations at Kirishima were high when January 9 arrived, but nothing happened. However, at Sakurajima an outburst of earthquake swarms transferred suspicions to that vent. Four hundred and seventeen earthquakes were recorded at Kagoshima between 4 am January 11 and 10 am January 12, after which the main eruption began. The morning was cloudy so that the activity was not visible until after 10 am when the



Meteorological Observatory on Sokojio Unzen, Japan.

clouds dissipated. At that time a swelling balloon of black smoke in the middle of the mountain was seen rising from the ground where an hour before there had been orange orchards and cultivated, terraced fields. The column of smoke went up some 30,000 feet in the air and then bent eastward, strewing dust all over Central Japan. A smaller column arose on the east flank of the mountain having started ten minutes after the western one with which it later merged. There were booming concussions, flashes of lightning and in the lower part of the cloud, being thrown to great heights were ashes, sand and bombs. At night these latter were seen to be red hot. At 6:29 pm a violent earthquake shook Kagoshima and it was in the destruction caused by this shock to buildings and in landslides that most of the casualties resulted. This shock was recorded on seismographs in Europe. It was followed by lava emissions. Their flow continued several months, filling in new craters, pouring into the sea and on the east side of the Island filling in a strait, changing the Island into a peninsula. This happened the afternoon of February 1. Much pumice was formed and so great was the quantity floating in the bay that boats traveled with difficulty. Fortunately for the City of Kagoshima the eruption was not concentrated at the one western vent pointed in its direction as its fate might have been similar to that of St. Pierre on the Island of Martinique when Mt. Pelee erupted in 1902. The water of the Bay around Sakurajima was warmed considerably and near the lava flows measured as high as 138° F. More than 4,000 acres of lava were poured out above sea level in two months. Ash measured 70 inches in depth near the volcano, a thin film 30 miles away and some even fell in Tokyo 600 miles away on the third day of the activity. Precise geodetic measurements of Sakurajima showed that an elevation on the mountain had risen 10 feet whereas a point submerged in the bay had lowered 10 feet. This would seem to indicate that the volcano had swollen with lava inside while the surrounding land had subsided with the release of pressure and emission of lava.

On April 18 of this year Sakurajima was quiet when visited. In the early morning a moderate cloud of fume or vapor was seen rising from the summit crater. This was obscured by clouds shortly before noon. A boat trip was made to the tip of the most westerly lava flows from Kagoshima. The party landed on a beach composed of pumice. The lava was of a rough fragmental nature, black in color, very similar to the aa of Hawaii. It is said to be a hypersthene-hornblende andesite. The flow at this locality was piled up probably two hundred feet in thickness. Reports said that the eastern flow was 300 feet above sea level in localities formerly covered by 200 feet of water. The upper slopes of the volcano were bare of vegetation, were light reddish in color and seemed composed of soft materials of the nature of ashes and cinders. Sakurajima is of the usual conical shape much like the volcanoes of the Cascade Range of the Northwestern United States. Although not now active in a spectacular way it is an inspiring sight.

Leaving Kagoshima by train, the City of Kumamoto was reached the evening of April 18. The night was spent at the Tsukasa Inn. Early the next morning the party, consisting of Mr. Matsumuro, Director of Aso National Park, Mr. Goto, the Assistant Director, and a Japanese policeman by the name of Jiro Kurageno, left Kumamoto for Mt. Aso Volcano. Mr. Matsumuro left the party after going a few miles out of Kumamoto. The policeman went along as translator, being the only Japanese of the group who could speak English. At Bochu a bus was taken for the point of greatest activity. The bus was a very sumptuous one including swivel chairs as in a railway parlor car. Besides the driver there were two Japanese girls, one who described the places of interest in sing-song Japanese and another who translated it into English. The latter girl's name was Sumi Araki formerly of Honolulu, Hawaii, and spoke excellent English. She is now employed by the Great Aso Motor Bus Company in charge of the other girl employees and as a translator for foreign visitors. The bus used was one which had been especially built the preceding year for the exclusive use of Prince Takamatsu when he was a visitor to Mt. Aso. At the summit Mr. Henry K. Haraguchi, owner of the park concessions, was the party guide. The road from Bochu to the summit was finished five years ago, having been built by the Imperial government, and is now operated by the National Parks Association of Japan. It is about nine miles long and at no point is the grade more than 1:12. At the end of the road, which was about one-half mile from the active crater, there was located a seismograph station. Here there was an instrument of moderate magnification registering on a smoked drum. In the valley below Aso, toward Kumamoto, the Kyoto Imperial University has an observatory where studies of all changes and activities at Aso are being continuously made.

The Aso Volcano is the largest of a chain of vents extending along a zone of crustal weakness from Mt. Kuju to the east to Mt. Unzen to the west. This zone of weakness is supposed to be a continuation westward of the depression zone of the Inland Sea. The mountain proper covers the major part of the two provinces of Higo and Bungo and its base extends 30 miles E-W and 28 miles N-S, including some 700 square miles. It consists of a "somma" which attains a height of 3,200 feet above sea level, topped by an oval crater, 10 miles wide and 15 miles long, the floor of which is sunk an average of about 1,600 feet below the rim of the outer slope. The wall of this caldera is nearly perpendicular with talus accumulated at its base. This huge crater is thought to have originated by depression, as have those of Hawaiian volcanoes, due to the outflow of immense volumes of lava. The caldera is attained from Kumamoto on the west through the Futaye Pass cut into the rim to a depth of over 2,000 feet. Another pass known as the Tateno Break occurs to the south of Futaye Pass. Breaks in the rim walls along fracture zones aided by water erosion are supposed to be responsible for these two gaps. Rising near the center of this huge crater, said to be the largest in the world, are the central cones called the "Five Peaks of Aso." The most important of these is one known as Naka-dake, the scene of current activity. Standing west of Naka-dake is the highest cone, Taka-dake, rising a mile above sea level and around 3,600 feet above the floor of the caldera. Surrounding these central cones are the plains extending to the crater wall which are known as the "atrios." The part to the north of the cones is the Aso valley and to the south is the Nango valley. These atrios, consisting of volcanic ash, sand, lapilli and gravel, form a fertile soil on which lives a population of some fifty thousand people including 11 villages. The stratification of the materials composing the crater floor suggests the existence of a former crater lake, which was later drained through the passes previously mentioned.

Naka-dake possesses a series of five pits composing the summit crater. These are numbered consecutively from north to south and share honors as centers of activity with the number 1 pit having the majority to its credit. Number 3 pit is next in frequency of eruptions. Number 4 pit was active 10 years ago and continued intermittently for several years. In 1926 number 2 pit was described as a small kettle-shaped depression, at times filled with water and never very active. At present this is a large depression and the center of activity. It broke out with an explosive eruption in 1934 which was the largest in 150 years. Bombs and boulders were thrown over three hundred feet in the air and literally peppered the ground for several square miles around the vent. Much ash and cinders were ejected but no lava flows. A huge column of

smoke now billows above the vent, rising high in the air and easily visible almost the entire trip from Kumamoto to Bochu. Viewed from the rim of the pit, it is seen to be rushing out with considerable force and is accompanied by loud roaring sounds below. Evidently this cloud of fume is composed principally of steam with considerable sulphur fumes, as shown by the amber color in reflected light and bluish in transmitted light. This pit is now over 3,000 feet long by 1,500 in width and is about 450 feet from the rim to the throat of the funnel-shaped aperture from which issues the huge cloud of vapor. The throat is supposed to be about 35 feet across. Occasionally incandescent material is visible below. Number 1 pit is about 400 feet, number 3 about 250 feet and number 4 about 475 feet in depth. Their floors are dotted with fumaroles and solfataras. Historical records indicate that Naka-dake has erupted between 60 and 70 times. These have always consisted of emissions of mud flows, ashes and fragmental materials but never any trace of a lava flow.

The rocks of Mt. Aso are petrographically classed as andesites and are comparatively basic, many of them containing olivine or angite or both. The olivine-bearing rocks are found in the central cones and are younger than hornblende-bearing rocks found on the outer slope of the crater.

Aso Volcano is without doubt one of the most interesting sights to be seen in Japan today. It is apparently putting on an excellent and impressive performance at all times whether of a violent nature or otherwise. Five hundred thousand visitors annually are reported to look into the awesome depths of the rumbling pit. As is true of Mihara and Asama, Aso seems to be an attractive spot for those Japanese suffering from suicide manias. An average of 200 of these unfortunates is reported to make the leap from the rim of number 2 crater per year.

The next volcanic district as a part of the Japanese itinerary was that of Unzen, also a National Park and a very popular hot springs resort, catering mostly to foreigners. It is located on the Shimabara Peninsula, western coast of the Island of Kyushu and is the western terminus of the volcanic chain of which Mt. Aso is a part. The group of mountains at Unzen consists of a central cone called Fugen-dake and associated peaks of Kunimi, Myoken, Takaiwa and Kinugasa. The whole mound consists of a more acidic type of rock than was found on Mt. Aso.

Within historic times there have been several recorded eruptions at Unzen. One is reported to have started in 1657 A.D. and marks a period of activity lasting for more than 20 years. Others occurred in 1663 and 1664. The most eventful activities started with a series of earthquakes in the winter of 1792. On the morning of February 9 that year, Fugen-dake erupted with loud explosions, throwing heavy smoke clouds, mud and rocks. Lava broke out in the valley of Anasako February 25, overwhelming the village of Semboki. This lasted several months. A heavy earthquake shock on March 11 was followed by over 300 slighter shocks that night and over 100 during each of the next two days. Around April 1 a huge landslide following earthquake shocks occurred on the southeastern part of Mea-yama, a mountain on the seacoast south of Shimabara. About one-sixth of the entire mountain mass slid into the sea, producing severe tidal waves. Two villages were completely buried under the debris. The portion of this huge mass which slid into the sea gave rise to between two and three hundred islets of which many still exist. Today these are called "Ninety-nine Islands" and are partly covered by vegetation. The boat which runs from Misumi to Shimabara affords excellent opportunity to see the scar left by the slide and the islands which resulted. Whether this was really a volcanic explosion or not is a moot question. Casual observation from the boat suggested structural failure rather than volcanic activity. Various phases of diminished activity continued until February, 1793. Eruptions of this nature are of interest in exhibiting, specifically, relationship to a marked degree of volcanic activity and seismic activity. Other than a heavy earthquake in December, 1922, and minor shocks from time to time no further evidence of activity except hot-spring and fumarolic emissions has occurred.

In the recently erupted flat dome of Obiyama, past volcanic activity is indicated by numerous hot springs and fumaroles. This is the famous spa district of Unzen where are located the many hotels for the thousands of visitors who come from all over the world annually. The springs are usually acidic and contain sulphur compounds. Near the vents, siliceous sinter and deposits of sulphur are being built up. The spa is 2,200 feet above sea level. A nine-hole golf course is located at the foot of Mt. Myoken.

An excellent view of the surrounding country may be had from the summit of Kinugasa-yama. This mountain, over 3,000 feet above sea level, is the location for a meteorological station under the control of the Nagasaki Prefecture. Here are housed various instruments such as barometers, anemometers and thermometers. In a separate building is an Omori seismograph and quarters for an attendant. Unzen posseses a charm deserving of its great popularity.

The supreme expression of volcanism in Japan, at least to the popular mind, is the world-famous Mt. Fuji. Rising to a height of over 12,000 feet above sea level, it is usually surrounded by clouds and during most of the year there is a mantle of gleaming snow on the upper portion. Wherever Japanese art has gone, there also has gone Fuji. It is the very symbol of Japan itself and as previously mentioned is held in sacred veneration by the Japanese people. It well deserves this consideration. Its perfect cone is considered the classic type shape for a volcano of the explosive type. When the weather is favorable, Mt. Fuji may be seen from Yokohama, where visitors from North America first land, from Kamakura, parts of Tokyo and from the main line railroad between Yokohama and Kobe.

Mt. Fuji is characterized by a long, gentle slope of similar inclinations on all sides except the southern, where there is an explosion crater. Halfway up the inclination is 17° and at the summit it is 34°. A typical summit crater is found at the top of the mountain which is a funnel-shaped depression, 720 feet deep and 1,970 feet in diameter at the uppermost level.

Mt. Fuji has been active several times within history. In 800 A.D. a lava stream flowed down the Katsura-gawa and eached the Enkyo bridge following a violent eruption. In 864 A.D. two great streams of lava poured down the northern slope. The last major activity occurred in 1707 when a large explosion took place on the southeastern flank, producing the Hoeisan Crater. No lava was emitted but great quantities of bombs were thrown out. This was followed by small explosions in 1708 and 1792. The volcano seems dormant at present although reports mention fumaroles on the east side and on the top, none of which are very active. Numerous spas and hot springs dot the countryside around Fuji, however, of which some of the best known were visited at Myanoshita and in the Hakone District. One of these, visited May 9, 1936, known as the "Big Hell," was emitting quantities of sulphurous vapors, was surrounded by sulphur deposits, and was of comparatively high temperature. At Myanoshita, waters from the hot springs are run into very imposingly appointed baths at the Fujiya Hotel for the use of guests. Dr. Tamura of the National Parks Association presented a bomb from the summit crater of Mt. Fuji to H. H. Waesche. This was a sister rock of the one

presented to Mt. Rainier National Park in the United States as an exchange of goodwill between the respective countries. They were both brought down by Mr. Kato, Landscape Architect of the Japanese National Parks. The bomb was oval-shaped and about seven or eight inches in maximum diameter. Like other Fuji rocks it is of an andesitic composition. One of the best views of Fuji is obtained from Nadao Pass to the south, reached by bus from the Fujiya Hotel at Myanoshita.

On May 11 a visit was made to the Tokyo Imperial University. Dr. Tsuboi, the head of the Department of Geology, was host to the party. Activities of the Geology Department were discussed and results exhibited. Geological work was in progress on the Mount Fuji region and much areal mapping had been done. Instruments used for petrographical and mineralogical work were inspected. The department was up to date in all respects and seemed to be carrying on an extensive as well as progressive program of research with emphasis on the geological phases of volcanism, earth movements and structures, petrography and mineralogy. There was a large collection of thin sections of rocks from all parts of Japan. Everything was being carried on with the customary Japanese thoroughness.

Dr. Ishimoto, Director of the Earthquake Research Department, next took charge of the visitors. He has a large, well-equipped department with many seismographs of various types. Most of them were modified Galitzins of the accelerometer type, having a vibration period in some cases as long as 0.7 second. One vertical instrument had a pendulum extending three stories up to the roof of the building with a period of 7.0 seconds. Photoelectric recording was the preferred method, although many instruments utilized very thinly smoked drums. In all cases the drums were rotated by means of synchronous motors. They made in most cases four revolutions per hour. A few seismographs used no timing. Instrument magnification ran from 100 to 500 and on low magnification instruments from 2 to 10. The time marks were recorded on the drums by means of electrical solenoids which jarred the frames, thus widening the pen's trace at that instant and were controlled by master clocks. Tilting of the ground in Tokyo is given considerable attention because of its possible value in earthquake predictions following observed tilts of blocks between fault lines. One very interesting tilt instrument consisted of a long horizontal pipe partially filled with water and buried several feet in the ground. The open end of the pipe was faced with glass where the water level could be seen. Regular daily micrometer measurements of the changes in level of the water were taken and from them tilt calculations made. This seemed to be quite practical for tilt measurements in one plane and had the advantage of being earthquake proof. One laboratory room was used for testing seismographs and accelerometers with a standard rocking machine. Various types of harmonic motion could be produced in this manner with known values, making possible the determination of instrument peculiarities and characteristics. A similar instrument is in the shop at the Hawaiian Volcano Observatory and has been used for tests on instruments now in use. A great deal of attention is given to initial movement determinations. Both vertical and horizontal instruments are used. Models of glass representing the disturbed area are made, with small silk threads showing deformation of the earth near the focus as indicated by interpretation of initial earth movements at a number of localities.* All the instruments at the Earthquake Research Laboratory are located one to two stories below the ground level for better control of variable conditions, such as temperature changes and in order to reach a good rigid sub-stratum. Gravity determinations of localities on the earth's surface is a source of much active research along with the seismological studies.

As guests of Dr. Ishimoto, luncheon was enjoyed at the faculty restaurant in the company of Drs. Tsuboi and Imamura, as well as the host. After luncheon Mr. Sager called at the Architectural Department while H. Waesche accompanied Dr. Imamura to the laboratories of the Seismological Institute, of which he is Director Emeritus. The Institute is an older organization than the Earthquake Research Institute. It was previously under the direction of the late Professor Omori, world-renowned seismologist, and is now directed by Dr. T. Matuzawa. Possibly the work of the two organizations overlaps. The primary interest of the Seismological Institute, though, seems to be the study of the cause and effect of earthquakes with their possible prediction of occurrence in mind. Here they are interested in what happened in Tokyo and Yokohama in 1923 and what can be done to prevent recurrence of such catastrophes. More attention is given to local shocks. The Earthquake Research Institute, on the other hand, is more interested in the theory of wave propagation, physics, and mathematics of seismology. The day was concluded with Drs. Matuzawa and Imamura conducting the remainder of the party through their laboratories. It was noticed that an instrument identical to the one in use at Uwekahuna was in operation. Many old obsolete seismographs were on display as well as various other instruments of a seismological nature. Pictures of earthquake destruction were plentiful. Seismology is taken seriously in Japan—and it should be, with the occurrence of such catastrophes as some of the past earthquakes have caused. These two seismological research institutions are working day and night to learn more about one of Japan's principal problems. Knowledge is not a guarantee of protection but it will go a long way toward making Tokyo a safer place in which to live, and prediction of earthquake activities more reliable.

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* From the Proceedings of the Imperial Academy, Vol. VIII (1932), No. 2, Sur le Mécanisme de la Production des Ondes Sismiques au Foyer: Existence d'une Source Quadruple au Foyer; and Vol. XI (1933), Part 2, la Deformation de la Croûte Terrestre et al Production des Ondes Sismiques au Foyer, par Mishio Ishimoto.

THE VOLCANO LETTER

No. 437—Monthly, Department of the Interior, National Park Service, July, 1936

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JULY, 1936

VOLCANOLOGY

A fresh scar was found on July 1 on the west end of the north wall of Pauahi Crater in the Chain of Craters. Other scars representing recent slides were noticed in Makaopuhi, along with an increase of fuming and sulphur stains.

The week ending July 12 was peculiar in that no rock slides were reported from Halemaumau. Fumes continued to issue from the west floor solfatara, and a more intense puff of fume than usual rose over the NW rim of pit July 11, 10:15 am.

Measurement of 32 marked concentric cracks around Halemaumau, showed changes each week from the week before, as follows, with certain notable openings of Crack No. 46, which is about 150 feet back from the ENE rim:

Six days ending July 3, 6 opened, 4 closed, aggregate opening 5.5 mm. Crack 46 opened 4.5 mm.

Eight days July 11, 13 opened, 2 closed, aggregate opening 11.0 mm. Crack 46 opened 5.5 mm.

Week ending July 18, 7 opened, 5 closed, aggregate opening 5.5 mm. Crack 46 opened 4.5 mm. Fresh cracks opened on the ENE rim.

Six days ending July 24, 7 opened, 1 closed, aggregate opening 9.0 mm. Crack 46 opened 6.0 mm.

Eight days ending August 1, 7 opened, 3 closed, aggregate opening 10.5 mm. Crack 46 opened 8.5 mm.

Thus through five weeks the aggregate openings have been 5.5, 11.0, 5.5, 9.0 and 10.5 mm, and crack 46 has opened 4.5, 5.5, 4.5, 6.0 and 10.5 mm, these facts showing progressive increase of yawning open of cracks northeast.

Rock Slides in Halemaumau

June 29, new dust on floor and scar on wall 400 feet below Crack No. 29, NE. At 12:45 pm a NE slide made dust cloud visible for 5 minutes.

June 30, 3:50 pm, small slide. Others occurred at 5:35 pm, 6:18 pm, 6:25 pm and 6:30 pm, all NE.

July 2, 8:55 pm, SW wall, 9:10 pm, NE wall.

July 13, two large slides sent up dust 3:20 and 3:24 pm.

July 18, 9:58 am, noise of rocks falling at SE wall.

July 20, avalanche scar NE.

July 21, noon and 3 pm, dust from slides NE, followed by dribbling slides.

July 22, more scars, small slide 9:37 am, a larger one 1:19 pm, and others 3:43 and 4:30 pm.

July 23, slides from NE wall 9:13 am, 9:52, 10:01, 10:07 am. Northeast chasms on the edge were widening.

July 24, dust clouds from slides 8:15 am and 1:24 pm.

There appear to have been increases in sliding northeast, along with the opening of cracks.

All of this means that a portion of the northeast wall of Halemaumau is "working," whether because of movement on the deep rift blocks, or because of lava motion, cannot yet be told. T.A.J.

TABLE

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant Earthquakes	Local* Seismicity
July 5	29	9	2	0	2	20.75
" 12	18	7	0	0	0	8.00
" 19	38	12	0	2	1	22.25
" 26	45	4	0	0	0	13.25
Aug. 2	44	3	0	0	0	18.50

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant quakes were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and, whenever possible, determinations of depth of focus have been made.

June 30, 7:28 am, very feeble, located 4.0 miles deep and 0.5 mile SW of Pit Seismograph. 19° 24' 0N; 155° 17 3W.

July 1, 2:31 pm, feeble, located 15.0 miles deep and 3.0 miles SW of Halemaumau in Kilauea SW Rift zone. 19° 22' 3N; 155° 18' 6W.

July 1, 2:32 pm, feeble, same locality as preceding quake and both reported felt in Hilo.

July 2, 12:47 pm, very feeble, probable location in rifts 2.3 miles west of Pauahi Crater.

July 3, 6:27 am, very feeble, located 4.0 miles deep and 1.6 miles S of Pit Seismograph, 1.0 mile west of Ahua Kamokukolau. 19° 22' 9N; 155° 17' 1W.

July 3, 1:25 pm, very feeble, located 1.8 miles deep in Kilauea Crater. 19° 24' 7N; 155° 16' 3W.

July 5, 7:04 pm, very feeble, 1.3 miles deep and 0.7 mile E of Pit Seismograph in Kilauea Crater. 19° 24' 4N; 155° 16' 4W.

July 6, 7:41 pm, very feeble, located 0.9 mile deep in Kilauea Crater, 0.5 mile W of Byron Ledge. 19° 24' 9N; 155° 16' 1W.

July 9, 8:48 am, very feeble, probable location under E portion of Kilauea Crater.

July 12, 6:22 am, very feeble, located 2.0 miles deep in Kilauea Crater. 19° 24' 7N; 155° 16' 3W.

* For local seismicity definition, see Volcano Letter 371.

July 12, 3:46 pm, very feeble, located 15.0 miles deep under N slope of Mauna Kea, 4.0 miles below summit. 19° 52' 6N; 155° 26' 5W.

July 15, 5:16 pm, very feeble, probable location in Kilauea Crater.

July 15, 9:40 pm, very feeble, located 1.7 miles deep and 0.5 mile S of Kilauea Iki. 19° 24' 4N; 155° 14' 9W.

July 15, 11:12 pm, very feeble, located 1.5 miles under SE rim of Kilauea Crater near Keanakakoi Crater. 19° 24' 4N; 155° 16' 2W.

July 15, 11:39 pm, slight, located 1.6 miles deep under S rim of Kilauea Iki. 19° 24' 7N; 155° 14' 9W. Reported felt in the Kilauea Area and in Hilo by several persons.

July 16, 4:14 am, very feeble, located 0.9 mile under Byron Ledge E rim of Kilauea Crater. 19° 25' 1N; 155° 15' 7W.

July 18, 6:21 am, very feeble, located 1.7 miles deep under NE rim of Kilauea Crater. 19° 25' 8N; 155° 16' 0W.

July 18, 8:24 am, slight, located 2.8 miles deep under SE portion of Kilauea Iki. 19° 24' 9N; 155° 14' 8W. Reported felt by several persons at Military Camp and at the Volcano House.

July 18, 12:45 pm, very feeble, probable location SE portion of Kilauea Crater.

July 20, 8:50 am, very feeble, located 1.8 miles deep, 3.3 miles SW of Pit Seismograph and 2.0 miles W of Aloi Crater. 19° 22' 0N; 155° 15' 3W.

July 23, 6:41 pm, very feeble, probable location Mauna Loa NE Rift, about 5.0 miles from Summit Crater.

July 25, 4:41 pm, very feeble, probable location under E slope of Hualalai about 5.0 miles from summit.

July 27, 4:58 pm, very feeble, probable location under Mokuaweoweo, Summit Crater of Mauna Loa.

The preliminary waves of a distant earthquake began recording at 4h 45m 14s HST, June 30. Newspapers reported quake as being 4100 miles NW of Pasadena, California. The distance from the Volcano Observatory was 3190 miles. Reports from the Central Station of the Jesuit Seismological Association gave the location near N portion of Japan Trough off the S end of the Kamchatka Peninsula. 51° 0N; 161' 1E. The preliminary waves of a distant earthquake began recording at 8h 37m 4s, HST, July 5. The estimated distance from Kilauea was 5650 miles. Reported location was the southern extremity of the Philippine Trough, N of Moluccas. 4° 0N; 124° 9E. The preliminary waves of a distant quake began recording at 12h 55m 45s, HST, July 13. Its estimated distance from Kilauea was 6480 miles. Reported location, in Chile Trough off the N coast of Chile.

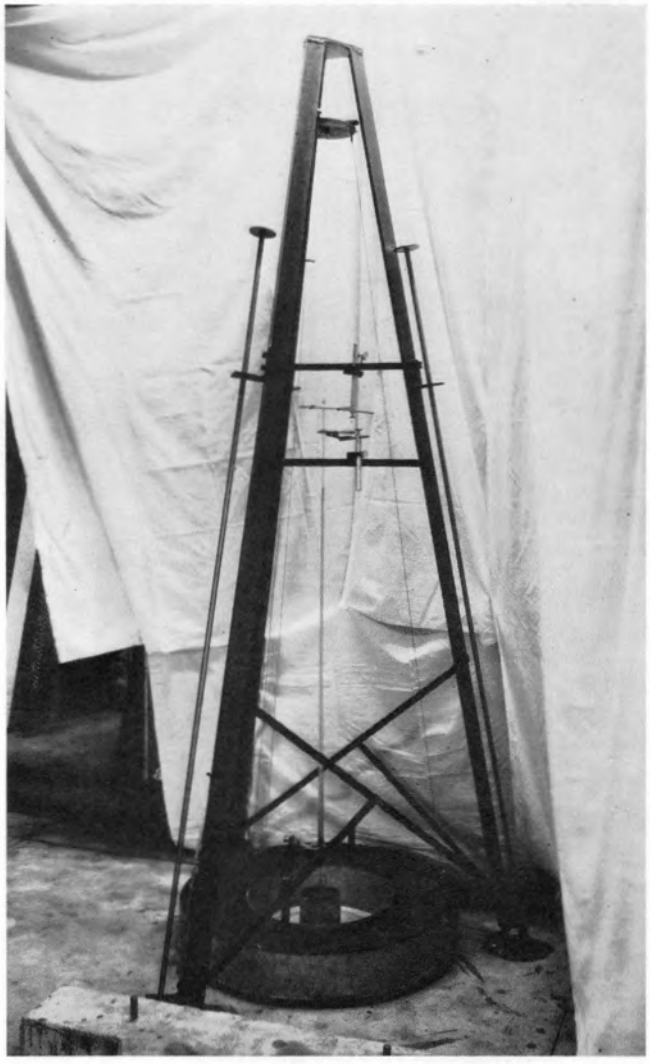
At 3:59 am, June 30, 28 minutes of continuous tremor began registering. At 7:38 pm, July 19, three minutes of continuous tremor began. 24 minutes of tremor began at 11:31 am July 30.

Microseismic motion of the ground at Kilauea was moderate July 15, 17 and 18; the remainder of the month it was light.

Tilting of the Ground

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts tor two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending August 2, was 4" 35N and 1" 81W.



The tiltmeter or clinoscope designed by Wingate and Jaggar, and installed in the three cellars around Halemaumau. A heavy ring weight in oil moves when the ground tilts the tripod. The top of the boom is pointing to a disc marked in directions and distances from a center. The reading of the bottom surface of the disc is made daily with a mirror. The adjusting rods on the tripod bring the boom back to center.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations		
		West	Southeast	Pit Resultant
July 5	0".76 N 16°W	5".22 N 83°W	3".73 N 4°E	2".15 from
" 12	0".39 N 15°W	3".23 S 60°W	3".92 N 29°W	0".90 toward
" 19	0".12 N 3°E	0".36 N 49°W	2".43 N 36°E	0".51 toward
" 26	0".30 N 28°W	9".24 N 64°W	1".20 S	8".87 from
Aug. 2	0".86 N 51°E	3".04 S 86°W	5".83 N 18°W	2".54 toward H. H. W.

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory, July 24, compared with similar measurements June 9, showed slight closing across Halemaumau and slight opening across the Crater from the SE rim to Uwekahuna on the NW rim. The amount July 6 was a closing across Halemaumau of 0".83 and an opening across the Crater of 0".4. Between July 6 and July 24, the Halemaumau angle opened 0".41 and the Crater angle opened 0".84.

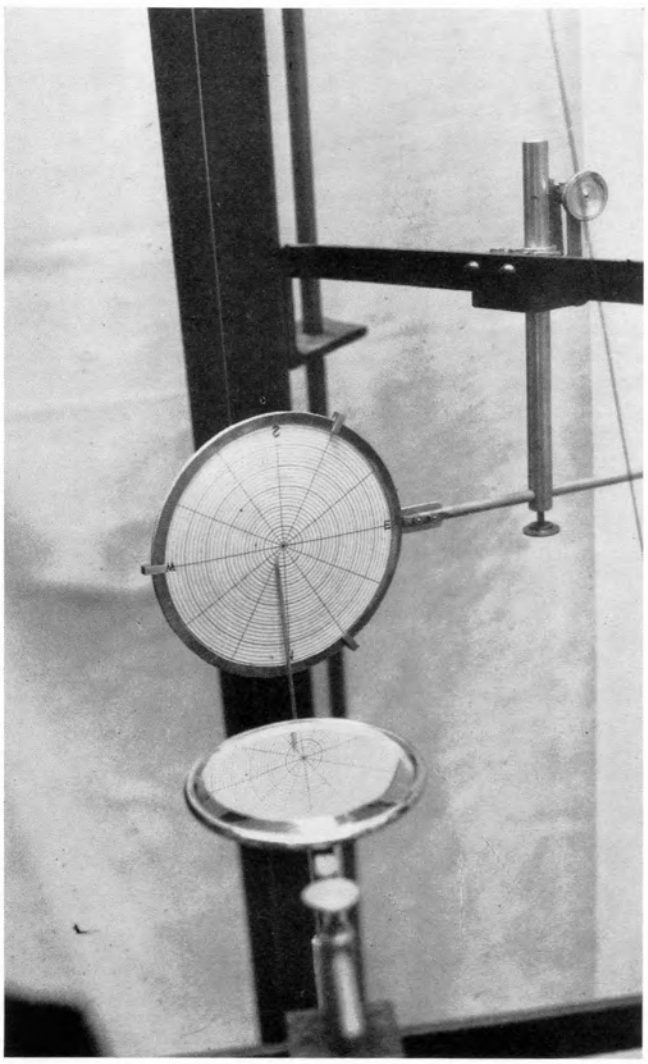
H. H. W.

MORE ABOUT VOLCANO OBSERVATORY METHODS

Tilt Measuring Instruments

We have seen in the May number and in the pictures of the April number, how the Hawaiian Volcano Observatory makes seismograms, measures cracks, receives time signals, collects gases, watches the weather, and surveys the land to prove its rising and falling, swelling and shrinking, and the spreading apart of the cliffs of the Crater.

Here and in Japan, the study of earthquakes has led the workers increasingly to watch the tipping or tilting of a piece of ground. Just what does this mean? It obviously does not mean that the ground was level before. It means that a plumb-bob, hung on a thread and allowed to come to rest, has its thread making a certain definite angle with the surface of the ground at any place. If the ground tilts between January and July, the thread will make another angle, in another direction, when the weight is hung over that same place.



Mirror and dial of Hawaiian Volcano Observatory clinoscopes.

What we need, then, is a weight hanging in one place from a support over a level floor, and a device for measuring the angle that the thread makes with the floor. If the floor were really level, the thread would be at right angles to it with reference to all points of the compass.

But no floor is level. We are not measuring in degrees but in seconds, and a second is one-thirty-six-hundredth part of a degree. A tilt of two seconds would be a disturbing event for the foundation of an astronomical telescope used for measuring the position of the stars. Imagine, then, how an astronomical telescope would fare, when the edge of Kilauea Crater tips eight seconds in two days!

Sometimes these tippings are sudden and are accompanied by earthquakes. This means that the mountain block where our level floor is built has suddenly shifted and our floor is no longer level. At other times the motion is more gradual as though the shell of the mountain were bending like a bow. There are many possibilities. The man of science must think of all these possibilities and select the one that fits best. We had a little seismograph station in February, 1929, at the southeast edge of Halemaumau, the inner pit of Kilauea Crater. The instrument was a pendulum hinged against an upright post like a door with the plane of the hanging at right angles to a radius of the pit. The outer end of the boom attached to the hanging weight wrote a line on smoked paper driven by clockwork. If the ring formed by the upper edge of the pit were lifted, the ground would tilt away and the boom would move away from the pit, and the line on the paper would move with it. On the other hand, if the mountain under the pit should shrink, the pit edge would lower and the door-like weight would swing toward the pit.

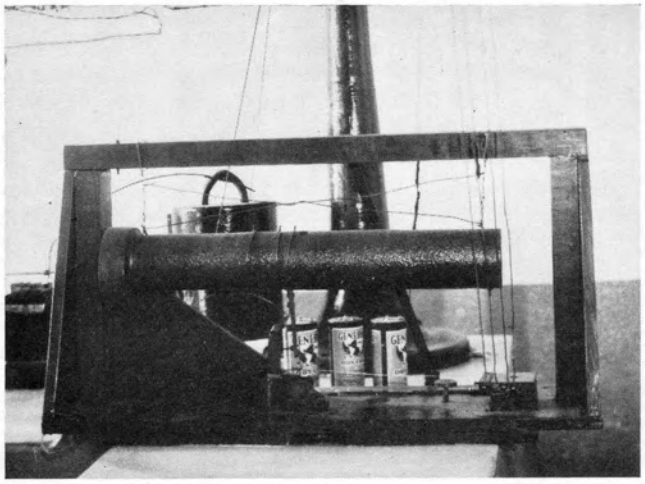
The main purpose of such an instrument is to write a zigzag when an earthquake occurs. But its second purpose is to measure tilting of the ground by the position of the line on the moving paper, with reference to a fixed mark on the instrument. It measures tilt in one line of direction only, and that is the line at right angles to the hanging plane.

On February 19, just before midnight, this instrument showed sudden tilting, accompanied by small earthquakes, straight away from the center of the pit, and the moving of the boom away from the pit increased, and kept it up for two hours. Then molten lava gushed up in the bottom of the pit, and the eruption lasted a day and a half. When the eruption ceased, the tilt pendulum moved back towards the center of the pit, and a trembling which it had registered while the lava fountains were operating, rather suddenly ceased.

This splendid demonstration of a relationship between tilt and eruption, the whole pit swelling before the eruption began, and the whole pit sinking when the eruption ended, at once suggested the importance of having two more instruments on other sides of the pit. Thus the idea of a special "Clinoscope" was born.

We proceeded to build the "Clinoscopes" in the Observatory shops. This tilt meter is shown with its parts in the accompanying pictures. It seemed desirable to make it show both direction and angular amount of the change in position of a weight hanging vertically from a single piano wire, so a heavy ring-shaped weight was hung from a seven-foot tripod in a bath of automobile oil, and a magnifying boom or lever was led vertically upward from the space in the middle of the

ring. A sharp point at the top of this lever nearly touches a horizontal circular card, which is ruled in points of the compass and in concentric circles. A mirror makes it convenient to read the bottom surface of the card and see where the sharp point lies. By centering it every day, after seeing how far and in what direction it has migrated, we can tell the direction and the amount of tilt of the floor of the cellar where the tripod is placed. The three cellars are at the points of an equilateral triangle around the pit and are built to avoid change



Earthquake Annunciator: Heavy cylinder hangs on wires. Connecting needle magnifies the motion. Tip makes mercury contact and rings bell.

of temperature. Each instrument is read every morning, and the findings are entered in the Observatory records.

The results of running these instruments for some years have not shown that all eruptions in the pit behave on the three sides the way the 1929 eruption behaved on the one side. The principal discovery made with the Clinoscope is that the Kilauea Rift Belt goes across the pit in a straight line and the tipping is right and left with reference to that belt. It is not "all around" with reference to the center of the pit on radial lines. This is very interesting. It means that the circular pit is only a detail of a linear crack. For tilt measurements the crack is the important thing, the blocks on each side of it lifting or tilting away from or towards the crack. We know where the crack crosses, and both the western and northern cellars are on the Mauna Loa side of the crack, while the cellar near the Tourists' Stand is on the ocean side of the crack.

The Clinoscopes are unfortunately not earthquake-proof. This gives us a great deal of trouble because fifty or sixty earthquakes and tremors occur every week. The large earthquakes certainly derange the delicate pivots. Any slightest derangement of a pivot makes the record erroneous where there is such high magnification. We are now redesigning the instruments and hope to make them entirely earthquake-proof, the reading to be done with a microscope without using any pivots. We ought to have a larger number of these instruments around the outer rim and inner floor of Mauna Loa Crater, and also around the rim of the larger Kilauea Crater, and at some distance away on the radiating highways.

An Earthquake Annunciator

Three of our pictures show respectively a rough hanging cylinder in a wooden frame, a very sensitive long needle under the cylinder balanced horizontally about a vertical axis, and a common electric bell annunciator showing four numbers just as used in the office of a hotel to show signals from four bedrooms.

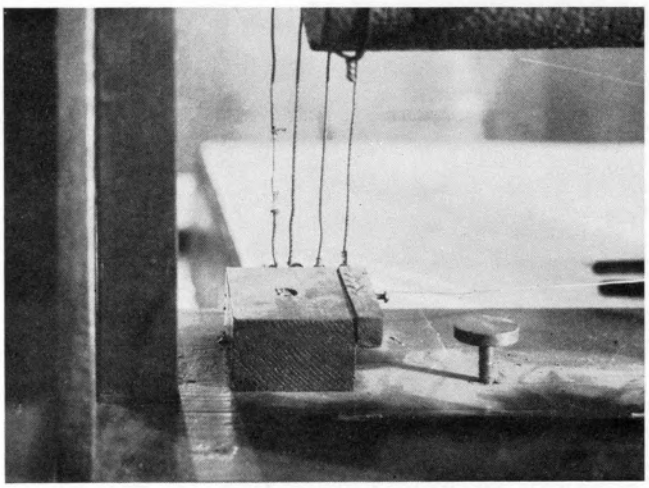
The hanging cylinder is in the seismograph cellar of the Observatory, the annunciator bell is in the seismologist's room above. The object of the device is to notify the seismologist when four different sizes of weak earthquakes occur, all in the class too feeble for him to feel. The bell rings, notifies him that an earthquake is going on, and he may take action accordingly.

The cylinder is a very heavy piece of shafting hung to swing from a beam in an east-west direction. It is appropriately connected with the short arm of an aluminum lever, the long needle. The magnification is about one hundred. This is like the magnification of our sensitive seismographs. The tip of the long arm of the lever, when an earthquake moves the beam back and forth, makes contact electrically with four drops of mercury spaced out in a line, progressively farther from the tip. If the earthquake is big enough to reach number four mercury drop, the number four arrow of the annunciator dial springs sideways and points to the figure four. The same with the other numbers.

This annunciator proved unexpectedly useful during the eruption of Halemaumau Pit, two miles from the Observatory, in September, 1934. The little cone on the floor of the pit became violent with gas explosions every few hours. These explosions were rhythmical. Every time they began, a tremor impulse or shock was sent through the earth to the distant Observatory, and the annunciator bell started ringing with a rhythm exactly accordant with the explosions. Thus a record could be kept by an observer sitting quietly in the Laboratory of the recurrent spasms of explosions at the Pit, two miles away.

Meteorological Instruments

There is little to be said about the thermograph, rain gauge, or the maximum and minimum thermometers, except that their showings have been recorded here for twenty-five years. The Observatory has been a volunteer station of the United States Weather Bureau. The wet- and dry-bulb thermometers, which Mr. Waesche is shown swinging in the breeze, attached to an instrument called the Hygrodeik, is for registering the moisture of the air; the relative humidity at the edge of Kilauea Crater is very high owing both to the climate and to the innumerable steam cracks.



Earthquake Annunciator: Tip of needle opposite four mercury cups. These are for four different intensities of earthquake motion.

Crack Movements at Halemaumau

This subject has already been illustrated on page three of the April issue, but it is just now an appropriate time to show another picture of a special caliper built for measuring the extremely large cracks on the edge of the pit.



Earthquake Annunciator: Bell and numbers record by arrows earthquake intensities 1, 2, 3 and 4. This notifies the seismologist what the seismographs are doing when he does not feel the quake. Shows also timepiece and mercurial barometer.

For several months, as indicated in the reports, we have had excessive movement at crack number forty-six, which lies some distance back from the northeast edge of the pit and this is merely an extension of a crack emerging at the edge of the pit as in the photograph. A section of the rim bounded by one of the regularly measured cracks, fell in between March 15 and March 22, 1936, and in our March issue we illustrated some of these cracks. The aggregate opening of all cracks on March 14 was more than 54 mm. This is excessive, and these movements of cracks at times have yielded very useful data for the National Park Service. The change will come gradually or suddenly and some portion of the rim of the pit may become dangerous and have to be roped off.

Just before the eruption of February, 1929, described above, there was such a disturbance at the eastern margin of Halemaumau so that the entire Tourists' Stand had to be changed in position and a new station built.

There appears to be a complicated relation between local earthquake, tilting of the ground, rise and fall of the pit rim, and the avalanches which fall from the walls of the pit. The complication concerns the question of whether the avalanching and the cracking make the local earthquakes or whether the local earthquakes make the avalanching and the cracking. Both kinds of relations have been discovered on different occasions. T. A. J.

DES MOINES SEISMOLOGICAL STATION

Editor's Note: We are privileged this month to publish a brief account of the only earthquake-recording station in America, designed, constructed and operated by a woman. To Mrs. M. M. Seeburger, a talented scientist from whose facile pen comes the article which follows, and to whose patient study and steadfast work seismology is indebted, we tender respectful esteem and cordial appreciation.—Ed.

The establishment of the Des Moines Seismological Station was the outgrowth of a number of years of study of volcanic activity by the writer. Inspired by annual visits to the Lassen Observatory in California, where the Hawaiian-type instruments were in use and the laboratories at Pasadena and Berkeley, where various types of optical instruments were developed and operated, the writer's interest in seismology grew, and plans were made to establish a station in Des Moines with teleseismic instruments sufficiently sensitive and accurate to supply needed records in the midwest area, where stations are far apart.

The instruments were designed and built by the writer, the first component being started in operation December 20, 1934, and the second March 15, 1935. They are modified Bosch-Omori in type, and record on smoked paper, one drum being used for both components. The period is 9 seconds and a magnification of 15 was used until this month, when it was increased to 25. A 24-kilogram heavy mass is used, this being adjustable along the pendulum. A pivot is used for the lower suspension and a fine piano-wire suspension at the top of the upright is adjustable back and forth for change of period and from right to left to correct tilt.



Weather Recording: Swinging wet-bulb and dry-bulb thermometers for relative moisture content of the air.

The magnifying system is a new device, designed to reduce friction, which is the great problem in lever magnification. A steel rod, attached to the end of the boom by a three-way adjusting device, ends in a U-shaped fork, having a needle eye at the end of each tine. The fork moves in the same plane as a clock wheel, mounted on a pinion, working in polished bearings in a frame, the wheel being mounted between the two ends of the fork. A groove is cut in the rim of the wheel. A fine silk thread, knotted at one needle eye, passes around the groove in the wheel, thence through the other needle eye and back to the steel rod, where it is kept at unvarying tension by a tiny weight. A 17 cm. recording arm of .006 aluminum is



Weather Recording: Thermograph, rain gauge, maximum thermometer, minimum thermometer.

riveted to the wheel, ending in a fork with an arbor set in polished bearings. The arbor carries the balanced stylus which has just enough weight to remain on the smoked paper. When a movement occurs the fork with the silk thread turns the wheel, oscillating the recording arm and resulting in the variation from the straight line which records the earthquake's message.

Oil damping is used. Time control is provided by a regulator clock closing a circuit every minute and lifting the stylus by means of an electromagnet. Time is checked twice a day by radio signal.

Records are sent to the United States Coast and Geodetic Survey and the Jesuit Seismological Society. During 1935, the first year of operation, 29 earthquakes were recorded at the Des Moines station, varying in distance from the Nebraska earthquake, March 1, 1935, 250 miles distant, to the December 26 shock near Sumatra, 9,700 miles distant. From January 1 to September 1, 1936, 20 shocks have been recorded.

The Seeburger family home offered a good location for the station, being located on a street undisturbed by heavy traffic. A special room was provided, with no windows, and well insulated to keep temperature as nearly uniform as possible. The cement work and casting of lead cylinders was done by the writer, assisted by her husband, who is city solicitor of Des Moines, and a high school son. The assistance of a machinist and a jeweler was required for some parts of the mechanism. Designing, experimenting, and final construction of the instruments required about a year's work.

ADVENTURES AND METHODS IN STUDYING WEST INDIAN VOLCANOES

The bombing of Mauna Loa December 27, 1935, was followed by the stoppage of the lava flow before it damaged Hilo. The preparation for this engineering job was twenty-four years of recording and experimenting on Kilauea and on Mauna Loa. The action taken was not suddenly inspired, but was methodically thought out sixteen years earlier. The coming of this particular 1935 eruption of Mauna Loa was published early in 1934 for time, place, possible direction, earthquake accompaniments, preparedness, and method of airplane attack.

The volcano excelled itself in coming to time. Predicting is the test of right interpretation of physical processes. At Hawaiian Volcano Observatory mere descriptions and photographs of eruptions gradually gave place after the first six years of work to systematic measurements of earthquakes, tilts, tremblings, gases, and temperature. The effort was always to see what lava is doing underground. Photographing and describing it above ground during eruptions, and comparing the earth motions during eruptions, gave information of what lava is and how it may be acting underground all the time. Gradually the non-erupting times became very interesting as pointing to the places and depths where lava was working its way upward.

This has all led to the investigation of three main projects which in scientific terms may be described as locating earthquake centers underground, measuring the year to year elevation or sideways motion of the ground, and measuring the ejection of matter, either lava or gas, or both. There is always gas being emitted, but not always lava. Sometimes the lava takes it out in lifting the mountain by swelling inside.

When I had opportunity in the spring of 1936 to visit Montserrat in the West Indies, which had been violently shaken by many earthquakes, I had these principles in mind. There was no observatory on Montserrat, but some good earthquake observers had made lists of shocks, and some agricultural chemists had studied the sulphur banks in the craters.

The West Indian volcanic adventures of the last few years have come on several different islands along a curved line of several hundred miles of active volcanoes. They are like the Hawaiian Islands in being thirty or forty miles apart, and long ages past they poured out black lava. But now they are shoving up stiff lavas which are more crystalline and contain more silica. These masses underground react violently with water, the way Kilauea did in 1924. The result was the terrible eruption of Mont Pelé in 1902, which sent out a downward blast of scalding steam and destroyed 26,000 people in St. Pierre. The day before this the volcano Soufrière in St. Vincent made a similar eruption with similar destruction. Mont Pelé during the next year sent up a stiff plug of siliceous lava from its crater. Soufrière did not do so, but filled its crater with a lake of hot water which gradually cooled off during the decades since. Mont Pelé renewed its eruptions in 1929 after twenty-four years of quiet and again increased its height by thrusting up a central plug.

It was just after this last event, which came to an end in 1932, that Montserrat started making a nauseating smell of sulphurous gases in its crater, which is 146 miles northwest of Mont Pelé. It is the same kind of a crater, with several valleys containing sulphur banks, and boiling springs and steaming chemicals. These are all the products of lava somewhere below and the reaction of its acid gases with the rocks of the island and with water. Immediately thereafter, Montserrat started to shake. About every six months in 1934 and 1935 the swarms of earthquakes increased in number and vio-

lence, and most of the churches were shaken down. The morale of the people was upset, for everyone remembered the scalding hot blasts of Mont Pelé.

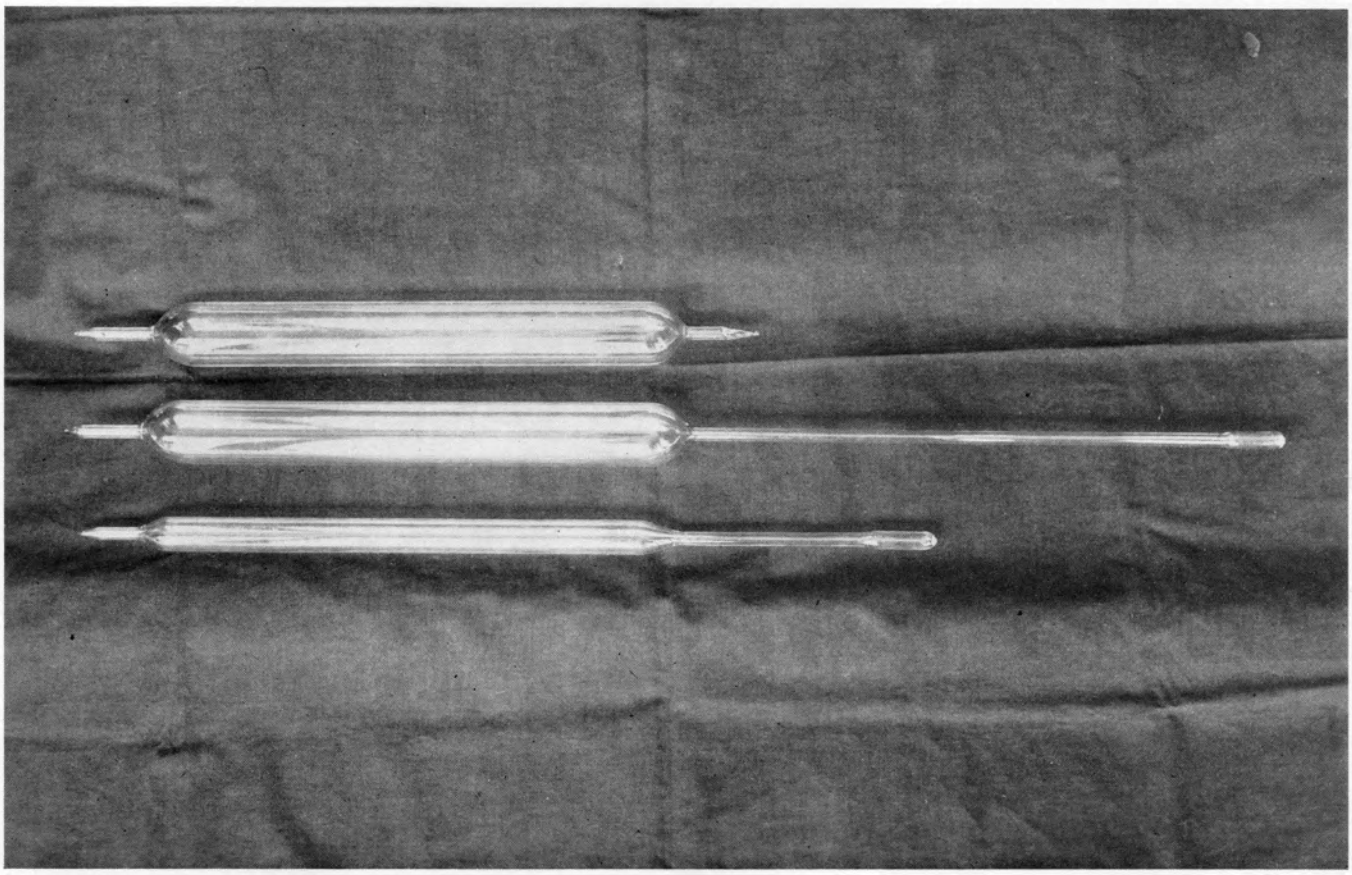
The shift of activity in 1902, 111 miles from St. Vincent to Mont Pelé in 17 hours, and the shift of activity of a different kind, 146 miles from Pelé to Montserrat in a year in 1933, shows that we have to deal with something like the shifts of activity from Kilauea to Mauna Loa, and also such changes from outside eruption to inside heaving, as we had in 1929 when Kilauea stopped erupting and North Kona started shaking. Here are shifts in Hawaii from one place to another, for much shorter distances, than the distances in the West Indies. But the kinds of action are much the same, with due allowance for a different kind of lava.

After making such allowances it is evident we can apply our three methods in the West Indies, if we locate earthquake origins, measure slow motions of the ground, and measure the kinds and temperatures of gases. All of these things are measurable there all the time. The chemistry of the hot solfataras, and there are scores of them in the West Indies, is very interesting and very significant. But before any predicting can be done it is essential to combine the changes in gases and the changes in sequences of earthquakes. This means we must know what the little earthquakes were in numbers and intensity during the quiet time before the crisis developed. For this same time we must know what the gases were and how hot they were before the nauseating and excessive gaseous emission became conspicuous. These are just the facts that we do not possess, in the absence of an observatory. The same thing was true in 1901, the year before Mont Pelé and Soufrière erupted.

What methods, then, should be recommended for understanding any such active volcano? Clearly the measurement must be repeated and continuous. The little earthquakes, the changing elevation of the ground, and the gases, must be measured every week or month or year, and the measurements entered in a record book. Montserrat appears now to have quieted down. What place in those ten or twelve active volcanoes, in those eight or nine islands, along those 350 miles of curved volcanic crack, is now going to do something unusual in 1937 or 1938 or 1939, following upon the shift from Martinique to Montserrat?

There have been many difficulties and disappointments in studying Kilauea and Mauna Loa. There are enormous difficulties and disappointments for the Dutch engineers in studying with airplane and otherwise the many volcanoes that destroy human beings in densely populated Java. But these Hollanders remained manfully at their posts in the jungle amid poisonous reptiles and poisonous gases, and they are getting results. This kind of work of the Geographical Engineer is growing more important, all the world over, because men must know the power and the materials of the earth that is their home.

T. A. J.



Vacuum tube styles for breaking or melting the tip in a gas-hole or volcanic flame: and one tube which has been sealed with gasoline torch.



Use of caliper for measuring large cracks at Halemaumau. The crack is equipped with copper studs and, after setting, the caliper opening is measured with steel tape. An improved caliper is made with arc and clamp.

THE VOLCANO LETTER

No. 438 monthly **Department of the Interior National Park Service** **August 1936**

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR AUGUST, 1936



Campfire Lecture. Grand Canyon, Arizona.

SCIENCE IN THE NATIONAL PARKS

The opening of the Uwekahuna Museum at Kilauea April 18, 1927, was the occasion for an address by the writer to the delegates of the "First Pan-Pacific Conference on Education, Rehabilitation, Reclamation, and Recreation," which met in Hawaii at the call of Secretary of the Interior Dr. Work. Mr. Stephen T. Mather, Director of the Park Service, attended this meeting and the subject of the talk was the geographical

opportunity that the Parks offer for experimental studies by measurement of geologic processes (Bulletin Hawaiian Volcano Observatory, April, 1927).

The present address was delivered to the University of Hawaii Summer School at Kilauea, June 20, 1935, in order to outline the growth of educational work in natural science in the National Parks (which has been greatly added to in the last few years), and to show how the several volcanic Parks may add important data to the science of volcanology that is being studied experimentally at Kilauea and Mauna Loa.

It was in 1872 that Yellowstone region was created the first National Park on earth "set apart as a public park or pleasuring ground for the benefit and enjoyment of the people; the preservation from injury of all natural features; and their retention in their natural condition."

The National Park Service as a great organization under the Department of Interior was established August 25, 1916, and owes its original solidity and growth very largely to Stephen T. Mather who was its guiding spirit until January 28, 1929. The idea of creating free nature guides for travellers began at Yosemite in 1919 and this became the Division of Research and Education under Dr. Harold C. Bryant in 1930. A large growth in numbers of Naturalists and Ranger Naturalists attached to the Parks took place during the formative period, and the importance of visual education and photographs* was accented after 1923.

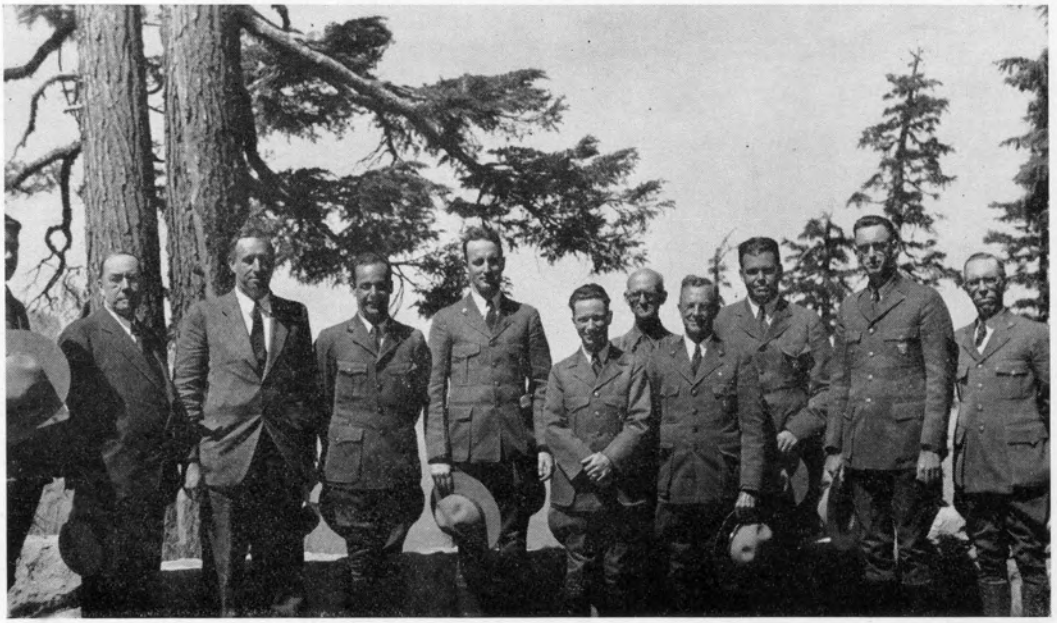
A committee on the educational problems in the Parks made an extended study of the question of developing museums in close proximity to the places where the exhibits came from. There were many places where the actual landscape spread out before the traveller gave life and reality to these exhibits. And there were many other places, like our footprints of the old Hawaiian natives in the Kau desert, where the whole significance of a specimen depends on seeing it in its natural environment. Hence arose the "trailside museum" where a group of fossils or crystals or objects of organic life may be both preserved from harm and seen in their natural relations under advantageous lighting.

The committee on the study of educational problems consisting of Messrs. Merriam, Bryant, Atwood, Bumpus, Kellogg, and Oastler made critical studies of such Parks as the Yellowstone, the Yosemite, Crater Lake, and Lassen; with the assistance of the American Association of Museums, the American Library Association and the Rockefeller Foundation.

From 1924 on, a field school of natural history had been established in the Yosemite. The expenses of the visiting committee of educators were provided after 1928 by the Laura Spelman Rockefeller Memorial which also supplied $118,000 for Yellowstone Museums, near Old Faithful and at Mammoth Hot Springs.

The report of the committee in 1929 pointed out the necessity and the advantage of further research in science as a service to the visiting public, and as service to educators and investigators, "to increase the general and special knowledge of the phenomena represented in the Parks."

In 1928 a trailside museum was built at Yavapai Point in the Grand Canyon. In 1929 the Museum at Yosemite was built. The Loomis Museum was accepted as a gift from private donors at Lassen.



A Group of Educators and Park Officials at Crater Lake in 1934.

Archeological museums were now springing up in Parks having remains of Cliff Dwellers and Indians, the cooperation of the Smithsonian Institution had been secured, fish culture was in progress, the preservation, feeding and study of animals in their native habitat had become a large branch of the work, and to this the Biological Survey contributed, as did the Bureau of Forestry to the protection of National Park Forests.

In 1930 at Craker Lake a memorial was built to Congressman Sinnott of Oregon. This is a rough stone observation station, inside the rim of the crater, with mounted field glasses, specimens and relief map, all in a commanding position with parapet overlooking the lake. An archeological museum was built at Mesa Verde, and an Indian museum at Acadia (Mount Desert).

At this time several Parks had adopted the practice of conducting automobile caravans from place to place in the care of trained naturalists, and the cooperation in research by government bureaus had become a regular practice. In the cliff dwellings of the southwest, Dr. A. E. Douglas, who had developed the science of interpretation of tree-rings in relation

to sun-spot intervals and the climatal changes that affected trees, applied his knowledge to the beam cores of the cliff dwellings, so as to determine their age.

In 1931 lectures and field trips had become the first aim of the Naturalist Branch, a Chief Historian was appointed to cover history and archeology, and Dr. Bumpus succeeded Dr. Merriam as Chairman of the Educational Advisory Board. The Fishing Bridge Museum and Trailside Shrine at Obsidian Cliff were built in Yellowstone Park. At Dinosaur National Monument in Utah an actual fossilized skeleton of a large extinct reptile was excavated in relief by the American Museum of Natural History in its natural site.

Three-year studies of wild life conditions were begun, particularly in the Yellowstone; and for the elk, a cooperative survey was made for the migration routes, the life history and the forage requirements. The Biological Survey, the Forest Service, and the Montana Fish and Game Commission collaborated in this.

In 1932, the native Indians were employed to show their arts and crafts. A ranger-naturalist at the Grand Canyon accompanied privately operated airplane flights. In Acadia a sunrise breakfast caravan was led to the top of Cadillac Mountain, and in the Yellowstone an evening caravan was led to suitable places for stalking game with the camera. Informal campfire talks to five hundred people at a time were held in the Yosemite and the Yellowstone.

The use of the National Parks by university classes was increasing; the principal subjects of investigation being the group relations to each other of plants and animals, and the geology. Graduates of the Yosemite Field School are now serving as ranger-naturalists in other Parks. Thus the Park Service becomes a University for training its own men.

In pure science, cosmic ray investigations have been made in Hawaii and at Mount McKinley. In the Yellowstone, and the Absaroka Mountains to the east of it, university groups of highly trained specialists have investigated the origin of granite, and the geology of the Rocky Mountains.

In 1933 the Emergency Conservation Program was at work in numerous C. C. C. Camps of the National Parks, and the preservation of historic sites was one of the activities of the Educational Board. Sea caravans of motorboats were added as a new feature at Acadia, to study sea-life. Indian pageants were organized, a wayside museum of archeology was built at the Grand Canyon, and a wayside exhibit of the life history of the beaver was established at Yellowstone. In two lookouts there, long-range telescopes were set up. Botanic gardens have been created at Yellowstone and Crater Lake, and a new garden was presented to Yosemite Park.

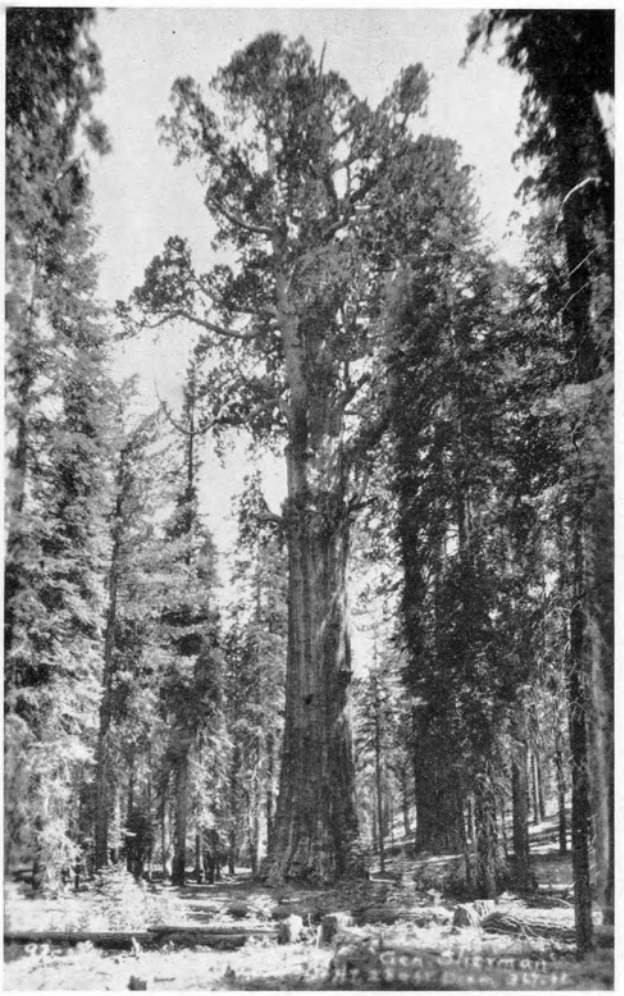
As examples of the utilization of cooperative research in the National Parks, we have had out here in Hawaii Dr. Meinecke of the Bureau of Plant Industry, and Drs. Day, Shepherd and Allen of the Carnegie Institution. Dr. Wetmore, ornithologist of the Smithsonian has taken a great interest in the Parks and has also been to Hawaii, and the Biological Survey has contributed the work of Drs. Palmer and Murie. Dr. Hommon of the Public Health Service has studied Park problems, and Dr. Hazard of the Bureau of Fisheries. In history Dr. Leland has called in the Council of Learned Societies and a group of leading historians for the numerous battlefields and other places related to the history of the country. So it is with the prehistoric sites where ancient man lived and worked and tilled the soil. The universities of Michigan and California have collaborated in studies of the Teton Range, a National Park in the Rocky Mountains immediately south of the Yellowstone.

National Park Science in Hawaii

The foregoing outline sketches the growth of public interest in the many branches of natural and human science that are related to the preservation forever of large tracts of natural wilderness, or smaller ones of historic land.

The tendency of industry is to tear the land to pieces for raw materials, agriculture, transportation or construction and congestion of cities.

The National Park idea has in some measure preserved the natural frontier which our forefathers met in their restless march seeking freedom and wealth. There is still a frontier and a restless march. The tools of the primitive American frontier were the axe, the plow and the rifle. The tools of the new frontier are the airplane, the radio, and the chemical bal-



Sequoia National Park. General Sherman Tree.
Height, 280 ft.; Diameter, 36½ ft.

ance. By the ever-widening range of these new tools, which look outward to the universe, and inward to the core of the earth, the frontier of the human spirit today knows no boundary.

The outlook of the Hawaiian Volcano Observatory on its frontier, hewing its way with metaphorical axe and plow and rifle to a visionary palace of science on the top of Mauna Loa Volcano, differs somewhat in its aim of education and research from most of the enumerated activities above outlined.

The word "research" means searching over again, and the historical viewpoint is conspicuous in the attitude of scholar-

ships. How did the elk and buffalo originally live? How did the beaver behave when undisturbed by man? How did the cliff dwellers live? How was that battle fought? How did those mountains grow? How did the dinosaur behave? How does the undisturbed trout breed and meet his enemies? How did the tree rings vary in the seventeenth century? What were the customs of the original Indians? How did the primitive forests grow?

It is a curious and inevitable trait of education and scholarship that the past is more detailed and elaborated than the present and the future, in current methods of research.

In contrast to this, the activities of the present are studied in the chemical laboratory, the growth of living cells in the microscope, the interaction of plants and animals on land and sea; and the effect of planting of gardens and forests and the culture of fish and insects.

The seismologists look inward at the shells of the globe for echoes from distant big earthquakes; and the magneticians and gravity physicists do the same with the compass needle and the pendulum.

The day to day changes, and the statistics of the present are used by laboratory and field science, and the widely distributed National Parks are very valuable for these sciences, whenever a variety of latitudes, elevations or climates affects the process that is being studied. Science goes to the beach when it has to study sea-life, and it goes to the mountain top when it has to study effects of elevation. The Middle Ground, between University and Universe, is apt to be neglected.

On the other hand, the astrophysicists study the universe, and the ultimate atomism of physics, but frankly acknowledge little interest in the earth, the moon and the planets. The earth is chiefly a nuisance, because of the disagreeable optical properties of its atmosphere.

These investigators are studying the light which left distant bodies in space hundreds of thousands or millions of years ago, and so they also are intensely interested in the past. Their observatories have the great advantage of being close to universities, and it is only occasionally that the hardship of an expedition is necessary for such an event as an eclipse. The frontier of the outer universe is the field of their restless march, and their tools are the telescope, the spectroscope, and the electro-magnet.

A part of science, therefore, leaps from the university microscope or electroscope, to the observatory telescope, in studying pinpoints of light. It leaves the study of the earth, the study of the great rough frontier, of the mountains, the rivers, the ice, the sea-bottoms and the volcanoes, to the great rough corporations and their engineers, who handle great rough bodies of labor in tearing up the earth for raw materials and for power.

But what of the earth itself, and its great and small natural processes on the surface, where man dwells, at the present day? And what of the future results of those same processes, many of them quite within the range of man's prediction, that will sweep his cities with hurricane, flood, drought, dust, insect plague, famine, fire, earthquake, blizzard and tidal wave?

The mathematical quantitative study of a point of light under a lens, and the explanation of the past by its aid, is so much more orderly than fighting the battles of the earth frontier; that the pure sciences of the interaction of the atmosphere with the earth, are somewhat left to engineers, and governments, and commerce.



Loomis Memorial Mission, Lassen Volcanic National Park.

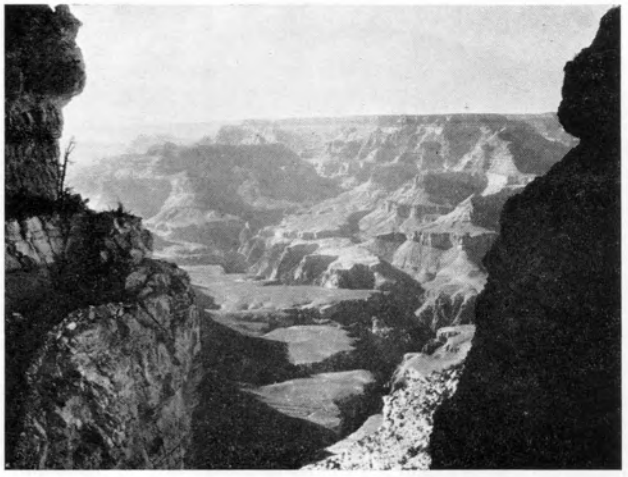
In relation to the looming bulk of those things in the economy of mankind, there is no adequate field science today of the inorganic processes, of oceans, rivers, shorelines, glaciers and earth movements.

The Hawaiian Volcano Observatory has stood for this field science of Experimental Geonomy from the time when it was first proposed in 1909. The object was to keep a diary of active volcanoes, and by patient effort to decipher their habits, to discover the swelling and shrinking of the land, the cycle of outbreaks, the location of centers of small localized earthquakes, and the peculiarities of lava when it pours forth. The island was treated as a working model of process. This followed a resolution of 1907 recommending the foundation of earthquake and volcano observatories, passed by the Geological Society of America.

In the same way the Mississippi might be treated as a model of river process, all the way from Yellowstone and Rocky Mountain National Parks to the delta in the Gulf of Mexico.

And the laboratory should be called an observatory, because its function is to observe and record forever.

The result of twenty-five years of work in Hawaii has been to show that the Hawaiian volcanoes are always predicting their own coming events. Sensitive instruments tell what is happening underground. Earth movements and earth chemis-



Grand Canyon, Arizona.

try never cease. There are some discovered emanations, in gases and wave movements; there are probably many undiscovered ones which are telling the times and places of future eruptions.

There is great importance to comparison with different places. Such different volcanic places are the Yellowstone and the northwestern volcanoes, the hot steam region north of San Francisco, the Aleutian Islands, and Arkansas Hot Springs. How do the undeciphered emanations there differ from the Hawaiian ones? And what difference do they predict for intrusion of lava underground, in contrast to the occasional and relatively rare extrusion, in places like Hawaii and Japan?

And so for the other processes of the earth, the making of new rock, the uplift of the land, the sweep of the waters, the rotting of the mountains, and the settling of the rubbish, we need never leave the National Park System to establish observatories of the behavior of the earth.

Glaciers are to be found in Glacier Park, Rainier and Mount McKinley. Mountains are rotting in different ways in the Great Smokies, the Grand Tetons and Yosemite. Rivers are telling their story in all of these, as well as at Platt, Hot Springs, Yellowstone and Grand Canyon. Volcanoes offer a variety at Lassen, Crater Lake, Rainier, Katmai, Craters of the Moon, Yellowstone and Hawaii. And sea-bottoms in great variety are close to Hawaii, Acadia, Katmai, Sitka and Olympus.

All of these places contain superb opportunity for establishment of permanent geonomical observatories. Here lie the mysteries of possible deciphering of the great powers that dwell in our own earth; which from second to second and minute to minute is being altered as man's habitation by the hot forces within it, and by both the hot and cold forces of its own interaction with water and air.

T. A. J.

Photographs herewith kindly supplied by Assistant Geologist H. H. Waesche.

VOLCANOLOGY

The month of August, at Halemaumau Pit of Kilauea Volcano, produced more slides and a widening of eastern cracks at the edge of the pit. Otherwise nothing of external happenings was conspicuous for the Hawaiian volcanoes during this month. The third week of the month was most active seismically and showed the highest weekly index per month, of local seismicity, since April, the sequence being for the weeks ending:

May	31,	Seismic	index	15.25
June	7,	"	"	11.25
July	19,	"	"	22.25
August	23,	"	"	45.50

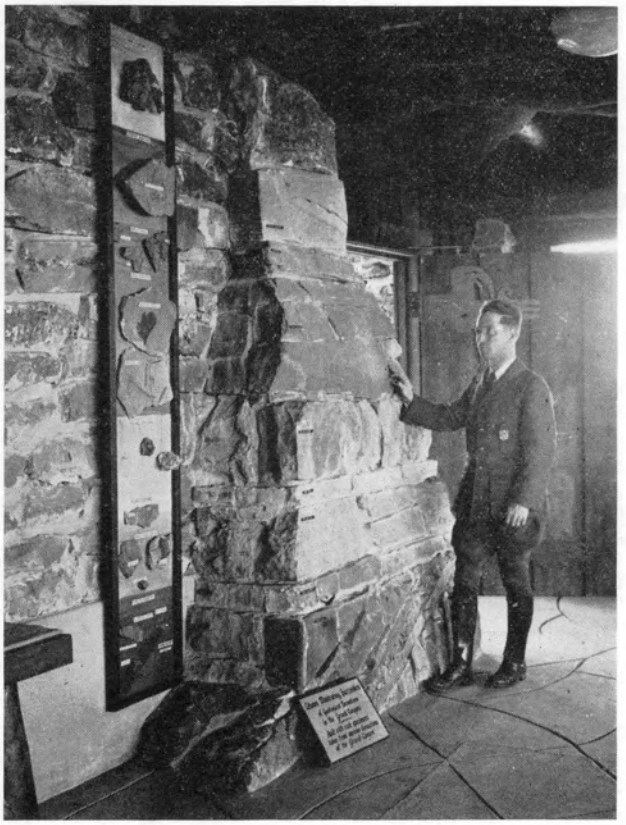
In the main this index is made up of tremors, and this summer these tremors have been greatly affected by slides from the walls of the pit. The total number of slides for the month, however, counted during daily forenoon visits and by dust cloud at other times does not accord with the above table of seismicity maxima:

Number of slides May	12
June	6
July	26
August	6

Slides at Halemaumau

Slides from the wall of the pit have been noted as follows:

August 6. Dust on floor of pit seemed to concentrate around the floor crack.



Columnar Sections of Natural Rocks and Fossils of Grand Canyon in Yavapai Museum.

August 9. Moderate slide NE wall 9:25 a.m., apparently from gaping outcrop of Crack No. 29.

August 18. Moderate slides 9:35, 9:42 and 10:42 a.m. NE wall under Crack No. 29. A little farther north some dis-

tance back is Crack No. 46, which has been opening. Still farther north Crack No. 34 caved in completely on March 22. This high part of NE wall, between E and NNE taluses, was getting ready to fall.

August 31. Moderate slide 8:03 a.m. under Crack No. 29, sending up thick dust cloud, leaving fresh scar, and thin dust on floor beneath.

August 31. Small slide same place 12:18 p.m.

lava cascades NW. These places are on a diagonal of the pit at right angles to the rift belt.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 32 marked places on rim cracks around the upper edge of Halemaumau Pit resulted as follows:

Week ending forenoon of:

August 8, 9 opened, 3 closed, aggregate opening 9.5 mm. Crack No. 46 opened 6.5 mm.



Mountain Lion. North Rim, Grand Canyon, Arizona.

Halemaumau Solfataras

There has been no notable change in the places at the edge of the floor, where yellow sulphur and white sulphates are depositing and blue fume rises, varying in visibility with the humidity of the air. The most conspicuous places are under the Tourists' Stand SE, and at the north end of the 1934

August 15, 6 opened, 4 closed, aggregate opening 8.5 mm. Crack No. 46 opened 7.0 mm.

August 22, 11 opened, 2 closed, aggregate opening 14.0 mm. Crack No. 46 opened 7.5 mm.

August 29, 8 opened, 2 closed, aggregate opening 12.0 mm. Crack No. 46 opened 8.0 mm.

T. A. J.

EARTHQUAKES

Table

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Slight Earthquakes	Distant Earthquakes	Local* Seismicity
August 9	84	5	0	0	23.50
" 16	17	6	0	0	7.25
" 23	140	19	1	1	45.50
" 30	47	7	0	1	15.25

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible, determinations of depth of focus have been made.

August 3, 10:36 pm, very feeble, probably located in Kilauea Crater.

August 7, 8:21 pm, very feeble, probably located near Puu Huluhulu, Chain of Craters Rift.

August 8, 7:13 pm, very feeble, probably located about 0.8 mile SW of center of Halemaumau.

August 8, 9:51 pm, very feeble, with location same as preceding quake.

August 10, 3:12 am, very feeble, probably located in SW rift zone of Kilauea, 0.9 mile W of Pit seismograph.

August 13, 12:25 pm, very feeble, probably located in vicinity of Kamakaia Hills about 10 miles SW of the Observatory.

August 16, 7:38 am, very feeble, probably located about 10 miles W of Hilo. Reported felt by several at Waimea Hotel.

August 18, 4:54 pm, very feeble, located 2.2 miles deep in Kilauea SW rift zone near Puu Koae. 19° 21' 8N; 155° 19' 3W.

August 18, 10:39 pm, very feeble, located 1.4 miles deep under Byron Ledge, SE portion of Kilauea Crater about half the distance between Keanakakoi and Kilauea Iki Craters. 19° 24' 5N; 155° 15' 6W.

August 19, 10:28 am, very feeble, located 1.9 miles deep in west portion of Kilauea Crater. 19° 25' 2N; 155° 17' 4W.

August 19, 11:05 am, very feeble, located 0.7 mile deep and 1.2 miles S of Pit Seismograph Station. 19° 23' 3N; 155° 17' 0W.

August 20, at 6:23 am, a slight earthquake occurred. It was probably of very shallow origin under SE rim of Kilauea Crater. The shock was not reported felt. 19° 24' 2N; 155° 16' 1W.

August 20, 9:41 am, very feeble, probably located under N rim of Kilauea Iki.

August 20, 6:04 pm, very feeble, located 2.4 miles deep in rifts 0.3 mile N of Ahua Kamokukolau. 19° 23' 2N; 155° 16' 3W.

August 21, 8:36 pm, very feeble, located 3.3 miles deep in rifts 0.9 mile SE of Ahua Kamokukolau. 19° 21' 5N; 155° 15' 4W.

August 24, 1:56 am, very feeble, located 6.2 miles deep in Chain of Craters rift near Devil's Throat. 19° 22' 8N; 155° 14' 5W.

August 24, 2:17 am, very feeble, located 2.3 miles deep and 0.3 mile NE of the Observatory. 155° 15' 5W; 19° 26' 1N.

There was a marked increase of seismic activity during the week of August 16-23. Many of the locations of the very feeble earthquakes of the month were difficult or impossible to make because of the lack of definite demarkation of phases. In most cases they waxed to maximum amplitude with little change from the initial type of movement. In this respect they resembled enlarged tremors.

At 8:34 pm, August 21, the preliminary waves of a teleseism began recording at 8h 33m 31s pm. Its reported location was in Formosa. 22° 3N; 121° 5E. The distance from Kilauea was 5,265 miles. Another teleseism registered its preliminary waves at the Volcano Observatory beginning at 10h 59m 6s am, August 26. Its estimated distance from Kilauea was 3,155 miles.

Periods of continuous tremor registered as follows: beginning at 9:32 am, August 4, 4 minutes; at 11:16 am, August 9, 30 minutes.

Microseismic motion of the ground at Kilauea was light for the entire month of August.

H. H. W.

TILTING OF THE GROUND

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending August 30, was 4" 67N and 0" 25E.

H. H. W.

* For local Seismicity definition, see Volcano Letter 371.

CRATER ANGLES

Measurement of Horizontal angles across Kilauea Crater from the Observatory, August 18, compared with similar measurements July 24, showed a slight closing both across the Crater and Halemaumau. From July 24 to August 7, there was closing from the SE rim of Kilauea to Uwekahuna of 2".5 and across Halemaumau from the Pit seismograph to the NW BM, closing of 1".25. From August 7 to August 18, the Crater angle opened 1".00 and the Halemaumau angle opened 0".67.

H. H. W.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations		
		West	Southeast	Pit Resultant
August 9	0".15 N 4°E	3".28 W	10".63 S 18°W	8".42 from
August 16	1".02 N 40°E	4".53 S 54°W	4".47 N 34°W	0".99 from
August 23	0".38 N 20°E	5".39 N 45°W	4".21 S 25°W	5".37 from
August 30	0".55 N 17°E	5".00 N 75°W	4".57 N 15°W	0".41 from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THE VOLCANO LETTER

No. 439 monthly Department of the Interior National Park Service September 1936

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

The succession of numbers of this journal in the autumn of 1936 will deal with the sequence of special studies, by the Volcanologist, that led to the bombing operation on Mauna Loa during the great lava flow that reached South Hilo District in December 1935.

The present number describes the summit crater eruption, the like of which is always followed by a flow from the flank.

The October number will print the Annual Address of March 1934 that showed the reasons for expecting that flow within two years at the north: with more illustrations of the 1933 eruption.

The November number will describe the Kilauea eruption of September 1934, with illustrations of that extraordinary cascading eruption of Halemaumau, keeping up the precedent of averaging one eruption a year for the Hawaiian system in the recent eleven-year cycle 1924-1935.

The December number will reprint, by permission, an article from "The Military Engineer", describing concisely the exact facts concerning the 1935 eruption, the bombing, and the stoppage of the flow towards the city of Hilo, with illustrations.

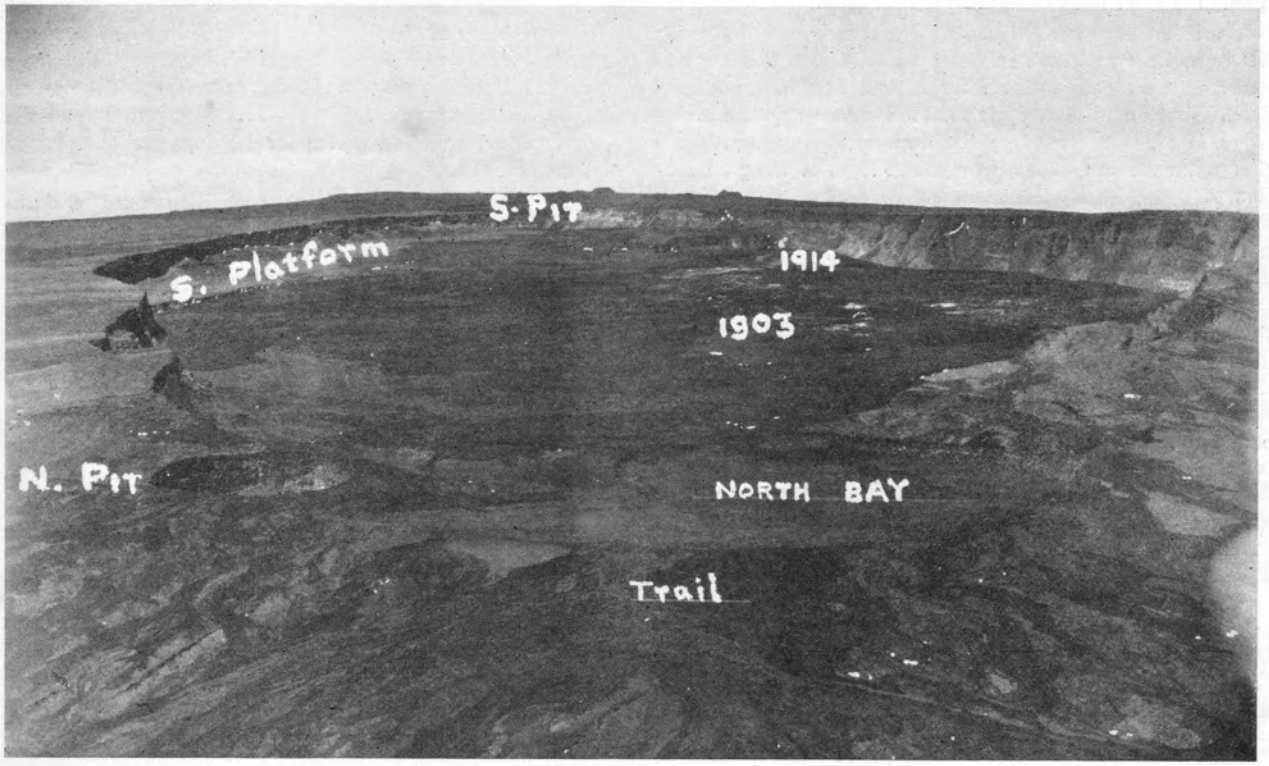


Figure 2. Mokuaweoweo from an airplane January 20, 1925, looking SSW. Condition before the 1933 eruption. Photo by 11th Photo Section, A.C., Wheeler Field, T. H. Elevation 14,600 feet (4450 meters).

SUMMIT OUTBREAK OF MAUNA LOA DECEMBER, 1933

T. A. Jaggar

Sequences Preceding 1933

Eruptive cycles of the Hawaiian volcanic system have indicated[1] that a complete eruption of Mauna Loa, and disregarding Kilauea, consists usually of one or more preliminary summit crater eruptions. These lead to one or more concluding lava outflows from an established rift that cuts across the mountain from southwest to northeast, with a slight bend at the summit crater.

The lava outflows so led up to, and occurring some years

after the crater outbreak, themselves begin with a summit gushing. This takes place a few days before the establishment of the flank outlet, which may be 6 to 12 miles (10 to 20 kilometers) from the central caldera.

The last complete cycle for Mauna Loa, preceding the one which is the subject of this paper, started in 1914. It began with an eruption of liquid lava, in the large summit sink-crater Mokuaweoweo, making a brilliant display at a fountaining cone, and flooding the crater floor from November 25, 1914, to January 11, 1915, a period of 48 days.

The later flank outflows, down the southwest rift of the mountain, were in 1916 and 1919; these came in May-June and September-November, and lasted respectively 17 days and 56 days.

The completion of a cycle for Mauna Loa may not be judged without taking account of Kilauea. Kilauea frothing lava spurted and subsided in sympathy with the two outbreaks of Mauna Loa 1914 and 1916. After the Hawaiian Observatory had plotted this sympathy, the 1919 outbreak induced us to publish the expectation of sudden subsidence of Kilauea, which was then flooding, as soon as the Mauna Loa outbreak was finished. This was verified and the lowering occurred in Halemaumau pit of Kilauea volcano 600 feet (180 meters) in one morning, November 28, 1919. The lava in the pit immediately recovered and rose nearly to the top in 24 days,[2] a lift of 560 feet (171 meters). Such sympathy appears in the Halemaumau pit only when the crateral pipe has free liquid lava in evidence within it. When it is plugged the sympathetic movements can only manifest themselves by seismic action.

As Kilauea proceeded during the four years following 1919 to make three flank outflows, while Mauna Loa stopped its action, the repose interval for Mauna Loa had evidently arrived. That an 11-year cycle for the Hawaiian system ended in May 1924, was proved by the unusual large steam-blasts and engulfments at Kilauea, with the collapse of the pit Halemaumau.

The platted curve of rise and fall of lava for both volcanoes[3] makes a complete 11-year cycle for the system, between 1913 and 1924.[4]

This brings us to the new cycle for Hawaii, which began with the return of a short-lived inflow of spurting liquid lava on the bottom of the cup of talus in Halemaumau pit, in July, 1924. Just as in the case of the last cycle when Kilauea had resumed vigorous activity in 1914 and was followed by the Mauna Loa eruption of 1916, so this inflow at Kilauea of 1924 was followed by the gushing of Mauna Loa in April, 1926. This began its outbreak at the south pit of the summit caldera Mokuaweoweo, then spread down the southern flank and the lava emerged at about 8,000 feet elevation, to pour into the sea at the village Hoopuloa. The eruption lasted 25 days.[5]

This eruption of Mauna Loa was followed by small gushings in the bottom of Halemaumau pit, each adding a layer 60 or more feet (about 18 meters) deep, in July 1927, January 1928 (thin), February 1929, July 1929, November 1930, and December 1931.

[1] The Hawaiian Volcanic Cycle. Volcano Letter No. 325, March 19, 1931. Volcanic Cycles and Sun Spots. Volcano Letter No. 326, March 26, 1931. The Peak of the Volcanic Cycle. Volcano Letter No. 330, April 23, 1931. Beginning of the Volcanic Cycle. Volcano Letter No. 332, May 7, 1931. When the Pit Lava Sinks. Volcano Letter No. 324, March 12, 1931. Copies of the references in this paper may usually be obtained by addressing the Hawaiian Volcano Observatory.

[2] Bulletin Hawaiian Observatory, Vol. VII, No. 11, November 1919, pages 166 and 169. Page 166 is from the press report issued before the collapse.

[3] Lava Tide, Seasonal Tilt and the Volcanic Cycle, by Jaggar, Finch and Emerson. Monthly Weather Review, March 1924, Fig. 4. Tilt Records for Thirteen Years at the Hawaiian Volcano Observatory, by Jaggar and Finch. Bulletin Seismological Society of America, March 1929, Fig. 3, page 41.

[4] The Eruption Cycles in Hawaii, by T. A. Jaggar. Thrum's Annual, Honolulu, 1932, pages 83 to 93, chart on page 84.

The Outbreak of Mauna Loa, 1933

The earthquakes associated with this eruption have been described by Jones in Journal Washington Academy of Sciences Vol. 24, No. 10, October 15, 1934. A cluster of notable shocks in October, 1933, felt strongly at Kapapala Ranch on the east side of the mountain, led to an investigation of the summit crater by E. G. Wingate and A. E. Jones, Nov. 1-2, 1933. The main crater showed puffing vapor from the 1914 cone[6] on the floor, fume was dense from the sunken area around it, and the western walls of the crater were dusty with fresh avalanche scars. There was nothing remarkable about sulphur fumes or vapors elsewhere. Later events proved that the dense fume and puffing vapor near the 1914 cone in the southern part of the main bowl of the big crater heralded at just that place the coming eruption of December 2.

The summit crater of Mauna Loa was split along the upper end of the southwest rift (see map of Hawaii November Volcano Letter 1935, and later), where frothy lava gushed up, at 5:43 a.m. December 2, 1933. The rift opened along a belt about two miles (three km.) long in the southwest part of the crater, trending south 27° west from the inner basin. The cracks crossed the south inner platform, extended up the cliff to the outside country, and then on to the south for a half mile (one km.), about 500 feet (150 meters) west of the lip of the South Pit. The breakage was then offset 500 feet (150 meters) to the east, a crack emerging from the west corner of this pit and continuing across the upland to the southwest, so that cascades of lava were poured both into the South Pit of the main crater, and into the next pit to the south, Lua Hohonu.[7] The gushings of these outside cracks were short-lived, and the main activity of the eruption which continued, was inside the main Mokuaweoweo basin, about 500 feet (150 meters) east of the cone of 1914. Here a line of gigantic fountains was formed, continued in action for 16 days and stopped gushing December 18.

The physical measurements at Kilauea crater, during the activity of Mauna Loa, were of considerable interest. Halemaumau pit had its bottom sealed with the lava plug of December-January, 1931-32, so that no liquid lava, to rise or fall, was observable at the time of the Mauna Loa eruptions of the last cycle. The weekly measurement of marked rim cracks around Halemaumau, and precise levellings during the week ended December 17, comparing Halemaumau rim with the southern gravel spit, and the readings of horizontal angles across the pit from the Observatory, measured twice during the month, revealed no unusual ground surface displacements.

The tremors, tilts both at the Observatory and Halemaumau, and the total local seismicity, showed striking changes accordant with the period of the Mauna Loa eruption.

The number of minutes of tremor for the week preceding the eruption, as measured at the Kilauea observatory, was 56, whereas for the week ending December 3, the day after the outbreak, the number was 1393. For the next two weeks, the weekly frequency of tremors dropped off to 345 and 580. Thereafter the figures were low and normal, the numbers of tremors per week being 20 and 34 for the last two weeks of December. It thus appears that the number of tremor spasms, or minutes of tremor, increased suddenly from figures counted in tens, to figures counted in hundreds, for the three weeks of the eruption.

[5] Bulletin Hawaiian Volcano Observatory, April 1926, with illustrations in May to December numbers, 1926. See also Volcano Letter, Nos. 68 to 72, April 15 to May 13, 1926.

[6] Effects in Mokuaweoweo of the Eruption of 1914, by H. O. Wood. Amer. Jour. Sci., May 1916.

[7] Geology of Kau District, Hawaii, by Stearns, Clark and Meinzer, Water Supply Paper 616, U. S. Geol. Surv., 1930, maps.

It is customary at the Hawaiian Volcano Observatory to compute local seismicity in terms of minutes of "tremor", feeble, slight, moderate and strong correspond to I, II, III, IV, of the Rossi-Forel scale. The local seismicity index for any

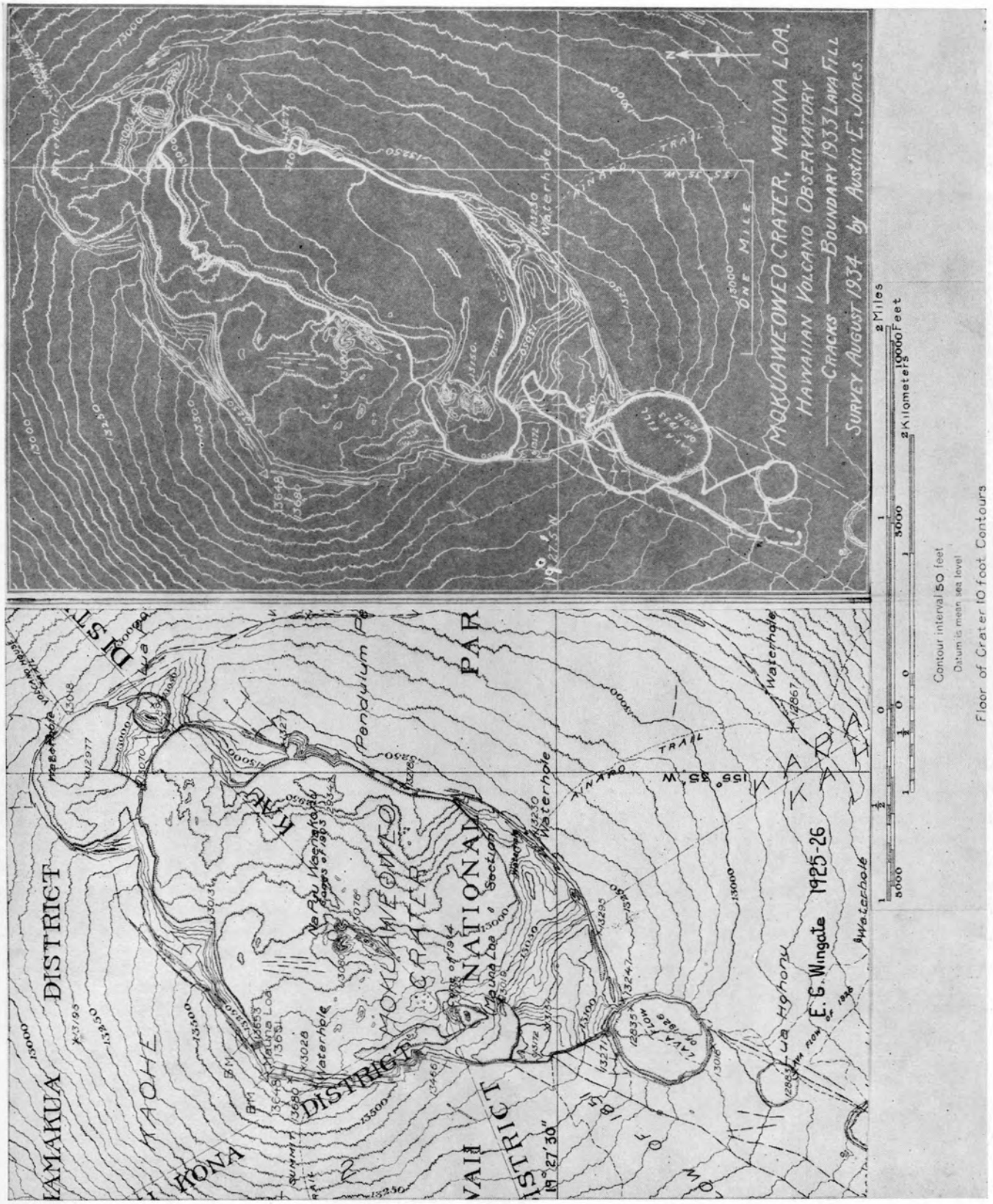


Figure 1. Maps of Mokuaweoweo before and after 1933 eruption.

unfelt or "very feeble" earthquakes, slightly felt or "feeble", felt or "slight", generally felt or "moderate", and "strong" representing earthquakes that are alarming. The grades

week is obtained by adding together the frequency numbers of arbitrary weights, corresponding each to one unit of each type of earthquake. The tremor unit is ¼, the very feeble shock is

½; feeble is 1, slight is 2, moderate is 3, and strong is 4. When a tremor lasts less than a minute it is evaluated as a single tremor unit; when it is continuous the unit is the minute of

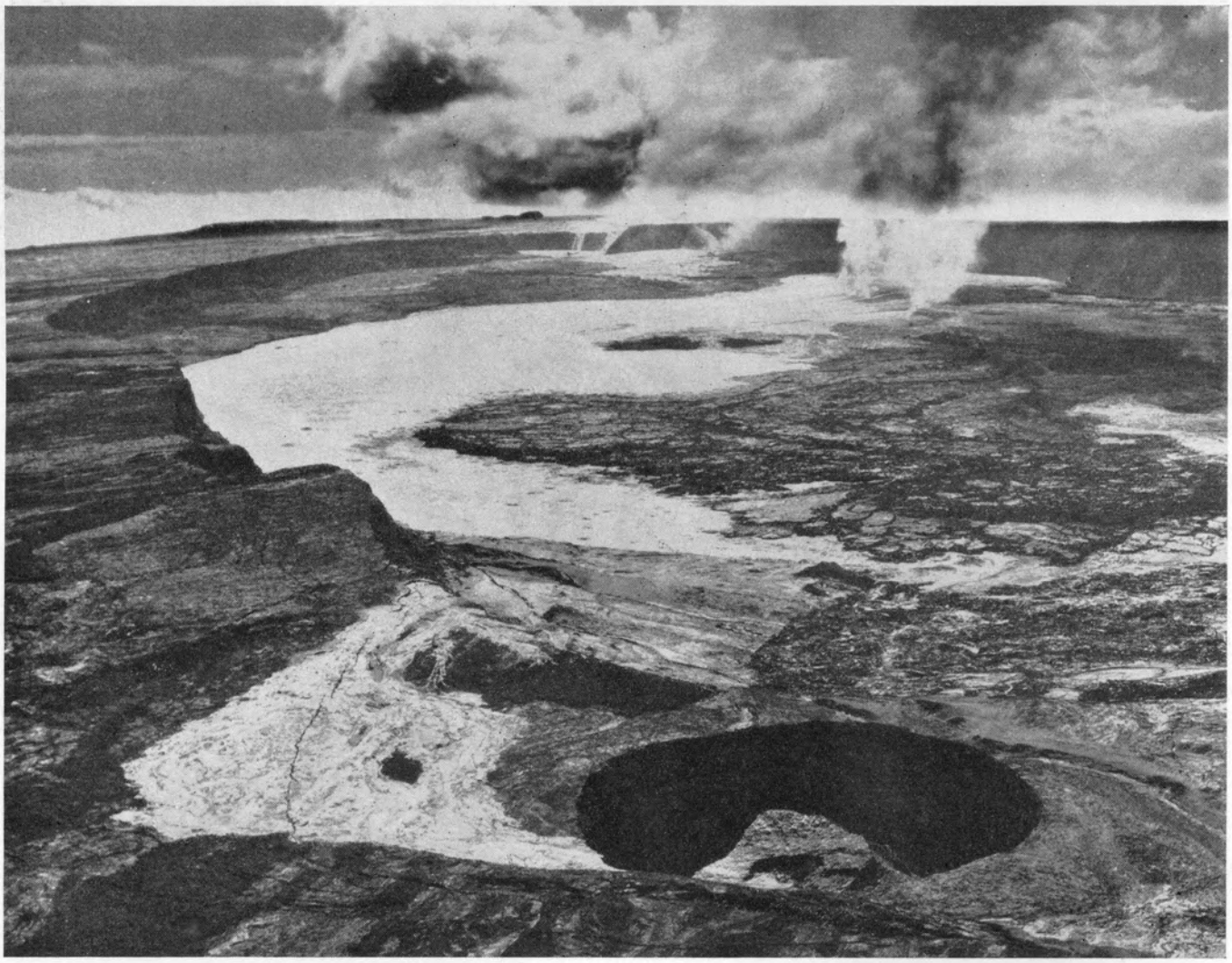


Figure 3. Mokuaweoweo eruption from 14,250 feet, 11 a.m. December 2, 1933, looking SW. North Pit in foreground, old lava gleaming to left of it. By permission Fleet Air Base, Pearl Harbor, U.S.N.

duration. If a week produced one of each of the six types the local seismic index, or summation of the weights would be 10¾. It will readily be seen that continuous tremor, measured in minutes, is a factor which greatly raises local seismicity values.

These values in 1933 were as follows, the eruption starting December 2:

	Seismicity
Week ending November 26	15.50
Week ending December 3	360.00
Week ending December 10	86.00
Week ending December 17	170.00
Week ending December 24	6.50
Week ending December 31	12.50

Tilting of the ground, measured at the Observatory on the northeast rim of Kilauea crater, was strong and northerly or easterly (away from the crater), before and after the Mauna Loa eruption, weaker and westerly during the eruption. The total tilt of the three clinoscope[8] cellars around Halemaumau pit, outward away from the pit, or inward toward the pit, measured on the radial lines from the center of the pit, and disregarding other directions of tilting, yielded interesting results. The aggregate tiliting at the pit had been notably inward for many months before the Mauna Loa eruption. The week of the outbreak it was strongly outward as though the Kilauea floor were swelling upward. After the outbreak it was **more** strongly inward, as though the sinking of the Kilauea floor followed the sinking back of lava under Mauna Loa. This sequence, for the lava fill, is just what happened at Kilauea, when the live lava in Halemaumau was visible during the Mauna Loa eruptions of 1914, 1916 and 1919; and the Mauna Loa crater is 22 miles (35 km.) away WNW.

[8] Volcano Letter, Nos. 382 and 392.

Maps of Mokuaweoweo Crater

In Figure 1 maps are shown of Mokuaweoweo crater before and after the 1933 eruption. The first is by E. G. Wingate, as mapped in the summer of 1926, after the eruption of that year. Contour intervals are 50 feet (15.24 m.) outside the crater, 10 feet (3.05 m.) within the crater floor. The lowest point of the main bowl showed elevation 12,934 feet (3942 m.) before the eruption, 13,035 feet (3973 m.) after the filling of 1933. The bottom of the South Pit showed elevation 12,835 feet (3912 m.) before the eruption, 12,912 feet

(3936 m.) after the filling. The eastern side of both bowls had been depressions before the eruption, but the fills made them relatively flat or level. The heavy outlines on the second map, a survey of August 1934 by A. E. Jones, indicate the two areas of fresh lava north and south. The northern area was fed by the north-south line of big cones approximately 100 feet (30 m.) high that built themselves up on a crack immediately east of the cone of 1914. This source made big floods of lava over the entire eastern side of the main bowl north of the southern lunate platform. These floods also filled the depression adjacent to the 1914 cone and made a new fill against the high western wall of the crater for a third of a mile (one-half kilometer).

The southern area of 1933 outbreak includes the two pits and the cracked upland west of them. A big fountain formed a cone at the foot of the bluff just north of the South Pit and sent a cascade for many hours into that pit. It is this cascade which produced and lies northeast of the small island mapped in the southern area of lava, shown on the northern side of the South Pit. The surface area of the southern lava tract is one square kilometer (0.39 sq. mi.) and of the northern tract three square kilometers (1.16 sq. mi.). The total volume produced in this eruption was of the order of 68 million cubic meters (2400 million cu. ft.).

1 sq. km. = 1 million sq. meters.

Max. thickness in pits southern area = 24 meters.

Mean thickness in south area = 8 meters—thin at the west.

Max. thickness in north area = 31 meters.

Mean thickness in north area = 20 meters counting the cones and west fill.

Area south = 1,000,000 sq. meters.
x 8 = 8,000,000 cu. meters.

Area north = 3,000,000 sq. meters.
x 20 = 60,000,000 cu. meters.

Add N & S = 68,000,000 cu. meters.

Progress of the Eruption

The estimated time of outbreak, 5:43 a.m., December 2, 1933, is that shown by the beginning of continuous volcanic tremor at the Kilauea seismographs. At 7:00 a.m. December 2 two dense white columns of vapor were rising, and by 9:00 a.m. there were three jets, the northern the largest and highest, the two southern ones each double. After the first two hours the white vapor columns became bluish and sulphurous, and these when seen in transmitted light were absinthe red. Filamentous glassy lava, or Pele's hair, fell in small amounts at Hookena 22 miles (35 km.) to leeward, west-southwest. There is reason to think that the division of the fume columns in three corresponded to the opening of three principal gashes on the rift belt. These are respectively the southern gash connecting the two outlying pits, the gash immediately west of the South Pit, and the gash inside the big crater offset still farther to the west and extended to the north. By 7:30 p.m. December 2, when the glow of the fountains at the base of each fume column could be seen, the glowing columns were three in number. The northern one was triple and very brilliant, representing three gigantic fountains east of the 1914 cone within the big crater. The second one was bright and stood over the big fountain at the southwestern border of the big crater, building a cone which vomited up a cascade that streamed down into the South Pit. The southern glow column was faint, and represented the last gushings of the southern gash after fourteen hours of action. The region near the southern pits went entirely out of action by the end of the first twenty-four hours.

Figure 2 shows a lengthwise view of Mokuaweoweo taken before the eruption from an army plane in 1925 at elevation 14,600 feet (4430 meters), looking from the region of the northeast rift towards the southwest rift cones in the distance.

The whole bowl of the caldera is exhibited for comparison with Figure 3, which shows the activity of the first forenoon of 1933 eruption. The line of fountains crosses the southern part of the large cauldron, cuts the northwest cliff-block of South Pit, and extends into the upland beyond, sending cascades of incandescent lava into the South Pit and the pit farther south. The three fume patches represent three principal fountaining areas, the first and largest just east of 1914 cone; the others north and west of South Pit, the floor of which has a new lava fill. Vast floods of pahoehoe in the picture are filling the depression near the cone of 1914, and also the basin of the east side of the main crater.

On the first day, December 2, there were about 35 fountains in the main basin, and 20 each at the two other localities. The basin fountains concentrated to a smaller number about built-up cones. These basin vents poured lava both east and west, but the eastern flows became the great feature. The western ones obliterated the pit of 1914, and made a fill against the western cliff of the south lunate platform. The South Pit outside of the main basin received a fill about 21 meters deep (70 feet) at the base of the cascade through the gap. The main flow area covered about 3 square kilometers (1.16 square miles) the second day, and the southern pits had received a quarter as much. The southernmost upland fissure made big fountains the first day, the lava cascading strongly into South Pit, and feebly into Lua Hohonu.

In the main crater there was liquid flooding of silvery sheets of lava the first day, but on the second day there were crusted floor flows, and flocculent skins appeared on the scarlet torrents of the main streams. On this day the outside southwestern cracks were steaming only. The flow lava of the crater was pahoehoe, but the cones were heaped with basaltic pumice, and Pele's hair lay on the ground to leeward. Milky-blue fume cirrus lay in belts across the sky during the next few days. There was glow over the crater at night, and a fume column by day. December 4 the southwest wall fountain stopped. December 5 the two central fountain groups were within throne-like conical heapings more than 100 feet (30 meters) high.

Figure 4 is a remarkable picture of lava-flow pattern. It shows a half-mile (0.6 kilometer) of the spouting rift inside Mokuaweoweo. It is the forenoon of December 3, when the fountains along the crack, about eighteen in the photograph, had built pumice cones. The jets were 100 to 400 feet (30 to 120 meters) high, and show indistinctly as light patches, for the camera was directed downward. The 1914 cone was smoking violently but still intact behind the second of the two larger fume columns. The left-hand or southern end of this particular fault-block rift crack, one of the echelon of cracks that erupted, is drowned under its own flood. This lake of lava spread to the western crater wall, in a local basin that had been left in 1914. The erupting crack is itself faulted down in the foreground, bounded by a higher block in the background west, and so building crescent half-cones on the step, and the lava flows away from the rise.

This last feature is highly significant of an age-long trend in the active rifts of Hawaii. They are breaking down in steps away from the summit. The same step-down to the east appeared in the 1926 eruption 3 kilometers (2 miles) south of here. The larger fault blocks of both Kilauea and Mauna Loa are sliding toward the southeastern bay of the island for the Kau district, and toward Kealakekua Bay for the Kona district. Something similar is going on in a northern embayment of Mauna Loa, on the Mauna Kea side. Probably dikes under-

ground form three hard ribs on the southwestern, northeastern and northwestern rifts, and between these, the weight of the flanks of the dome breaks it on slipping planes.

The foreground of the photograph shows the great rivers of golden pahoehoe which filled the eastern half of Mokuaweoweo with 30 meters' depth (100 feet) of new lava. The two main fume columns are over the two persistent fountaining heaps, destined to build up cones 80 to 100 feet (25 to 30 meters) high and to envelop the 1914 cone as shown on maps, Figure 1.

The peculiar flocculent pattern of the surface of the liquid rivers is occasioned by the forming and rending of skins of solidification. Each of these skin belts may be traced to its fountain source, the wider ones to the bigger cups, and the contact of skin against skin produces lines longitudinally like the medial moraines of a glacier. Each skin belt tends to wrinkle in festoons of ropes, with convexity down-stream, so that the lines are occasioned by the meeting of the curtains at the frictional drag, where each festooned crescent flows more slowly at the sides. The writer had opportunity to inspect this scene from an airplane, and this was the first time in the history of Mauna Loa when its summit eruption was repeatedly so inspected, by regular passenger planes. By this method far more could be determined in a few minutes, concerning the progress of the eruption, exploring from an airport 65 km. (40 miles) away, than through days and weeks of camping trips, wherein only a small part of the field could be seen at one time.

The flows within Mokuaweoweo proper continued to spread against the east wall; the eastern part of the cliff on the north side of the south lunate platform became obliterated (See Figure 2). Airplanes carried visitors day after day to watch the fan-like rush of lava pouring eastward from the two cone-filled gashes in the crater. The fountains of the northern gash, by December 12, had dwindled to two small ones. December 13 there was only one fountain, with occasional jets from other vents. The fume and glow as seen from Kilauea continued until December 17, becoming faint. The last fountain died down at 2 a.m., December 18, revived slightly after daylight, and thereafter went out of action. The Mokuaweoweo crater area remained very hot and fumy with many jar-rings and rumblings.

A party visiting the crater January 6 to 7, 1934, found that the new lava was somewhat broken up in places near the fronts of the flows. There was much heat about the new cones, rumbles and sharp cracking noises were heard during the night, coming at intervals of three or four minutes, and a few sharp earthquake shocks were felt.

During the mapping expedition, July 30 to August 3, 1934, the new summit resthouse of the national park was occupied by Mr. A. E. Jones and his men, and gave much protection against the cold. The temperature was 32° F. at sunset, and 20° F. at daylight. There were occasional sounds of falling rocks, much of the new shell-lava broke easily and was dangerous to walk on, the lava near the vents was hot enough to be uncomfortable, and sulphurous fume was locally strong.

The results of mapping show the new lava field in the eastern half of the main Mokuaweoweo bowl to be over three kilometers (nearly two miles) long, and something more than one kilometer (0.6 mile) wide, with a thickness of 30 meters (100 feet). The source cones are 30 meters (100 feet) high; the lower basins of the crater are now at the north and at the southeast. The new lava heap is an elongate dome, highest at the southwest in a ridge athwart the crater sink, with its longer axis northeast-southwest.

Hawaiian Volcano Observatory Report for September 1936

VOLCANOLOGY

During the month of September the number of slides from the ENE wall of Halemaumau Pit at Kilauea Volcano increased. Eighteen were reported as compared with six for August.

The following tabulation shows the relation for the month between local seismicity, number of reported slides, and aggregate opening in millimeters of the measured cracks:

Week	Seismicity	Number of slides	Aggregate crack openings
First	7.00	0	10.5 mm.
Second	12.50	3	13.5 mm.
Third	24.75	6	17.5 mm.
Fourth	20.25	5	14.5 mm.
Fifth	27.75	4	28.0 mm.

It is evident that these phenomena as a whole increased during this month that ended with the fortnight that followed the equinox. The crack opening was much larger than August, but not the seismicity.

Slides at Halemaumau

The NE rim of Halemaumau had been roped off, owing to the menace of crack opening and of slides, and the latter from the wall of the pit have been noted as follows:

September 7, Rocks were heard dribbling down the NE wall 9:12 a.m.

September 9, Moderate slide from E rim, near Crack No. 31, 9:50 a.m.

September 9, Rocks dribbling NE 9:58 a.m.

September 14, Large fresh scar over dust on floor, 150 feet below rim, under Crack No. 29. Rocks there were still in motion during forenoon visit.

September 15, Slide under NE rim 10:50 a.m.

September 16, Dribbling rocks NE 1:40 p.m.

September 19, Rocks in motion NE 9:30 to 11:00 a.m. Central part of NE talus had been increased with debris falls from fresh scar above.

September 25, Big noisy slide ENE at 9:42 a.m., and a new scar had appeared 100 feet below ENE rim near Crack No. 29. Rocks dribbled down wall throughout forenoon visit.

September 26, Small slide E wall 10:04 a.m.

September 26, Another at same place 10:24 a.m.

September 29, Small rocks fell WNW wall 9:40 a.m., and a larger slide had left a scar there 300 feet below rim.

October 1, Large dust cloud arose ENE rim, 2:20 p.m.

October 3, Small slide NE rim 11:00 a.m.

Halemaumau Solfataras

September 19 fume was rising from SE and NW Solfataras at edge of floor. This was not unusual.

Measurement of Halemaumau Rim Cracks

After the middle of the month, all along the ENE rim, the opening of cracks shown by the measurements was supplemented by breaks in the surface soil. At the NE flag the slumped slabs under the rim had moved down. By the end of the month the cracks ENE had widened and broken the soil extensively, with marked increase in rate of opening since the September equinox.

Weekly measurements of 32 marked places on rim cracks around the upper edge of Halemaumau Pit resulted as follows:

Week ending forenoon of:

September 5, 7 opened, 6 closed, aggregate opening 10.5 mm. Crack No. 46 opened 9.0 mm.

September 19, 6 opened, 0 closed, aggregate opening 7.5 mm. Crack No. 46 opened 11.0 mm., and Crack No. 31 opened 3.5 mm. Crack No. 31 is east, No. 46 northeast.

September 26, 3 opened, 4 closed, aggregate opening 14.5 mm. No. 46 opened 13.0 mm., No. 31, 3.5 mm.

October 3, 12 opened, 1 closed, aggregate opening 28.0 mm. No. 46 opened 17.0 mm., No. 31, 6.0 mm.

—T. A. J.

EARTHQUAKES

Table

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant Earthquakes	Local* Seismicity
Sept. 6	20	4	0	0	0	7.00
Sept. 13	40	3	0	1	0	12.50
Sept. 20	91	4	0	0	0	24.75
Sept. 27	73	4	0	0	1	20.25
Oct. 4	87	10	1	0	1	27.75

* For local seismicity definition, see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible, determinations of depth of focus have been made.

September 4, 6:06 am, very feeble, probable location under NE portion of Kilauea Crater.

September 4, 8:03 am, very feeble, probable location in Kilauea Crater about midway from the Pit to the Observatory.

September 4, 9:38 pm, very feeble, located 18 miles deep near the old Halfway House 13.0 miles SW of the Observatory. 19° 20′ 5N; 155° 26′ 0W.

September 6, 6:25 am, very feeble, probable location under NE rim of Kilauea Crater, 0.5 mile west of the Observatory.

September 7, 4:18 am, very feeble, located 0.8 mile deep, under NE edge of Kilauea Crater floor. 19° 25′ 4N; 155° 15′ 7W.

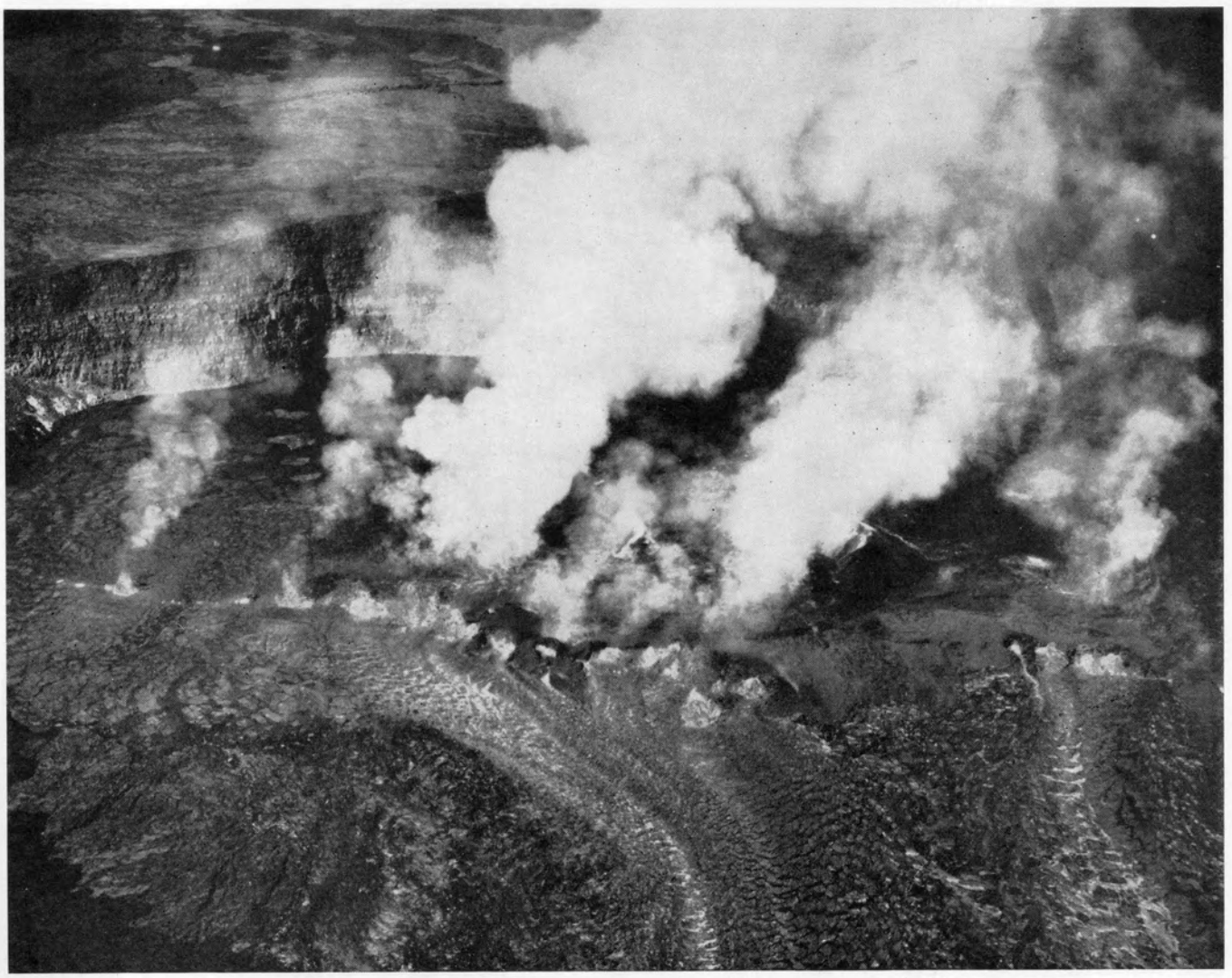


Figure 4. Line of main fountains inside Mokuaweoweo looking west, the second day December 3. The cone of 1914 is seen back of fume column. Lava-pattern, west cliff and outside Mauna Loa slope. From elevation 14,500 feet. By permission Fleet Air Base, U. S. Navy, Pearl Harbor.

September 8, 7:17 pm, very feeble, located 13.0 miles deep and 4.0 miles S of Makaopuhi Crater in the Hilina-Kapukapu Fault. 19° 18′ 8N; 155° 10′ 6W.

September 9, 5:46 pm, a slight shock felt by a few in Volcano district. Located 2.3 miles deep and 1.3 miles SE of the Pit Seismograph Station. 19° 23′ 4N; 155° 16′ 1W.

September 14, 3:39 pm, very feeble, located 4.0 miles deep and 2.0 miles NE of east entrance to Hawaii National Park. 19° 26′ 6N; 155° 12′ 9W.

September 15, 12:07 pm, very feeble, located 1.2 miles under NE portion of Halemaumau. 19° 24′ 7N; 155° 17′ 0W.

September 17, 1:37 am, very feeble, probably located under NE rim of Halemaumau.

September 20, 2:44 am, very feeble, located under SE rim of Kilauea Crater near Keanakakoi Crater. 19° 24′ 4N; 155° 16′ 2W.

September 21, 3:56 am, very feeble, located 5.5 miles deep under that portion of Kilauea Crater immediately to the east of Halemaumau and 0.4 miles N of Pit Seismograph. 19° 24′ 6N; 155° 16′ 9W.

September 23, 1:11 pm, very feeble, located 4.0 miles deep and 3.3 miles N of Uwekahuna. 19° 28′ 2N; 155° 17′ 4W.

September 24, 1:25 pm, very feeble, probably located in SE portion of Kilauea Crater.

September 28, 2:06 am, feeble, located 2.2 miles deep and 3.6 miles E of the Pit seismograph. 19° 24′ 1N; 155° 13′ 6W.

September 28, 3:08 am, very feeble, located 3.7 miles deep and 2.1 miles N by E of the Volcano Observatory. 19° 27′ 6N; 155° 15′ 1W.

September 29, 4.12 am, very feeble, probably located in NE rift of Mauna Loa near Puu Ulaula.

October 4, 12:02 pm, very feeble, probably located 1.0 mile NE of Kilauea Crater.

The surface (L) waves of a telesism began recording 2h 37m 41s, HST, September 25. Reported location was approximately 300 miles off W Coast of Southern Oregon, 2140 miles from Kilauea. 42° 5N; 131° 4W. Registration of the preliminary waves of another distant earthquake began at 11h 26m 25s, HST, October 4. It was 5340 miles SW by W of the Island of Hawaii and the reported location was the northern border of the Banda Sea east of Celebes Island. 3° N; 126° 4E.

Periods of continuous tremor registered as follows:

September 20, 3:49 am, 6 minutes and October 1, 12:33 pm, 4 minutes.

Microseismic motion of the ground at Kilauea was moderate September 16, 17 and 18, the remainder of the month it was light.

H. H. W.

CRATER ANGLES

Measurement of horizontal angles across Kilauea Crater from the Observatory on September 23, showed slight opening across Halemaumau and slight closing across the Crater as compared with similar measurements August 18. From Kilauea SE rim to Uwekahuna the angle closed 1″.92 August 18-September 1; September 1 to September 11 an opening of 2″.67; September 11 to September 23, an opening of 1″.25; total closing 0″.6. From the Pit seismograph to the NW Pit station there was a closing of 1″.00, August 18-September 1; September 1 to September 11, a closing of 1″.83 and September 11 to 23, an opening of 3″.33. Total opening 1″.50.

H. H. W.

SPIRIT LEVELLING

Spirit levelling across Halemaumau from the Spit SE edge of Kilauea Crater to the NW Pit BM showed a lowering of the NW Pit BM with reference to Spit of 5.5 centimeters between February 10 and September 3, 1936.

H. H. W.

TILTING OF THE GROUND

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending August 30, was 4.″23 N and 1″.1 E.

TABLE OF TILT

Week Ending	Observatory	Halemaumau Clinoscope Stations		
		West	Southeast	Pit Resultant
September 6	0″.23 W	4″.71 N 58°W	4″.34 N 31°W	0″.65 toward
September 13	1″.00 N 72°E	4″.02 S 79°W	4″.28 N 19°W	0″.12 from
September 20	0″.00	1″.04 N 10°W	3″.30 S 31°W	1″.30 from
September 27	0″.50 N 71°E	5″.18 N 77°W	3″.82 N 31°W	1″.67 from
October 4	0″.95 N 65°E	2″.59 S 60°W	2″.92 N 6°W	0″.76 from

H. H. W.

THE VOLCANO LETTER

No. 440 monthly Department of the Interior National Park Service October 1936

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

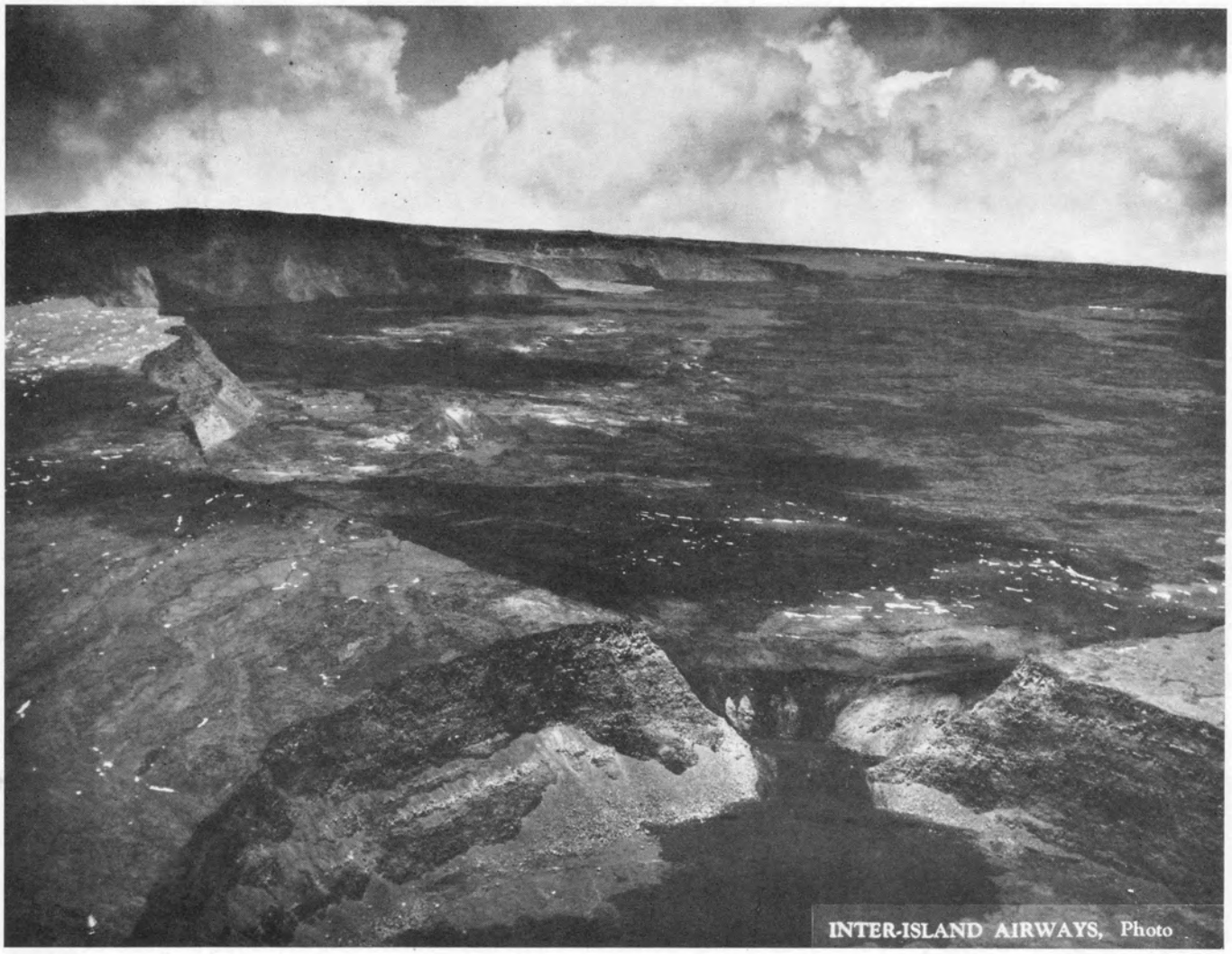


Figure 1. General view from plane of the Inter-Island Airways, Ltd., winter 1932-33 looking north. Mokuaweoweo, summit crater Mauna Loa, before December eruption of 1933. South Pit in foreground, 1914 cone on left, 1903 cones in center.

THE COMING LAVA FLOW

The Most Serious Responsibility in Our History

T. A. Jaggar

Annual Address, March 26, 1934, Hawaiian Volcano Research Association*

Mauna Loa at its summit crater has recently made a spectacular lava gushing December 2-18, 1933. This 17 days of summit activity should be followed by an outflow over somebody's land within a period of from 16 to 37 months.

This expectancy is the serious responsibility which rests on the shoulders of the Hawaiian Volcano Research Association. The words are not "the most serious lava flow in history." They are "serious responsibility." It is serious if we take our 22 years of volcano observing seriously, because we are called upon to make good, to make the forecast as careful as possible, and to advise the community soberly and preparedly.

* In sequence of dates to preceding and following Volcano Letters.

There is no call for fear. There is every appeal for an intellectual and practical victory over nature. Prediction and resulting preparation are what exhibit science at her best.

What are the Facts about the Past of Mauna Loa?

There are listed 23 summit crater eruptions of Mauna Loa, in 90 years, between 1843 and 1933. This is without counting some small summit effusions which may have gone unrecorded.

Between 1832 and 1899 there were nine NORTHERN and EASTERN flank outflows, with one source as low as 8500 feet elevation on this 14,000-foot mountain, namely 1852.

Between 1868 and 1926 there were eight SOUTHERN and WESTERN flows, with one source as low as 3500 feet elevation in 1868, and one below sea-level in 1877.

The districts invaded by Mauna Loa have been NORTH KONA, SOUTH KONA, KAU, SOUTH HILO, NORTH HILO INLAND, HAMAKUA INLAND, and even SOUTH KOHALA was touched by the prehistoric but recent Keamuku flow west of Humuula. The very voluminous 1843 flow at the same place might well have found its way to South Kohala. Puna and North Kohala are the only districts of the Island not visited by fiery lavas from Mauna Loa sources, and Puna has been abundantly invaded by flows from Kilauea volcano.

What are the Intervals between Crater Eruptions and Outflows?

There are two classes of Mauna Loa eruptions, those at or near the summit crater lasting days, weeks or months, and followed by a major lava flow, usually some years later; and secondly, those at or near the summit, but not necessarily in the crater, often making small preliminary flows on the upper rifts, always lasting only a few minutes, hours or days, and then followed immediately by an outflow from a vent farther down the mountain. This second class is the SOME YEARS LATER group of the first class.

In other words, all great lava flows are preceded immediately by high-level gushing, and some are preceded by a summit crater eruption a few years before which announces that a flow is coming; but this preliminary summit crater outbreak may announce that a GROUP OF SUCCESSIVE OUTFLOWS is coming.

In like manner, all eruptions exclusively in the summit crater, like our recent display of December, 1933, are followed eventually in a few years by one or more low-level outflows with their immediately accompanying summit gushings; but it is possible for such summit crater eruptions of the preliminary class to follow one another in a GROUP OF SUCCESSIVE SUMMIT CRATER ERUPTIONS, before the mountain breaks to emit an outflow lower down.

Applying these facts of history to December, 1933, for discovering what is to follow, we may expect either one or more additional summit crater extrusions, or one or more lava flow eruptions.

Eruptions wholly at the summit Crater

Year	Duration	Interval	Next Succeeding Outflow
1832	3 weeks	10½ years	1843
1849	3 weeks	2 years	1851
1865-66	4 months	2 years	1868
1870	2 weeks	7 years	1877
1872	2 months	5 years	1877
1873	10 months	4 years	1877
1874	10 months	3 years	1877
1875	2 months	2 years	1877
1876	1 week	1 year	1877
1880 (May)	6 days	6 months	1880 (Nov.)
1892	3 days	7 years	1899
1896	15 days	3 years	1899
1903	9 weeks	4 years	1907
1914	6 weeks	2 years	1916
1933	17 days		

Flank Outflow Eruptions with Near-Summit Beginnings

Year	Duration	Interval Between Near-Summit Start and Outflow	Elevation of Flow Source
1843	3 months	7 days	10,000 feet
1851	4 days	minutes?	13,000 feet
1852	4 months	3 days	8,500 feet
1855	16 months	hours?	11,000 feet
1859	10 months	minutes?	11,000 feet
1868	4 days	10 days	3,500 feet
1877	few days	10 days	30 fathoms submarine
1880 (Nov.)	9 months	5 days	10,500 feet
1887	10 days	2 days	6,250 feet
1899	26 days	5 days	10,800 feet
1907	14 days	4 hours	6,500 feet
1916	17 days	3 days	7,300 feet
1919	40 days	3 days	7,600 feet
1926	1 day	minutes?	13,000 feet
1926	19 days	3 days	8,000 feet

Summary of Frequency for Mauna Loa Eruptions

There were 30 summit or near-summit events on Mauna Loa between 1832 and 1933, within the period of 101 years. As all the lava outflows begin with a near-summit outburst, this number includes all the Mauna Loa eruptions recorded in the white man's occupancy of Hawaii.

There was probably an average of just as many Mauna Loa eruptions in the eighteenth century and the first quarter of the nineteenth, but the icy wastes of the high mountains were too remote to interest Hawaiians. Lava flows lower down were taken as a matter of course and were not recorded. White explorers like Captain Cook and Vancouver did not usually happen to arrive at eruptive dates. Captain Cook apparently never heard of Kilauea and records Mauna Loa as extinct.

What are the Average Intervals for Mauna Loa?

The average is one outbreak in three and a third years near the Mauna Loa summit. There are 14 flows between 1843 and 1926, in the period of 83 years, averaging one outflow from the flank of Mauna Loa, as perceived by man, either above sea-level or close to sea-level under water, every six years. It must be remembered that commonest interval is by no means identical with average interval. Reviewing:

Intervals, SUMMIT AVERAGE, 3⅓ YEARS.

Intervals, FLOW AVERAGE 6 YEARS.

There were probably several submarine outflows under deep water, not perceptible to man, but indicated by extraordinary crater collapses, like those at Kilauea in 1790, 1894 and 1924. The reason for thinking this is that observed outflows close above sea-level caused similar collapses, as in 1823, 1840 and 1868. The submarine outflow in Kealakekua Bay in 1877, made very slight impression on mankind, but as it drained Mauna Loa of lava after seven years of summit activity, it may have been one of the greatest lava flows of history, down that cold, dark, wet slope, tipping away steeply 12,000 feet off Kona. The crater collapses of Mauna Loa have gone unnoticed, as nobody lives there. There is plenty of room in this globe for it to do colossally big things without informing mankind, until such time as it occurs to man to distribute and live in numerous observatories of the earth.

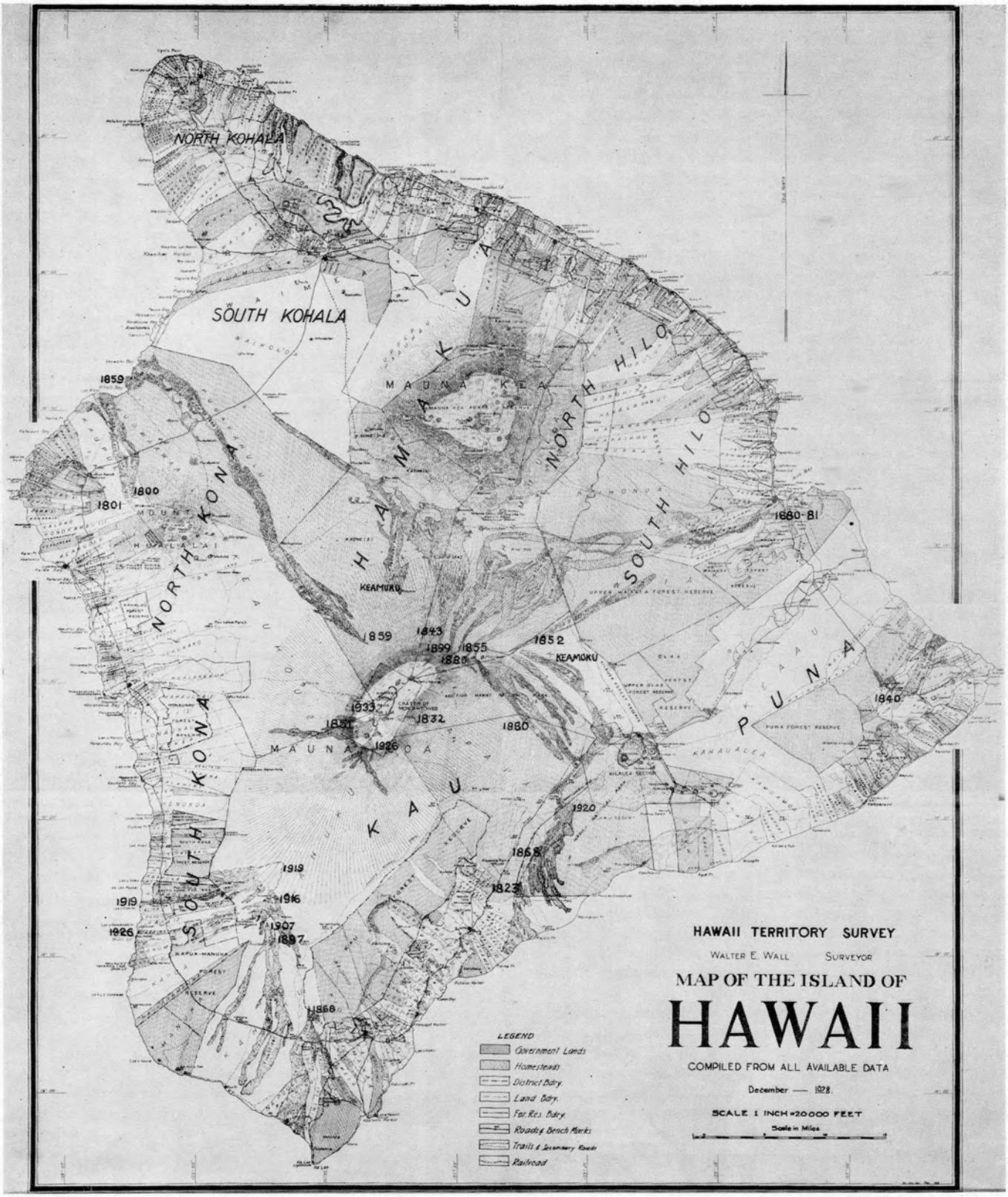
The frequency and continuity of lava activity at Kilauea have been even greater than on Mauna Loa, and there have been contributions within 200 years from Hualalai and Haleakala volcanoes, but this discussion is concerned only with Mauna Loa.

How the Lava Breaks the Dome

With summit eruptions of Mauna Loa every 3⅓ years, and outflows every 6 years, it appears to be nearly twice as easy for the lava and gas to squirt through the summit vents, as to break the flank of the great dome. We have to think of the expanding gas-charged paste swelling the mountain all the

time through hundreds of thousands of years, dammed back by its own accumulations which have built the mountain. An eruption is determined by the yielding of the heap to a never-ending force.

The breaking of the flank ranges from 180 feet below sea-level, to elevations on Kilauea mountain 700 feet (1840), on Hualalai mountain 1500 feet (1801), and on Mauna Loa slopes approximately 3,000, 8,000, 10,000, 11,000, and 13,000 feet above sea-level for the statistics of only one century.



What Class was the Recent Eruption in?

The outbreak in Mokuaweoweo crater of Mauna Loa volcano in December, 1933, was not in the Class II of the second list, where the outflow follows the summit gushing by a few hours or days. No outflow has appeared. Therefore, the flow is yet to come, and when it comes it will begin at the top.

This concentrates interest in the first list where the summit eruptions lasted from three days to ten months, and were followed each by one or several flows of the second list, after repose intervals of from six months to ten and a half years.

By analogy the 1933 outbreak lasted 17 days; other eruptions of one to three weeks at the summit were those of 1832, 1849, 1870, 1876, 1880 and 1896. Imagining 1933 to be like one of these, let us see what happened:

Samples of Eruptions like the 1933 Outbreak

After 1832, June, at the summit, the interval was 10½ years to January, 1843. The 1843 flow poured for more than six weeks, largely pahoehoe as mapped today, filling the Mauna Loa-Mauna Kea saddle, flowing north and northwest 14 miles, starting at an elevation of 10,000 feet.

After 1849, May, at the summit, the interval was two years and two months to August, 1851. The 1851 flow poured only four days, pahoehoe lava above and aa lava below. It went towards Honaunau, very high up on Mauna Loa, moving due west eight and a half miles, starting from the southern pits of Mokuaweoweo at an elevation of 13,000 feet.

After 1870, January, at the summit, "steam and smoke," introducing seven years of summit activities, the interval was seven years to February, 1877. The other summit gushings lasted two months in 1872, 10 months in 1873, 10 months in 1874, two months in 1875, one week in 1876 and 10 days in 1877 just before the outflow. What was seen of the 1877 flow lasted only half a day. It was frothy lumps of hot pahoehoe under the sea in Kealakekua Bay in 30 fathoms of water a half mile off Keei. The pieces bubbled up and floated while hot and were collected. No one knows how far the flow went under the sea, nor how long it may have pushed onward under its water-chilled skin.

After 1876, February, the interval was one year to the Kona submarine flow February, 1877.

After 1880, May, the interval was six months to the flow of November 5, 1880. The 1880-1881 flow poured for nine months in several branches, aa at first, pahoehoe afterwards. A first aa flow went to Ohaikea in Kapapala, 11½ miles, after four days of preliminary upland flowing. Then aa flows went towards Mauna Kea and towards Hilo. Always the vent lavas were pahoehoe, changing to aa a short distance away by stirring. Finally the source pahoehoe overrode the previous flows and pushed its way to Hilo town. The length of the flow was 30 miles. It stopped in August, 1881, in the outskirts of Waiakea, one mile from the city center (August 10). The source was on the northeast rift of Mauna Loa at an elevation of 10,500 feet. The lower extremity of the flow is about 100 feet above sea-level.

After 1896, April, the interval was 3 years 2 months to July 1, 1899. The 1899 flow poured ten to fifteen miles northeast for 26 days, starting at elevation 10,800 feet on the northeast rifts of Mauna Loa. It headed for the upper Wailuku drainage back of Hilo, but did not reach it. It was aa at first over most of its course, but pahoehoe as mapped, in a final stream, eight miles long. One account states that an early branch headed towards Kau, as in the case of 1880.

Is the Present Time like 1870-1877?

The 1870-1872 time was critical for comparison with 1933, if it should happen that 1933 is the prelude to a new shift of flow sources, from the southern vents of the last thirty years, to northern vents in the near future.

Seismic happenings now in 1934, and the location of earthquakes under the mountain at the north in 1933, point to activity under the northeast rift of Mauna Loa. The progressive higher elevations of flow sources in 1868, 1887, 1907, 1916, 1919, 1926 and 1933, all on the southwest rift, point strongly to the probability that the cracking open of vents will cross the summit to the northern rifts. For the 1933 eruption, though mostly in Mokuaweoweo ,crater, began along southern cracks, just outside the crater and where the 1926 eruption left off.

If we make this expected shift a basis for comparison with the 1870's, there may come numerous summit crater eruptions for some years. Thereafter the northern flank will split open. Compound eruptions, involving numerous vents, for Mauna Loa, have occurred not only in the seventies, but also in the fifties, the eighties, the nineties and after 1914. Something similar is to be expected at present, as the combination 1926-1933 is already compound, and not yet finished. There is an eleven-year cycle following the profound crisis of 1924, which has been discussed elsewhere (Thrum's Annual 1932) for the Kilauea-Mauna Loa volcanic system.

How can we use Average Intervals?

The average interval, between summit eruption and outflow, for these six selected occasions that resembled 1933 in duration, was 4.1 years. The average interval for all the summit eruptions of the first list was 3.8 years. The range between longest and shortest intervals for all was from one-half year to ten and a half years. If we leave out the exceptionally long intervals of 1832, 1870 and 1892, we get an average interval of 2.6 years, and a range from one-half year to five years. The Mauna Loa average for all flows, and the probability of a cycle, ending in 1935, make two years after 1933 a probable limit of time within which the next event should come.

The National Park rangers right now report increasing fumes of sulphur at the summit crater vents of last December. Earthquakes have almost ceased under the southern half of Mauna Loa, where until recently they were most abundant. The suggestion of a coming flow on the Hilo side is inescapable. Let us summarize the probabilities:

Summary of the Expectations

1. A lava flow from Mauna Loa, or else another summit eruption, is expected within two years.

2. If it is a lava flow, the history of sixty-six years indicates sealing of the southwest rift, and coming outbreak at the north.

3. The resulting flow may push in any direction between North Kona and Kilauea. A likely direction is towards Hilo.

4. The change from Kau flows to Hilo flows is likely to be accompanied by a severe earthquake. This is what happened when the change was from Hilo flows to Kau flows in the terrific earthquake of 1868.

5. Severe earthquakes on the northern Mauna Loa rifts have already begun, at Hualalai, in the autumn of 1929.

6. Opening of the northeast rift of Mauna Loa after its repose and solidification for thirty-five years may make a world-shaking earthquake, for the whole east side of the island Hawaii, just before the outflow starts. The earthquake of 1868 was felt all the way to the island Kauai, and strongly felt.

Responsibility for the Protection of Property

To point out these probabilities is not to set dates for the events. To fail to point them out would be to suppress truth.

Hilo knows all these things, is completely organized to meet them, and has been instructed about the relief committees of Napier, Long Beach and Sakurajima. A statement of the Mauna Loa problem for the Hilo Chamber of Commerce appeared in Volcano Letter No. 338.

New Zealand, California and Japan have taught us lessons in earthquake insurance. With us the local government, the National Park administration, the National Guard, the Ameri-

can Legion, the Coast Guard, the Navy and the Army all know what they will be called upon to do. On December 11, 1933, the superintendent of Hawaii National Park called a meeting



Figure 2. Similar view to Figure 1, during eruption December 3, 1933, from altitude 14,500 feet, airplane photograph by permission Fleet Air Base, Pearl Harbor, T. H. Note offset in active rift cracks, new floor of South Pit, new and old cascades, and in upper left corner the trace of rim of ancient caldera.

of an emergency committee of these organizations in Hilo to discuss Mauna Loa, and it was done quietly and efficiently. Honolulu is also organized.

The Volcano Observatory at Kilauea was founded in 1911 under the Whitney Fund of the Massachusetts Institute of Technology, with these words: "To be conducted with a view to the protection of human life and property."

That charge was accepted by the Hawaiian Volcano Research Association. A fire department, which in dry weather with high winds did not take special precautions, would neglect its duty.

This address definitely announces that volcano dwellers in Hawaii should now take precautions, for **Mauna Loa has definitely mobilized and declared war.**

What Precautions Can Be Taken?

The answer is as follows:

1. The northeast slope of Mauna Loa must be made accessible. The roadway proposed should be built at once, no matter how roughly. It should extend from the top of the mountain to Kilauea.

2. The Hawaiian Volcano Research Association should increase from 180 to 1000 members and patrons. Government funds for the Observatory have been cut 83 per cent since 1932. Twenty thousand dollars are needed when the lava flow comes, which might be this summer, if 1880 is repeated.

3. The staff is now two scientists, and not even a typist. With a suitable staff, the Hawaiian Volcano Observatory can resume its scientific publication, which amounted to 3500 pages prior to 1932. It can keep the community properly informed. It can organize more volunteer observers to report small earth movements. It can patrol Mauna Loa with more expeditions. It can man an observatory on Mauna Loa when the rough road is built. It can organize preliminary plans for volunteer assistance by airplane services and other public relief, and prepare special maps. It can improve everything it is doing now in concentrating on Mauna Loa, if it has the requisite man-power. You cannot make war without money and men. The patrolling of an area as large as Mauna Loa is not a small job.

4. The actual details of how a northern Mauna Loa flow will lap up Hilo's water supply, as it has done it in the past, is set forth on page 3, Volcano Letter 338, under the title "Preparedness against Disaster."

5. Japan has had her Earthquake Investigation Committee, and does not hush up anything. The most important precaution to be taken we may copy from Japan. It is to face the situation, and not cry about bad advertising, and cry of wolf, and fear of scaring tourists. Tourists come from Los Angeles and Santa Barbara and San Francisco, and they know the game, and that Hawaii is not more dangerous than their own homeland.

6. A foreseen Mauna Loa flow can be made the best advertisement Hawaii has ever had. The headlines will read "Hawaii meets lava flow with complete preparation." "First time in history when mankind has been prepared." "Everybody in Hawaii rejoices and goes to the flow." "Everyone in Hawaii a member of Volcano Association." "Hawaiian lava flow scares nobody."

The introduction said: "There is every appeal for an intellectual and practical victory over Nature."

If every firm, engineer, officer, doctor, teacher and homemaker, if every business man will turn to and join the association now, if those who can't afford it will take an interest and get behind the Observatory at Kilauea, if every educated person will help and not kick, then this Territory can laugh at the fiery fountains and make them an asset. They may gush and bubble as inflammably as they choose, and we shall rub our hands with glee. Our engineers and aviators and bombers will rejoice at the opportunity to show their prowess. And finally, a program of generalship will be laid down, with advice from all experts, which can be carried out as an object lesson to the world. The Volcano Observatory cannot do it, but we can unite and do it, using the motto of volcanology, "Be always ready, and never hysterical."

Hawaiian Volcano Observatory Report for October 1936

VOLCANOLOGY

The month of October at Halemaumau Pit of Kilauea Volcano produced the culmination of the landsliding and crack opening which has been disturbing the NE edge of Halemaumau for two years. This took the form of a large avalanche on October 22. The records of crack opening and wall sliding increased to a maximum at this time, but the local seismicity, while greater because of the many tremors generated by the slides did not vary directly with the figures for sliding and crack opening. The following is the abridged table of these movements:

Week	Seismicity	Number of Slides	Aggregate Crack Openings
First	8.00	13	42.5
Second	17.50	12	93.0
Third	39.00	50+	Infinite
Fourth	20.25	16	26.0

For the first week slides increased to 13 from 4 the week before and crack opening to 42.5 from 28. For this same week seismicity decreased from 27.75 to 8.00. It should be remembered that the number of slides is merely the record for a short period of observation, not a quantitative expression of the measurable number, which is uncountable with any present apparatus. The word "infinite" for the third week in crack opening means that the big avalanche carried away the cracks.

Sequence of Events by Weeks

The first week produced many slides from the E and NE walls and along with this went excessive opening of ENE rim cracks.

The second week increased the cracking open of the rim and the sliding of the NE walls, while fresh cracks in the soil opened in many places. It is evident from the map of the pit outline, that the breaking down of this wall was eliminating one of the straight parts of the circular outline of the pit. This straight part was a nearly vertical cliff between the peaks of the E and NNE talus cones. The form of stability that will result for the pit will extend the circular curve in plan, and make the inner slope more a funnel and less a cliff.

The third week produced the large avalanche at 5:54 a.m. October 22, along with many other slides. This extended peeling of the wall for months has removed a length of 1500 feet along the rim ENE, to a maximum distance back near Crack No. 46 of more than 100 feet. Following the collapse of the former Crack No. 34 in March 1936, there were now obliterated Cracks Nos. 29, 30, 31, 32 and 46. This reduced our marked crack locations from 32 to 27.

The beginning of this yawning open of the cracks can be traced to measurements two years ago when Halemaumau erupted in September 1934. A marked increase of the gaping open, however, began in October 1935 just when the premonitory earthquakes were heralding the coming November outbreak of Mauna Loa.

The many slides kept a dust cloud over Halemaumau for most of the week. The result was a very large new talus cone halfway up the wall, over the middle of the white ledge known as the Canoe Sill. The new break is adjacent to the dykes of the Rift Belt on their eastern side. The whole of this part of the wall has fallen to form the heap, overlapping the 1934 floor about a third of the distance to the center of the pit, and covering the ENE floor cracks, the depression that lay along the wall, and part of the 1934 lake-basin. Crack No. 46 lay N 57° E from the pit center, and this direction is along the line of the former cracks across the bottom that were mapped after the eruption of 1931-32. (See mapping, Volcano Letter 394). The limit of destruction of the rim was slightly beyond No. 46, and movement on the deep rift possibly stimulated this landslide.

During the fourth week smaller slides ENE continued, the surface cracks in the ground had opened to the Volcano House Trail, so that on November 1 this area had to be roped off, and the trail was established farther back. The new breakage of the ground is southward from the great avalanche of October 22. The opening of measured cracks was now near the E corner of the pit.

Slides at Halemaumau

Slides from the wall of the pit have been noted as follows, but these are only a part of what actually occurred:

October 6, 9:40 a.m., moderate NE near Crack No. 29; fresh scar near No. 31.

October 6, 3:00 p.m., numerous avalanches.

October 7, 7:56 a.m., small rock sliding NE near Crack No. 31.

October 8, 9:11 a.m., rocks moving under Crack No. 29: scar 150 feet below it, new rocks and dust on floor.

October 9, 12:30 p.m., avalanche dust arose.

October 10, 10:15 a.m., moderate slide below Crack No. 34 NE.

October 10, 12:50 p.m., moderate avalanche and dust cloud NE.

October 11, forenoon, rocks sliding, east talus enlarged, more rocks and dust on floor, and fresh mark under Crack No. 31 perhaps due to earthquake of 4:05 a.m. Much cracking of soil ENE.

October 11, 1:30 to 1:45 p.m., numerous slides S of Crack No. 46.

October 11, 4:15 p.m., slide under Crack No. 31.

October 12, 2:00 p.m., dust from slide E.

October 12, 3:50 p.m., dust from slide E.

October 15, 9:05 a.m., dust from large slide E: changes in walls E and NE.

October 15, 10:00 a.m., small slide in motion.

October 16, 9:44 a.m., noisy NE slide: new scar 200 feet below edge there.

October 17, 10:25 a.m., big avalanche NE: heavy sliding during forenoon measurement with continuous dribbling of rocks down wall.

October 17, 11:55 a.m., big avalanche NE.

October 18, 9:20 a.m., moderate slide E, starting 300 feet below edge.

October 19, 9:20 to 9:49 a.m., thirteen slides NE; of these one at 9:20 was moderate, those at 9:30 and 9:40 were noisy and started 150 to 400 feet below edge under Cracks Nos. 29 and 31.

October 20, 4:19 a.m., loud roar of slide.

October 20, 2:00 to 3:40 p.m., continuous dribble of rocks NE half-way down.

October 20, 2:40 p.m., moderate slide.

October 22, 5:54 a.m., the great avalanche.

October 22, 8:30 a.m. to 2:45 p.m., 18 slides listed, the larger ones at 8:55, 11:20, 11:30 a.m., and 2:05 p.m.

October 22, 5:00 p.m., large cloud of dust lasting 20 minutes.

October 23, 8:30 a.m. to afternoon, continuous rock falls, with occasional moderate slides. Slides diminished between 5:00 and 6:00 p.m.

October 26, 9:20 a.m., moderate slide ENE.

October 26, 9:24, 9:47, 9:49, 9:57, 10:00, 10:04, 10:09 and so on, showing intervals for this period between small or moderate slides.

October 27, 9:23 a.m., slide making dust cloud, followed by dribbling of rocks.

October 27, 10:00 a.m., moderate slide: followed by smaller ones 10:03, 10:11, 10:15 a.m., etc.

October 28, 9:33 a.m., slide making thick dust cloud.

October 31, 10:20 a.m., large slide near dyke NE.

November 1, 12:50 p.m., dust over pit: this period showed some tendency to increase of slides just after the noon hour.

Halemaumau Solfataras

Fume from the sulphurous vents from the floor was conspicuous during forenoon crack measurements October 17, but nothing during this period of avalanching indicated anything unusual about the fuming of the solfataric vents.

Measurement of Halemaumau Rim Cracks

Weekly measurement of the 32 marked rim crack localities, reduced to 27 after October 22, around the upper edge of Halemaumau Pit resulted as follows:

Week ending forenoon of:

October 10, 9 opened, 4 closed, aggregate opening 42.5 mm. No. 46 opened 24.0 mm. No. 31 opened 14.0 mm.

October 17, 7 opened, 2 closed, aggregate opening 93.0 mm. No. 46 opened 47.0 mm., No. 25 2.0 mm., No. 31 43.0 mm.

October 24, five cracks had gone. Of the remainder many of them not on the avalanching sector; 8 opened, 3 closed, aggregate opening 12.0 mm.

October 31, 8 opened, 3 closed, aggregate opening 26.0 mm. Cracks at E corner of pit partly opened, while others closed as the rim blocks tilted: No. 24 close to the rim closed 1.0 mm., No. 25 a little farther back opened 11.5 mm.; No. 28 in the same region closed 1.0 mm.; No. 45 farther north opened 7.0 mm.

T. A. J.

TOPOGRAPHIC DATA

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory on October 20, showed slight opening across the Crater and closing across Halemaumau as compared with similar measurements September 23. From Kilauea SE rim to Uwekahuna there was an opening of 0".5, September 23 to October 6 and an opening of 0".41, October 6 to October 20. Total opening—0".91. From the Pit Seismograph to the NW Pit Station there was an opening of 0".33, September 23 to October 6 and closing of 1".17 October 6 to 20. Total closing —0".84.

Spirit Leveling

Spirit levelling across Halemaumau from the Spit SE edge of Kilauea Crater to the NW Pit BM showed a lowering of the NW Pit BM with reference to the Spit of 6.4 centimeters between September 3 and October 23. H.H.W.

SEISMOLOGICAL DATA

EARTHQUAKES

Table

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant Earthquakes	Local* Seismicity
Oct. 11	26	3	0	0	0	8.00
Oct. 18	50	15	1	0	0	17.50
Oct. 25	134	7	0	1	1	39.00
Nov. 1	67	7	0	0	1	20.25

* For local seismicity definition, see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began recording at the times indicated and whenever possible, determinations of depth of focus have been made.

October 11, 4:05 am, very feeble, accompanying rock slide in Halemaumau.

October 11, 5:39 pm, very feeble, located 3.3 miles deep and 0.7 mile NW of Pit Seismograph Station. NW rim of Halemaumau. 19° 24' 8N; 155° 17' 3W.

October 12, 4:44 pm, very feeble, located 1.0 mile deep in Kilauea Crater, 0.6 mile SW of Volcano Observatory. 19° 25' 6N; 155° 16' 1W.

October 12, 4:59 pm, very feeble, of shallow focus SE portion of Kilauea Crater in immediate vicinity of Pit Seismograph.

October 14, 2:45 am, very feeble, 0.9 mile deep under fissures immediately W of Keanakakoi Crater. 19° 24' 1N; 155° 16' 3W.

October 15, 1:15 am, feeble, 2.3 miles deep under N rim of Kilauea Crater. 19° 26' 1N; 155° 16' 7W.

October 15, 8:15 am, very feeble, 3.5 miles deep and 1.0 mile SE of the Twin Craters. 19° 24' 5N; 155° 13' 7W.

October 15, 9:02 am, very feeble, 0.9 mile deep under fissures immediately W of Keanakakoi Crater. 19° 24' 1N; 155° 16' 3W.

October 15, 9:03 am, very feeble, probably located under Waldron Ledge E rim of Kilauea Crater.

October 15, 5:48 pm, very feeble, 1.1 miles deep under fissures 0.5 mile N of Puu Ohale. 19° 21' 8N; 155° 17' 3W. This quake was succeeded by one October 16, at 12:10 am and another at 6:41 am, both of latter very feeble and all three of same location.

October 16, 10:18 am, very feeble, 1.0 mile deep in E portion of Kilauea Crater adjacent to Kilauea Iki. 19° 24' 9N; 155° 15' 8W.

October 17, 5:17 pm, very feeble, 1.8 miles deep near Stone Corral, Kilauea Crater. 19° 24' 8N; 155° 16' 2W.

October 18, 7:15 pm, very feeble, 2.0 miles deep near center of Kilauea Crater, 1.2 miles SW of the Observatory. 19° 25' 1N; 155° 16' 4W.

October 19, 8:52 pm, very feeble, 1.4 miles deep under E rim of Kilauea Iki. 19° 25' 0N; 155° 14' 8W.

October 20, 4:19 am, very feeble, accompanying slide from NE rim and by roaring sound from Halemaumau heard on NE rim of Kilauea Crater.

October 21, 8:18 am, very feeble, 3.4 miles deep NW rim of Kilauea Crater 0.6 mile NE of Uwekahuna. 19° 25' 6N; 155° 17' 0W.

October 21, 5:53 am, very feeble, 5.0 miles deep near center of Kilauea Crater. 19° 25' 1N; 155° 16' 4W.

On October 22, at 5:54 am a slight earthquake occurred simultaneously with a large avalanche from the E and NE wall of Halemaumau. Lack of definite preliminary phases prevented exact location but a review of the seismograms from Halemaumau and Uwekahuna showed it to be of Kilauea origin and was possibly caused by the fall of the unusually large mass of material.

October 22, 8:55 am, very feeble, accompanying slide in Halemaumau.

October 29, 7:36 pm and 7:37 pm, very feeble, probably caused by slides in Halemaumau.

October 31, 6:11 am, very feeble, probably located in fissure zone immediately west of Keaankakoi Crater.

The preliminary waves of a distant earthquake began recording at 8h 02m 09s pm HST, October 22. It was located 2835 miles from Kilauea and was reported by radio to have occurred in Alaska. The preliminary waves of a teleseism began to register at 8h 18m 40.0s am HST, October 29. It occurred 3960 miles from Kilauea and reports indicated the location as the Marianas Trough south of the Island of Guam.

A period of harmonic tremor lasting twenty-two minutes began at 2:56 pm October 19.

Microseismic motion of the ground at Kilauea was strong October 25, moderate October 7, 11, 12, 13, 15, 16, 17, 21, 24, 26, 27, 29 and November 1, and was light the remainder of the month.

TILTING OF THE GROUND

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending November 1, was 4" 0N.

Table of Tilt

Week Ending	Observatory
October 11	0".00
October 18	0".35 S 15°E
October 25	0".89 N 78°E
November 1	0".38 S 77°E

	Halemaumau Clinoscope Stations		
	West	Southeast	Pit Resultant
Oct. 11	1".85 N 60°W	3".05 N 33°W	1".43 toward
Oct. 18	2".24 S 89°W	4".86 S 88°W	0".03 toward
Oct. 25	7".12 N 62°W	8".81 N 18°W	2".47 toward
Nov. 1	3".34 N 31°W	17".50 S 72°W	4".17 toward H.H.W.

THE VOLCANO LETTER

No. 441 monthly Department of the Interior National Park Service November 1936

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Figure 1. "The line of people is like a concourse of fire worshippers. At the bottom is a pool of blood-red molten slag." Halemaumau September 6, 1934, 5 p.m. Photo, 11th Photo Section, A.C., Wheeler Field, T. H.

ERUPTION OF KILAUEA VOLCANO SEPTEMBER 1934

T. A. Jaggar

This will show first the dramatic aspects of such an eruption and its effect on people living in Hawaii. Then there will be presented the scientific data describing the phases of the eruption. Here are two broadcasts by the Honolulu Advertiser, the first September 10, for the Hawaiian Islands, from Hawaii National Park: the second September 11, in a thunderstorm on the actual edge of Halemaumau pit, a national broadcast that was heard distinctly by listeners from Canada to Mexico, along with the detonations of the lava bursts on the floor of the pit 800 feet below. The eruption had started in the very early morning of September 6.

"September 10, Volcano House. Tonight in presence of the fire-pit, with the glowing lava again gushing and pounding and shaking the seismographs, I am asked to tell you something of the scientific meaning of it.

"We have established here a very small observatory. The University is helping and has made some experiments with the blasts at Moiliili quarry. The Bishop Museum is studying all

the Polynesian islands. The plantations are trying to find more water underground, and want to prevent their soils from washing into the sea. The engineers were baffled by the ocean at Mala, when they found that steamers cannot tie up to the wharf.

"These volcano changes, and shakings, and the building of coral islands, and the movements of the waters, are forces either useful or antagonistic to ourselves. We use gasoline from the earth which fifty years ago was hardly dreamed of for anything but cleaning gloves. The earth is full of secrets like this new force of petroleum. Six miles from Kilauea in the Kau Desert, we can light a stick at a crack. Here is a mysterious volcanic force from the ground, where continuously for fourteen years just past, we could have boiled water for making steam at those cracks.

We know a lava-flow is coming out of Mauna Loa. Where and when? The answer is written on that big, round, formidable mountain, with its cracks and caverns and sulphur and fume.

"We feel sure that a lava flow of 1924 lies under the sea east of Hawaii. Nobody has yet tried to discover it by sounding. A clever exploration there, with sonic sounding, wire sounding, bottom sampling, experiments, would make one of the great mappings of science, and would set a new standard.

"There is a job for fifty trained men for fifty years in unravelling the tangles of sea and land that beset us right here in Hawaii. This science of the earth will take men away from the cities. That is what the science of forestry is doing in the great public works program. That is what the Tennessee power plant is doing. That is what Boulder Dam is doing.

"It is astonishing that people with power, people who can employ labor, people with imagination, people who want to make a name or honor a name, cannot see the vision of the earth, and all the wonders it will yield. They see visions of the stars, but they do not see visions of the earth.

"Here in the light of the fiery lava which has risen thirty miles through the crust of the earth, which makes earthquakes for our seismographs twenty miles underground, which pours out under the sea or spouts up colossally on top of Mauna Loa, ought we not to be reminded of earth power?

"An Institute of Earth Research at Hilo could make a name for its donor that would live forever if it discovered the source of that rock heat at Mauna Iki, and the use of the powers of the living earth.

"September 11, crater's edge. Smooth miles in a noiseless car through hibiscus and stately tree ferns and summer habitations of men. No trace of volcanoes or brimstone in all that Hawaiian loveliness. And then in a flash you come upon a smoking fire-hole.

"A thousand people at the active crater Kilauea in Hawaii are standing here, on the edge of a vast circular pit three quarters of a mile across. The line of motionless white faces, all turned towards the setting sun, is like a concourse of fire worshippers. Sulphur of the volcano is in their nostrils. All are looking down, over a ring of precipice 800 feet high.

"At the bottom is a pool of blood-red molten slag. Through it come bursting fountains, making slow surges outward of fiery melt. Away from the fountains radiate zigzag bright lines. They are brilliant orange color, they are cracks eternally splitting the dark crust.

"Between them is a pattern of watered silk, in the black satiny robe that clothes Pele' the fire goddess. This magnificent garment lies over a bowl of the earth's glowing substance, molten, glassy, basaltic foam.

"Before the outbreak, a week ago, there was a hard lava floor, black or rusty, with a conelet at one side. The conelet is nearly drowned. The whole floor was the top of a taper cork, over converging slopes of debris. The live lava beneath lifted the cork and tipped it, escaping violently at one side of the neck of the bottle crater. Along with it, it lifted an upright slab of the wall four hundred feet high, and the glowing stuff squirted up the crack behind the slab.

"The eruption was the result. It was a quiet, instantaneous and unexpected gushing, in the dark before dawn, September 6. The evening before, nothing. The week before, nothing. The month before, nothing. People woke up, rubbed their eyes at three a.m., saw a brilliant glow and a vast cloud at the big inner pit two miles away. No one is frightened. Everybody cheers in Hawaii. Pele' has come back!

"It was all arranged as though the tourist stand, on the southeast side of the fire-pit, had been laid out by Pele' herself. In twenty minutes people were standing there, within a thousand feet of the near side of the lava lake, and just where the President's car stood a month and a half ago. There was no danger, the air was clear, the tremendous fire fountains and cataracts were all on the opposite side, and so were the whirlwinds. The best photographs were all made right there.

"The most spectacular and unusual feature of this lava rising was what happened at the wall slab, an immense cascade of incandescent liquid rock. Ribbon cataracts four hundred feet high, about twenty-five of them side by side, along a horizontal crack nine hundred feet long, fell from half-way up the wall of the pit. The liquid coalesced into a Niagara of fire at the side of talus. These cascades stopped flowing about three hours after the beginning of the eruption.

"A short distance to the north, at the edge of the glowing lake, were brilliant jets squirting up as though from hose nozzles, and criss-crossing against another slide-rock slope. These were more noisy, with deep rumble, than any of the other phenomena of the eruption. This rumble is due to gases rushing and shakng the whole volcano.

"Still farther around out in the lake was a tremendous fountain, shooting up three hundred feet in huge ropy flings, which slopped down onto the surface of the lake. The lake itself was indescribably beautiful, a vast labyrinth of glowing cobweb pattern ever changing radial and concentric to the central fountain group. The fire surf pounds on the shore, and the shore itself changes in the course of a few days of activity. A beach rampart forms. Then as the lake rises, slabs of crust pile up higher and higher on this rampart. It is like an ocean barrier beach of big flakes of stone, only the sea is made of fireworks.

"The deep shaking was such that all our seismographic instruments were vibrating violently, in unison with the trembling of the fire goddess.

"One of these machines is an annunciator, which rings a bell in the room above. When on the second day of the eruption, the big fountain started banging away like a big gun, this bell would ring in the Observatory building. Every detonation two miles away completely announced itself, as though Pele' were pressing the button.

"The whirlwinds were set going by the very hot rush of gas on the side of the pit away from the people. A strong trade wind threw this into cyclonic motion. Fragments of pumice, red hot, were falling on the west floor of Kilauea the first day. Some of them were a foot long. The whirls merged together and swept up the gravel on the ground as though with a giant's broom. I walked through this region on the first morning, in the light of the glowing pit, in order to read the tilt-meter in our cellar on the west side. My assistant picked up a pumice fragment with enough glow inside to light his cigarette. Now and then we had to crouch down to keep from being blown over. The gas and flying sand were trying, but the mighty yellow clouds shooting up above us, full of light fragments that floated down, made a marvellous spectacle. And the great billows of cloud rolled away to leeward for fifty miles in a straight

battalion of brownish volutes, tinged with pink by the rising sun. Pele' had declared war!

"What does it all mean to science? Do you say? Eight eruptions in ten years have laid new layers of lava on the bottom of Halemaumau pit in Kilauea crater. The layers average about sixty feet each. The pit is now about 800 feet deep.

"We have three active volcanoes in Hawaii, Kilauea, Mauna Loa and Hualalai. Mauna Loa had an outflow to the sea and destroyed a village in 1926. It erupted gloriously at its summit crater last December, and the travellers visited it in airplanes. We had a steam-blast eruption from Kilauea in 1924, and probably a mighty lava-flow poured out under the ocean to the east, where the water is 18,000 feet deep. We had a great trembling and shaking, thousands of earthquakes in a few weeks, from the volcano Hualalai on the west side of Hawaii in 1929. Add these things to Kilauea and you get eleven events in ten years. Who shall say that the Goddess is dead?

"A lava flow is soon coming from Mauna Loa. The scientific observatory of Hawaii National Park has been accumulating records for twenty-two years. Hawaii is the most perfect natural laboratory in the world. Here new land is being made, wind and weather act upon it, ocean and rivers sweep down the rubbish, and under all the crust of the globe is lifted. The Observatory will measure everything for a century to come. The measurement of the living earth and its breathing is just as important to your state as to Hawaii. Volcanoes in the past erupted in the Carolinas, Virginia, Pennsylvania, New Jersey, New York—your Palisades are a mass of Hawaiian lava—and in Connecticut, Massachusetts and Nova Scotia. But here in Hawaii you can take the pulse and breath and temperature of new rock when it is a-borning, and when it is making earthquakes. All over the globe there is need for more explorers for the study of the living earth.

"And now, listen to the Fire Goddess Pele' herself in the throes of her birth-pangs, listen to the pounding of liquid lava, to the bursts of earth puffing, to the surging of the waves of molten rock on the shore, all carried to you on the wings of radio, 180,000 miles a second—"

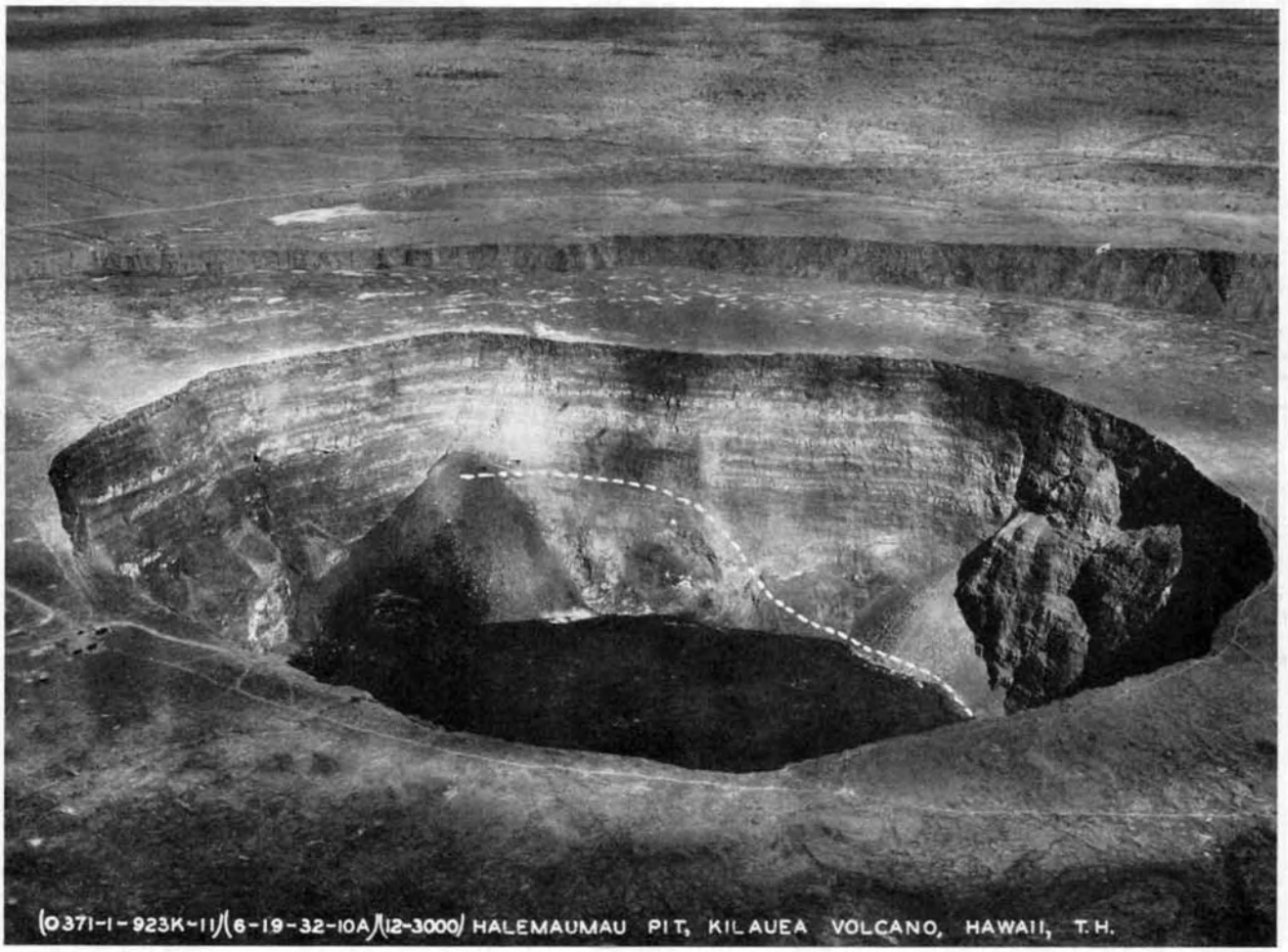


Figure 2. Halemaumau looking west from airplane June 19, 1932. Dotted line shows where the plug of 1931-32 lava lifted a wall slab to open the vent of 1934. Photo, 11th Photo Section, A.C., Luke Field, T. H.

ERUPTION OF KILAUEA VOLCANO, 1934

T. A. Jaggar

The seismic events in Hawaii that accompanied the outbreak of Mauna Loa in 1933 were reviewed by A. E. Jones in Journal Washington Academy Sciences for October 15, 1934, and those associated with the 1934 eruption of Kilauea in the number of October 15, 1935. In an earlier communication the writer has described and illustrated the 1933 eruption of Mauna Loa.

In Halemaumau pit there were slides before and after noon September 5, 1934, and the seimograph in a cellar near the southeast rim of the pit registered southwesterly tilt on the afternoon of this day. This was the first conspicuous premonitory symptom of the gushing up of lava in the bottom of the pit about 2:44 a.m. September 6.

Tremor spasms recorded seismometrically began at 1:07 a.m. and occured at intervals of a few minutes. Shocks close to the pit accompanied the outbreak, a feeble one at 2:44 a.m.



Figure 3. Halemaumau 4:30 a.m., September 6, 1934. Looking northwest, "twenty-five ribbon cataracts four hundred feet high, and brilliant jets squirting up below." Photo Maehara.

being followed by the continuous tremor which is characteristic of the rush of gas that accompanies fountaining. At the same time the bright glow of inpouring lava appeared, and clouds of fume arose. The fountaining places began at the edge of the lava floor at the bottom of Halemaumau on the north, northwest and west sides. The gush of gas bringing with it lava foam emerged through talus slopes at the first two places. The third was altogether different, and unique in the experience of the Observatory.

This was the gushing up of lava along an extensive fissure, forming a vertical crack back of a western buttress of the wall. The lava squirted up in 25 jets along a horizontal line half way up the wall of the pit. The frothy lava so ejected cascaded down the wall in ribbon cataracts. They poured over the large west talus between 3 a.m. and 6 a.m., and then went out of action. Ten main vents persisted until 6 a.m. along the cascade crack, the cascades being from 300 to 400 feet high, and there were two or three subordinate cascades, on an extension of the crack which opened on the northern side of the buttress. This buttress was in the nature of a fault slab, with the live dike fissure behind it. The wall of a pit of this kind is made up of several such imbricating fault blocks, produced by the caving away of the rim portions, and the leaving of a remnant buttress below. The vertical crack behind such a buttress is often not at all in evidence, and is frequently covered by talus.

The two photographs shown in Figures 3 and 4 are published by permission of K. Maehara for the night scene, and of the Eleventh Photo Section, Air Corps, Wheeler Field, U.S. Army, Territory of Hawaii, for the daylight view, which was made from an airplane. Both pictures were made from the southeastern side of the pit, the night scene about 4 a.m. September 6, while the cascades were in action, the daytime view at 9:30 a.m. September 7, the second day of the eruption, after the big western fountains had entirely ceased action. The two views show the contrast between the liquid flood of the first few hours of one of these pit eruptions, and the chilling around the borders which rapidly takes place afterward. The extraordinary feature of these photographs is the great western cascade. The upright fracture along the middle of the wall slope was 900 feet long and extended under the large west talus so that some of the fountains gushed through the talus along a horizontal belt, others poured over the rock buttress where there is an old intrusive body of irregular form, and still others cascaded out of the crack on the north side of the buttress, and it will be seen that the crack behind resisted the splitting effect for a quarter of its length. The most violent fountains were those at the northwest side of the pit shown at the right of the

night photograph. These were several hundred feet high, like jets from hose nozzles, covering the northwest wall and talus with pumiceous lava. The fragments of pumice were ejected several hundred feet above the rim of the pit the early morning of September 6, and fell in light spongy fragments as much as a foot long over the floor of Kilauea crater to the southwest. There was not much Pele's hair, but coarser needles of basaltic glass were common.

Phases of the Eruption

This eruption of Kilauea may be divided into four phases: (1) the large liquid pool of September 6; (2) the small lake heap and overflows which developed September 7 to 20; (3) border trickle flows from the wall-crack dike September 20 to 30 and (4) the period of subsidences, with detonations and intrusion from September 22 to October 8. These phases were more illuminating in revealing new explanations of some habits of Hawaiian lava, than anything which has happened here for many years.

Phase One: The Large Liquid Pool

This is the phase illustrated by the night photograph, and its decline is shown by the picture of September 7. Sulphurous fume of absinthe red color in transmitted light boiled up several thousand feet during the first 12 hours. The reflected fountain light was yellow-green to orange. The noise was a rumbling, and a rushing of gas, while hundreds of whirlwinds swept clouds of surface dust west and southwest of Halemaumau, and the odor was that of sulphur dioxide.

At 4 a.m. September 6 there were 30 jet fountains, and by 8 a.m. the new pool had covered the former floor 60 feet deep. Its area was 90 acres and its volume nine million cubic yards. Only the top of the 1933 border cone was still emergent. At noon the north fountains had dwindled, the northwestern ones were very violent, and the lava lake was covered with a bright-line pattern and black silky skins. A bench and rampart of crusts developed around the lake, wider at the talus slopes where the submerged slope was flatter. Between 3 and 4 p.m. the violent northwest fountaining stopped rather suddenly, and only thin blue fume was left rising from the north central fountains within the lake area itself.

Shrinkage of the lake now started in, so that by September 9 there was an inner lake 1100 feet in diameter surrounded by a floor which had shrunk and lowered beneath the border rampart 10 to 20 feet. The remnant lake was concentrating about the fountains at the NNE side of the floor. On all sides there was a slump scarp at the inner border of the rampart. The lake September 10 measured 1000 feet east-west by 400 feet north-south and became defined as an oval plateau on top of a terraced heap surrounded by a rim, over which went overflows. (See map). Within the lake spatter banks formed behind the two bigger fountains, showing that the lake was shallow, and that only the fountains were over source wells.

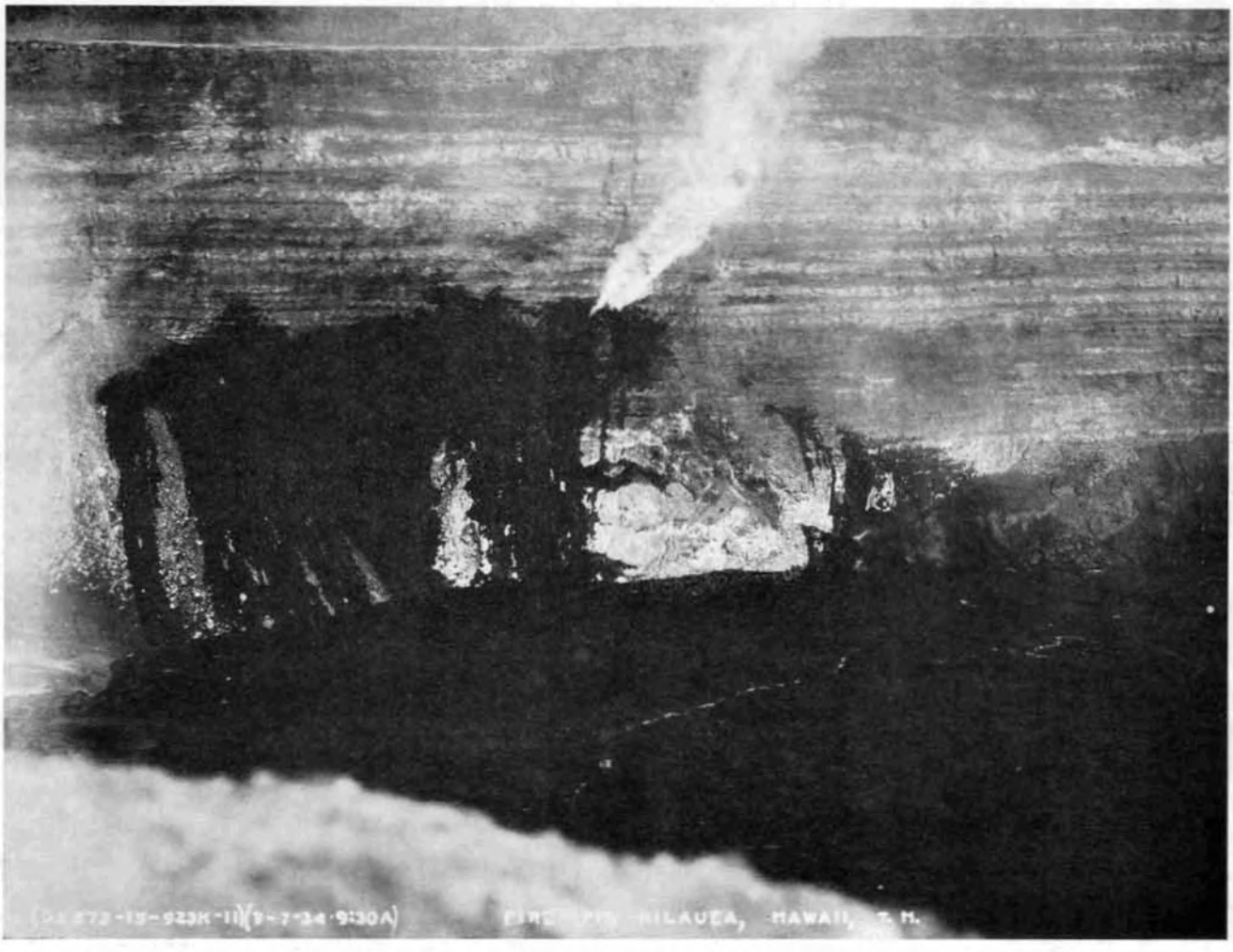


Figure 4. Halemaumau 9:30 a.m., September 7, 1934. Compare with Figures 2 and 3. Looking northwest. 11th Photo Section, A.C. Wheeler Field, T. H.

Phase Two: Small Lake Heap and Overflow

As early as September 7, temporary tremor increase rang the seismometric annunciator bell at the Observatory two miles

away. This meant that the larger fountain was making blast-like detonations, flinging up lava froth 300 feet, and emitting brown puffs. These detonations from the fountain wells increased as the vents clogged. September 15 there were five principal fountains, and a line of shoals across the lake. The reduced lake began to develop an interior topography, with a cone and crater around the large western fountain and nine other fountaining vents amid six islands and a peninsula.

By September 20 the floor measured 2700 by 2200 feet, and the lake oval was a detail within it at the north measuring 744 by 390 feet. The lake pool was on a heap 38 feet above the floor, and the highest grotto heap piled by the fountains stood 136 feet above the pre-eruption floor immediately under it. The average 1932 floor level was 2796 feet above sea-level, while the average 1934 new level was 2874 feet.

Overflows built up the new lake heap and 10 cracks developed in the outer floor radial to the lake, indicating that the lake heap was over a laccolithic swelling. Within the lake the streaming was from west fountains to east fountains, and sometimes the latter exhibited inward cascading downward. Evidently a convectional circulation was being established. Finally the sinkhole well tended to explode with detonations. Overflows were numerous from the lake so that it was being built up on a slag heap.

Phase Three: Lava Trickle up the Wall Crack

A new feature appeared September 20 around the extreme edges of the floor in the shape of a welling up of red lava, between the talus and the cake of 1934 fill, which constituted the floor. This was the first time any glowing lava had appeared from a source away from the fountaining wells. They began along the talus edges, but eventually extended to places where the floor made contact with the rock wall of the pit. In no case did they cascade over the slump scarp inward, but the lava rose as a dike between the floor cake and the containing funnel. The band of border extrusion was 20 feet wide in places, and it gradaully extended to all sides of the floor with the exception of the north edge that was closest to the lake. The marginal extrusion was always simultaneous with extra pressure at the lake, accompanied by overflow. It was evident that intrusive action was going on under the floor. Transit surveys in the course of the eruptive period showed that the outer floor rose, and the lake area gradually lost its relief.

Phase Four: Subsidence with Detonations

Detonation spells from both east and west wells, which had built cones within the lake, recurred from time to time during September 22. This usually happened when the east fountain had been transformed into a sinkhole grotto at the level of the lake, big bursts of gas and flame came up, and downpouring would last from 10 to 20 minutes. Then the pot would resume ordinary fountaining with outward flowing streams. During the detonation spells, tremor increased at the seismographs. By September 23 the west fountain had become a pool in a raised craterlet, from which a cascade poured into the lake. This craterlet also made noisy explosions, and four avalanches were noticed at the north wall of the pit close by.

About 2 p.m. September 23 the lake drained away through the eastern sinkhole leaving a saucer 20 feet deep, and then the liquid poured in again. These drainages increased in duration until October 1. Their violence also increased, they lasted from half an hour to two hours, and the intervals between them were notably about six hours. The detonations were finally heard three miles away.

It now appeared that the whole floor was swelling by intrusion, and a concentric ridge around the edge of the floor replaced the former slump scarp. Apparently the pulsations of lowering the lake basin were occasioned by inflow of the liquid under the shell of floor crust. The floor was lifted and the lake area went down. Gradually they were brought to a common level. The explosions were due to clogging of the gases in the increasingly viscous lava of the wells, and to the confinement of a small shaft. Failing to overflow the wells became gun-barrels. With each detonation an umbrella-shaped fling of stiff lava would shoot up, sometimes 400 feet, the roofs of the grottos would be blown to pieces, and fragments would clatter down all over the surrounding surfaces. Toward the end the explosive spells would be followed by complete quiet for a half hour. Then the liquid would quietly recover in the wells and restore the lake to a period of four or five hours of quiet streaming.

The detail of a sinking spell was as follows: At 9 a.m. the west fountain cone was cascading over its flank; at 11 a.m. the lake saucer was 25 feet deep, with shoals on its bottom, and both east and west wells were cannonading vertically, long squirts of viscous melt were sent up 200 feet or more, the intervals between detonations or hisses were from 5 to 10 seconds. The lava pooled in the wells and came back with quiet fountaining just after noon. The explosions gradually lessened, a fan-shaped flow on the lake bed from the west fountain encountered an expanding puddle from the east fountain in mid-lake, and the entire body of new liquid overrode the foundered crusts that formed the floor of the lake.

September 28 and 29, and again on October 1 occurred the last overflows of the lake margin. The extraordinary intrusion ridge at the edge of the floor at the foot of the east talus had become 25 feet high, crevassed along its crest, and the floor on the inner side of this ridge, which had been 15 feet below the slump scarp around the margins, was now 25 feet above it. The actual lift of the floor therefore, above its slumped position of three weeks before was of the order of 40 feet.

The lake area was gradually converted into several ponds. By October 3 three quarters of the lake basin had become a slag heap, with the northern pool a depression in its flank 300 feet long. There were evidently tunnels leading from the cone pots to the lakes. Several pots had developed and these became smoke holes. October 5 the lake area had collapsed, blowing noise was audible and some streaming was still visible. Thudding noise was heard in the western part of the swelling floor, and prolonged slides at the north wall of the pit showed that slumping of the lake area was in progress. The eruption ended October 8 and subsequent shrinkage caused numerous slides from the pit walls.

Level Changes

From time to time the Observatory runs levels from a bench mark on the gravel spit south of Kilauea crater as a base, so as to close a circuit around the rim of Halemaumau pit. After the eruption, October 17-25, A. E. Jones ran such a leveling circuit to discover changes since July 2, 1934. Treating "Spit" bench mark as stationary, results showed a stretch of the north rim of Halemaumau 1800 feet long to show positive elevation to a maximum of 1.28 feet; along 1000 feet of the rim on each side of the elevated tract, negative elevation to a maximum of 0.5 foot occurred northwest and northeast of Halemaumau. The remainder of the rim showed diminishing depression southward to a line of no change 400 feet SSE from the pit.

It should be observed that the north tilt cellar near the pit rim was much less disturbed by the eruption than the two other cellars southeast and west, as though the north were comparatively rigid ground. The rift belt of the mountain crosses the pit from southwest to northeast. The bench mark "Spit" lies within an old graben fault block on the side of downthrow relative to the north side of the rift belt. It seems likely that the evacuation of magma produced by the eruption undermined this fault block, that the northern country remained relatively stable, and that what is really represented by the level change



Figure 5. Halemaumau from Observatory September 6, 1934. Heavy fume column over lava fountains. Photo Jaggar.

is a lowering of the bench mark, rather than an elevation of the northern pit rim.

Hawaiian Volcano Observatory Report for November 1936

VOLCANOLOGY

The month of November at Halemaumau Pit of Kilauea Volcano continued the slides from the walls which have been so conspicuous of late.

The following is the abridged table of movements:

Week Ending	Seismicity	Number of Slides	Aggregate Crack Opening
November 8	15.50	20	518.5 mm.
November 15	19.75	14	20.0 mm.
November 22	11.75	14	5.5 mm.
November 29	7.50	16	0.5 mm.

Sequence of Events by Weeks

The first week slides and cracking of the NE rim continued with more debris added to the talus slopes, and much breaking of rim ground. Crack No. 34, a chasm close to the cliff edge, opened 501 mm.; this accounting for the excessive value above.

The second week kept up these processes, with a marked tendency to continuous dribbling of rocks down the E and NE walls about the noon hour.

The NE surveying station monument, the third week, was left unstable at the extreme edge of pit, undermined by slides.

The fourth week showed a change of habit, with much lower seismicity, much **closing** of cracks, so as to make the lowest record of weekly crack opening since September 20, 1935, and uplift instead of sinking for the levelling measurements of Kilauea floor at Halemaumau pit rim. The slides extended their operations to the north wall of the pit.

Slides at Halemaumau

Slides from the wall of the pit have been noted as follows, but these are only a part of what actually occurred:

November 2, 10:00 am., continuous sliding NE wall 12 to 1:30 p.m., dust from slides until 3:00 p.m., continuing slides N and NE.

November 3, 9:42 and 9:53 a.m., small slides.

November 5, 9:00, 9:40, 10:15 a.m., moderate slides. 9:55 a.m., small slide. 11:53 a.m., 12:55 p.m., slides. 2:20 p.m., 3:36 p.m., large slides NE station. 1:30, 5:00 p.m., continuous sliding. 3:18 p.m., earthquake rang No. 1 Annunciator Bell, dust cloud at pit NE. 3:46 p.m., No. 1 Bell again, dust continues. Below Crack No. 34, 200 feet, a dark spot in the wall was caving away.

November 6, 9:22, 9:30 a.m., moderate slides NE.

November 10, 9:02 a.m., a large slide had left a scar, and small rocks dribbled down the wall E, sending up light dust. 9:37 a.m., moderate slide NE, 100 feet below Crack No. 34. 9:51 a.m., large slide ENE.

November 11, 9:54 a.m., small slide sending up light dust E. The Volcano House trail near the pit ENE had now lost 100 feet of length by caving in, a new notch here indented the edge of the pit, and fresh cracks farther back had started to open.

November 12, 10 to 11 a.m., rocks falling continuously from E wall.

November 13, 8:50 a.m., rocks dribbling down wall. 11:55 a.m., 12:40 p.m., moderate slides send up dust.

November 14, 10:15 a.m., moderate slide E. 11:16 a.m., big noisy slide E.

November 15, 9:24 a.m., 9:55 a.m., moderate slides ENE with small slides in interim.

November 16, 9:45 a.m., moderate slide NE. 9:50 a.m., larger slide ENE, preceded for 15 minutes by dribbling stones. Slides during day undermining NNE wall and removing 100 feet of edge east of NE station.

November 17, 9:56 a.m., rocks dribbling at new scar NNE.

November 19, 10:12 a.m., rocks dribbling NNE.

November 21, 9:25 a.m., dust NE wall. 9:46 a.m., continuous small sliding ENE. 9:54 a.m., 10:17 a.m., moderate slides NE and ENE.

November 24, 9:00 a.m., NE dust cloud. 9:45, 9:47 a.m., small slides ENE. 9:50 a.m., large dust cloud. 10:15 a.m., moderate slide ENE and dust cloud under NE station. 10:22 a.m., large slide there leaving scar. 10:30 a.m., 10:45 a.m., large dust clouds N. 11:15 a.m., large dust cloud ENE. 2:50 p.m., dust cloud NE station. 4:00 p.m., moderate slide 400 feet west of NE station. 4:10 p.m., large slide same place. 3:00 to 4:00 p.m., continuous falling of rocks there, which ceased after the large slide.

November 25, 10:55 a.m., noise of moderate slide heard, followed by continuous dribble on wall 300 feet W of NE station.

November 27, 11:15 a.m., dust from slide NE.

Halemaumau Solfataras

Fume of bluish color continued to rise at the edge of floor of pit NW and SE. On November 13 it appeared dense at 8:50 a.m., and thinner at 9:40 a.m. It was reported "not conspicuous" the third week.

On November 19 a fresh slide was reported to have left a scar in the SE corner of Hiiaka Crater in the Chain of Craters east of Kilauea.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 27 marked rim-crack localities, reduced to 26 the third week, resulted as follows. Some time before November 21 possibly during the earthquake of November 16, sliding carried away the southern ledge of Crack No. 34.

Week ending forenoon of:

November 7, 11 opened, 1 closed, aggregate opening 518.5 mm.

November 14, 9 opened, 2 closed, aggregate opening 20.0 mm.

November 21, 9 opened, 1 closed, aggregate opening 5.5 mm.

November 28, 6 opened, 8 closed, aggregate opening 0.5 mm.

Crack No. 34 on November 7 was found yawning excessively and collapsed in the middle of the month. It is a chasm over the NE extension of the Kau Desert rift which crosses Halemaumau. Omitting it the general opening November 7 was 17.5 mm.; No. 17 opened 2.5, No. 25 8.0, and No. 45 2.0 mm. No. 17 is SSE, the others E (See map of pit, rim figures).

On November 14, the opening of cracks was in gradations to a maximum of 9.0 mm. at No. 28, where the edge had broken back the most. No. 34 NE opened only 2.0 mm., in contrast to November 17, when it opened 510 mm.

November 21, the destruction of No. 34 over the deep rift made the sixth marked crack on the rim destroyed within a month. The rift belt crosses the pit (see map) from SW Pit Station to NE Pit Station.

SEISMOLOGICAL DATA

EARTHQUAKES

Table

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant† Earthquakes	Local* Seismicity
Nov. 8	22	15	1	0	2	15.50
Nov. 15	65	7	0	0	2	19.75
Nov. 22	21	8	0	1	0	11.75
Nov. 29	12	9	0	0	1	7.50

† Includes teleseisms or those shocks over 5000 kilometers distant.

* For local seismicity definition, see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began recording at the times indicated and whenever possible, determinations of depth of focus have been made.

November 3, 5:28 pm, very feeble, located in fissure zone 0.5 mile NE of Ahua Kamokukolau and 2.4 miles deep. 19° 23' 1N; 155° 17' 2W.

November 5, 3:18 pm, very feeble, in Kilauea SW Rift Zone near the Kamakaia Hills and 16.0 miles deep. 19° 19' 5N; 155° 21' 0W.

November 5, 11:26 pm, very feeble, probable location, Mauna Loa NE rift about 18 miles SW of Hilo.

November 7, 1:43 pm, very feeble, 1.8 miles deep and 0.6 mile N of Kalanaokuaiki Pali. 19° 21' 7N; 155° 15' 3W.

November 7, 2:19 pm, very feeble, 3.3 miles deep, 2.0 miles S of Halemaumau and 1.4 miles W of Ahua Kamokukolau. 19° 22' 8N; 155° 17' 4W.

November 7, 3:47 pm, feeble, located 4.8 miles deep and 0.6 mile E of Keanakakoi Crater. 19° 24' 3N; 155° 15' 4W.

November 12, 4:25 am, very feeble, located near center of Kilauea and of shallow depth.

November 16, 1:44 am, very feeble, located 1.0 mile NW of Kilauea Military Camp and 4.0 miles deep. 19° 27' 1N; 155° 17' 0W.

November 16, 4:42 am, very feeble, located 4.2 miles deep in vicinity of Kilauea Military Camp. 19° 26' 3N; 155° 16' 2W.

November 16, 8:33 am, very feeble, 1.0 mile deep under NE edge of Kilauea Crater. 19° 26' 0N; 155° 16' 2W.

November 16, 8:36 am, very feeble, 0.9 mile deep under western portion of Kilauea Iki. 19° 25' 1N; 155° 15' 2W.

November 16, 10:14 am, very feeble, 5.0 miles deep in Kilauea Crater adjacent E edge of Halemaumau. 19° 24' 7N; 155° 16' 9W.

November 16, at 1:08 pm a slight to moderate earthquake registered on all the Observatory seismographs. It was located immediately to the SE of Kilauea Iki Crater, 1.4 miles E of Byron Ledge E rim of Kilauea Crater. Reports indicated that it was felt slightly by many people in Hilo. The shock was felt by a few in the Kilauea Area and very strongly in the vicinity of Puu Koae on the Kau Desert SW of Kilauea Crater. 19° 24' 8N; 155° 14' 4W.

November 16, 5:11 pm, very feeble, 4.8 miles deep near juncture of Pali Lele o Kalihipao and Kalanaokuaiki Pali. 19° 21' 1N; 155° 16' 0W.

November 16, 5:52 pm, very feeble, 0.4 mile N of N edge of Kilauea Iki, 3.5 miles deep. 19° 25' 5N; 155° 14' 9W.

November 16, 7:36 pm, very feeble, located 3.4 miles deep under E portion of Kilauea Iki. 19° 24' 9N; 155° 14' 7W.

November 18, 1:51 pm, very feeble, located 9.0 miles deep and 5.0 miles E of Mauna Loa Summit Crater.

November 23, 5:48 am, very feeble, probably located in the vicinity of Ahua Kamokukolau, 2.0 miles SE of Halemaumau.

November 25, 1:02 pm, very feeble, probable location under center portion of Kilauea Crater.

November 27, 9:39 am, very feeble, probably located under SE rim of Kilauea Crater.

November 28, 10:06 am, very feeble, probably located in fissure zone 1.3 miles SE of Ahua Kamokukolau.

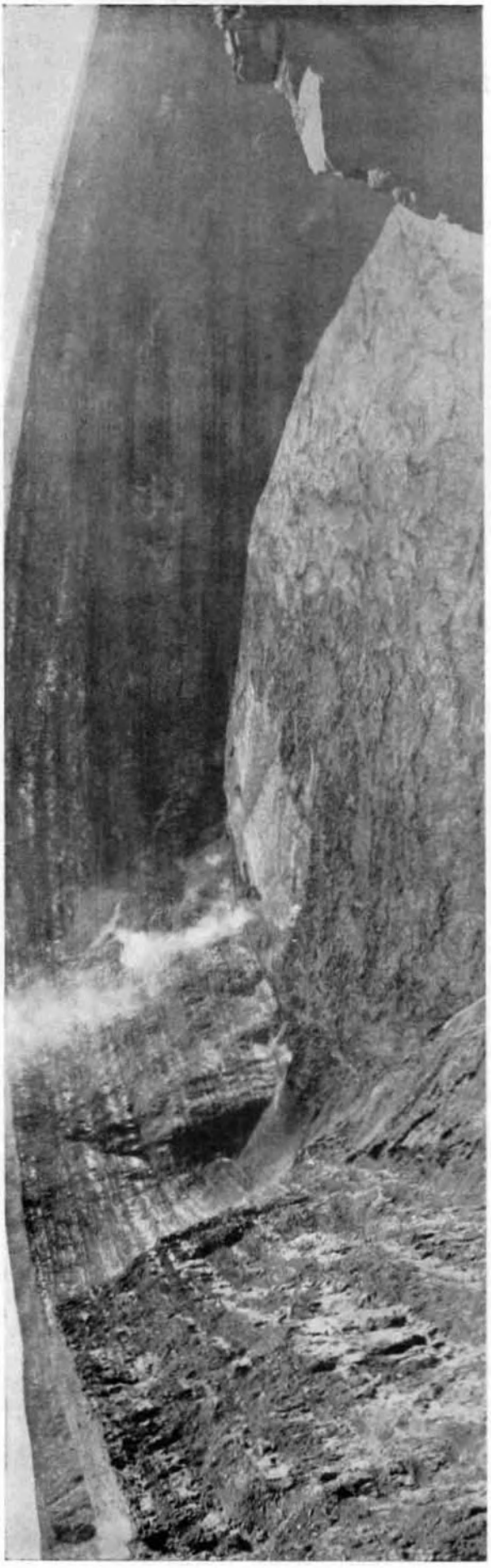


Figure 6. Halemaumau looking NE September 13, 1934, when the inner lake had formed at the top of a heap. Photo Jaggar.

The following very feeble earthquakes occurred simultaneously with, and are probably associated with rock slides from the E, NE or N walls of Halemaumau. November 5, at 2:03, 2:20, 2:28, 3:36, 4:40, 4:41 and 4:49 pm.

November 14, at 11:13 and 11:17 am.

November 24, at 2:13 and 4:08 pm.

Periods of continuous (harmonic) tremor registered during the month as follows: beginning at 5:41 am November 5, six (6) minutes; 6:54 pm, November 13, twenty-eight (28) minutes.

Microseismic motion of the ground at Kilauea was light November 4, 13 and 28; strong November 8, 9, 14 to 21 inclusive and 24; the remainder of the month it was moderate.

Teleseisms or Distant Earthquakes began registering on the Observatory seismograph as follows: November 2, the preliminary (P) waves at 4h 36m 39s H.S.T., thought to be located near Guam, 3485 miles from Kilauea. November 2, (P) waves at 10h 25m 48s H.S.T., 3850 miles from Kilauea, reported location off the coast of Honshu west edge of Japan Trough 38° N; 142° E (U.S.C.G.S.). November 12, (P) waves at 9h 43m 51s H.S.T., 3905 miles from Kilauea. November 13, (P) waves at 2h 10m 11s H.S.T., 3305 miles from Kilauea, reported location near Kamchatka Peninsula N of Japan Trough 57° N; 164° E (U.S.C.G.S.). November 25, (P) waves at 10h 10m 50s H.S.T., 2200 miles distant from the Volcano Observatory. November 28, Secondary waves (transverse) at 8h 21m 45s probably associated with news reports of disturbances in Alaska.

H. H. W.

TILTING OF THE GROUND

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending November 29, was 4" 85N and 3" 66W.

Table of Tilt

Week Ending	Observatory	Halemaumau West Station
November 8	1".90 N 30°E	1".82 S 35°W
November 15	1".18 S 70°W	2".59 N 38°W
November 22	0".50 N 12°W	5".78 N 88°W
November 29	0".33 S 61°W	5".22 S 52°W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
November 8	4".92 N 17°W	3".'50 toward
November 15	1".20 S 69°E	1".86 from
November 22	6".67 N 16°W	0".35 toward
November 29	5".12 N 19°W	3".39 toward

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory November 23, showed closing across the Crater and slight opening across Halemaumau as compared with similar measurements October 20. From Kilauea SE rim to Uwekahuna there was closing 2".75, October 20 to November 2; closing of 0".66, November 2 to 13 and opening of 1".00, November 13 to 23. Total Closing 2".42. From the Pit Seismograph to the NW Pit B.M. there was opening 0".25, October 25 to November 2; closing of 0".58, November 2 to November 13 and opening of 0".67, November 13 to November 23. Total opening 0".34.

Spirit Levelling

Spirit levelling across Halemaumau from the Spit, SE edge of Kilauea Crater to the NW Pit B.M. showed elevation of the NW Pit B.M. with reference to the Spit of 6.4 centimeters. This is the first indication of elevation since before the 1934 eruption of Kilauea. H. H. W.

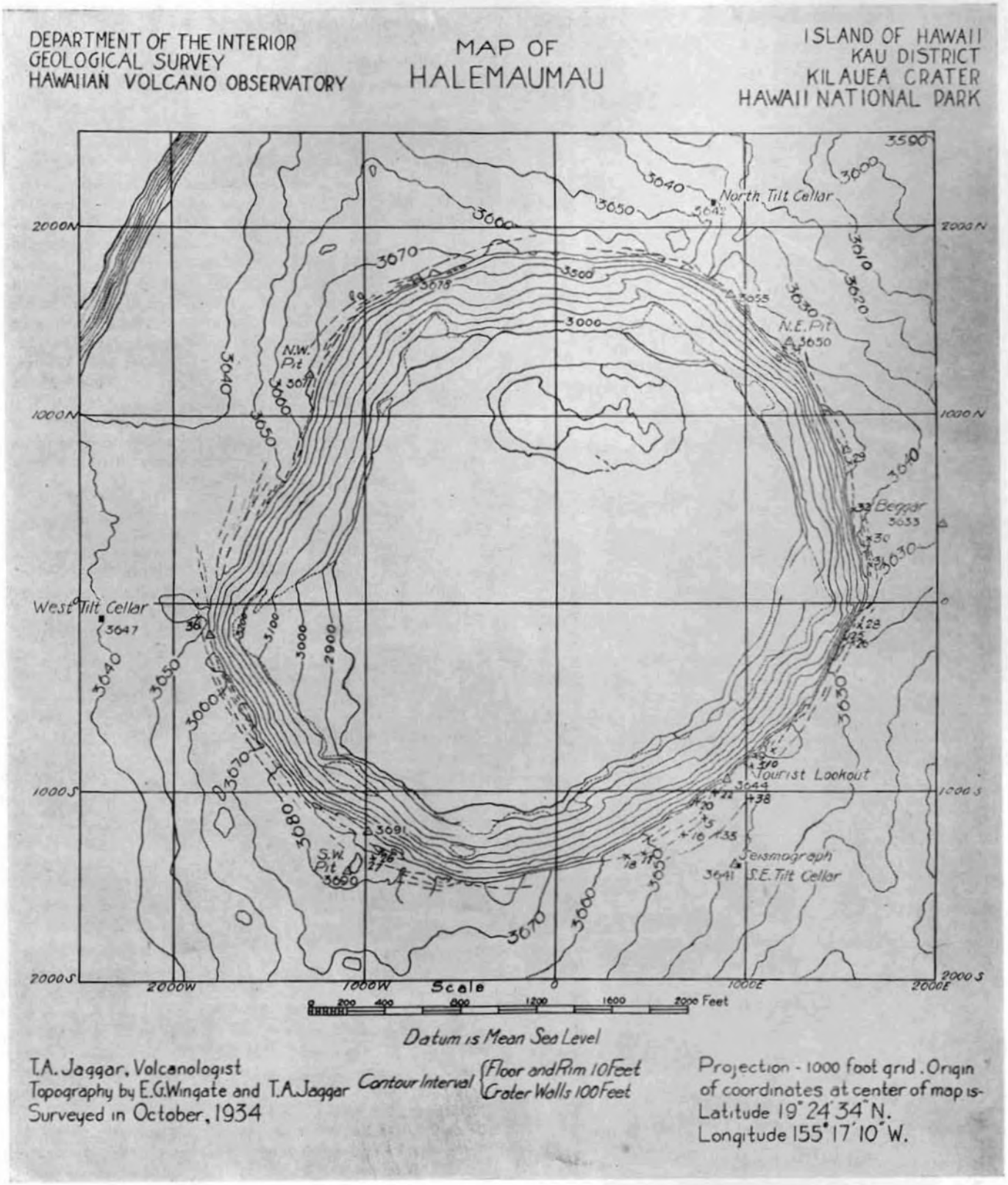
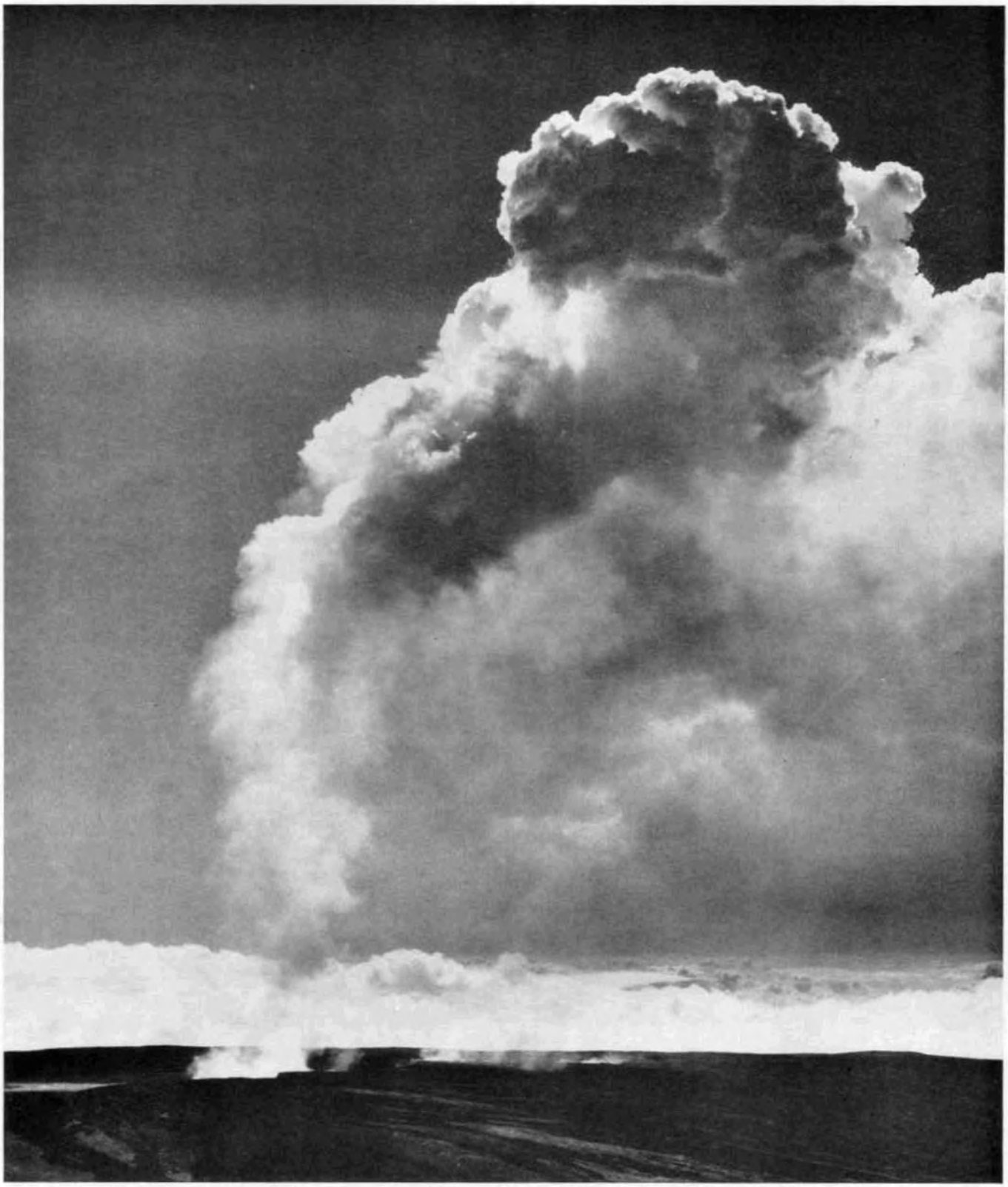


Figure 7. Map of Halemaumau October, 1934. Compare Volcano Letter No. 395 for map before 1934 eruption.



A remarkable photograph taken from an airplane above Makuaweoweo Crater, Mauna Loa, at an elevation of 14,500 feet. Thin fume rising from lava fountains playing within the crater, merges into dense white cumulus of atmospheric moisture above. By permission Fleet Air Base, Pearl Harbor, T. H.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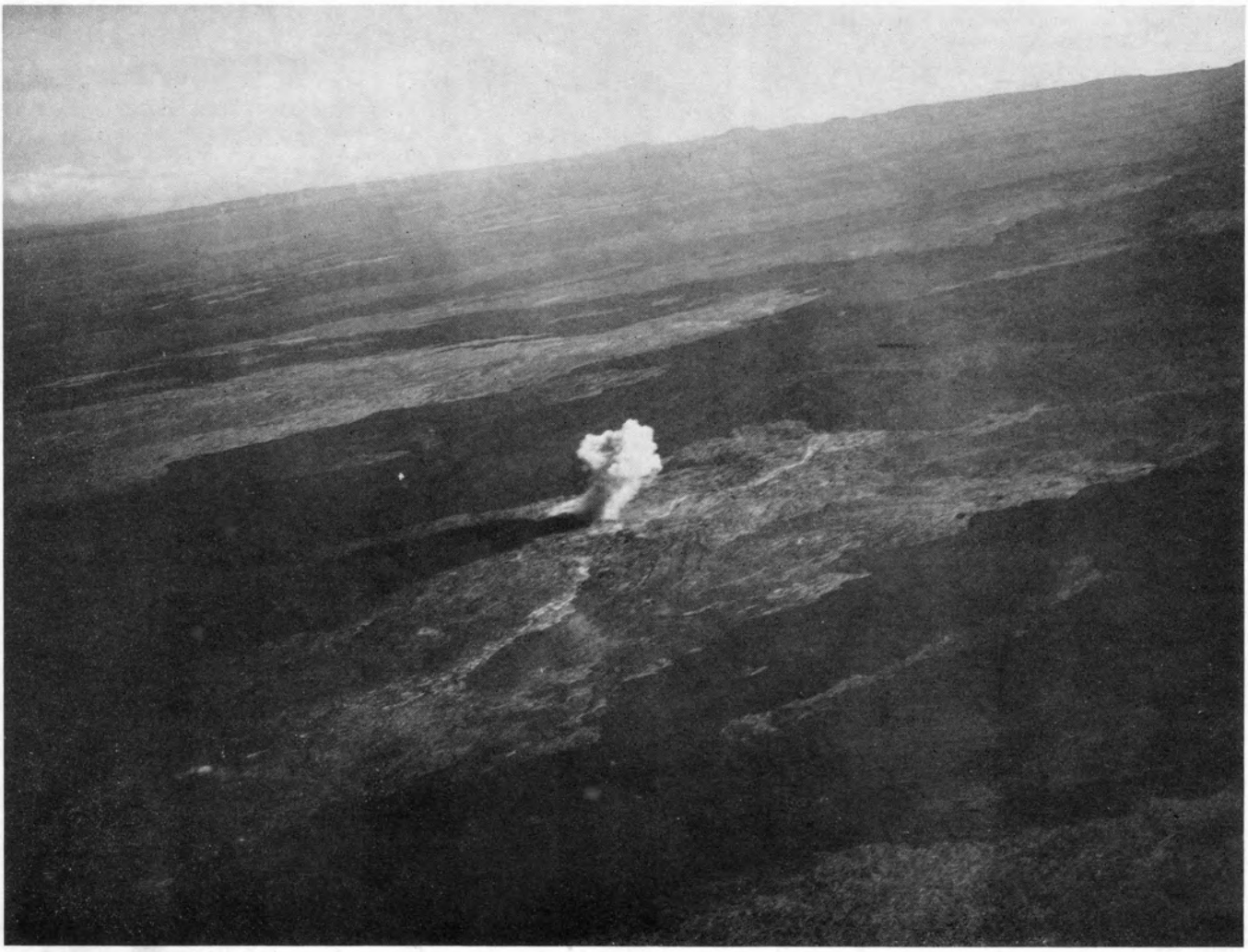
THE VOLCANO LETTER

No. 442 monthly Department of the Interior National Park Service December 1936

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



The mountainside and a channel hit. Photo, 11th Photo Section, U.S.A.

THE BOMBING OF MAUNA LOA, 1935*

T. A. Jaggar

Summit crater lava eruptions of Mauna Loa are always followed eventually by a breaking open of the mountain flank and emission of lava there. Mauna Loa crater filled with 100 feet of fresh lava December 2-18, 1933, and on March 26, 1934, the following statements were published: (1) A lava flow is expected within two years; (2) It should come at the north; (3) A likely direction is toward Hilo; (4) Several earthquakes, or one severe earthquake, may happen at Hilo.

Eight earthquakes came, one about every three months, close to equinox and solstice, some of them alarming shocks in Hilo. They occurred throughout the two years, and this relieved the city from any single cataclysm.

The lava flows came on the north side of the mountain, November 21, 1935. The near-summit gushing of fume, from the new rift which ejected the lava, continued into March. The

* Reprinted from the July-August 1936 issue of The Military Engineer, The Mills Building, Washington, D. C.

prolonged flow, which developed a vitreous cover, moved crookedly north, then, on December 22, bent east toward Hilo after pooling in the saddle between Mauna Loa and Mauna Kea. It was about 15 miles long including its meanders, and had 20 miles more to go to reach Hilo.

Expectancy and Policy for Emergencies

Apart from earthquake probability, above noted, the Hawaiian Volcano Observatory has experimented with preparation for emergencies for many years. The work is based on statistics and has been useful in many eruptions. Hilo is organized through its police and Red Cross systems, and these have the collaboration of the National Guard and the American Legion. A Conference of the Associated Engineers of Hawaii on January 16, 1918, was advised of the exact facts concerning Hawaiian volcanic blasts and lava flows, earthquakes and tidal waves. A Conference of the Chamber of Commerce, June 9, 1931, was advised of the Napier, New Zealand, unpreparedness. Organizations for discipline, communication, rescue, relief, funds, refugees, and rebuilding were considered.

Hilo understands that it is committed to future lava flows. The Volcanologist in the 1931 address stated: "A vitreous lava, flowing under crust in tunnels, but doing damage on lower mountain slopes, could be blown up at the source tunnel about the 9,000-foot level. This would open the tunnel, dam the lava stream with rocks, and force it to flow anew out of the blocked tunnel and channel over the surface of the upper country by a changed course. If the previous flow took 5 months to get near Hilo, the renewed flow 30 miles up the mountain would require as much, and the city would be given 5 months' respite."

The Crisis of December 22, 1935

The map shows the relation of the 1935 flow areas to earlier flows of definite years. The expectancy of a north flow was based on the succession of south flank outflows from 1868 to 1926, moving progressively up the mountain along the southwestern rift belt. The belt crosses the summit. Each flow on cooling seals the rift at its orifices. The next flow after 1933 was expected across the summit, and it so happened.

The expectation that 1935 would be the year was based on average intervals and past history. The expectation of northern earthquakes was based on a southward crossing of the summit in 1868 and southern earthquakes therewith. If there were a northward crossing of the summit now, northern earthquakes might be expected to accompany the rupture of the north rift. The likelihood of advance towards Hilo was based on the precedents of 1852, 1855, and 1881.

Without recounting all the detail of the 1935 eruption, it may be said that the first rapid flows, between November 21 and November 26, from a near-summit source, swept 8 miles northward and stopped. The loss of gas, heat, and energy of emission was very rapid the first day. The clinker slag cools from below upward, releases fixed gases that react exothermally to heat the top surface, and the stirring crystallizes the melt so that solidification is by crystalline frosting or sprouting. The Hawaiian name of this clinker lava is **aa** (pronounced ah-ah). The sprouts break up into boulders during viscous flow.

Beginning November 27, an entirely new flow vent appeared. This was 4,000 feet below the summit and 10 miles northeast from the top of Mauna Loa. An ancient tunnel or fissure was opened underground to drain the central well. From this orifice a new clinker-lava stream poured north toward Mauna Kea, between the 1899 and 1843 flows. The near-summit vent of the first outbreak clogged itself, and became noisy with gas bursts and viscous blobs. Then its lava subsided into the shaft, clouds of yellow smoke puffed up, and sulphur was deposited on the conelet. This upper vent was at about 12,000 feet elevation. The new lower vent was at 9,000 feet.

It was this lower flow that turned towards Hilo on December 22. Before that date there was doubt. The lava pooled in the saddle. It might have drained westward into waste lands, but the 1843 flow blocked it and it turned eastward a mile a day into valuable pastures, steeply sloping into the well-watered drainage of Wailuku River. This is part of the Hilo water supply. By December 26 it had flowed 5 miles of the 20 that would put it into Hilo.

During the month the lava had changed its character from clinker lava to vitreous, or glassy-skinned, lava. This the Hawaiians call **pahoehoe** (pah-hoy-hoy). It is exactly the same chemically as clinker lava, but is totally different physically. With less of stirred "sugaring," the glass may rise to the top of basaltic melt. It forms a gas-tight skin. The gas-making slag then pours onward under a heat-insulating crust of thickening membranes. This is the "ropy lava" of geology. It is silvery, smooth and vesicular, and unlike the clinker type, it cools and solidifies from the surface downward. The skins, ever reforming over bulbous toes which push down the hill, confine the heat and create a mechanism of tunnels. There is a single tunnel near the source, and there are distributary tunnels at the fronts. It is this vitreous-coated lava which may hold its heat and push forward for 40 miles. It is in sensitive equilibrium isothermally to its own evolution of self-heating gas bubbles, to the chill of the air, to the pressure on its pipe walls, and to the source pressure, which is both hydrostatic and effervescent—that is, the lava from inside the mountain is really a glassy foam.

The point of all this is that if the single source tunnel is broken open, a pressure-temperature adjustment of gas-in-slag is destroyed. Not only does this let the higher fluid escape and rob the lower distributary frontal tunnels, but also it lets loose the gas and heat, and solidifies the fluid **back into the source vent.** A lava filled shaft, after a month of violent release, is no longer a resistless mountain-breaker. The weight of the mountain and the cooling have reasserted themselves as dominant.

The Army Called In

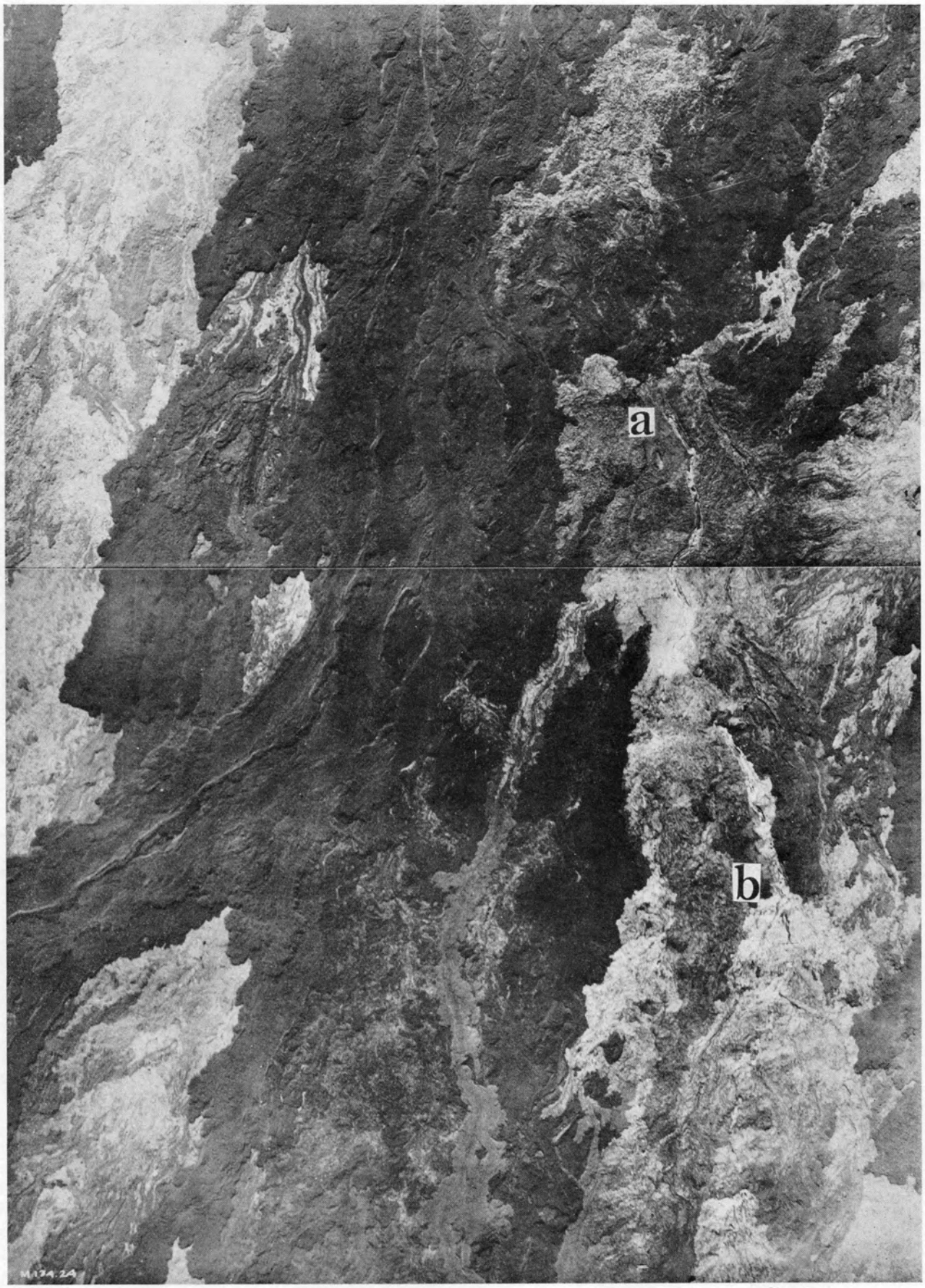
Monday morning, December 23, the Volcanologist, Dr. T. A. Jaggar, consulted Maj. Hugh C. Gilchrist, commanding Kilauea Military Camp. Before that time bombing would have been dangerous, for it might have diverted the flow **toward** Hilo, but now the flow was definitely headed thither. Major Gilchrist sent a radio at once to the Chief of Staff, Col. Daniel Van Voorhis. The Commanding General, Hawaiian Department, sent a plane from Honolulu with three officers of the bombing squadron that afternoon to inspect the lava flow area. At noon the next day a conference was held in Hilo with Col. Delos C. Emmons, Department Air Officer; Lieut. Col. V. L. Peterson, Department Engineer; Capt. J. J. Ladd, bombing officer; Lieut. J. W. Cox, Third Engineers; Lieut. B. J. Webster; Major Gilchrist; Mr. Stanley Elmore, President of Hilo Chamber of Commerce; Superintendent E. G. Wingate of Hawaii National Park; and the Volcanologist.

Col. Delos C. Emmons, Air Officer of the Hawaiian Department, reported that he and Lieut. Col. Virgil L. Peterson, Corps of Engineers, examined the lava flow from the air December 24 and held the conference above recorded with the Volcanologist, and with other officials. They jointly reported:

a. That lava flow actually threatened the headwaters of Wailuku River, which provides water to Hilo. There also seemed to be a possibility that this flow might endanger the city of Hilo with its valuable harbor.

b. That public opinion demanded that something be done to divert or stop this lava flow.

c. We recommend that twenty 600-pound bombs be dropped in an effort to divert the lava flow.



Vertical airplane photo of Target a, the uppermost channel, and Target b, a mile downstream.
Photo, 11th Photo Section, U.S.A.

Dr. Jaggar stated that there was a strong probability that properly directed bombs would help the situation materially; that there was always the possibility in the future of a more serious eruption which might destroy Hilo unless preventive steps were taken, and that it should be found out now whether or not aerial bombs would stop or divert a lava flow. The Secretary of War, during a recent visit, had expressed great interest in the aerial bombing of a lava flow, and Dr. Jaggar had been assured that, if an emergency arose, the Department Commander would assist in protecting life and property threatened by lava.



Aa and pahoehoe lavas of 1935. Jaggar photo.

The Conduct of Operations

It was decided, after the Volcanologist had outlined the problem, to conduct the operation December 27. The Army Transport **Royal T. Frank** brought twenty 600-pound TNT bombs; and as many 300-pound pointer bombs were brought by the planes and were charged in Hilo with black powder and sand.

On December 26, the Volcanologist accompanied a group of Bombing Squadron officers over the target in a Douglas amphibian plane in order to point out the area to be bombed. They, in turn, took up other officers later in the day, so that all should be acquainted with the terrain. The Volcanologist recommended that the uppermost channel of the actual flow be bombarded at elevation approximately 8,500 feet on the north flank of Mauna Loa. The channel about a mile down the lava stream was indicated as a second target. This was to be demolished in the event that the upper target had been successfully hit, so that if any liquid still trickled through the tunnel, it would encounter a second obstacle. Both parts of the channel were crusted over, but glimpses of the liquid lava appeared in open parts of the tube where the crust had caved in. By demolishing the tunnel roof, the operation would block the tube with debris, force the liquid within to overflow, cool it and release gas, and thereby rob the tube system farther down the mountain where the front of the flow was being fed with lava through this tunnel.

Special Orders Number 304, December 26, 1935, sent twenty officers and thirty-seven men, including sixteen sergeants and corporals, by air from Luke Field, Honolulu, to the island of Hawaii, in command of Lieut. Col. Asa N. Duncan, Air Corps. They represented the 23d and 72d Bombardment Squadrons, a Signal Corps operator of Headquarters Detachment, four men from Wheeler Field, including photographers of the 11th Photo Section, and one each from the 4th and 50th Observation Squadrons.

The departure for Hilo from Honolulu was at 8:30 a.m., December 26, in ten bombing planes, two observation planes, and two amphibians. Upon arrival at Hilo, work was begun immediately in locating the targets with the aid of the Volcanologist. The Ordnance Department sent two civilian employees to supervise fusing and loading of bombs.

Colonel Duncan's report shows that, in the operation of December 27, the first bombing plane took off at 8:45 a.m. from Hilo and was followed by four others at twenty-minute intervals. Each plane was loaded with two 600-pound demolition bombs, armed with 0.1 second delayed-action fuse, and two 300-pound practice bombs for sighting shots. The bombs were dropped from an altitude of 12,000 feet, approximately 3,500 feet above the target. Two photographic airplanes accompanied the bombers and carried cameras for still and moving pictures. The first mission showed that individual bombing produced good results, so that the salvo method, using five planes in formation, was not used.

Observation of the Bombing

Colonel Duncan and staff at Hilo Airport maintained short-wave radio communication with the airplanes; and telephone communication with Dr. Jaggar, the Volcanologist, who had established a station at Puu Oo ranch high up on Mauna Kea mountainside, to observe the bombing. Twenty demolition bombs were dropped between 9:30 a.m. and 3:00 p.m.

From the high post of the Volcanologist at Puu Oo ranch house, elevation 6,300 feet, the front of the flow was seen to be pushing through the valley 4 miles away in the foreground; Hilo airport was discernible with field glasses 23 miles away to the east; and the lava source targets were in full view up the mountain southwest, 12 miles in a bee line. The planes were moaning overhead all day long, and the bombers climbed high, poised, pitched forward, and a gray ball of smoke and dust boiled up from the upper lava channel.

The hits were noted at 9:43 a.m., there was a flash, 60 seconds interval, then a deep boom; at 9:49, a flash and a weak smoke column; at 10:15, a high column and noise after one minute; at 10:18, a soft column and the detonation; at 10:28, a high puff, interval, and booming; at 10:32, the same; and, at 10:59, a double puff, as though two bombs hit together. All the early shots were at the extreme upper tip of the gleaming silvery lava field, narrowing to a point at the source.

After 11 a.m. the lower target, the lava channel a mile below the source, was evidently the goal. One bomb exploded



The great bend of the flow towards Hilo, pahoehoe lava: a tunnel lies underneath. Jaggar photo.

with very deep penetration and heavy concussion in the depths of the incandescent stream, and great sheets of glowing melt shot hundreds of feet into the air, orange red, glistening, and spreading like a fan. When this was seen the Volcanologist knew that the single channel of the upper tunnel could not stand such punishment without damming itself, freezing, and spilling over. That tunnel lay at the bottom of a trench 10 feet wide and 40 feet deep in places; and a 600-pound bomb

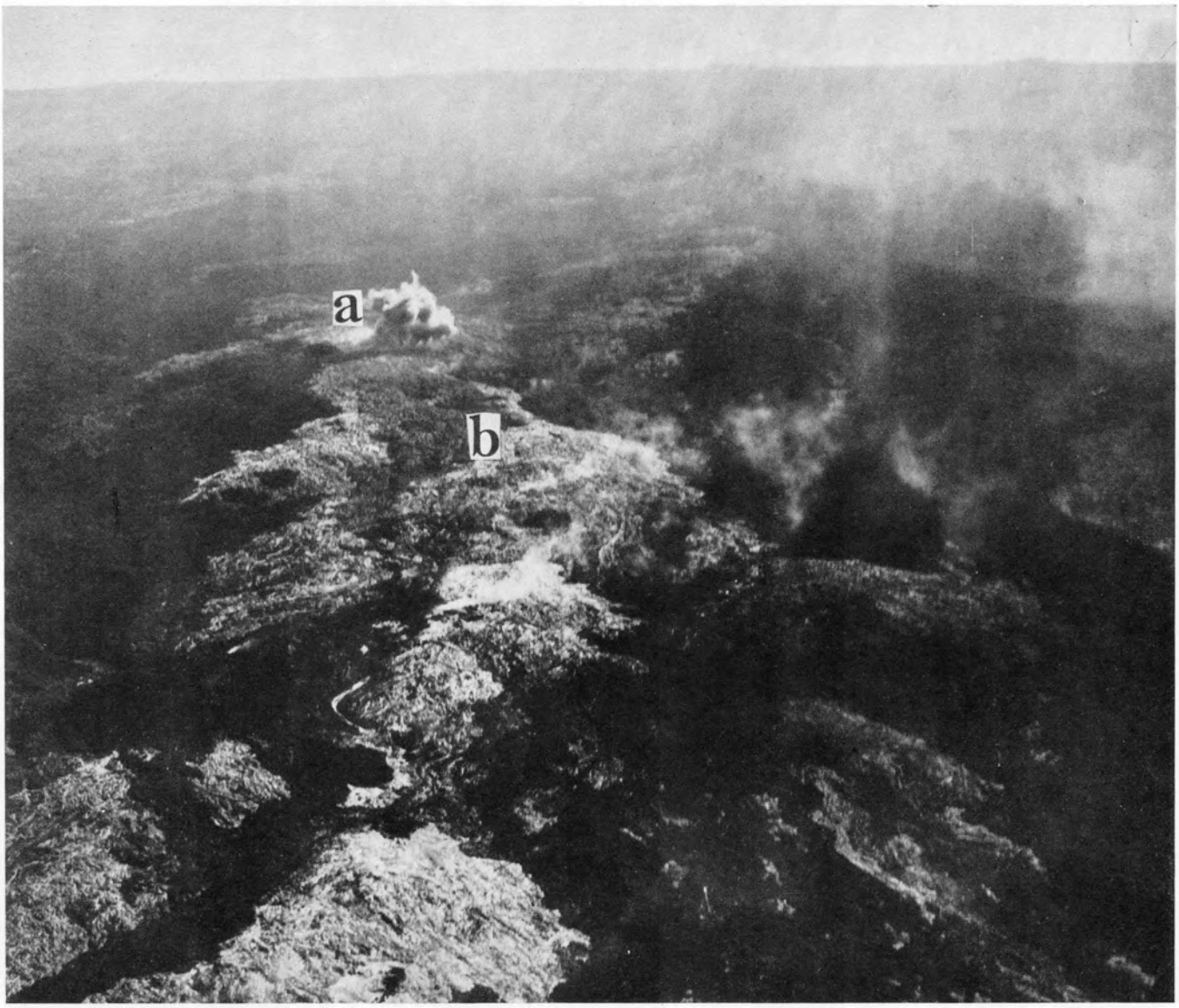
crater might be blasted 20 feet wide and 5 feet deep in hard rock; hitting a trench of the size noted, it could hardly fail to wreck it. Hitting it in five places directly along the upper mile of its course (the 25 per cent of direct hits reported by Colonel Duncan) might be counted on to block the channels and leave the lower tube system to empty itself and collapse.

Other bombings were observed until 2:37 p.m. and notes were made of the soft black powder explosions, in contrast to the heavy puffs and thunder claps of the demolition shells.

The Stoppage of the Flow

The evening of December 28 all motion at the front stopped temporarily. This was a totally new phenomenon, for the preceding week had shown the front making a mile a day; and the front lay on an increasingly steep slope, averaging 157 feet to the mile for the 7 miles of eastward flow from the lake of lava in the saddle.

The bombing thus smashed and dammed the source tunnel, released lava there, and beginning at the noon hour of the



The lava heaps of the flow source; a direct hit near upper source channel target a: and a collapsed tunnel near foreground showing a glowing stream inside. Photo, 11th Photo Section, U.S.A.

Meanwhile the front of the flow pushed ahead, passing successive tree markers which had been photographed. All day photographs were taken to show the changing progress. At 11:15 a.m. the front of the flow piled itself 30 feet high, entered woods, and sent up clouds of black dust and flames, while explosions of carbon gas made noisy detonations in old caverns. That night, December 27, the flow was more brilliant than ever, for oxygen had been admitted to the tunnel system by its collapse. Up at the bombed area, ten or twelve glow spots were visible where liquid lava was welling up bomb holes. A side branch of smooth lava made out from the main flow below the saddle.

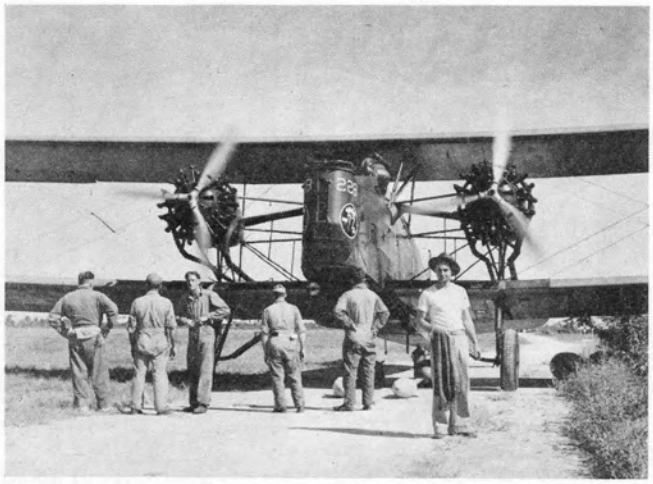
bombing date, the speed of frontal motion was:

12:00	noon	December 27	800 feet per hour
4:00	p.m.	December 27	150 feet per hour
10:30	a.m.	December 28	44 feet per hour
6:00	p.m.	December 28	0 feet per hour

The release of liquid lava at the source tunnel was confirmed as follows: December 26 the Volcanologist flew over and could see no liquid on the surface. During the bombing, December 27, the pilots could see liquid in short stretches of collapsed tunnel roof. Next day air inspection showed a rapid glowing stream at the source itself, on the surface of the lava

field. On December 31 all motion on the surface had ceased at the source.

This last fact was an unexpected development and was not the end of the eruption. But it was the end of the outflow. The inside eruption was manifest by clouds of sulphurous vapor from internal lava effervescing in the near-summit crater, showing that the well beneath was still charged with liquid;



A bombing plane with the bombs beneath. Maehara photo.

and this continued until March, 1936. An earthquake crisis in that month definitely ended the eruptive period.

That the bombing would end the source outflow was theoretically probable. The direct hits were sufficient in number to blast open the roofed channel and release to the air the vitreous froth called basaltic lava. The equilibrium of self-heating was destroyed and the slag, after spilling over for two days, stiffened, slowed down, and solidified into the source vent. Pilots who flew over on the second and third days after the shelling reported that the released liquid stream at the source had stopped.

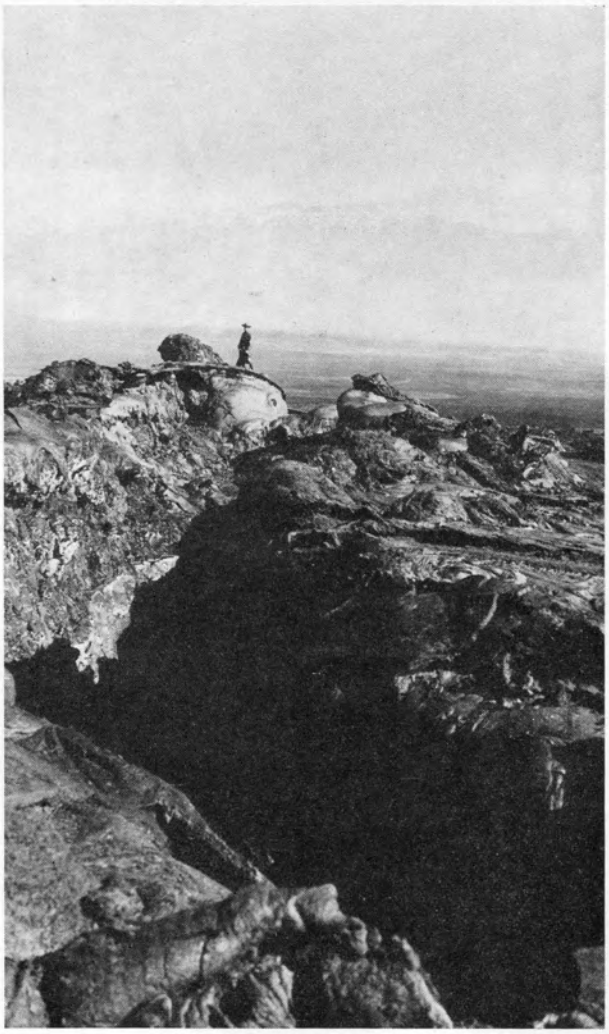
The remainder of the activity of frontal flowing towards Hilo was a spilling of remnant lava from the tunnels and streamways. This was partly over the sides of the lava fields, partly lengthening of the front. There was a notable sudden gushing out of clinker lava at the front on December 30 for 1,000 feet. The final tongues became narrower, and one of these slightly passed the Forest Reserve fence east of Puu Oo ranch January 1 at 11 a.m. The last motion of the tip of this finger, only 100 yards wide, was at 2 a.m., January 2. The position of this final front was in the drainage basin, 8 miles east of the saddle, and 12 miles short of the Kaumana Road in Hilo. The total movement forward after the bombing was 1 mile in 6 days. If the flow rate of the Christmas season had continued, the front would have been in Hilo on January 9.

The following is quoted from a report of the operation: "After the bombing was completed, a reconnaissance was made of the shelled area. It was found that five bombs hit the stream itself, three in the flowing lava of the first target (source stream), and two directly above the tube of molten lava of the second target (one mile downhill). One of these caved in the tunnel and the other failed to penetrate. Three other craters were within 5 feet of the stream, the explosion throwing debris into the red lava. Two others were within 20 feet of the target. From the sensing of the pilots, seven other bombs fell within 50 feet of the stream. Those who witnessed the bombing declare that the execution of the mission was superb; that the bombs had been placed exactly where they should have been; and that this aerial bombing of a lava flow made history for science in performing a great geological experiment which was a success. From a military viewpoint of the bombing, Colonel Emmons says: 'Very valuable tactical training was received as a result of this mission, well worth the cost. Excellent co-operation was received from the Quartermaster Depot, the Ordnance Depot, and the commanding officer, Kilauea Military Camp'."

Hilo Chamber of Commerce furnishes the following minimum approximation of values, apart from life, good-will and natural assets like the harbor:

Sewers	$ 1,200,000
Streets	2,125,000
Schools and churches	2,883,804
Water supply	1,000,000
Piers, breakwater, dredging	7,500,000
Taxable land	10,387,824
Taxable improvements	12,408,300
Territorial property	2,224,395
Federal property	350,000
Personal property, growing crops, etc.	11,000,000
	$51,079,323

Supposing that the flying, transportation, ammunition, and payroll cost $25,000, the operation of December 27 appears to have been more than justified. An experiment pouring



Detail of collapsed tunnel near Target B, Mauna Kea in distance. Jaggar photo.

liquid clay on a scale model of Hawaii showed that this flow would have extended itself down Wailuku Canyon so as completely to fill Hilo breakwater and wipe out the second harbor of the Territory. Just such a flow in 1859 extended the land at Kiholo. As there will be more flows on the Hilo side, the bombing experiment has furnished a new weapon to civilization.

The Volcano Observatory at Kilauea was founded in 1911 by the Whitney Fund of the Massachusetts Institute of Technology with the words: "To be conducted with a view to protection of human life and property." That responsibility was accepted by the Hawaiian Volcano Research Association and the National Park Service. The 1934 address announced that "Mauna Loa has definitely mobilized and declared war, there is every appeal for an intellectual and practical victory over Nature, and a program can be laid down whereby our engineers and aviators and bombers will rejoice at the opportunity to show their prowess." All honor to the Army for an excellent peace-time achievement.

Hawaiian Volcano Observatory Report for December 1936

VOLCANOLOGY

The coming of December, and the elapse of a year since the last outbreak of the Mauna Loa-Kilauea system, are both reasons for expecting return of lava to Halemaumau. The winter solstice has produced more eruptions here than any other season. And the average of intervals has been one year. But nothing happened in December 1936 except a sudden quietness the last week of the month. This may mean uplift under Kilauea crater, following the slumping that caused the October avalanches.

All the movements were fewer than in November, as shown (see Volcano Letter 441) by the following tabulation, that indicates by weeks the local seismicity, the counted number of slides in Halemaumau pit when it was under routine observation, the amount of aggregate opening of marked rim cracks at Halemaumau by weeks, and the seimograph count of local tremors and quakes:

Week Ending	Seismicity	Slides	Cracks	Quakes
December 6	5.00	1	6.0 mm.	12
December 13	8.75	0	6.0 mm.	13
December 20	7.75	2	5.0 mm.	25
December 27	12.75	1	2.5 mm.	33
January 3	0.50	0	0.0 mm.	2

Sequence of Events by Weeks

The first week the pit was generally quiet, and the second week showed no slides at all, and remarkable constancy.

The third week slightly increased seismic motion and dust from a few slides. The shocks were mostly from Kilauea.

The fourth week tremors increased, and fume from the NW floor solfatara was notable.

The new year opened with unparalleled quiet, no slides, very slight crack movements, and seismic activity confined to two tremors in seven days.

Slides at Halemaumau

Slides from the wall of the Pit have been noted as follows, mostly from a distance, or at type periods of visitation:

December 6, 4:10 p.m., small dust clouds east edge.

December 17, 11:00 a.m., dust at NE wall, and scar from a recent slide there.

December 27, 4:00 p.m., dribbling of small rocks down NE wall.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 26 rim crack locations resulted as follows:

Week ending forenoon of:

December 5, 10 opened, 0 closed, aggregate opening 6.0 mm.

December 12, 7 opened, 4 closed, aggregate opening 6.0 mm.

December 19, 11 opened, 4 closed, aggregate opening 5.0 mm.

December 26, 7 opened, 2 closed, aggregate opening 2.5 mm.

January 3, 4 opened, 2 closed, aggregate change 0.0 mm.

It is of interest as showing consistency among the subjects selected for measurement after years of experience at the Observatory, that crack widening, numbers of quakes, intensity of quakes, and number of slides all dwindled simultaneously the last week. This shows Halemaumau to be an index vent for all Hawaii, as some of the usual earthquakes originate under other parts of the Island, and those regions also were quiet the last week of the year. It would seem also, with seismicity suddenly lowering along with crater values, that all the island seismicity is clearly volcanic. T. A. J.

SEISMOLOGICAL DATA

EARTHQUAKES

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Distant† Earthquakes	Local* Seismicity
December 6	14	3	0	5.00
December 13	31	2	1	8.75
December 20	19	6	0	7.75
December 27	47	2	1	12.75
January 3	2	0	1	0.50

† Includes teleseisms or those shocks over 5000 kilometers distant.

* For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began recording at the times indicated and whenever possible, determinations of depths of focus have been made.

December 3, 11:17 pm, very feeble, located under SE rim of Kilauea Crater adjacent to Keanakakoi Crater and 1.5 miles deep. 19° 24' 4N; 155° 16' 2W.

December 4, 12:11 am, very feeble, located under N rim of Kilauea Crater 0.3 mile SW of Kilauea Military Camp and 2.0 miles deep. 19° 26' 1N; 155° 16' 7W.

December 11, 7:20 pm, very feeble, probably located under SE portion of Kilauea Crater.

December 16, 3:05 am, very feeble, located 0.7 mile NW of Ahua Kamukokulau S of Kilauea Crater and 0.8 mile deep. 19° 23' 4N; 155° 16' 6W.

December 16, 10:20 am, very feeble, located 1.1 miles SE of Pit Seismograph and 5.0 miles deep. 19° 23' 6N; 155° 16' 4W.

December 17, 5:52 pm, very feeble, located deep under SE slope of Mauna Loa. 19° 19' 0N; 155° 33' 2W. Reported felt at Hookena.

December 18, 3:22 pm, very feeble, probably located in SE portion of Kilauea Crater.

December 19, 5:56 am, very feeble, of Kilauea origin.

December 27, 12:06 am, very feeble, located deep under Kilauea SW Rift 5.0 miles SW of the Volcano Observatory. 19° 22' 0N; 155° 14' 5W.

Periods of continuous (harmonic) tremor registered on the Observatory seismograph as follows: beginning at 12:04 pm, December 1, six (6) minutes; 9:11 pm, December 13, twenty-one (21) minutes and 4:24 pm, December 26, seventeen (17) minutes.

Microseismic motion of the ground at Kilauea was light December 2, 3, and 5; moderate November 30 and December 1, 4, 6, 7 and strong the remainder of the month.

Registration of Distant Earthquakes at the Observatory was as follows: December 13, the preliminary waves at 11h 10m 37s am, HST, with 3020 miles as the distance of focus from Kilauea; probable location in the Kamchatka Peninsula as reported by newspapers. At 8h 50m 37s am, HST, December 21, the surface waves of a teleseism began recording. Its distance was undetermined. At 4h 27m 40s am, HST, December 29, the preliminary waves of a teleseism began recording. Its location was 3550 miles from Kilauea.

TILTING OF THE GROUND

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending January 3, 1937, was 3.60" N and 0.24" W.

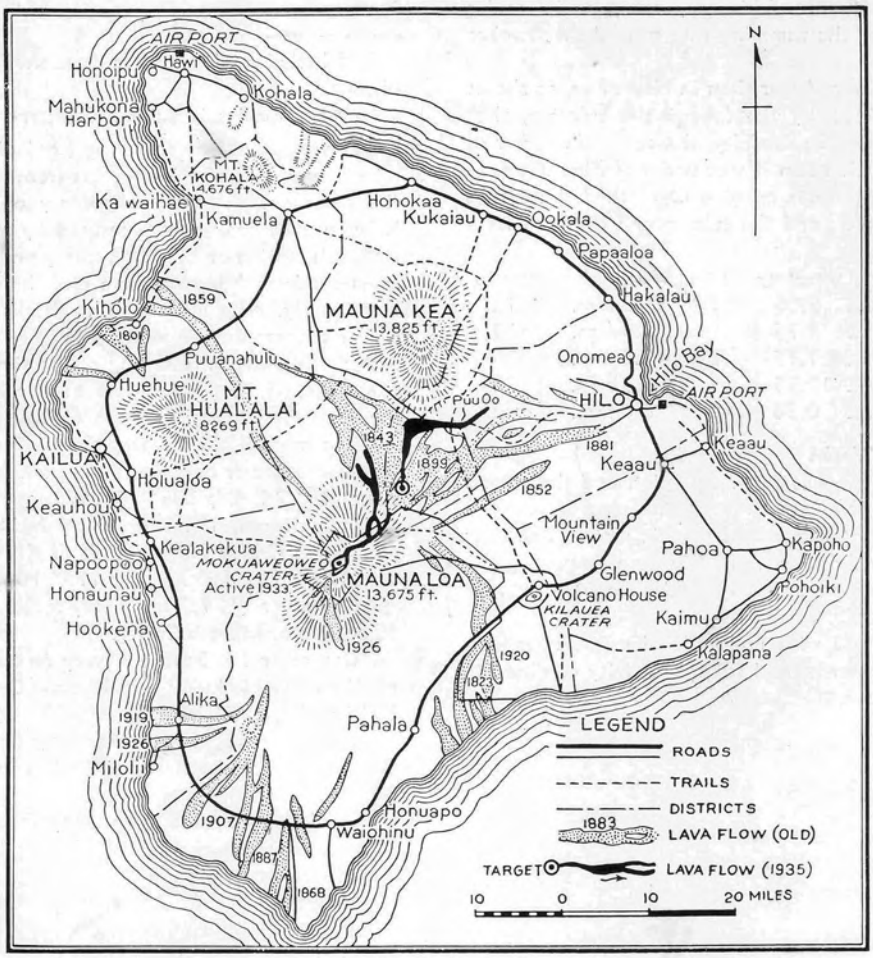
Table of Tilt

Week Ending	Observatory	Halemaumau West Station
December 6	0.62" S 78° E	3.19" N 57° W
December 13	1.10" N 43° E	2.15" S 65° W
December 20	0.74" N 38° W	9.86" W
December 27	1.05" S 33° W	3.75" S 61° W
January 3	1.18" S 02° E	5.13" N 64° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
December 6	3.79" N 11° E	0.26" from
December 13	1.46" N 34° W	0.63" from
December 20	2.20" N 61° W	7.75" from
December 27	3.11" S 21° W	5.05" from
January 3	5.61" S 81° W	2.04" from

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory, December 26, showed a closing of the Halemaumau value and an opening of the crater value compared with similar measurements made November 23. From Kilauea SE rim to Uwekahuna there was opening 0.42" November 23 to December 11 and closing of 0.08" December 11 to December 26. Total opening 0.34". From the Pit Seismograph to the NW Pit B.M. there was a closing of 0.84" November 23 to December 11 and closing of 1.16" December 11 to 26. Total closing 2.00". H. H. W.



The Island of Hawaii

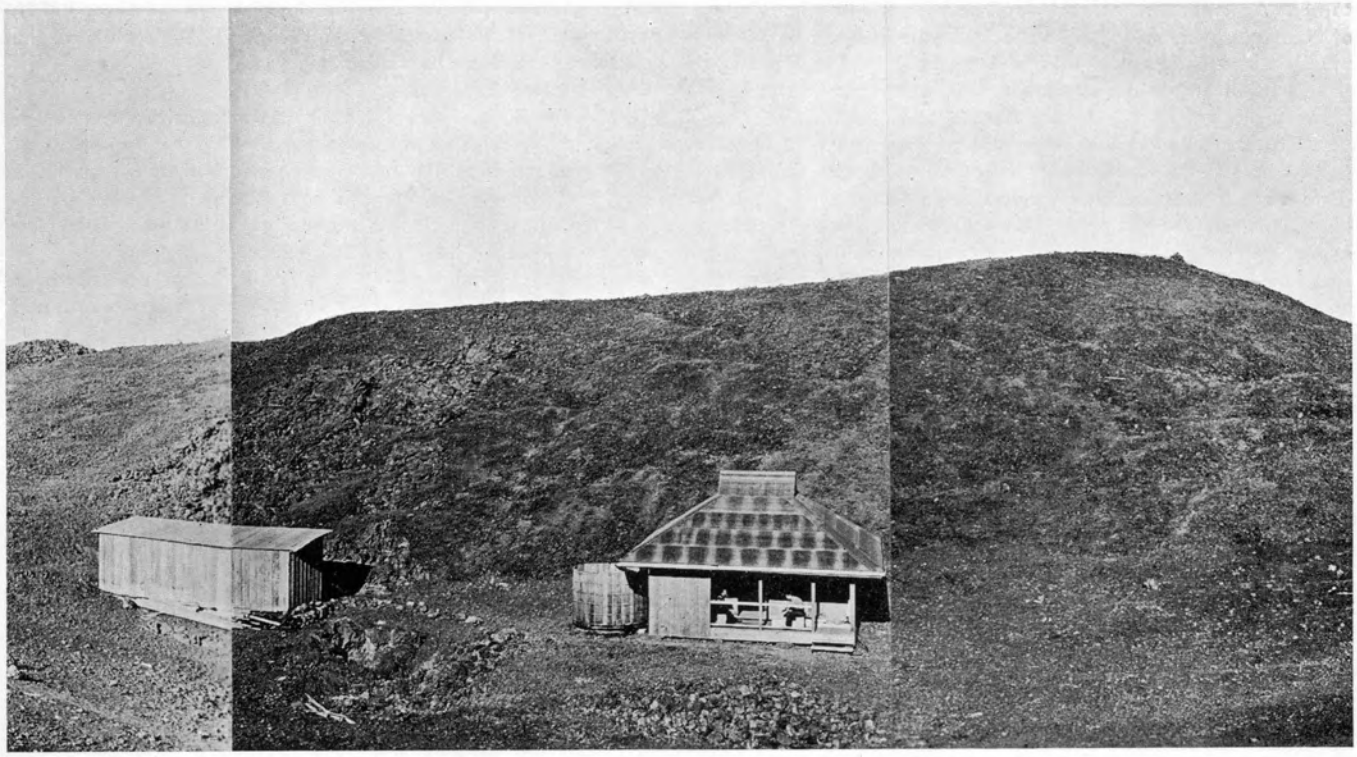
Map of Hawaii, from the Military Engineer.

THE VOLCANO LETTER

No. 443 monthly Department of the Interior National Park Service January 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Red Hill, at 10,000 Feet Northeast Rift of Mauna Loa, with Resthouse and Stable

PROTECTION OF HILO FROM COMING LAVA FLOWS*

By T. A. Jaggar

Observatory Plans 1936

The following paragraphs are from the special report of December, 1936, from the Volcanologist to the Superintendent of Hawaii National Park. They concern, not a new and sudden alarm, but a serious project for safeguarding the industries of Hawaii from the lava flows of Mauna Loa. It has long been the intention of the Hawaiian Volcano Research Association to make Mauna Loa its principal center of study, and the time has come to do this.

"It is just one year since the Mauna Loa Flow of 1935, which seriously threatened Hilo, and ceased flowing in sequence upon artificial bombing. The law of cycle recurrence on Mauna Loa for 101 years is one crater outbreak every three and a third years, and one lava flow every six years. The north rift is open and smoking, and the next outbreak may threaten Hilo again, by analogy with nineteenth century sequences.

"The National Park with CCC labor has finished nine and nine-tenths miles of truck roadway up Mauna Loa east slope, going WNW from Bird Park. The resources of volcano research should be brought to bear on the engineering problem of protecting Hilo with the planning aided by 1935 experience. In like manner the 1933 crater eruption of Mauna Loa furnished data for forecasting the 1935 outflow of lava.

"There are four issues involved, namely: more Park land on Mauna Loa, an embankment to deflect lava flows near the source, other embankments lower down, and a survey of the rift land. Discussion of the project has the approval of the park superintendent, and is on the initiative of the Hawaiian Volcano Research Association.

"The embankment proposed is entirely distinct from the

* Address delivered at Annual Meeting of Chamber of Commerce of Hilo, Hawaii, January 19, 1937.

bombing method. The latter is a last resort measure, intended for lava flows of the tunnel-flowing variety called 'pahoehoe,' which appear in late stages of an eruption. The embankment-deflection is for the early and most dangerous liquid stage of an eruption, lava called 'aa,' which we saw naturally deflected November 22, 1935, by old lava banks. There is abundant loose rock on Mauna Loa for construction. There is no question but that an artificial embankment aligned downhill oblique to flowing slag would deflect it. A lava flow fills as a liquid. It does not push as a solid.

"The source belt, a mile wide, is a series of definite cracks trending N 70 deg. E from the summit crater for eleven miles. The distance to Hilo in the same direction is 35 miles. The divide between Puu Kipu, and Puu Ulaula called 'Red Hill,' is the parting line between old Hilo flows and southward flows, and the line trends N 85 deg. E.

"An embankment from Red Hill N 20 deg. W, five miles long, would steer any flows such as 1855, 1880, and 1899 to safety. An embankment north and south, with Puu Huluhulu of Humuula in its middle, about a half mile in each direction, would hold the flow pool steered into the Humuula lands by the Red Hill embankment, and send it west from the saddle between Mauna Loa and Mauna Kea.

"The short Puu Huluhulu embankment would be about 20 feet high; and the Red Hill embankment, oblique to the flows down a steep slope, need be only about 15 feet high.

"With reference to a line survey of the proposed embankments, and an aerial photographic mosaic of the entire northeast flow belt from the rift to Hilo, General Drum has expressed approval of the project.

"There the matter stands at the end of 1936. The volcanologist recommends that the establishment of Observatory volcanologic work on Mauna Loa at Red Hill shall be the main purpose of 1937 plans of the Hawaiian Volcano Observatory. The founding of Mauna Loa seismological measurement, and rift patrol, appear essential to the safety of the community."

Motive of the Work Proposed

From a small village threatened by numerous lava flows, with upper land destroyed by two of them, and the main water source invaded by three of them, Hilo has grown to a city, a port, and an airport.

These things have been improved at great expense from time to time, and the population has grown from a few hundred to 20,000 people. The harbor dredging and breakwater, the airport, wharfs and real estate will all be improved much more, and the adjacent plantations in health, labor, insect control, transport, agronomy, water supply, and milling are models of scientific advance in aggressiveness and in defense against evils. Hilo is their harbor.

The shadow of the lava menace is just as removable as the shadow of malaria, tuberculosis or yellow fever, the noxious mosquitoes, the leaf hopper, or the plague fleas and rats. It merely never occurred to anyone to remove it.

There is just one way to do this, and that is to face the exact facts, and then act with decision and unanimity at this present time of Government employment of labor. Remove the lava shadow, and watch Hilo go ahead by leaps and bounds.

Expectable Intervals and Flow Sources

Using the data of the 1934 article (Volcano Letter, October, 1936) for the history of Mauna Loa flows, the average of Mauna Loa eruptions is one summit outbreak every three and a third years between 1832 and 1933, and one flank outflow every six years.

There were six Mauna Loa eruptions between 1914 and 1935, making present average three and a half years. There were four flank flows, making outflow average 5.5 years. Thus the twentieth century holds up the general average.

The succession of newly opened vents since 1868 was from elevation 3,500 feet that year at the southern end of the Mauna Loa rift, progressively up the rift to 13,000 feet in 1926, 13,150 feet inside the crater in 1933; and 12,000 feet in 1935, on the northern extension of the rift down the Hilo slope.

This was approximately five miles north of the 1933 eruption, and if the next flank outflow comes out five miles farther north, the place will be a half-mile above Red Hill, close to the source of the 1881 flow, which entered the city of Hilo.

It should not be understood that the next eruption of Mauna Loa will be a flank outflow. Furthermore it may not come in three and a half years; that figure is merely an average. It may come in the summit crater or on some other flank, as alternations between the two sides of the mountain are common.

We know, however, that fume and steam are rising, that the ground is hot, and that sulphur is depositing at the line of source cracks of 1935. That means that the north rift of Mauna Loa in the Hilo direction is open and ready for action which was not the case between 1900 and 1926, when all the outflows were from the south rift.

Eruptions Now Expectable

On the basis, then, of the same historical data that the Hawaiian Volcano Observatory collected for the argument of 1934, we can state that a succession of eruptions is expectable now from the Hilo rift, some of them making outflows down the northeastern flank of the mountain, at intervals averaging three and a half years for all eruptions.

A change began with the great series of bad northern earthquakes of 1929, whereby the northern rifts were opened and the southern ones were closed.

The historical flow sources of the northern rifts may be thought of as lying in a semicircle around the north side of Mauna Loa all the way from Huehue to Nanawale, making a set of radial fractures from the summit of Mauna Loa northwest, north, northeast and east, the northwestern one being the Hualalai rift, and the eastern one the Kilauea rift.

The Huehue Flow at the west poured into the sea from elevation 2,000 feet in 1801, and the Nanawale Flow at the east poured into the sea from elevation 650 feet in 1840. Note what low sources are possible.

It is fortunate for Hilo that the northeast rift bends eastward at elevation 8,000 feet; and we have no historic record of a flow source, of Hilo flows, lower than 8,424 feet, at the head of the 1852 flow. But there were many pre-historic ones that formed the entire south side of Hilo bay, when the ancient shore line extended from Waiakea Kai to Olaa Mill. The range of speeds of sudden aa flows has been 1 to 20 miles a day.

The Lava Cycles of the Nineteenth Century

There is good evidence in recent history for eleven year cycles, 1903-1913, 1914-1924, 1925-1935. These include both Mauna Loa and Kilauea, each with at least two eruptions Mauna Loa; Kilauea pit variously spouting, fluctuating, or rising, and the lava as a whole effervescing strongly and sinking at the end of the cycle.

The cycle is terminated by a very quiet year or years. The quiet years were 1913, 1925, and 1936; we are now approaching the end of the 1936 lull. The distinctive character of this 1936-1937 repose period, leading to an assumed 1936-1946 cycle, is that it is the first repose period following Kau flows and leading to Hilo flows, since 1840.

Leaving aside theories about cycles for 1840, as structural resistance to breaking is the real control, the significant feature of that year, with reference to the structure of the island, was that it made an outflow into the ocean from the eastern Kilauea rift, and it followed southern outflows from both Kilauea and Mauna Loa of 1823 and 1832. A characteristic of 1840 was that it was followed in the next cycle by two northern

outflows of Mauna Loa, 1843 and 1852, both beginning just where our 1935 eruption began.

Disregarding intervals, as structural sequence is more important and comparing 1924 with 1840, we had the eastern Kilauea rift erupting 1922 to 1924, following after southern outflows from both Mauna Loa and Kilauea, respectively, 1916, 1919, and 1920. This was very much like the sequence 1823 to 1840.

The parallel is made still more remarkable by the fact that the 1916-1924 sequence of southern and eastern outflows for the whole island has been followed in 1935 by an outbreak at the north in the same place as the eruption of 1843 from Mauna Loa, with the flow in very nearly the same volume and filling the saddle between Mauna Kea and Mauna Loa in just the same way.

This parallelism to the first half of the nineteenth century leads one to suspect that the unrecorded period of Mauna Loa activity preceding 1932 produced flows in Kau just as did the twentieth century period preceding 1935.

Loa summit, and travelled for seven months 38 miles into the sea at Kiholo Bay. There it filled the northeastern half of the bay making new land two miles along shore and a mile out to sea. Its first gushing of aa reached the sea in seven days at Wainanalii.

The next north flow was 1881 starting in the northeast rift and travelling 29 miles for nine months towards Hilo, with a side branch at first to Kapapala that flowed ten miles in a day. It stopped one mile from the city center.

The Fortification of a Harbor

The first flows are always very liquid aa. They travel far in a few days, and are the most dangerous to property if they get into industrial lands. For such flows bombing would be wasteful and useless.

It was this kind of flowing which destroyed Bosco tre Case on Vesuvius in 1906, and also Mascali, a large town of 7,000 inhabitants, on the railroad east of Etna in 1928. In either of these cases it would have been possible to fortify the town, if suitable earthworks oblique to the course of an expected lava



Rapid Lava Flow Pouring Into Ocean Destroying Hoopuloa Village in 1926

We know that the middle of the nineteenth century, beginning with 1843 and continuing to 1881, produced a tremendous volume of flows to the north from Mauna Loa, those of 1852, 1855, and 1881 ending progressively closer and closer to Hilo; 1855 and 1881 might have been successfully bombed.

Add to these 1935, straight down the Wailuku River valley, which if it had not been bombed might have filled Hilo harbor, and we find indication that the threat to Hilo is increasing. We now in 1937 find ourselves with the island structure broken wide open for a succession of lava flows historically similar to the series 1852-1881.

Early Series

That series was 1849 at the summit crater; 1851 west of the summit for 10 miles towards Kona; 1852 from the northeast end of the Hilo rift for 15 miles in 20 days straight toward the city, ending 11 miles from the Federal building.

1855 started at the northeast rift farther west than 1852, and travelled 25 miles for 15 months in a curved course to the Wailuku drainage, ending seven miles from the city.

1859 started at elevation 11,000 feet northwest of Mauna

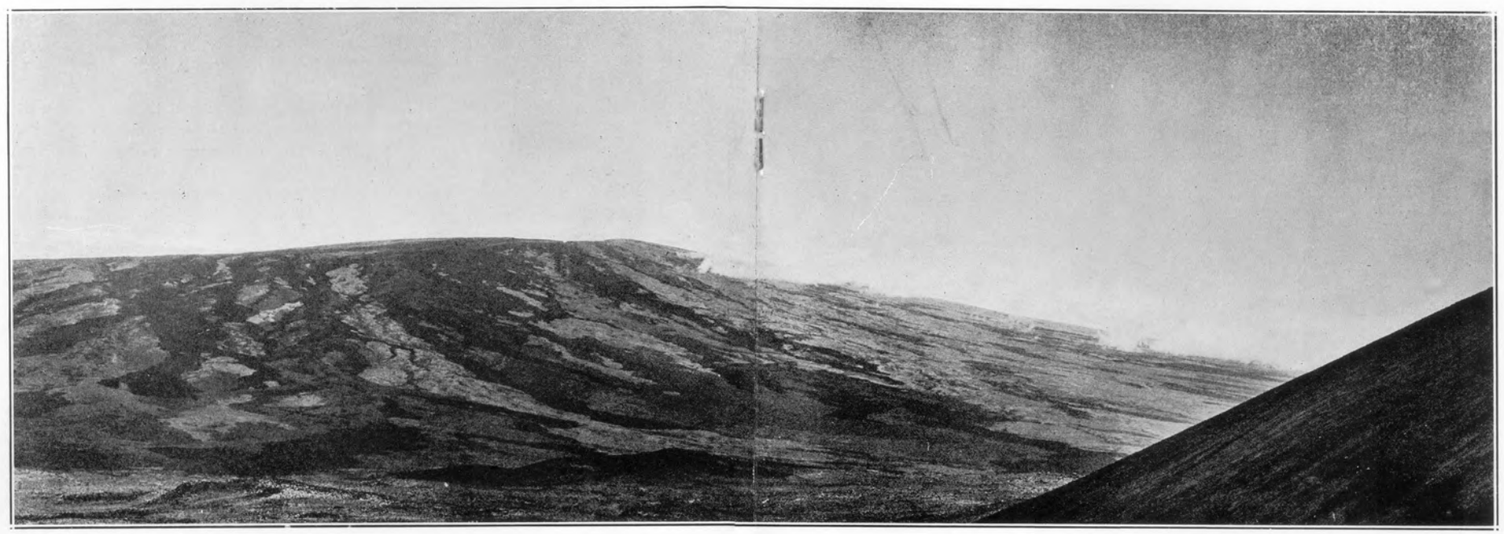
flow had been erected in advance, at a site selected to divert such a flow into a valley leading to agricultural or forest lands.

In neither of these cases was any harbor involved. A harbor is a national asset, it usually lies where a valley emerges on the ocean, and if a mass of new rock, a mile seaward and miles long, fills a developed port, the calamity cannot be reckoned in money. A harbor is vastly more valuable as a natural feature than all the millions spent on houses, roads, sewers, and public utilities.

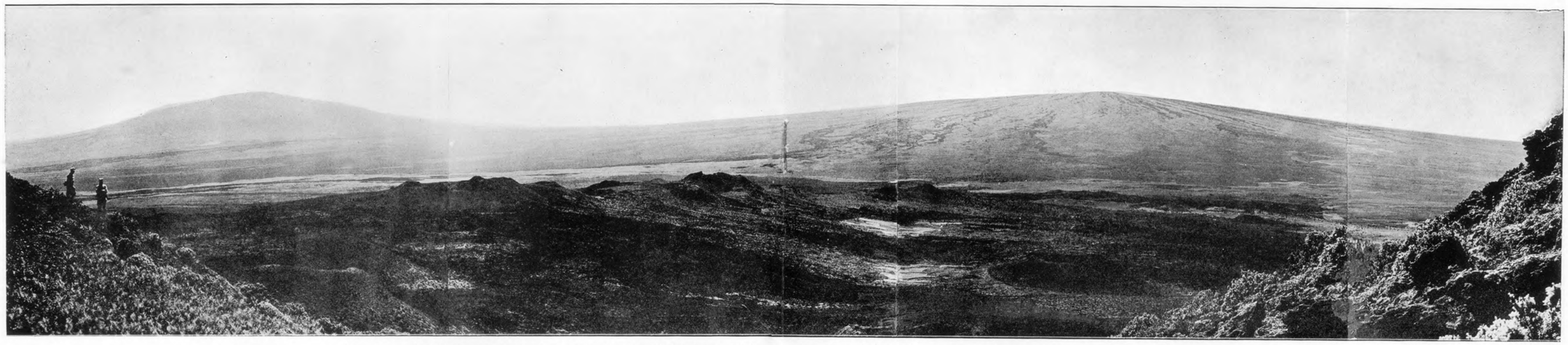
The Situation of Hilo

Hilo lies at the meeting place of three valleys all straight below the dangerous end of the Red Hill rift of Mauna Loa. These we may call the Wailuku Valley, the Kaumana Valley, and the Waiakea Valley. The first is the contact of lava flows against Mauna Kea drainage. The other two are seepage remnants of buried valleys on the east slope of Mauna Loa.

All three would lead a new rapid lava flow straight into the harbor. The distance is only 20 miles from the nearest possible lava source, Puu Kipu at Helipo Camp. Puu Kipu is right in the line of the east bend of the live rift. An existing heavy aa flow from it in the forest extends half way to Hilo.



North Face of Mauna Loa Volcano, Showing Net of Lava Flows Mutually Deflected; the Area of the Red Hill and Humuula Barriers



Mauna Loa (right) from Hualalai, Showing the Hualalai Rift Belt Line of Cones in Foreground: Behind Them aa Lava of 1859 (dark), and Pahoehoe Lava (light).

A new flow on its north side would sweep about 24 miles to Waiakea Fishpond, and at the rate of the 1859 flow would reach the sea in five days.

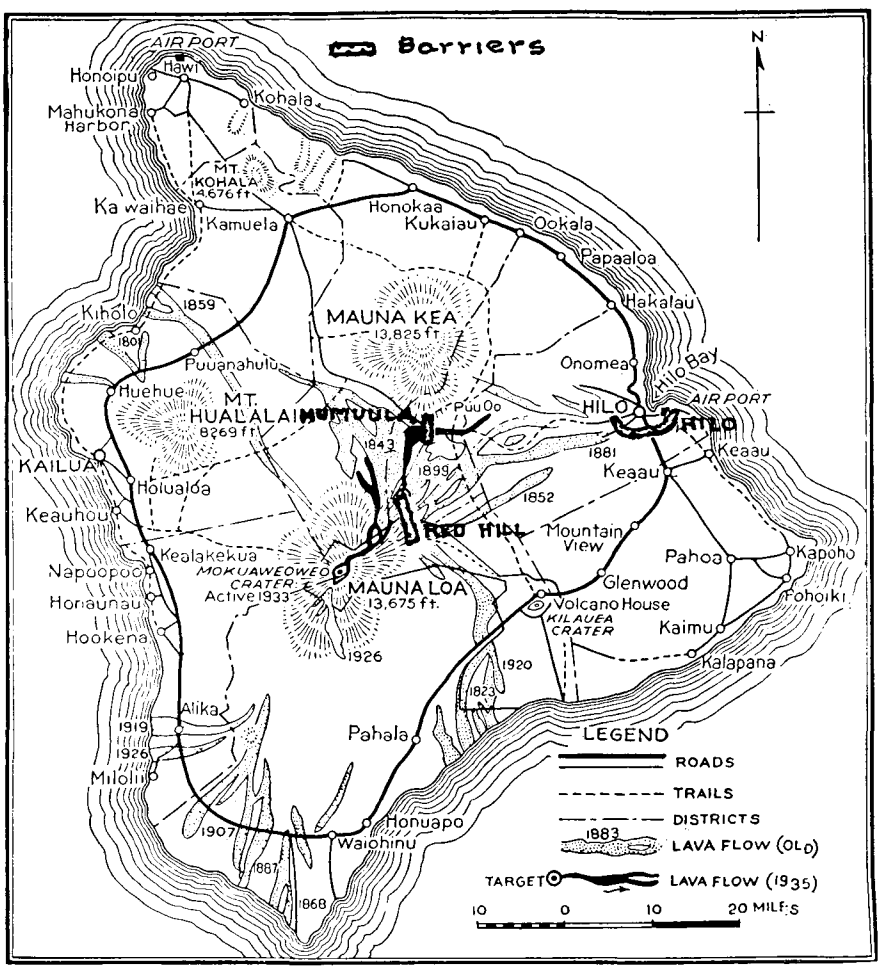
A flow from the 1852 source at the same rate would travel 26 miles, take six days, follow the southeast side of the 1881 flow and Alenaio stream, and enter the sea at Mooheau Park.

A flow from an old cone at elevation 8,750 feet 2¾ miles north of Red Hill, at the same rate, would flow 27 miles between the 1881 and 1855 flows, reach the Wailuku River by Kahoama stream and the gorge above Waiale Falls, pass Piihonua and reach the railway bridge over the Wailuku River in something like six days.

All these distances are shorter than the 1859 flow, which travelled 38 miles in seven days from a point 11,000 feet up.

There are three elements in the Hilo problem. One is to steer lava flows with obstacles, near their sources, into safe places like Humuula while they are liquid. The second is to build an obstacle at the Humuula pass that will protect Hilo's water supply. The third is to build a final protection for the harbor in Hilo itself in case of (1) an unexpected low vent or orifice in the mountain; (2) a vent too far east for the obstacles constructed; (3) the failure of all upper obstacles.

The first two obstacles have been mentioned in the preamble. One is the Red Hill embankment, which, along with natural features, will extend about five miles N 20 deg. W from near Red Hill, will steer such flows at 1855, 1881 and 1899 to Humuula, will be about 15 feet high down a relatively steep slope, and may take 300 men two years to finish.



Map of Hawaii 1937, Showing Proposed Barriers Exaggerated

If the 1859 flow had come out at Puu Kipu with the same energy, it probably would have done the 24 miles to Hilo Bay in four days and piled up the material of its remaining 14 miles of first gushing in Hilo breakwaster. The breakwater would probably hold it and tongues of aa like the Laupahoehoe flat would spread out in a leaf delta to the north of Hilo harbor, after the harbor was transformed into the same kind of land as Keaukaha.

Defense of Hilo

The foregoing is a legitimate picture of what we have to fortify against. Fortification in war consists of two elements, protection and obstacle. Lava flows are the enemy. Protection will shield Hilo from a lava flow when it comes. Obstacle will prevent the lava flow from coming to close quarters if possible.

This is partially prepared for by the CCC camp at Hawaii National Park, which has built 9 9/10 miles of truck roadway up Mauna Loa, and has about eight miles more to go to reach Red Hill. The work of laying a 15-foot bank down natural grade, with double track for dump trucks on top, and using loose aa blocks, without much grading and almost no cutting, taking advantage of natural spurs, is simpler than building a road. It will be necessary to extend the present road as a rough track as fast as possible to Red Hill. A volcano observatory will be established there this year.

At Puu Huluhulu, the forested hill in front of Humuula sheep station, a bank 20 feet high will be built north against Mauna Kea about a half mile long. A similar one will be built south against Mauna Loa for the same distance until its top is

at grade. These, with the hill, will be at a height where a lava pool in the saddle will spill west over the top of the 1843 flow. The Red Hill bank will steer flows near the 1935 and 1843 flows. Such flows will pool in the saddle and spill west. The combined obstacles will protect the projected Kaumana-Kona road, the water supply of Wailuku River, and stave off 80% of expectable flows, including a low northern or Humuula vent. This steers flows to Keamuku, not to Puuwaawaa.

The Puu Huluhulu bank is prepared for by the improvement in the Humuula road made by the Pohakuloa CCC camp, and by the camp itself as a nucleus for labor, and as a shelter for laborers. The work will take a year, with perhaps 200 men.

The Hilo Causeway, or Lava Guard

At first it was thought that to construct a fortress against lava attack in Hilo would be impossible. So it would be if we threw up earthworks in a wide circle around the outer city limits. But a study of the topographic map has revealed a strategic line for a Hilo Causeway, or Lava Guard Embankment, which will not be excessively expensive, and may be used (1) as a parkway drive, (2) for possible impounding of water, (3) as a cross-connection for existing roads and (4) as a possible start for the Kaumana-Kona driveway.

As no lava flow on a slope is likely to be more than 12 feet high here, this embankment will average 18 feet in height, being higher where it has to cross low ground. It will start at Wailuku valley above Piihonua over the head of Waiale Falls, with a culvert or arch for the river. This is above the big Mauna Kea tributaries, so that it will not get maximum floods. The culvert construction will have to provide a steel gate capable of closing the arch to small dimensions in case of lava flow.

The line will start about South 70 deg. East for a mile from the river and then run east; the grade downhill to Lanikaula Street is 200 feet to the mile, and obliquely crosses all the valleys. The bank will cross only the Kaumana and Volcano roads, and will make a smooth curve northeast before reaching the railway near the quarries. It will then cross the railway fork, may be lowered to 15 feet, and carry far enough on the Keaukaha spur to guard the harbor as far as Keokea Point.

The roads and railways will pass under bridges in the embankment, and there also the uphill face of the causeway will hold rolling steel gates inclined at the natural slope of the bank. These will be kept rolled to one side. Remember that the lands outside the guard are protected by the upper two obstacles.

The total length of the Lava Guard will be seven miles to the top of the Keaukaha spur. The fundamental object of the guard is to protect Hilo and Hilo harbor, the second harbor of the Territory. If everything fails in the upper obstacles, if the water of one or the other valleys were buried, Hilo could still find water. But if a quick flow comes into Hilo itself and the harbor, there will be no motive left to find any water. There will be no Hilo. Remember what we watched as the 1926 flow swallowed Hoopuloa.

The Lava Guard will require heavy quarrying on the uphill side of the bank, the places being chosen to create a channel across obstacles.

I estimate roughly the Hilo job will occupy two years, and give work to 600 men.

The costs for the three jobs may be:

Red Hill	$300,000
Humuula	100,000
Hilo	400,000
Total	$800,000

If any of these embankments has a lava flow piled up against it, it will be more an obstacle than ever, strengthened for its work.

The Hilo Causeway will be the Hindenburg Line, the final protection. It should be begun first and it is most important. It is near labor and a base of supplies and subsistence. On that account it is much easier than the Red Hill job. The first thing to do is to run the line surveys. The second is for all organizations to pull together to get all three jobs done, for they completely interlock.

The Parallel With Kiholo Bay

In 1800 the Kaupulehu Flow poured from Hualalai into the south end of Kiholo Bay. It filled three miles of shoreline, and out to sea one mile. In 1859 the flow from Mauna Loa poured into the north end of Kiholo Bay. It filled the harbor a mile out, along two miles of shoreline.

The Puuwaawaa valley may well have been like the Hilo valleys centuries ago, ending in a deep indentation. Here were only 60 years of the nineteenth century, and the harbor that on the west side of the island corresponds exactly to Hilo, had five miles of length filled one mile wide.

From Mauna Loa Kiholo was protected by Puuwaawaa hill, Hualalai Mountain, and Puu Anahulu. The 1859 flow was not stopped at all by Puu Anahulu flats. The whole South Kohala shore as far as Puako is a filling of Mauna Loa flows. The early 18th century filled west. Seventy-five per cent of present-day flows are to the east.

Hilo has no hills whatever between it and the most dangerous present active rifts of Mauna Loa. It is on a valley which Mauna Loa is perfectly certain to fill up in time. It is 34 per cent nearer to the active vents than Kiholo is to the 1859 source. It has been attacked five times in 83 years, mostly when it was a small village. Last year it was attacked in its urban maturity, and it was saved by bombing pahoehoe. The next flow may be of different kind, when nothing will save Hilo but fortification.

The lava surface equal to the Kiholo fill would be five square miles. This would fill Hilo harbor from a point a mile north of Wainaku across to a place in the sea a half-mile north of Keaukaha. There would be no city, no Iron Works, no Canec, no Waiakea, no railway yards, no airport, no wharves, no electric works, no telephone center.

The city is worth $51,000,000; the harbor possibly $500,000,000 to the Territory, to commerce, and to the Nation. There are only two real harbors on Hawaii Island, Kealakekua and Hilo.

The river would find a new channel in one of the northern gulches. The people would sit on the Halai Hills and watch another layer added north from Reeds Bay and Onekahakaha, both of which are Mauna Loa lava flows. The Oil Tanks would blow up, the sugar in Kuhio wharf would be buried, and the lumber mills would burn, just as we watched the Hoopuloa wharf burn.

If a foreign Hobson were going to scuttle Merrimac hulks in the breakwater entrance, we would ask the Government to line up a blockading fleet. That is exactly what we are called upon to do against Mauna Loa. You have created an intelligence service, the Observatory. It is making its report soberly and conservatively. This is not alarmist sensationalism.

Conclusion

The thing I would suggest that the Hilo Chamber of Commerce do, is to have a meeting, for discussion of this question, with representative engineers, business men and the supervisors. At that meeting may be decided whether or how to approach the Governor.

I would suggest having representatives of the National Park, the Army, Navy, Parker Ranch, Shipman Ranch, and the Bishop Estate; with the Land Commissioner to represent the Governor. I have discussed the matter with Mr. Whitehouse, and with several of these administrators of Mauna Loa lands,

and also General Drum, and the presidents of the Hawaiian Volcano Research Association and the University. The protection of Hilo needs no argument, and these gentlemen have great respect for Mauna Loa.

The things to do are:

1. Extend the Mauna Loa road.
2. Equip a Red Hill Observatory and patrol.
3. Acquire the upper Mauna Loa waste lands.
4. Design and start the Hilo Lava-guard Causeway.
5. Design and start the Humuula Obstacle.
6. Design and start the Red Hill Embankment.

For all of these the appeal, started by myself as volcanologist of Hawaii National Park and the Hawaiian Volcano Research Association, for which I take full responsibility, should probably proceed through the Hilo Chamber to the Governor, who will take whatever action seems wise.

If we do these things you can sleep in Hilo and feel jubilant for your future and your business. Read the pathetic letters of Mrs. Severance to Miss Gordon-Cumming in 1881, when the flow was in Hilo, if you want to know the depression of it (book called "Fire Fountains," Gordon-Cumming). Or see the volcano film of Etna at the National Park museum. And after the embankments are built we still have bombing in reserve for the slow smooth flows.

More than all else, you will set an example to the world. Italy, Japan, the Philippines, Java and Central America will all watch Hilo. Hilo has not said "Manana" (tomorrow), nor "Shikata ga nai" (it can't be helped). The trails of the Hawaiians go straight to the goal with the motto "Eternal is the life of the land in righteousness." Righteousness means straightness. Let us perpetuate the life of the land in Hilo.

Hawaiian Volcano Observatory Report for January 1937

VOLCANOLOGY

The month of January indicated continuance of the quiet conditions which had begun rather suddenly the last week of December. The winter proved exceptionally rainy, with much stormy weather and high winds, occasioning deep ground swells that broke on the rocky cliffs of the island. As a result microseismic motion has been strong, and appears to vary with the impact of waves on the shore.

Observation of Mauna Loa

On January 2 a party from the Observatory, S. Sato and A. Okuda, accompanied soldiers from the Red Hill Resthouse up the Mauna Loa trail, encountering fresh snow from a point a mile and a half above the house. The old steam crack east of the trail was making vapor with snow close to its edge. The 1935 cones at about 12,000 feet elevation showed sulphur coatings that were too hot to hold the snow, and both vapor and blue fume were noted there. After exposure to snow glare from seven to ten hours, some of the party were snowblinded, and had to be led down the trail on the return. This experience of snowblindness has been repeated by other parties on Mauna Kea, where a new trail built by Civil Conservation Relief Workers has induced many to go skiing.

From the Observatory at Kilauea the 1935 cone on Mauna Loa, 18 miles away, was seen to make visible fume the hour before noon on January 6.

Observations of Kilauea

The following tabulation for January shows somewhat higher values for the Kilauea Volcano Observatory data than in the week ending January 3, but mostly lower values than December. There are indicated by weeks the local seismicity, the counted number of slides in Halemaumau pit when it happened to be observed, the amount at Halemaumau of aggregate opening of marked rim cracks by weeks and the Observatory count of local seismographic tremors and quakes:

Week Ending	Seismicity	Slides	Cracks	Quakes
January 10	7.25	3	2.5 mm.	11
" 17	2.75	4	3.0 mm.	9
" 24	3.00	3	6.0 mm.	8
" 31	7.00	0	3.0 mm.	14

Sequence of Events by Weeks

The first week produced two felt earthquakes and some sliding from the Halemaumau wall.

The second week had lower seismicity and small slides continued.

The third week produced occasional dust from slides and no change in the seismicity.

The fourth week of heavy rains filled the pit with large clouds of water vapor, surmounted by cauliflower clouds caused by convectional displacement, and the nucleation due to fume issuing from vents on the floor of the pit. There were some felt earthquakes, and southerly tilt was strong.

Slides at Halemaumau

Slides from the wall of the pit have been noted as follows, either from a distance or at typical times of visitation:

January 6, 12:45 p.m., dust rose from a small slide NE, while blue fume was seen at E and W Solfataras.

January 7, 9:30 a.m., small rocks dribbled down west wall, and at 1:30 p.m. dust arose NE.

January 8, at 2:18 p.m., a moderate slide fell from NNW wall.

January 15, 9:33 a.m., a small slide fell N.

January 17, 12:03, 12:27, and 12:35, dust clouds from slides arose NW; all were small.

January 22, 12:45 p.m., dust arose N rim.

January 23, A scar on the west wall indicated new sliding, and small rocks were in process of dribbling down there.

The last week was too stormy for observation of slides.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 26 rim crack locations resulted in aggregate movement as follows: week ending forenoon of

January 8, 5 opened, 2 closed, opening 2.5 mm.
" 15, 7 opened, 4 closed, opening 3.0 mm.
" 22, 6 opened, 1 closed, opening 6.0 mm.
" 29, 9 opened, 4 closed, opening 3.0 mm.

T. A. J.

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory, January 21, showed an opening of the Halemaumau value and an opening of the Crater value compared with similar measurements made December 26, 1936. From Kilauea SE rim to Uwekahuna there was closing of 0.17", December 26 to January 8 and opening of 0.84", January 8 to January 21. Total opening, 0.67". From the Pit Seismograph to the NW Pit B.M. there was an opening of 0.17", December 26 to January 8, and an opening of 0.83", January 8 to January 21. Total opening, 1.00".

H. H. W.

Spirit Levelling

A recheck of levels run in Kilauea Crater after February, 1936, indicates that values reported for elevation changes are erroneous. Improper corrections and poor instrumental adjustments have been responsible for the discrepancies. Proper corrections will be made and results reported in a later edition of the Volcano Letter.

H. H. W.

Note: Seismological Data for January, 1937, will appear in February issue.

THE VOLCANO LETTER

No. 444 monthly Department of the Interior National Park Service February 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

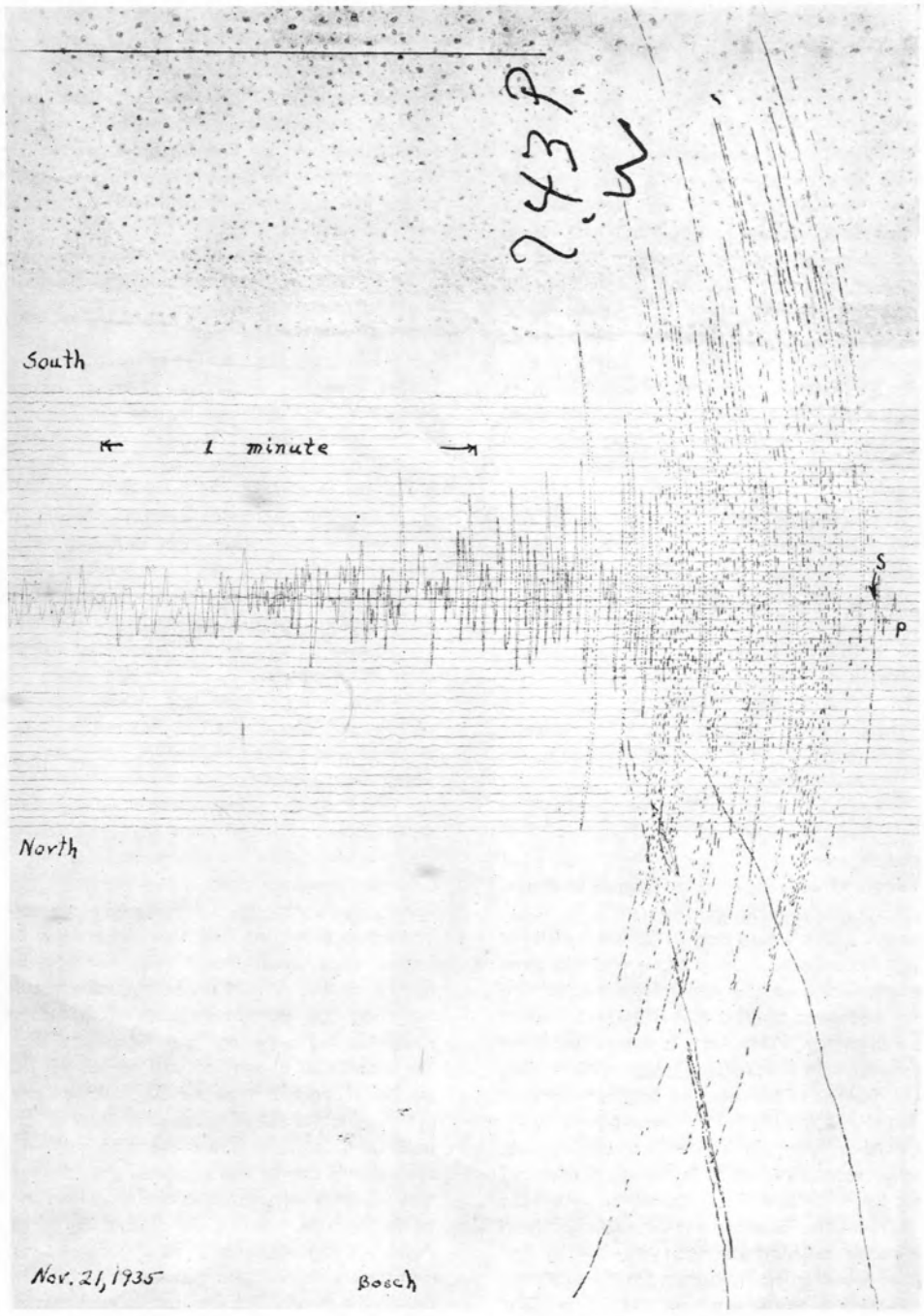


Figure 1.—N. S. component seismogram from Bosch-Omori instrument at the Hawaiian Volcano Observatory, November 21, 1935, 1:11 a.m. Preceded Mauna Loa eruption by seventeen hours.

EARTHQUAKES*

By Hugh H. Waesche, Asst. Geologist, H.N.P.,
Hawaiian Volcano Observatory

A very commonplace phrase or question in Hawaii is, "Did you feel the earthquake last night?" Sometimes there was one, more often imagination has played someone a trick and there was none. We are all earthquake conscious here on this island, and justifiably so, as fairly frequent earthquake shocks are as much a part of the region as are the volcanoes of Hawaii National Park, the City of Refuge at Honaunau or the Black Sands of Kalapana. Hawaii being volcanic, is at the same time an active earthquake center. This condition is true of other parts of the world. It has been discovered that earthquakes occur most commonly in two zones or belts on the earth's surface. One of these zones starts at the southern tip of South America and runs northward following the course of the Andes, passes through Central America, continues through Mexico and the U. S., following the Rocky Mountains, Sierra Nevada and Cascade Ranges to Alaska from where it follows the Aleutian Chain to Japan, passes on to Java and Sumatra of the Dutch East Indies and finally swings back eastward across the South Pacific. The other belt runs diagonally across this one and includes the Caribbean, the Mediterranean Sea, the Caucasus and Himalaya Mountains and the East Indies. It is interesting to note that these two zones also roughly indicate regions of volcanic activity. However, from that relation it must not be inferred that the one is the cause of the other. It would be better to think that both earthquakes and volcanoes are the resulting effects of disturbances or movements in zones of evident crustal weakness. Earthquakes can and do occur in these regions without volcanic activity. Volcanoes can and do erupt without being accompanied by major earthquakes although they usually occur simultaneously with local earthquake shocks, or are preceded by the latter. In Hawaii we often have earthquakes of various intensities without any sign of activity. They are usually located near features of structural importance such as under one of the five volcanic masses of the island or rifts associated with them. How these locations are determined will be described later.

The exact cause of earthquakes is still open to question but is always an interesting point. When a person feels the so-called ground under him shaking violently or possibly rocking like a ship at sea he wants to know what is causing the disturbance. This is a natural reaction and the early Greeks and Romans of the Mediterranean areas who were quite familiar with both volcanoes and earthquakes asked that question just as do their successors. They were contented though with a much more simple, and to them, logical explanation. Some of these explanations, connected with gigantic underground explosions, wind blowing through tunnels in the earth and the caving-in of subterranean caves would not fit in too well with modern concepts along those lines. Today three possible general causes are suspected. The first and generally accepted one is the most important and goes by the rather high sounding name of elastic rebound theory. This type is associated with the making of new fractures in the earth's crust or remaking of old ones such as the making of earthquake cracks in Hawaii in 1868 or a split along the Mauna Loa Northeast rift in 1935. In spite of the name of this theory, it is simple to understand. Most everyone has had the experience of breaking a piece of kindling wood over his knee. When the wood partially breaks with a snap there is a jar in the hand and knee. This jar is in reality a small hand-made earthquake and was felt by the rebound of the pieces of wood to their former position as they snapped back from the bent position across the knee. The bending is the elastic part of the theory name and the snapping back of the wood is the rebound. The same thing happens in most natural earthquakes, large or small, depending on the strength and snap of the material concerned. Stresses tend to build up on either side of a rift or crack in the earth's crust and so continue accumulating until like in the case of the stick of wood—it gives and the ends snap back into position and then everybody says "Oh! did you feel the earthquake?" and the telephone starts ringing at the Volcano Observatory. The second type of earthquake is spoken of as volcanic. Many of these occur around any active volcano and their originating cause is somewhat doubtful. They may be of the same origin as the first-mentioned group, caused by lava and gas pressure changes on the rocks composing the volcano. Explosive volcanic activity likewise results in earthquake movements. Another possibility would be the sudden stopping of a lava column with the same general effect as the jar in a hydraulic ram or the stopping of a weight in a pile driver. Rapidly flowing lava or gas produces earth vibration just as water flowing from the end of a hose nozzle will vibrate one's hand. In any event, although volcanic earthquakes as we all know here, can be quite strong locally, they are seldom felt at a great distance. This is characteristic of such disturbances. An exception was in the case of the great shock in Hawaii in 1868 which was classed as one of world-shaking variety. The elastic rebound type of earthquake first discussed is given the credit for causing practically all major disturbances. Typical examples of this great class are the Charleston earthquake of 1886, the Yakutat Bay earthquake of 1898 when a good-sized mountain range raised itself forty-two feet, the San Francisco earthquake of 1906 where in places the ground slipped as much as twenty feet sideways along the San Andreas rift, and the Tokyo earthquake of 1923 which practically destroyed Yokohama and Tokyo. Most any of the great world-shaking earthquakes one might mention belong to this class. A third and very minor cause of earthquakes is still listed in most textbooks. This theory is concerned with the caving-in of underground openings or caverns. The strong shocks of the New Madrid, Missouri region in 1812 were thought by some to have originated in this fashion. Subsidence of the ground certainly did occur but it would be hard to conceive of underground spaces of sufficient size to produce such disturbances.

From time to time one reads in the newspapers that an earthquake occurred at such and such a place and that its distance was a number of miles from some given locality. Sometimes these reports are based on someone reporting having felt the shock at the point where it occurred or on the basis of its destruction but more often the detection of the quake and its location is based on instrumental evidence. That is, scattered over the world at more or less strategic points are instruments known as seismographs which make a record of the earthquake at that locality. At first this all seems a little mystic until one knows more about the activity generated in the earth's crust by the shock. When an earthquake occurs, waves are set up radiating out from the center of disturbance in all directions much as the waves go out from where a stone or fly strikes the surface of a pond of still water. In the case of the earthquake, three different kinds of waves are started simultaneously. The fastest of these goes through the earth and vibrates back and forth in the same direction in which it moves. A second and slower wave follows the same path as the first type and vibrates crossways to the direction in which it moves just as do the waves on a tight clothesline which is struck sideways. A third and the slowest type of wave follows the earth's surface and makes the biggest movement of all. It, too, vibrates crossways. By means of experiments and mathematical calculations the respective speeds of these types of waves are known and it is this knowledge that makes distances from the earthquake to

* Radio talk, KHBC, Hilo, Hawaii, February 23, 1937.

seismograph stations determinable. Since the first group or longitudinal waves and the second group or transverse waves start together but travel at different speeds they must arrive at some other point at different times with the longitudinal waves arriving first. Tables have been made which show directly the distance a shock is from a station for any given time difference in time of arrivals of these waves. That means that it is only necessary to have some method of detecting and recording the wave movements and then for one experienced to identify the specified waves on the record which must have some time control. The first-mentioned wave travels moderate distances at about seven miles per second. However, as the distance increases the rate also increases. The waves that travel around the surface travel at a constant rate of about two and a half miles per second regardless of distance.

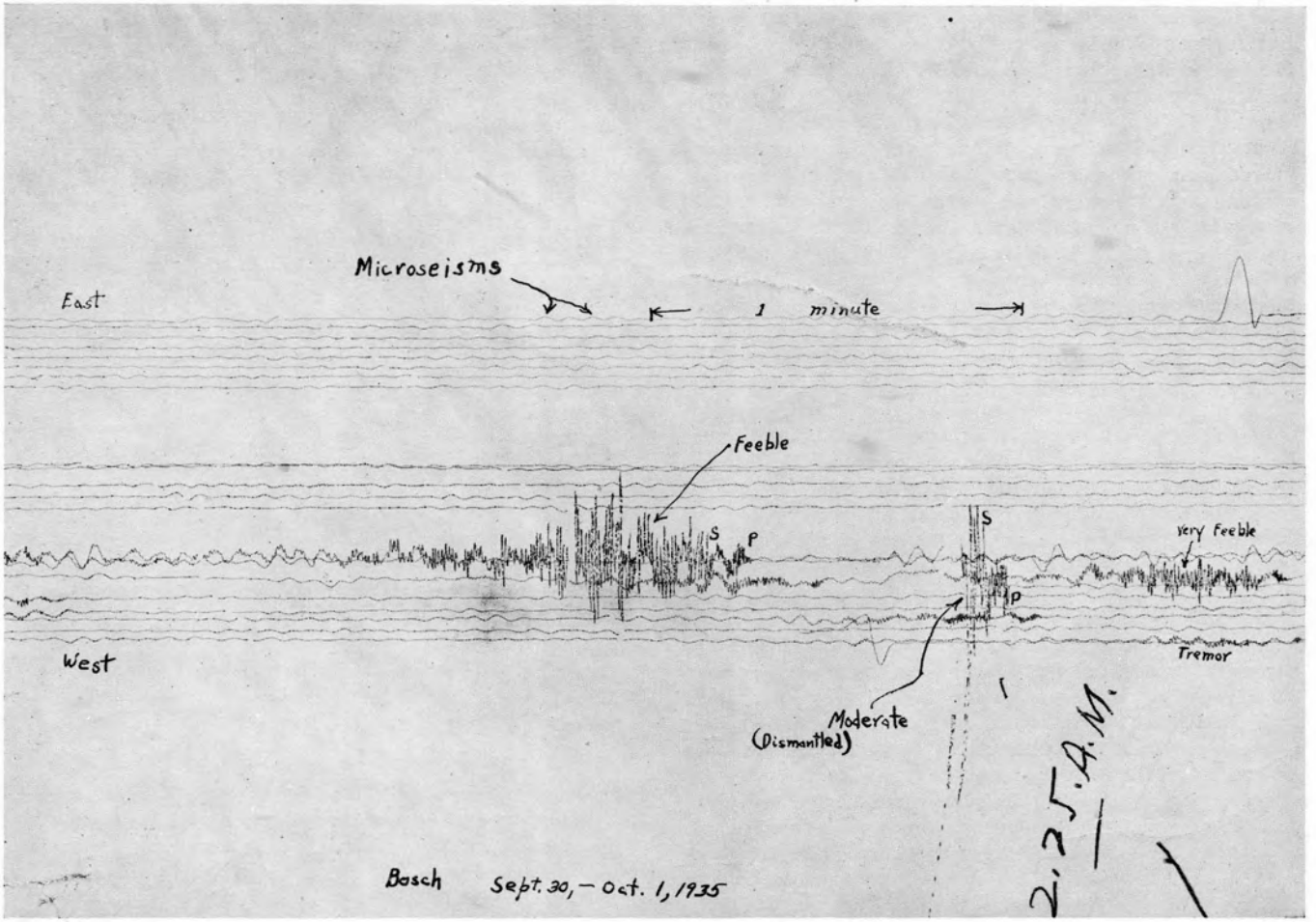


Figure 2.—East-West component of part of earthquake series of September 30-October 1, 1935. Observatory Bosch-Omori instrument, static magnification 115.

Now to return to the seismograph which is the instrument that records the earth's movements, we find a comparatively simple apparatus which nevertheless must be well constructed for proper results. It is a well-known fact that if a heavy object is at rest a lot of extra force is necessary to move it. When a fast-moving car stops suddenly the people are thrown forward, when the car starts the passengers are jerked backward. This is the same property and is known as inertia. No doubt you have all heard that word applied to some people with reason—and for the same reason. Anyhow, it is this property which makes the seismograph work. In these instruments a weight is suspended from a support which is attached solidly to the earth much as is the pendulum in a clock only in this case the earth swings in an earthquake and the weight stays still. Now, if the weight is connected properly to some device which will trace the record of the earthquake on a piece of paper then we have a seismograph. Since earth motions even of strong quakes seldom exceed, at most, a quarter of an inch the motion must be magnified so that the waves may be large enough on the record to study. This is accomplished by either of three methods, first, by mechanical levers, second, by electrical magnification and, third, by light beams as levers. Usually in the most sensitive instruments a combination of the last two is used for distant quakes. At the Volcano Observatory, mechanical levers are used, with magnification of the actual earth movement of about one hundred. Two common methods of registering are used. The first uses a sheet of paper which has been smoked with a kerosene flame, revolving on a drum at a known constant speed and in which a very light steel point attached to the pendulum through the levers draws a line. When nothing happens this mark is straight but zigzags when an earthquake occurs. The other type of recording uses a sheet of photographic paper and a beam of light takes the place of the steel pen of the first type. Magnification in the second type sometimes is as high as one thousand. The movement of the ground in Hawaiian earthquakes ranges between about one one-thousandth of an inch and a tenth of an inch. Remember the one of June 28, 1935, which knocked down a few chimneys and cracked several walls in Hilo? The ground movement at the Volcano Observatory was only slightly more than a tenth of an inch and the earthquake was centered as close to the Park as it was to Hilo. Yes, when mother earth moves even a little bit —and does it rapidly—you are going to know it. That earth-

quake was probably the first official herald of the Mauna Loa eruption in November.

A completely equipped seismograph station has three separate pendulums or instruments. They are usually so arranged that one records only earth movements north and south, another only east and west and the third, up and down. The advantage to this arrangement is that under favorable conditions an earthquake can be located from the one station. This is possible because the first longitudinal wave to arrive will move the pen east or west, another north or south and the third up or down on the record exactly proportional to the direction and intensity. The best recent example was the case of the earthquake of November 21, 1935 (Figure 1) which occurred at one-eleven a.m. and was pretty strongly felt all over the island. At the Observatory the east-west pen moved east one-half millimeter; the north-south pen moved south three millimeters. That meant the earthquake was a little south of east of us, or a little north of west. The time space between the first waves and the second waves showed it to be about nineteen miles away. Inspection of the up-down record showed that the ground had gone down at the Observatory, meaning that the wave was contracting and therefore the earthquake was nineteen miles, slightly north of west from the Observatory right on the Mauna Loa northeast rift about five miles below the summit. Seventeen hours later Mauna Loa was pouring streams of lava from around that spot. But don't be misled—they do not all come out that well.

The Volcano Observatory operates other stations than the one mentioned. It has one at Kealakekua, one at Hilo, one on the southeast edge of Halemaumau and one at Uwekahuna Museum at the Park Naturalist's headquarters. In locating the general run of shocks all of these stations are used. Distances are determined from each and laid off as circles on a map. Lines are drawn connecting the circle intersections and the point where these lines cross shows the earthquake center. But that is not all—by a little descriptive geometry the earthquake is ferreted up to the surface and the distance it was under ground is determined. Preceding the Mauna Loa eruption, the heavy shocks of September-October, 1935 (Figures 2, 3 and 4), ranged as deep as twenty-five miles. The shock of November 21 was not over five miles deep and those which occurred with the outbreak were so shallow that depths could not be determined. By no means are all the earthquakes which occur on this island located. Roughly, forty per cent are located within reason and half of this number are located with comparative accuracy and the large remainder are located only in a general sort of way as a Kilauea shock, a Mauna Loa shock a Hualalai shock, and so on. There is good reason for this deficiency. A large per cent of the shocks do not oblige by having nicely defined wave groups; many are close to only one station so cannot be checked on the others, because they are too weak to record that far away. Sometimes clockworks which rotate drums get stuck, time marks interfere and portions of the quake are lost and if the earthquake is strong and close by, dismantles the instrument before it can make a clear record—and some earthquakes just go by the name of "Maud" and both stubbornly and impudently defy you to locate them, but it makes a reasonably exciting chase at that.

At the Observatory some five different sizes of shocks are recognized as earthquakes. These are very feeble, feeble, slight, moderate and strong. By far the greatest per cent of them are very feeble with feeble a poor second. Both of these are only instrumental and are only felt where they are some distance from the instrument and near an observer. Slight earthquakes are usually felt by many people slightly near their origin. Moderate earthquakes are generally felt all over the island and produce visible effects such as moving objects, rattling doors and the like. A strong quake is anything resulting in some damage and many people frightened. The only really strong shock of the last two years was the one which was previously mentioned, June 28, 1935. Moderate shocks occurred frequently in 1935 averaging about one a month. Outstanding ones were January 2, June 25, a whole series of them, some of which bordered on strong the night of September 30, October 1 and November 21 (see Figures 2, 3 and 4). A still smaller vibration than the very feeble earthquake is one known as a tremor. Some of these last several minutes and always continuously accompany the play of fountains during eruptions. During 1935, 296 earthquakes of all sizes registered at the Volcano Observatory and besides these there were 6,227 tremors. In 1936 332 earthquakes of all sizes registered and only 2,078 tremors. That is an average of almost one earthquake a day—if we assume that the earth rests on Sundays and holidays it looks as though there may be a better average than one a day. I shall leave that for the individual to work out, meanwhile most of the strong earthquakes of 1935 were under Mauna Loa and it erupted; most of the strong ones of 1936 were under or near Kilauea and nothing happened. Let's all watch the earthquakes of 1937 and—what's next?

Hawaiian Volcano Observatory Report for February 1937

VOLCANOLOGY

The month of February showed marked increase of seismic activity, and of opening of cracks around the rim of Halemaumau pit in Kilauea Crater. Microseismic motion continued strong. The cold, rainy weather continued. The winter rainfall has been as follows:

December, 18.93 in., maximum day December 30, 5.12 in.
January, 22.01 in., maximum day January 14, 6.12 in.
February, 20.46 in., maximum day February 18, 4.87 in.

Total 61.40 inches.

The following are the monthly data for observations at the Observatory near Kilauea Crater:

Week Ending	Seismicity	Slides	Crack Openings mm.	Local Quakes
February 7	7.75	3	16.5	24
" 14	9.00	0	23.5	28
" 21	10.25	2	19.5	32
" 28	5.50	3	16.0	12

Sequence of Events by Weeks

The first week showed dense vapor from Halemaumau lava floor, due to rainfall and some sliding there.

The second week showed increase of seismicity and of crack opening.

The third week continued the increase in tremor and slides were small.

The fourth week showed less quaking and crack opening.

Slides at Halemaumau

Slides from the walls of the pit have been noted as follows:

February 2, 10:03 am, a small slide S; 10:08 am, rocks dribbling down NE wall.

February 3, 8:58 am, rocks falling NE wall.

February 19, 10:45 am, small slide NE wall; 5:23 pm, noisy slide N wall.

February 27, 10:08 am, slides NW and N walls.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 26 rim crack locations resulted in aggregate movement as follows: week ending forenoon of—

February 5, 14 opened, 1 closed, opening 16.5 mm.
" 12, 19 opened, 2 closed, opening 23.5 mm.
" 19, 13 opened, 1 closed, opening 19.5 mm.
" 26, 10 opened, 0 closed, opening 16.0 mm.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant† Earthquakes	Local* Seismicity
January 10.....	5	4	0	2	1	7.25
" 17.....	7	2	0	0	0	2.75
" 24.....	4	4	0	0	2	3.00
" 31.....	8	4	1	1	0	7.00

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began recording at the times indicated and whenever possible determinations of depths of focus have been made:

January 6, 9:13 am, very feeble, located 0.5 mile S of Bird Park area and 4.1 miles deep. 19° 26.2′ N; 155° 18.7′ W.

January 7, 11:35 pm, very feeble, probably located in vicinity of Ahua Kamokukolau.

January 8, 6:53 am, slight, probably located in Hilina Fault system S of Puu O hale.

January 8, 10:56 am, very feeble, probably located in vicinity of Kilauea Iki.

† Includes teleseisms or those shocks over 5,000 kilometers distant.
* For local seismicity definition see Volcano Letter 371.

January 10, 10:50 pm, slight, located in Kilauea SE rift zone 2.5 miles SE of Makaopuhi Crater and 7.0 miles deep. Reported felt in Hawaii National Park, in Hilo and at Honomu. 19° 20.5′ N; 155° 9.2′ W.

January 11, 9:06 pm, very feeble, located 1.8 miles NW of the Volcano Observatory and 4.1 miles deep. 19° 26.9′ N; 155° 18.7′ W.

January 13, 9:40 am, very feeble, located 4.1 miles deep under Bird Park area. 19° 26.5′ N; 155° 18.3′ W.

January 20, 9:56 am, very feeble, located 1.1 miles deep near center of Kilauea Crater. 19° 24.8′ N; 155° 16.3′ W.

January 24, 7:31 pm, very feeble, probable location in ocean 20 miles N of Upolu Point. Reported felt at Hilo, Hakalau and Puu Waawaa.

January 24, 9:38 pm, very feeble, located 2.8 miles deep, Kilauea SE rift near Hiiaki Crater. 19° 22.6′ N; 155° 14.0′ W.

At 3:39 am, January 25, a disturbance which recorded as a tremor at the Observatory was reported felt at Puu Waawaa.

January 25, 5:37 pm, very feeble, located 13.0 miles deep off coast near Keauhou Point, 4 miles S of Hilina Pali. 19° 15.1′ N; 155° 16.2′ W.

January 28, 6:05 pm, feeble, located 0.5 mile deep in E portion of Kilauea Crater near Byron Ledge. 19° 24.9′ N; 155° 16.0′ W.

January 29, 4:38 pm, very feeble, probably located in Kilauea Crater.

January 30, 4:00 am, very feeble, probably located in Kilauea Crater.

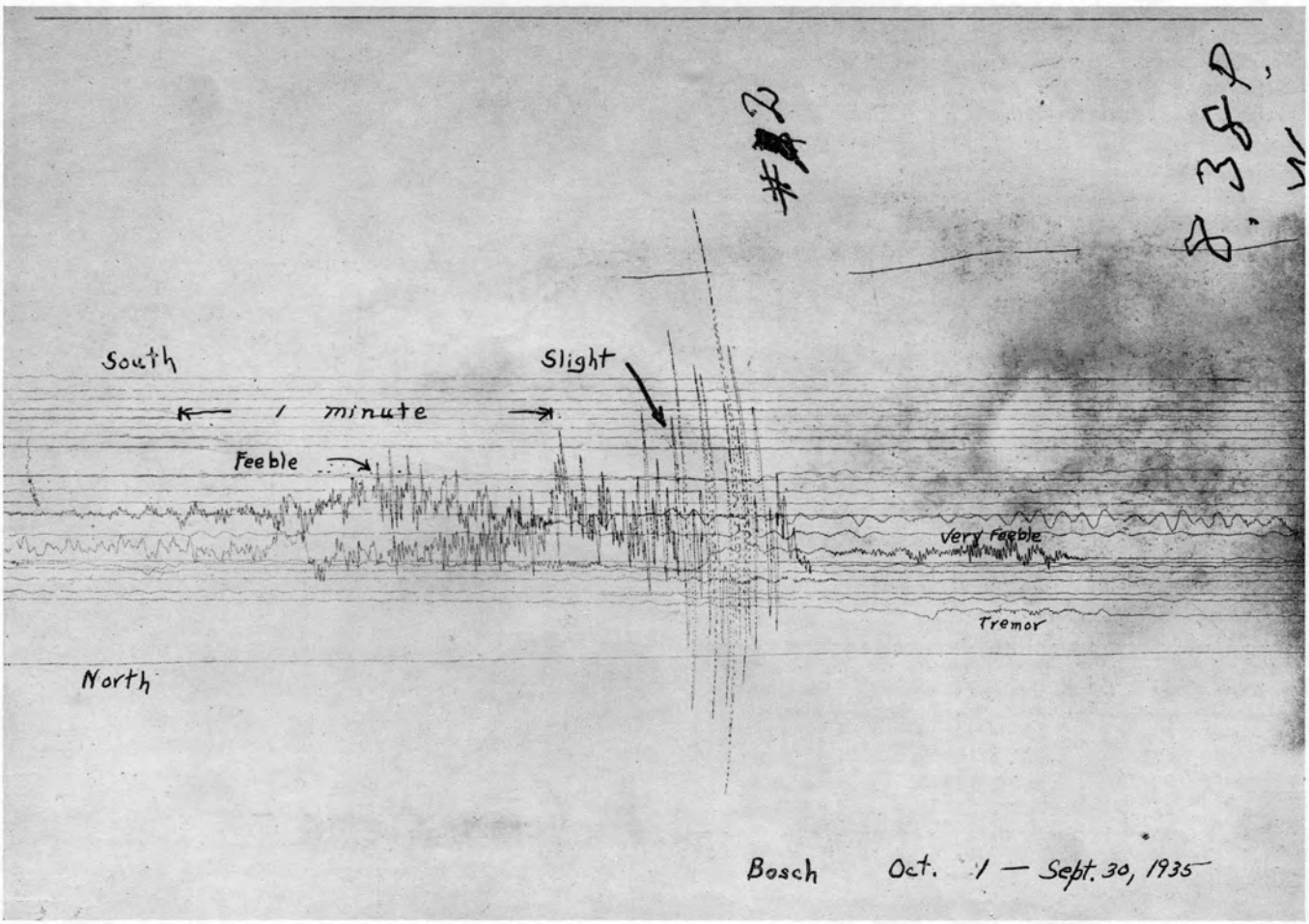


Figure 3.—North-South component of same series illustrated in Figure 2.

January 30, 11:26 am, very feeble, probable location 14 miles deep in marine extension of Kilauea SW Rift Zone, 5.0 miles E of Palima Point. 19° 9.3′ N; 155° 22.7′ W.

January 31, 7:33 am, slight, located 18 miles deep and 6.0 miles NW of summit of Mt. Hualalai. Reported felt at Hookena and at Kamuela. 19° 45.5′ N; 155° 55.3′ W.

Microseismic motion of the ground at Kilauea was strong throughout the month.

Registration of distant earthquakes at the Observatory was as follows:

January 7, the preliminary waves at 3h 04m 12s am, H.S.T., with a probable focal distance from Kilauea of about 6,100 miles. Radio reports indicated this disturbance as contemporaneous with a strong earthquake in Central Asia. The preliminary waves of a teleseism began recording at 12h 35m 38s am, H.S.T., January 23; estimated distance from Kilauea was 3,720 miles. The preliminary waves of a teleseism began recording at 8h 13m 23s, pm, H.S.T., January 24. Its estimated distance from Kilauea was 3,400 miles.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending January 31 was 2.05″ S. and 1.57″ W.

Table of Tilt

Week Ending	Observatory	Halemaumau West Station
January 10	0.44″ S 58° E	5.81″ N 70° W
" 17	1.22″ S 14° E	6.29″ N 78° W
" 24	1.36″ S 8° W	5.96″ N 88° W
" 31	3.92″ S 23° W	6.85″ N 62° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
January 10	6.84″ N 47° W	1.57″ toward
" 17	5.22″ S 75° W	4.01″ from
" 24	3.73″ S 74° W	3.18″ from
" 31	10.72″ S 62° W	5.84″ from

H. H. W.

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Slight Earthquakes	Distant† Earthquakes	Local* Seismicity
February 7.....	17	7	0	0	7.75
" 14.....	20	8	0	0	9.00
" 21.....	23	9	0	1	10.25
" 28.....	8	3	1	0	5.50

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began recording at the times indicated and whenever possible, a determination of depth of focus has been made.

† Includes teleseisms or those shocks over 5,000 kilometers distant.
* For local seismicity definition see Volcano Letter 371.

At 12:23 am, February 1, a tremor was recorded at the Observatory corresponding in time with a recorded Feeble earthquake at Kealakekua. It was reported felt in the Kona district.

February 2, 2:05 pm, very feeble, located 0.5 mile deep, E portion of Kilauea Crater, near Byron Ledge. 19° 24.9′ N; 155° 16.0′ W.

February 2, 8:59 pm, very feeble, a shallow quake located

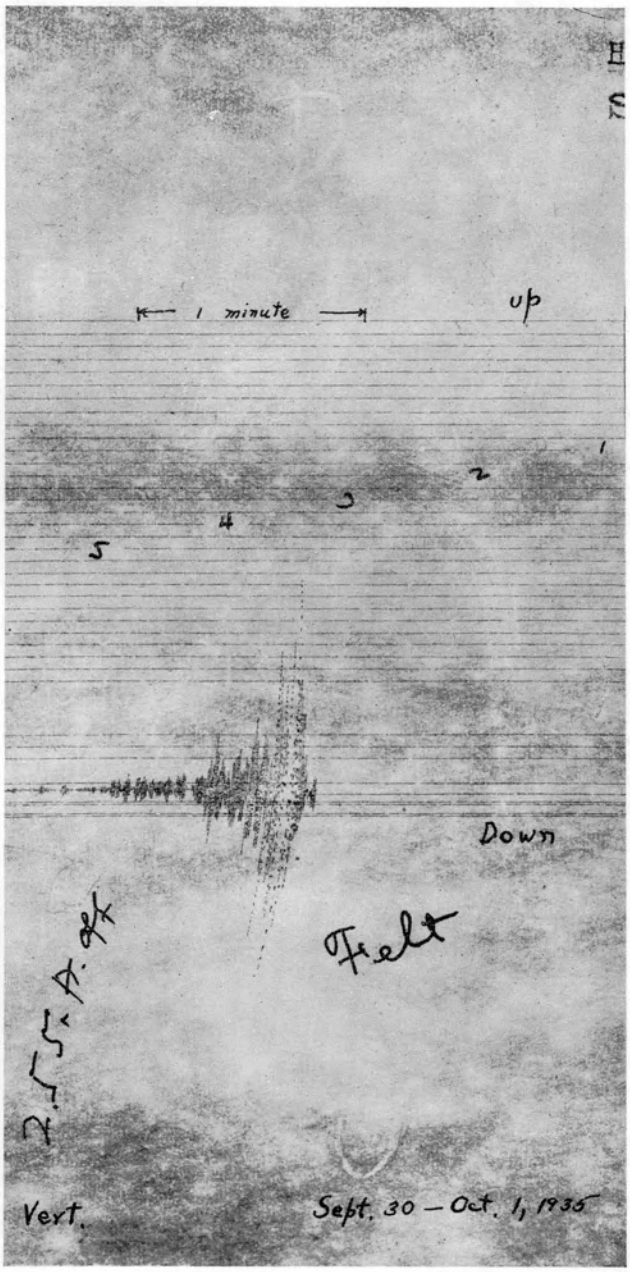


Figure 4.—Illustrates undamped vertical component of largest earthquake shown in Figures 2 and 3.

immediately south of Keanakakoi Crater. 19° 23.9′ N; 155° 16.0′ W.

February 3, 7:13 am, very feeble, located 1 mile deep and 0.4 mile NE Pit Seismograph. 19° 24.7′ N; 155° 16.7′ W.

February 3, 6:06 pm, very feeble, located in Kilauea Rim Crack Zone immediately north of Keanakakoi Crater. 1.2 miles deep. 19° 24.5′ N; 155° 15.9′ W.

February 3, 6:10 pm, very feeble, located 1.5 miles deep in NW portion of Kilauea Crater. 19° 24.7′ N; 155° 16.7′ W.

February 7, 4:22 pm, very feeble, probably located 0.8 mile NW of Kilauea Crater.

February 8, 10:47 am, very feeble, located 1.4 miles deep under SE rim section of Kilauea Crater. 19° 24.4′ N; 155° 16.1′ W.

February 9, 5:45 am, very feeble, located 4.0 miles deep and 12 miles S of Volcano Observatory at Keauhou Point. 19° 15.8′ N; 155° 13.7′ W.

February 10, 12:49 am, very feeble, probably located in Kilauea Crater.

February 10, 6:50 am, very feeble, located 1.2 miles under NW rim of Kilauea Crater in vicinity of Uwekahuna. 19° 25.5′ N; 155° 17.2′ W.

February 10, 12:40 pm, very feeble, located 0.5 mile deep under E rim of Kilauea Crater. 19° 15.8′ N; 155° 24.7′ W.

February 15, 5:09 am, very feeble, located 6.0 miles SE of Puu Ulaula, SE slope of Mauna Loa and 18 miles deep. 19° 29.3′ N; 155° 24.6′ W.

February 16, 3:50 pm, very feeble, probably located at shallow depth near center of Kilauea Crater.

February 16, 4:06 pm, very feeble, located 1.6 miles deep and 3.0 miles E of Kilauea Crater. 19° 25.5′ N; 155° 11.9′ W.

February 18, 2:38 am, very feeble, probably of moderate depth under SW portion of Mokuaweoweo Crater, summit of Mauna Loa.

February 18, 5:20 am, very feeble, located 2.0 miles deep in Chain of Craters Rift Zone, near Devil's Throat. 19° 22.6′ N; 155° 14.0′ W.

February 23, 6:20 am, very feeble, probably located in SE portion of Kilauea Crater.

February 26, 8:04 pm, slight, located 8.0 miles SE of Halemaumau near Hilina Pali and 10.0 miles deep. 19° 20.0′ N; 155° 23.3′ W. This shock was reported felt by many in Hilo and in Hawaii National Park.

February 28, 7:34 am, very feeble, probable location in E portion of Kilauea Crater.

Microseismic motion of the ground at Kilauea was strong throughout the month.

The preliminary waves of a teleseism began recording at Kilauea at 8h 42m 01s pm, H.S.T., February 20. Estimated distance was 3,430 miles.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending February 28 was 5.56″ S and 0.60″ W.

Week Ending	Observatory	Halemaumau West Station
February 7	3.80″ S 32° W	3.81″ N 62° W
" 14	0.85″ S 69° E	5.10″ S 77° W
" 21	2.11″ S 27° W	3.10″ S 67° W
" 28	0.97″ S 4° E	6.88″ N 86° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
February 7	3.24″ S 56° W	3.27″ from
" 14	24.17″ N 32° W	19.06″ toward
" 21	4.11″ S 23° W	5.09″ from
" 28	8.26″ N 68° W	0.54″ from

H. H. W.

Crater Angles

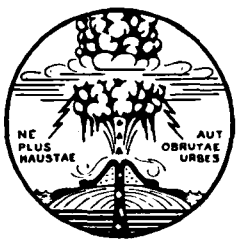
Measurement of Horizontal Angles across Kilauea Crater from the Observatory, February 25, showed closing of the Halemaumau value and an opening of the Crater value compared with similar measurements made January 21. From Kilauea SE rim to Uwekahuna there was closing of 0.84″, January 21 to February 3; opening of 4.59″, February 3 to February 12, and closing of 1.08″, February 12 to 25. Total opening 2.67″. From the Pit Seismograph to the NW Pit B.M. there was opening of 0.83″, January 21 to February 3; closing of 2.08″, February 3 to February 12, and closing of 2.25″, February 12 to February 25. Total closing 3.50″. H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.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THE VOLCANO LETTER

No. 445 monthly Department of the Interior National Park Service March 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

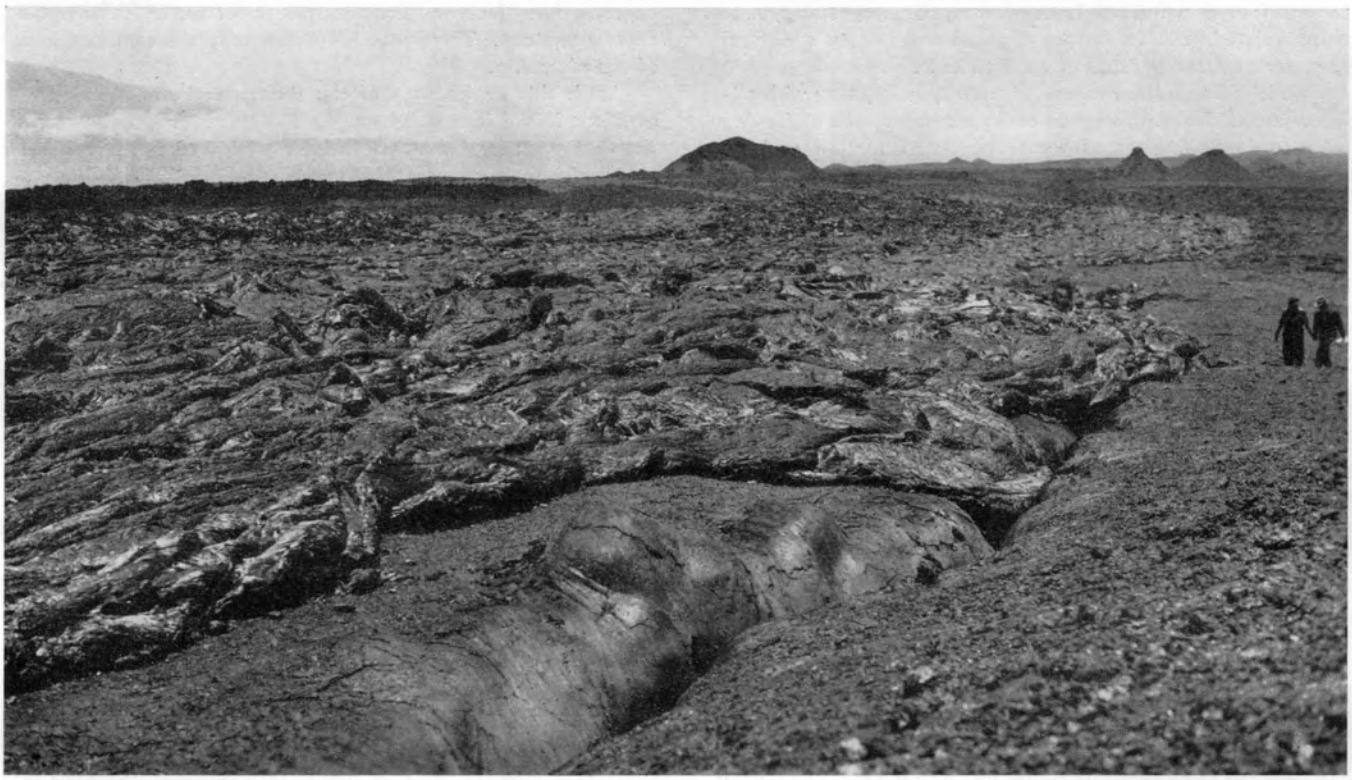


Figure 1. 1935 lava covering trail below summit crater.

MAUNA LOA*

We went up Mauna Loa from Kilauea on March 1st. The party included Mr. Coffman, chief forester of the Park Service, and Mr. Tillett, Superintendent of Territorial Emergency Conservation Work. The Red Hill resthouse was occupied as base.

We walked west two miles and studied the mountain slope towards Humuula. It is an even slope, interrupted by a few cones. In detail it is very rough where aa flows alternate with smooth ones of pahoehoe.

The proposed bank or wall to protect Hilo, across the Red Hill rift, where the flows emerge, will extend obliquely down the mountain north, when it is built. It will take advantage of existing depressions, where they are in the right direction. It will block them where they are not, diverting the stream.

This will create a channel towards Mauna Kea. The barrier would force any new flow obliquely down the slope towards the Hilo-Kona saddle.

There at the saddle the flow would make a lake. East of it on the Hilo side there would be a short high dam constructed. This would be between Puu Huluhulu and Mauna Kea, and it would extend south from Puu Huluhulu to Mauna Loa. It would block off the lava from Hilo.

It would be high enough to hold the lake until it spilled west towards Keamuku. This would protect the Ainahou and Puu Oo pasture land, and the Hilo drainage that supplies water to the city. Damming is practicable only where lava is a flat pool.

* Radio talk, KHBC, Hilo, Hawaii, March 9, 1937, and KGU, Honolulu, April 1, by T. A. Jaggar, Volcanologist, Hawaiian Volcano Observatory.

After the party had looked over this slope, and sized up the possibilities for a roadway from the Rest House down the rift northeast to some large cones, where the wall, five miles long, might start—there is smooth 1881 lava along this route —we spent the night in the Rest House, and the temperature was mild.

Next day against a bitter cold wind we rode up the rift five miles to the upper 1935 cone. This is yellow with sulphur, and steaming. It is one of many in a line. Here on November 21, 1935, the great eruption began.

At that time fountains of golden yellow slaggy foam shot up 500 feet. The whole crack for six miles from the summit crater was gushing. The torrents from it swept in many ribbons down the steep north slope away from the rift.

The liquid so bubbled and stirred itself as to crystallize in sugary lumps and sprouts. This is what is meant by aa lava. Near the actual vents the liquid that congeals is like candy or toffee. This is pahoehoe lava. It may be very stringy like coarse worsted. But its surface of ropes and folds is a natural glass, dark colored because of the iron in it.

The lava inside the mountain is mostly glassy slag with olivine crystals. The transition to aa in a quarter-mile of flowing is due to the boiling out of gases, the violent motion, and the rapid crystallization such as takes place in the centrifugals of a sugar mill.

Accompanying these changes there is great loss of heat. In the first 12 hours of an eruption there is enormous expenditure of energy. The gases are heat makers. Much more gas escapes than lava. The ebullition of gas comes from profound depths. The eruption pulls the cork. The opening of the mountain produces violent gas fizzing due to foaming up. The gas comes from whatever underground lava is relieved of pressure. Probably a big piece of mountain is lifted by the sudden frothing. The effervescence makes the inside lava swell. If you loosen the cork in a beer bottle, and start all the gas, and then try to put the cork back, you must make all that gas dissolve again, or else let it out. The volcano gases are heaters and liquefiers of the slag.

Probably some big force like the settling of the shell of the globe is always forcing the stiff inside lava up these volcano cracks. When the mountain gives way we get an eruption. Right now the lava is pressing up under Kilauea Volcano, the cork will lift, and the lava gas will spout up around the edges of the bottom of the pit.

What made the flow start out of the north flank in 1935? This came a week later than the big initial fountains. And the flow lava emerged from a crack 3,000 feet lower down the mountain slope. The answer appears to be that the internal swelling spreads down a rift belt, an old zone of vertical cracks that extend deep and are full of lava.

The top of the mountain is very heavy. The rift belt goes across the top. When splitting of the rift starts, the swelling lava inside acts as a wedge. The rapid foaming on top shrinks the lava inside as it loses heat and gas. Possibly the plug inside the top crater settles a little. The heavy summit squeezes together.

Down at the 9,000-foot level small cracks can still open in brittle old rock and let out the lowered liquid. It requires an enormous force to lift heavy slag to 12,000 feet elevation. The shrunken lava that has partly cooled glues together the top cracks. This hot paste is very tough like red-hot iron, and old places break more easily. The lower lava escaping at 9,000 feet still has gases heating and expanding it. It quietly welled forth and pushed down to lower places on the mountain. The smooth pahoehoe catches up with the aa, and finally passes the aa front. The movement is slow enough to let the glassy candy float to the top and make skin.

Then a strange and sudden change happens. Where the front that people visit had been a tumbling bed of coals, there quickly appears a gleaming glossy stream covered with beautiful membranes. These skins wrinkle, and festoon and tear and belch out glowing porridge. They puff into elephant toes. The top is silvery or opalescent, smooth and bulbous, flaming with the gas of burning sod below. Inside this crust the liquid has formed a tunnel for itself.

It was this tunnel that made the bombing effective. Let us imagine the water supply to a house under a cliff. The liquid enters the house from a hillside to the third floor. The inside pipe is broken and making a flood in the cellar. If you smash the source pipe and let out the water on the hillside, there will be no more flood in the cellar except for what liquid remains in the house plumbing.

The crusted flow on the mountain was the house. The top story inlet pipe was at 9,000 feet. The aviators of the Army bombed that place and smashed the upper tunnel. The liquid there came out. There was left below only the remnant lava of the plumbing.

With this explanation of the difference between the tremendous initial lava floods of the November, 1935, fountains the first week, and the smooth later flow, let us return to the proposed walls for protecting Hilo.

No bombing could have altered those first voluminous gushings of 1935. They travelled eight miles in a half day! If the lower vent had not opened they might have reached the sea in South Kohala in a week. Just this happened in 1859, a little farther west, for a very long and rapid aa flow.

Suppose such a flood were to burst out at the eastern or Hilo end of the northeast rift. This would be somewhere below Red Hill. It would enter Hilo Harbor in a week. It would burst forth with terrific fountains and might average five miles a day. The distance to Hilo is twenty-six miles. Mr. W. H. Shipman is among the people who can remember back to 1859.

Such lava would be intensely liquid and if it met barricades aligned down hill oblique to its natural course it would follow them. There is no question of damming across it. That is only for flat lakes. The plan is to create an artificial channel in the general direction of the natural slope. There are many natural channels. By taking advantage of them the cost of construction can be reduced.

The final Hilo Wall from Piihonua to Keaukaha is to be on such a natural slope. Its object is to give final protection to the harbor. It must be high enough to catch any flow in the Wailuku or Wailoa drainage valleys and deflect it eastward to the flat lauhala land of the cape south of Hilo Bay.

That land is all old Mauna Loa flows.

This Hilo project takes precedence of the Red Hill and Humuula projects for first construction. But it will not do to trust to the Hilo wall only. There are all the water supplies to protect, and the farms and suburbs and forest reserves. It is never good strategy to trust to one fortress for winning a battle.

The three projects interlock. They should all be started in the next three years. By average intervals, the next Mauna Loa eruption should be ready for outburst any year after 1939. Let us hope that it will be in the summit crater or at some other harmless location!

Mauna Loa in the textbooks is called the most active and bulkiest volcano on earth. Mauna Loa is the center of present-day activity in the Hawaiian Islands. Insurance against Mauna Loa eruptions and earthquakes, and consequent fires and floods, agitates the companies to know what rate to charge. If Hilo is safe the rate will be low. Marine insurance is equally important. Federal dredging to accommodate the biggest ships in Hilo harbor will be influenced by the harbor's safety. If they think it possible Hilo commerce will have to move to Kealake-

kua, the harbor will be less important. The army, the navy and shipping are all concerned. The Volcano Observatory has plans for a seismograph cellar on the Mauna Loa road soon to be constructed by C.C.C. labor. New instruments will be placed around Mauna Loa. Mauna Loa is just now the most interesting of world volcanoes. Hilo cannot afford to join the ranks of the world's disasters.

THE ILLUSTRATIONS

These photographs illustrate conditions at the north end of the summit region of Mauna Loa, as photographed by Ranger P. F. Murray June 15, 1936. At that time the upper cone at the 12,000-foot elevation was still emitting much hot sulphurous fume and yellow sulphur stained the cone. In Figure 1 this cone is beyond the large cone shown, this being a view close to the summit looking down the northeast rift. The trail here was covered for about a half mile with a new 1935 flow of thin shell pahoehoe shown in the foreground. A typical old crack of the rift belt is in the extreme foreground. The source of this flow was about three hundred yards northwest of the summit resthouse, from a crack that was probably the outlet for the 1935 lava lake that occupied the North Bay of Mokuaweoweo. Part of the flow poured down the open crack like the one in the foreground and the trail was covered within the area shown.

Figure 2 shows the 1935 fill of the North Bay, from the summit resthouse. The pahoehoe lava cascaded from a rim crack into the bay.

Figure 3 shows this rim crack in the foreground on the shelf where the resthouse is seated. A new small lava cone about ten feet high was built up only two hundred feet from the old stable of the resthouse. Some of this lava flowed toward the resthouse along the crater wall and disappeared through an upright crack in the wall; the remainder flowed to the right into the North Bay. The filling of the bay had been to a depth of some forty feet, and the pahoehoe surface stands within fifteen feet of the resthouse level. As shown by Figure 3, thin slabs of lava about four inches thick can be seen slumping down the wall crack completely around the north side of the bay from a level approximately fifteen feet below the house. This plainly marked rim crack extends around to the opening from the bay into the main bowl of Mokuaweoweo, according to Ranger Murray.

Figure 4 shows the summit resthouse of Mauna Loa, photographed in May, 1935, of iron and stone construction, and built with Hui o Pele funds.

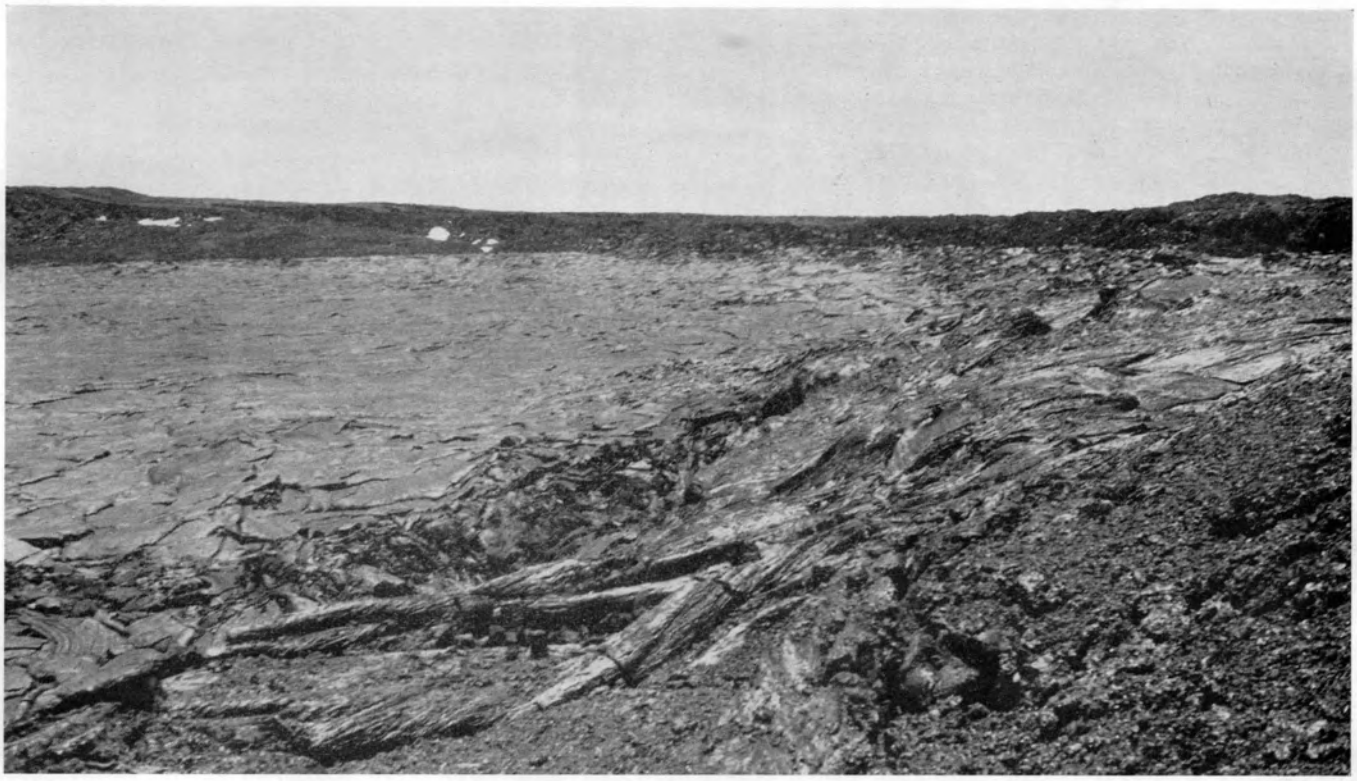


Figure 2. North Bay of Mokuaweoweo from resthouse region. New 1935 lava.

Hawaiian Volcano Observatory Report for March 1937

VOLCANOLOGY

The northeast rift of Mauna Loa was inspected March 2, the upper cones of 1935 were steaming mildly and one of them was stained with sulphur.

The following are the weekly data for observations of the Observatory near Kilauea Crater:

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Quakes
March 7	11.25	0	23.0	37
" 14	9.50	0	23.5	30
" 21	26.25	5	16.5	69
" 28	13.00	0	14.5	39

There were light earthquakes during the month perceptible at Kilauea and of Kilauea origin. There were three at Mauna Loa distances, and one felt strongly at Kailua, believed to originate east of Hualalai.

Sequence of Events by Weeks

The first week showed quiet conditions at Halemaumau.

The second week no slides were noticed, and blue fumes from the sulphurous patches at the bottom of pit were only slightly in evidence.

The third week, which had the most earthquakes, produced several slides.

The fourth week produced no reports of slides and there was fuming from SE and NW bottom solfataras.

Slides at Halemaumau

Slides from the wall of the pit have been noted as follows:

March 16, a fresh scar appeared on NE wall 300 feet below edge.

March 17, slides fell from the end buttress, 10:30 a.m. and 3:40 p.m. The earthquake 12:30 p.m. set going a slide NE, followed by dribbling of rocks more than an hour.

March 21, 5:20 p.m. slide started at NE rim.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 26 rim crack locations resulted in aggregate movement as follows: week ending forenoon of—

March 5, 15 opened, 2 closed, opening 23.0 mm.
" 12, 16 opened, 0 closed, opening 16.5 mm.
" 19, 12 opened, 0 closed, opening 16.5 mm.
" 26, 6 opened, 4 closed, opening 14.5 mm.

12 mm. of this was contributed by Crack No. 25, at the east end of the pit. This crack has opened continuously since the heavy sliding of October-November, 1936.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant† Earthquakes	Weekly* Seismicity
March 7	29	6	0	0	0	11.25
" 14	24	5	1	0	0	9.50
" 21	49	16	2	2	0	26.25
" 28	36	2	3	0	1	13.00

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began recording at the times indicated and whenever possible a determination of depth of focus has been made.

March 1, 7:28 pm, very feeble, probably originated in NE portion of Kilauea Crater.

March 2, 1:26 am, very feeble, located 18.0 miles deep under Mauna Loa NE rift zone in vicinity of Puu Ulaula. 19° 32.5′ N; 155° 26.6′ W.

March 3, 8:42 am, very feeble, located deep under SE portion of Mauna Loa 13.0 miles W of the Observatory. 19° 26.0′ N; 155° 27.5′ W.

March 4, 1:24 pm, very feeble, probably originated in NE portion of Kilauea Crater.

March 8, 12:17 pm, very feeble, located 1.0 mile deep near center of Kilauea Crater, 1.4 miles from the Observatory. 19° 25.1′ N; 155° 16.6′ W.

March 9, 6:56 am, very feeble, probable origin under NE rim of Kilauea Crater.

March 10, 3:04 am, very feeble, located in N portion of Kilauea Crater, 0.9 mile deep. 19° 25.7′ N; 155° 16.7′ W.

March 10, 6:05 pm, very feeble, located in fissures at SE rim of Kilauea Crater immediately west of Keanakakoi. 19° 24.2′ N; 155° 16.1′ W.

March 10, 10:09 pm, very feeble, located 12 miles deep, 6.0 miles NE of Puu Ulaula, Mauna Loa NE rift. 19° 35.0′ N; 155° 23.0′ W.

March 11, 7:10 pm, feeble, located 5.0 miles deep under shoreline at Apua Point, 13.0 miles SSE of the Observatory. Reported felt in Hawaii National Park and at Mountain View. 19° 15.8′ N; 155° 11.0′ W.

March 15, 12:41 pm, very feeble, located 1.0 mile deep, SE rim of Kilauea Crater and 0.5 mile SE of Pit seismograph station. 19° 24.0′ N; 155° 16.6′ W.

March 15, 12:50 pm, feeble, located 0.6 mile NE of Pit seismograph station in Kilauea Crater. 0.4 mile deep. Reported felt strongly by many in Hawaii National Park with particular strength at Kilauea Military Camp, N rim of Kilauea Crater. 19° 24.8′ N; 155° 16.7′ W.

March 16, 11:00 am, very feeble, located 1.0 mile deep under SE rim area of Halemaumau. 19° 24.5′ N; 155° 16.9′ W.

March 16, 1:13 pm, very feeble, located under S portion of Halemaumau, 1.6 miles deep. 19° 24.5′ N; 155° 17.2′ W.

March 17, 3:05 am, very feeble, located under NE rim fault zone, Kilauea Crater, 1.0 mile deep. 19° 25.4′ N; 155° 15.8′ W.

March 17, 12:29 pm, slight, located 1.0 mile deep, 0.6 mile E of E rim of Halemaumau in Kilauea Crater. Felt by many persons in Volcano area and to a point 2.0 miles E of the crater. 19° 24.5′ N; 155° 16.6′ W.

March 18, 2:36 am, very feeble, same location as preceding shock.

March 18, 12:10 pm, very feeble, located 16.0 miles deep and 8.0 miles E of summit of Hualalai. Reported felt strongly at Puuwaawaa Ranch and at Kailua, Kona. Dismantled Kona seismograph. 19° 41.0′ N; 155° 44.5′ W.

March 19, 8:39 am, slight, located 1.4 miles deep in fissure zone SE rim of Kilauea Crater and 0.9 mile E of Halemaumau. Reported felt at CCC Camp. 19° 24.4′ N; 155° 16.2′ W.

March 20, 12:15 pm, feeble, located 1.8 miles deep near the Old Stone Corral in Kilauea Crater. 19° 24.8′ N; 155° 16.3′ W.

March 20, 7:13 pm, very feeble, located 1.6 miles deep and 1.2 miles SE of Pit seismograph station. 19° 23.6′ N; 155° 16.2′ W.

March 20, 7:14 pm, very feeble, probably originated in Kilauea Crater about 1.0 mile SE of the Observatory.

March 21, 6:10 am, very feeble, located 4.6 miles deep and 0.9 mile northwest of Cone Peak, Kilauea SW rift zone. 19° 24.0′ N; 155° 19.3′ W.

March 21, 3:37 pm, very feeble, probably located under Halemaumau.

March 22, 10:50 am, feeble, located 1.4 miles deep, 0.4 mile S of Kilauea Iki. 19° 24.5′ N; 155° 15.1′ W.

March 22, 11:12 am, feeble, located 0.4 mile N of Ahua Kamakokulau, 2.0 miles deep. 19° 23.3′ N; 155° 16.2′ W.

March 24, 7:11 pm, very feeble, located in Kilauea SW rift zone, 4.3 miles deep and 2.5 miles SW of Halemaumau. 19° 23.0′ N; 155° 19.0′ W.

March 24, 9:35 pm, very feeble, located 10.0 miles E of summit Crater of Mauna Loa, 7.0 miles deep. 19° 24.4′ N; 155° 32.0′ W.

March 26, 8:29 pm, feeble, located 8.0 miles deep and 7.0 miles S of Kilauea Crater in Hilina Pali Fault System. 19° 19.0′ N; 155° 16.0′ W.

Three minutes of continuous tremor registered March 26, beginning at 5:12 pm.

Microseismic motion of the ground at the Observatory was strong the entire month with the exception of March 25 when it was moderate.

The maximum wave of a teleseism recorded at 6h 37m 39s

† Includes teleseisms or those shocks over 5000 kilometers distant.
* For local seismicity definition see Volcano Letter 371.

am, H.S.T., March 25. It was probably associated with reported shocks in California of that time and date.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts towards or away from the Pit.



Figure 3. Mokuaweoweo Resthouse.

At the Observatory the total accumulated tilt for the year ending March 28 was 7.83" S and 2.6" W.

Week Ending	Observatory	Halemaumau West Station
March 7	1.23" S 71° E	4.77" N 77° W
" 14	0.94" N 35° E	6.29" N 73° W
" 21	3.33" S 49° W	6.88" N 4° W
" 28	1.42" S 45° W	4.29" S 78° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
March 7	4:15" N 60° W	0.58" from
" 14	7.06" N 51° W	0.99" toward
" 21	13.22" S 35° W	3.90" from
" 28	5.90" N 22° W	1.35" toward

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory, March 24, compared with similar measurements of February 25, showed opening of 2.5" across Halemaumau and an opening of 0:41 across the Crater from the SE rim to Uwekahuna.

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
REPORT OF THE SECRETARY
ANNUAL MEETING, HONOLULU, 31st MARCH, 1937

To the Members of the
Hawaiian Volcano Research Association*

I have the honor to report upon the work of your association for the year ending at this date.

A year ago it was announced that a plan was being initiated for cooperation with the University of Hawaii. This plan was carried out and has proved to be helpful and advantageous. The services of Dr. Ballard—an expert physicist—were made available to us through its operation and important work in gas collection and spectroscopic analyses was undertaken. We were also able to add a permanent member to the clerical staff at Kilauea with a resultant saving to the Director of much necessary but time-occupying detail work in the sorting and classifying of documents and correct indexing of the very large number of exchange publications.

This saving of time has made it possible to devote proper attention to our monthly publication, The Volcano Letter, which has now been brought up to date—while the transferring of the detail work of editing and publication to Honolulu office has enabled it to be issued and distributed at the proper intervals.

The Volcano Letter in its enlarged and illustrated format has aroused considerable interest in many parts of the world and it has been gratifying to receive very many most favorable comments upon it. The now historic period, ending with the bombing of Mauna Loa in 1935, has been exhaustively dealt

* At this meeting an address by Dr. Jaggar dealt with the "Protection of Hilo Harbor."

with in this medium—no less than four successive issues having been required thoroughly to cover the subject.

Other publication work has been undertaken, such as an illustrated article upon the "Bombing of Mauna Loa," in the American Military Engineer, and "The Life of Bundjiro Kato" in the Bulletin of the Geological Society of America—both by Dr. Jaggar. A request story of the Mauna Loa incident has been completed by your Secretary in French, for a French-Canadian Journal of international circulation.

ciation of Volcanology which next meets in Washington in 1939.

While at the moment it may be said that the publications and the Observatory plant have been restored to their pre-depression efficiency—it is increasingly evident from the now-existing situation with respect to Mauna Loa that greater responsibilities than ever before are devolving upon this Association. We cannot escape the fact that it is we—as an agency, distinctively Hawaiian but recognized by the world of science

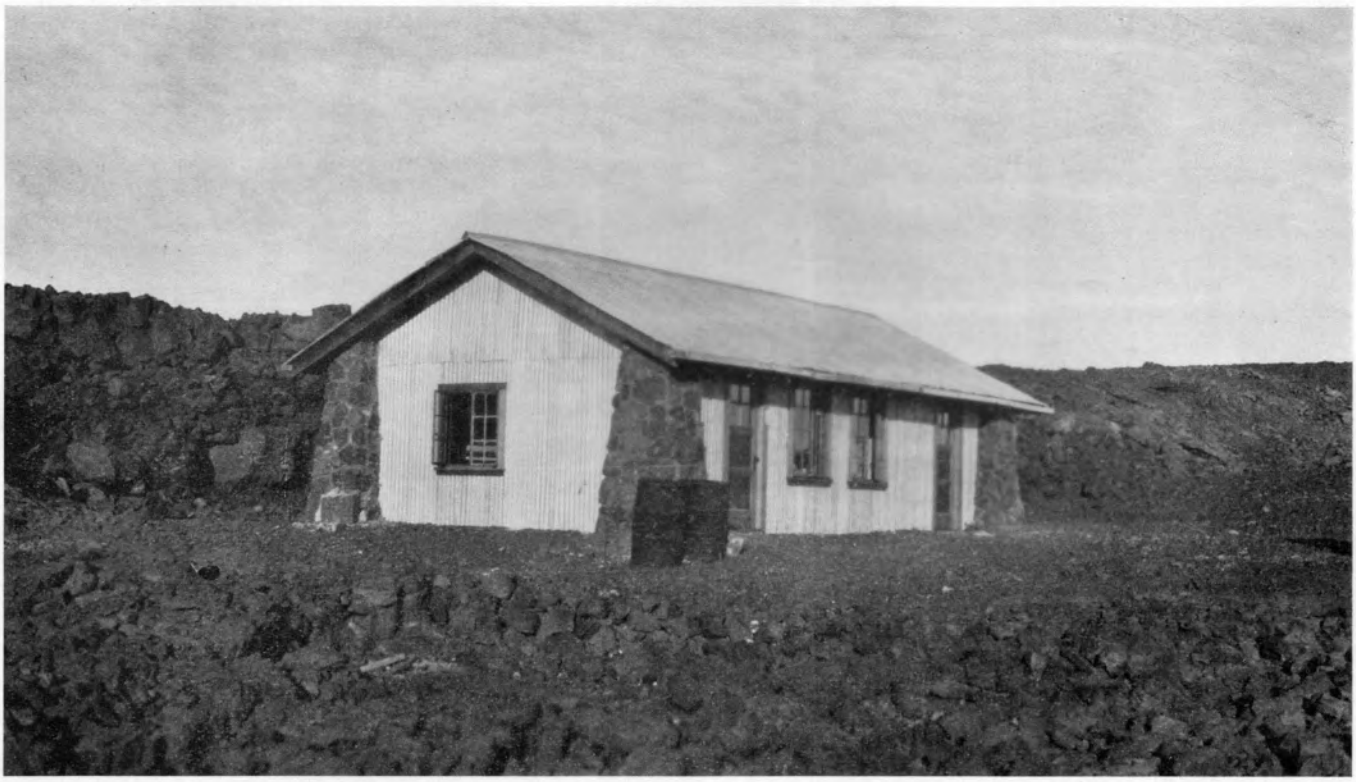


Figure 4. Resthouse, summit of Mauna Loa, constructed with Hui o Pele funds. May, 1935.

While on the subject of Mauna Loa, it may be mentioned that the great lava flow ended on January 2nd, 1936: summit emission of gas dwindled in March, but fuming and deposit of sulphur continued throughout the year. One of the most valuable lessons learned from this eruption by the people of Hawaii was that of the serious menace to Hilo and its nationally important harbor. It is upon this subject that Dr. Jaggar will address you tonight.*

In the spring of the year came an urgent request from the Royal Society of London for Dr. Jaggar to visit Montserrat in the British West Indies to help and advise in a serious seismic crisis that seemed to presage the possibility of a disaster comparable to that of St. Pierre in Martinique in 1902. Accordingly, Dr. Jaggar proceeded thither in April and, after thoroughly examining the situation, formulated a comprehensive program that—should disaster eventually occur—may be the means of saving very many valuable lives. It is of interest to recall that upon arrival in Montserrat, he found a number of Jaggar Shock Recorders were in use by the British authorities —having been made in the Kew Observatory near London. It should also be mentioned that the cost of this expedition was refunded to us by the Royal Society.

Your Association is honored by the election in Edinburgh of Dr. Jaggar as first vice-president of the International Asso-

as a pioneer—who are permanently called upon to direct and foster the progress of volcano research in Hawaii. It is not, as soom seem to think, a function of the Federal Government to educate our community here in Hawaii to an awareness of inimical forces close at hand. It is our function to do all that we can through our publications—and to take the initiative in matters of public safety. We have only to look back to as recent a time as December, 1935, to realize that, had we during the depression shirked this responsibility and been unprepared—a great disaster might have come upon the Territory; and the Federal Government might have been deprived of a harbor that may well prove vital in both war and commerce. It was this Association that saved the Volcano Observatory from extinction in 1934.

The whole question of safety for Hilo and its harbor, which looms large at this very moment, is one that—as we shall presently hear—is already receiving much serious thought in the Department of the Interior; in Hilo, and in Honolulu through the Territorial and other organizations whose interests are concerned.

It is our duty to undertake the initiative, to plan and to direct, and this is being done. Already, under the direction of the National Park Service—the Mauna Loa road—of supreme importance as a means of access to the mountain, is being extended towards Red Hill—a vital, strategic point for future operations—and has been completed by C.C.C. labor for nearly

* See Volcano Letter, January 1937.

ten miles at $5000 per mile. This is probably one of the most economical applications of labor on record in Hawaii.

A Mauna Loa Observatory is of paramount importance to the near future. It will entail staff additions to the Kilauea Station and we must promote the means to take care of it. We are extremely fortunate at the moment in the hearty cooperation extended to us by the National Park Service in Hawaii. Its work during the critical period at the end of 1935 was beyond all praise, and we are hopeful that this cooperation may long continue.

But the lesson of that time has taught us that there is very much to be done and we have but little money with which to do it. We depend entirely upon a continuance of the support which has been so loyally given to us in the past and for which we are profoundly grateful.

A year ago an appeal was made to our members to help us by interesting their friends. While our membership has increased steadily during the year it is noticeable that most of the increase has come from the mainland and from foreign countries. It takes a lot of members at $5.00 a year to produce an income sufficient to enable us to undertake important projects—and it is possible that the very nearness of the people of these islands to all that we are trying to do—blinds them to its real importance. That we have been able to carry on for a quarter of a century, however, is a tribute to the generosity of our community leaders who have done so much to make Hawaii one of America's chief assets.

It is appropriate here to state, for libraries and institutions at a distance, that their memberships in this Association are supporting unique scientific research and publication. They are not merely subscribing to a magazine. The Volcano Letter and technical papers—for numerous recent ones we are indebted to the University cooperation—are efforts to make this research known. The Government through the National Park Service is not financed to publish technical articles. The Association in Hawaii assumes this task. It has been difficult to combine interesting the general public as well as the scientific reader, along with prompt report upon volcanic activity. These three motives have been wrestled with for twenty-five years, with very feeble sinews of war.

This Volcano Research Association in the central Pacific stands for a world study of world processes of nature. Its publications and their indexing are limited by the money available for printing. May our generous leaders in Hawaii soon receive the support that will pay for the printing of numerous manuscripts now filed away, awaiting suitable publication, and the indexing of the serial ones.

Respectfully submitted,

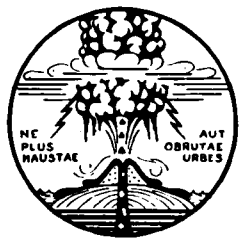
L. W. de VIS-NORTON,
Secretary and Assistant Treasurer.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.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THE VOLCANO LETTER

No. 446 monthly **Department of the Interior** **National Park Service** **April 1937**

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

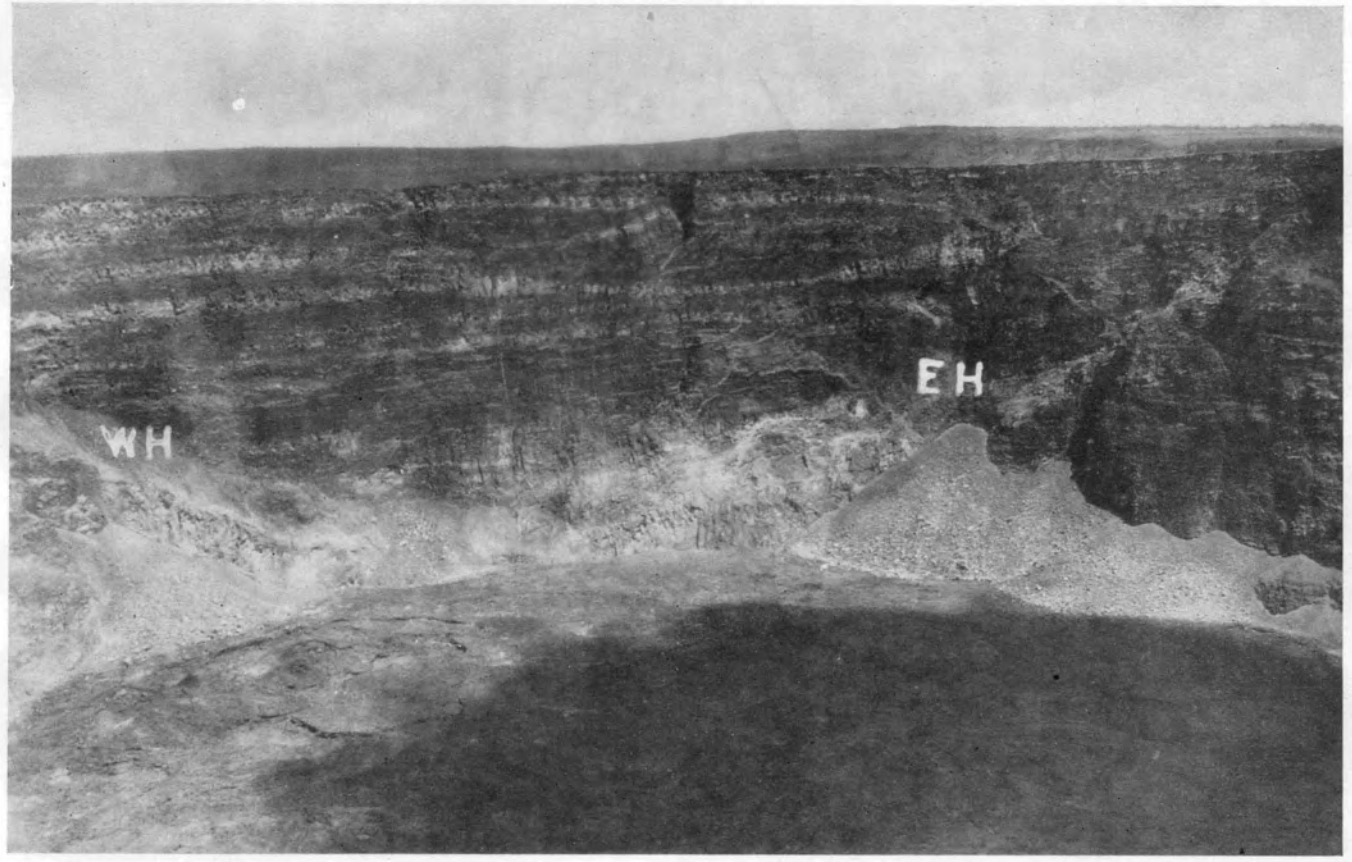


Figure 1. North wall Halemaumau before the landslip: WH the west horn, EH the east horn, of Canoe Sill.

CRACK MEASUREMENT AND TILT AT THE HAWAIIAN VOLCANO OBSERVATORY*

On February twenty-third of this year I had the pleasure of telling you something about the earthquakes on this island, their relation to the volcanoes, how they are detected and how located. It was a long subject to cover in fifteen minutes—in fact, I did not cover the subject in that time but went four minutes over the allotted amount. One might suspect from that state of affairs that earthquake studies took up about all of the time available to the personnel at the Observatory. It is true that the earthquake studies do consume a lot of time and energy, and they are a very important part of volcanologic research but they are by no means the only source of current information concerning the welfare of the volcano. There are other means of feeling out underground movements—not so spectacular but none-the-less important and probably even less ambiguous than earthshakings.

Each week there appears in the local newspapers a report of conditions for the preceding week, ending at twelve midnight Sunday. Among other things, the movement of cracks around Halemaumau and the tilt at the Observatory are reported. Not reported in the papers, but of great interest as significant observations are the results of triangulation and leveling determinations.

On the floor of Kilauea Crater and surrounding the rim of Halemaumau and roughly concentric to it, are a series of cracks. These cracks vary in width and depth from a few inches to several feet, and from some there issue considerable heat and steam. Every Friday morning two members of the

* Radio talk, KHBC, Hilo, Hawaii, April 6, 1937, by Hugh H. Waesche, Asst. Geologist, Hawaiian Volcano Observatory.

Observatory staff make a round of the pit and measure with a millimeter steel tape certain selected, marked localities along these cracks. The marks are copper studs on which are cut crosses for accurate reference. These studs are either cemented to or driven into the solid rock forming the respective sides of the crack toward or away from the pit. Thus, by regular measurement every appreciable movement may be and is detected. Gases and lava pressing up under the crater floor should open the cracks whereas a recession of lava and lowering of gas pressures should cause the cracks to close. It is possible also that tidal forces in the earth caused by moon and sun relationships may cause some changes in the cracks. Another factor, near the rim of Halemaumau, is undoubtedly the force of gravity ever tending to pull the large rim blocks bounded by these cracks, into the pit. Because of regular measurement of cracks indicating comparative movement the likelihood of material sliding in large amounts from certain localities around Halemaumau rim is known well in advance. The large slide of October twenty-second of last year was heralded by excessive crack opening, and a month before this occurred, the northeast area of the pit rim was wired off and warning signs were put up. The results of the crack measurements are plotted up on the basis of percentage opening for the total which makes an irregular curve and on the basis of actual amounts of opening for individual cracks. The latter curves are comparatively smooth and show that as the time approaches for a section of the rim to give away and fall into the depths below, the rate of opening increases more and more rapidly, or is accelerated.

In March, 1936, thirty-two crack localities were being measured. In March of this year only twenty-six were being measured. One crack at the northeast triangulation station gave way during the latter part of March last year. A new one was established twenty feet further back. This one was doomed to a short life. It disappeared with five others along the northeast and east rim of the pit last October and November. One crack, the famous number forty-six, began to show movement of a definitely progressive nature over a year before it fell in with the other just referred to. It opened by ever-increasing amounts, a total of thirty-six centimeters or approximately a foot and a half in about twenty-two months. In the last month alone, it opened ten centimeters, or about four inches, and this crack was nearly two hundred feet back from the rim. On Tuesday afternoon Naturalist Lamb and myself were taking pictures of the region. Thursday morning, October twenty-second, the ground where we had been was at the bottom of Halemaumau and the north side of crack forty-six was the rim of the pit.

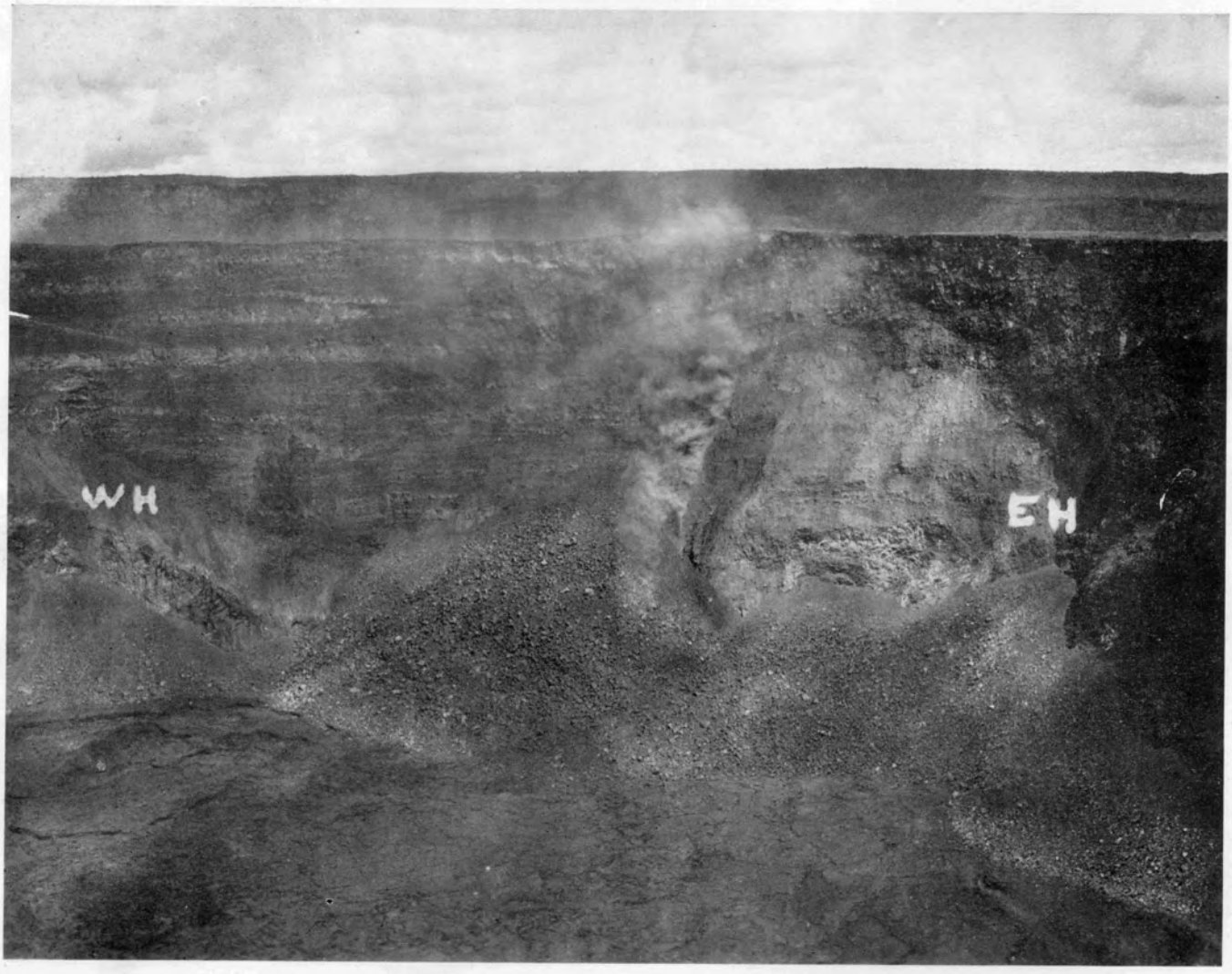


Figure 2. After collapse, October 22, 1936.

Generally speaking, all of the measured cracks have opened

by varying amounts continuously during the period following the Halemaumau eruption of 1934. One exception is number forty-one, about eight hundred feet southwest of the pit. It has shown no change in the same time period. At present, crack number twenty-five on the east rim is moving most rapidly and some large rock falls from that portion of the pit should be imminent and are anticipated.

One of the earliest established and probably one of the most significant branches of routine research at the Hawaiian Volcano Observatory is that related to what is referred to in reports as tilt or tilting of the ground. This action, although well identified, is by no means too easy to measure. At the Observatory and at Halemaumau tilt is measured by the wanderings of the seismograph pens, with relation to a fixed value recorded on the smoked seismograph drum. Also, tilt around Halemaumau is measured by a special apparatus known as a clinoscope. Two of these are now in operation, one on the southeast rim, and one to the west of Halemaumau. A third instrument was located northeast of the pit but was disrupted by an earthquake. It is the earthquake situation which makes tilt measuring difficult here. The problem is to have an instrument as sensitive as a seismograph, of high magnification, which would be inexpensive but accurate, and earthquake proof. In Japan a partial solution, at least, seems to be a sealed horizontal pipe, about half full of water with means of measuring changes of level of the water at the ends of the tube.

Tilt has been defined by Dr. Jaggar and R. H. Finch as "a change in angular relation between a portion of the earth's surface and the plumb line." A plumb bob suspended from an arm on a tall flagpole should illustrate this by the bob swinging to or from the pole, or sideways as the ground tilted, thus changing the angle of the pole with relation to the horizontal. If it were possible to attach a pen to the top of the flagpole and this pen wrote on a sheet of paper which was permanently fixed to the sky in its position, then the pen would trace a picture of the tilt graphically on the sheet of paper, the size of the drawing depending upon the height of the pole, the taller the pole the larger the drawing.



Figure 3. Crack No. 46 looking north before landslip.

Something of this nature is done at the Observatory. No flagpole is used but measured daily tilt on the Bosch-Omori seismograph is transcribed to a sheet of coordinate paper. Since the two pendulums of the seismograph are oriented north-south and east-west, these directions are used and all component directions resolved therefrom and a picture of what the top of the flagpole would have done is shown. It has been discovered that the ground on the northeast rim of Kilauea makes an



Figure 4. Crack No. 46 looking south after landslip (man in Figure 3 would be in air beyond A).

annual loop as much as twenty seconds of rotational arc for the greater diameter which runs northeast, southwest. Minor irregularities and loops occur in the major annual loop. Marked directional tilts have occurred preceding eruptions both of Kilauea and Mauna Loa. In the first week of October, 1935, tilt at the Observatory began to move, following the vigorous earthquakes of September thirty-October one, in a southeasterly direction and continued to do so until November seventeenth, when the tilt direction changed back to the northeast and on November twenty-one Mauna Loa erupted, thus relieving the pressure which had tilted the ground some two or three seconds at the Observatory. The tilt resumed its normal trend and made its usual annual loop in 1936. So far this year the tilt has moved slightly west of south very rapidly, necessitating adjustment of the seismograph to take care of the change quite frequently. However, this movement seems to have slacked up now and little tilt of any kind has occurred in the past week or ten days. What this may mean is a little uncertain but may mean considerable lowering of downward pressure under the crater.

The clinoscopes previously referred to as located around Halemaumau are quite different from seismographs. They consist of a circular heavy mass of iron suspended from a tripod frame supported by piano wires. The mass is damped by a tank of oil in which it moves. Thus, the arrangement is that of a plumb bob or pendulum attached to delicate levers and pivots which extend up in the tripodal frame. At the end of the light lever or boom is a point which approaches the face of a target-like indicator. This target indicator is graduated into concentric circles with a separation of two millimeters. From the center point are radiating lines corresponding to the cardinal points of the compass. The migration of the lever pointer indicates tilt by amount and direction. The magnification of the clinoscope has been previously calculated so that actual angular and directional daily tilts of the ground may be plotted graphically just as in the case of the seismograph at the Observatory. Since the clinoscopes are on widely separated portions of the pit rim, and the direction of the center of the pit is known with reference to the tilt stations, it becomes possible to resolve the components in such a way as to determine the radial tilt to or from the pit. Tilt toward the pit should indicate lowering in that direction accompanying decreased pressures with the reverse being true of tilting from the pit.

Dr. Jaggar and Mr. Finch in 1929 described tilt records and results for the thirteen years from 1913 to 1925 inclusive. Their very interesting conclusions will bear repeating and are as follows:

"1. Seasonal tilts of twenty seconds or more in a half-year



Figure 5. Before notch caved in 5:54 a.m. October 22 (taken October 20).

vary with air temperature, easterly tilts corresponding to cold months, westerly tilts to hot months.

"2. The range of angular tilting per half-year is greater when measured gushing up of lava is greater. The gushing up of lava and easterly tilting have been regularly greater in autumn and winter.

"3. There is practically no correlation between tilt and rainfall.

"4. Between 1913 and 1920 there was a northeasterly tilt of about eighty seconds accumulated at Kilauea, and an elevation of about 0.6 meters in the central part of the mountain, diminishing apparently to zero in a radius of ten kilometers. This was a partial eruptive cycle, characterized by rising lava.

"5. Between 1920 and 1926 there was a southwesterly tilt of about ninety-three seconds, accumulated at Kilauea and a depression at the central part of the mountain (distinct from collapse at the pit) of about four meters, diminishing in a radius of twenty-two kilometers to 0.09 meters. This was an extraordinary half-cycle of lava subsidence plus explosive eruption with engulfment.

"6. The total void computed from the engulfment and subsidence data is approximately 757 million cubic meters, of form suggesting the evacuation left by an intrusive sill of about thirty kilometers radius, swollen in the center.

"7. Local earthquake frequency and centripetal tilt accompany lava subsidence, otherwise there is little correlation between tilt and earthquakes.

"8. There is perfect correlation between Kilauea lava movement and Mauna Loa lava movement, whenever the Kilauea lava pit is not sealed. The east-west tilt curve exhibited accumulation of easterly tilt preceding every Mauna Loa eruption. The north-south tilt curve followed consistently the overflow and subsidence phases of Kilauea. These facts agree with the position of the instruments, north of Kilauea and east of Mauna Loa.

"9. Explanation of the correspondence between easterly tilt and lava gushing, on the one hand, and winter atmospheric mean lower temperature, on the other, is difficult. Two possible explanations are: (a) that solar heating in the summer checks volcanic radiation, whereas outward conduction is stimulated by the winter cold; (b) that a winter solstice tidal effect acts on the east-west fissure of the Hawaiian ridge, owing to a solar pull southward on the great mass of the ridge and on the equatorial protuberance. this might produce trigger stress for winter effervescence and tumescence, if the lava sponge below were in nice adjustment for gas-pressure release. Possibly both (a) and (b) work in concert."

If I may talk to you again at some future date, I should like to tell about level and triangulation values in the vicinity of the local volcanoes with corroboration of their action by volcanoes in other parts of the world.

Meanwhile, don't lose patience with Pele—Kilauea is going to erupt. However, I am glad this is a radio, so no one can ask me "when". Thank you.

Hawaiian Volcano Observatory Report for April, 1937

VOLCANOLOGY

The following are weekly data for observations of the Observatory near Kilauea Crater, including slides and rim-crack openings of Halemaumau Pit, the center of expected eruptions of the crater:

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Quakes
April 4	25.00	1	25.0 mm.	75
" 11	30.75	6	34.0 mm.	89
" 25	15.50	5	44.5 mm.	42
" 28	13.25	10	28.0 mm.	42
May 2	12.50	2	47.0 mm.	46

Slides continued the third week, 7 quakes were from Kilauea, 2 probably Mauna Loa, 1 at Hualalai.

The fourth week continued noisy slides and increased opening of eastern cracks, 4 quakes including a perceptible one were at Kilauea, 2 were probably at Mauna Loa.

The fifth week ending May 2 showed fewer slides but increased opening of an eastern crack, indicating approaching collapse of that rim. A distant earthquake released a prolonged local tremor April 29. Eight quakes were from Kilauea, two probably Mauna Loa.

Slides at Halemaumau, and fumes

Slides from the wall of the pit have been noted as follows:
April 4, 2:50 pm, small slide made dust east.

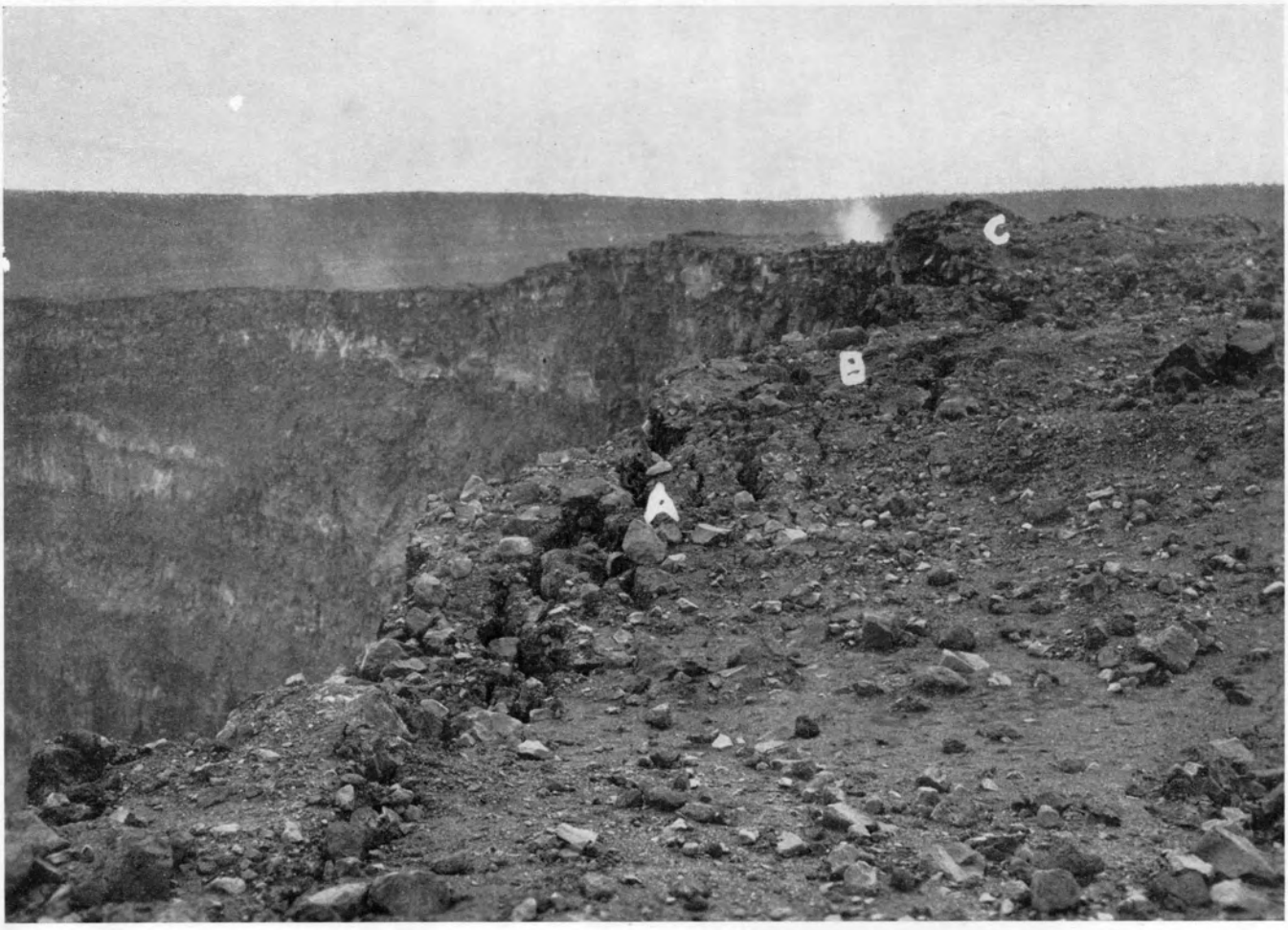


Figure 6. After the caving in, taken October 22.

Of felt earthquakes there were two in the feeble class, April 1 under Pahala (felt at Hookena), and Kau Desert, one under Hualalai felt strongly at Puuwaawaa ranch and otherwise generally felt April 18, and two April 30 at Kilauea.

Sequence of Events by Weeks

The first week ending April 4 had the Pahala shock and one reported slide at Halemaumau. There were 13 Kilauea quakes, four at northeast Mauna Loa rift, and one at southwest rift Mauna Loa.

The second week had numerous slides at east wall of Halemaumau, 15 quakes at Kilauea, 7 at Mauna Loa, including 2 stronger ones.

April 7, morning showed small slides had left scars on wall 400 feet under east cliff.

April 8, slides making dust NNE and E 12:38 pm, 1:05 pm, 1:10 pm, with rumbling heard at Uwekahuna, dust continuing to 1:20 pm. Intermittent dribbling of rocks 2:00 to 3:30 pm.

April 10, similar dribbling east 9:57 am. Fuming from solfataras at edges of floor was slight, becoming visible after April 9.

April 12, 3:20 pm, slide made dust cloud NE.

April 14, 3:25 pm, another at same place.

April 15, 11:47 am, slide made loud rumble, no dust.

April 16, all day 9 am to 5 pm, rock slides N and E, a noisy one sending up dust 11:30 am.

April 18, SE solfatara sent up conspicuous blue fume along with vapor of excessive humidity, noted 3 to 4 pm.

April 21, 9:57 am, small noisy slide NE.

April 25, 9:49 am, moderate slide NE after two small earlier ones, and followed by a large noisy slide 9:54 am, making dust cloud.

April 26, scars showed recent slides, and a small slide made the sound of falling rocks heard at Uwekahuna 11:30 am, and sent up dust.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 26 rim crack locations resulted in aggregate movement as follows: week ending forenoon of—

April 2, 12 opened, 2 closed, opening 25.0 mm.
" 9, 14 opened, 0 closed, opening 34.0 mm.
" 16, 10 opened, 3 closed, opening 28.0 mm.
" 23, 8 opened, 1 closed, opening 44.5 mm.
" 30 9 opened, 3 closed, opening 47.0 mm.

On April 23 two cracks close to the east edge contributed most of the opening: No. 24 5.5 mm., No. 25 36.0 mm., and these are behind rim blocks of rock extending southward the edge that collapsed in October, 1936; they are going to fall soon. On April 30, crack No. 25 contributed 42 mm.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Moderate Earthquakes	Distant† Earthquakes	Weekly* Seismicity
April 4	56	16	3	0	0	0	25.00
" 11	67	20	1	0	1	0	30.75
" 18	31	9	1	0	0	1	13.25
" 25	36	5	1	0	0	0	12.50
May 2	35	8	1	1	0	1	15.75

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible, a determination of depth of focus has been made.

March 29, 7:53 am, very feeble, probably located in Mauna Loa NE rift near Puu Ulaula.

March 29, 9:15 am, very feeble, located in Kilauea Crater.

March 29, 6:52 pm, very feeble, located in Kilauea Crater.

April 1, 5:31 pm, feeble, located in the vicinity of Pahala near the Kaapao Pali, and 20.0 miles deep. Reported felt in Hookena, where buildings creaked and hanging objects moved. 19° 13.3' N; 155° 30.2' W.

April 1, 6:49 pm, feeble, located 3.7 miles deep under Kalanaokuaiki Pali 1.3 miles SW of Puu Ohale. 19° 20.7' N; 155° 17.8' W.

April 3, 9:30 am, very feeble, located in vicinity of Kipuka Puaulu (Bird Park), 3.8 miles deep. 19° 26.5' N; 155° 18.3' W.

April 3, 10:55 am, very feeble, probably located under N rim of Kilauea Crater.

April 4, 1:52 am, feeble, located 0.5 mile west of Puhimau Crater 1.5 miles deep. 19° 23.7' N; 155° 15.5' W.

April 4, 8:10 am, very feeble, located 4.5 miles NW of the Observatory 1.4 miles deep. 19° 28.6' N; 155° 18.9' W.

April 4, 11:59 am, very feeble, thought to have been located in Chain of Craters area SE of Kilauea near Hiiaka Crater.

April 4, 5:11 pm, very feeble, probably located in SE portion of Kilauea Crater near Keanakakoi.

April 4, 11:41 pm, very feeble, of Mauna Loa origin.

April 5, 6:18 am, very feeble, probable location, Kilauea SW rift 0.7 miles NE of Cone Peak.

April 5, 9:47 am, very feeble, thought to have been located in Chain of Craters area, near Devil's Throat.

April 5, 10:57 pm, very feeble, located in Mauna Loa NE rift near Puu Ulaula and 18.0 miles deep. 19° 30.5' N; 155° 29.0' W.

April 6, 12:37 am, very feeble, located 1.5 miles W of Puhimau Crater and 0.5 mile SW of Kilauea Crater, 4.2 miles deep. 19° 23.7' N; 155° 16.5' W.

April 6, 11:15 am, very feeble, located 5.1 miles deep and 1.2 miles east of Kilauea Iki Crater. 19° 24.8' N; 155° 13.5' W.

April 6, 4:46 pm, very feeble, located 4.2 miles deep and 2.0 miles W by N of Uwekahuna. 19° 26.0' N; 155° 19.8' W.

April 7, 12:18 am, very feeble, located in vicinity of Lua Manu Crater 2.4 miles deep. 19° 24.1' N; 155° 15.6' W.

April 7, 9:51 am, very feeble. Probably located 2.3 miles SE of pit seismograph.

April 7, 11:02 pm, very feeble, located 4.2 miles deep in Kilauea SW rift zone near Cone Peak. 19° 21.9' N; 155° 19.3' W.

April 9, 12:18 am, very feeble, thought to have been located under Halemaumau.

April 9, 7:29 am, moderate, located near seacoast at Apua Point 3.0 miles S of Hilina Fault system and 7.0 miles deep. 19° 16.3' N; 155° 12.2' W.

April 9, 5:46 pm, very feeble, probably located in Kilauea SW rift, 3.8 miles from Halemaumau.

April 10, 9:24 am, very feeble, probably located 0.5 mile NE of Kilauea Crater.

April 10, 1:21 pm, very feeble, located 2.8 miles deep in Chain of Craters area near Hiiaka Crater. 19° 22.6' N; 155° 14.0' W.

April 11, 2:52 am, feeble, located near Mauna Loa NE rift 3.5 miles S of Puu Ulaula, 13.0 miles deep. 19° 29.4' N; 155° 29.3' W.

April 12, 7:38 pm, very feeble, located 2.4 miles deep near Lua Manu Crater. 19° 24.1' N; 155° 15.6' W.

April 13, 7:03 am, very feeble, located in rifts 0.4 mile N of Puu o Hale, 1.5 miles deep. 19° 21.5' N; 155° 16.6' W.

April 13, 8:33 am, very feeble, probably located 1.5 miles NE of Kilauea Crater.

April 15, 6:28 am, very feeble, located in cracks near NE rim of Keanakakoi Crater, SE portion of Kilauea Crater. 19° 24.2' N; 155° 15.1' W.

April 15, 6:21 am, very feeble, thought to have originated in Kaapo Pali near Pahala.

April 17, 12:14 am, very feeble, of Kilauea Crater origin.

April 17, 2:17 pm, very feeble, of Kilauea Crater origin.

April 18, 2:44 am, very feeble, located 1.2 miles deep under Byron Ledge, SE rim of Kilauea Crater and 1.0 mile east of Halemaumau. 19° 24.6' N; 155° 15.9' W.

April 18, 4:10 am, feeble, originated under Hualalai Volcano. Reported felt at 29.0 miles on Volcano Road, Hilo, Kamuela, and very strongly at Puu Waawaa Ranch House.

April 18, 8:50 pm, very feeble, probably located 1.5 miles E of Kilauea Crater and 1.0 mile S of Kilauea Iki.

April 19, 5:59 am, feeble, located under SE rim of Kilauea Crater, 1.2 miles deep. 19° 24.5' N; 155° 15.5' W.

April 20, 4:08 pm, very feeble, probably located in Hilina Fault zone N of Apua Point.

April 21, 11:59 pm, very feeble, probably located in Mauna Loa NE rift about 5.0 miles NE of Puu Ulaula.

† Includes teleseisms or those shocks over 5000 kilometers distant.
* For local seismicity definition see Volcano Letter 371.

April 23, 4:08 am, very feeble, probably located in Chain of Craters area near Devil's Throat.

April 30, 3:08 am, very feeble, located 0.7 mile deep near center of Kilauea Crater 19° 24.9' N; 155° 16.3' W.

April 30, 3:40 am, slight, located 0.8 mile deep near E edge of Keanakakoi Crater SE portion of Kilauea Crater. Reported strongly felt at the CCC Camp, felt at 29.0 miles on Volcano Hilo Road and dismantled pit seismograph. 19° 24.2' N; 155° 15.9' W.

April 30, 9:29 am, feeble, probably same location as preceding.

April 30, 12:35 pm, very feeble, thought to be of Kilauea origin.

May 2, 5:26 pm, very feeble, 5:27 pm, very feeble, and 5:29 pm, very feeble, all thought to be of Kilauea Crater origin.

Four minutes of continuous tremor began recording at the Observatory at 9:06 am, April 29.

Microseismic motion of the ground at the Observatory was strong throughout the month except from April 25 to 30 inclusive and April 18, when it was moderate.

The preliminary waves of a distant earthquake began to register at Kilauea at 4 hr. 39 min. 25 sec. pm, H.S.T., April 15. It was estimated to have occurred 2,700 miles distant, probably in Alaska. The preliminary waves of a teleseism began recording at Kilauea at 8 hr. 29 min. 41 sec. am, H.S.T., April 29. It was estimated to have been 3,560 miles distant.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending May 2, was 8.47" S and 0.76" W.

Week Ending	Observatory	Halemaumau West Station
April 4	1.64" N 45° E	3.37" N 60° W
" 11	0.73" N 51° W	6.05" S 76° W
" 18	1.11" S 37° W	5.54" N 67° W
" 25	0.17" S 44° E	5.22" S 73° W
May 2	1.17" S 31° W	4.32" N 71° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
April 4	7.23" N 3° W	3.32" Toward
" 11	4.47" N 27° W	1.59" From
" 18	4.99" N 3° E	1.04" From
" 25	6.48" N 53° W	1.90" From
May 2	3.95" S 42° W	4.68" From

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory, April 21, showed slight closing of both Halemaumau and Crater values compared with similar measurements March 24. From Kilauea SE rim to Uwekahuna there was closing of 1.75", March 24 to April 8, and opening of 1.67", April 8 to April 21. Total closing 0.08". From the Pit Seismograph to NW Pit B.M. there was closing of 2.00", March 24 to April 8, and opening of 1.66" April 8 to April 21. Total closing 0.33".

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

THE VOLCANO LETTER

No. 447 monthly **Department of the Interior** **National Park Service** **May 1937**

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Figure 1. Rim of Kilauea fire-pit falling in as lava below escaped to the submarine slope 1924. The collapse alternated with explosions of steam. An earth event limited to a single month.—Photo by Tai Sing Loo.

TRENDS IN THE PHILOSOPHY OF SCIENCE

T. A. Jaggar*

By the philosophy of science is meant the definition of its motives. What has a group of scientists in common? How has the motive of their labors changed in a hundred years since Darwin and Faraday worked? Whither are we bound, and what are the boundaries, in the professions called scientific?

Science is said to be any knowledge that appraises data with logic and care, and uses the method of classifying, generalizing, induction and deduction. But this would apply in some measure to literature, education, languages, history and economics.

The modern meaning of science is limited to the nature sciences, for which the earth is the chief subject, with its kinsfolk the stars, and its products and processes including man himself.

Language is the chief instrument of science, including mathematics, which Willard Gibbs defined as a language. Observation and experiment are the chief activities. Application to human service, and the reform of that service to man's benefit, are the chief goals of science.

Language, the chief promoter of science

It is curious there is no chapter on "language" in Karl Pearson's "Grammar of Science". We learn much of the unreality of matter, force, space and time, "intellectual concepts describing our perceptual routine". We learn about constructs, ejects, contingency and correlation. We are told that science lives upon inference and is a classification and analysis of the contents of the mind. But not a word appears to show that those contents, in the form of thinking, are what Watson calls "sub-vocal talking". An important eject is "other-consciousness", which must agree that two normal perceptive faculties construct practically the same universe. But do we always agree to this? Similarity of perceptive and reasoning faculties depends on a common thought-language.

This point appears frequently missed. Language, mathematics, and logic are not science. But they are the stuff without which science could neither be conceived nor conveyed. Clearly written and spoken language is at the root of accuracy. If you cannot say what you think, you cannot think what you think you cannot say.

Take the subject of forecast. Science is the study of nature; **natural** universe, earth, force, life; origin, progress and future of each of these. Do not omit the future. Science is the first human craft to treat prophecy without superstition. Prophecy based on measured accuracy is the supreme test of science. Astronomy can understand a Babylonian eclipse in the light of mathematical forecast, a new language. Truthful history by its cycles may illumine prophecy. Language by its structure is itself history. What is "prophecy" but the Greek for "speaking before"? It is important to know the history of mother-tongue, and to talk and think foreign tongues.

If we say "inevitable" we are using a French word. Our word "passenger" is not identical with "voyageur". We have no word to connote "geschwister", meaning either brother or sister. We have no word such as an imaginary "menwo", meaning either men or women; "persons" or "people" is not an identical sense. "Onto" is not good English, but is a needed word. We have "widen", but we have no "smallen". "Scientist" hardly includes the ladies, and "men of science" certainly leaves them out. Such are the limitations of thinking.

One can be scientific in speech without language being a science. One can be mathematical in business without business being mathematical. One can be either qualitative or quantitative in science, without science being mathematics. So in the scientific laboratory one can be humanistic, artistic, businesslike or religious. But language is supreme in reasoning, and needs history and all scholarship for scientific use.

"The American Language" by Mencken shows how Americans are remodeling the thinking of the British empire by their straight-shooting lingo. Such language remodels thought and science. Illustrations of vividness are the phrases "What is your reaction?" and "That is not in the picture". The pencil or blackboard chalk illustrates the incessant use of pictographic language in science: we cannot explain without a map, curve, section, formula or sketch as we talk or think.

It may seem strange to stress the importance of words. The diplomats have an expression, "finding a formula". If they had "found a formula" August 1, 1914, the difference might have been to avoid the Great War. Writing science that is understood by the people may get suggestions for progress from a hundred minds; illustrations are the camera, telescope, and radio hobbies. How different this is from the jealousy for priority in Europe. "The best test of the truth", wrote Mr. Justice Holmes, "is the power of the thought to get itself accepted in the competition of the market".

Does science spend as much effort over its phrases as it does over its differential equations? Does it consider the comparative value for progress, of writing a sound newspaper editorial rather than a technical paper? Does it compare the outreach, in selling the goods, of spoken thought compared with the printed word? Spoken speech is creating classes for adults all over the world, because of the realization of our slovenly voices and use of words that people get from listening to radio. Radio is itself a means for propagation of the gospel of science.

Our technical memoirs are long, boresome and addressed to specialists. Difficulties of reading and abstracting, and photographic methods of filing, mean that the short paper has come to stay. The scientist counts on these to sell his goods, but technical terms hide scientists even from each other. Even school teachers have a jargon of technicalities, ratings and curves along with I.Q., P.Q., Hi/Y and as many alphabets as a British army corps. The passion for abbreviation in America is only exceeded by invention of words; realtor, cosmetician, groceteria, mortician, and lubritorium. Non-mathematical scientific papers might sometimes, in the same space, be made intelligible. Remember that mathematics is a different language.

University teachers, in my own experience of Munich, Heidelberg, and Harvard, defeated their own sciences for me as a budding student. Rosenbusch set me to work on one felspar crystal all summer, when I wanted petrography of field rocks. Groth fascinated me with mounted crystals, but I ought to have had association of minerals in nature. Germanized, I returned to Harvard and wrote a doctor's thesis designed to test the abrasion hardness of a large number of crystalline minerals measured with a microscopical instrument that I invented. Result, my Harvard professors said "a mere instrument would not be enough for a doctor's degree", and dissipated my efforts on a double thesis adding a field subject in geology. Here everything turned on the wrong interpretation of three words, "a mere instrument". It all threw me out of mineral collections, and into volcanic craters.

Science is learning the power of speech on the public. Commerce, engineering and industry employ all our sciences in advertising: right there by clear and forceful speech science may educate commerce, engineering and industry.

Experiment, the chief activity of science

In my youth Audubon was my ideal as a scientist, motionless for hours watching wild turkeys in the forest, sketching and painting them, and combining system and art in large

* Address at Hawaiian Academy of Science, Honolulu, May 6, 1937.

volumes of colored plates. Darwin extended this idea to breeding experiments with domestic turkeys. Faraday, Darwin and Pasteur established experiment as the final arbiter of science.

Probably ninety per cent of my audience are laboratory people. Even when your constructive work is in the field, as in the innumerable branches of engineering that have grown up since Audubon's time, you make laboratory tests before you act. Engineering is the most important scientific application in the world today. Vital sciences have been taken in as the soul and body of commerce, including industrial psychology, physical chemistry, biology, preventive medicine and public health, meteorology and radio. Even experimental ethics and social service are commercial sciences. This is a far cry from the lonely impoverished French artist watching the bird in the wet jungles of Louisiana.

Science holds men and women because today it is interested in people and action. It produces results. Engineers are interested in designs, professors in research, merchants in growth of service, sea-captains in increased efficiency, doctors in visible cures.

The old geology, zoology, botany, chemistry, physics and astronomy are being replaced by geophysics, biometry, experimental physiology, electro-chemistry, atomic physics and astrophysics.

Medieval science mingled art, religion and science. We have learned to separate the compartments, the experimental field today is unlimited, and the method involves a quest of objective proof in America, started by Benjamin Franklin using common sense, and willing to tackle any subject from thunderstorms to volcanoes.

Just a word about the old physics of the nineteenth century, which considered solids, liquids and gases in motion, at controllable room temperature and pressure as the subjects of investigation. We human beings, and the soil we dwell upon, are solids, liquids and gases in motion. We are constantly told that the old physics thought it had nothing more to discover. We are practically told by the atomists that, as organic human subjects of bio-physics, unless we can be agitated at high voltage as a rarefied gas, we are not interesting.

This appears to me to be pure hokum. The nineteenth century never had such complacency. There was never a time of such immense foresight and development as from Faraday, through Clerk Maxwell, Elihu Thomson, Hertz, Kelvin, Helmholtz, Roentgen, the Curie Family, and J. J. Thomson. Look at the other sciences, Humboldt, Lyell, Darwin, Haeckel, Huxley, and Bergson the philosopher: Virchow, Koch, Pasteur, and Osler: and in America, Rumford, Gray, Newcomb, Dana, Rowland, Agassiz, father and son, and Welch. The twentieth cen-

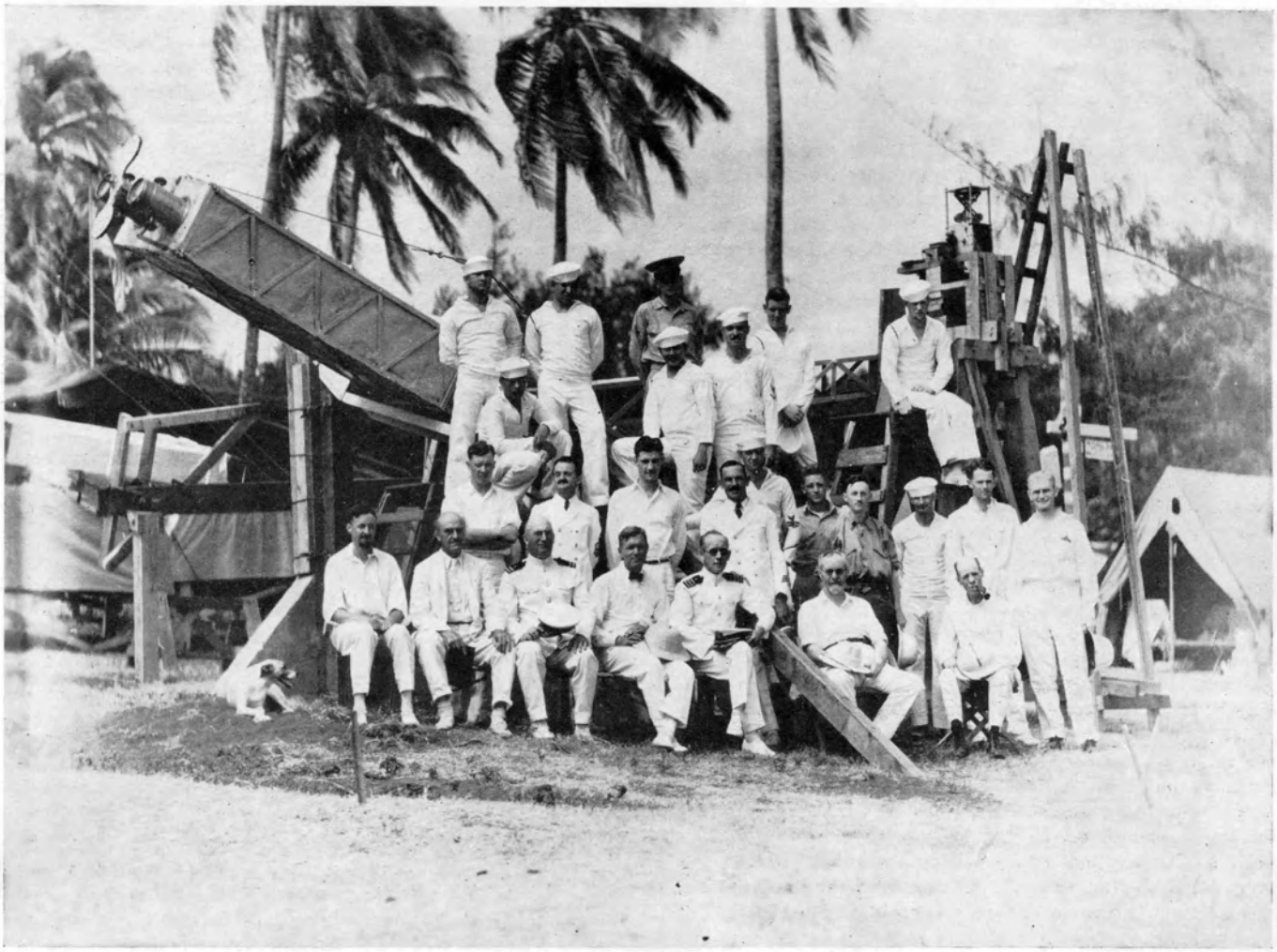


Figure 2. An expedition travels 12,000 miles for a single earth event—to photograph an eclipse of the sun—Navy Expedition, 1930, Niuafoou Island.

tury has barely scratched the surface with a few mathematical philosophers who are primarily linguists groping for ultimates. Otherwise we are working through corporate laboratories rather than individuals. This is good, but there is no sense in decrying the nineteenth century, nor in forgetting that our own seventy kilograms of flesh on solid rock has a problem apart from high voltage.

Reform, the chief goal of science

As science has become increasingly serviceable, so has it become less selfish. Stoddard has said "those peoples who first grasp and act upon the basic principles of the new knowledge will rightfully be the heirs of the future". Who will do it, the Germans, Italians, Russians or Americans? Reform has been disguised as research.

The twentieth century outlook on science has been jolted by the War and the Depression into seeing the need for more practical results, and the conquest of the world by extroversion. Here is a case of a new **word** for successful personality, the soul that opens outward instead of inward. We may have extrovert people, laboratories, cities, factories and nations. In this century the Wrights, the General Electric and Eastman Laboratories, the Peking Medical Center, Henry Ford, the Carnegie Institution, Rockefeller Medical Research, the Mayos, the Cancer Research Laboratories, and the Brookings Institute are all working on a theory of competitive donation. The Nobel and Cecil Rhodes Foundations and others are doing the same in Europe, Africa, Asia and South America.

Our government is extrovert, following upon the vague beginnings of the Monroe Doctrine, our missionary wars, the Open Door, and the Bryan and Kellogg Pacts. The South American pact and the Neutrality Law are a direct heritage of Woodrow Wilson. His League of Nations may seem eclipsed for the moment, but its scientific commissions are at work all over the world, and youth is arrayed against the armament trust. The present employment agencies and large engineering enterprises of the American government are extrovert science. Look over the list, and remember it is not confined to America. Public health, engineering, social security, public housing, slum clearance, agricultural relief, flood control, economic sciences, eugenics, home economics, home workshops, and adult education; add to this forestry, the great irrigation projects, the Tennessee Valley Authority, and the proposal to change the name of the Department of the Interior, which originally exploited our land in Audubon's time, to the Department of Conservation; and you have a world that would certainly astonish Andrew Jackson. Our extrovert government is opposed by the ancient acquisitive society of business. But science is responsible for our social consciousness of our kind. If psychology does what insurance has done, it may develop a cooperation of all science to higher accuracy, and higher truth than physics and mathematics.

The three fundamental concepts of all science are uniformity, evolution and value. Possibly evolution, uniformity, symmetry and rhythm are in Nature herself. Probably value and number are wholly human.

A tremendous gain over the nineteenth century is that physics, psychology and biology have all learned to distrust mechanism and to welcome positive liberalism. The intuitive of emotion, art, religion and philosophy, the elegance, symmetry, rhythm and universality of these cultures are more and more welcomed by science. Cosmopolitan demands will no longer allow science to dwell in a monastic cell.

Glenn Frank says that all laboratories have socially usable ideas that would lift the tone and temper of modern life. Our universities must dig up and put out the usable social ideas buried in each laboratory. Social science explores human nature for truth, searches for new ways, studies the "how", tests and "sees if", and finds out "whether". If your laboratory has an utterly new and usable idea, some island council should make you extrovert about it.

The Earth, the chief subject of science.

If you are studying the tonsils or teeth of school children or measuring binary stars, you may wonder what the earth has to do with it. This philosophy of science will be a success if it raises more questions than it answers. Science means the cooperation of all specialties. If they deal with human beings, they are concerned with civilization. The Polish Corridor, the Pyrenees, and Gibraltar are affecting the blood of future school children today. Civilization in America will be greatly affected by the eighty chemical plants in thirty different states of the DuPont de Nemours Company. They are placed in part for what the ground produces to make the earth yield up her increase.

Laboratory science likes to experiment with something like the fruit fly or white mice that will yield repetitions and controls. The earth, in explosive eruptions where lava flows drain out at the bottom of the sea (Figure 1), or in others capable of being bombed to save a city; the earth, in receiving the shadow of the moon (Figures 2 and 3) enduring seven minutes, does not admit of ten repetitions and ten experimental controls. But very important laws may be discovered from a single event.

The insurance man has the same problem; in life insurance he has hundreds of repetitions, and hundreds of controls. In disaster earthquake insurance, or in conflagrations, he has very few. Nevertheless, he learned something for his science in San Francisco, Tokyo and Napier. Henry Cabot Lodge, in spite of his opposition to Woodrow Wilson, said in a commencement address, "it is through the search for Utopias that the real advances have been made". Whatever your specialty in science, something about it may directly serve mankind out on the surface of the earth, and away from the congestion of cities. Science works either to discover the internal mind of nature, like Isaac Newton, or for a humanist love of nature like Audubon. The earth is a middle ground out of which we came ourselves; out of it comes all our food as well as the petroleum, iron and power that frame our civilization. The love of ultimates, describing something we cannot see in language which we do not understand, has tied science to cities.

But the age of infinite electric power is just across the threshold. Science is entering that door. The thing that created America was the frontier where man with axe and plow and rifle robbed nature and won freedom. The science of power is creating a new frontier that sees no limit to the materials and the arts that will build with the rock of the hill and the mud of the sea bottom. This is what is meant by the assertion that the earth is the chief subject of science.

It is the earth that affects our drinking water and our glands. It is the earth that produces a Utopia like the T.V.A. It is the earth that yields the atmosphere through which our airplanes fly. Seventy-two per cent of the earth's surface is a gigantic unexplored wilderness of fascinating possibilities possibly containing radium and all the rare earths and only just scratched for the first time by a recent invention that has taken a core six feet long from the mud covering this mysterious land. The core was obtained by shooting a tube straight down into the ground with a high-powered submarine gun (Figure 4). This wilderness is the bottom of the ocean.

The earth is necessarily the chief subject of science. It is conclusively so because science serves man. And man as the object of scientific effort is earthly, he is not celestial or electro-magnetic. It is in part science that is to blame, for

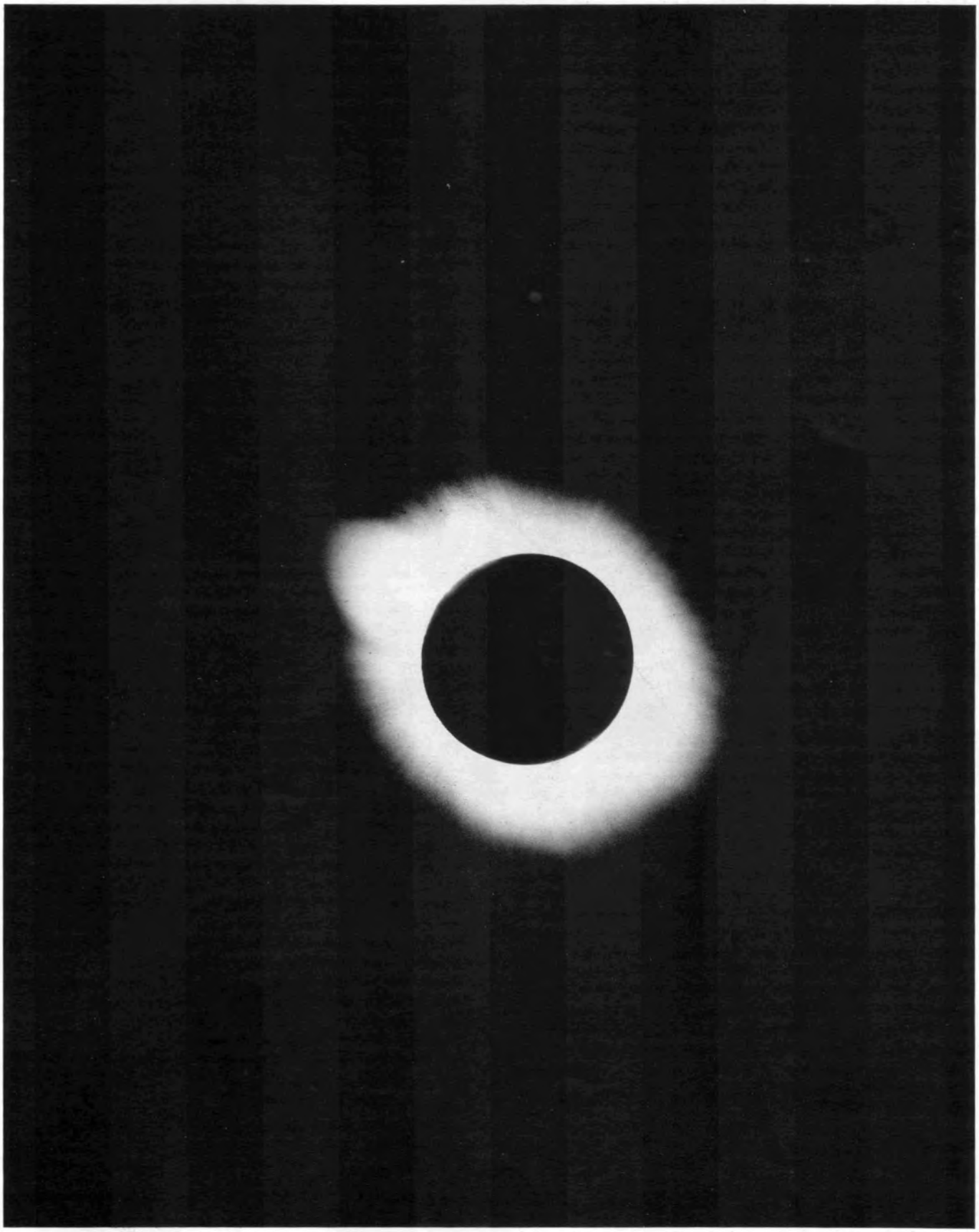


Figure 3. Photograph of the moon covering the sun's face. Niuafoou Island, October 21, 1930. Seventy men work three months for this photograph of an event lasting ninety-four seconds.

the misuse of science, that does not sufficiently consider man's happiness. Science agrees without protest to raising children in the sky-scraping gear wheels of a high stone-crusher like New York City, when there are thousands of square miles of country available with babbling brooks, grassy glades and sweet mountain air.

Science and education agree to an acquisitive society without protest, when every instinct of hygiene, sociality, uplift, public interest and experiment in the anthropometric laboratory suggests that human happiness lies in freedom, and in extroversion rather than acquisition. Science knows that an extrovert society will be more successful than an acquisitive one. Science has conquered distance and sluggishness, storm and savagery, famine and dearth.

But science shrugs its shoulder at the demand upon it to decentralize, to distribute and to invent a system of extrovert markets. Science knows it controls business, but it shrinks from reformation.

The terrestrial globe, the subject of the middle ground, producing the materials of physics and humanity intermediate between the electron and the germ cell, is pretty much left by the scientist to the rough and ready experiments of the prospector and pioneer, to the mountaineer and explorer, to the construction engineer and the navigator.

Laboratory science does not like to live in wild places. When we populate Howland, Jarvis and Wake Islands with a view to precise experiments in radio engineering and navigation of the air, we pick a group of Polynesian natives. If we were doing it in Antarctica we would pick a group of Eskimos or Icelanders. The suggestion is implied that no man or woman of European origin could reasonably be expected to live in a different climate. We are told that the Japanese have had similar difficulty in transporting their nationals to a colder belt. The earth is awaiting exploration by means of the new implements of modern science, but if modern laboratory science is afraid to dwell where the weather is hot, cold, dry or wet, the globe will remain undeveloped for the service of humanity.

Summary of trends in science

An attempt has been made in this essay for the speaker to review what fifty years of observation of natural history have impressed him as remaining unsaid and neglected in such general journals as "Nature" and "Science". The subject has been divided into four parts, in reviewing what seem to be the trends of scientific work in relation to human life for a century.

(1) First comes the overpowering importance of **Language,** both for thinking, and for arriving at agreement. Many scientists seem not to have realized with Willard Gibbs that logic, which comes from a Greek root meaning words, and mathematics, are languages and not sciences. It is not fair to say **mere** languages, because language itself, in the sense of the spoken tongue, is historically and constructively the most important implement in the whole range of all the sciences.

(2) Secondly, **Experiment** has been brought forward as the chief activity of science today. This is a great change from the time of Francis Bacon, who proposed categories, and extensions of science, which required observation rather than the invention of inductive tests.

A group of geologists, botanists, zoologists, and anatomists, meeting with natural philosophers and chemists at the Royal Society in 1845, was startled and delighted when Faraday sent in his nineteenth series of "experimental researches", to show that magnetic force produced an effect on polarized light. Medicine knew observational anatomy, and botany knew a systematic flora, but experimental physiology, phytometry, and phyto-chemistry had never been heard of.

There is of course nothing new nowadays in recognition of experimental work as a first essential of science. In my own science geology, however, the idea of experimental work in the field is decidedly new as a branch of pure science, and description of such work is notably lacking in the scientific journals.

(3) The third topic here considered, **Reformation** of the habits of mankind as the chief goal of science, is recognized by the gigantic efforts of special laboratories that the wealth of nations has produced, but is very little spoken of as an ethical ideal. The ethics of science emerges in the medical profession, and in some government activities actuated by political reform. In too many laboratories, however, science considers itself free, monastic, and privileged, or else it is frankly subservient to mercenary despotism.

The timidity of science in a bellicose world of overpowering industrialism and politics has had something to do with the two great catastrophies of the twentieth century.

(4) The last topic here considered, the **Earth** as the chief subject of science, involves a philosophical consideration, that few of you have ever thought of. Your own compartment was enough, and the earth could be left to the geologists.

What is the result? Thousands of men are at work building sensitive instruments, elaborating closed spaces for every possible temperature, pressure, and electrical condition, breeding insects, birds, animals, plants and bacteria for every possible service, and creating instruments of superlative grandeur, for evaluating the physical and chemical conditions of the universe of the stars. But all of this has preserved the habit of inertia in dwelling close to congestion centers, that existed in London in 1845.

It is only recently that the surface of the globe begins to be encased in a human net, demanding knowledge of the matter in outer atmosphere, mountain and plain, river and shoreline, sea-bottom and island; it is only recently that volcano and earthquake, simoon and flood, forest conflagration and drought, insect plague and blight, erosion and silt, have assumed proportions, where the interlocking of nations has made the misfortune of one a catastrophe for all.

Thus have sprung up geophysics, climatology, ecology, comparative anthropology, epidemiology, critical quarantine, and remedial construction in the service of insurance.

The people of London who looked upon Humboldt, Darwin and Livingstone as great explorers, have today barely begun to realize that travel is no longer a scientific virtue.

The discovery of the natural history of the earth by science can only be done by distributed laboratories that take pride in leading human enterprise to wealth that now is unsuspected. That wealth is partly materials, partly power, partly education. In metals China owns most of the tungsten, Canada the nickel, Peru the vanadium, South Africa the chromium, and America the molybdenum. The now precious xenon and krypton of the atmosphere are exercising the electric industry. The power of the sunshine and the tides is coming. **Science** it will be who shall educate the world to sheathe the sword, because happiness lies in experiments with mutual giving by men.

Hawaiian Volcano Observatory Report for May, 1937

VOLCANOLOGY

At Kilauea volcano the inner pit of the crater called "Halemaumau" went through another crisis of rim cracking on May 7, the east edge caving in, and carrying away a marked measurement-crack. This was an extension of the rim-breaking northeast that happened in October-November, 1936. Later in May the opening of eastern cracks diminished. There were two slight earthquakes, May 15 and May 30, the first of doubtful origin, the second about the Hilo end of the northeast rift of Mauna Loa. Thirteen very feeble shocks appeared to originate under Kilauea.

The following are the weekly Observatory totals for Halemaumau and the seismographs:

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Quakes
May 9	6.75	1	65.0	22
" 16	10.75	2	46.0	31
" 23	4.25	3	19.0	13
" 30	10.50	1	16.5	29

Sequence of Events by weeks

The first week produced the crisis of rim breakage at Halemaumau on the east side, just south of the notch which caved in last October. The description and photographs of that collapse appeared in Volcano Letter 446. The cracks there for several weeks have exhibited excessive opening. The index fissure was Crack No. 25, which expanded its opening 36, 42 and 57 millimeters respectively April 23, April 30 and May 7. On the last date came the falling in.

The second week showed eastern cracks continuing to widen and break the soil, and to make hot vapor.

The third week produced less widening of cracks and a few slides. New measurement marks back of northeast rim were established by placing copper studs on opposite sides of cracks. Seismicity declined.

The fourth week continued the lessening of crack-opening. In the wall of Halemaumau below the edge east an upright chasm was uncovered by a slide.

Slides at Halemaumau

Slides, and their effects, from the wall of the pit have been noted as follows:

May 7, evening, a length of about 40 feet along the rim caved in, probably 15 feet wide at the place of maximum breakage. Within this piece Crack No. 28 was destroyed and removed; this crack had not been opening, but was rigid with the rock that fell.

May 15, 2:35 p.m., a slide east, dust cloud and noise of falling rocks.

May 16, 8:30 a.m., a moderate slide sent up a dust cloud north.

May 18, 4:30 p.m., dust cloud from a slide northeast.

May 20, 11:05 a.m., a slide east sent a cloud of dust floating away westward.

May 21, 3:50 p.m., an east-northeast slide occurred.

May 25-26, night, a slide from the east wall uncovered an upright chasm, in the area of recent active caving fenced off from the Volcano House trail.

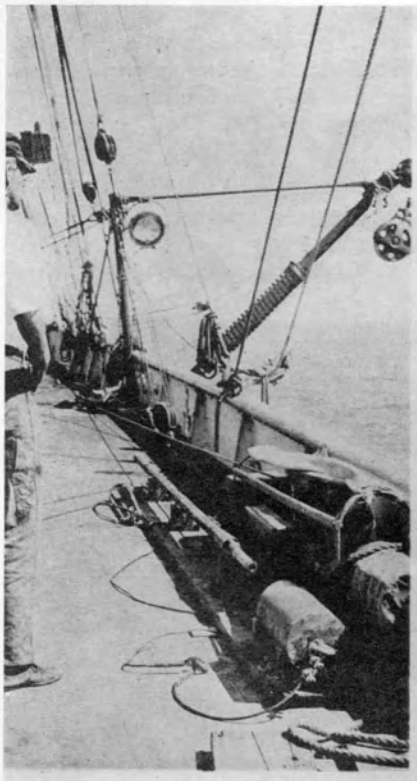


Figure 1. Apparatus in chocks on deck

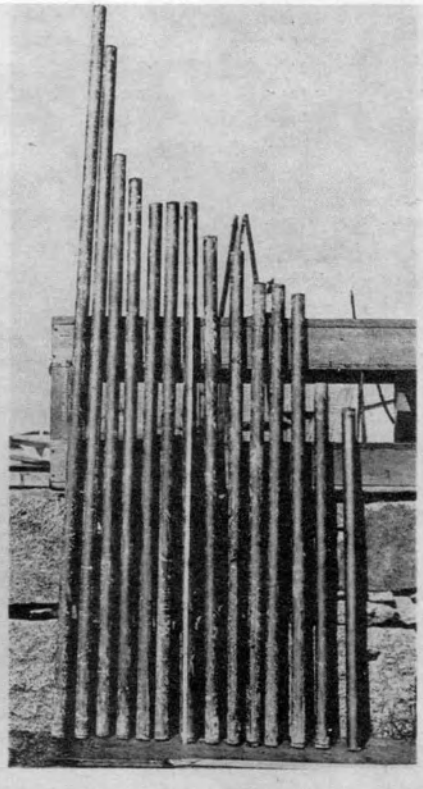


Figure 2. Cores taken August 1935 from depths of 200 to 1250 fathoms

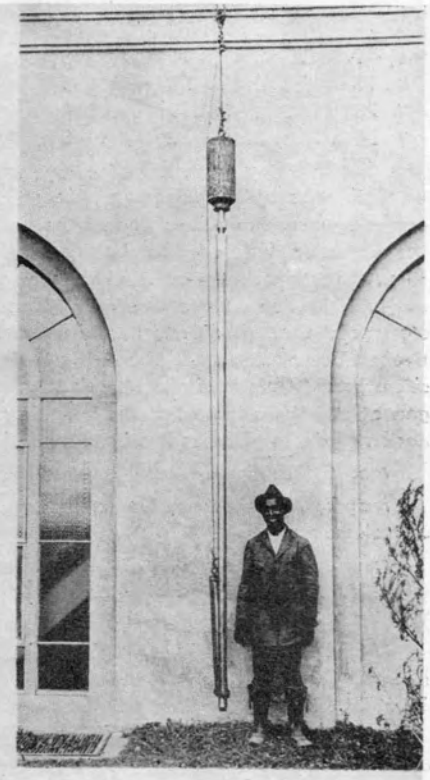


Figure 3. Core sounding apparatus ready for use

Figure 4. Core-drilling harpoon of Dr. Piggot. (Bull. Geol. Soc. Amer.—1936.) To sample the seventy-two per cent of unknown land—the sea-bottom. The gun takes cores 6 to 8 feet long in 200 to 1,250 fathoms of water.

Measurement of Halemaumau Rim Cracks

Weekly measurement of a varying number of rim crack locations destroyed and reconstructed during the month of May, resulted in aggregate movement as follows: week ending forenoon of—

May 7, 26 locations, 9 opened, 1 closed, opening 65.0 mm. collapse in evening destroyed No. 28.

May 14, 25 locations, 9 opened, 1 closed, opening 46.0 mm., to which Crack No. 25 contributed 40 mm. A new location, No. 37a, was established east of the road on an extension of Crack No. 37.

May 21, 26 locations, 7 opened, 1 closed, opening 19.0 mm., to which No. 25 contributed 14.0 mm. Four new measurement marks were established at northeast rim.

May 28, 30 locations, 13 opened, 1 closed, opening 16.5

mm., to which Crack No. 25 contributed 9.0 mm., showing marked decrease of rate. The ground extending the lost cracks of the east notch, after May 7, to the south of the notch, was broken and hot, with the soil ruptured and weeds browned with new vapor. Measurement with thermometer May 11 of the cracks south of Nos. 24 and 25, at 10:00 a.m., air 24°C., showed maximum crack temperature 64°C.

The break across the road southeast of Halemaumau, on the eastern extension of Crack No. 37, recently repaired, is moving again. Slowly this crack has opened: it is over the old sulphur beds on the Kilauea floor margin. The extension of the crack east of the road gave maximum temperature 50°C.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Slight Earthquakes	Weekly* Seismicity
May 9	17	5	0	6.75
" 16	25	5	1	10.75
" 23	9	4	0	4.25
" 30	22	6	1	10.50

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible, a determination of depth of focus has been made.

May 6, 10:06 am, very feeble, of Kilauea origin.

May 7, 7:44 pm, very feeble, accompanied a slide at E rim of Halemaumau.

May 8, 12:22 am, very feeble, located 2.7 miles deep 0.4 mile NW of Kilauea Military Camp. 19° 26.4′ N; 155° 16.7′ W.

May 14, 3:13 pm, very feeble, located 0.6 mile deep in Kilauea Crater adjacent to Kilauea Iki. 19° 25.3′ N; 155° 15.9′ W.

May 14, 3:29 pm, very feeble, located 1.3 miles deep under E rim of Kilauea Crater. 19° 24.9′ N; 155° 15.8′ W.

May 14, 3:56 pm, very feeble, same epicenter as preceding except 0.9 mile deep.

May 14, 5:37 pm, very feeble, of shallow depth in cracks immediately east of Keanakakoi Crater. 19° 25.4′ N; 155° 15.6′ W.

May 15, 1:18 am, a slight earthquake was recorded at the Observatory, Uwekahuna and the Pit. It registered as very feeble in Hilo and as a tremor in Kealakekua. Because of lack of definite phases its location was not determined although it is thought to have been of Kilauea origin.

* For local seismicity definition see Volcano Letter 371.

May 16, 7:42 am, very feeble, probably located 0.7 mile NE of Kilauea Crater.

May 21, 1:20 pm, very feeble, tentative location in Kilauea SW Rift about 10 miles from Halemaumau.

May 28, 12:09 am, very feeble, located in cracks east of Keanakakoi, SE portion of Kilauea Crater, 0.9 mile deep. 19° 24.1′ N; 155° 16.4′ W.

May 28, 6:12 am, very feeble, located 1.3 miles deep under east rim of Kilauea Crater near Kilauea Iki. 19° 24.9′ N; 155° 15.8′ W.

May 28, 8:50 am, very feeble, located 0.8 mile deep and 0.5 mile S of Kilauea Iki. 19° 24.6′ N; 155° 15.3′ W.

May 30, 2:53 am, very feeble, probably located under N rim of Kilauea Crater and near Kilauea Military Camp.

May 30, 3:03 am, slight, tentative location Mauna Loa NE Rift about 10 miles from Hilo. Reported felt one mile east of Hawaii National Park entrance.

Microseismic motion of the ground was strong May 3 to 16, May 22 to 24 inclusive, and was moderate the remainder of the month with the exception of May 30 when it was light.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau the algebraic sum of radial tilts towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending May 30 was 8.98″ S and 1.35″ E.

Week Ending	Observatory	Halemaumau West Station
May 9	0.83″ N 77° E	4.50″ S
" 16	1.03″ N 48° E	2.86″ N 37° W
" 23	0.45″ N 60° W	1.73″ N 71° W
" 30	0.62″ N 3.5° E	0.75″ S 12° E

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
May 9	8.10″ S 84° W	3.60″ Toward
" 16	8.94″ N 27° E	2.71″ Toward
" 23	1.49″ N 40° W	0.18″ From
" 30	3.63″ N 49° W	3.42″ Toward

H. H. W.

Crater Angles

Measurement of Horizontal angles across Kilauea Crater from the Observatory, May 27, showed slight closing of both Halemaumau and Crater values compared with similar measurements April 21. From Kilauea NE rim to Uwekahuna there was closing of 2.50″, April 21 to May 11, and opening of 0.84″ May 11 to May 27. Total closing 1.66″. From the Pit seismograph to NW Pit B.M. there was closing of 2.50″, April 21 to May 11, and closing of 0.42″ May 11 to May 27. Total closing 2.92″.

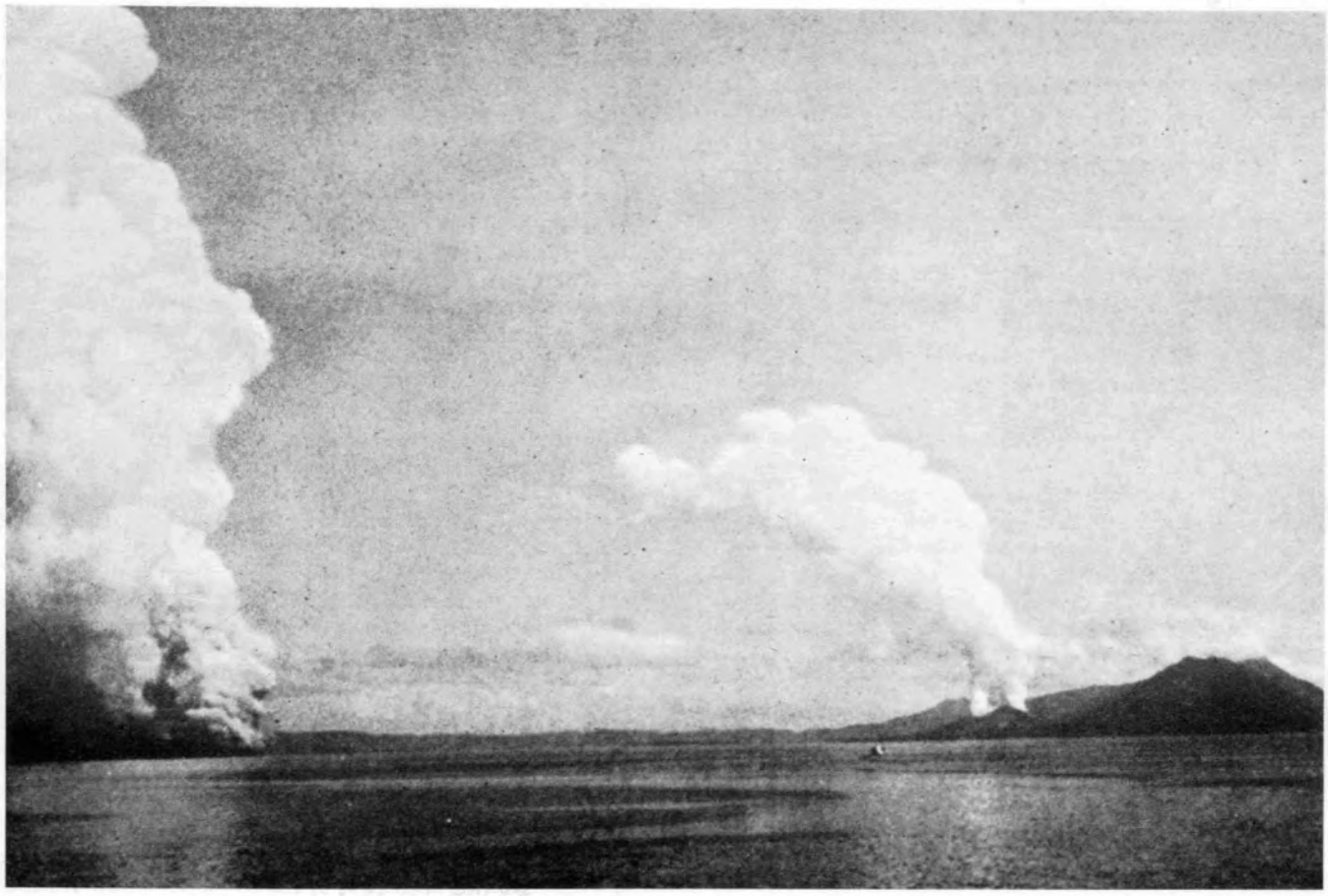
H. H. W.

THE VOLCANO LETTER

No. 448 monthly **Department of the Interior** **National Park Service** **June 1937**

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Volcanic eruptions that caused a temporary evacuation of Rabaul: Clouds of steam rising from the craters of Matupi (on the right) and Vulcan Island, the more violent of the two.

ERUPTIONS AT RABAUL, NEW GUINEA

Volcanoes of New Britain

At the northeast end of New Britain (formerly New Pommern), the middle larger island of the three that constitute the British mandated territory of New Guinea, the capital town in that tropical land of missions, mines and copra (Lat. 5° South, Long. 152° East) is called Rabaul.

It is on a protected harbor. An east-west arcuate belt of active volcanoes encloses the Bismark Archipelago to the north, and the middle of the bow, bellied southward, contains the volcano "Ritter Island". This island cone threw up flames and lava fountains in March, 1700, poured lava cascades in June, 1793, and made explosive eruption in March, 1888 (west of Mt. Nangila on map) that caused a tidal wave and ejected more than a third of a cubic mile of dust, gravel and rocks.

Ten years earlier two volcanoes erupted at the north end of the Gazelle peninsula where Rabaul now is; they were called "Ghaie" or Matupi, and "Raluan" or Vulcan. Matupi, 800 feet high, is a solfataric hill southeast of and close to Rabaul on the northeastern tip of the volcanic arc. The rift crosses Blanche Bay (Rabaul harbor) from southwest to northeast, and Vulcan island on the southwest side of the bay appeared above the waves in the 1878 eruption.

This eruption included both Vulcan and Matupi along a steam-blast rupture; it started February 4 and lasted four days for Vulcan and three weeks for Matupi. It made two tidal waves, and built at Vulcan a flat cone 70 feet high and 900 feet across; from a new crater on Matupi smoke, flames and pumice were ejected, piling dust and pumice on the country and blocking the channel.

Thus Matupi was the more violent in 1878, but it appears that Vulcan was the culprit in 1937. Vulcan had subsided to half its height by 1897; Matupi is a subsidiary crater to "Mount Mother", a mountain back of the town, and is visited for its steaming hot spring.

We are indebted to the Sydney "Mail" of June 9 for the following data about the town, the Papuan natives, and the eruptions:

With a northeast wind the fumes from Matupi start the natives talking about earthuakes, and about the memories of the terrifying eruption of sixty years ago; when the Beehive Islands at the entrance to the harbor lowered to their present height; and Vulcan Island was built up next to the southwestern shore of the bay, so that their banana plantations were weighted down with heavy ash; and fish and turtles were found cooked in the steaming waters.

About twenty years ago an "eruption" is reported whereby the Matupi Peninsula sank about eighteen inches, and rose to its former level within a few hours. One wonders whether this story might not refer to tidal wave effects of the "Father" eruption of 1912.

The natives of course attribute very feeble earthquakes, which are frequent in Rabaul, to "debbil-debbils", and just as the Hawaiian legend of Pele migrating from Kauai to Hawaii agrees with geology, so the shrewd Papuan observations tally with science.

Folklore has it that the active volcano "Father" (see Map) or "Ulawun" to the southwest, with two other hills known as "South Son" and "North Son", alternates in "smoking" with the Rabaul volcanoes known as "Mother", with her two offspring "North Daughter" and "South Daughter". It is of course the subsidiary crater of Matupi that does the smoking.

Geologists know that the "Father" group and the "Mother" group are on the northeast-southwest rift line of New Britain, and the alternation of activity is probable, just as between Mauna Loa and Kilauea.

Rabaul is built over volcanic ash and it is said to be extremely difficult sometimes to get an earth terminal for an electric circuit.

Vulcan Island after the nineteenth century was left about 100 acres in size, some 5 miles from Rabaul, a cone unconnected with the shore. It was 900 feet in diameter, 30 feet high, and fuming from solfataric vents.

The mission stations of Walour and Taviji were on the southwest shore of the bay close to this island, along the driveway leading from Rabaul around the bay. This leads to Kokopo, a village on the eastern point of New Britain, facing the strait that separates New Britain from New Ireland.

The 1937 Eruptions

During the past year earthquakes have been unusually numerous in Rabaul. Vulcan Island began to show signs of volcanic activity Friday morning, May 28, 1937, when the mission stations experienced severe earthquakes, and landslips were observed on the island. The earthquakes increased in violence during that day and the next.

On the afternoon of May 29 Vulcan Island broke forth into explosive eruption, throwing up clouds of fume, dust, ash, gravel and bowlders so thickly that day was turned into night.

An observer at one of the missions thought that the dusk was coming a few hours earlier than usual. Then he noticed that Vulcan Island was throwing bowlders many hundred feet into the air, and pumice was falling everywhere. He described seeing a ball of fire running along the top of the cone, this being followed by a terrific explosion.

Then Matupi Volcano broke out in sympathy, sending up sulphurous steam, cauliflower clouds, ash and pumice, but the main eruption that darkened the entire landscape was from Vulcan Island.

The water became violently agitated. The succession of explosive steam blasts came from the side of Vulcan Island apparently on a rift line extending in the direction of the Beehive Islands and Matupi Crater to the northeast. A dome-shaped jet of water was seen to shoot up about 50 feet, followed by another explosion hurling sea water up 100 feet. Then many explosions occurred at Vulcan Island itself, flinging up rocks and debris, the cauliflower clouds rising 4,000 to 5,000 feet.

Some of the longshore roads developed crater depressions and all were blocked with gravel and ashes. Plantations were damaged for many miles, crops of coffee and bananas were ruined and the coconut trees had their leaves broken down with heavy gray ash.

The dense black cloud appeared to descend from above on some of the mission villages, earthquakes were numerous, thunderstorms developed, trees were struck by lightning and were seen falling in earthquakes, heavy rains fell, and motor cars were choked with the dust and had to be abandoned in the mud.

Volcanologic evidence

We shall have to await scientific statements for an account of what happened in changes of the sea-bottom. The sea-bed is said to have changed in elevation so as to make a new survey necessary.

As usual with explosive eruptions great quantities of floating pumice appeared on the surface of Blanche Bay, and some of this was thought to be a new bank of sand and mud blocking the outer entrance to Rabaul Harbor. The ocean currents swept this out to sea within a week, and it was found that the outer channel was still navigable. Shipping could enter Blanche Bay and reach the wharves with safety.

What happened to Vulcan Island itself may well have been a rising of stiff magma along with the building up of a symmetrical cone and cup, as shown in the pictures. We learn from the accounts that the island has been raised from 30 feet to a large hill more than 700 feet high, and from an island 900 feet across, to a peninsula three-quarters of a mile in diameter connected with the mainland by the new accumulations.

There is no evidence nor probability that liquid lava flow occurred. The worst of the eruption was on Sunday, May 30. The eruption died away very rapidly. When Vulcan Island was enveloped in smoke, the first impression of the onlookers was that it had disappeared.

One observer described a sudden lift of the island when the water waves occurred which played havoc with many of the smaller vessels, some of them being beached high and dry on the foreshores. Soundings were taken by a survey ship on Saturday, June 5, showing plenty of depth in the main channel.

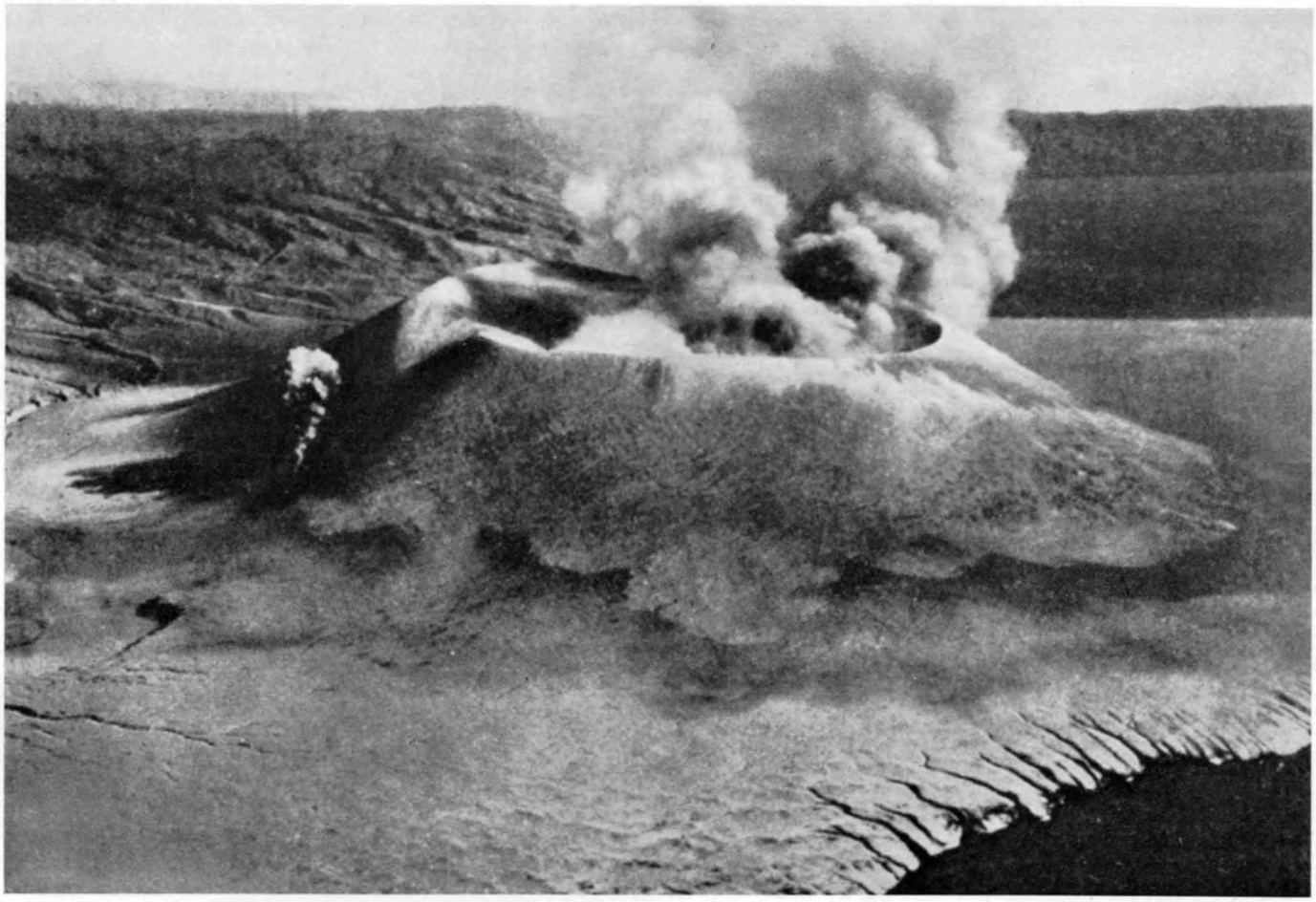
like "Anak Krakatoa", of a constructive effort of rising magma acting through the ages, and reacting with groundwater.

We may conclude that the nature of this eruption was not particularly different from other eruptions of this volcanic belt, and to judge from Sapper's report concerning Father Volcano in 1912, and Ritter Island in 1793, this belt of volcanoes is quite capable of pouring out lava occasionally.

Von Wolff reports the recorded specimens of lava from this bay to be pyroxene andesite, and of pumice from New Britain to be andesite pumice. The minerals are plagioclase, angite, hypersthene and magnetite. Silica varies from 57% to 62%, and iron oxides from 6% to 8%. Specific gravity is 2.36 to 2.51.

Effects on the People

The evacuation of Rabaul was ordered, and was carried out efficiently with the aid of ships that moved the people from Nodup (a village close to Rabaul), to Kokopo, twenty miles south. Some 4,500 people were moved, and about 20



The erupting crater of Vulcan Island (normally low-lying) seen from the air: a view showing molten pumice building the cone hundreds of feet high and flowing into the sea.

The observer in question reported that Vulcan Island rose rapidly at the time of the tidal crisis so that where there had been water and a few rocks, solid land appeared. The interpretation of the airplane photographs was that "flowing pumice" spread down the sides of the cone.

There was the usual reddish glow seen in the reflections from the crater on the clouds. This and the presence of pumice show that frothing magma took part in the groundwater explosions, and it is probable that this is just one more example,

stayed to guard the place. The rain of ashes and mud was the principal cause of damage in the town, the heavy weight breaking down structures and destroying vegetation. Food supplies were transported from Nodup to Kokopo by schooners, and a large camp was made at Kokopo with sanitation directed by the government. The refugees included 3,000 natives, 800 Chinese, and 700 whites.

Within a week the harbor was clear, and progress had been made in cleaning the town. The island superintendent of one

trading firm suggested moving his headquarters to Madang, on the coast of New Guinea. This company's wharves at Rabaul were valued at $150,000, and could not be shifted. Moreover, the harbor is better at Rabaul than at Madang.

However, the trading firms had grave doubts about building and expanding on a place between two active volcanoes.

Ship Reports

Two larger steamers were in harbor, the "Golden Bear" of the Matson Line, and the "Montoro" of the Burns Philp Line. These were not injured and were instrumental in evacuating the population. Two steamers and a schooner were swamped.

At 1:00 P.M., May 28, the "Montoro" passengers, with ship moored to the pier at Rabaul, suddenly felt violent earthquakes and saw buildings rocking and palm trees falling, so that the roadways were blocked with fallen timber. Quakes continued throughout the afternoon and at 5:00 P.M. the "Montoro" sailed.

The "Golden Bear" was loading copra at a pier in the harbor when the eruption started the next afternoon, May 29, and a radio was sent to ask the "Montoro", then 120 miles at sea, to return. The land radio station was put out of commission by the eruption. The "Montoro" was showered with dust 100 miles away and in approaching the harbor found the ocean surface covered with pumice.

The columns of steam above the volcano rose white and fluffy, with an inky black inner column that exhibited rocketing bowlders falling back into the crater. With every new jet lightning and thunder occurred.

The explosion of Matupi came at 12:45 A.M., May 30, and large pieces of rock were flung up from its crater.

Captain Olsen of the "Golden Bear" had been doing heroic work, taking on board at Nodup hysterical women and children, hospital patients, and the Chinese population.

"The "Golden Bear" had at first been tied up at the wharf in Rabaul right in the path of the dust from Vulcan Island, and the falling pumice, heat and gasses were such that the danger was great, while the tidal waves chafed the lines, and grounded the ship. The water was covered with pumice and the outward channel looked as though new sand-bars had risen.

There might not be any channel and the course out involved passing close to the spouting volcano. The captain did not hesitate, but let go his moorings, ordered his crew below decks, cleared the channel and reached the open sea in a magnificent performance of seamanship. Then he turned about and anchored off Nodup.

The natives were loaded ten deep on the decks of both ships along with their dogs, cats and parrots. There was no panic. The launches pulled three boats at a time. The mission at Kokopo did splendid work in housing and feeding refugees.

The "Montoro" left on June 9, Captain Mitchie of that ship clearing for Sydney with some 200 refugees.

Some details of the eruptions

Rabaul was covered in places with dust four feet deep, and boats had been washed up into the streets. The tropical trees and shrubs were all broken and not a green or living thing was in sight. The water, light, and telephone systems were broken down, hardly a roof was intact, the roads were a mass of ruts, and the health commissioner could not allow any one to live there until the place was cleaned up.

Captain Olsen himself described the detail of the eruption as follows:

The ship was tied up at a dock near Rabaul at the time. Before doors or portholes could be closed a foot of pumice dust had settled in every nook and cranny of the ship, destroying clothes and other property. Most of the crew were ashore at the time of the terrific outburst of Vulcan Island. All returned to the ship, however, except Radio Operator V. M. Costner, who in the darkness may have fallen into the sea from the wharf, when attempting to grope his way back through the blinding, choking gaseous smoke which enveloped the town.

Captain Olsen is quoted as follows (Honolulu Star-Bulletin, July 12):

"About 4:10 P.M., May 29, I was outside on the starboard side of the lower bridge deck. Looking toward Vulcan Island, I saw a small white speck on the water near the island which swelled and rolled over, with the appearance of a large, fluffy cotton ball.

"It was only when the ball began to ascend into the air that I realized it was a volcanic eruption. After three or four minutes the island suddenly burst wide open, and with a tremendous roar sent a column of white steam and black lava smoke thousands of feet into the air.

"The mixture of gas and lava enveloped Vulcan Island and drifted in a northwesterly direction over the mainland, but after the first outburst the wind suddenly switched and sent the cloud of black smoke and debris in the direction of the "Golden Bear".

"The ship was enveloped in a cloud of gaseous ashes. All visibility was completely obscured. We left the ship under conditions difficult to describe. We crawled along on the wharf on our hands and knees. We felt our way along the car-tracks. We nearly suffocated. Fortunately, the wharf office door was unlocked and we all took shelter there against the heavy downpour of ashes."

A check of the men revealed Mr. Costner missing. In the late afternoon the Captain and the crew returned to the "Golden Bear" and succeeded in keeping her from being materially damaged by a series of minor tidal waves.

After reaching the Kokopo anchorage, May 30, Captain Olsen had a view looking northwest of the two volcanoes in action. Two great columns of white and black smoke ascended for thousands of feet. Spreading out and coming together at the top, they formed a gigantic archway over the entrance to the harbor.

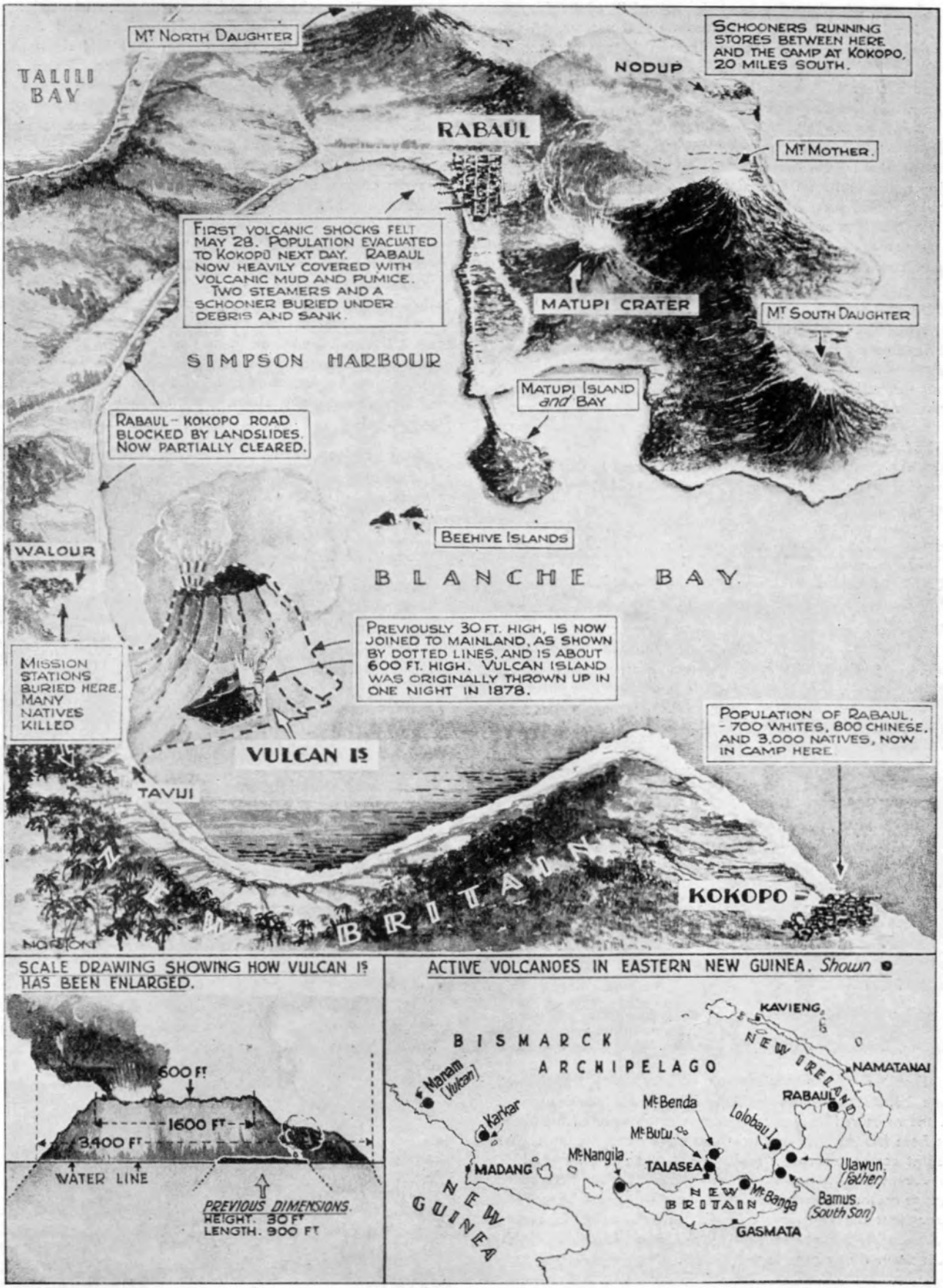
Vulcan Island, the largest and heaviest of the two eruptions, was a magnificent sight during the night. Great masses of fire would be thrown into the air for distances of 4,000 feet, measured by sextant. The barrage would curve over and outwards and, exploding, fall back to the earth in a rain of fire.

J. W. Faulkner took the place of the lost radio operator on the "Golden Bear" in Rabaul. His ship, the "Durour", was on a marine railway close to Vulcan Island when the outbreak occurred. He and his companion barely succeeded in escaping to Rabaul in a motor boat. His ship, with the natives on board, was completely engulfed and sank out of sight.

Faulkner described the rising of a reef some 10 feet above water near Vulcan Island. This happened during the earthquakes that occurred in the 24 hours before the eruption.

Conditions at first in Rabaul were terrible during the eruption. While refugees were being transferred to outside plantations, it was necessary to erect temporary dormitories for the sick and injured. Rescue parties went from house to house searching for any who might be trapped.

In Kokopo there was an acute shortage of food and water, bad sanitary conditions prevailed and anxiety was expressed over the possibility of dysentery and typhoid. The mosquitoes were bad and the people were destitute. The swimming pools were thrown open to the women and children, many of whom maintained a stoic calm throughout the ordeal. The casualty cases were attended by one doctor and numerous nurses.



The tragic course of events in stricken Rabaul.

Captain Olsen's estimate of the loss of life caused by the eruption was reported as approximately 250 natives, 10 Chinese children, and 1 European. In the Sydney account the losses of life were known to be two white men, and in the missions close to Vulcan Island not less than thirty native women and children, overwhelmed by mud and ash.

Whatever the fact, this small loss of life in a harbor populated by 5,000, with an active pair of volcanoes athwart it, is a splendid tribute to the efficiency of the sailormen, traders, missionaries and local authorities in facing a sudden crisis and moving 4,500 people. They were assisted by ships, airplanes and radio. It seems likely that a volcanologic observatory and a system of earthquake stations might learn the cycles of recurrence, and greatly assist the New Guinea government.

T. A. J.

VOLCANOLOGY

After the May crisis of caving in of the eastern rim of Halemaumau pit, Kilauea Crater entered upon a period of comparative quiet. The establishment of thirty marked crack locations around the rim of Halemaumau, which had been renovated in May, exhibited in June only a quarter of the aggregate crack opening of May. The numbers of quakes, tremors and slides remained about the same.

The following are the weekly Observatory totals for Halemaumau and the seismographs:

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Quakes
June 6	15.00	0	11.0	20
" 13	11.25	1	10.0	35
" 20	12.75	4	10.5	36
" 27	5.50	2	9.5	16



A car covered with six inches of volcanic ash, which stopped the engine and compelled its owner, who was leaving for Kopoko, to abandon it: a typical scene of desolation in Rabaul.

Feeble shocks somewhat felt occurred May 31, June 3, June 13, June 16, two on June 20, June 21 and June 25. Of the measured local earthquakes, sixteen were from Kilauea, six from Mauna Loa, and two from more distant sources. Two distant earthquakes were registered June 21 and June 24.

A remarkable slow horizontally-moving fireball from southwest to northeast, with flaming tail, and without noise was seen throughout the Territory of Hawaii at 9:50 p.m., June 4. It was probably seventy or eighty miles away to the southward from the middle of the larger islands.

Sequence of Events by Weeks

The first week produced nothing important at Halemaumau. Crack widening, seismic frequency and sliding had all lessened. The yellow sulphur heap at the northwest margin of Halemaumau floor continued to fume hotly, and there was much cracking and sulphurous stain that had developed at the S.S.E. and N.N.W. edges of the floor. These places steamed occasionally, especially during wet weather. The northeast edge of the floor was now completely covered by new overlapping talus heaps from the north to the east sides of the pit. These have all been added to between October, 1936, and May, 1937. The wall above is raw and freshly scarred, and the rim of the pit is considerably changed by notches which have enlarged its circumference.

The second week produced a lessening of seismicity and widening of cracks, and one slide was noticed.

The third week there were more slides, characterized by location on three sides of the pit, a new feature in that nearly all slides during the previous years had been from the east and northeast walls. Seismicity and crack widening continued about the same, with much of the latter limited to a single crack at the east rim.

The last week showed notable decline in all the measured features of seismicity, slides, crack openings, and numbers of quakes.

Slides at Halemaumau

Slides from the wall of the pit Halemaumau have been noted as follows:

June 9, 8:57 a.m., a slide at the northeast wall.
June 14, 2:07 p.m., rocks fell from the east wall.
June 17, 9:57 a.m., a slide started from about half-way down the south wall.
4:35 p.m., a slide occurred at the east.
June 19, 10:45 a.m., a large slide occurred on the west side of the pit.
June 22, 11:25 a.m., a slide at the east wall made a small dust cloud.
June 23, 8:30 a.m., a slide at the northwest wall made a fairly large dust cloud. Slides south, west and northwest have been very unusual for the last year.

Measurement of Halemaumau Rim Cracks

Weekly measurement of a constant number of rim crack locations as reconstructed during the month of May, resulted during June in aggregate movements as follows:

Week ending forenoon of:

June 4, 30 locations, 8 opened, 3 closed, opening 11.0 mm.

June 11, 30 locations, 7 opened, 4 closed, opening 10.0 mm.

June 18, 30 locations, 10 opened, 5 closed, opening 10.5 mm., of which 6 mm. was accounted for by Crack No. 25 at east rim.

June 25, 30 locations, 10 opened, 2 closed, opening 9.5 mm., of which Crack No. 25 accounted for 5.0 mm. Crack No. 25 is one of the steaming extensions of the caved-in cracks of the east notch that collapsed May 7.

T. A. J.

SEISMOLOGICAL DATA

TABLE

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant* Earthquakes	Weekly§ Seismicity
June 6	46	3	2	0	15.00
June 13	27	7	1	0	11.25
June 20	27	6	3	0	12.75
June 27	14	0	2	2	5.50

§ For local seismicity definition see Volcano Letter 371.
* Including teleseisms or those shocks over 5000 km. distant.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory, and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the times indicated and, whenever possible, a determination of depth of focus has been made.

May 31, 6:18 am, very feeble, located 1.2 miles deep in Kilauea Crater near the old Stone Corral. 19° 24.8′ N; 155° 16.3′ W.

May 31, 6:29 am, feeble, located in N portion of Kilauea Crater 1.0 mile E of Uwekahuna. 19° 25.5′ N; 155° 16.5′ W.

May 31, 7:32 am, very feeble, probably located in SE portion of Kilauea Crater.

June 3, 3:07 am, feeble, located in Hilina Pali Fault system 9.0 miles S of Halemaumau 10 miles deep. 19° 17.2′ N; 155° 18.5′ W.

June 4, 10:40 am, very feeble, probable location in Kilauea Crater.

June 7, 6:46 am, very feeble, located 25.0 miles deep in Kohala District 5.0 miles east of Mahukona. 20° 10.3′ N; 155° 49.0′ W. Reported strongly felt in Kohala and at Kamuela.

June 9, 9:12 am, very feeble, of Kilauea origin.

June 12, 11:29 pm, very feeble, located 0.8 mile deep in E portion of Kilauea Crater. 19° 24.9′ N; 155° 16.1′ W.

June 13, 9:21 pm, very feble, located 3.8 miles deep in vicinity of the old Prison Camp 1.2 miles NW of Uwekahuna. 19° 25.8′ N; 155° 18.3′ W.

June 14, 7:01 am, very feeble, located 4.3 miles deep under N rim of Kilauea Crater 0.5 mile NW of Volcano House. 19° 26.2′ N; 155° 15.9′ W.

June 16, 4:52 am, feeble, located 0.5 mile E of center of Halemaumau in Kilauea Crater 1.0 mile deep. 19° 24.5′ N; 155° 16.7′ W. Reported felt rather strongly at CCC Camp on SE rim of Kilauea Crater and moderately felt near Park Headquarters.

June 16, 10:35 pm, very feeble, located in Kilauea Crater.

June 17, 11:27 am, very feble, thought to have been located in SE portion of Kilauea Crater near Keanakakoi.

June 21, 2:16 pm, feeble, probably located in Chain of Craters rift near Puhimau Crater.

June 25, 6:20 am, feeble, probably located 9.0 miles S of the Volcano Observatory in the Hilina Pali fault zone.

Seventeen minutes of continuous tremor began recording at the Observatory at 12:13 pm, June 5 and sixteen minutes of continuous tremor began recording at 9:22 am, June 6.



Trees stripped of foliage and their broken branches strewn on the ground: havoc caused by volcanic showers during the eruptions near Rabaul, the capital of New Britain.

Microseismic motion of the ground at the Observatory was light May 31, strong June 5, 6, 8, 15, 16, 17 and 19 and moderate the remainder of the month.

The preliminary waves of a teleseism began to register at Kilauea at 4h 55m 8s, am H.S.T., June 21. It was estimated to have occurred 5450 miles away. There was a partial trace of a teleseism recording at the Observatory June 24, 3:18 am H.S.T.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending June 27 was 8.8" S. and 1.35" E.

TABLE OF TILT

Week Ending	Observatory	Halemaumau West Station
June 6	0.60" N 4° E	1.49" N 79° W
June 13	0.60" S 4° W	2.24" N 87° W
June 20	0.60" N 4° E	1.49" N 80° W
June 27	0.50" N 4° E	1.40" S 70° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
June 6	1.75" N 55° E	1.16" from
June 13	4.01" N 72° W	1.16" toward
June 20	4.18" S 71° E	5.06" from
June 27	7.65" N 28° W	6.12" toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory June 19, slight closing of the Halemaumau value and opening of the crater value as compared with similar measurements May 27. From Kilauea SE rim to Uwekahuna there was opening of 0.82" and from the Pit seismograph to NW Pit B.M. there was closing of 2.01".

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Ascsociation was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

THE VOLCANO LETTER

No. 449 monthly Department of the Interior National Park Service July 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

WORK OF F. A. PERRET ON MONTSERRAT

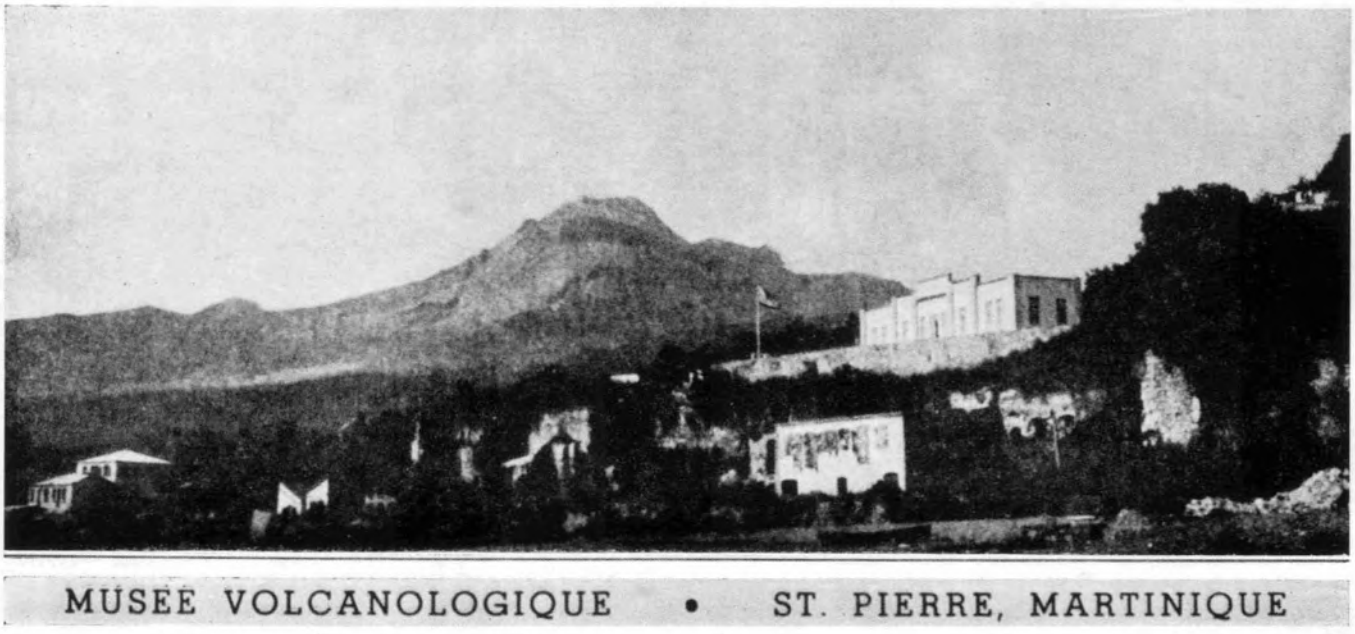


Figure 1. Museum at the ruins of St. Pierre, Martinique.

The Monserrat earthquake crisis of 1933-1936 was described in Volcano Letter No. 437, July 1936. Frank A. Perret, the volcanologist whose museum at St. Pierre, Martinique, is shown in Figure 1 (with the great new andesite dome of Mont Pele in the background) was called in to help by the governor of the Leeward Islands Presidency. Perret helped us in Hawaii in 1911, and his whole career has been devoted, as a volcanologist, to helping people in stricken volcanic lands. It may be of interest to show how such a man works. The Montserrat crisis was an apt illustration of such work, an island suddenly rushed into earthquake disaster in 1934, and its administration instinctively summoning the nearest expert for assistance.

The course of development of the Montserrat earthquake crisis, and its decline, are shown in the accompanying diagram, Figure 2. The columns are monthly seismicity. The four high ones May and December 1934, May and November 1935, were all times when churches and other masonry buildings fell, landslips occurred, and people were injured. These were earthquakes of grade VIII to IX Rossi-Forel. Frequency varied with intensity, and the sequence was from several and small shocks in 1933, itself a most unusual spell, to hundreds and severe earthquakes in summer and winter of the next two years. A terrifying feature of the crisis was the centering of these quakes at Gage's Soufriere, a crater gorge directly above the town Plymouth and only two miles away.

E. O. Hovey in revisiting the West Indies in 1903, after

careful work on Mont Pele in 1902, described these "principal craters of Montserrat as appearing to be in almost exactly the same condition as that of Pele, before the 1902 series of eruptions began."

Along with the coming of the quakes, the Montserrat solfatara gorge started vomiting up noxious odors of hydrogen sulphide, whose "rotten-egg" smell penetrated the town, and the gas actually darkened the white paint of steamers lying at anchor in Plymouth harbor. (Map, Figure 3.)

A striking feature of the map is the 100-fathom dotted line at the north. This contour under the sea is a half-circle. It outlines an ancient big volcano. The volcanic activity of recent ages has migrated to the south end at the Soufriere Hills. These hills have hot solfataras steaming and depositing sulphur on three sides. The ancient northern volcano is mostly eroded away by the ocean, leaving a platform 20 to 30 fathoms beneath the waves.

The new gas development was noted in April 1933 and earthquakes that year were most frequent at St. George's north of Soufriere Hills. They increased in force and number to April, 1934 and the government commissioner sent telegrams to inquire about volcanic conditions, which were found not to have changed in St. Vincent, Martinique, Guadeloupe and Dominica.

New sulphur vents were opening at the Montserrat solfataras. The hospital and private buildings were damaged by a sharp shock April 9, 1934. Revising the whole method of building was suggested.

Vague reports were at hand of a volcano scientist camped

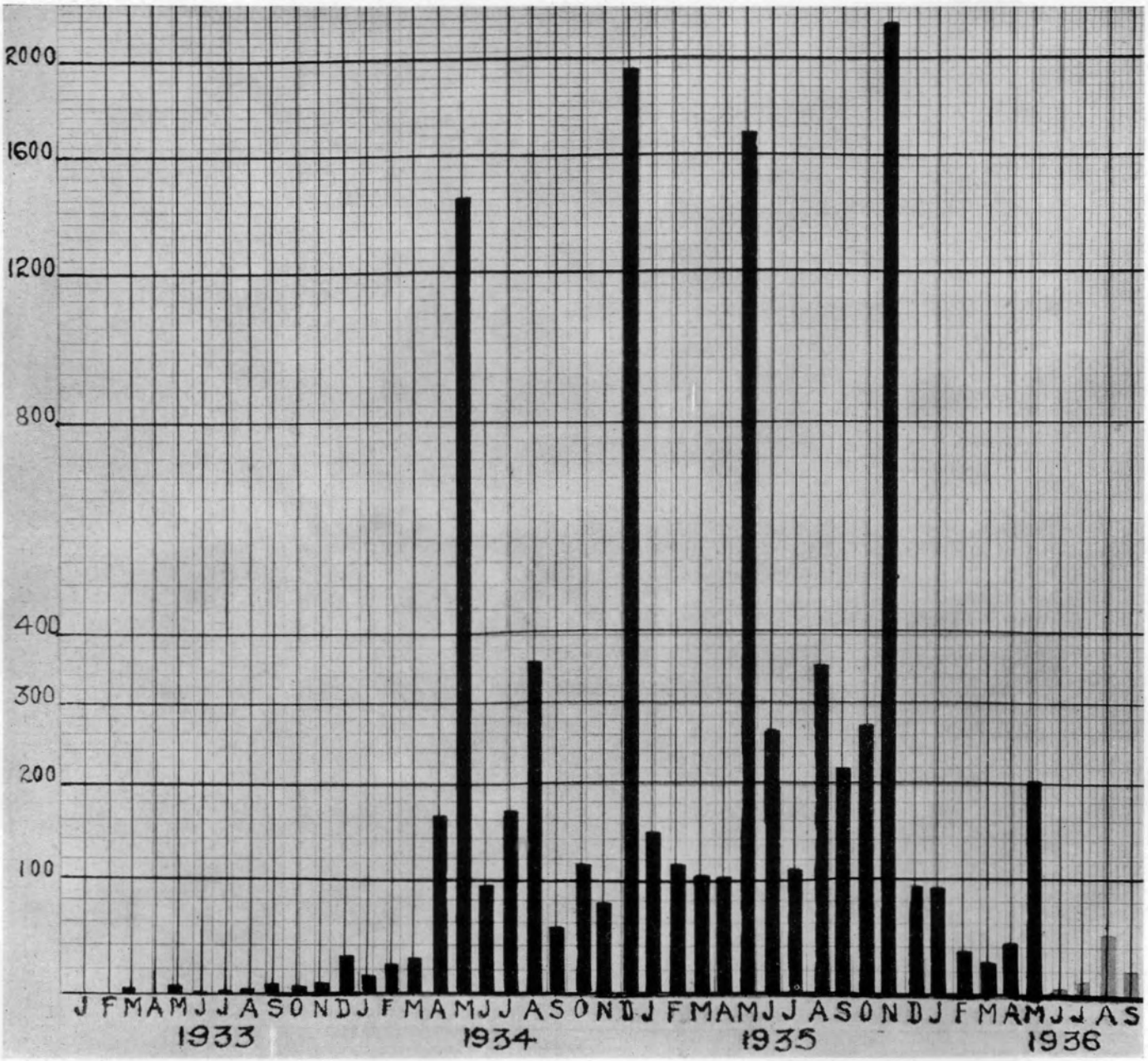


Figure 2. Chart of the rise and fall of earthquake activity in Montserrat.

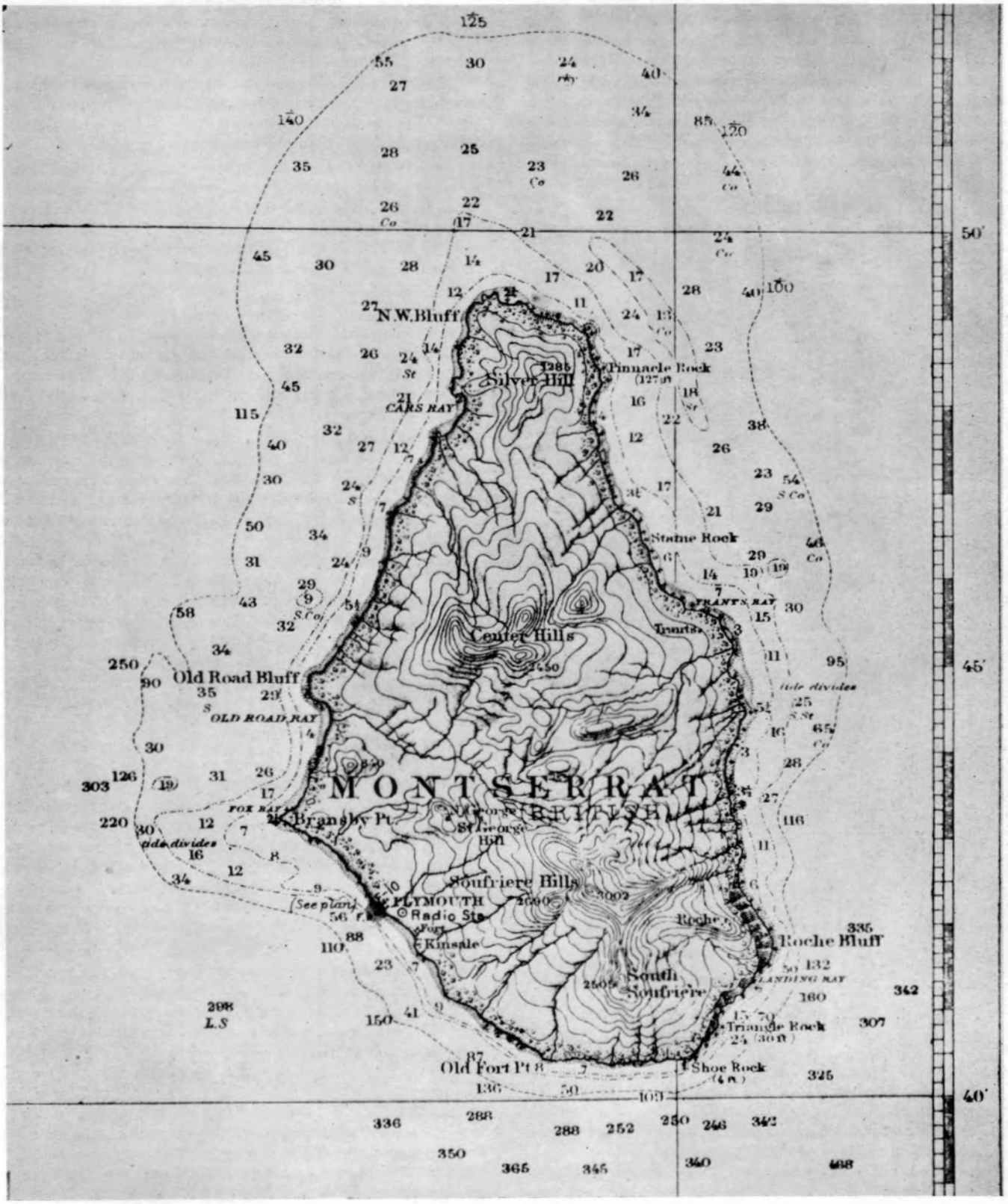


Figure 3. Chart of Montserrat, an island about ten miles long.

on Mont Pele with microphones in the soil. The British consul in Martinique phoned Perret, who was the reported scientist very much alive, and who reported Pele quiet.

May 13-14, 1934 produced sixty shocks, which cracked houses during an exceptional jolt at 2 a.m., the worst in thirty years. All of this was racking and weakening the old masonry.

Perret came by on a steamer en route to New York, visited Gage's Soufriere May 13th, predicted more shocks that day which duly came, and warned of more danger. A terrible shock came at 3 p.m. the 14th, seriously damaging the courthouse, all business was suspended, disorganization and disrupted sanitation were threatened.

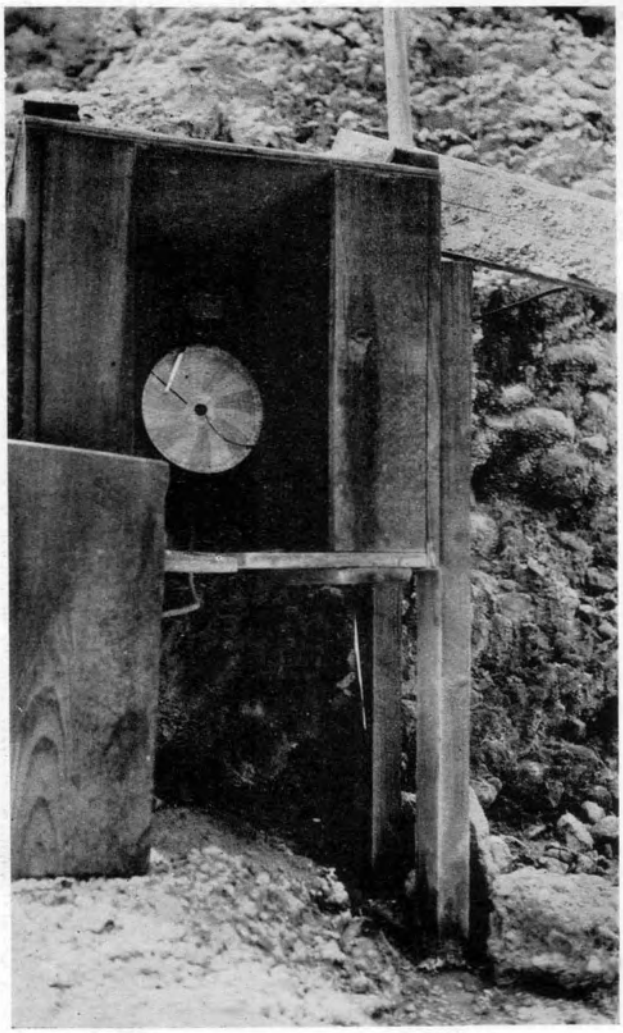


Figure 4. Bristol thermograph at Gage's Soufriere.

A warship was summoned and came May 21-31 to calm the people; earthquakes kept swarming. Following Perret's advice counts were made of the quakes, scientists of the agricultural station made daily visits to Gage's Soufriere and took temperatures, and notes were made on the chemistry of the waters and gases.

In July Mr. Perret was invited to return and install instruments; he had taken a water sample to Washington from the solfatara. No seismograph had yet been supplied.

Mr. Perret wrote Mr. Gomez, the director of agricultural station, suggesting a direction-finding seismoscope which was duly installed: "Suspend a series of weights of one pound each with fine wire as simple pendulums, of lengths varying 6, 12, 24, 48 and 96 inches. By watching these when shock occurs, some will swing, others not, showing period and direction of earth vibration. By setting up sets in different places much may be learned regarding the source of the shocks by coordinating directions."

Perret's hope is for a research organization eventually endowed for the Caribbees; with a base, a motor yacht with apparatus, ready to proceed without delay to any locality where trouble is reported, there to land and investigate conditions.

In Washington he secured support from the Carnegie Institution for investigating the Montserrat crisis, and sent vacuum tubes for collecting gases. He secured a Bristol gas-expansion recording thermograph with weekly charts, the lead-covered bulb to be buried in a gas fissure at Gage's solfatara; also microphone, and maximum thermometers.

He arrived and set up the instruments the end of November. Throughout his work he watched closely the luni-solar combinations, which might influence earth-tide stress in relation to gas tension in subterranean magma. The gas tension is localized in the crust. The earth tide varies seasonally, and varies exceptionally with certain sun and moon positions. The whole crust pumps with the earth tide.

The sudden frothing of volcanic magma in a subterranean fissure is a large force accumulated locally of a different kind, subject to release if the small tidal force relieves pressure exceptionally on certain dates. It is quite possible that deep plutonic earthquakes are so released, and are concerned with changes of state of magma.

Perret's reports to the governor were printed in the Leeward Islands Gazette between December 12, 1934 and May 19, 1936 in a series of letters from Montserrat, on the occasions of his several visits, coming sometimes by steamer, sometimes in haste by airplane and sloop from Martinique through Antigua. For a man of seventy they show extraordinary vigor; he made nine reports; and he built a hut within the crater gorge where he actually tried to sleep, until he injured throat and eyes with the deadly gases.

The Bristol thermograph (Figure 4) was set up in the bottom of the steaming gorge at Gage's. It registered 105° C. and the strong shocks also made of it a seismograph, by disturbing the ink pen. Mercury in saucers, for observation of small tremor, was placed in four localities. Gas tests were made with lead acetate and litmus paper. The hydrogen sulphide was tested thus even at Plymouth. The litmus at Gage's showed water sour with sulphuric acid, and air in the gorge which was alkaline. A gas irritating to eyes was thought to be hydrogen persulphide. Photographs were taken.

Vacuum tube collections were sent to Washington for gas analysis. The water analysis showed heavy charge of hydrogen sulphide, iron, alumina, sulphur, silica and organic matter; acidity 0.1 per cent, chlorine a trace; the gas analysis showed equal amounts of sulphur and chlorine. No fluorine could be detected in the waters.

A very sharp culmination of many earthquakes at 11 a.m. December 12, 1934 did more damage, was experienced by Perret, and differed from the widely felt May shocks in being highly localized, near Gage's, as though from magma close to the surface. This was disquieting with reference to possible eruption. The gas pressure had increased and spread at Gage's. The hydrogen sulphide was diagnosed as coming from dry vents lower than the wet solfatara. No tremors actuated the mercury surfaces between shocks, and the latter were sharp and brief. Absence of volcanic tremor indicated absence of moving magma, and the microphone confirmed this. The local observers were instructed to carry on with the instruments when Perret returned to Martinique.

Perret's second visit was in February-March 1935, and systematic observations had meanwhile been reported by the local men. He occupied his hut (Figure 5) in the crater gorge, observing the thermograph; the mercury bath with bell-glass cover mounted in a niche; a microphone buried in the ground; an air-microphone for the pressure-note of gas emission; a seismic pendulum for detecting direction of movement in earth shocks, with a mirror reflecting the beam from an electric torch at night.

A new hydrogen sulphide vent opened whistling the night of February 20, 1935. The other acrid alkaline gas that affected eye tissue made night stays impracticable. Tight-fitting goggles helped in daytime. Some subterranean sound was heard occasionally. The Bristol thermograph gave a deceptive indication of rising temperature on the record, which proved to be due to corrosion and weakening of the metal spiral. Check with thermometer proved error. "Bread-crust" bombs like Pele's were found in the gorge. Perret expressed intention of return in May, the critical month of 1933 and 1934.

The next visits of the American volcanologist were in April and May, 1935 and a severe, prolonged and deep shock did more damage on May 6, and exhibited much horizontal movement. The area shaken was farther north. The earthquake was preceded by early morning tremors, and very heavy rains came at 3:55 p.m. and were followed by aftershocks all night. The wide-spread effect relieved apprehension of volcanic eruption for Perret; the disturbance was not craterally localized.

Perret called attention to the sum total of the energy released and dissipated in the long series of earthquakes. If this energy had been concentrated in a single shock, like the Tokyo earthquake of 1923, the wreckage and loss of life might have been far worse. The comportment of the population, largely Negro, was good.

The deeper and more diffuse quality of the May 6 shock of 1935 satisfied the investigator that the volcano eruption danger had culminated at the December 1934 shocks, when high gas pressure and temperatures were dominant at the solfataras. Both had diminished in May 1935 when the deep earthquake came, and did tremendous seismic damage. Mr. Perret stated definitely to the authorities that possibility of more strong shocks remained, but that we might "now discard all likelihood of volcanic eruption."

To make such a statement as this required courage. The event bore out its accuracy. In a paragraph of his final report when the Royal Society Committee was about to take his place he says, "It has been inspiring to work in such an atmosphere of discipline and good will, and I shall remember with pleasure **—in spite of such anxiety and responsibility as cannot be imagined by those who do not know**—the days of my investigations here."

The boldface are the reviewer's. Here is a man working devoted and alone. He is working that black men may live and their habitations be preserved, in a hot and humid climate amid poison gas. He is apt to receive for it the nosey snubbing of "superior" men of science who dwell in superior laboratories in the urban atmosphere of a superior climate, and who do not dirty their fingers with the poisonous solfataras of volcanoes.

Withal his inventive ingenuity never relaxed. He finally installed at Howes Estate near the solfatara a "Seismeter" of his own construction made out of three pedometers of the pace-counting watch pattern. This is shown in Figure 6. Two are laid horizontally with their pendulum interiors at right angles to each other, to beat and record on their dials the "paces" of the earth east-west and north-south respectively. The third is laid vertically, as it would be if attached to a man's belt in walking, and records the upright jolts of the earth. All shocks above a certain minimum of intensity will record. By reading the three dials after one of the savage shakings of the earth, the number of units above the intensity minimum, prescribed by the sensitivity of the pedometer, for each direction, describes what has happened at the instrument locality.

Thus the quake of November 10, 1935 gave 1v, 9n, 3e; that of November 11 was much more vertical, 7½v, 6n, 5e; while that of November 12 was intermediate, 4½v, 2n, 1e. In these v is vertical, n is north-south, and e is east-west.

The seismeter has the further quality that its dials may be read after any shock series, but not changed; and it goes on summing up, just as the pedometer does for a pedestrian, the totality of earthquakes for any period of time, regardless of whether there is present an observer to read it. Thus this extraordinary worker in the wilderness finds time to invent and add to the progress of science, even in the midst of quakes and ruins and fumes!

T. A. J.



View of Field Station and Head of Gorge - Gages Soufriere, Montserrat, B. W. I.

Hawaiian Volcano Observatory Report for July 1937

VOLCANOLOGY

The only events of importance at Kilauea Crater have been two spells of local earthquakes lasting about a day each July 22 and July 30. Each of these produced moderate earthquakes which were felt. Numerous distant earthquakes were recorded.

The following are the weekly Observatory totals for Halemaumau and the seismographs:

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Tremors and Quakes
July 4.....	8.00	2	6.0	22
" 11.....	9.25	0	7.0	37
" 18.....	6.50	0	9.5	18
" 25.....	26.00	0	11.5	84
Aug. 1.....	22.75	0	5.5	45

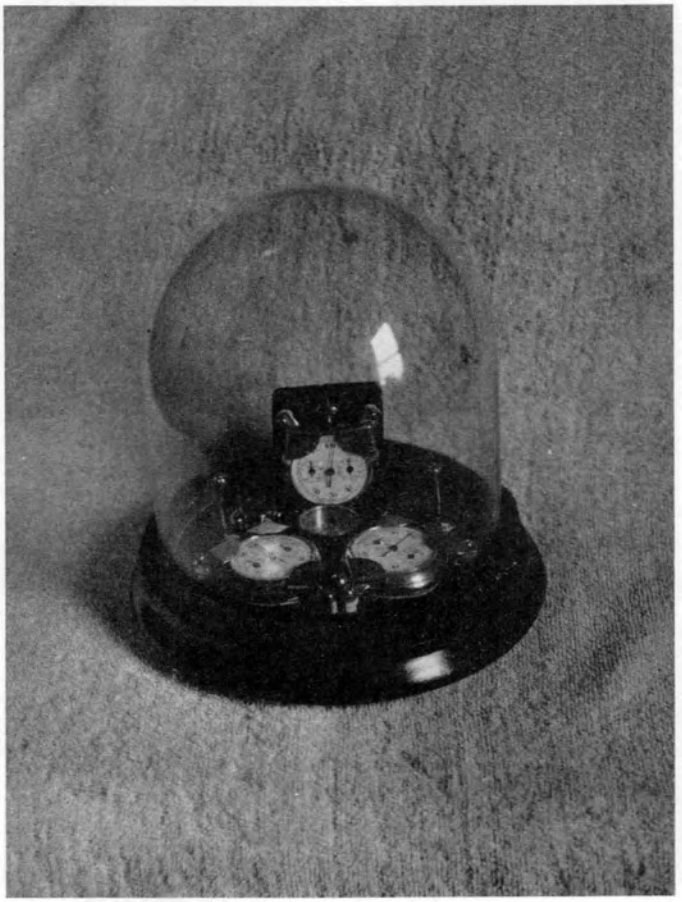


Figure 6. Experimental Seismeter installed at Gage's Oct. 25, 1935, records and integrates ground movement in vertical and horizontal components. (3) Totalizes on 9 dials (3 on each pedometer).

Frank A. Perret.

Sequence of Events by Weeks

The first week produced nothing more conspicuous at Halemaumau pit than two small slides.

The second week showed the pit still quieter.

The third week nothing was noted at Halemaumau but on July 14 Park officers on the upper Mauna Loa trail reported steam from a cone on the Northeast Rift at about elevation 11,000 feet, and bluish fume from cracks a quarter mile farther south.

The fourth week no slides were reported but the earthquakes of July 22 probably made avalanches. It was noticed July 25 that the northeast wall of Halemaumau has developed a buttress resulting from landslips on each side. The talus slopes NE, NW, SW, SSE, and E from the pit center all have buttresses of rock between them. The migration of landslip area from year to year since 1924 has kept the pit fairly symmetrical. The talus cones were made by such landslips and the buttresses are each backed by cracks concentric with the rim, and below the rim, that were formerly fissures in the upper country.

The last week produced excessive rainfall (more than 16 inches July 31-August 1), and a spell of earthquakes July 30.

Slides at Halemaumau

The only recorded slides from the wall of the pit were:

July 1, 1:22 p.m., made dust and noise.

July 2, 9:17 a.m., rocks fell from east wall 200 feet below rim.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim-crack locations resulted during July in aggregate movement as follows:

Week ending forenoon of:

July 2, 30 locations, 9 opened, 5 closed, opening 6.0 mm. At the east Crack No. 52 closed 4.5 mm.

July 9, 30 locations, 7 opened, 4 closed, opening 7 mm.

July 16, 30 locations, 8 opened, 1 closed, opening 9.5 mm.

July 23, 30 locations, 11 opened, 1 closed, opening 11.5 mm.

July 30, 30 locations, 3 opened, 4 closed, opening 5.5 mm. Most of this was at Crack No. 25, east rim.

SEISMOLOGICAL DATA

TABLE

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Moderate Earthquakes	Distant† Earthquakes	Weekly* Seismicity
July 4.....	16	4	0	1	0	1	8.00
" 11.....	35	1	0	0	0	1	9.25
" 18.....	12	5	1	0	0	0	6.50
" 25.....	70	9	1	0	1	3	26.00
Aug. 1.....	29	9	4	2	1	0	22.75

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible a determination of depth of focus has been made.

June 30, 5:43 am, very feeble, located 3.5 miles deep under area 1.5 miles west of Kilauea Crater. 19° 25.0′ N; 155° 18.9′ W.

June 30, 8:46 am, very feeble, a deep quake with epicenter near Honokaa. 20° 4.0′ N; 155° 33.0′ W.

July 2, 9:16 am, very feeble, 2.6 miles deep and 2.0 miles west of Kilauea Crater. 19° 24.8′ N; 155° 19.4′ W.

July 3, 6:49 am, slight, 3.0 miles deep and 1.0 mile SW of Ahua Kamokukolau, 19° 22.0′ N; 155° 17.0′ W.

July 10, 9:43 pm, very feeble, thought to be of shallow origin near center of Kilauea Crater.

* For local seismicity definition see Volcano Letter 371.

† Includes teleseisms and distant earthquakes.

July 13, 5:40 pm, very feeble, originated near SE rim of Kilauea Crater.

July 16, 3:20 pm, very feeble, probably originated in rifts 1.5 miles S of Ahua Kamokukolau.

July 16, 6:51 pm, feeble, 3.5 miles deep in vicinity of Kipuka Ki, 2.0 miles NW of Uwekahuna. 19° 27.3′ N; 155° 19.2′ W.

July 18, 10:55 am, very feeble, 1.7 miles deep in W portion of Kilauea Crater near Uwekahuna Bluff. 19° 25.3′ N; 155° 17.0′ W.

July 18, 10:56 am, very feeble, 1.6 miles deep under Kilauea Crater rim near Uwekahuna Bluff. 19° 25.6′ N; 155° 17.1′ W.

July 18, 7:29 pm, very feeble, probably originated in NE rift of Mauna Loa near summit crater.

July 19, 8:36 am, very feeble, 1.7 miles deep in Kilauea Crater near the old Stone Corral. 19° 24.7′ N; 155° 16.3′ W.

July 22, 8:53 am, very feeble, probable origin, Kilauea SW rift near Cone Peak.

July 22, 10:38 am, feeble, probable origin in Chain of Craters near Puhimau.

July 22, 10:41 am, very feeble, 1.5 miles deep under SE rim of Kilauea Crater near Keanakakoi. 19° 24.5′ N; 155° 15.9′ W.

July 22, 10:53 am, very feeble, 2.2 miles deep, 6.0 miles N of Ahua Kamokukolau. 19° 23.3′ N; 155° 16.3′ W.

July 22, 11:14 am, very feeble, probably originated in Kilauea Crater near Halemaumau.

July 22, 11:18 am, very feeble, 1.6 miles deep, 1.8 miles NW of Puu Ohale. 19° 22.3′ N; 155° 17.9′ W.

July 22, 11:40 am, moderate, 1.8 miles deep and 1.7 miles SE of Pit seismograph. 19° 23.5′ N; 155° 15.8′ W. Reported felt in Park Headquarters Area; and at Kilauea Military Camp.

July 22, 11:45 pm, very feeble, 3.0 miles deep SE rim of Kilauea Crater near Keanakakoi. 19° 23.0′ N; 155° 15.6′ W.

July 23, 3:30 pm, very feeble, probably of shallow origin near center of Kilauea Crater.

July 24, 3:20 pm, very feeble, probably originated in Chain of Craters Area near Puhimau.

July 30, 2:40 pm, moderate, probable origin, Mauna Loa NE rift near Puu Ulaula.

July 30, 3:46 pm, feeble 2.8 miles deep in vicinity of old Koa Mill, 1.5 miles N of Kilauea Crater. 19° 27.1′ N; 155° 17.0′ W.

July 30, 3:50 pm, feeble, 2.8 miles deep in Chain of Craters rift near Lua Mau Crater. 19° 23.9′ N; 155° 15.4′ W.

July 30, 8:05 pm, very feeble, 5.5 miles deep in Chain of Craters rift near Kokoolau. 19° 23.1′ N; 155° 14.0′ W.

July 30, 8:17 pm, very feeble, 3.5 miles deep near Kipuka Puaulu, 2.5 miles NW of Kilauea Crater. 19° 27.0′ N; 155° 18.9′ W.

July 30, 8:46 pm, very feeble, 2.4 miles deep near Ainahou Ranch House. 19° 20.8′ N; 155° 14.0′ W.

July 30, 9:14 pm, very feeble, probably originated in Chain of Craters near Pauahi.

July 30, 9:29 pm, feeble, 2.7 miles deep and 0.7 mile E of Hiiaki Crater, Chain of Craters rift. 19° 22.8′ N; 155° 13.5′ W.

July 31, 10:11 pm, slight, 4.7 miles deep under Kilauea Crater rim 0.5 mile NE of Uwekahuna. 19° 25.7′ N; 155° 17.3′ W.

July 31, 10:13 pm, slight, location of focus same as preceding quake.

July 31, 10:27 pm, very feeble, 5.0 miles deep and 1.0 mile NE of Volcano Observatory. 19° 26.5′ N; 155° 15.3′ W.

August 1, 2:56 am, feeble, location of focus same as preceding quake.

August 1, 9:43 am, very feeble, 2.8 miles deep in rift area 0.8 mile N of Puu Ohale. 19° 21.9′ N; 155° 16.8′ W.

A period of continuous tremor lasting 26 minutes began at 9:24 am, July 6.

Microseismic motion of the ground at the Observatory was light July 5, 10 to 13, 17, 19 to 21, and July 26; moderate June 28 to 30, July 4, 7 to 9, 14 to 15, 18, 22 to 23, 27 to 30, and August 1; strong remainder of month.

Teleseisms or Distant Earthquakes registered at Kilauea as follows: July 1, 4h 28m pm, H.S.T., undetermined phase; July 3, 7h 46m 19s pm, H.S.T., undetermined phase; July 11, 7h 13m 55s am, undetermined phase, reported by Central Station of the Jesuit Seismological Association as located 20° 7′ N; 108° 3 W (west coast of Mexico); July 22, preliminary phase, 6h 47m 56s am, originated 3,010 miles from Kilauea and epicenter reported by Central Station of Jesuit Seismological Association as 64° 5′ N; 145° W (Central Alaska); July 25, preliminary phase, 5h 26m 44s pm, H.S.T., distance—3,780 miles and July 25, 10h 18m pm, undetermined phase.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending August 1 was 9.8″ S and 1.85″ E.

TABLE OF TILT

Week Ending	Observatory	Halemaumau West Station
July 4	0.26″ N 20° W	1.55″ N 60° W
July 11	0.00	2.17″ N 68° W
July 18	1.13″ N 17° E	10.13″ N 82° W
July 25	0.36″ S 47° W	11.02″ N 71° W
Aug. 1	0.51″ S 60° E	6.35″ N 55° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
July 4	3.75″ N 60° W	2.22″ toward
July 11	3.40″ S 60° W	1.62″ from
July 18	10.85″ N 43° W	0.72″ toward
July 25	5.31″ N 86° E	12.89″ from
Aug. 1	10.37″ S 41° W	7.19″ from

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis-Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

THE VOLCANO LETTER

No. 450 monthly Department of the Interior National Park Service August 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Mount Rainier National Park. Washington.

VOLCANOES IN THE NATIONAL PARKS—

Radio Talk, KHBC, Sept. 28, 1937, Hugh H. Waesche

Because of their spectacular nature and their interference with man's activities, volcanoes have always been of intense interest to the human race. With primitive peoples they have been associated with the supernatural, but when attacked by modern scientific thought they serve as major stepping stones in the solution of many problems concerning the origin and history of the earth on which we live. Most advanced, and going beyond previous thought is the systematic study of volcanoes with protection of life and property in mind.

Many of our National Park areas contain volcanoes as major features. Other National Parks contain volcanic features of secondary importance. Of twenty-seven National Parks listed August first of this year, five have volcanic histories of major interest, and at least nine others contain some evidence of past volcanic history. So, more than half of our National Parks have a geologic story to tell of which some portion is volcanic.

In this series of Parks, volcanic conditions of practically every kind known are demonstrated, from the currently very active lava volcanoes in Hawaii, to ash deposits laid down in Shenandoah and Mammoth Cave National Parks many millions of years ago in that geologic period known as the Ordovician, when man's arrival on earth was in the very distant future and probably all life was still confined to the oceans. This variety of volcanic evidence applies equally to both kinds of activity, and amounts of activity.

Five National Parks illustrate stages of volcanic activity very clearly. Hawaii National Park heads the list as the most active, being the location of Kilauea and Mauna Loa. Lassen Volcano in Northern California illustrates a second stage of activity as well as holding the unique position of being rated the only active volcano within the boundaries of continental United States, excepting Alaska. Mount Rainier in Washington represents the dormant stage, Crater Lake a dormant or extinct volcano with a special history, and Yellowstone, an ancient volcanic region much eroded but with enough residual heat to produce a very special type of geyser activity found at only three localities in the world.

Not one of these volcanoes has been listed definitely as extinct, as that is a term which should not be applied too hastily. No doubt some of these volcanoes are extinct, but definite statement to that effect would certainly be open to question. Vesuvius in Italy was considered extinct until seventy-nine A. D. but that opinion was rudely changed with the destruction of Pompeii.

Aside from the volcanoes in the National Parks there are others in National Monuments such as Katmai in Alaska, Sunset Crater, Arizona, Capulin Mountain, New Mexico, and the Lava Beds of California. Various types of volcanic structures are also exhibited in Craters of the Moon in Idaho, Devil's Post Pile in California, Devil's Tower, Wyoming, Grand Canyon National Monument and Death Valley National Monument.

It is not surprising that the first and greatest area to be set aside as a national park was volcanic. Only a volcanic region could produce the superlative and dynamic landscape which holds this honor. Everyone has heard of and knows something of Yellowstone, the "Grand Old Man" of all the parks, both in the United States and elsewhere. It is located in the northwestern corner of Wyoming with a slight overlap into the states of Idaho and Montana. This region was rather inaccessible and practically unknown until the middle of the last century. A few men had visited the region, however, and brought back glowing tales of the wonders to be seen there. As far as these reports were concerned the public was very incredulous and the situation was such that few dared to tell of the things they had seen, as several lecturers were actually stoned in the streets as imposters. The first official and accredited exploration of the Yellowstone region was made by the Washburn-Langford expedition of 1869. Their glowing reports of the wonders of the region led to its establishment as our first National Park in 1872.

The feature of greatest interest in Yellowstone is that unusual form of volcanic activity, the geyser. It is justly celebrated in this respect as there are only two other places in the world where geysers are common, New Zealand and Icelana, and Yellowstone has more geysers than those two combined. There are more than three thousand geysers or hot springs within the Park and every conceivable type or form of either is represented.

A geyser may be thought of as a water volcano. They can occur only in places where the internal heat of the earth is near the surface. Water from the surface plus some added from depth flows into an opening in the form of a more or less tubular vent, or maybe even a crack, and eventually reaches regions of highly heated rocks below. When this happens steam is formed but does not escape because of the heavy column of water above. After a time, however, the steam pressure becomes equal to or slightly greater than that exerted by the water column and as soon as this condition is reached the water is forced out and appears at the surface as a fountain.

The height of the fountain, frequency of play, and force of the water depend on conditions which vary widely with the different geysers. Such conditions are size of orifice at the surface, temperature below the surface, length and size of the tube leading to the hot rocks, ground water level, and probably other conditions which are not known.

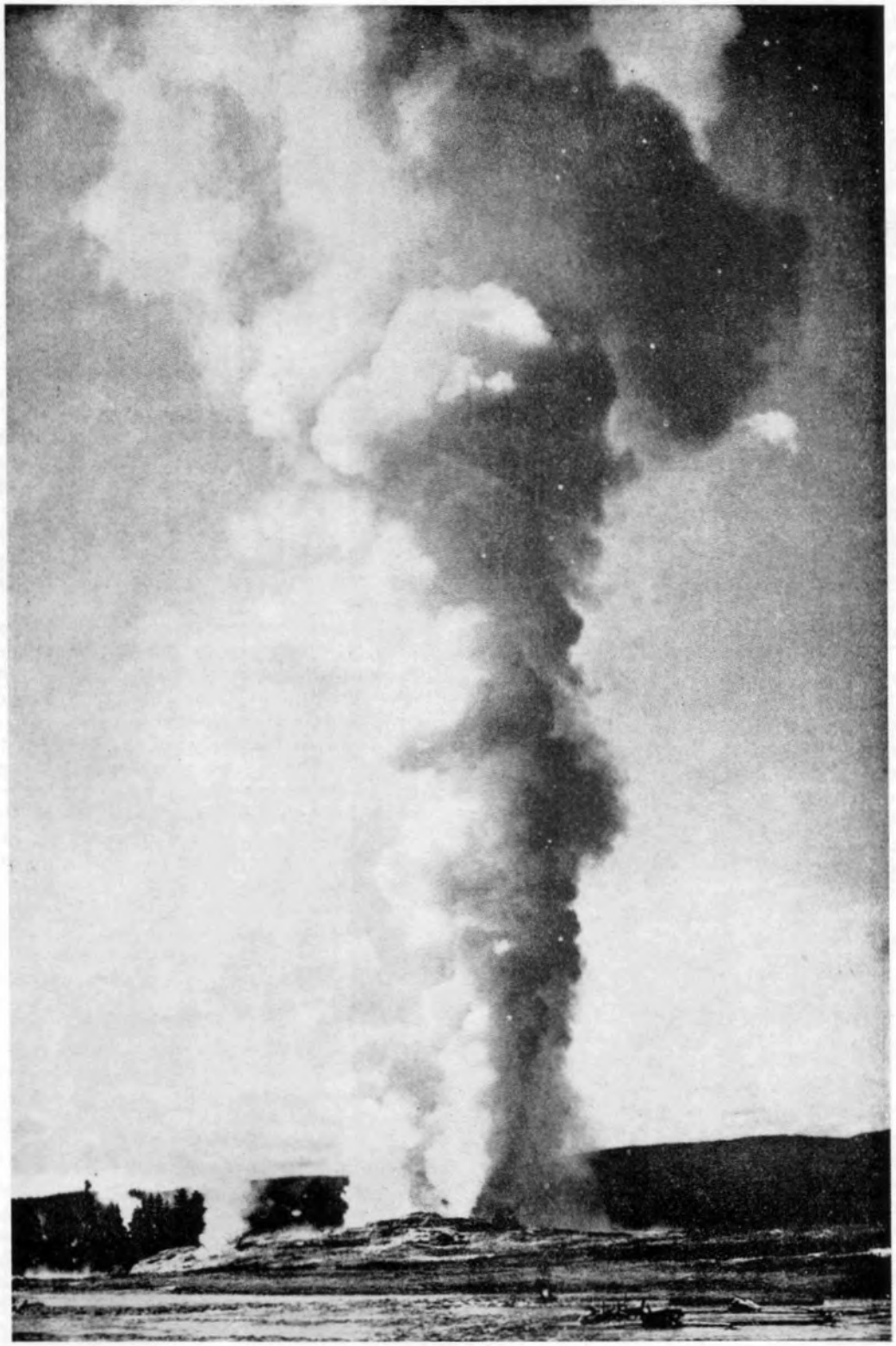
There are six principal geyser basins in the Yellowstone, all lying in the west and south-central sections of the Park. Some geysers erupt quite regularly. The most famous of these are Old Faithful, Daisy and Riverside. Old Faithful erupts about once an hour year in and year out and shoots a shaft of water over one hundred and fifty feet in the air for four minutes. The water temperature is about two hundred degrees Fahrenheit. Besides the geysers, the entire region contains many hot springs which are in most cases clear water with a beautifully colored background of orange, yellow, green or blue created by algae which live on the rocks forming the container. Other springs are filled with mud in constant agitation which, in one case, is named the Paint Pot. At Mammoth Hot Springs the water has brought to the surface large amounts of lime in solution which is precipitated on reaching the air. These mineral deposits build high terraces of beautifully encrusted basins over which the water flows.

Practically the entre region incorporated in Yellowstone is volcanic. Not only the surrounding mountains but the great interior plain is made of material once ejected as ash and lava from depths far below the surface. In some places entire forests have been buried by ashes blown from these ancient volcanoes, in another place lava which poured out on the surface cooled so rapidly that volcanic glass was formed, now represented by the famed Obsidian Cliffs. Yellowstone's volcanoes were probably active in that geologic age known as the Tertiary, millions of years ago. Since that time the region has quieted down, and has even been through a period of glaciation. The stage of erosion there, plus the lack of recent activity, marks the area as one in which a great volcanic exhibition had been through its youth, maturity and is now in advanced old age with only enough heat left over to keep the geysers busy.

Several hundred miles west of Yellowstone lies an area of a quarter million square miles which is the greatest field of volcanic activity in the United States and one of the greatest in the world. Large portions of the States of Washington and Oregon, and lesser portions of California, Nevada, Idaho, Montana and Wyoming are within this area. It includes the Cascade Range of Mountains extending from northern California across Oregon into Washington.

Within this range are three of our National Parks, all volcanoes, and they are, in order, south to north, Lassen Peak, Crater Lake and Mt. Rainier. Of this group, only Lassen is considered active. Crater Lake was probably active as recently as eight hundred years ago. Mt. Rainier near Tacoma, Washington, is considered "king" of all the towering volcanoes of this region. It is a huge volcanic cone over 14,000 feet in height and covering more than 100 square miles. A few steaming vents and hot springs are all that remain of activity which was evidently on a very grand scale in its past history. Now this huge mass of lava, cinders and ashes is covered by snow and ice resulting in a glacier system. Mt. Rainier is now an imperect cone, but once it was complete like the famous Fujiyama of Japan. Then it was probably 16,000 feet high. Sometime in its late history an explosion or engulfment occurred which took 2,000 feet off the top and left Mt. Rainier beheaded. Indian legends tell of a great eruption, but no man really knows when this great mountain was last active.

The southern limit of the Cascade Range is marked by Lassen Peak. This volcanic pile is the only aggressive member of the group to which it belongs. It had been quiet for over two hundred years although one or more doubtful eruptions are reported, and "mud" flows have occurred within the last five hundred years as estimated from buried logs.



Yellowstone National Park. Wyoming.

On May 30, 1914, a series of eruptions began from Lassen which lasted through June of 1917. The first eruption was short and mild, opening a new vent in the summit crater. The materials thrown out the first year were not excessively hot. By March of 1915 over one hundred and fifty explosions had occurred, probably aided by water from an unusually heavy winter snowfall. On May 19, 1915, there appeared the first glowing lava which spilled over the western edge of the crater to flow down the slope one thousand feet. That night several destructive mud flows poured into valleys down the slope.

Three days later a mushroom-shaped cloud of smoke and dust arose four miles in the air accompanied by a hot blast of gas which rushed down the northeast slope destroying every living thing for ten miles. So violent was this blast that trees on Raker Peak three miles away were all felled uniformly in the direction of the outburst. The heat turned snow in its path to water. After this convulsion the energy of the Volcano was mostly spent although occasional outbursts of steam and ash continued for two years when it finally subsided.

At the present time Lassen is quiet, although from time to time there are earthquake shocks. There are many hot springs, boiling mud pots and sulfurous deposits in and around Lassen Peak. A seismograph station is maintained at Lassen for recording earthquakes as is done here in Hawaii. Lassen was formerly a part of the study program of the Hawaiian Volcano Observatory. Lassen Peak is 10,453 feet above sea level and is surround by lava fields, and other volcanic cones illustrating many phases of volcanic activity. Lassen's activity will probably be resumed in the future.

Although Grand Canyon National Park is set aside as a great example of stream erosion, it has some evidences of volcanic activity of a minor nature which occurred millions of years ago. However, within sixty miles of Grand Canyon is one of the largest extinct volcanoes in the United States. This is the San Francisco Mountain area of Arizona. Included in this region is Sunset Crater, a 700-foot cinder cone and associated lava fields. The latter locality has been recently active—that is within a thousand years. Some of the lava associated with Sunset Crater is very similar to our Hawaiian aa. Sunset Crater is a National Monument.

The Devil's Tower in Wyoming is an interesting volcanic exhibit. It is a 600-foot pile of vertical jointed lava similar to that to be seen in Makaopuhi Crater here in Hawaii National Park. It tops a 600-foot mound of sedimentary rock and can be seen for a hundred miles in any direction. Some people think it is an intrusive plug, but there are others who think it is a remnant of an old intrusive sheet, and there is a lot of evidence to back this latter theory.

In the country north of Lassen National Park there is an area in California near the Oregon line known as the Lava Beds National Monument. This large region is typical of its name and contains many lava tubes similar to our Thurston Lava Tube. Some of the tubes contain ice the year around and are known as ice caves.

Alaska is one of the most active volcanic regions of the world. A belt of volcanoes extends for 1,500 miles through the Alaskan Peninsula to the west part of the Aleutian Islands. Katmai is one of this series of volcanoes. It is 6,970 feet high, located on treacherous Shelikof Strait, opposite Kodiak Island.

Very little attention was paid to Katmai until June, 1912, when it announced itself to the world with an explosion that was heard in Juneau, 750 miles away. Earthquakes followed this blast and then came a spell of smoke and dust causing sixty hours of darkness in Kodiak, a hundred miles away. Dust fell in Ketchikan, 900 miles away and fume was carried by the wind to Vancouver, fifteen hundred miles away. Hazy atmosphere was noted over the United States the succeeding weeks and even peculiar atmospheric effects were noticed in Europe the following summer.

The scene of this explosion was made a National Monument in 1918. One of the most interesting phases of development at Katmai was the formation of the valley of 10,000 smokes near by. This has been described at length in the National Geographic Society's publications.

This review of volcanic National Parks and Monuments is by no means conclusive. However, it does give an idea of the great variety of volcanic activity to be found within the United States and its territories, with unlimited possibilities for study and research, or entertainment for those who prefer a spicier type of geologic story, connected with their Parks. Volcanoes can be depended upon to put on a good show when they are so minded in spite of their temperamental natures. To people of Hawaii, visits to the other areas should be interesting.

Kilauea Lava Flow of 1823

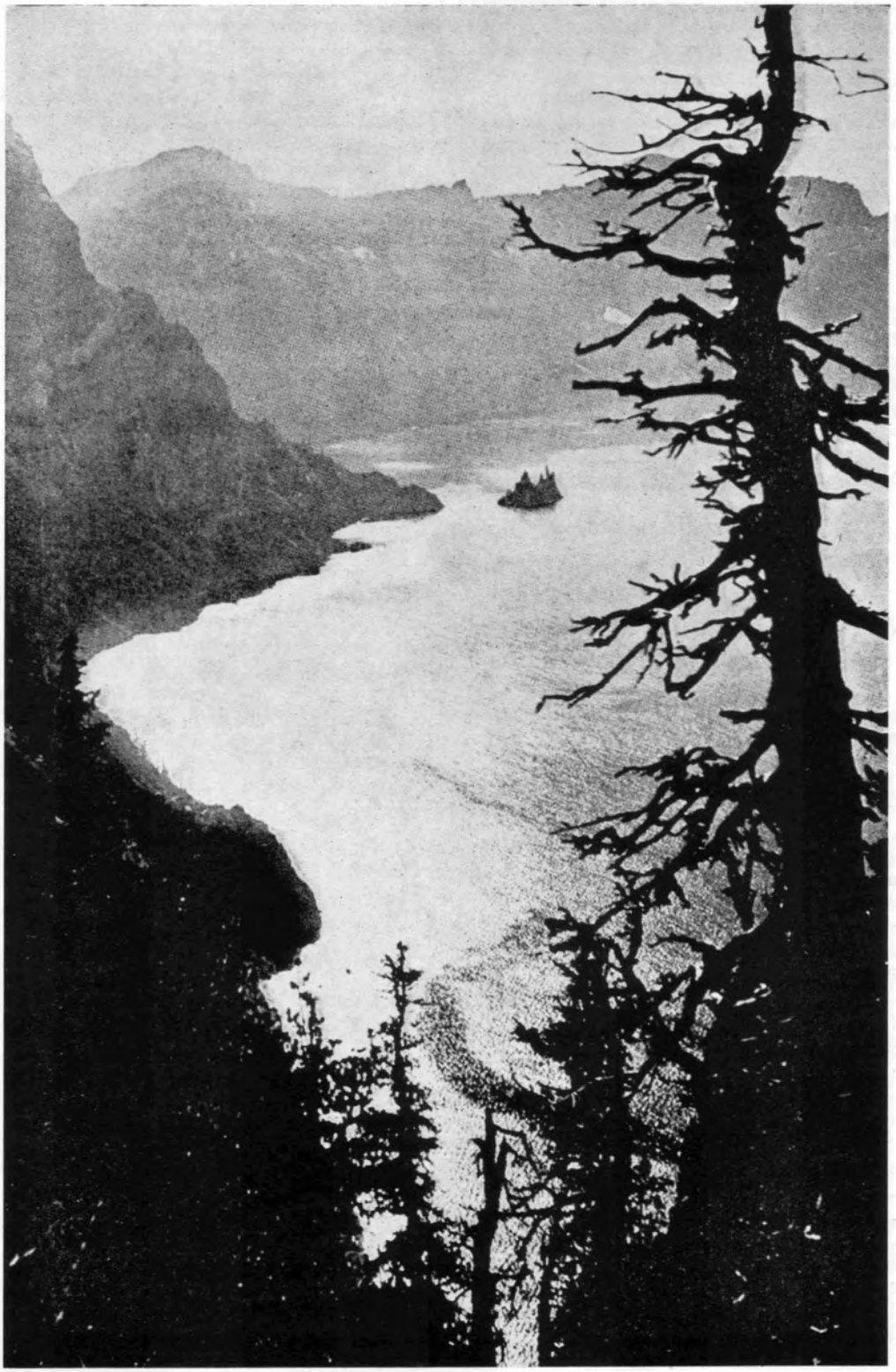
A major structural feature of Kilauea is the fracture zone extending twenty miles SW of the Crater, in the general direction of Pahala. This rift disappears out into the sea. It is commonly spoken of as the Kilauea SW Rift and is the feature indicated by that term frequently used in the Volcano Letter.

Although most of the Kilauea eruptions have occurred in the summit crater within historic times, some major activity has taken place in the regions associated with the SW Rift. The numerous prominent cinder cones and flows of the Kau desert in this vicinity testify to abundant activity before historic recording began.

The first nineteenth century flow from Kilauea occurred in 1823. It issued from the "Great Crack" twelve miles SW of Kilauea Crater. A minor flow took place in the SW rift zone eight miles from the Crater in 1868. The identity of this flow has often been confused with the more extensive flow of 1823. The confusion, however, has been straightened out with reasonable certainty by Stone, Stearns, and Jaggar, who have covered the question in published articles. The third and last SW Rift flow was that of 1920, resulting in the formation of Maunaiki. All of these flows are correctly shown on the latest maps. In the last 110 years there have been only three known periods of activity in the SW Rift.

The morning of February 26, 1937, a party of National Park officials visited the area of the Keaiwa Flow (local name for 1823 flow). This group included Mr. John D. Coffman, Chief Forester of the National Park Service, and Mr. E. E. Tillett, Field Supervisor of the Emergency Conservation work for the Islands.

The 1823 flow was found to be of considerable interest and unusual in that it seemed to have issued from the Great Crack which probably opened up immediately preceding the eruption and, no doubt, was accompanied by rather strong earthquakes. By Ellis' dates the outflow was about February, 1823, and the most serious earthquake about May. The lava formed a comparatively thin skin over older flows, leaving many small kipukas or islands of the older material and thus indicating a very fluid condition. Lining the Great Crack, there are rounded lava balls similar in appearance to bombs but of a much different origin and in two localities there are indications of phreatic explosions. The lava balls are accretion-spheres formed of hardened liquid lava around fragments in the chasm, swept out by later gushes which embedded them. The absence of cinder or driblet cones would indicate that the lava issued from the earth in a somewhat different fashion from the usual Hawaiian flow which has both at its source. A very striking and prominent feature is the presence of many tree molds. These are of a wide variety as to form. Some are several feet in thickness and



Crater Lake National Park. Oregon.

as much as six feet in height. The forms of the trees responsible are well preserved and the relative position of trunk and branches is often indicated. None of the molds observed was apparently formed by trees with a trunk of more than three or four inches in diameter. The direction of flow is clearly indicated by the flow lines around the molds and a piling up of the lava on their north sides. The flow definitely moved south as it should across the contours, toward the sea.

The history and general description of the flow has been so thoroughly covered by several writers that no further discussion will be given here. Those wishing to know more of an unusual Kilauea Rift flow are referred to the following articles:

1. Harold T. Stearns, "The Keaiwa or 1823 Lava Flow from Kilauea Volcano, Hawaii, Journal of Geology, Vol. XXXIV, No. 4, May-June, 1926.

2. Harold T. Stearns and W. O. Clark, "Geology and Water Resources of the Kau District, Hawaii," Water Supply Paper 616, U. S. Geological Survey, 1930.

3. T. A. Jaggar and Oliver Emerson, "Bulletin of the Hawaiian Volcano Observatory," May, 1924, pp. 34-35, and Nov., 1924, pp. 110-111; U. S. Geol. Surv. Figures 13-16, Vol. XIII, No. 6, June, 1925.

4. "The Keaiwa Flow of 1823, Hawaii," by John B. Stone, Amer. Jour. Sci., May, 1926.

5. "The 1823 Lava Flow from Kilauea," by R. H. Finch, Volcano Letter No. 18, 1925.

6. "Ball Lava," by J. A. Thomson, New Zealand Journal of Science and Technology, about 1925.

H. H. W.

Hawaiian Volcano Observatory Report for August 1937

VOLCANOLOGY

The most important event at Kilauea Crater was a fall of the rim rock of Halemaumau pit at the east, at 8:41 am August 22, carrying away the measurement marks of Crack No. 25 and also No. 24; at Crack No. 25 excessive opening had been revealed by measurement for weeks. The crash of the avalanche produced earthquake disturbance marked on the seismographs. The disturbance of the rim occasioned by this avalanche caused many subsequent slides, enlarging the talus, and gradually adjusting the cliff. There was increase of tremors for the last fortnight of the month, but no good method has yet been developed to prove cause and effect in the relation between slides and tremors. It is of interest to note, however, that the succession of cliff adjustments following a big avalanche is not unlike the succession of aftershocks following an earthquake.

The following are the weekly Observatory totals for Halemaumau and the seismographs.

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Tremors and Quakes
August 8.....	9.50	1	25.0	26
" 15.....	10.75	1	40.5	34
" 22.....	11.75	22	95.5	35
" 29.....	17.50	3	15.0	47

There were felt shocks of Kilauea origin August 3, 7, 10, 23, and 27; and two others of Mauna Loa and Hualalai origin August 16 and 18, felt on the west side of the island. Of all the measured shocks 27 indicated Kilauea distances of origin and three were from Mauna Loa or beyond. Distant earthquakes August 10 and August 20 indicated origins about 5,500 miles away, the second reported of destructive intensity on Luzon in the Philippines.

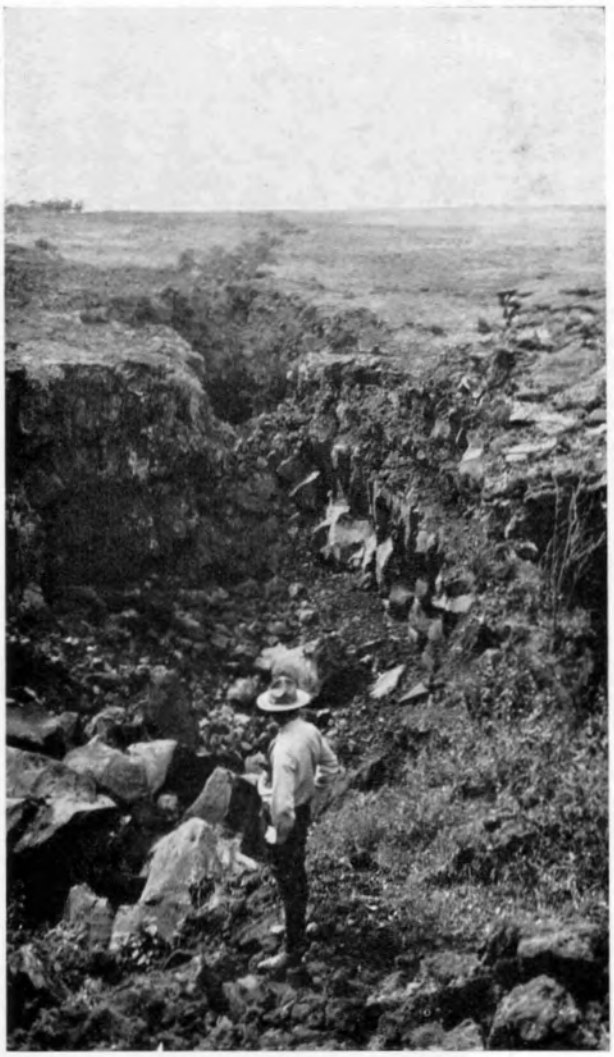
Sequence of Events by Weeks

The first week produced low seismicity and nothing more at Halemaumau pit than the excessive opening of Crack No. 25 at the east, which was one of the steaming extensions of the caved-in cracks of the east notch that had collapsed destroying Crack No. 28 on May 7. This opening of Crack No. 25 had been noticed repeatedly since May.

The second week produced only one slide, but the rate of opening of Crack No. 25 almost doubled.

The third week produced the avalanching crisis with Crack No. 25 opening three times as much as the week before and the observed slides numbering 22. Seismicity, owing to the increased numbers of tremors, rose steadily during the month.

The fourth week produced only three observed slides, the taluses at the base of Halemaumau wall had been enlarged, aggregate crack opening dwindled, but seismicity continued to increase.



Looking south along the great crack from which issued 1823 flow as viewed at Puna Trail crossing. Waesche.

Slides at Halemaumau

The recorded slides from the wall of the pit were:

August 2, 2:20 a.m., a noise like sliding during excessive rain, possibly a cataract at Uwekahuna.

August 12, 1:00 p.m., dust from west side of pit.

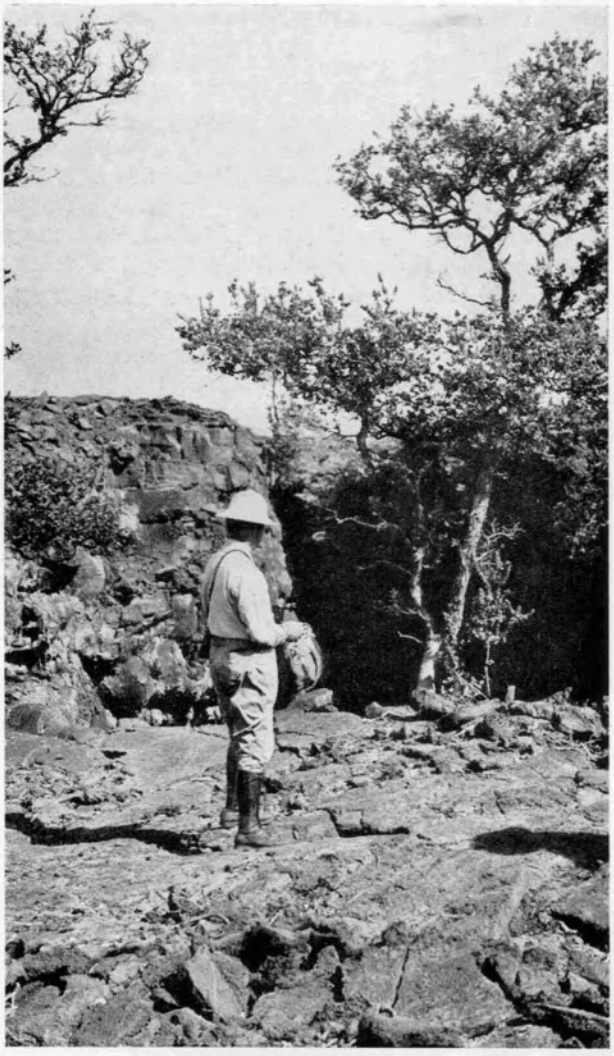
August 17, 2:30 p.m., eastern slide.

August 20, 11:20 a.m., western slide.

August 21, 11:40 a.m., noisy east slide, leaving scar 30 feet down.

August 22, 8:40 a.m., very large slide east making very feeble earthquake on seismograms.

August 22, 9:45 a.m., large dust cloud east.
August 22, 9:57 a.m., dust floated westward.
August 22, 10:28 a.m., eastern slide.
August 22, 10:35 a.m., eastern slide.
August 22, 10:50 a.m., slides continued.
August 22, 11:00 a.m., more slides.
August 22, 11:05 a.m., more of east rim fell.
August 22, 11:19 a.m., slide west-northwest.
August 22, 11:20 a.m., very large eastern slide.
August 22, 11:30 a.m., more slides.
August 22, 11:33 a.m., " "
August 22, 11:45 a.m., " "
August 22, 11:50 a.m., " "
August 22, 11:55 a.m., " "



Looking north along the great crack from same locality. Waesche.

August 22, 12:10 p.m., " "
August 22, 12:19 p.m., " "
August 22, 12:20 p.m., rim rock fell and slides continued.
August 22, 3:00 p.m., rim rock fell in a large slide east; talus below now showed great enlargement.
August 24, 3:45 p.m., eastern slide.
August 25, 12:50 p.m., large dust cloud northwest rim.
August 26, 9:38 a.m., slight northwest slide.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted August in aggregate movement as follows:

Week ending forenoon of:

August 6, 30 locations, 12 opened, 1 closed, opening 25.0 mm. Crack No. 25 east opened 18.0 mm.

August 13, 30 locations, 13 opened, 1 closed, opening 40.5 mm. Crack No. 25 opened 31 mm.

August 20, 30 locations, 7 opened, 6 closed, opening 95.5 mm. Total opening was 99 mm., six cracks exhibiting a closing of 3.5 mm. Crack No. 25 by weeks had exhibited the following:

July 30, 6.0 mm. opened.

August 6, 18.0 mm. opened.

August 13, 31.0 mm. opened.

August 20, 96.0 mm. opened.

August 22, the cracked block collapsed, showing that the rate of opening had made forecast of the rim breakage.

August 27, 27 locations, 17 opened, 00 closed, opening 15.0 mm.

Cracks 24 and 25 had been destroyed August 22 and No. 51 on northeast rim was mutilated by unknown causes.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant† Earthquakes	Weekly* Seismicity
Aug. 8.....	18	6	2	0	0	9.50
Aug. 15.....	27	6	1	0	1	10.75
Aug. 22.....	27	6	2	0	1	11.75
Aug. 29.....	36	9	0	2	0	17.50

*For local seismicity definition see Volcano Letter 371.
†Including teleseisms or those shocks over 5,000 km. distant.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible, a determination of depth of focus has been made.

August 2, 3:45 am, very feeble, 1.3 miles deep E rim of Kilauea Crater near junction of Byron and Waldron Ledges. 19° 25.3′ N; 155° 15.6′ W.

August 3, 1:39 am, very feeble, probably originated in NE portion of Kilauea Crater.

August 3, 8:52 am, feeble, probably originated in Chain of Craters near Hiiaka.

August 6, 10:41 pm, very feeble, 2.4 miles deep, S rim of Kilauea Iki. 19° 24.8′ N; 155° 14.8′ W.

August 7, 7:09 am, feeble, 5.7 miles deep, SE rim of Kilauea Crater. 19° 24.2′ N; 155° 16.2′ W.

August 8, 4:40 pm, very feeble, of Kilauea origin.

August 8, 5:06 pm, very feeble, of Kilauea origin.

August 9, 5:39 pm, very feeble, 0.9 mile deep in rifts 0.4 mile W of Keanakakoi Crater. 19° 24.2′ N; 155° 16.4′ W.

August 9, 8:57 pm, very feeble, 3.6 miles deep in area 1.5 miles W of Kilauea Crater. 19° 25.0′ N; 155° 18.9′ W.

August 10, 5:13 am, very feeble, 0.7 mile deep SE rim of Kilauea Crater near Keanakakoi. 19° 24.4′ N; 155° 16.2′ W.

August 10, 5:00 pm, feeble, 2.3 miles deep, E portion of Kilauea Crater near Kilauea Iki. 19° 25.2′ N; 155° 15.9′ W.

August 11, 4:57 am, very feeble, 5.0 miles deep, 3.8 miles SE of Observatory. 19° 23.7′ N; 155° 13.1′ W.

August 12, 11:56 am, very feeble, of Kilauea origin.

August 12, 2:21 pm, very feeble, thought to have originated in Kilauea Crater immediately NE of Halemaumau.

August 16, 4:39 am, feeble, 18 miles deep, SW slope of Mauna Loa, 13 miles from Summit Crater. 19° 16.0′ N; 155° 38.0′ W.



Tree mold in 1823 Lava Flow. Waesche.

August 18, 5:27 pm, feeble, probably of deep origin under Hualalai. Felt in Kona and dismantled seismograph at Kealakekua.

August 18, 9:31 pm, very feeble, of MaunaLoa origin.

August 19, 3:22 am, very feeble, 1.0 mile deep, N portion of Kilauea Crater near Kilauea Military Camp. 19° 25.8′ N; 155° 16.6′ W.

August 21, 10:49 pm, very feeble, 0.8 mile deep, Kilauea Crater near E rim of Halemaumau, 0.4 mile N of Pit seismograph. 19° 24.7′ N; 155° 16.9′ W.

August 22, 4:21 am, very feeble, 3.8 miles deep, 3.2 miles N of Uwekahuna. 19° 28.2′ N; 155° 17.3′ W.

August 22, 8:41 am, very feeble, caused by slide from E rim of Halemaumau.

August 22, 11:49 pm, very feeble, E portion of Kilauea Crater 0.5 mile deep. 19° 25.0′ N; 155 ° 15.9′ W.

August 23, 12:45 am, very feeble, of shallow depth, Kilauea Crater 0.7 mile SSW of the Observatory. 19° 25.3′ N; 155° 15.9′ W.

August 23, 3:02 am, slight, 0.5 mile deep E portion of Kilauea Crater. Dismantled Pit seismograph. 19° 25.0′ N; 155° 15.9′ W.

August 23, 2:20 pm, very feeble, 1.0 mile deep, W edge of Keanakakoi Crater (SE rim of Kilauea Crater). 19° 24.1′ N; 155° 16.1′ W.

August 23, 7:41 pm, very feeble, 4.3 miles deep, 0.7 mile NW of Uwekahuna. 19° 25.6′ N; 155° 18.0′ W.

August 25, 12:04 am, very feeble, 0.7 mile deep under SE rim of Halemaumau. 19° 24.4′ N; 155° 16.9′ W.

August 27, 12:12 am, slight, 1.5 miles deep SE rim of Kilauea Crater, 0.3 mile NE of Keanakakoi. Reported felt by few near Hawaii National Park Headquarters and at CCC Camp. 19° 24.4′ N; 155° 15.8′ W.

August 27, 12:15 am, very feeble, 0.9 mile deep, Kilauea Crater, 0.3 mile N of Keanakakoi. 19° 24.6′ N; 155° 16.0′ W.

August 29, 7:36 am, very feeble, thought to have originated near Pit seismograph and shallow depth.

The preliminary waves of a teleseism began to register at Kilauea at 2h 38m 1s, pm, H.S.T. August 10. Distance was 5,520 miles. The preliminary waves of another teleseism began registering at 1h 41m 29s, am, H.S.T. August 20. Distance from Kilauea was 5.465 miles and reported location was in the Philippine Islands, where it was of destructive intensity, especially on the Island of Luzon.

Microseismic activity of the ground at the Observatory was light August 5 to 9, 18, 21, 27 to 29, strong August 3, 4, 24, 25 and moderate the remainder of the month.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending August 29 was 10.80″ S and 0.46″ E.

Week Ending	Observatory	Halemaumau West Station
August 8	1.12″ N 53° E	5.78″ S 82° W
August 15	1.17″ S 69° W	5.04″ N 40° W
August 22	0.31″ S 8° E	6.73″ S 73° W
August 29	0.58″ N 45° W	2.62″ S 44° W

Week Ending	Halemaumau Southeast Station	Pit Resultant
August 8	7.29″ N 63° W	0.67″ toward
August 15	0.23″ S 66° W	2.67″ from
August 22	5.18″ N 45° W	1.53″ from
August 29	7.78″ N 17° W	5.35″ toward

H. H. W.

THE VOLCANO LETTER

No. 451 monthly Department of the Interior National Park Service September 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

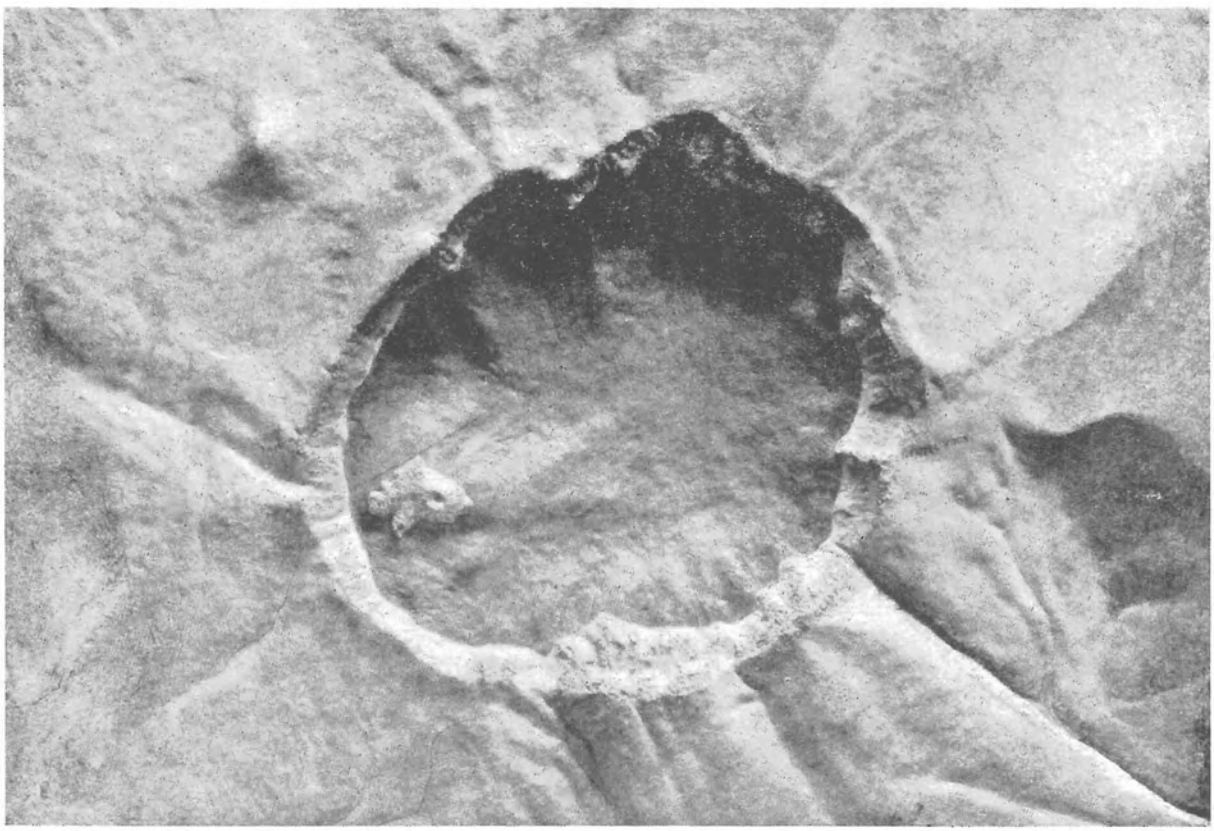


Fig. 1. Model of Crater Lake (after Diller).

CRATER LAKE NATIONAL PARK—

By H. H. Waesche

Certain areas in the United States and its territories have been set aside by the Federal Government as National Parks. Included in these are such well known places as Yellowstone, Grand Canyon and Yosemite Valley. National Parks are of importance because they contain within their boundaries some feature of both exceptional beauty and scientific interest which should be protected for the pleasure and benefit of the notion. Crater Lake National Park is one in this great system of recreational areas. It is probably not so well known as those mentioned but it is a region of unusual beauty and of great geologic interest.

The Park is located in south central Oregon, about seventy-five miles north of the California line. The central feature of the Park is Crater Lake which is a body of pure, sapphire blue water. The water is so blue that the officials often jokingly are accused by visitors of having put bluing in it. The Lake is relatively large, being from four to six miles across and two thousand feet deep. It is surrounded by cliff-like walls rising from five hundred to two thousand feet above the surface of the water. The walls are of many colors with reds, grays, purples, yellows and browns predominating. It is no wonder that such a spot is spoken of as the gem of our National Parks. Its moods are many, with color in unbelievable variations, ever changing with light alterations from sunrise to sunset. As a background and giving additional color there are many trees forming numerous patterns and designs of green. A gasp of admiration is

the first expression offered by most visitors, followed by a moment of silence as though they were trying to believe that such a place could be real. As is true of most scenes of nature that are so striking, Crater Lake cannot be described, so we sholl deal in this discussion with its history and geologic story.

Although pioneers entered what is naw the state of Oregon at o comparatively early date, it was around eighteen fifty before they began to filter into the southern port of the stote. The region was none tao accessible and the sparse population was in constant dread of Indian wars. Gold had been discovered in California and many people were moving westward. Many of these, disappointed in California, migrated to Oregan. It was not long before gold was discovered there too and exploration and prospecting in southern Oregon advanced accordingly. A band of California prospectars came to the mining town of Jacksonville to prepare for a trip into the mountains, keeping their purpose a secret. They were betrayed by one of their members ta a group of Oregon miners who learned that they were searching for a "Lost Cabin Mine," supposed ta be near the head of the Rogue River. The Oregon group immediately started after the California party which tried unsuccessfully to evade them. Both parties eventually ran aut of food and through the effarts of John Wesley Hillman, leader of the Oregon group, the parties combined in order to hunt for game. On June 12, eighteen fifty-three, Hillman went ahead of the hunting group, and rode up a deep canyon, which, judging from its size, he thought would lead to a higher slope. He let the mule pick its own way while he peered through the woads for game. Imagine his astonishment when the mule stopped on the rim of a deep blue lake lying many hundreds of feet below. Here he beheld a scene of unsurpassed beauty. Other members of the party soon joined the leader and they agreed to call the body of water "Deep Blue Lake."

Gold and Indian wars caused men soon to forget Crater Lake sa that in eighteen sixty-two anather group of miners "rediscovered" the lake only to learn afterwards of the Hillman party's previous visit. A third "discavery" was made in eighteen sixty-five by soldiers from Fort Klamath who called it Lake Majesty. The name was changed to Crater Lake in eighteen sixty-nine by some visitors from Jacksonville and it has been known by that name ever since.

In eighteen eighty-five William Gladstone Steel first visited Crater Lake. He had heard of this natural wonder as a school boy and had resolved to visit the locality. He came to Oregon in eighteen seventy-twa but it was nine years later before he could find anyone who had heard of the lake and several more years passed before he found anyone who had seen it. He was so impressed when he finally reached his destination that he immediately started agitation to make the area a National Park. Seventeen years later his efforts were rewarded. Congress established Crater Lake National Park in May, nineteen hundred and two. Judge Steel devoted the rest of his life to the development of the park and was for years Park Commissioner. He died in October of 1934.

The U. S. Geological Survey made a survey of the area in eighteen hundred eighty-six and at the same time sounded the Lake.

Paved roads are now to be found in the Park and it is visited by over one hundred and sixty thousand persons annually.

The story of the origin of Crater Lake is coupled with the geology of the Cascade range of mountains. These mountains are formed an the surface of volcanic rocks which have been poured out through a series of vents along a weak zone of the earth's crust. The vents are represented by a long line of volcanoes extending from Lassen Peak in northern California ta Mt. Baker in Washington. Others of this series are Mt. Shasta in California, Mt. Theilsan, the Three Sisters and Mt. Hood in Oregon, and Mt. Rainier in Washington. All af them are now extinct or dormant, although hot springs and steam vents are found on Mt. Shasta, Mt. Rainier and Mt. Hood. Within historic times only one of the entire group has been conspicuously octive. This one is Mt. Lassen in California which erupted in nineteen fourteen and again in nineteen twenty-three. Previously it had been inactive like the others but early explorers and Indians reported some eruptions. All of these volcanic peaks are comparatively high, ronging from ten thousand to nearly fifteen thousand feet abave sea level. All are snow-capped the year around and abound in glaciers. They are some of the most picturesque and rugged mountains of the United States.

Crater Lake now occupies a yawning pit which marks the site of an old volcanic peak of this group which probably rivaled in grandeur the towering Mt. Rainier or Mt. Shasta. It is supposed ta have been at least fourteen thousand feet high and may have reached the fifteen thausand foot mark. This former mountain has been given the name Mt. Mazama. Crater Lake is naw six thousand feet and the rim is between seven and eight thousand feet above sea level. How do we know a mountain formerly existed here? What has become of that ten thausand foot mass of rock that once extended to the summit? That is the mystery of Crater Lake! Scientists are still trying to solve this great geologic mystery drama. A number af possible solutians have been offered but none seems satisfactorily to fit the facts af the case. Apparently where now all is peaceful and quiet, formerly gigantic forces of nature waged a fierce, spectacular struggle with each other.

The walls of Crater Lake are built up of alternate layers of rock. Some of these are dense and athers are fragmental. This shows that Mt. Mazama was built by a series of explosions alternating with periods when molten lavas poured out of its vent and down its slopes. The explosions blew material high into the air which settled back around the old vent. The accumulation of explosive materials plus the outpourings of molten lava resulted in the building of the cone of Mt. Mazama. There must have been times when Mt. Mazama was quiet over periods of many years. This is shown by the irregular form of the rim and af materials deposited by running water and glaciers. At several points the Lake rim is indented by large U-shaped depressions which have the typical outlines of glacial valleys. These valleys have been cut off, as their cross sections show that they must have extended much farther up mountain slopes since destroyed. At other localities loose gravels and assorted materials show the effect of glacial deposition. In a few cases running water has cut "V" shaped valleys. One of the most interesting valleys of all is one which is filled by a great lava flow. Here one can see evidence of a regular succession of events which helps to prove the existence of Mt. Mazama, of glacial action, stream action and intermittent volcanic activity. First a "U"-shaped valley was formed in the alternate lava flows of Mt. Mazama, by a glacier, which represents a long period of snow accumulation and volcanic inactivity. Then the glacier receded and streams cut a "V"-shaped valley in the old glacial valley. This was followed by explosive activity which filled the floor of the valley with pumice, a light frothy volcanic rock. Soon after the explosion the valley was completely filled by a massive lava flow which even overflowed on the broader mountain slopes. Another explosion covered the lava flow with a layer of pumice similar to that over which it had flowed. At times forests grew on the slopes of Mt. Mazama as they do on Mt. Rainier today. The trees were even similar to those of the present. Charred logs, buried in volcanic ash, give mute evidence of the fate which overtook these trees. All of the rock layers do nat run parallel to the mountain slopes. In a number of places peculiar layers cut across the other more horizontal layers at right angles. These forms are known as dikes. They show that the column of molten material in the old vent was under pressure and that there were weak places in the wall af the cone. The

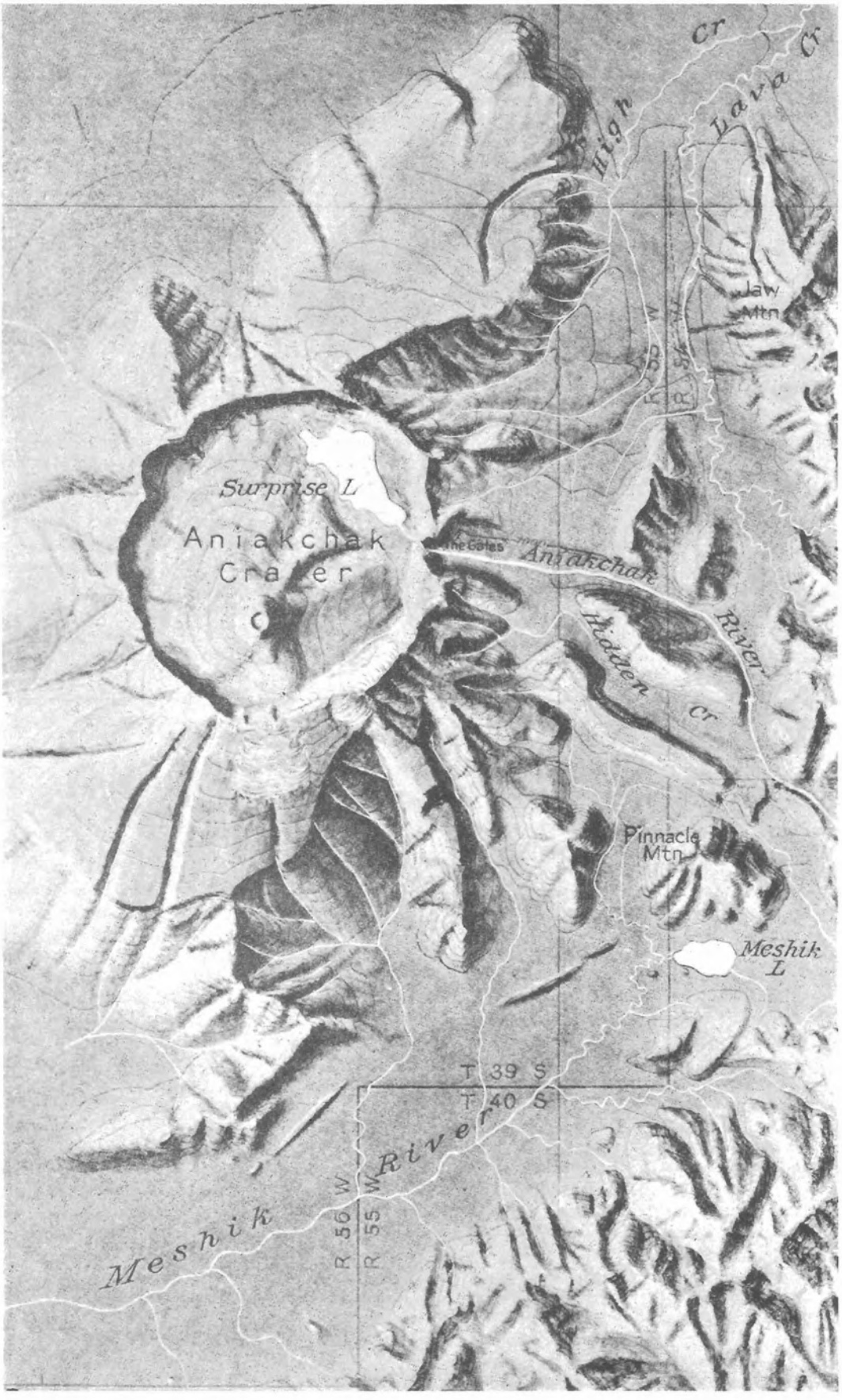


Fig. 2. Relief Map of Aniakchak Crater and Vicinity, Alaska Peninsula (after W. R. Smith).

pressure caused molten rock to flow into these weak zones, producing a number of radiating rib-like rocks which project from the flows because of their greater resistonce to weathering. Such forms, likewise, indicate a former volcano.

The building of Mt. Mazama is no mystery—it is the destruction of the mountain which leads to extensive speculation. There are three explanations which have been offered to account for this great catastrophe. The first and oldest one has been the most popular. According to this theory the lava in Mt. Mazama's vent gradually receded into the earth becouse of the eruptions of a neighboring volcano. This removed the support af the upper part of the cone which caved in ond was engulfed, leaving the large crater which the Lake now occupies. The second supposition was that gigantic explosions blew the mountain top off, and distributed it over the londscape for possibly hundreds of miles in every direction. The third possibility was a process similar to that going on today in Hawaiian volcanoes. There the molten lava rises and falls periodically in a large pit and in so doing causes sections of the rim of the pit to fracture and perhaps to fuse in the lava column.

The lack of lorge frogmentol materials in the vicinity of Crater Lake which should be present if explosion had occurred, caused the earlier thinkers to accept the subsidence theory. More detailed examination of the surrounding areas by later investigators shows that explosive materials several hundred feet in thickness extend for many miles in every direction. Furthermore, some of the lava loyers near the lake turn abruptly upward as though some force had bent them in that position; then, too, there is no known case of a whole volcano subsiding and it seems to be contrary to lows of eorth structure for seventeen cubic miles of rock to go back into the earth where pressures should be high. On the other hand, numerous mountains of the same type as Mt. Mozamo hove been known to destroy themselves by explosian. Examples of the latter are the great explosion of Katmai in Alaska in 1912 and Krakatoa in Java in 1883. The best explanation at present seems to be a modification of the first two ideas. That is, the croter wos probobly produced from old Mt. Mazama by one or more explosions followed by slumping of the walls which sank into the pit, leaving the original upturned edges caused by the explosion in several places. Be that as it may—Mt. Mazama did exist and was destroyed, leaving a crater around four thausand feet in depth and averaging obout five miles in diameter. And we still hove our mystery!

Following the great mountain destruction, volcanic activity started again and built severol small cones inside the crater. Two of these are now submerged below the lake but the third is over seven hundred feet in height and is quite a good sized volcano in its own right os it rises twenty-seven hundred feet above the crater floor. It possibly represents the last gasp of a dying volcano.

Meanwhile woter was beginning to accumulate in the croter. The precipitation at Croter Lake National Park averages about seventy inches per year. At that rate any depression would soon tend to fill up, praviding seepage and evaporatian were nat tao great. This is what has happened. Figures show that evaporation at Crater Lake amounts to about fifty-five inches per year and that leaves fifteen inches to account for seepage thraugh the lower slopes awoy from the Lake. There are no known major streams flowing into the Lake ond none flowing out on the surface. The water is not salty but is quite fresh. Since rain water is practically distilled water ond only slight solution of the rock walls takes place, this condition is easily exploined.

Geologically speaking, Crater Lake is a young feature on the earth's surface. The extensive glaciatian af the slope of Mt. Mozama indicates that it probobly existed during the glociol age so that its destructian must have come about since that time. The last glacial periad was between twenty-five and fifty thousand years ago. The age of the trees on Wizard Island, the largest of the cones in the crater, ranges up to eight hundred years. It is thought that Wizard Island was last active not more than two hundred years before the date of the aldest tree. That means thot it was probably active within the last thousand years. To look at this young volcano ane would think it had been active only yesterday, so fresh are its lavas and so little has it been affected by the erosive forces of the weather. The steepness of the crater walls and the rapid rate of erosion now going an show that the Crater is fairly new as the walls seem to be little changed by erosion.

The region around the Lake is heavily forested with hemlocks, pines ond firs. Where these grow within the rim they both aid and retard erosion. They split the rocks with their growing roots and hald the soil in place on steep slopes by these same roots. Trees play an important part in the geology of this region.

Crater Lake, as is true of all lakes, is at best a temporary earth feature. Erosion of the walls with a consequent filling of the lake, aided by stream valleys cutting back the outer slopes, will eventually cause this mysteriously beautiful lake to be destroyed. However, it will take generations to accomplish this end so that man will enjoy this superb spot for many years to come.

ORIGIN OF CRATER LAKE CUP—

Mr. Waesche's moderate statement of the controversy about the origin of Crater Lake cup should be supplemented by the following reading for anyone interested:

1. Crater Lake National Park. Natinal Pork Service pamphlet, Washington, 1936, page 9, "Destruction of the Mountain."
2. Mount Mazama: explosion versus callapse, by W. D. Smith and C. R. Sworzlow. Bull. Geol. Soc. Amer., Vol. 47, p. 1809. 1936.
3. The Glacial History of an extinct volcano, Crater Lake Nationol Park, W. W. Atwood Jr. Journ. Geol., Vol. XLIII, No. 2, February-Morch, 1935.
4. Gealogical History of Crater Lake, by J. S. Diller, Department of the Interior, 1912 (Gov't Printing Office, Washington, 10 cents).
5. Engulfment ot Krakatoa 1883. Review of Stehn, Volcano Letter No. 234, June 20, 1929.
6. Geology ond Geography of Niuafoou Volcano, mop and sections, Volcano Letter No. 318, January 29, 1931.
7. Volume relations of Explosive Eruption 1924 (Kilauea) Monthly Bulletin Haw'n Volc. Obs'y., Vol. XII, No. 12, December, 1924.
8. Gealogy and Mineral Resources af the Aniakchak District, Alaska, by R. S. Knoppen, Bulletin U. S. G. S. 797-F, 1929.

There is no reason for such an immoderate controversial position favoring only the explosive process as is taken by No. 2 above. Nature works gradually even at active volcanoes. The great steam blast eruptions of the world hove been accompanied by what Mercalli called "sprafandomenti", deepenings by callapse.

Atwood ond Stehn, Nos. 3 and 5, cited for support of explosion by No. 2, both endarsed engulfment. The Notional Park pamphlet No. 1 states a moderate position. Diller was moderate in all his writings, and a judicial observer (No. 4).

Niuafoou (No. 6) is cleorly an **engulfment plus steam-blast** kind of sink crater, the dome was quite like Kilauea, and the crater lake was formed millions of years ago (cited in No. 2 (p. 1828) os formed in 1886; when in fact a mere minor steam-blast accurred).

Kilauea steam-blast eruptions are no different from those of basaltic valconoes anywhere, and the combined engulfment and explasion of 1924 removed valumes one part by explosion and 250 parts by engulfment. (No. 7).

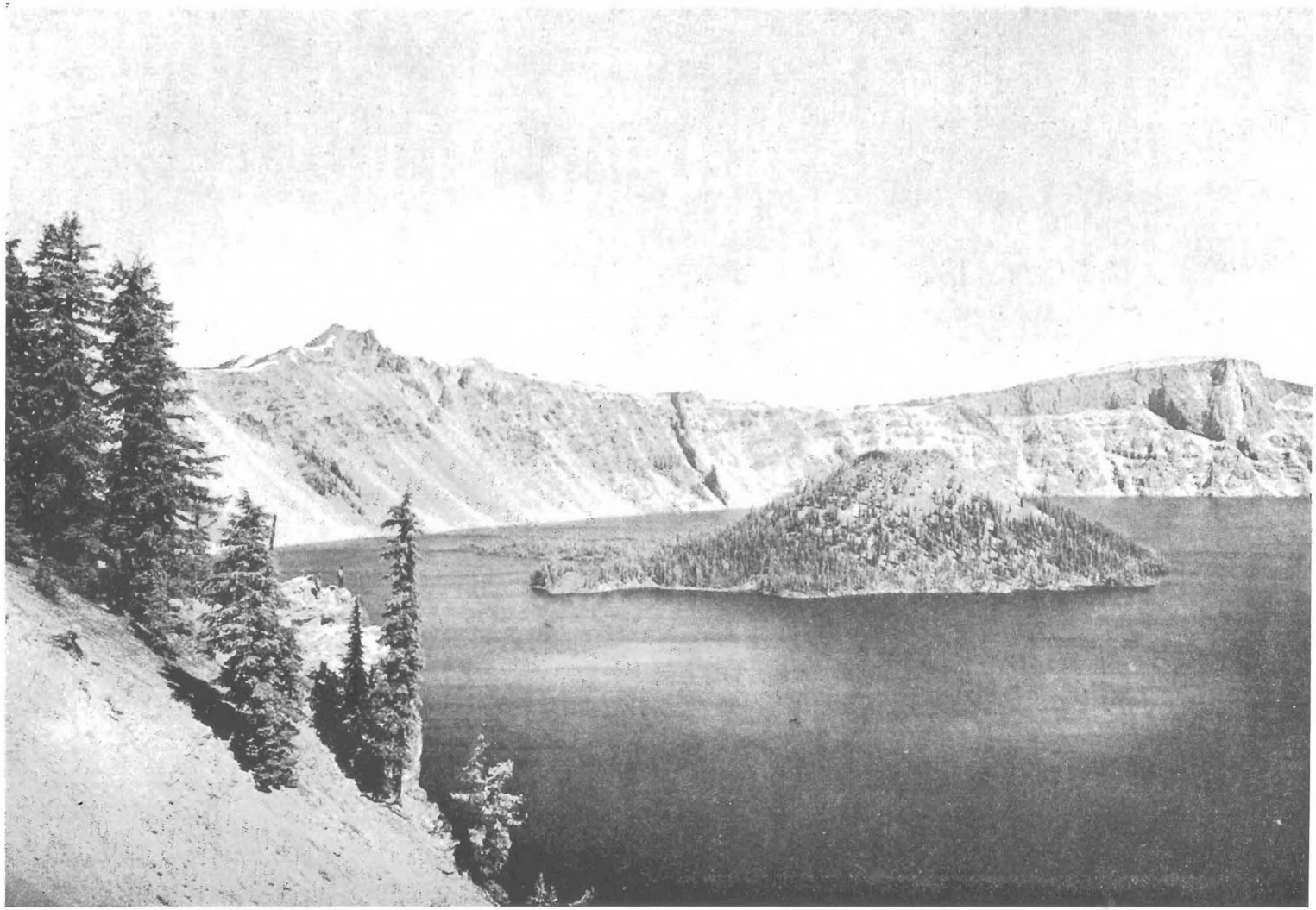


Fig. 3. Western Border of Crater Lake, from Victor Rock to Llao Rock (after Diller).

The basis for reconstruction of mountains over such saucer craters as Crater Lake, Niuafaou, Aniakchak, Batoer in Bali, or Aso in Kyushu, was stated admirably by Diller (No. 4, p. 24): "The glaciation and structure of the rim clearly establish the former existence of Mount Mazama but there may well be doubt as to its **exact form and size".**

Veniaminof Crater west of Aniakchok, (No. 8) but 5000 feet higher, is a triplicate of Aniakchak and Crater Lake, but full of ice spilling over in valley glaciers. It is the same height and size as Crater Lake, 6 miles across, and 8000 feet above sea-level; but it is a mountain, because it rises from sea-level.

Restore glaciation to the Cascade Range and you don't need a mighty peak of five cubic miles to scratch ledges, deposit till, and make U-shape valleys. The great Veniaminoff cup is itself at the **top** of a peak.

Finally, the geologist objection to voids underground is answered by underground intrusive bodies with straight-sided fracture boundaries that would fit together if the igneous matter (lava) were removed. If a void can form to let **up** the lava, it can form to let down the lava into crevices when whole mountain ranges are faulting and rifting.

At the Hawaiian volcanoes when lava lakes are rising and falling, this is happening all the time. The craters are on down-slipping fault rifts.

The tremendous event of the Vesuvian crisis, when a steam-blast eruption happens, is a "sprofondamento", a deepening. The amount of surface lava, dust and rocks is trivial compared to the croterol evacuation.

But the notion that such a volume as the contents of Monte Somma was left by the single evacuation of the Pompeiian eruption, is as fantastic as that Niuafoou crater was completely made in 1886.

The total volume of everything poured out and blown out of Vesuvius from 79 A. D. to the present would scarcely change the profile of the volcano. We know the history (Sapper). And we know that such eruptions as 1631 and 1906 engulfed the peak, which was subsequently restored from within.

A process of caving in and filling up again is normal extrusive volcanism and normal intrusive volcanism. The normal result is a gas loss to the atmosphere, a magma loss into crevices of the crust; and a compensating igneous bulk in the crust, for the substratum loss of igneous volume.

When the magma loss is a few cubic miles from a big cauldron, it means there has been a cycle of inflation; followed by a cycle of deflation, made up of hundreds of events such as submarine lava flows, or interstitial intrusive dikes along rifts tectonically opened.

The Hawaiian vents systematically robbed each other at progressively lower levels from 1855 to 1924. The 1924 vent was under the ocean where there is a slope to levels 18000 feet below sea-level in forty miles horizontally.

There was every opportunity for graben and cross-fault lava drainage in California and Oregon, from Miocene to Pleistocene time, for 20000 feet of depth, from the rim of Crater Lake to the broken shore blocks under the Pacific. And extrusive volcanism decayed from Miocene to the Present.—T.A.J.

Hawaiian Volcano Observatory Report for September 1937

VOLCANOLOGY

The month was notable at Kilauea Volcano for a decline of seismic phenomena and pit movements, except for a group of large distant earthquakes about the equinox, and at the same time a revival of many slides at Halemaumau in a new place, namely at the north.

The following are the weekly Observatory totals for Halemaumau and the seismographs.

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Tremors and Quakes
September 5.....	6.00	3	3.00	20
" 12.....	5.25	9	0.50	18
" 19.....	3.50	7	6.00	9
" 26.....	2.25	27	6.50	9
October 3.....	5.25	7	4.00	18

A shock was felt near Kilauea Crater September 15. Most of the very feeble shocks were of Kilauea origin, and most of the local disturbances were tremors. Distant earthquakes were registered September 3, 15, 19, 20, 23 and 29.

Sequence of Events by Weeks

The first week produced three slides in Halemaumau.

The second week produced nine slides and the smallest total opening of cracks since November 28, 1936.

The third week produced seven slides and declining seismicity.

The fourth week produced crumbling of the Halemaumau wall at the north and northwest taluses, twenty-seven slides being counted, while seismicity continued to decline.

The fifth week produced seven slides, mostly at the northeast wall, and increased numbers of tremors.

Slides at Halemaumau

The recorded slides from the wall of the pit were:

August 30, 9:25 a.m., making fresh scar 300 feet below northwest rim, and recording an Halemaumau seismograph.

August 31, 11:00 a. m., large slide NW, sending up dust.

September 3, 12:30 p.m., eastern slide extending the notch of August 22 southward.

September 6, 9:47 a.m., noise of falling rocks east.

September 6, 9:57 a.m., dust at the east.

September 6, 11:05 a.m., dust at the east.

September 6, 12:10 p.m., dust at the east.

September 6, 12:33 and 12.38 p.m., more dust.

September 7, forenoon, slides had carried away part of the east edge.

September 8, 12:39 p.m., slide from 50 feet below rim east.

September 8, 1:10 p.m., large slide north.

September 8, 2:18 p.m., dust east.

September 15, 2:33 p.m., rim rock fell east.

September 18, 8:53 a.m., slide east without noise.

September 18, 9:00 a.m., dust at the east.

September 18, 9:10 a.m., heavy dust cloud east.

September 18, 1:00 p.m., eastern dust.

September 19, 12:20 p.m., thick dust cloud north.

September 19, 2:55 p.m., noise of falling rocks east side.

September 20, 9:30 a.m., noise of northern slide.

September 20, 9:45 a.m., northern dust cloud.

September 20, 10:30 a.m., northern dust cloud.

September 20, 10:35 a.m., northern dust cloud.

September 20, 11:25 a.m., dust seen from Observatory, north.

September 20, 12:40 p.m., noise of falling rocks north.

September 20, 12:45 p.m., largest slide of this day, noise and dust north.

September 20, 12:55 p.m., 2:40 p.m., 3:25 p.m., northern slides making dust.

September 21, 9:20 a.m., northwest dust clouds.

September 21, 9:25 a.m., northern slide.

September 21, 9:30, 9:52, 10:00, 10:05, 10:13, 10:17, 10:20, 10:24, 10:49, 11:05 a.m., and 12:05 p.m., northwestern slides making dust.

September 25, 10:25 a.m., dust and noise from the west.

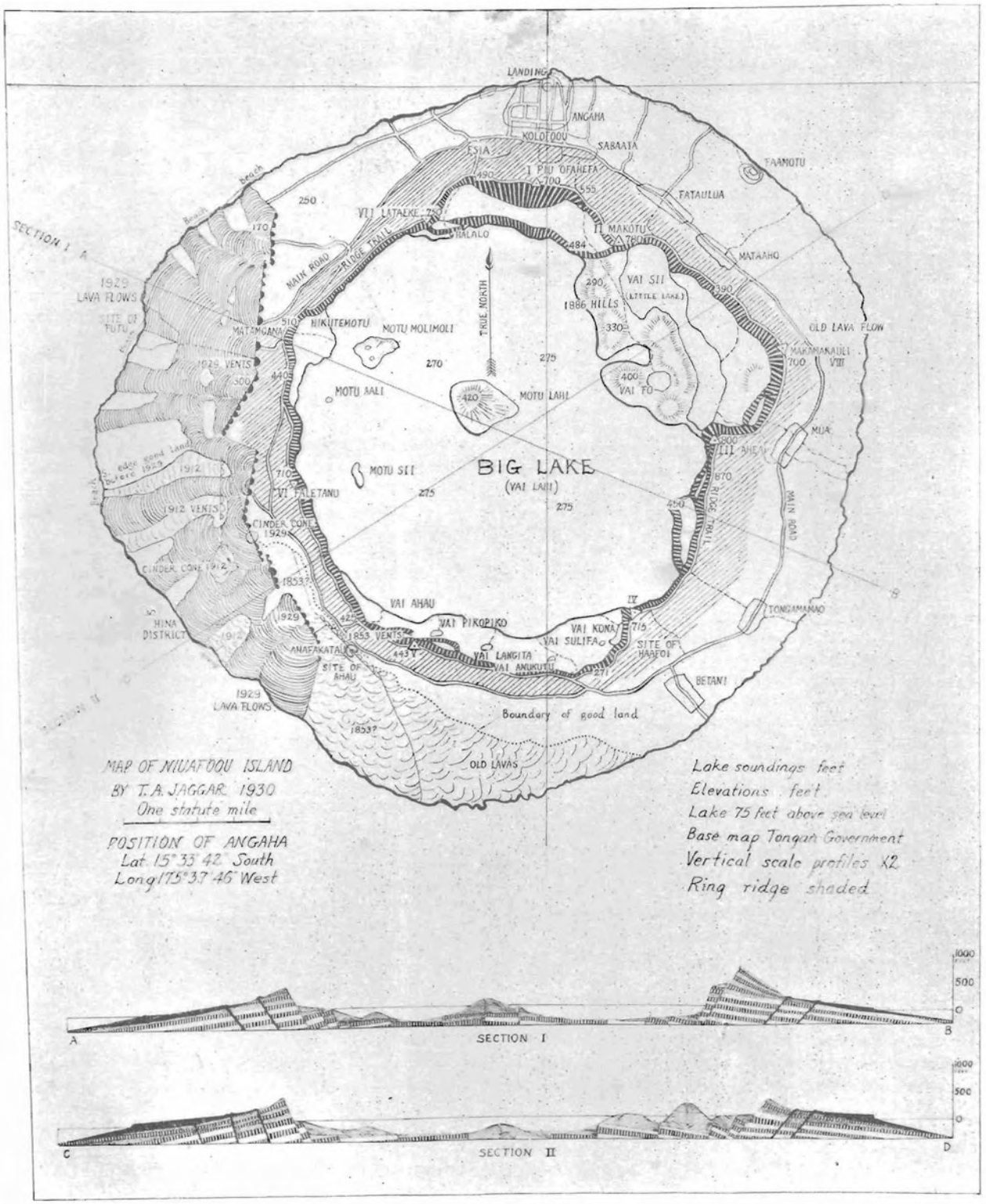


Fig. 4. Map of Niuafoou.

September 26, 10:02 a.m., 1:15 p.m., and 2:15 p.m., slides at the north side.

September 29, 10:25 a.m., slide at northwestern wall.

September 29, 1:10 p.m., sliding under both NE and N walls.

September 29, 1:15 p.m., 1:45 p.m., 1:50 p.m., and 3:25 p.m., slides from northeast wall.

October 1, 2:00 p.m., large slide at east wall.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted during September in aggregate movement as follows:

Week ending forenoon of:

September 3, 27 locations, 4 opened, 1 closed, opening 3.0 mm.

September 10, 27 locations, 3 opened, 4 closed, opening 0.5 mm.

September 17, 27 locations, 8 opened, 1 closed, opening 6.0 mm.

September 24, 27 locations, 6 opened, 0 closed, opening 6.5 mm.

October 1, 27 locations, 7 opened, 1 closed, opening 4.0 mm.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant† Earthquakes	Weekly* Seismicity
Sept. 5.....	16	4	0	1	6.00
" 12.....	15	3	0	0	5.25
" 19.....	6	2	1	3	3.50
" 26.....	9	0	0	2	2.25
Oct. 3.....	15	3	0	1	5.25

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of depth of focus has been made.

August 31, 10:51 am, very feeble, 12 miles deep, Hilina Kapukapu Fault, 2.0 miles N of Keauhou Point. 19° 17.5′ N; 155° 14.1′ W.

September 1, 8:34 pm, very feeble, 1.4 miles deep and 0.6 miles NW of Uwekahuna. 19° 25.8′ N; 155° 17.7′ W.

September 1, 8:55 pm, very feeble, location same as preceding.

September 5, 6:44 pm, a tremor at the Observatory, very feeble in Kona. Probably originated under W slope of Hualalai near seacoast and about 10 miles N of Kealakekua.

September 9, very feeble 1.3 miles deep, NE portion of Kilauea Crater, 8:08 am, 0.8 mile SW of the Observatory. 19° 25.5′ N; 155° 16.2′ W.

September 12, 4:30 am, very feeble, 2.6 miles deep, N rim of Kilauea Crater, 0.6 mile W of Kilauea Military Camp. 19° 26.1′ N; 155° 17.1′ W.

September 12, 4:32 am, very feeble, 1.0 mile deep, 0.4 mile SE of Keanakakai, 19° 24.1′ N; 155° 15.7′ W.

September 13, 3:56 am, very feeble, probably originated in area 1.0 mile E of Kilauea Iki.

September 15, 8:04 pm, feeble, 0.8 mile deep, Kilauea Crater 0.5 mile W of Byron Ledge, 19° 24.6′ N; 155° 16.2′ W. Reported felt by many in "CCC" Camp and near Park Headquarters.

September 19, 6:07 am, very feeble, 3.0 miles deep, 1.6 miles N of N rim of Kilauea Crater. 19° 27.6′ N; 155° 16.6′ W.

September 19, a tremor at the Observatory, very feeble on Kona instrument. Probably originated in Mauna Loa SW rift near 1919 source cone.

September 21, 8:59 pm, tremor at H.V.O., very feeble in Hilo, dismantled Kona seismograph, 25.0 miles deep, NE rift of Mauna Loa 4.0 miles W of Puu Ulaula, 19° 31.6′ N; 155° 31.0′ W.

September 27, 7:01 am, very feeble, of Kilauea origin.

October 1, 9:34 am, very feeble, 2.8 miles deep and 0.8 mile SE of the Observatory and 0.5 mile N of Kilauea Iki. 19° 25.6′ N; 155° 15.0′ W.

October 1, 7:05 pm, very feeble, 1.2 miles deep E portion of Kilauea Crater near Byron Ledge, 19° 24.9′ N; 155° 15.7′ W.

Microseismic motion of the ground at the Observatory was light September 2-7, 20, 22, and 28-30; strong September 10, 12, and 25; and was moderate the remainder of the month. All dates inclusive.

Teleseisms registered as follows:

September 3, "P" waves at 8h 25m 17s am, distance from Kilauea 2415 miles.

September 15, "P" waves at 2h 06m 45s am, distance from Kilauea 3485. Reported location Solomon Islands. 9° S; 164° E.

September 15, undetermined portion at 9h 26m am.

September 19, "P" waves, 8h 54m 15s, pm, no determination of distance.

September 20, undetermined portion at 11h 21m 50s pm.

September 23, "P" waves at 2h 45m 47s am, distance from Kilauea 3390 miles. Reported location, Solomon Islands 6° S; 154° E.

September 29, undetermined portion, 1h 16 m 6s am. Reported felt and to have been located in Japan.

Hawaiian Standard Time used for above reports.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau the algebraic sum of radial tilts toward or away from the pit.

At the Observatory the total accumulated tilt for the year ending October 3 was 10.85" S and 0.12" E.

Week Ending	Observatory	Halemaumau West Station
September 5	0.20" S 50° W	7.75" S 83° W
September 12	0.33" N 4° E	1.55" S 59° E
September 19	0.75" N 57° E	4.32" N 74° W
September 26	0.63" N 38° E	1.49" S 60° W
October 3	0.88" S 85° E	2.68" S 87° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
September 5	8.46" N 45° W	0.51" Toward
September 12	1.20" N 60° W	2.32" Toward
September 19	2.11" N 86° W	2.72" From
September 26	4.70" N 2° E	2.39" Toward
October 3	1.75" S 73° W	2.05" From

Crater Angles

Crater angles measured September 5, showed closing of 2.65" across Halemaumau and opening of 0.58" as compared with similar measurements of June 29, 1937.

H. H. W.

* For local seismicity definition see Volcano Letter 371.
† Including teleseisms or earthquakes over 5000 km from Kilauea.

THE VOLCANO LETTER

No. 452 monthly Department of the Interior National Park Service October 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

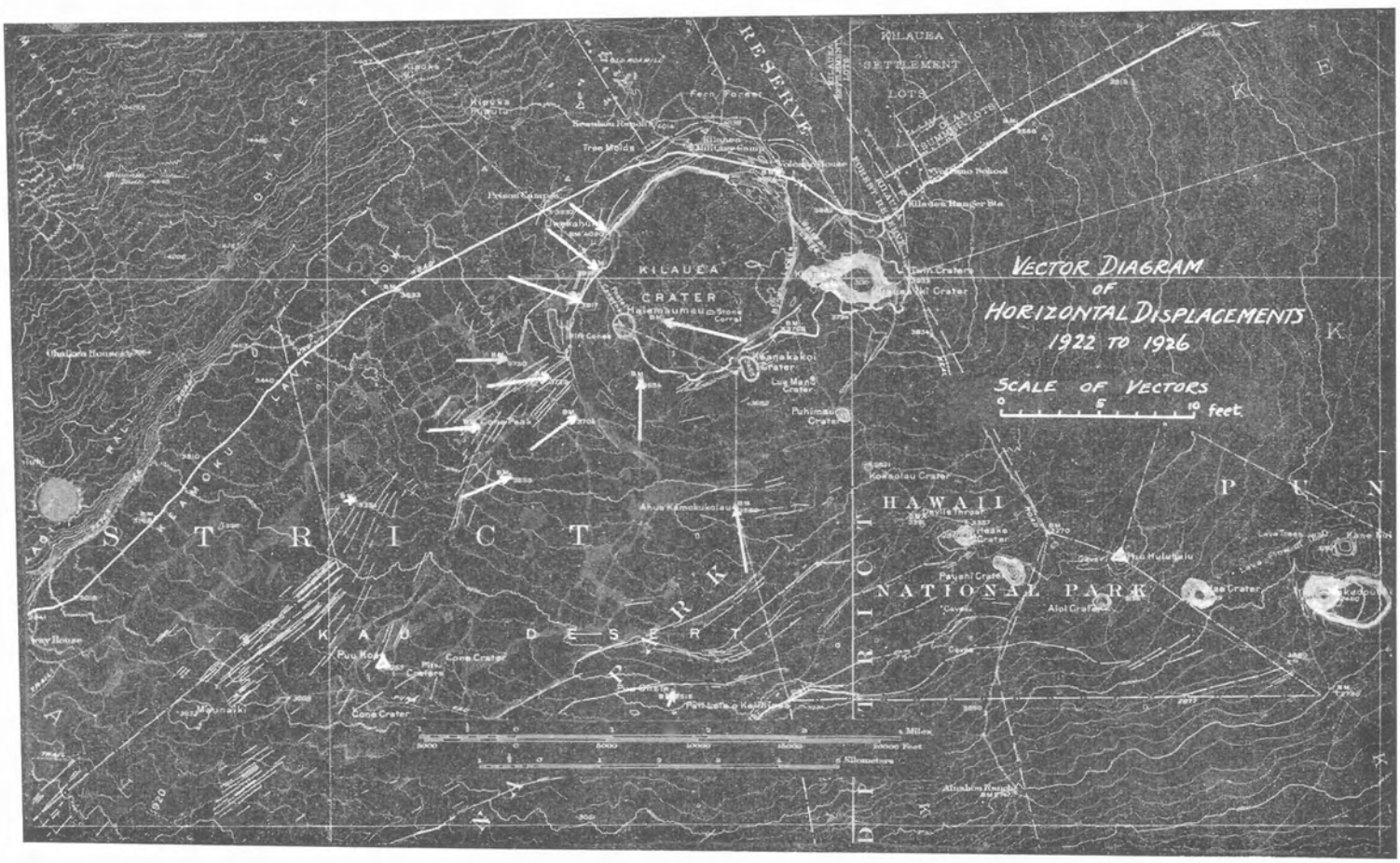


Figure 1. Map of Kilauea Crater; the tip of each white arrow on a monument; proved to move toward the center about 1924; by as many feet as the arrow is long by the scale.

TRIANGULATION AND LEVEL CHANGES AT KILAUEA—
Radio Talk June 22, 1937

By Hugh Waesche, Assistant Geologist, Hawaii National Park

On previous occasions (Volcano Letter February and April, 1937) I discussed earthquakes, crack measurements and tilting of the ground at Kilauea. Most of you probably are somewhat familiar with these phases of our work. Today I shall attempt to tell you about two other studies which have proved most interesting from the scientific standpoint but which are probably not so well known by the general public. (See also May and July 1936, Volcano Letter.)

Movements of the large volumes of lava below the earth's crust should create changes on the earth's surface. These movements in all probability would not be visible to the human eye, although in many cases they actually are. Two, well established, and reliable means of detecting such disturbances are by using instruments which would show by actual measurements, amounts of change of elevation and amount of horizontal dis-

placement in and around volcanic areas. For changes of a vertical nature the precise level and far horizontal displacements on engineer's transit are used, to establish measurements of a refined type just as is done by the U.S. Coast and Geodetic Survey and the U.S. Geological Survey in their land survey and location work. A great amount of triangulation and leveling has been done in volcanic regions in Japan, particularly at Asama, with very definite and positive results. Similar work has been done in California along earthquake-making faults, with a great deal of success.

Measurements of this nature have been a part of the working program at Kilauea since the establishment of the Observatory in 1912. In 1920 at the First Pan-Pacific Scientific Congress in Hawaii, there was published among its recommendations the following: "Great earthquakes and volcanic eruptions are often preceded and followed by elevations, depressions and horizontal displacements in the regions concerned; therefore this Conference **recommends** that precise leveling and triangulation be carried on at definite intervals in selected seismic and volcanic districts in order to ascertain precursory and other changes in underground stress accompanying great seismic and volcanic disturbances."

Horizontal ground displacements may be thought of as expanding or contracting areas of the earth's surface. Their measurement with a transit is called triangulation. At Kilauea there have been four epochs or periods of such surveys. The first was as a part of the original Hawaiian Government Survey of 1871, reaching Kilauea in 1897; the second was by R. M. Wilson of the U.S. Geological Survey in 1922; the third was by J. C. Beam in 1926 and the fourth by Wilson in 1926. Inasmuch as the second and fourth were run by the same engineer under as near identical circumstances as possible, they are considered of greatest value. These two epochs are also of special interest in that respectively they precede and follow the explosive activity of Kilauea in 1924. Kilauea crater and the outer slope of the volcano, as far south as Puu O Hale, were a part of the surveyed area.

In triangulation procedure various points in a given area are selected as the key or control locations. From these stations angles are turned off repeatedly to other stations in the system or net, and from the average angle values, azimuth determinations and intervening distance calculations and relative positions are determined. It of course is not so simple as this may have sounded, as there are many sources of error, such as refraction because of heat and moving air and poor visibility. Corrections are made for all of these.

Careful comparison of results showed quite definitely that the older surveys did not agree with the newer ones, nor did the survey of 1922 agree with that of 1926. Of the sixteen stations used probably the most familiar to you are, the monument in front of the Volcano House, the Little Beggar on Kilauea crater floor, Uwekahuna and the Spit. Another quite familiar location point is on the summit of Puu Hulu Hulu which may be seen on a trip down the Chain of Craters road. In a general sort of way it was found that there was little or no change between certain specifically selected points well outside of Kilauea crater such as the Observatory, Ohale, Koae, and Puu Hulu Hulu. On the other hand, relative to these fixed stations other locations showed considerable movement toward Halemaumau accompanying the collapse after the explosive eruption. A map was plotted using vectors to show this movement. More or less radial movement toward the pit from all directions was thus definitely shown. (Figure 1.)

Triangulation on a minor scale is still carried on from the Observatory. The same "Berger" transit used by Wilson in his earlier surveys is set up on the Observatory bench mark about every ten days, and the angles across Kilauea crater, from its southeast rim to Uwekahuna on the northwest rim, and across Halemaumau in the same direction, are determined. Each angle is measured six times in a forward or clockwise direction and then repeated in a reverse direction in the same manner. The results are then averaged and calculations made, and this in turn plotted for comparison on coardinate paper; so that a continuous relative picture of opening or closing of the crater, and of the pit, is available. Over longer periods changes are readily observed, but for short periods, due to errors which are unavoidable, changes are not so marked. The probable error calculated by Wilson was plus or minus two and one half seconds of arc, which is more than the usual variations which are now encountered from one reading to the next. Recent readings since the Mauna Loa eruption of 1935 seem to indicate, to date, a gradual closing of both crater and pit angles, as though the lava underneath Kilauea may have receded following that eruption. It would be safer, however, to say that no apparent change of appreciable magnitude has occurred within the past two years.

As was the case with the triangulation surveys, the level surveys may be divided into epochs. There were three of them. The first run was made in 1912 by the Birdseye party of the U.S. Geological Survey; the second by R. M. Wilson in 1921 and 1922, and the third in 1926 and 1927, also by R. M. Wilson. The instrument used is shown in Figure 2, sighting on a rod not shown. Just as with the triangulation, the last two of these runs were made before and after the explosive eruption in 1924. There were two classes of level determinations. One class consisted of lines run from tidal bench marks at sea level to the summits of Kilauea and Mauna Loa. The second class was of a local nature run only in the vicinity of Kilauea. The first two were what is known as "third order" leveling and the third run was "first order" leveling. In "first order" leveling invar metal rods are used and the level is shaded; in earlier runs wooden rods were used. Accuracy is of a very high degree in "first order" levels.

Probably the greatest problem encountered in running the levels from Hilo to the Volcano was changes of rod length. The wooden rods of the early surveys were found to vary from their original Bureau of Standards length. This variation was usually an increase in length with increase of moisture absorption. After very careful analyses Wilson applied corrections to take care of this. His conclusions are published in Research Publication number 10 of the University of Hawaii (Ground Surface movements at Kilauea Volcano) and are most interesting. The level results seem to check the triangulation and tilt values and, at the same time, seem to be more tangible in their demonstration of a factor in volcanic change, which had been suspected here and demonstrated elsewhere.

It would be hard for a visitor who has been to Kilauea frequently to realize how great the level changes were after that 1924 eruption. The Volcano House seems quite substantially located on the northeast rim of Kilauea crater, yet between 1921 and 1926, the Volcano House went down nearly four feet (3.56). Uwekahuna too looks firmly planted—a sort of Gibraltar, yet it sank nearly five feet (4.56) in the same period. As far south as Puu Hulu Hulu and Puu Koae the ground sank between three and four feet. In a general way and as would be expected, amounts of depression increased toward Halemaumau, reaching a maximum sinking of thirteen feet near the old spatter cone, "Little Beggar," about two-tenths of a mile east of Halemaumau. In fact, it seems pretty certain from tilt and levelling data, that between 1912 and 1921 the entire slope of Kilauea to sea level rose; and then sank between 1921 and 1927 in gradually increased amounts as the crater of Kilauea

was approached, and with a very rapid rate of change at Halemaumau. Hilo was thought possibly to have risen slightly, and then to have gone down about six-tenths of an inch after 1924.

Local levels in Kilauea crater were run regularly in 1934 and 1935 and until February 1936. This line started at the Spit bench mark, southeast rim of the crater and made a loop around Halemaumau. Occasionally the run was made just to the northwest bench mark on that rim of Halemaumau. This particular line is used in order to obtain relative displacements between the actual crater floor and its rim. Plotted results of this level line have proven very significont. Among other things it hos been discovered that a relative chonge in Kilauea crater of several millimeters within twenty-four hours is not unusual. Following the 1934 eruption of Kilauea the northwest rim of Holemaumau apporently settled about six inches with reference to the southeast crater rim. In August 1935 the lowering ceased, and the value remained unchanged until Mauna Loa erupted in November. Immediately the Kilauea crater floor began to settle again, and by February 1936 it had settled another two inches. Apparently settling has continued and as soon as possible new determinations will be made.

From this brief review it will be seen that surveys of this sort are very important and informative parts of the Hawaiian Volcano Observatory program. This work will be continued and the results noted with interest relative to future eruptions and thus more knowledge of our volcanoes will be accumulated, and activity predictions made more accurate.

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Tremors and Quakes
October 10.....	7.00	4	7.00 mm.	12
" 17.....	6.25	0	0.00 mm.	12
" 24.....	4.75	4	2.50 mm.	14
" 31.....	6.00	2	4.75 mm.	16

A feeble shock October 18 and a stronger one classed os "slight" October 25 were felt in National Pork and Hilo, and were Kilauea movements. Of nine measured shocks for the month seven were from Kilauea, one from Mauna Loa, and one from Mauna Kea.

Sequence of Events by Weeks

The first week produced four observed slides, the second week was very quiet, the third week with its four slides may have had them started by the earthquake of October 18. The fourth week showed only two slides that were observed, and an increase in number of spasmodic tremors.

Slides at Halemaumau

The recorded slides from the wall of the pit were:

October 4, 9:33 a.m., large slide NE.

October 4, 11:13 a.m., dust NE.

October 4, 11:18 a.m., dust from slide NW.

October 4, 1:39 p.m., another slide NW.

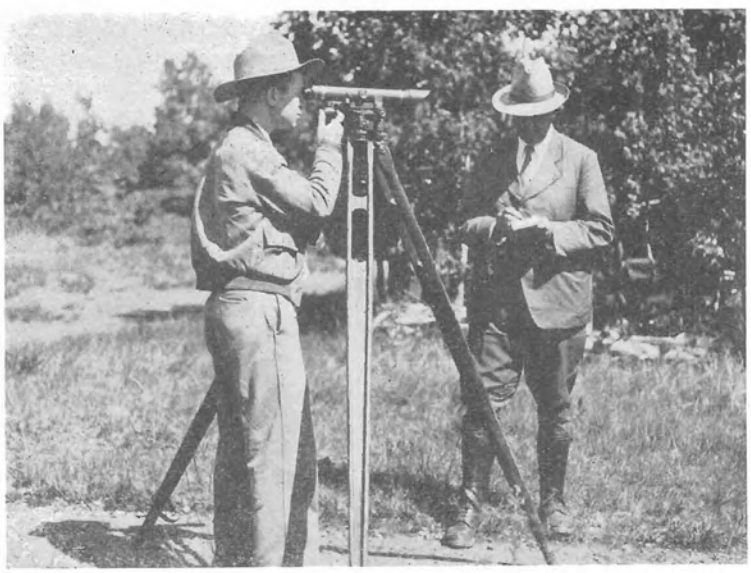


Figure 2. Precise level sighted on a rod marked in decimals of a foot, held upright by a rodman (not shown). Waesche sighting, Jaggar entering notes.

Hawaiian Volcano Observatory Report for October 1937

VOLCANOLOGY

The month at Kilauea Volcano showed little change in local tremors and movements about Halemaumau pit. As in September, there was a revival of slides from the walls toward the end of the month.

The following are the weekly Observatory totals for Halemaumau and the seismographs.

October 18, 11:15 a.m., dust observed over north rim.

October 18, 12:15 p.m., another slide at the same place.

October 19, 9:31 a.m., slide from NW wall heard at Uwekahuna Museum.

October 19, 10:08 a.m., slide at east rim observed from Tourists' Stand.

October 31, 11:20 a.m., dust rising at north wall.

October 31, 2:10 p.m., slide at the west wall.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted during October in aggregate movement as follows:

Week ending forenoon of:

October 8, 28 locations, 11 opened, 3 closed, opening 7.0 mm.

October 15, 28 locations, 2 opened, 3 closed, opening 0.0 mm.

October 22, 28 locations, 6 opened, 2 closed, opening 2.5 mm.

October 29, 28 locations, 10 opened, 2 closed, opening 4.5 mm.

T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquake	Distant† Earthquakes	Weekly* Seismicity
Oct. 10.....	26	1	0	0	2	7.00
" 17.....	15	5	0	0	0	6.25
" 24.....	11	2	1	0	0	4.75
" 31.....	14	1	0	1	0	6.00

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible a determination of depth of focus has been made.

October 7, 1:49 am, very feeble, 15 miles deep under Mauna Kea. 19° 48.7′ N; 155° 30.4′ W.

October 14, 10:32 am, very feeble, 1.8 miles deep in Kilauea Crater 0.5 mile W of Byron Ledge, 19° 24.6′ N; 155° 16.2′ W.

October 15, 3:24 pm, very feeble, of shallow origin in cracks SW of Keanakakoi. 19° 24.1′ N; 155° 16.2′ W.

October 17, 12:58 am, very feeble, 0.5 mile deep in cracks near SE rim of Kilauea Crater 0.5 mile SE of Pit seismograph. 19° 24.1′ N; 155° 16.6′ W.

October 18, 12:44 am, feeble, 28.0 miles deep, SE slope of Mauna Loa 10 miles west of Kilauea Crater. 19° 26.3′ N; 155° 25.0′ W. Reported felt at Hawaii National Park Headquarters and in Hilo.

October 19, 5:56 am, very feeble, 1.1 mile deep in Kilauea Crater 0.4 mile E of Pit seismagraph. 19° 24.4′ N; 155° 16.7′ W.

October 22, 11:36 pm, very feeble, of shallow origin, SE rim of Kilauea Crater. 19° 24.0′ N; 155° 16.4′ W.

October 25, 5:43 am, slight, 9.0 miles deep in Hilina Fault system 8.0 miles S of the Volcano Observatory. 19° 19.8′ N; 155° 15.0′ W. Felt by many at Hawaii National Park Headquarters and in Hilo.

October 30, 11:44 am, very feeble, 4.1 miles deep and 0.4 mile W of Ahua Kamokukolau. 19° 22.9′ N; 155° 16.4′ W.

Microseismic motion of the ground at the Observatory was moderate October 4 and 5 and strong the remainder of the month.

A portion of a teleseism was recorded at Kilauea beginning at approximately 8h 11m pm, HST., October 4. Reported location was 3200 miles ESE of Hawaii; 22° N; 108° W. An unidentified portion of another teleseism began recording at approximately 7h 00m am, HST, October 6.

Periods of continuous tremor which registered on the Observatory seismograph were: 16 minutes beginning at 10:30 pm, October 6, and 9 minutes beginning at 1:43 pm October 16.

H.H.W.

* For local seismicity definition see Volcano Letter 371.
† Including teleseisms or earthquakes over 5000 km from Kilauea.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau the algebraic sum of radial tilts toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending October 31, was 9.83″ S and 0.38″ W.

Week Ending	Observatory	Halemaumau West Station
October 10	1.25″ N 9° E	1.55″ West
October 17	1.41″ S 35° W	3.37″ N 78° W
October 24	0.58″ S 11° E	1.43″ N 29° E
October 31	1.62″ N 40″ E	4.17″ S 53° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
October 10	3.47″ N 54° W	1.75″ Toward
October 17	3.99″ N 43° W	0.92″ Toward
October 24	3.18″ S 70° E	2.01″ From
October 31	8.29″ N 29° W	4.68″ Toward

H.H.W.

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory October 16, showed slight opening of the Halemaumau value, and closing of the Kilauea Crater value, compared with similar measurements September 15. From Kilauea Crater SE rim to Uwekahuna there was closing 1.16″, September 15 to October 6 and closing 2.68″, October 6 to October 16. Total closing 3.84″. From the SE Pit B. M. to NW Pit B. M. there was opening 1.57″, September 15 to October 6 and closing 1.48″, October 6 to 16. Total opening 0.09″.

Levelling at Kilauea

October 12 and 13, a series of levels was run from the Spit B.M. on the SE rim of Kilauea Crater, to the NW Pit B. M. on the NW rim of Halemaumau. A Stanley level was used, and the results obtained were the first check on this determination since February 10, 1936 when a U. S. Geological Survey model precise level was used. Between September 3, 1936 and January 26, 1937, five sets of levels over the same line were run, using a new U. S. Coast and Geodetic Survey type precise level. These in no case gave satisfactory checks on closure of the circuit. The run made with the Stanley level giving a satisfactory check, October 12, 1937 showed that results obtained with the Geodetic Survey level were of value in spite of inaccuracies, in that they were of qualitative value indicating continuous relative lowering of the floor of Kilauea Crater with reference to the SE rim since October 1934 at the close of the Halemaumau inflow at that time. Level determinations of October 12, 1937 showed that the NE rim of Halemaumau (floor of Kilauea) had relatively lowered 19.7 centimeters since February 10, 1936 (closing stages of Mauna Loa Eruption) and 37.8 centimeters since October 17, 1934, with reference to Spit B. M. SE rim of Kilauea. Between August 13, 1935 and November 26, 1935, relative change of elevation between the same stations was 4.0 millimeters, or essentially no change in the period leading up to the Mauna Loa eruption. The termination of the Mauna Loa eruption marked the beginning of another period of relative lowering of Kilauea Crater floor which has continued up to the present time. The period of unchecked levels run between September 3, 1936 and January 26, 1937 in general confirmed this apparent downward movement. It must be remembered that Spit B. M. on SE rim of the greater crater might have been relatively elevated, hence the word "apparent".

H.H.W.

THE VOLCANO LETTER

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Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

KILAUEA VOLCANO LABORATORY
OF THE UNIVERSITY OF HAWAII 1937—

By T. A. Jaggar

Research at the Kilauea Volcano Loboratory with workers from the University began on July 13 with the arrival of Dr. Stanley S. Ballord, accomponied by Mr. Paul Gow, chemist of the Hawaiian Sugar Planters' Association. They made preliminary chemical tests for three days, setting in operation oxy-flomo blow-pipe opporotus for melting glass. This ond numerous items of equipment ond supplies for making vocuum tubes, and collecting volcanic gases were put in working condition.

Spectrograms made with the large quortz spectrograph of the H.S.P.A. in Honolulu shaw domination of carbon monaxide. An onalysis carried out at the University by Assistant Professor J. H. Poyne shows carbon dioxide, sulphur dioxide, nitrogen and oxygen, but no corbon monaxide nor hydrogen. The results shaw chemical reactions in progress even at the relatively low temperoture of Sulphur Bonk. The analysis residue is used for spectroscopic work. On August 17 Dr. Bollord and Dr. Eller set up new apparatus, and during the ensuing fortnight Dr. Bollord collected samples af speciolly dried gas with filter tubes for removing excess of corbon ond sulphur.

Dr. Ballard reports as follows:

I left Honolulu baund for Hila via Inter-Island steamer on Friday, August 13, arriving there the following day. We left the Big Island to return to Honolulu on Sunday, August 29. The two weeks spent at the volcano observatory were most worth while from the research point of view. The major accomplishment was the collection of four tubes of solfataric gas from the Sulphur Banks wells. One of these tubes was filled, using a method similar to that used for some of the collections of last year, in order to determine whether any major changes in the constitution af the gas had occurred since then. The other three were collected thraugh an ice pack in order to condense out the large steam content and through two traps containing concentrated patassium hydroxide. The gases were passed thraugh the potassium hydroxide solution in order to absorb the large content of carban dioxide and sulphur dioxide which had been detected spectrographically and chemically in the 1936 collections. Spectrographic examinations had shown that so much carban monoxide, carban diaxide, or arganic matter was present that other constituents could not be detected by this method. The chemical analyses canducted by Dr. J. H. Payne, Assistant Professar of Chemistry, had revealed a large sulphur diaxide content, sa large in fact that the determination of nitrogen, axygen, and combustible gases wos difficult and uncertain.

Figure 1 shows 250 cc. tube connected with 70-foot well drilled at Sulphur Bank, Kilauea. This is set up for sucking the well gas through an ice pack. The inner box is packed with ice and covered. A hand suction pump is used.

Figure 2 shows the gas being drown through two bulbs packed with ice and salt and a Milligan gas tower absorption bulb contoining a 50% solution of caustic potash. A three-way stop-cock below is used to flush the line before collection. The bulbs are for the purpose of obsorbing steam, carbon dioxide ond sulphur dioxide.

Instructor Iwao Miyake did the following important work in checking aver the Observatory shop tools and the seismographs of Halemaumou, Hilo, Uwekahuna and Kana:

1. Mode a list of necessory shop supplies.
2. Turned out flonge and mounted the new chuck for the Observatary shop lathe.
3. Overhouled the Uwekahuna seismograph. The vertical component wos nat working.
4. Overhauled the Pit seismograph and adjusted the clock contacts.
5. Built seismograph constant measuring device.
6. Overhauled the Kana seismograph and took complete data necessary far constant determinotion:
   a. Established known points an seismograph boom for future canstant checking measurements.
   b. Worked out a routine for constant checking measurement and taught same to Mr. Yasunaka.
7. Overhauled Uwekahuna seismograph drive clock.
8. Installed and adjusted new electric contact points an Uwekahuna time marking clock.
9. Overhauled the Hilo seismograph and took complete data necessary for constant determination:
   a. Established known points an seismograph baam for future constant checking.
   b. Rebuilt timing clock and put in new electric contact points far time marking.

Mr. Miyake arrived July 14 and Dr. Eller July 31. Special studies were made of all the seismological instruments an the island of Hawaii, and the constants of the instruments were determined.

Mr. Miyake finished his shap work and seismographic tests August 4. Professor Eller continued wark here until August 18.

Dr. Eller reports as follows an his new tilt-meter:

"As my main interest in the work at the H. V. O. is the study af tilt measurement, most af my time there was spent in that connection. Several trips ta the pit and to the country around Kilauea served to make the general lay of the land

familiar to me. This wos followed by a study of maps of the region, for the purpose of planning possible points for future placing of tiltmeters for an extended program of tilt measurement.

"Also o recording tiltmeter, constructed in Honolulu, wos adjusted and put in proper working order, and installed in the seismograph room at the Hawaiian Volcano Observatory. This is of a design which I hope will be found useful for future work. This meter is still in operation and I am receiving records from it eoch week. So far these records show little change from the original setting, due to slight activity in the Kilauea region during the past few months.

"A considerable study was mode of the tilt records available at the Observatory, and notes taken from them for future study."

Dr. Jaggar was greatly assisted by the physicists in his work of designing and building a set of ten earthquake recorders to

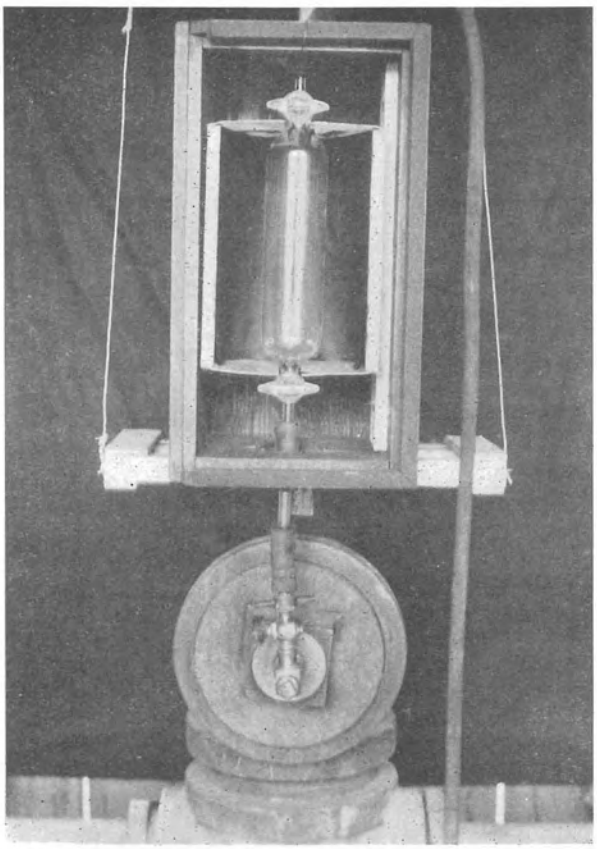

Figure 1. A tube for gas collection over Sulphur Bank well by suction and packing in ice.

be located at the telephone exchanges of the island. Several of these instruments have been tested out, at the Kilouea laboratories with a view to progressive improvement of detail.

The investigations of the summer of 1937 on volcanologic physics, by Professors Jaggar, Eller ond Ballord, Instructor Miyake, and geophysical assistant Sato, aided by the mechanical staff of the Hawaiian Volcano Research Association, namely H. Yasunaka and A. Okuda, have started new work that will be carried out both here and in the University laboratories throughout the coming year. Aided by the Department of Chemistry and by the large spectroscope of the Sugar Planters' Association, a new effort is under way to understand the gas action and rock crystallization that constitute volcanic activity, and eventually makes the soil, air, and water of Hawaii.

The following address was delivered at Radio Station KHBC, Hilo, August 17, 1937, by Professor Eller:

"TILTING OF THE GROUND"

Two yeors ago plans began to develop at the University of Hawaii for cooperation in the work of the Hawaiian Volcano Observatory. So far active participation has been restricted to a few weeks during the summer when members of the teaching stoff were free to work at Kilauea.

The Deportment of Physics of the University has entered into this program from several angles, as there are many problems connected with the work of the Hawaiian Volcano Observotory that are more physical than purely geological. In the main these are: the study of the gases from the volcano, and the volcanic rock, which are being examined spectroscopically to determine their constituents, both as to the elements present and their quantity; and the study of movement of the earth, both temporary and permanent.

Earth movements and displacements af seismic origin are of interest because of their possibilities in forecasting earthquakes ar eruptions. The earth movements at Kilauea are observed primarily for the purpose of studying volcanic activity which might result in eruption. They are in the nature of quakes of varying degrees of magnitude, and tilting af the earth's surface. Observations and measurements of these movements were begun early in the history of the Hawaiian Volcano Observatory.

The earthquakes are recorded by several seismographs, three of which are at Kilauea, one in Kona and one at Hilo. From the records of these instruments it is possible to determine the magnitude, character and location of quakes originating in various parts of the island of Hawaii, say in Halemaumau, or Mauna Loa, both af which are sources of many of the disturbances noted. These quakes result from movement of the underlying lava, and by their nature assist in the forecasting of eruptions.

Tilting of the ground, sometimes sudden, but more often gradual, accompanies the movement of the underlying lava. A tilt is a change in the angular relation between a portion of the earth's surface and the horizontal. Tilting is usually very slight, and is measured in seconds of arc. A tilt of one second, which is fairly large as tilts go, represents the angle through which a line about three and one-half miles long is rotated about one end when the other end is raised one inch. Such ground movements can be measured by precise leveling, but this method is expensive and slow, and not suitable except over a fairly extended area.

It is apparent, then, that an instrument for measuring a localized tilt must be very sensitive to change af angle of its supports. The seismographs, such as are in use for earthquake measurement, are utilized for tilt measurement, and are sufficiently sensitive, but a seismograph installation is much too expensive to use for the large number of tilt stations that are needed.

A type af tiltmeter has been developed at the Hawaiian Volcano Observatory which is very satisfactory for indicating the tilt, both in magnitude and direction, but has the disadvantage that it is not a recording instrument. It must be visited and read to determine the tilt. Two of these instruments are in use on the floor of Kilauea crater, near Halemaumau, and are read at twenty-four hour intervals, but there is no record of any variations that might occur between readings, nor of the time when any particular amount of tilt takes place. Furthermore, these instruments are not of a type to be made self-recording, except photographically, and that has its disadvantages.

There is need for a tilt-measuring device that is sensitive, economical in construction and operation, which will record the tilt hourly, at least, and that need be visited not oftener than once a week, at which time the record can be removed and

replaced by a new, blank record sheet. Many such instruments could be placed around Kilauea crater and the rifts about this region and a very complete record of the tilting of the ground obtained which would be of great value in the study of the lava movements below the ground, as well as in the prediction of future eruptions.

It is in connection with the development of such an instrument that I am spending a few weeks at the Hawaiian Volcano Observatory this summer. I have a model in operation from which daily records are now being obtained. This model appears to have possibilities for development into the type of device required for the more widespread study of tilts which I have mentioned.

At the present time tilting is being measured at Halemaumau, as before stated, and also at some of the seismograph stations, by measurements taken from the seismographs. Such measurements have been carried on continuously at the Obser-

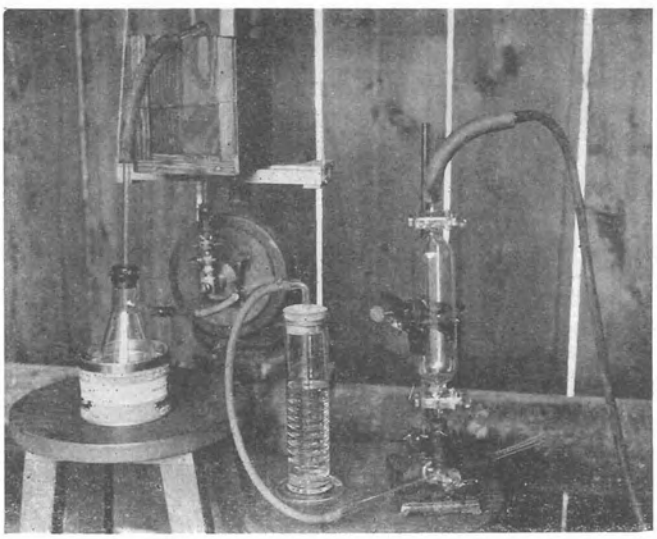

Figure 2. Gas drawn through salt-and-ice mixtures and KOH before reaching collecting tube.

vatory for many years, and have shown that volcano tilts coordinate with lava movement, and that seasonal tilts also occur over large areas. The annual variation of tilt at the main Hawaiian Volcano Observatory station takes place along a line about NNE and SSW. The tilt is greatest to the NNE about the end of December and the greatest SSW value is in May or June, and varies through a range of from twelve to eighteen seconds of arc in the different years. At the same time there is now a slight residual tilt toward the west which is at the rate of less than one second per year.

The tilt stations on the crater floor, near Halemaumau, indicate in general, tilts to or from the pit as being predominant. This shows a swelling and subsidence with the rising and recession of the underlying lava, or one might say, a sort of diaphragm action of the crater floor. These movements at the pit are very localized, and do not show ground movements over a larger area as would stations around the crater rim, or at points on Mauna Loa.

In most cases the tilts as measured at the various stations have been gradual, with small daily change. Likewise a tilt of one day might be in an entirely different direction from that of the day before, but in general, over a period of several days, or in many cases several months, the tendency of the tilt is in one definite direction. Then there may be a reversal of the tilt over an extended period, so that at no point does the tilt continue indefinitely in one direction.

At times, especially of considerable seismic disturbance, a tilt of several seconds may occur between readings of the instruments. This large change probably takes place in a few seconds of time, at the time of the quake. But whether the tilt be large or small, gradual or sudden, it gives definite information of movement of underlying lava, and an extended tilt study should assist greatly in following the course of this movement.

Hawaiian Volcano Observatory Report for November 1937

VOLCANOLOGY

The Hawaiian volcanoes were quiet during the month, and there was little motion in the walls of Halemaumau pit at Kilauea.

The following are the weekly Observatory totals for Halemoumou and the seismographs.

Week Ending	Seismicity	Slides	Crack Openings	Local Tremors and Quakes
November 7.....	6.75	2	3.00 mm.	19
" 14.....	3.75	0	5.05 mm.	11
" 21.....	4.00	2	0.00 mm.	11
" 28.....	9.75	0	0.00 mm.	24

The slight earthquake November 27 damaged the Holemaumau seismograph and was felt in National Park. Of the measurable local seismic disturbances, sixteen were from Kilauea, one from Mauna Loa and one from northwest of Mauna Kea.

Sequence of Events by Weeks

The first week produced two slides from Halemaumau walls, two more were noted during the third week and on November 28 scars of a slide appeared in Puu Huluhulu crater after the sharp jerk of the earthquake of November 27.

Slides at Halemaumau

The recorded slides from the wall of the pit were:

November 1, 11:05 a.m., dust arose at NW wall.

November 2, 9:00 a.m., another slide in the same place.

November 21, 1:45 p.m., two slides north wall.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted during November in aggregate movement as follows:

Week ending forenoon of:

November 5, 28 locations, 6 opened, 4 closed, opening 3.00 mm.

November 12, 28 locations, 12 opened, 3 closed, opening 5.5 mm.

November 19, 28 locations, 6 opened, 4 closed, opening 0.0 mm.

November 26, 28 locations, 6 opened, 5 closed, opening 0.0 mm.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant† Earthquakes	Seismicity Weekly*
Nov. 7.....	13	5	1	0	0	6.75
" 14.....	7	4	0	0	1	3.75
" 21.....	12	2	0	0	0	4.00
" 28.....	15	8	0	1	0	9.75

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seis-

* For local seismicity definition see Volcano Letter 371.

† Including teleseisms or earthquakes over 5000 km from Kilauea.

mograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hila and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of the depth af focus has been made.

November 1, 2:49 a.m., very feeble, probably originated in area immediately NE of the Observatory, NE rim of Kilauea Crater.

November 1, 5:50 p.m., very feeble, 38.0 miles deep in vicinity of Waimea Table Land about 18.0 miles NNW of Summit of Mauna Kea. 19° 59.0′ N; 155° 30.8′ W.

November 3, 1:59 p.m., feeble, probably originated in Kilauea Crater near SE portion of Halemaumau.

November 6, 4:18 p.m., very feeble, probably originated in NE portion of Kilauea Crater.

November 8, 8:58 a.m., very feeble, 1.1 miles under Byron Ledge. 19° 25.0′ N; 155° 15.6′ W.

November 8, 10:13 a.m., very feeble, location same as preceding quakes but of slightly deeper focus.

November 8, 10:25 p.m., very feeble, probably orginated in SE rim area of Kilauea Crater near Keanakakoi.

November 11, 12:02 a.m., very feeble, probably originated in Western portion of Kilauea Crater near Uwekahuna.

November 17, 12:24 p.m., very feeble, 3.9 miles deep, 3.4 miles NW of the Observatory. 19° 27.8′ N; 155° 18.0′ W.

November 23, 4:37 p.m., very feeble, probably originated in NE rift of Mauna Loa about 15.0 miles from Hilo.

November 25, 10:10 p.m., very feeble, 2.2 miles deep NE rim Halemaumau, Kilauea Crater. 19° 24.9′ N; 155° 17.0′ W.

November 25, 10:11 p.m., very feeble, 1.4 miles deep NW portion af Kilauea Crater. 19° 25.6′ N; 155° 17.0′ W.

November 25, 10:23 p.m., very feeble, 1.5 miles deep in SE rim cracks, Kilauea Crater immediately NE of Keanakokoi. 19° 24.4′ N; 155° 16.2′ W.

November 25, 10:26 p.m. very feeble, location same as preceding quake.

November 26, 12:44 a.m., very feeble, af shallow origin SE rim cracks Kilauea Crater. 19° 24.2′ N; 155° 16.3′ W.

November 26, 11:50 p.m., very feeble, probably originated in E portion of Kilauea Crater.

November 27, 11:26 a.m., very feeble, 5.0 miles deep, SW rift zone at junction with Kilauea Crater. 19° 24.5′ N; 155° 17.7′ W.

November 27, 6:35 p.m., slight, 1.1 miles deep, 0.3 mile E of E rim Halemaumau and 0.4 mile from Pit seismograph. Reported felt at CCC Camp, SE rim of Kilauea Crater and around the National Park residential area. Pit seismograph was dismantled and the supports of N-S component broken. 19° 24.4′ N; 155° 16.7′ W.

Microseismic motion of the ground at the Observatory was strong throughout the month.

Four (4) minutes of continuous tremor began recording at the Observatory 3:53 a.m., November 21.

An unidentified portion of a teleseism began registering at Kilauea at 9h 03m 28s, p.m., H.S.T., November 9.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau the algebraic sum of radial tilts toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending November 28, was 10.05″ S and 1.55″ E.

Week Ending	Observatory	Halemaumau West Station
November 7	1.38″ N 48° E	2.62″ N 31° W
November 14	0.65″ N 61° W	2.80″ N 80° W
November 21	0.00″ 0	5.16″ N 82° W
November 28	1.00″ N 79° E	4.14″ N 71° W

Week Ending	Southeast Station Halemaumau	Halemaumau Resultant
November 7	1.62″ S 34° W	1.69″ From
November 14	3.43″ N 46° W	0.89″ Toward
November 21	6.42″ N 28° W	2.79″ From
November 28	8.59″ S 16° E	4.37″ From

H. H. W.

Crater Angles

Meosurement of Horizontal Angles across Kilauea Crater from the Observatory November 27, showed slight closing of the Kilauea Crater value and slight opening of the Halemaumau value as compared to similar measurements October 16. From Kilauea Crater SE rim to Uwekahuna there was opening 0.09″, October 16 to November 10, and closing of 0.25″, November 16 to 20. Total closing 0.16″. From the SE Pit B. M. to NW Pit B. M. there was opening 1.40″, October 16 to November 10, and closing of 0.84″, November 10 to November 27. Total opening 0.56″.

H.H.W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis-Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

THE VOLCANO LETTER

No. 454 monthly Department of the Interior National Park Service December 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

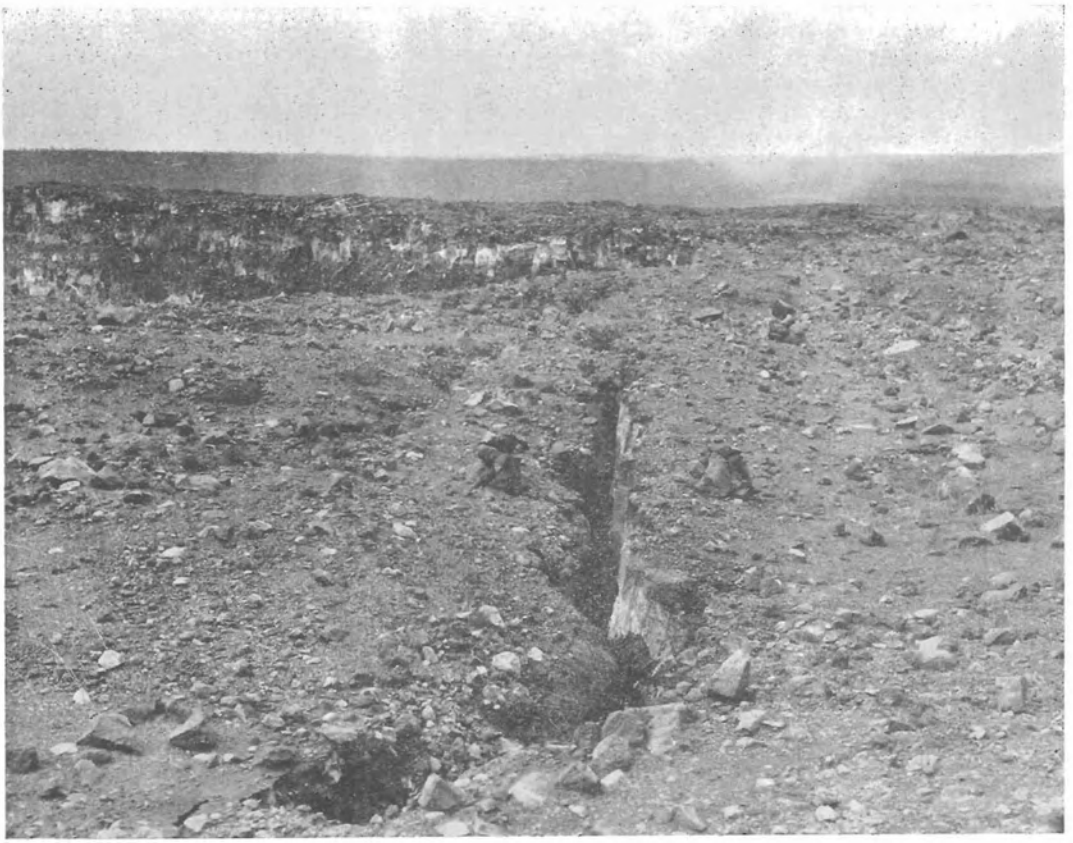

Figure 1. Crack on east margin of Halemaumau No. 25. Note two stone piles right side of crack, May 10, 1937.

WORK OF THE OBSERVATORY 1937—

The Hawaiian Volcano Observatory is administered under the Branch of Research and Education of the National Park Service. In collaboration is the Hawaiian Volcano Research Association, an educational corporotion of the Territory of Hawaii which supplements the work of the Government. The staff in 1937 was:

T. A. Jaggar, Volcanologist
H. H. Waesche, Assistant Geologist in charge of seismology
S. Sato, Librarian
H. Yasunaga, General Assistant
A. Okuda, Mechanic

Associates of the Observatory in Honolulu are:

Willard H. Eller, Associate Professor of Physics
Stanley S. Ballard, Assistant Professor of Physics
Iwao Miyake, Instructor in Physics
L. W. de Vis-Norton, Secretary and Assistant Treosurer, Hawaiian Volcano Research Association
Mrs. B. Y. Ching, Clerk

The Directors of the Hawaiian Volcano Research Association are:

F. C. Athertan, Castle & Cooke, Ltd.
R. A. Cooke, C. Brewer and Co., Ltd.
D. L. Crawford, University of Hawaii
A. L. Dean, Alexander and Baldwin, President

W. F. Dillingham, Oahu Railway & Lond Co.
J. R. Farrington, Honolulu Star-Bulletin
W. F. Frear, Bishop Trust Building
L. T. Peck, Stangenwald Building
W. W. Thayer, Stangenwald Building
L. P. Thurston, Honolulu Advertiser

Volunteer operators of seismographs for the Research Association on the island of Hawaii are:

R. V. Woods, Kealakekua
St. Mary's School, Hilo

The routine of the Observatory, besides the accumulation of data exhibited in the Volcano Letter, which involves attention to five seismographs, two clinographs, weather records, levelling and triangulotion, and measurements at Halemaumau pit, includes also circulation of a weekly press report for Island newspapers, transmittal of a monthly report to the National Pork Service, transmittol weekly ond monthly of weather data to U.S. Weather Bureau and preparation of scientific papers.

Mauna Loa and Proposed Hilo Barriers

As outlined in Volcano Letter of January and March, this subject has been throughout 1937 an important activity of the Observatory, involving os it does a large engineering program for the protection of Hilo, the acquisition of additional land on Mauna Loa, and the establishment of a Mauna Loa seismograph at the terminus of the Park Road.

The Barrier Project for defending Hila from lava flows was announced at a lecture by T. A. Jaggar to Hilo Chamber of Commerce January 19, followed by the proposal of the Hawaiian Volcano Research Association to acquire all lands on Mauna Loa above 7,000 feet that might be needed for patral by the National Park Service. This action was authorized in February by the Board of Directars af the Research Association and an expedition over the ground on Mauna Loa was made in March by Chief Farester Caffman of the Park Service, and Mr. Tillett, Superintendent of Hawaiian Emergency Conservation Wark, along with Superintendent Wingate, the Volconologist and athers. March 23 a resalution by Hila Chamber af Commerce requested the Rivers and Harbors Committee of Congress ta provide for a survey af the barriers for the protectian of Hila harbor. This was incorporated in the Rivers and Harbors Bill in May, and the bill was passed in August. The several awners af the upper lands on Mauna Loa, including the Territarial Government, expressed tentative approval of the enlargement af the Park, as might be later demanded by Act af Congress. In July and August Colonels Thamas and Browne of the U.S. Engineers went over the lands on Mauna Loa, Mauna Kea and at Hilo where the barriers would be constructed. General Markham, Chief of Engineers, inspected the field in November, and the U.S. Engineer in charge af Hawaii, Major P. E. Bermel, held a hearing in Hilo December 17 where the harbor protectian was discussed.

On September 9 a site was selected on the upper side af the present terminus of the Mauna Loa road far a cellar of concrete with double walls to hause a seismograph of Hawaiian type, and this cellar was nearly completed at the end of the year, built by Emergency Conservation labar.

Seismology and Engineering

Mr. Waesche was engaged in January in applying a relay to the radia apparatus receiving time signals, so that these signals were written directly an seismagraph drums. He prepared earthquake maps of Kilauea crater and the island af Hawaii. He assisted in arrangements for a new kiosk at Halemaumau ta exhibit ta travelers histary of eruptions. A levelling instrument gave much trauble during the year, but a substitute instrument was obtained, and it was discavered that the northwest Halemaumau benchmark had lowered relative ta the Sand Spit south af Kilauea about fifteen inches since October 1934. In December a rotary wind-measuring instrument was set up on the Observatory roof, so as to record directly on the chronographs of the seismograph cellar. A similar instrument was obtained for the Rest House on Mauna Loa.

Investigation of simplified seismological instruments for volunteers has occupied the staff. Four new model shock recorders were built during the first half of the year having in view the recording of three components of motion by means of weights suspended by flat springs.

In May a second series of experiments was begun with normal pendulums designed to actuate a mercury contact, ring a bell, and exhibit intensity by length of swing.

The object of this work wos to install annunciators at telephone exchanges which would give a numerical value to intensity of an earthquake. The operators would enter the number on o postal card sent the Observatory. It was finally decided to use a rectangular heavy mass capable of swinging in one direction only, with a very light horizontal high-magnification lever, making contacts with mercury in six cups. These connect with a six-point annunciator, grades one to six being shocks progressively stronger.

The normal activities of the Observatory in seismalogy and engineering will be found described in the articles by Mr. Woesche in Volcano Letters of February, April and October. The instrument that will be placed in the Mauna Loa cellar consists of a pair of pendulums built in our shop, magnifying earth motian one hundred times, and writing an smoked paper wrapped round a drum driven by clockwork. This instrument will be visited once a day by a member of the staff who will change the drum. The location is eleven miles fram the Observatory WNW, an the Mauna Loa slape ten miles below the resthouse. This will give the Observatary a definite check an shacks occurring under the rift belt of Mauna Loa.

The shock recorders and annunciatars are simple instruments in wooden cases designed ta screw an a wall anywhere, announce an unfelt earthquake by ringing a bell, and proclaim its size by the distance to which the pendulum swings. When an electric annunciator dial is used the length af the swing is indicated by a number. The operatar after noting the hour and the number, sets the annunciator back ta zero. Plans far making one af the madels self-recording are nat yet perfected, but tests have been made with ink, smaked paper, and photographic film.

Kilauea Laboratory, University of Hawaii

The wark of the University physicists was outlined in November Volcano Letter. S. Sata, a University assistant, is resident at the Observatory as librarian and has introduced order into the library by classifying, filing and card cataloging the earthquake and eruptian natices clipped fram the press, also the books, pamphlets, notes, and photographic negatives that are parts af the invaluable Kilauea records.

Among things filed are the lang smaked paper seismograms, fixed with shellac varnish and stared by thausands. The wark af classifying finds these congested by overflow fram the metal case originally made for them. All the records are in a room eighteen feet square fram which baoks had ta be ejected with transfer to the University building five hundred yards away. In the attempt at economy of space, there have been packaging and staring surplus publicatians, correspandence, and the less used baoks, in the hat, dry, wooden Observatary attic; transferring seismalagical pamphlets to the Assistant Geologist's wooden office, and lastly filing, selecting reserves, and setting apart sets far binding, of the Observatory Bulletin and of the Volcano Letter, the entire file af the latter being kept in the ald wooden Observatory building. This building alsa houses as fire hazards chemical and phatagraphic work, electric saldering irons, and kerasene smoking apparatus for the daily seismagraph routine

in the basement. Here also are main switchboxes and fuses; and battery equipment for radio time signals.

This situation is a continuous fire menace for the storage of the valuable records and publication files of the twenty-six years of work of the Hawaiian Volcano Research Association. The record material cannot even be studied properly, for there is no room for large tables nor for modern filing cases and everything has to be distributed to five rooms in three different buildings.

There is no solution for this problem of congestion other than the creation of a new large fireproof Hawaiian Volcano Observatory building.

Dr. H. Nagaoka of the Institute of Physical and Chemical Research in Tokyo has discovered at Asama Volcano that a magnetometer needle moves suddenly during underground volcanic disturbance. Theoretically this should be true, for liquid lava on solidifying or liquefying changes its magnetic attroctiveness. At Asama various intermittent disturbances of the magnetic needle are observed several weeks before an explosion

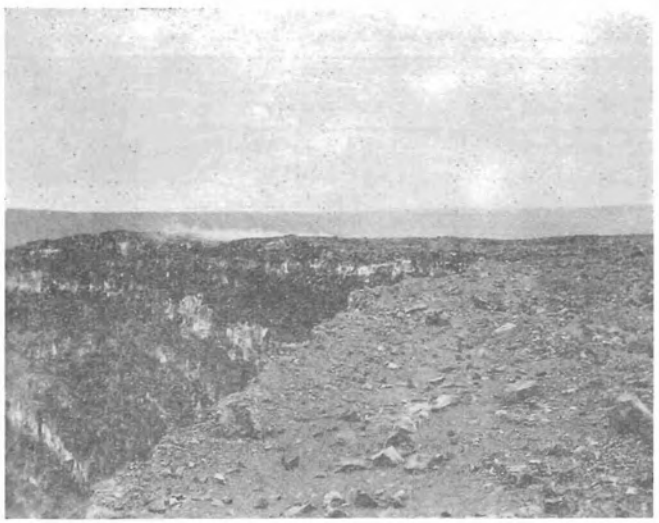

Figure 2. Crack locality No. 25 after caving into pit August 22, 1937. Photographs by Waesche.

of the volcano, and the rumbling is always accompanied by great magnetic changes. A specialized magnetograph was constructed giving the value of the time-rate of variation, serving as an indicator of rapid magnetic disturbances and registering the vertical component. It is relatively insensitive to magnetic storms. Professor Eller is greatly interested in the possibilities which this apparatus has for exhibiting the melting or the congealing of Hawaiian eruptive lava underground. Experiments are in progress for melting the lava and studying its change of magnetic properties.

As candidate for the degree of Master of Science Mr. A. E. Jones presented a thesis at the University of Hawaii on "Empirical Studies of the Seismic Phenomena of Hawaii" and on September 23, came up for examination which he passed satisfactorily. This thesis presents a statistical investigation of many seismograms of the Hawaiian Volcano Observatory.

In these days of Kodachrome photography an appeal may be made to amateur photographers interested in the Hawaiian volcanoes to explore the great rift belts and to photograph them. Either still or motion pictures in color, for purposes of projection and exhibition, should be made of the hundreds of subjects, such as cracks and pits and canes, that lie along the southwest rift of Mauna Loa in Kahuku, the northeast rift near the Rest House, the vicinity of Kulani; and the great extent of the Kilauea rift in the forest to the east of the Chain-of-Craters; and along the many pits and cones of the Kau Desert. There is here a magnificent opportunity for photographic exploration in the wilderness, something that few people seem to care to do.

Hawaiian Volcano Observatory Report for December 1937

VOLCANOLOGY

Until the solstice season of December 20, the month at Halemaumau pit of Kilauea volcano was extraordinarily quiet. After solstice local seismicity became three times as great, and five large distant earthquakes were recorded, in part from the Mexico-Central America region. Sixteen of the local shocks were from Kilauea, one from Mauna Loa and one from Hualalai.

The following are the weekly Observatory totals for Halemaumau and the seismographs:

Week Ending		Seismicity	Slides	Openings Crack	Local Tremors and Quakes
December	5.....	3.75	0	3.5 mm.	10
"	12.....	2.25	0	1.0 mm.	7
"	19.....	2.00	0	6.0 mm.	7
"	26.....	6.50	1	0.0 mm.	20
January	2.....	7.50	0	2.5 mm.	19

Perceptible earthquakes occurred in Hilo December 28, Kona December 30, and at National Park January 1.

Sequence of Events by Weeks

The first week was quiet, with noticeable blue fume showing over Halemaumau during humid Kona weather.

The second week was even quieter, and the seismic index for the third week was astonishingly small just as it was a year ago at this period. This was interrupted by a landslip in Halemaumau the fourth week, and the fifth week showed increased numbers of earthquakes near and far.

Slide at Halemaumau

A recorded slide from the wall of the pit was:

December 21, 4:08 p.m., a considerable slide from the north rim.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted during December in aggregate movement as follows:

Week ending forenoon of:

December 3, 28 locations, 11 opened, 6 closed, opening 3.5 mm.

December 10, 28 locations, 8 opened, 6 closed, opening 1.0 mm.

December 17, 28 locations, 10 opened, 2 closed, opening 6.0 mm.

December 24, 28 locations, 6 opened, 4 closed, opening 0.0 mm.

December 31, 28 locations, 8 opened, 3 closed, opening 2.5 mm.

T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending		Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant* Earthquakes	Weekly† Seismicity
Dec.	5.....	7	3	0	0	3.75
Dec.	12.....	5	2	0	0	2.25
Dec.	19.....	6	1	0	0	2.00
Dec.	26.....	14	6	0	3	6.50
Jan.	2.....	10	8	1	2	7.50

* Including teleseisms of earthquakes over 5000 km. from Kilauea.
† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Valcano Observatory on the Island of Hawoii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances begon at the time indicated and whenever possible, a determinatian of the depth of focus has been mode.

December 1, 9:15 am, very feeble, probably originated in Kilauea S W rift, 19 miles from the Observatory and 4.0 miles N of Palina Point.

December 2, 8:00 pm, very feeble, 3.1 miles deep, W rim of Kilauea Crater 0.6 mile SW of Uwekahuna, 19° 25.2' N; 155° 17.9' W.

December 3, 6:58 am, very feeble, 1.4 miles deep and 0.8 mile W of Puhimau Crater. 19° 23.6' N; 155° 15.8' W.

December 7, 12:47 pm, very feeble, 11.0 miles deep, 7.0 miles W of Volcano House. 19° 26.9' N; 155° 21.8' W.

December 12, 5:30 pm, very feeble, 21.0 miles deep under Hualalai. 19° 41.5' N; 155° 50.7' W. Felt in Kohala and at Paauilo.

December 25, 2:18 pm, very feeble, 2.5 miles deep and 0.4 mile SW Kokoolau Crater. 19° 23.1' N; 155° 15.2' W.

December 25, 5:26 pm, very feeble, 6.0 miles deep Kilauea SW rift 7.5 miles from Halemaumau. 19° 20.2' N; 155° 22.2' W.

December 26, 1:58 am, very feeble, probably originated in SW portion Kilauea Crater in vicinity af Halemaumau.

December 26, 6:42 am, very feeble, location of epicenter same as preceding but probably of slightly greater depth.

December 27, 2:19 pm, very feeble, 06. mile deep under W portion of Kilauea Iki, 0.2 mile E of Kilauea Crater rim. 19° 25.1' N; 155° 15.4' W.

December 28, 11:27 am, very feeble, 1.5 miles deep in Kilauea Crater immediately W of Kilauea Iki. 19° 25.3' N; 155° 15.8' W.

December 28, 7:15 pm, very feeble, 11.0 miles deep and 4.0 miles off coast S af Hilina Pali. 19° 12.6' N; 155° 14.2' W. Reported felt in Hilo.

December 29, 6:18 pm, very feeble, probably originated in Kilauea SW Rift.

December 31, 4:34 pm, very feeble, probably originated near center of Kilauea Crater.

January 1, 2:39 am, very feeble, 17.0 miles deep in Hilina Fault 3.5 miles S of Kamakaia Hills. 19° 16.0' N; 155° 20.3' W.

January 1, 9:16 am, feeble, 4.8 miles deep near Heake Crater, 19° 22.6' N; 155° 14.1' W.

January 1, 10:44 pm, very feeble, 13.0 miles deep under SW slope af Mauna Loa 5.0 miles NE of Kauna Point. 19° 05.6' N; 155° 49.5' W.

January 2, 6:01 pm, very feeble, probably originated in area approximately 12.0 miles NE of the Observatory.

Microseismic motian of the ground at the Observatory was moderate, December 16 to 21 and on December 24; the remainder of the month, the motion was strong.

Teleseisms registered as follows:

December 21, "P" waves at 5h 19m 20s pm, distance from Kilauea was about 3,200 miles and epicenter was apparently off W Coost of Mexico. 17° N; 106° W, by preliminory determination U. S. Coast and Geodetic Survey.

December 21, 9h 08m pm, no information obtained on location.

December 23, 2h 57m 25s pm, "P" waves, distance from Kilauea was appraximately 3,700 miles. Epicential location 16° N; 98° W, by preliminary determination, U. S. Coast and Geodetic Survey.

January 1, 1h 07m 41s pm, "P" waves. No determination of distance.

January 2, 12h 06m 50s pm, "P" waves, probable distance from Kilouea, 3,600 miles.

Hawaiian standard time used for all preceding reports.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau the algebraic sum of radial tilts toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending January 2, was 9.7" S and 0.47" E.

Week Ending	Observatory	Halemaumau West Station
December 5	0.46" S 41° W	2.92" S 81° W
December 12	1.01" S 50° W	2.98" N 33° W
December 19	0.97" N 65° E	2.38" S 66° W
December 26	0.82" S 26° E	4.23" N 58° W
January 2	0.25" N 27° W	0.00 Unchanged

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
December 5	9.17" S 67" W	0.56" From
December 12	10.40" S 73° W	1.91"Toward
December 19	10.08" N 12° E	4.24" Toward
December 26	1.62" S	4.72" From
January 2	6.29" N 15°W	5.83" Toward

Crater Angles

Measurement of horizontal angles acrass Kilauea Crater from the Observatory, December 22, indicated opening of both the Halemaumau and Kilauea Crater values compared with similar measurements made November 27. At that time the Halemaumau value from the SE Pit B.M. to the NW Pit B.M. increosed 2.51" and the Kilauea Crater value from the SE rim to Uwekahuna increased 0.44".

Leveling at Kilauea

On December 9, a series of levels similar to that of October 12 was run in Kilauea Crater fram the Spit B. M., SE rim of Kilauea Crater to NW Pit B. M. an the NW rim of Halemaumau. Results af this run indicated relatively no change or not more than 4 millimeter lowering of the NW Pit B. M. relative to Spit B. M. The Lietz, Coast and Geadetic Survey type precise level was used far the December levelling. It checked favorably with the Stanley "Wye" level used far the October determinatian.

H. H. W.

THE VOLCANO LETTER

No. 455 monthly Department of the Interior National Park Service January 1938

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

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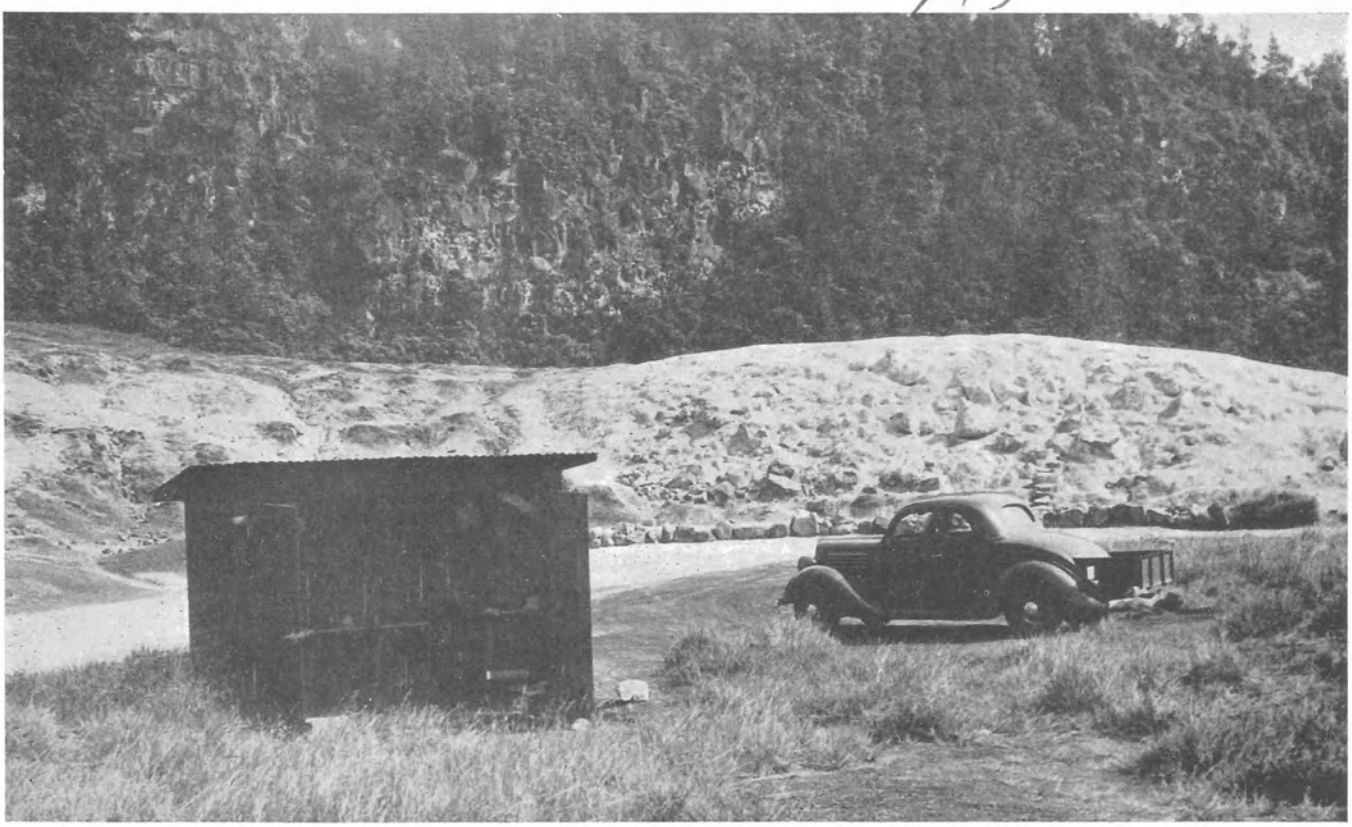

View of the Sulphur Bank, Kilauea. Notice the cliff in the background which is doubtless the wall of a Kilauea crater much older than the present one. Most of the gas collections were made at the wells which are beneath the temporary laboratory building in the left foreground.—National Park Service Photo.

THE VOLCANIC GAS PROBLEM

By Stanley S. Ballard

Research Associate in Geophysics, Hawaii National Park, and Assistant Professor of Physics in the University of Hawaii.

More and more attention is being focused upon the problem of the analysis of volcanic gases. Overlooked almost entirely until recent years, the evolution of gas is now considered to be one of the major phenomena accompanying a volcanic eruption. In fact some volcanologists feel that a satisfactory solution of the volcanic gas problem will shed much light on the fundamental problems of volcanology. In particular, it is thought that here may be found the source of some of the enormous quantity of heat that is given off at the time of eruption. The volcanic gases appear to have their origin underground in the fluid magma. As the magma rises during an eruption the hydrostatic pressure upon it is greatly decreased and at the earth's surface is so small that the gases here come out of solution and are given off into the atmosphere, usually in flames. Fortunately they can be analysed by chemists and physicists, the results of analysis being of course turned over to the volcanologist or the geochemist for interpretation.

There are at least four distinct approaches to the volcanic gas problem. First there is the possibility of photographing the spectra of the burning gases at the time of eruption. This would involve setting up a light portable spectrograph in the field near the fluid lava and focusing upon the slit of this instrument by suitable lenses the light from the flames of the burning gases emanating from cracks in the advancing lava flow. The photographs thus obtained would not be pictures of the flames themselves, but would be spectra of the substances burning in the flames. A trained spectroscopist could readily interpret these spectrograms to tell what elements or molecules in the burning gas gave rise to each of the spectrum lines. In the past vol-

canic flames have sometimes been examined through small hand spectroscopes, but the writer doubts whether results obtained in this woy are particularly significant. Even a person experienced in spectroscopy can easily mistoke the colored line of one element for some neighboring line of another element and thereby make an incorrect visual anolysis. For this reason it is felt that the photographic method, giving a permanent record which can be compared later with standord spectrograms of the various suspected elements, is much preferable. It is hoped that a small field spectrogroph can be obtained for use in this connection at the next eruption of Kilaueo or Mauna Loa.

The second approach to the problem is through the collection of gases emanoting from the fluid lova at the time of eruption, and their subsequent onalysis in the laboratory by chemicol and spectroscopic means. It is important to collect the gases **before** they burn, if possible, and to make the collections so as to exclude air from the surrounding atmosphere as completely as possible. Collections of volcanic gases were made at Kilauea in 1912 by Drs. Day and Shepherd of the Geophysical Laboratory of the Carnegie Institution of Washington, ond further collections were made in 1917, 1918 and 1919 by Dr. Shepherd and Dr. Joggor at Kilouea ond at Mauna Loa. These samples were onalysed in the Washington laboratory by Dr. Shepherd, the results being reported in papers appearing in the monthly bulletins of the Hawaiian Volcano Observatory and in national geological journals. No opportunity to collect volcanic gases has presented itself since the writer has been in the Territory, but a new type af collecting tube which it is hoped is somewhat of an improvement upon the vacuum tubes used previously has been devised. This new type of tube is described below.

The third approach consists of extracting dissolved gases fram samples of cold lava after the eruption is over, and then anolysing these gases. The extraction is performed by heating a ground portion of the rock in a vacuum furnace. When the rock comes up to the softening temperature large volumes of occluded gos, mony times the volume of the rock in some cases, are driven off. The chief difficulty here appears to be in developing analytical methods for handling accurately the rather small somples of gas obtained. Suitable methods have been warked aut by Dr. Shepherd and some analyses of gases driven off in the vacuum furnace from lava samples are given in his 1925 poper in the Journal af Geology. An attractive feature of this approach to the volcanic gas problem is that collections need not be made at the time af eruption when field conditions are seldom ideal, but may be made some weeks later after the excitement is over. In fact one should be able to go oround the island of Hawaii, stop at the various doted lova flows and obtain suitable samples of rock, take them back to the laboratory, drive off their occluded goses, analyse these gas somples, and have a time-history of the composition of Howoiian volcanic gas.

The lost approach to the volcanic gas problem is by far the least direct of the four. It involves the collection and analysis of the sulphuraus fumes emanating from vents in the immediate neighborhood of the croter. Of course there is often a general steam crack activity in a volcanic region, but the emonotions here seem to consist largely af steam. This is doubtless ground water that has seeped down into the warmer regions af the ground, been vaporized and returned to the atmosphere as steam. There are often, however, small areas at which free sulphur is brought up from the depths and deposited at the surface, building up the so-colled sulphur banks. The emanations in these cases consist of steam, sulphur vapor and oddi-tional gases. The important question here is as ta haw intimotely volcanic these solfataras can be considered to be. Da same af the gases rise directly from the bed of molten magma that is thought to underlie the volcanic region? If so, the analysis of the reodily accessible and continuously fuming solfataric goses should afford an index to the activities of the magma below. In the case of Kilauea, sulphurous fuming regions can be seen around the bottom edge of Holemaumau pit, around the edge of Kilauea crater beneath the present CCC camp, and at the edge of a still older, prehistoric Kiloueo crater. This lost area is located near the Hawaiian Volcano Observotory and the Kilouea Volcano House and is the Sulphur Bank that is visited by practically oll tourists to the Pork, being but 100 yards off the main highway. At this location collections of solfataric gases were made some 16 years ago by Dr. E. T. Allen of the Geophysicol Laboratory. His results as published in the Bulletin of the Hawaiian Volcano Observatory for August 1922 are os follows:

Steam	96.2%
Fixed Gases	3.7
Sulphur Dioxide	.096
Sulphur Vapor	.004
Hydrogen Chloride	Trace

These are volume percentages far a temperature of 95.5° C ond a pressure of 646 mm.

There are discussed below the collections and onolyses of Kilauea Sulphur Bonk gases which have been carried out by the writer during the last two years. The chief purpose of this investigotion was to study the less obvious solfataric gases, that is, those other than steam ond sulphur vopor. The actuol collec-tians were made at various times during an interval of over a year, and it wos hoped thot some variation in the constitutian af the gases might be found. No significant variation hos appeared, but the writer feels that collections and anolyses should continue to be made at perhaps monthly intervals, the program lasting long enough to include o period of activity of Halemaumau. If voriations in constitution are faund to occur during the period of activity, the results will surely justify the work involved. In fact there is the possibility ond hope thot such variations might exist and might be correlated with volcanic octivity sufficiently to enable predictions of eruptians to be made through gos anlaysis as well os through a study of seismic records. Whether such prediction will ever be possible or whether this is only a fond dream, only time can tell.

Collection of Volcanic Gases

The collection of the goses billowing forth from fluid lava at the time of eruption is ordinorily effected by the use of vacuum-type collecting tubes. A typical tube consists of a large bulb of several hundred cubic centimeters copocity to which is joined a long, narrow glass tube which moy be severol feet in length. The whole assembly is originally evacuated to o high degree. Then when the end of the long glass tube is thrust into the volconic flame and the tip of the tube is broken off or melted through, gas will rush into the evacuated volume. If it can be successfully tropped there, the collection is complete. A desirable feature is thot outside air may be eliminated fram the collection as completely as possible.

Vacuum-type tubes of the sort used in the collections of Drs. Day, Shepherd ond Jaggor ore pictured on page 7 of Volcano Letter Number 437 for July 1936. The largest tube in this figure is the smallest tube shawn in Figure 1. Above this tube is the largest vacuum-type tube used by them. Note the long drawn-out tip which could easily be broken off by striking the end of the tube against the lava when the time ta make the collection arrived. Note olso the narrowed portion of the slender tube near the lorge bulb which is designed for reody sealing off with a gasoline torch after the callectian is completed. The tip of the lower tube has in its end a plug of glass af law melting point which should soften quickly in the intense heat of the volcanic flame, allowing the gas to rush in. The chief difficulties encountered with these tubes were in causing the tip ta

break or melt at the appropriate time, and in sealing the tube quickly before contaminating air entered.

The top tube in Figure 1 is the first vacuum-type collecting tube designed by the writer in collaboration with Mr. Paul Gow, Assistant Chemist at the Experiment Station of the Hawaiian Sugar Planters' Association. Features of this tube are a type of tip which is certain in its action, and a method of sealing the collected sample quickly so that no outside air can enter to contaminate it. The breakable tip is simply a crook-necked tip which is scored with a file to insure breaking at the bend, the breaking being effected by a quick jerk on a wire attached at one end to the crook and at the other to the collector's right hand, the tube being held in his left hand. After the gas has

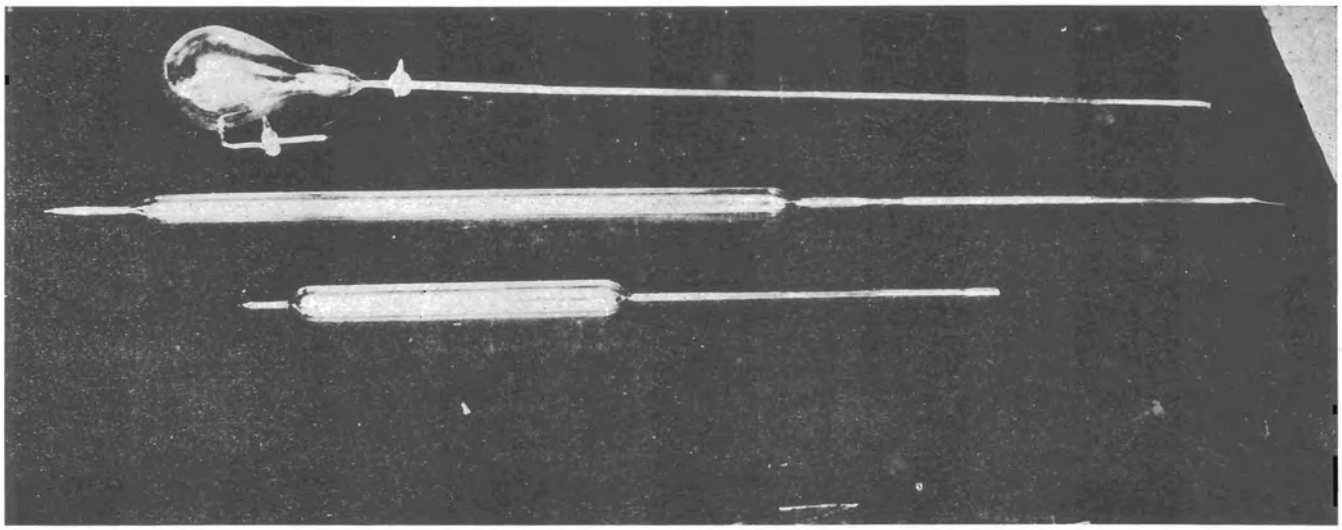

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Figure 1. Old and new vacuum-type volcanic gas collecting tubes. Capacities are approximately as follows: Upper (new style) tube, 800 cc.; center tube, 450 cc.; lower tube, 350 cc.—National Park Service Photo.

rushed into the evacuated volume it is trapped there simply by turning through ninety degrees (i.e. from open to closed position) the large vacuum-ground stopcock between the three-foot long slender glass tube and the large bulb. In Figure 2 is pictured the original tube along with two later "stream-lined" models. These differ from the original tube in two important respects. First, the side arm with small stopcock which was attached to the large reservoir bulb has been eliminated. This attachment was used in evacuating the bulb. Evacuation is now effected through a small side tube which is sealed off with an oxy-gas flame when the tube is evacuated to as high a degree as possible. The second improvement is in the greater mechanical strength obtained by making the weld between the large bulb and the stopcock very short and hence very sturdy. These latest tubes are made to order by a New York glass-blowing firm. The long slender tube is added locally in order to save freight charges. Then the breakable tip is drawn out and the tube is evacuated. The price complete per tube is under five dollars. The tubes may also be clamped to a sturdy pole, the stopcock being rotated by a "remote-control" device not shown in the figure. This recourse would be necessary in cases where the collector could not approach to within three or four feet of suitable gas sources.

No opportunity to test these tubes under actual field eruption-time conditions has presented itself as yet. The original tube pictured in the figures was tested at the Sulphur Bank in the summer of 1936, however, and appeared to work most satisfactorily. The difficulties which might be encountered with the tubes would be the result of the fragile nature of any piece of glass apparatus or of the failure of the vacuum-ground stopcock to hold a vacuum in the tubes while they are in storage awaiting eruptions. In general these stopcocks have been found to be quite satisfactory, two tubes now at the Hawaiian Volcano Observatory having held a vacuum perfectly for six or eight months to date. It should be remarked that at the Observatory there is now a complete outfit for evacuating these tubes and for doing any glass blowing and repairing that might be necessary.

Collection and Analysis of Solfataric Gases

The analyses about to be reported upon should be thought of still as preliminary studies which supplement the first analyses made by Dr. Allen in 1922. The purposes were to establish the identity of the 3.7 per cent of "fixed gases" reported by Allen, to see if there were any gases being given off which were unusual in nature, and to establish what definitely volcanic gases were emanating from the solfataras. Interest was centered particularly upon the combustible gases hydrogen and carbon monoxide which are known to burn in volcanic flames; sulphur vapor, another known volcanic gas, is very evidently a constituent of the solfataric gases. The analyses therefore do not concern themselves with either the amount of the sulphur vapor or the steam that was being given off at the vents.

The first collections were made in August and September of 1936. A temporary shack suitable to house collecting equipment was erected by the Park Service over the wells that had been sunk at the Sulphur Bank area some fifteen years ago. The best collections were made from the manifold connecting these three wells, the side wells being 15 feet deep and the center well some 70 feet deep. The figure on page 2 of Volcano Letter Number 453 for November 1937 illustrates the "vertical wet" method of collection from the wells. In this case the sulphurous fumes are drawn by a hand-vacuum pump through a collecting tube until it is thoroughly flushed with the gas, whereupon the collection is effected simply by shutting off the collecting tube stopcocks, thereby trapping some of the gas inside. By surrounding the tube with an ice pack much of the steam is made to condense and run back into the walls, thus giving a sample which is considerably enriched in the fixed gases. This type of collecting has proved the most satisfactory and dependable of the several methods tried, and a sample has been collected using this method each time the region has been visited by the writer. There were also made field collections at sulphurous fuming spots in the vicinity of the Sulphur Bank. As a "control" we collected a sample using the field collection technic at the steaming bluffs a mile or two from the Sulphur Bank along the

government road, in a region where no sulphur fumes could be detected. It is interesting to note that even in this non-sulphurous area sulphur dioxide to the extent of 1.3 per cent of the dry gas (i.e. air and carbon dioxide) was detected.

Upon returning to Honolulu one of the samples was tested spectrographically using the excellent spectroscopic facilities of the Experiment Station of the Hawaiian Sugar Planters' Association. The only lines or bands detected on the spectrum plates were those of carbon monoxide and hydrogen. The hydrogen lines were undoubtedly due to water vapor (steam) present in the sample, whose molecules are broken down by the high voltages applied to the spectrum tube to hydrogen and oxygen atoms, the hydrogen lines showing clearly. The predominance of carbon monoxide bands cannot be taken as a guarantee of the presence of carbon monoxide in the sample, as indeed later chemical analysis showed. It is well known to spectroscopists that carbon dioxide gas as well as almost any organic material will break down under the extreme electrical conditions existing in a spectrum tube into carbon monoxide, which has a very strong and easily excited spectrum. These spectroscopic analyses therefore served only to show that it would be necessary to subject the samples to chemical analysis. It was at this point in the investigation that the writer called upon Assistant Professor John H. Payne of the University of Hawaii Department of Chemistry for assistance. And the Ballard-Payne collaboration has continued harmoniously since that time.

Chemical analyses were made by Dr. Payne in his university laboratory using the standard Burrell gas analysis equipment and methods. His results showed that sulphur dioxide was the chief constituent (other than steam, of course) of the solfataric gases collected. Other constituents were carbon dioxide and air, the latter being principally nitrogen and oxygen. In none of the dozen-odd samples analysed was any significant trace of combustible gases such as carbon monoxide, hydrogen, hydrocarbons, etc., found. The occurrence of definite amounts of these gases would have established beyond question of doubt the intimately volcanic origin of the Sulphur Bank gases. The amount of air present in the samples varied greatly from sample to sample, depending upon the method of collection as well as the place of collection. A sample analysis of a vertical wet collection is as follows:

Sulphur Dioxide	58.6%
Carbon Dioxide	4.6%
Oxygen	7.0%
Residue	29.8%
Combustibles	None

These are volume percentages at room temperature and pressure in Honolulu; that is, approximately 20° C and 760 mm. All analyses were conducted with saturated water vapor present, so that the percentages are those of the **dry** gases. The residue was tested spectroscopically and found to be nitrogen, as expected. The ratio of nitrogen to oxygen is seen to be approximately 4:1, the normal atmospheric ratio. The air in the samples is hence thought to be of atmospheric origin, having leaked into the porous ground and come up again with the solfataric gases. The analysis of the 1936 gases showed that so much sulphur dioxide was present, as high as 90 per cent in some cases, that any relatively rare constituents might indeed escape detection. Therefore, we decided to make the 1937 collections in such a fashion as to eliminate this large SO_2 content.

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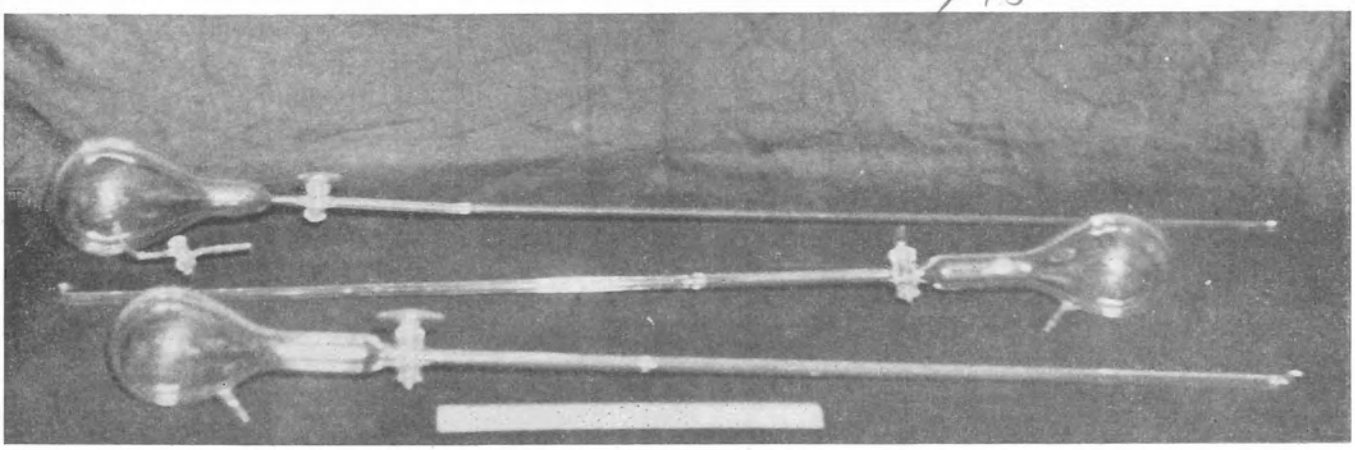

Figure 2. Improved vacuum-type volcanic gas collecting tubes. The upper tube has a capacity of 800 cc. (see Fig. 1). The two lower tubes are of the newer, sturdier construction and have capacities of 500 cc. each. Note the foot ruler which gives the scale of the figure.—University of Hawaii Photo.

Several samples of gas were collected in September 1937. As illustrated in the picture printed on page 3 of Volcano Letter Number 453 for November 1937, the gas was drawn first through a condenser which was packed with ice and salt and hence removed a large portion of the steam, then through two absorption tubes which contained a 50 per cent caustic potash solution. The function of the potassium hydroxide was to absorb the major percentage of the sulphur dioxide and carbon dioxide, allowing the minor constituents of the gas, if any, to be concentrated in the sample. Analysis of these collections showed that the absorption of the sulphur and carbon dioxides was not complete. However, the last traces of these gases were removed in the laboratory and the residue was treated with hot lime and magnesium in order to absorb the nitrogen content known to be present. The gas remaining after this operation was examined spectroscopically as shown in Figure 3 and found to consist chiefly of argon, which is known to be present to the extent of about 1 per cent in the atmosphere. No traces of the other rare gases, helium, neon, krypton and xenon, could be detected. In Figure 3 is shown the complete analytical equipment which consists of the chemical train of seven pipettes which hold the solutions to absorb the various gases, the gases being forced through the solutions by the mercury-filled leveling tube held in Dr. Payne's right hand. The gas is then forced into the long horizontal tube in the center of the picture, where upon heating the calcium-magnesium mixture its nitrogen content is absorbed. Then the gas is forced over to the right into the spectrum tube, whereupon its spectrum can be observed and measured using the wavelength spectrometer shown.

It was decided that collections should be made in which there was definitely no sulphur dioxide present, and in Decem-

ber 1937 Dr. Payne and the writer made a flying trip to Hawaii for this purpase. This time the gas was pumped through **four** absorptian tubes cantaining caustic potash, and this time no sulphur diaxide got through! Analysis of these samples showed nothing present but air.

In conclusion, one can state the results of these preliminary analyses as follows: The Kilauea solfataric gases tested cansisted of steam, sulphur vapor, sulphur diaxide, carbon dioxide, and air (that is, nitrogen, oxygen and argon). No new combustible gases and no rare gases other than argan were detected. It is hoped, however, that when larger samples can be collected, larger residues af argan can be obtained which can be studied monthly and cantinued long enaugh to include a period of volcanic activity it could readily be established whether this ratia in solfataric gases affords an index of valcanicity. It shauld alsa be af interest ta make a **complete** analysis comparable ta Dr. Allen's, particularly to see whether there has really been a marked increase in the amount of sulphur dioxide present in relatian to the steam content, as suggested above.

This pragram is being supported jointly by the University af Hawaii, the Hawaiian Valcana Research Association, and the Hawaii Natianal Park. Acknowledgment is made of the kind cooperatian on the part af the Experiment Station of the Hawaiian Sugar Planters' Association in making available the glass-

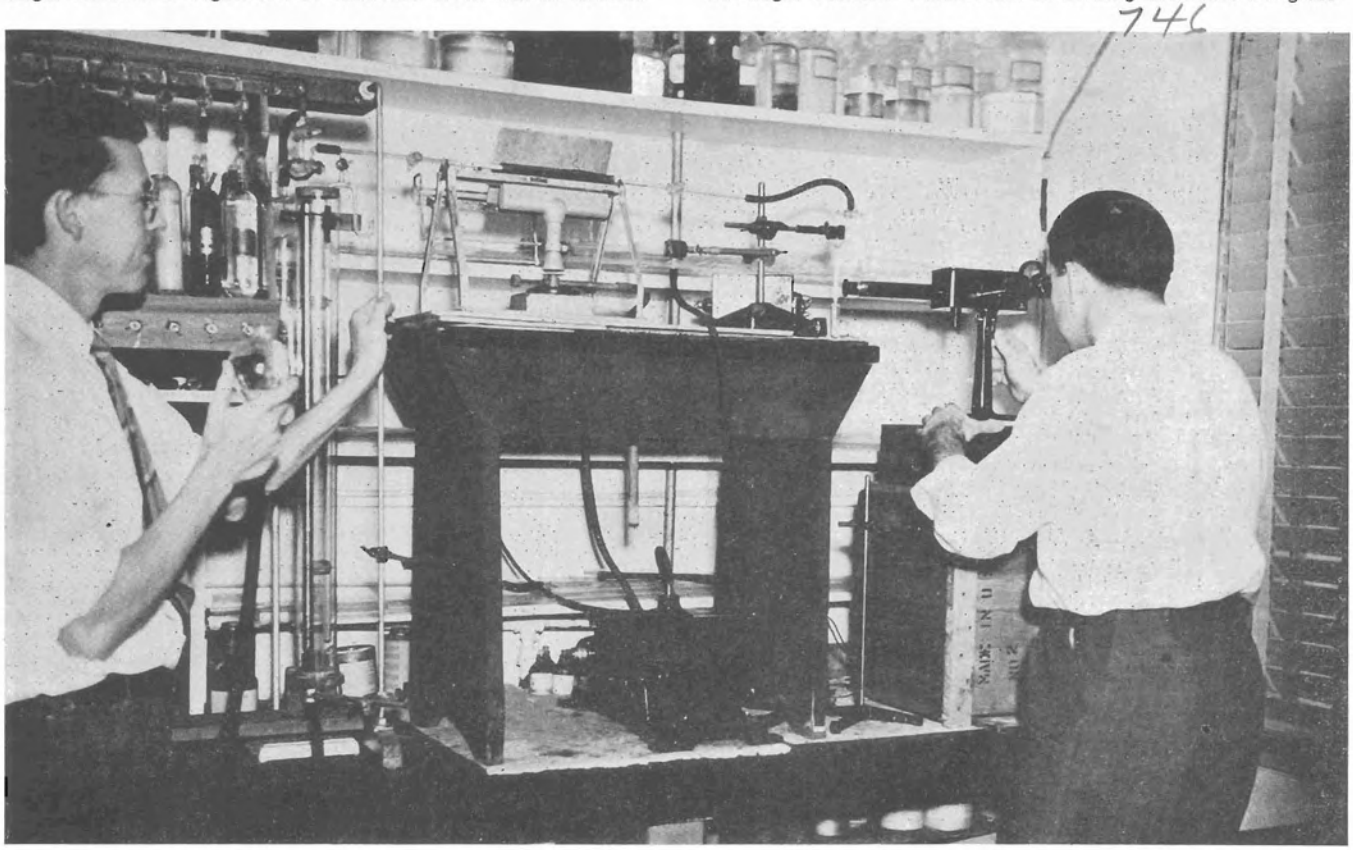

Figure 3. Apparatus set up in the University of Hawaii chemistry labaratory for the chemical and spectroscopic analysis of solfataric gases. Dr. Payne is farcing gas into the nitrogen absarption tube (center af the picture) and Dr. Ballard is measuring the spectrum of the residual gas with a wavelength spectrameter.—University af Hawaii Phata.

by mare searching **spectrographic** methods which may possibly reveal traces of helium and athër rare gases which could nat be detected by the visuol spectrascopic methods here employed. Referring again ta Dr. Allen's analyses, we would judge that his 3.7 per cent of fixed gases was air and carbon dioxide. If the sulphur dioxide content af the gases has not changed since 1922, then Allen's collections must have been very badly cantaminated with air. It is interesting to note that A. Brun of Geneva made partial analyses of these gases in 1910 and detected **no** sulphur dioxide. Twelve years later Allen detected a very definite amount of sulphur dioxide, and fifteen years still later sulphur dioxide was faund to be by far the predaminating gas, save water vapor. We are preparing for publication elsewhere a paper which will describe more fully the technical details of this program of analysis.

As regards future plans for solfataric gas anolysis, we hope to establish a fixed technic af sampling—probably the vertical wet collection method, and continue to test the sulphur dioxide vs. carbon dioxide ratio, which ratio has been in the range 10:1 to 15:1 for comparable collections. If collections could be made

blowing skill af Mr. Gow and the facilities af the spectroscopic laboratary. Obviously the successful completion af the solfataric gas analyses was made possible only through the active cooperation af Dr. Payne and of his student assistant, Mr. Luther Foster, to whom thanks are due.

Hawaiian Volcano Observatory Report for January 1938

VOLCANOLOGY

The volcanoes of Hawaii have remained quiet. The seismicity which had increased about the solstice, again trebled in value the first three weeks of January. The most notable event of the month was a very strong earthquake January 22 that centered on Maui, doing much damage there. It was very strong on Malokai, Lanai and Kahoolawe, and alarming at Honolulu and in Kohala. It was generally felt in the Hawaiian Islands.

Apparently the middle belt of this earthquake extended from central Maui westward towards Kahoolawe. The serious character of the shock raised questions of earthquake-proof canstructian in Honalulu. It is of interest that the strong 1868

earthquakes offected the eost-west foults of south end of Hawaii islond; the 1929 disostrous shocks of north Kona extended to Mauna Kea and affected a nartheast-southwest belt there; the 1938 cotaclysm affects an eost-west belt through Moui; and this series suggests a migration of fault movements on the transverse fractures across the west-northwest line of the Hawaiian Islands. The next important transverse fracture is the one crossing the north side of Molokai, which extended westward would poss Honolulu close to Diamand Head. If this fracture should move, it might be disastrous for Honolulu.

Of the meosured earthquakes 22 were from Kilauea, 5 were from Mauno Loo, and 8 were beyond Mouna Loa. Feeble shacks somewhat felt occurred January 3, 14 and 17. A slight shock wos felt in Hilo Jonuary 9. After the big Moui shock there wos marked decline in seismicity. The first week of the month had been notable for some earthquakes indicating distances of origin corresponding to north Kono and Kohala.

The following are the weekly Observatory totals for Halemaumau and the seismographs.

Week Ending	Seismicity	Slides	Crack Opening	Local Tremors and Quakes
January 9.....	16.75	2	6.5 mm.	40
" 16.....	16.00	1	0.5 mm.	49
" 23.....	17.50	2	3.0 mm.	21
" 30.....	6.75	0	11.3 mm.	21

Slides at Halemaumau

The recorded slides from the wall af the pit were:

January 5, 1:25 p.m., narth rim of pit.

January 9, 3:46 p.m., dust arose during moderate earthquake.

Januory 14, 9:25 a.m., slide from north wall, noise of falling stones heard at a distance and cloud of dust.

January 21, 9:45 a.m., north rim.

January 22, 10:03 p.m., noise of slides heard accompanying earthquake.

A fresh scar from a slide on the wall was found at Alealea pit af the Chain-af-Craters.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locatians resulted during Jonuary in aggregate movement as follows:

Week ending forenoon af:

January 7, 28 locatians, 11 opened, 3 closed, opening 6.5 mm.

January 14, 28 locations, 5 opened, 4 closed, opening 0.5 mm.

January 21, 28 locations, 10 opened, 4 closed, opening 3.0 mm.

Jonuary 30 (nine days), 28 lacations, 13 opened, 2 closed, opening 11.3 mm.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Moderate Earthquakes	Distant† Earthquakes	Weekly* Seismicity
Jan. 9....	29	8	1	1	1	0	16.75
Jan. 16....	36	12	1	0	0	0	16.00
Jan. 23....	40	5	1	0	1	0	17.50
Jan. 30....	15	6	0	0	0	1	6.75

* For local seismicity definition see Volcano Letter 371.
† Including teleseisms or earthquakes over 5000 km from Kilauea.

Epicenters af the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcana Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the twa subsidiary stations at Uwekahuna and the SE rim af Halemaumau respectively. The more distant shocks were located with the aid of seismogroms from Hilo and Kealakekuo. The disturbonces began at the time indicated and whenever possible, a determination af depth of focus has been made.

Januory 3, 11:36 om, very feeble, 40 miles deep under Hualalai. 20° 42.8′ N; 155° 48.0′ W.

January 3, 12:33 pm, feeble, located 47 miles deep under Mauna Loa NE rift zone. 19° 30.7′ N; 155° 25.7′ W.

Jonuary 3, 6:02 pm, very feeble, 40 miles deep under summit crater area of Mauna Loa. 19° 26.2′ N; 155° 35.8′ W.

January 3, 8:51 pm, very feeble, 1.0 mile deep, 0.5 mile SE af Pit seismagraph. 19° 24.0′ N; 155° 16.7′ W.

January 5, 2:31 am, slight, 5.0 miles deep in Hilina Kopukano Fault system, 3.0 miles N of Apuo Point. 19° 18.1′ N; 155° 11.6′ W.

Januory 9, 2:49 am, very feeble, of Kilauea origin.

Jonuary 9, 3:47 pm, moderate, 3.8 miles deep near SW rim of Kiloueo Iki. 19° 24.8′ N; 155° 15.2′ W. Dismantled Pit and Observatory seismographs. Reparted felt by many at CCC Camp, SE rim of Kilauea Crater ond by severol oround the National Park Headquarters areo.

January 9, 4:40 pm, very feeble, 3.4 miles deep and 3.5 miles NW of H.V.O. 19° 27.9′ N; 155° 18.0′ W.

Jonuary 10, 4:55 pm, very feeble, 1.8 miles deep and 2.8 miles SE af the Volcano Observatary. 19° 24.5′ N; 155° 13.5′ W.

Januory 10, 6:04 pm, very feeble, 1.3 miles deep NW rim of Kilauea Crater, 0.8 miles N NE of Uwekahuna. 19° 26.0′ N; 155° 17.2′ W.

Jonuory 10, 6:11 pm, very feeble, 4.2 miles deep in vicinity of Kipuka Puaulu. 19° 27.0′ N; 155° 18.3′ W.

January 10, 10:24 pm, very feeble, 0.8 mile deep in Byran Ledge Area, E rim of Kilauea Crater. 19° 24.6′ N; 155° 15.3′ W.

January 11, 11:37 pm, very feeble, 1.8 miles deep in Kilauea Crater, 1.0 mile SW of the Observatory. 19° 24.6′ N; 155° 16.7′ W.

January 12, 12:21 am, very feeble, 1.6 miles deep under Byron Ledge, E rim af Kilauea Crater. 19° 24.8′ N; 155° 15.6′ W.

January 13, 2:36 pm, very feeble, af shallow arigin, SE rim of Kilauea Crater. 19° 23.9′ N; 155° 16.2′ W.

January 13, 3:39 pm, very feeble, of shallow origin in orea immediately SE of Keanakakoi. 19° 24.0′ N; 155° 15.6′ W.

January 13, 3:29 pm, very feeble, of shallow origin, SE rim of Kilaueo Crater. 19° 24.4′ N; 155° 15.6′ W.

January 13, 5:45 pm, very feeble, 0.4 mile E of Pit seismograph, 0.7 mile deep. 19° 24.3′ N; 155° 16.6′ W. Dismantled Pit seismograph.

Januory 14, 6:19 am, very feeble, 1.5 miles deep near SW rim of Kilauea Iki. 19° 24.8′ N; 155° 15.2′ W.

January 14, 5:40 pm, feeble, 8.0 miles deep, along seacoast 3.5 miles S of Hilina Pali. 19° 15.0′ N; 155° 17.0′ W. Reported felt in city af Hilo.

January 15, 5:33 pm, very feeble, probably ariginated in Mauna Loa NE rift 4.0 miles NE of Puu Ulaula.

January 17, 11:39 am, feeble, 0.8 mile deep E portian af Crater, 1.0 mile E af Halemaumau. 19° 24.6′ N; 155° 15.9′ W. Reported felt on NE rim of Kilauea Crater.

January 17, 4:27 pm, very feeble, 1.0 mile deep, in Kilauea Crater near W end of Kilauea Iki. 19° 24.9′ N; 155° 15.5′ W.

January 22, 4:36 am, very feeble, located in Mauna Loa NE rift in vicinity of Puu Ulaula. 19° 32.0′ N; 155° 26.6′ W.

January 22, 10:03 pm, maderate to strang near shock, probably centered about 60 miles below the ocean surface near a point 25 miles N of Pauwala Point, Maui. 21° 12′ N; 156°

06′ W. This shock was felt throughout the Hawaiian Islands and recorded on seismographs throughout the world. It was felt most strongly on the Island of Maui and by nearly everyone. Damage to property was estimated to have been about $150,000, and included disruption of water tanks and dams, interruption of telephone service, cracked walls and roads, slides along roads and upsetting of objects in buildings. The road to Hana, Maui, was closed by slides from steep adjoining slopes. Greatest damage was in vicinity of Wailuku and Kahului. On Oahu the intensity of the shack was considerably less thon on Maui but is thought to have been greater than on Hawaii. In Honolulu mony people were alarmed and theatre patrons rushed hurriedly out of the buildings. Light flashes visible for 20 miles were reported from Hilo; radio transmission interference was reported on the shorter wove lengths. In the Volcano district, Hawaii, long swinging motions were described causing loose objects to move and tall slender objects such as floor lomps to swoy. Pheasants squawked, dogs barked and most sleepers were awakened. Buildings creaked ond doors swung on their hinges. A report from Hilo indicated that ceiling lights swung in an E NE-W SW direction. All seismographs in operation in the Hawaiian Islands were dismantled with the exceptian of the strong motion instrument at the Hawoiian Volcono Observatory. This instrument made a complete record. Felt portion of quake was thought to have lasted, one and one-half to two minutes.

January 26, 9:01 pm, very feeble, located 1.1 miles deep, in Kilauea Crater, 1.0 mile NE of Pit seismograph. 19° 24.9′ N; 155° 16.2′ W.

January 27, 5:22 om, very feeble, 2.0 miles deep, 1.3 miles SW af the Observatory in Kilauea Croter. 19° 25.2′ N; 155° 16.4′ W.

January 28, 2:23 am, very feeble, 2.5 miles deep and 0.7 mile N of Uwekahuno NW rim of Kilouea Croter. 19° 26.0′ N; 155° 17.5′ W.

January 29, 6:02 am, very feeble, probably of shallow origin neor center of Kilauea Crater.

Microseismic motion of the ground at the Observatory was strong throughout the month.

27 minutes of continuous tremor began to register at the Observatory at 3:35 am, January 19.

An unidentified portion of a teleseism began recording at Kilauea at 12h 58m 25s, H.S.T., January 24.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Holemaumau the algebraic sum of radial tilt toward or away from the Pit.

At the Observatory the totol accumulated tilt for the year ending January 30, was 6.3″ S and 0.48″ W.

Week Ending	Observatory	Halemaumou West Station
January 9	0.75″ N 53° W	5.07″ N 48° W
Januory 16	0.86″ S 5° E	6.26″ S 65° W
January 23	0.51″ S 4° W	8.70″ S 44° W
January 30	1.58″ S 30° W	4.38″ N 19° E

Week Ending	Holemaumau Southeast Station	Halemaumau Resultant
January 9	2.59″ N 87° W	1.84″ From
January 16	6.41″ N 80° W	1.28″ From
January 23	3.73″ N 57° W	3.29″ From
January 30	16.20″ S 18° W	7.45″ From

H. H. W.

Crater Angles

Measurement of horizontal angles across Kilouea Crater from the Observatory, January 11, indicated closing of the Halemaumou value and slight opening of the Kilauea Crater value compared with similar measurements made December 22. The Halemaumau measurement from the SE Pit B. M. to NW Pit B. M. showed a decrease of 1.51″ and the Kilauea Crater value from the SE rim to Uwekahuna showed an increase of 0.67″.

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcono, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations ot various ploces on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations far which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.


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THE VOLCANO LETTER

No. 456 monthly Department of the Interior National Park Service February 1938

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

PUBLICATIONS RELATING TO HAWAIIAN VOLCANOES
T. A. Jaggar

As supplement to an address delivered by the writer at the Annual Meeting March 31, 1932, of the Hawaiian Volcano Research Association in Honolulu, there was published in Volcano Letter No. 384, May 5, 1932, a list of publications.

Since 1932 numerous articles, popular and scientific, have accumulated as the output of workers at the Hawaiian Volcano Observatory. Many of these are on hand as reprints, one of which will be sent while they last to anyone interested who addresses The Hawaiian Volcano Observatory, Hawaii National Park.

Publications of the Observatory

The suspension of the Volcano Letter. Jaggar, Volcano Letter No. 385, May 12, 1932.

Eruption in Lake Rotorua, New Zealand. Jaggar, Volcano Letter 386, May 19, 1932.

Ash Eruptions in the Andes. Jaggar, Volcano Letter 386, May 19, 1932.

Eruption of Merapi in Java. Joggar, Volcano Letter 387, May 26, 1932.

A Note on Kamtchatkan Volcanoes. Jones, Volcano Letter 390, August 1932.

Results of One Year's Crack Measurements. Wingate, Volcano Letter 393, November 1932.

Lassen Report No. 32. Finch, Volcano Letter 395, January 1933.

Earthquake-Tidal Wave March 2, 1933. Jaggar, Volcano Letter 397, March 1933.

Puna Triangulation. Wingate, Volcano Letter 400, June 1933.

Lassen Report No. 33. Finch Volcano Letter 401, July, 1933.

What May be Learned From Tilt. Wingate, Volcano Letter 432, February 1936.

How to Make a Simple Seismograph. Finch, Volcano Letter 433, March 1936.

A Trip Up the 1935 Mauna Loa Flow. Waesche, Volcano Letter 433, March 1936.

Lassen Volcano, California. Farmer, Volcano Letter 433, March 1936.

Earthquakes in the U. S. de Vis-Norton, Volcano Letter 434, April 1936.

Volcanic Area of Bufumbira, Uganda. Palmer, Volcano Letter 434, April 1936.

The Influence of Volcanic Research in Hawaii. Joggar, Volcano Letter 434, April 1936.

University of Hawaii Summer Session. Jaggar, Volcano Letter 434, April 1936.

Earthquakes at Lassen, May 1936. Swartzlow, Volcano Letter 435, May 1936.

Methods of the Hawaiian Volcano Observatory. Jaggar, Volcano Letter 435, May 1936.

Japanese Volcanology and Seismological Research. Waesche, Volcano Letter 436, June 1936.

Adventures and Methods in Studying West Indian Volcanoes. Jaggar, Volcano Letter 437, July 1936.

Des Moines Seismological Station. de Vis-Norton, Volcano Letter 437, July 1936.

More About Volcano Observatory Methods. Jaggar, Volcano Letter 437, July 1936.

Science in the National Parks. Jaggar, Volcano Letter 438, August 1936.

Summit Outbreak of Mauna Loa, December 1933. Volcano Letter 439, September 1936.

The Coming Lava Flow, the Most Serious Responsibility in Our History. Jaggar, Volcano Letter 440, October 1936.

Eruption of Kilauea Volcano September 1934. Jaggar, Volcano Letter 441, November 1936.

The Bombing of Mauna Loa 1935. Jaggar, Volcano Letter 442, December 1936.

Protection of Hilo From Coming Lava Flows. Jaggar, Volcano Letter 443, January 1937.

Earthquakes. Woesche, Volcano Letter 444, February 1937.

Annual Report of Secretary, Hawaiian Volcano Research Association. de Vis-Norton, Volcano Letter 445, March 1937.

Mauna Loa. Jaggar, Volcano Letter 445, March 1937.

Crack Measurement and Tilt at the Hawaiian Volcano Observatory. Waesche, Volcano Letter 446, April 1937.

Trends in the Philosophy of Science. Jaggar, Volcano Letter 447, May 1937.

Eruptions at Rabaul, New Guinea. Jaggar, Volcano Letter 448, June 1937.

Work of F. A. Perret on Montserrat. Joggar, Volcano Letter 449, July 1937.

Kilauea Lava Flow of 1823. Waesche, Volcano Letter 450, August 1937.

Volcanoes in the National Parks. Waesche, Volcano Letter 450, August 1937.

Crater Lake National Park. Woesche and Jaggar, Volcano Letter 451, September 1937.

Triangulation and Level Changes at Kilauea. Waesche, Volcano Letter 452, October 1937.

Kilauea Volcano Laboratory of the University of Hawaii 1937. Jaggar, Volcano Letter 453, November 1937.

Work of the Observatory 1937. Jaggar, Volcano Letter 454, December 1937.

The Volcanic Gas Problem. Ballard, Volcano Letter 455, January 1938.

Publications of the Observatory. Jaggar, Volcano Letter 456, February 1938.

Publications Outside the Observatory

Ballard, S. S., and Gow, P. L.

An Improved Vacuum-Type Tube for Collecting Volcanic Gas. Proc. Haw'n Acad. Sci., Spec. Pub. No. 31, B. P. Bishop Mus. 1937. 1 page.

Finch, R. H.

Slump Scarps. Jour. Geol. XLI, No. 6, Aug.-Sept. 1933, pp. 647-649.

Burnt Lava-flow in Northern California. Zeitschrift fur Vulkanologie 1933, XV, pp. 180-183, 2 plates.

Block Lava. Jour. Geol., XLI, No. 7, Oct.-Nov. 1933, pp. 769-770.

Shishaldin Volcano. Proc. Fifth Pac. Sci. Cong., Vancouver 1933, Univ. Toronto Press 1934, A7. 21, pp. 2369-2376.

On the Mechanics of Nuees Ardentes. Jour. Geol. XLIII, No. 5, July-Aug. 1935, pp. 545-550.

Akutan Volcano. Zeitschrift fur Vulkanologie, 1935, XVI, pp. 155-160, 4 plates.

A Tree-ring Calendar for Dating Volcanic Events at Cinder Cone, Lassen National Park, California. Amer. Jour. Sci. XXXIII, Feb. 1937, pp. 140-146.

Jaggar, T. A.

History of Mauna Loa. Paradise of the Pacific, Honolulu, Vol. 46, No. 2, Feb. 1934, p. 5.

Hot Places at Kilauea. Paradise of the Pacific, Vol. 46, No. 7, 3 pages.

Fossil Human Footprints in the Kau Desert. Paradise of the Pacific, May 1932, Vol. 46, No. 5, 5 pages.

Shipboard Plane-table and Azimuth Camera: An Experiment in Navigation. Proc. Haw'n Acad. Sci., B. P. Bishop Mus. Spec. Pub. 26, 1935, pp. 13-14.

Living on a Volcano (Tin Can Island). Nat. Geog. Mag. July 1935, pp. 91-106.

Kilauea's Lost Lava Flow. Paradise of the Pacific, Vol. 46, No. 6.

Pele's Secret. Paradise of the Pacific, Vol. 46, No. 8.

The Breathing of Pele. Paradise of the Pacific, Vol. 46, No. 9, Sept. 1934.

Eruption of Halemaumau 1934 (broadcast from crater). Paradise of the Pacific, Vol. 46, No. 10, Oct. 1934.

Elevation Changes, Horizontal Shift and Tilt at Kilauea Volcano. Proc. Geol. Soc. Wash. 494th meeting, Journ. Wash. Acad. Sci., Val. 23, No. 2, Feb. 15, 1933, pp. 113-114.

The Coming Lava Flow. Reprinted from Honolulu Advertiser, March 27, 1934.

Protection of Hilo from Coming Lava Flows. Reprinted from Hilo Tribune-Herald Jan. 20, 1937, 8 pp. (Alsa Volcano Letter No. 443, January 1937).

The Bombing of Mauna Loa 1935. The Military Engineer, July-Aug. 1936, 8 pp. (also Volcano Letter No. 442, December 1936).

Trends in the Philosophy of Science. Proc. Haw'n Acad. Sci. 1937, B. P. Bishop Mus. Spec. Pub. 31, 1 page. (Also in full Volcano Letter 447, May 1937.)

New Seismographs for Mauna Loa. Proc. Haw'n Acad. Sci. 1937, B. P. Bishop Mus. Spec. Pub. 31.

Memorial of Bundjiro Koto. Proc. Geol. Soc. Amer. 1935, pp. 263-272.

Methods of the Hawaiian Volcano Observatory. Proc. Haw'n Acad. Sci. 1936, B. P. Bishop Mus. Spec. Pub. No. 30, 1937, p. 9. (See also Volcano Letter Nos. 435 and 437, May and July, 1936.)

Jones, A. E.

Earthquakes Associated with the 1934 Eruption of Kilauea, Hawaii. Jour. Wash. Acad. Sci. Vol. 25, No. 10. Oct. 15, 1935, pp. 429-435.

Earthquakes Associated with the 1933 Eruption of Mauna Loa, Hawaii. Jour. Wash. Acad. Sci., Vol. 24, No. 10, Oct. 15, 1934, pp. 413-418.

Hawaiian Travel Times. Bull. Seis. Soc. Amer., Vol. 25, No. 1, January 1935, pp. 33-61.

A Seismologic Study of the Kilauea Eruption 1931-1932. Univ. Hawaii Research Pub. No. 9, 1935, 60 pages.

Ground Surface Displacements and Earthquakes at Kilauea, Hawaii, first half-year 1935. Bull. Seis. Soc. Amer., Vol. 27, No. 2, 1937, pp. 112-138. (Also B. P. Bishop Mus. Spec. Pub. No. 30, pp. 9-10, 1937.)

The Formation of Basaltic Lava Flows. Jour. Geol. XLV, No. 8, Nov.-Dec. 1937, pp. 872-880.

de Vis-Norton, L. W.

Una Nueva Aplicacion Cientifica. (Bombing Mauna Loa Lava Flow 1935.) Revista Geografica Americana August 1936, Ano. III, Vol. VI, Num. 35, Buenos Aires, Argentina.

La Science sauve une Ville. La Revue Colombienne, Quebec, Beauceville, May 1937, p. 6.

Palmer, H. S., and Powers, H. A.

Pits in Coastal Pahoehoe Lavas Controlled by Gas Bubbles. Jour. Geol. XLIII, No. 6, Aug.-Sept. 1935, pp. 639-643.

Powers, Howard A.

The Lavas of the Modoc Lava-bed Quadrangle, California. California American Mineralogist, Vol. 17, July 1932, pp. 253-294.

Stone, J. B., and Earl Ingerson

Some Volcanoes of Southern Chile (with petrography). Amer. Jour. Sci. XXVIII, Oct. 1934, pp. 269-287.

Stone, J. B.

The Volcanoes of Southern Chile. Zeitschr. fur Vulk. 1935, XVI, pp. 81-97, 8 plates.

Wentworth, C. K., and Howel Williams

Classification and Terminology of the Pyroclastic Rocks. Bull. Nat. Research Council U. S., No. 89, 1932.

Williams, H.

Geology of the Lassen Volcanic National Park, California. Geol. Bull. Univ. Cal., Vol. 21, No. 8, 1932, pp. 195-385.

Wilson, R. M.

Ground Surface Movements at Kilauea Volcano, Hawaii. Univ. Hawaii Research Pub. No. 10, 1935. 56 pages.

Hawaiian Volcano Observatory Report for February 1938

VOLCANOLOGY

Much study was given the question of the meaning of the strong earthquake that affected Honolulu January 22. Parallels exist in the history of the Observatory, and several earthquakes in the past quarter century centered under Maui.

Measurements about Halemaumau pit showed increase of motion throughaut February. Alternation between motions on the Hualalai-Mauna Loa rifts and much higher frequency on the Kilauea fractures continued. This alternation may imply lowering of lava under Hualalai-Mauna Loa after the 1929 and 1935 crises, and return of lova under Kilauea especially along the eastern rift belt, for an eruption that is near ot hand.

The following are the weekly Observatary totals for Halemaumau pit of Kilauea Crater and the seismographs:

Week Ending	Seismicity	Slides	Crack Opening	Local Tremors and Quakes
February 6.....	11.75	0	2.5 mm.	37
" 13.....	10.00	1	6.0 mm.	36
" 20.....	23.25	5	10.0 mm.	55
" 27.....	12.50	9	9.5 mm.	38

Notable shocks were a moderate one on northeast rift of Mauna Loa February 17, and one the next day at Kilauea. There were two feeble Kilauea shocks February 20 and 21. A slight shock of Mauna Loa origin dismantled the Kona seismograph February 25. These illustrate the alternation referred to. Of all measured shocks, twenty-three were from Kilauea, two from Mauna Loa, two from Hualalai, and one from Mauna Kea.

Sequence of Events by Weeks

The first week produced nothing of importance except two distant earthquakes. The second week Kilauea remained quiet. The third week showed notable increase of tremors, number and strength of earthquakes, and some slides, with decrease of tilt at the Kilauea rim and increase at Halemaumau. Seismicity was cut in half the fourth week, though slides continued: tilt at Halemaumau changed from inward to outward by 18 seconds, and at the Observatory tripled in amount westerly. The opening of cracks at Halemaumau rim increased during the month.

Slides at Halemaumau

The recorded slides from the wall of Halemaumau were:
February 8, 9:30 a.m., fresh scars and dribbling rocks SE.
February 8, 4:22 p.m., slide north wall.
February 9, 9:11 a.m., slides at north cliff.
February 14, 9:42 a.m., dribbling rocks north.
February 20, 11:35 a.m., dust from slide N.
February 20, 12:07 p.m., slide NE.
February 21, 11:10 a.m., slide NE.
February 21, 11:30 a.m., dust rising NE.
February 21, 12:05 p.m., dust rising NE.
February 25, 9:53 a.m., slide north.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations around Halemaumau resulted during February in aggregate movement as follows:

Week ending forenoon of:

February 4 (5 days only), 28 locations, 7 opened, 2 closed, opening 2.5 mm.

February 11, 28 locations, 9 opened, 1 closed, opening 6.0 mm.

February 18, 28 locations, 11 opened, none closed, opening 10.0 mm.

February 25, 28 locations, 14 opened, 1 closed, opening 9.5 mm.

T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Moderate Earthquakes	Distant† Earthquakes	Weekly* Seismicity
February 6..	27	10	0	0	2	11.75
" 13..	32	4	0	0	0	10.0
" 20..	39	13	1	2	0	23.25
" 27..	28	9	1	0	0	12.50

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of depth of focus has been made.

January 31, 3:57 pm, very feeble, located approximately 5.0 miles ENE summit of Hualalai at a depth of 29.0 miles. 19° 43.3′ N; 155° 47.5′ W.

February 1, 8:43 am, very feeble, probably located in Kilauea SW rift zone.

February 1, 5:44 pm, very feeble, probably originated in Chain of Craters to SE of Kilauea Crater.

February 3, 12:23 am, very feeble, 0.6 mile deep in Kilauea Crater 0.6 mile NE of Halemaumau. 19° 24.7′ N; 155° 16.4′ W.

February 3, 7:09 am, very feeble, probably originated in N portion of Kilauea Crater.

Februory 6, 8:05 pm, very feeble, 25.0 miles deep, 7.0 miles NW of Humuula. 19° 45.5′ N; 155° 32.8′ W.

February 6, 10:14 pm, very feeble, 11.0 miles deep, 2.0 miles SE of Kilauea Crater. 19° 23.5′ N; 155° 15.5′ W.

February 7, 11:10 pm, very feeble, 1.1 miles deep near center of Kilauea Crater. 19° 25.1′ N; 155° 16.6′ W.

February 8, 2:07 am, very feeble, 35.0 miles deep and 3.5 miles NW of summit of Hualalai. 19° 44.2′ N; 155° 53.3′ W.

February 8, 8:20 pm, very feeble, 1.2 miles deep, SE rim of Kilauea Crater, 1.2 miles E of Halemaumau. 19° 24.5′ N; 155° 15.9′ W. Report felt at CCC Camp (ald).

February 9, 1:07 pm, very feeble, 1.5 miles deep SE portion Kilauea Crater. 19° 24.2′ N; 155° 16.2′ W.

February 14, 10:15 pm, very feeble, 3.3 miles deep 0.3 mile N of Puhimau Crater. 19° 24.1′ N; 155° 15.0′ W.

February 15, 10:13 am, very feeble, probably originated in Kilauea Crater near NE rim.

February 16, 3:54 pm, very feeble, 2.0 mile deep in SW portion of Kilauea Crater near SW edge of Halemaumau. 19° 24.6′ N; 155° 17.3′ W.

February 17, 2:18 am, moderate, 8.0 miles deep in NE rift zone, Mauna Loa near Puu Ulaula. 19° 33.0′ N; 155° 27.0′ W. Dismantled seismographs at Observatory and Pit, reported felt strongly in Kona and in Hawaii National Park. Felt slightly by many in Hilo.

February 17, 2:38 am, very feeble, 7.0 miles deep, Mauna Loa NE rift. 19° 32.0′ N; 155° 26.6′ W.

February 17, 4:05 am, very feeble, 1.3 miles deep in Kilauea Crater, near N rim of Halemaumau. 19° 24.9′ N; 155° 17.1′ W.

February 17, 8:41 am, very feeble, 2.0 miles deep near Keauhou Ranch House, 1.3 miles N by E of Uwekahuna. 19° 26.5′ N; 155° 17.1′ W.

February 18, 11:22 am, very feeble, of shallow origin in area between Keanakakoi and Lua Manu Crater. 19° 24.2′ N; 155° 15.7′ W.

February 18, 1:18 pm, very feeble, 2.0 miles deep near center Kilauea Crater. 19° 25.1′ N; 155° 16.4′ W.

February 18, 10:53 pm, moderate, 0.5 mile deep in E portion of Kilauea Crater. 19° 24.9′ N; 155° 15.9′ W. Felt only locally in Hawaii National Park near Kilauea Crater.

February 19, 3:15 am, very feeble, probably originated in NE portion of Kilauea Crater.

February 20, 1:37 am, feeble, 3.5 miles deep under SE portion of Kilauea Crater. 19° 24.4′ N; 155° 16.1′ W.

February 21, 3:45 am, feeble, 2.0 miles deep SE portion of Kilauea Crater. 19° 24.1′ N; 155° 16.0′ W.

† Including teleseisms or earthquakes over 5000 km from Kilauea.
* For local seismicity definition see Volcano Letter 371.

February 23, 1:23 pm, very feeble, probably originated NE portion of Kilauea Crater.

February 24, 2:19 pm, very feeble, probably originated near center of Kilauea Crater.

February 25, 6:00 am, very feeble, "P" lost in hour mark on Observatory record. No definite locotion but apparently of Hualalai origin. Reported felt in Kona.

February 26, 9:16 am, very feeble, of Kilauea origin.

Februory 26, 4:35 pm, very feeble, of Kilauea origin.

At 8h 46m 07s am, HST February 1, the "P" waves of a teleseism began to record at the Observatory. Distance from Kilauea 5,150 miles. Reported location was west of Aru Island in Banda Sea region of the Malay Archipelago, 4.0° S; 132.50 E. Another teleseism began to register ot 4h 5m 27s pm HST, February 4. Distance undetermined.

Microseismic motion of the ground ot the Observotory was moderate February 2, 3, 12, 13, 14, and February 21; strong the remainder of the month.

Tilting of the ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, and at Halemaumau the algebraic sum of radial tilt toward or away from the Pit.

At the Observatory the total occumulated tilt for the year ending February 27, was 3.76" S and 3.91" W.

Week Ending	Observatory	Halemaumau West Station
February 6	2.06" S 54° W	1.82" N 2° W
February 13	1.83" S 44° W	4.38" N 10° E
February 20	0.85" S 49° W	5.00" S 65° W
February 27	2.68" S 53° W	14.75" N 61° W

Week Ending	Holemaumau Southeast Station	Halemoumau Resultant
February 6	5.90" N 54° W	4.02" Toward
February 13	3.95" S 70° W	2.17" Toword
February 20	6.42" N 51° W	8.19" Toward
February 27	2.14" N 72° W	10.28" From

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory February 21, indicated no change in the Halemaumau value and slight closing of the Crater value compared with similar meosurements of January 11. The Halemaumau meosurement from the SE Pit B. M. to NW Pit B. M., showed opening of 1.42", January 11 to February 3 but closed 1.42" between February 3 and February 21 for a total no change. The Crater measurement from the SE rim to Uwekahuna showed o closing of 0.17" January 11 to February 3 and closing of 0.67" Februory 3 to February 21. Total closing 0.84".

H.H.W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawoii, is leosed and operated by the United States Gavernment, Department of the Interior, National Park Service. The Association mointains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, r search fellows, instrumental plonts, explorations and special investigations for which there is no gavernmental provision.

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THE VOLCANO LETTER

No. 457 monthly Department of the Interior National Park Service March 1938

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Slides at Waikane bridge, Hana belt road.

THE MAUI EARTHQUAKE OF JANUARY 22, 1938

On the evening of January 22, 1938 at about 10:03 a moderate to strong earthquake registered on all the seismographs operated by the Hawaiian Volcano Observatory. The Hilo and Kona seismographs apparently dismantled at the arrival of the first impulse of the secondary waves. The instrument at the SE rim of Halemaumau as well as that at Uwekahuna NW rim of Kilauea Crater were dismantled shortly after the preliminary waves had started to register. At the Observatory the Bosch-Omori seismograph was dismantled within a few seconds after the beginning of the preliminary wave registration as was the vertical mation instrument. The only instrument to receive a complete record of the quake was the low magnificatian instrument at the Valcano Observatory, NE rim of Kilauea Crater. The latter was specifically designed and built in the Observatory shops to register local shocks of strong intensities. It magnifies ground movement about eleven times.

The earthquake was classified as a near shock which includes those from 100 to 750 miles distant. It was felt throughout the Hawaiian archipelago and registered on seismographs as far away as Fordham University in New York City. In this respect it differed from the usual quakes so common in the Territory, and particularly on the Island of Hawaii, which sel-

dom are felt more than a few miles from their point of origin and practically never register off the island on which they occur. Inasmuch os there are ot leost three volconoes on the Island of Hawaii which ore considered octive, earthquakes there of varying intensities and of olmost daily occurrence, are expected and do occur. On the other islonds, eorthquokes though comparotively rare, are not uncommon.

The January 22 earthquoke was an exception: it definitely was not located on the Island of Howaii. It was felt about equally on Oahu and Hawaii. The Island of Kauai was apparently least disturbed, although it was reported as being the strongest ever felt there by older residents. All indications, both instrumental and by reports, were that the center of the disturbance was in the vicinity of the Island of Moui. The exact center was difficult to locate because of the disruption of seismographs and somewhat misleading observations received from persons near the epicenter. The final location, as determined by the Observatary, by the Coast and Geodetic Survey and by the Jesuit Seismalogical Assaciatian is in very clase agreement. Toking on average af these determinations, the epicenter would be located in the ocean about eighteen miles north of Pauwala Point on the Island of Maui.

First reoctions of some af the Oahu residents were interesting. Felt quakes in Hanalulu are comparatively rore ond the people of that city ore inclined to overlaok the fact that they most certainly live in a region where earthquakes are assured, ond thot strong ones moy occur ot ony time. Consequently when this shack was felt no one suspected that such o thing os an earthquake could possibly be centered nearer Hanolulu than to Kiloueo Volcono on the Island of Hawaii. Consequently, the rodio stations and telephone communicotions between the Islands were busy with calls from Honolulu trying to find aut whether the "Big Island" had been completely blown off the mop or hod sunk into the seo. Their first thought wos thot if the shack was that strong in Honolulu, it must be terrific on Hawaii. The Observatary was swamped with calls from all directions. It is suspected that there was o tinge of disoppointment from those elsewhere who discovered that on this island the earthquake not only had been of relatively moderate intensity but thot most of the people seemed octually to hove enjoyed it.

REPORTS FROM THE SEVERAL ISLANDS

Kauai:

Reported as severest quoke in memory of older residents. Felt as two separote shocks resulting in some minor damoge to some household articles.

Oahu:

Because of the early hour at which it occurred most of the people apparently felt the earthquake. A great deal of excitement resulted. Hotels ond theaters were filled with people; at the Alexander Young Hotel elevators stuck, dancers on the roof were forced to scurry down the stairs, orchestras continued to play while entertainers went on with their performances. There was a rush from all the downtown theaters. The Waikiki Theater was completely emptied in a few minutes. The excitement of persons downtown was shared by those in private homes who rushed from their houses ta see what had occurred. Residents of Manoa Valley reported three separate shocks, at 10:03, five minutes later, and a third shock at 10:23. A check by the County palice division showed that no bridges nor roads had been damaged, no highways blocked, though apparently 40 racks rolled on the Kamehameha highway at Kipapa Gulch. The largest was about twa feet in diameter. One automobile was damaged when it struck a rock in the road, but there were no injuries. At the Oahu Prison a four pound strip of ceiling fell in one cell. Preparations were made for the removal of prisoners if the tremor continued. However, no damage apparently was done to either telephone or power lines. Damoge on Oahu seemingly wos limited to breokage of crockery ond glassware. Hanging objects swung from the ceilings and some small articles were knocked from shelves.

Molokai:

The quoke here opened cracks between two and three inches in width ond twenty five to one hundred feet in length on the east Molokoi road at Mapulehu. From Ohia to Mapulehu stone walls collapsed, otherwise damage was confined ta crockery and other household possessions.

Lanai:

A radiogram received ot the Observotory from the monager of the Pineapple Company an Lanai, stated that "the quake did no damage ta the reservoir or water development project. There was a twa inch crack in the breakwater twenty feet leeward of the light, accampanied by slight settling. The pipe lines of the Maunalei Gulch abave and below the pumphouse were broken in several places by falling rocks. There was na damage ta pipes running over palis ta the reservoir. Slight damoge accurred to plumbing in houses. In stores some supplies were thrown on the floar. A crack 10 feet wide and 15 feet deep was reparted in the Maunalei region."

Maui:

The north caost of East Moui was prabably the hardest hit of any portion of the Territory. There the earthquoke took no toll of life, and resulted in few injuries, but inflicted considerable property damage throughout Maui's most isolated communities. Two large oil tonks owned by the Standord Oil Company were lost. Both tanks, containing diesel oil and kerosene respectively, were shattered. Thirty thousand gallons af the ail flowed into the neorby sea from the domoged tanks. The little town of Hana, Maui, was completely blacked by road slides between Poliku and Hana. The worst landslide was at Waikane. The Kaupo-Kieahu troil wos blocked by bod landslides. The Keanae stone crusher was completely covered by a londslide. The powerhouse of the Koeleku Sugar Company was thrown out of commission. Immediotely following the quake Hano was without lights for fifteen minutes. Ronches in southern Moui suffered heavy domoge as water tanks and stone walls were razed by the quake. Mr. H. A. Baldwin of the Maui Agricultural Company, Ltd. reports as follows:

"Your letter of the 4th inst. to hand some time ago and I apologize for not replying sooner; however, I have not yet been able to learn definitely just whot hoppened on Kahoolawe during the earthquake. I hope to get this information within o few doys and will write you again. I know there was considerable of a shoke up os a watertonk on the northern coast of the Island, which was set on a comparatively salid foundation, was turned over. I think part of the foundatian was built of loose rocks.

"You say you wish to know if Pauwela or Kahoolawe gat the severest shock. I think the idea that Pauwela experienced more of a shock thon other portions of Maui is erroneous. Certainly the greatest damage in the way of slides an gulch sides and road cuts was east of Pauwela. The country from Koilua on to Nahiku received what was apparently a very much heavier shock than at any time during my life, which goes back 67 years. The road has nat yet been fully opened up and there were numerous slides blocking up our ditches for considerable distances up the gulches."

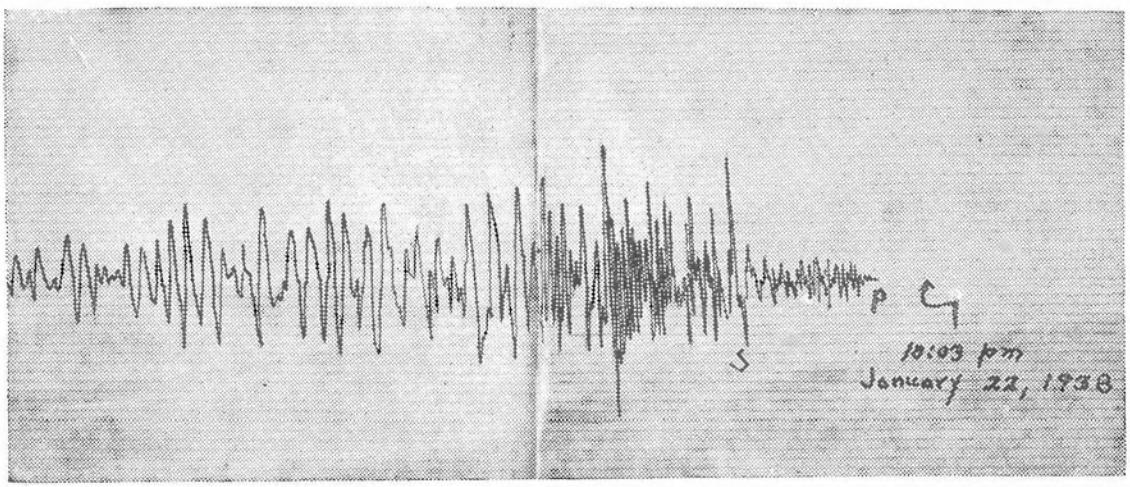
Concrete buildings in Lahaina were cracked. A landslide broke the intake pipe near the Lahaina River and flumes were used Sunday ta carry water from the stream to the old intake. Storage tanks between Wailuku and Kahului were damaged. Kahului was without water for a brief period. At Wailuku the Hollister drugstore, the Kress store, and the Courthouse showed

some damage to the interiors of the three buildings. Walls of the Kahului Theater were cracked by the quake, while the fire station tower was moved one-half inch. According to Mr. Edgecomb of the US Lighthouse Service mercury wos thrown from the floats of the revolving mechanism of some of the big lighthouses on Maui. District Ranger Peck of the Hawaii National Park stationed at Haleakala on Maui reported as follows:

"The earthquake that occurred on the evening of the 22nd jarred many tons of rocks into the road, several of them very large, and a number of small cracks appeared in the pavement. Fortunately the road was not completely blocked and by noon today we had it cleared enough to make it safely passable.

"I think we can clear the road in a reasonable length of time with the one man I have for help, pravided mother earth does not soon decide to go into another dance.

"I have not yet had time to inspect the Halemauu trail, which I fear may be in bad shape. I will inspect it very soon and report.



This seismograph record shows plainly the vibrations set up by the earthquake of January 22nd, 1938. Reading from right to left—note the normal line at the right, the intensification of the record and then the still disturbed line which shows that tremors were running through the earth long after they could be felt by human beings.

"No apparent damage was done to any of the buildings. Numerous cracks appeared in the road below the park area, some of them one and one half inches wide."

Communication with the town of Hana was completely severed, for several days. The only cammunication was by way of observation from an airplane which was chartered in Honolulu.

Hawaii:

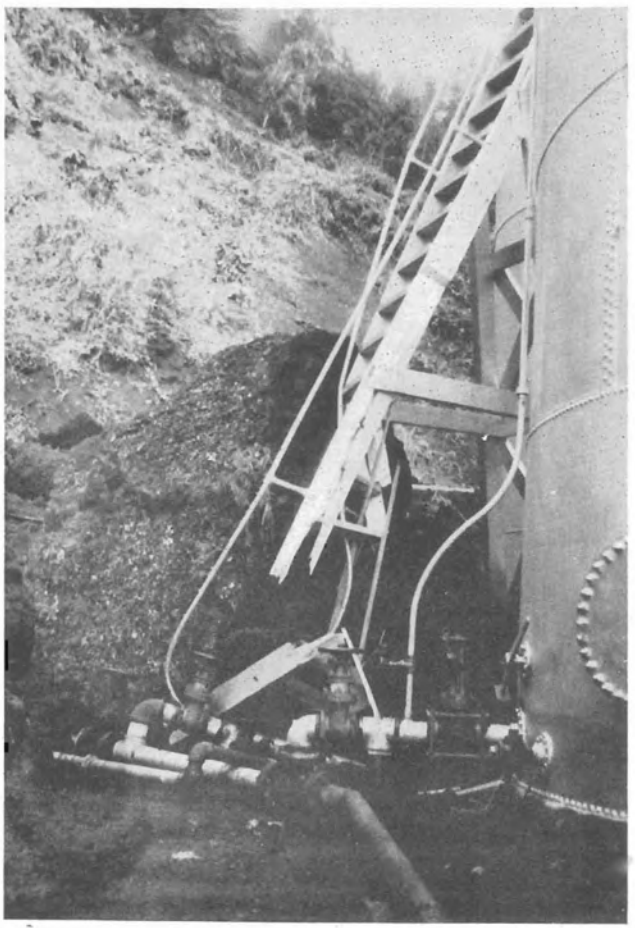
Compared with the residents of the other islands, those on the Island af Hawaii were quite calm. The shock was felt by mast people but was na greater in intensity in most parts of the island than shocks which commonly occur here. At first Mauna Loa ar Kilauea were thought to be responsible for this earthquake. Examination of the records at the Observatary, however, changed that opinion and by the next morning the evidence indicated a near shock 100 miles or more from Kilauea. Throughout this island the earthquake motion was apparently of a slow, swaying type. Cancensus of opinion expressed by residents throughout the Big Island was that the quake, while one of the longest ever experienced, was not as severe as some of the big shocks af 1929, which climaxed the series of earthquakes, apparently centered under the Hualalai district. Certainly the intensity af this quake was not as great as that recorded June 28, 1935, when stone walls in Hilo were cracked, nar was this quake as great in intensity on the records of the Volcano Observatory as that of 11:58 p.m. the night of September 30, 1935. Reports indicate that the shock was strongly felt in the Kohala district and gradually became less intense toward the southern tip of the Island of Hawaii. In Kohala, dishes were broken in many homes throughout the district. Pictures were knocked from walls, chandeliers crashed to the floor and furniture was generally disarranged. Small landslides occurred along the Kohala Mountain road. The shock was likewise strongly felt alang the Hamakua Coast district. At the home of George Becker in Honomu many dishes were broken when china cabinets swayed and their contents crashed to the floar. At the home of John M. Ramsay, Manager of the Honomu Plantation, a large crack appeared in the ceiling going straight through the house from front to back. Despite the severity of the shock, there was no panic in any section of the island. In Hilo, people were awakened and ran from their homes but the excitement soon subsided. It appears to have been most strongly felt in the Pueo district, which usually reports earthquakes as stronger than in other sections of town. In that area some homes reported that stoves and iceboxes were moved as much as two ar three inches from their original positions.

Location of the Epicenter by Seismograms

Only one complete record of the earthquoke was available for study. That recard was the one from the low magnification instrument located ot the Hawaiian Volcano Observatory, NE rim of Kilauea Crater. Partial records were available from the US Coast and Geodetic Survey seismograph located at the University of Hawaii in Honolulu, and instruments aperated by the Volcano Observatory in Hilo, Kealakekua, Uwekahuna Bluff (Kilauea Crater), SE rim of Halemaumau, the Bosch-Omori at the Observatory and a vertical component instrument also at the Observatory. All of these were dismantled at either the beginning of the preliminary phases or a few seconds afterward. The Hilo and Kona instruments apparently dismantled with the first impulse of the secondary phase.

The location was made from azimuths determined by the first impulses of the preliminary waves on the several seismograms and from Hawaiian travel times compiled by Mr. A. E. Jones, formerly of this organization. Also available was the preliminary arrival time at the Honolulu station, which is in charge of Commander J. H. Peters, who is making an intensive study of all phases of the earthquake. Assembly af all the

information available resulted in a comparatively reliable location although considerable checking and rechecking of the data was necessary to attain this end. First reports from the Volcano Observatory placed the disturbed area 154 miles N, 55° W of Kilauea. The distance was determined by the S-P interval of 22.8 seconds from the low magnification record and the ozimuth indicated by the Bosch-Omori instrument to the same lacation. From these data the epicenter was tentatively placed at a point in the sea 20 miles S of Palaaa Paint, Lanai. Comdr. Peters in Honolulu, using the first impulse time value at the University of Hawaii in conjunction with that at the Observatary, made his preliminary lacatian at a point off the South Point af Maui, Cape Hanamanioa. The preliminary waves began to register at Kilauea at 10h 03m 20s p.m. HST; at the University of Hawaii at 1h 03m 15s p.m. HST. Using these twa time values the lacatian was definitely on a line running raughly



Baulder which hit S. O. Ca. tanks at Hana in slide fram north slape of Kauiki hill.

NE-SW through the western partian of Kahaolawe and Pauwela Paint, Maui. On the basis af direction determined from the Bosch-Omori instrument the quake was thaught to be about sixty ar seventy miles deep and in the vicinity of the channel between Maui and Kahaolawe.

When seismograms from Kana, Hilo and other statians around Kilauea were examined directions did not agree with those af the Basch-Omori. Macraseismic reports likewise did not agree completely with the preliminary location. Directions from all the statians except the Observatary converged an a general locality to the north of Pauwala Paint north of Maui. The directions were:

Volcano Observatory	N 55° W
Pit Seismograph	N 24° W
Uwekahuna	N 23° W
Hilo	N 28° W
Kealakekua	N 3° W

Meanwhile, it appeared that the Hilo and Kealakekua instruments had nat dismantled until the beginning of the secondary phase. On this assumptian the graphical methad of Isikawa was applied ta the three stations, Hila, Kealakekua and Volcana Observatory, using the Jones travel times far the S-P values determined. Mare careful study placed the Basch-Omari S-P value at 22.3 seconds. The resulting location agreed roughly with directians indicated abave, amitting the Observatary. A depth of 65 miles was indicated. This was the final lacatian as determined fram the Observatory (See Volcano Letter 455, January 1938). The epicenter thus determined was a paint 25 miles N af Pauwala Point, Maui, 21° 12′ N; 156° 06′ W. By ather methods Commander Peters had arrived at appraximately the same location. The final computations from completely assembled data of local as well as distant statians places the epicenter at the above value. Time of origin was 10h 03m 08s p.m. HST.

Rassi-Farel Intensity values for a few localities an the Island of Hawaii were

Kilauea	IV
Kealakekua	IV-V
Puu Waawaa	VI
Haakena	IV

Kohala—probably same as Puu Waawaa

Excerpts from the Volcana Observatory Recard Baak:

Bosch-Omori

Period	Trace Amplitude	Phase	*Time (HST)	
0.2	— 0.3 mm	i P ENZ	10:03: 20.0 p.m.	
	+ 0.2			
0.7	— 4.0	i E	10:22: 07.0	}
	+ 2.0			} Dismantled
	+ 90.0	i N	11:23: 07.0	}

* Ten and one half hours behind Greenwich Time.

Law Magnification Instrument

		i PEN	10:03: 20.0 pm
		i SEN	10:03: 42.3
		f N	03: 53.3
0.9	—20.0 m		
	+ 11.0	i ME	04: 05.0
	— 9.0		
	—19.0	i MN	04: 15.4
		F E	10 42±

Same of the local residents thought this was probably the heaviest earthquake in 20 years. Dr. Jaggar has gone over the records since 1912 and has compiled the following list of near shocks showing that their accurrence has been relatively frequent.

Quakes—Hawaiian Volcano Observatory—150 to 500 Km

1912—Oct. 13, record imperfect
Dec. 5, 279 miles
1913—July 31, 136 miles
1914—Mar. 30, 93 miles
Aug. 8, 140 miles

1916—June 6, 93 miles
June 7, 125 miles
July 23, 140 miles
1918—June 14 ..? Felt Maui?
Nov. 2 ? Felt Maui
1919—Jan. 29, 177 miles, felt in Honolulu.
Sept. 14 ? Maui?
Sept. 18 ? Felt Maui?
1920—Mar. 30, 33 miles, felt Maui?
May 15, 60 miles, felt Maui? and Honolulu.
1923—Dec. 25 ? Felt Lanai, Maui, Honolulu and Molokai.
1926—Mar. 19, 124 miles, felt Maui and Honolulu. Mauna Loa eruption came April 10.
1927—Mar. 20, 110 miles from HVO. 4:52 a.m. Seismogram illustrated Fig. 14. Bulletin March, 1927. Felt in all Hawaiian Islands.
Aug. 3, felt in Honolulu? 9:42 a.m., moderate.

Hawaiian Volcano Observatory Report for March 1938

VOLCANOLOGY

The month at Kilauea Volcano showed decline in seismicity and apening of cracks, but some increase of slides during the last two weeks. The following are the weekly Observatary totals for Halemaumau and the seismographs.

Week Ending	Seismicity	Slides	Crack Openings	Local Tremors and Quakes
March 6	27.50	0	6.5 mm.	62
" 13	11.50	1	15.0 mm.	40
" 20	4.75	0	7.0 mm.	11
" 27	11.50	10	7.0 mm.	39
April 3	5.50	4	3.0 mm.	20



Crack in Wailua pali road above Keanae flats.

The writer has examined the records of the ones of March 1926 and 1927. They are in many respects similar to that of January 22, 1938. Their distances of 124 and 110 miles respectively would be correct for East Maui with Haleakala in mind.

It is very definitely a mistake to think that eorthquakes are unlikely in other parts of Hawaii. The imposing list shown here is proof that they can and may occur at frequent intervals. Their intensity is unpredictable and consequently it would be well to take that into consideration in discussing constructional developments in the Hawaiian Islands.

Twenty-seven of the measured shocks were of Kilauea origin, four were of Mauna Loa, and four were from beyond Mauna Loa. A moderate felt shack of Kilauea origin occurred February 28, slight felt shocks occurred March 2 and 7, the first under Kilauea Crater, and the second a deep source under Kilauea.

Distant earthquakes were registered March 22 and 25, this occurrence just after equinox being usual.

Sequence of Events by Weeks

The first week produced nothing of importance except that

the tilt at Halemaumau continued to be away from the pit. This tendency lasted until March 20, and with it the Observatory cellar began to show northeasterly tilts. The second week there were some sliding and increased opening of cracks. The third week was quiet. The fourth week showed notable increase of slides, and just after the equinox the tilt at the Halemaumau cellars turned inward. The fifth week was quiet.

Slides at Halemaumau

The recorded slides from the wall of the pit were:
March 8, 4:34 p.m., small slide NE wall.
March 22, 10:19 a.m., slide heord from W cellar.
March 22, 10:30 a.m., slide from N wall.
March 25, 10:23 a.m., small slide N wall, from near bottom.
March 25, 10:55 a.m., dust cloud from W wall.
March 25, 11:03 a.m., dribble of rock, N wall.
March 25, 11:06 a.m., dust above W wall.
March 25, 11:11 a.m., dust over W wall.
March 25, 11:20 a.m., dribbling of rock N and W wall.
March 25, 3:15 and 4:15 p.m., dust above N wall.
March 26, 10:20 p.m., noise of slide in pit.
March 29, 1:25 p.m., noise below W rim.
March 29, 2:20 p.m., noise from N wall.
March 30, 9:25 a.m., noise of slide NE and NW walls.
March 30, 5:43 p.m., dust cloud over NE rim.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted during March in aggregate movement as follows:

Week ending forenoon of:

March 4, 28 locations, 10 opened, 2 closed, opening 6.5 mm.

March 11, 28 locations, 15 opened, 0 closed, opening 15.0 mm.

March 18, 28 locations, 10 opened, 1 closed, opening 7.0 mm.

March 25, 28 locations, 11 opened, 0 closed, opening 7.0 mm.

April 1, 28 locations, 6 opened, 1 closed, opening 3.0 mm.

T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Moderate Earthquakes	Distant† Earthquakes	Weekly* Seismicity
March 6	52	13	3	1	1	0	27.50
" 13	16	5	2	0	1	1	11.50
" 20	11	4	0	0	0	0	4.75
" 27	32	7	0	0	0	2	11.50
April 3	18	2	0	0	0	0	5.50

* Including teleseisms or earthquakes of over 5000 km from Kilauea.

† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of depth of focus has been made.

February 28, 5:44 pm, very feeble, 2.1 miles deep in Kilauea Crater 0.6 mile E of Halemaumau. 19° 24.6′ N; 155° 16.2′ W.

February 28, 9:40 pm, moderate, dismantled both components of Observatory seismograph and felt at Hawaii National Park Headquarters area; 2.8 miles deep in Kilauea Crater near N rim of Halemaumau. 19° 24.8′ N; 155° 17.1′ W.

March 1, 7:58 am, very feeble, 2.4 miles deep in Kilauea Crater 0.4 mile NE of Halemaumau. 19° 25.0′ N; 155° 16.7′ W.

March 1, 1:20 pm, very feeble 1.0 mile deep near center of Kilauea Crater. 19° 24.9′ N; 155° 16.5′ W.

March 1, 1:48 pm, feeble, 1.6 mile deep under Byron Ledge, E rim of Kilauea Crater. 19° 24.8′ N; 155° 15.7′ W.

March 1, 2:40 pm, very feeble, 1.0 mile deep in NE portion of Kilauea Crater. 19° 25.4′ N; 155° 15.8′ W.

March 1, 6:24 pm, very feeble, 1.3 mile deep SE rim area of Kilauea Crater. 19° 24.4′ N; 155° 15.4′ W.

March 1, 7:29 pm, feeble, 2.1 miles deep in Kilauea Crater 0.6 mile E of Halemaumau.

March 1, 9:52 pm, very feeble; of Kilauea Crater origin.

March 1, 10:50 pm, very feeble, of Kilauea Crater origin.

March 2, 3:16 am, slight, 2.7 miles deep, Chain of Craters rift near Kokoolau Crater. 19° 21.9′ N; 155° 15.1′ W.

March 2, 4:22 am, very feeble, 1.3 mile deep SE rim area of Kilauea Crater. 19° 24.4′ N; 155° 15.4′ W.

March 3, 3:47 am, of shallow origin probably near center of Kilauea Crater.

March 3, 5:13 am, feeble, probably originated near SE rim of Kilauea Crater in vicinity of Keanakakai.

March 3, 6:00 am, very feeble, probably originated in NE portion of Kilauea Crater.

March 4, 5:53 am, probably of Kilauea origin.

March 7, 12:04 am, very feeble, 30.0 miles deep in saddle between Mauna Loa and Mauna Kea. 19° 43.0′ N; 155° 27.0′ W.

March 7, 5:56 am, moderate, 28.0 miles deep, Mauna Loa NE rift about 8.0 miles SW of Hilo. 19° 42.0′ N; 155° 32.0′ W. Reported felt by many in Hilo, Kona and Hawaii National Park.

March 8, 4:05 am, feeble, probably of Kilauea origin.

March 8, 4:06 a.m., very feeble, of shallow origin in Kilauea Crater.

March 10, 4:15 am, very feeble, probably originated in NE portion of Kilauea Crater.

March 10, 6:42 am, feeble, probably originated near Halemaumau in Kilauea Crater.

March 15, 1:30 am, very feeble, originated in NE portion of Kilauea Crater.

March 15, 11:12 am, very feeble, 1.5 miles deep, Kilauea Crater 0.8 mile E of Halemaumau. 19° 24.7′ N; 155° 16.3′ W.

March 20, 11:00 am, very feeble, 20.0 miles deep under Mauna Loa summit Crater. 19° 27.0′ N; 155° 37.0′ W.

March 21, 10:02 am, very feeble, probably originated near Halemaumau in Kilauea Crater.

March 25, 6:14 pm, very feeble, probably originated in Mauna Loa SW rift.

March 26, 9:12 pm, very feeble, of Hualalai origin. Windows reported to have rattled in building in Hookena.

March 31, 9:05 am, very feeble, probably originated in Mauna Loa NE rift.

April 3, 2:56 pm, very feeble, 4.0 miles deep, 1.7 miles NW of Kilauea Crater in vicinity of Kipuka Puaulu. 19° 26.1′ N; 155° 18.7′ W.

Teleseisms were:

Morch 7, 7h 30m 06s pm HST, beginning of unidentified portion.

March 22, 5h 5m 34s am, HST, beginning af secondary wave recording. Location by reports from U. S. Coast and Geadetic Survey, 53° N; 131°8 W, in vicinity af Queen Charlotte Island, Southern Alaska.

March 25, 5h 36m 35s am, HST, beginning af unidentified portion.

Microseismic motion of the ground at the Observatory was:

Light, March 20, 22 and 23.

Moderate, March 4, 5, 6, 7, 12, 13, 14, 15, 16, 21, 31. April 1 and 2.

Strong, the remainder of the month.

Tilting of the ground:

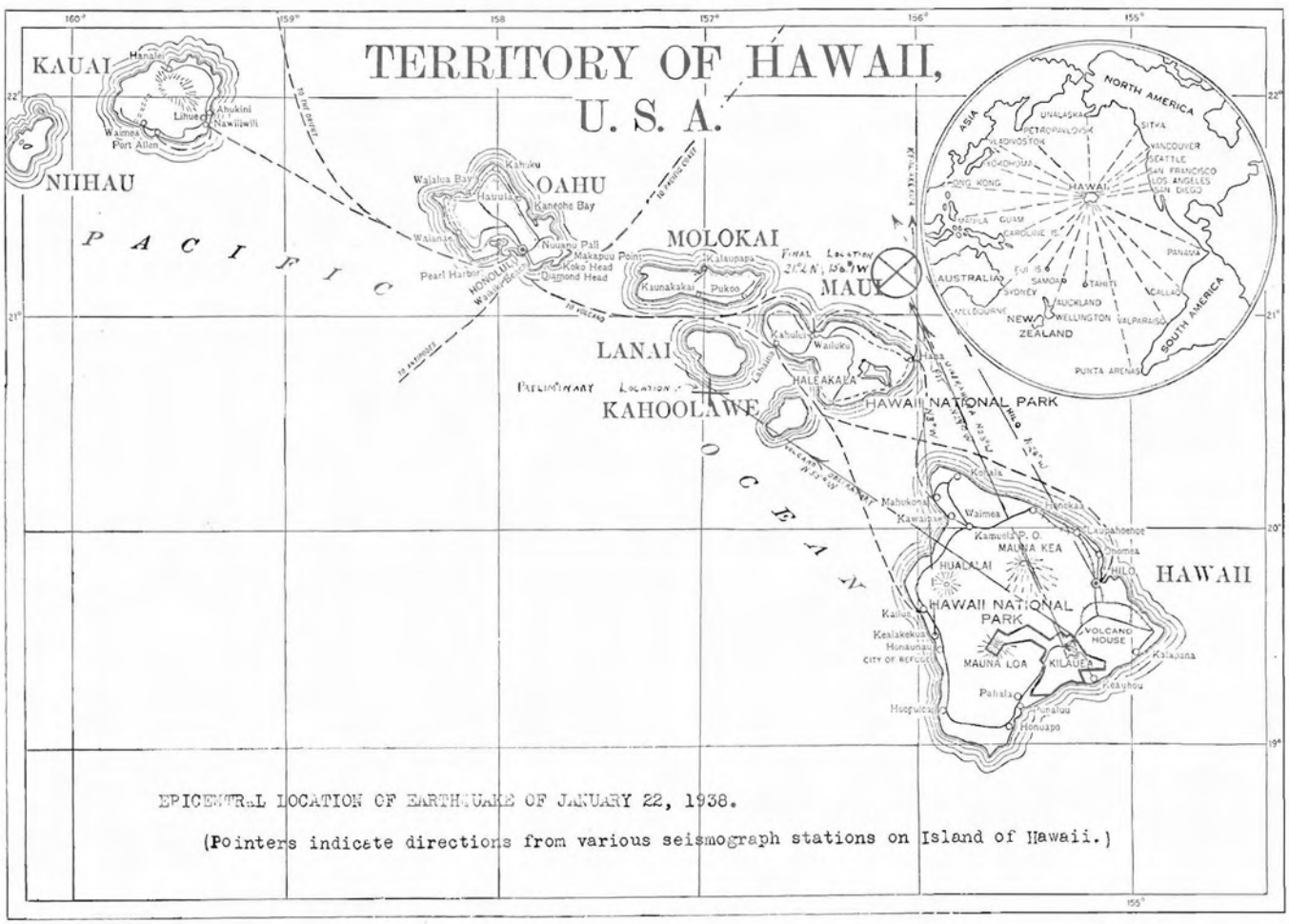
The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau, the algebraic sum of radial tilt toward or away from the Pit:

At the Observatory the total accumulated tilt for the year ending April 3, was 3.64"S and 4.42"W.

Week Ending	Observotory	Halemaumau West Station
March 6	1.81" S 27° W	9.54" N 85° W
March 13	1.40" N 66° E	5.90" S 74° W
March 20	0.66° S 75° W	5.90" N 80° W
March 27	1.52" S 55° W	3.07" N 12° W
April 3	0.20" N 40° E	4.17" N 80° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
March 6	2.59" S 79° W	8.94" from
March 13	6.48" N 29° W	0.51" toward
March 20	2.33" S 22° W	6.79" from
March 27	5.18" N 24° W	4.72" taward
April 3	7.52" N 13° W	2.78" toward

H.H.W.



EPICENTRAL LOCATION OF EARTHQUAKE OF JANUARY 22, 1938.

(Pointers indicate directions from various seismograph stations on Island of Hawaii.)

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

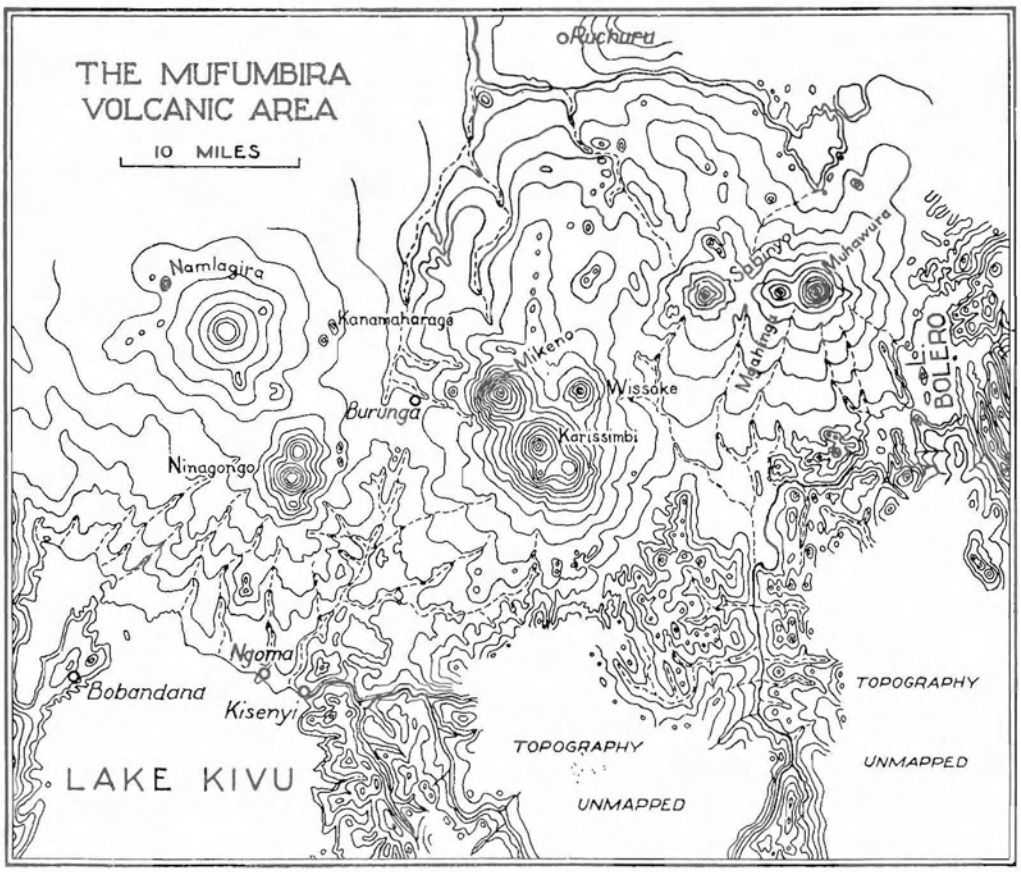
The Secretary of the Association is Mr. L. W. de Vis Narton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

THE VOLCANO LETTER

No. 458 monthly Department of the Interior National Park Service April 1938

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Map of Virunga or Mufumbiro Volcanoes (after Bowen).

EXCURSION TO NYAMLAGIRA VOLCANO, VIRUNGA OR MUFUMBIRO RANGE, PARC NATIONAL ALBERT

By P. PHILIPPSON
(Translated by Jaggar)
(Bulletin de Club Alpine Belge Sept.-Dec. 1934, p. 137)

In order to reach Lake Kivu in coming from the north by the mail route of Rutshuru the automobile road crosses the Virunga volcanic belt, passing between imposing profiles of the extinct volcanoes Mikeno (4,437 meters) and Karisimbi (4,506 meters) on the East; and the active volcanoes Nyamlagira (3,058 meters) and Niragongo (3,470 meters). The most active unit and doubtless the most recent of the whole group is Nyamlagira, situated about 15 kilometers from the route that we leave, when an hour's march south from the Mission of Tongres-Ste-Marie, in order to enter upon a pilgrimage across a plain of lava of more or less ancient origin. The most recent fields of lava were crossed first showing a vegetation of ferns and shrubs growing in the crevices of the rock, whereas on the flank of the mountain proper the very old age of the lava flows shows decomposition with the formation of soil and development of forest.

Nyamlagira is a dome, shaped like a turtle back, and is thereby distinguished from the other volcanoes of the chain, some of which are pointed (Karisimbi) or truncated cones (Niragongo) and others have peaks of jagged rock (Mikeno and Sebinyo). There are fresh tracks of herds of elephants; pigeons flap their wings on all sides, brilliantly colored butterflies flit about the undergrowth or are abundant on the orchids that are both terrestrial and aerial. One of the most remarkable kinds is an orchid possessing a white flower with a scarlet heart seen in large numbers during June and July on tree trunks covered with moss; another species is much smaller with fleshy flowers that are blood red.

Along the trail there are frequent leopard tracks, and occasionally the mark of lions. At places where the lava is covered with earth and moss, the footprints of the wild animals show with remarkable distinctness.

The track had been recently cleared and we travelled without difficulty, but this appears to be not invariable; the guide told us that shortly the trail would be blocked again by trees overthrown by elephants, or by windfalls that result from storms of extraordinary violence. Some months before our visit, four native porters had been frozen to death by a storm of hail that took them by surprise on the flank of the mountain.

After a march of about two hours and a half we passed a pond in the bottom of old craters. It is the watering place of elephants, for everywhere one sees their tracks. The water, which is the product of rain, is foul. This is the only water found between here and Kannusi, which is about four hours' march beyond this place.

On emerging from the crater we reach immediately the camp called Mushumangabo that commands a superb view of the whole country. Off to the east the magnificent cones of Mikeno and Karisimbi stand out in sharp relief; to the south is Niragonga and to the west Nyamlagira. Toward the south and southwest, between the two last named volcanoes, numerous subsidiary volcanoes produce an impression of much volcanic outpouring.

We continue our march toward the camp Mumurima, on the north side of the volcano close to 2,400 meters of altitude. The trail traverses a lava plain apparently older than the first part crossed before arriving at Mushumangabo. The jungle becomes denser and in places we passed through lovely old forests where the lava with bare surfaces is not so often seen.

A few hundred meters before arriving at the camp, we crossed the bed of a lava torrent and after a short climb found ourselves in a clearing where there are huts for the porters. Here we pitched our tent and soon the night enveloped us. In the big trees around the camp a goodly number of wood pigeons roosted and out of the bush came the calls of the wood partridge, more properly called francolins. We could also distinguish the whistle of the rock rabbit (hyrax) and from the valley came the bleat of a "harness" antelope calling to its mate. The landscape by moonlight was splendid; the ocean of jungle on the Rutshuru plain extended away to infinity, framed both east and west by a border of mountains.

Early the next morning we set out for the mountain top. Vegetation gradually disappeared. First through a cold lava channel, in the midst of equatorial plants and giant shrubs, then over a desert region, we arrived at the rim of the crater. It was truly fantastic. In a depression 2.3 km. in diameter bluish water vapor and greenish sulphur fume surrounded a rocky islet: truly a vision of the magic castle of the fairy stories. From the bottom of this enormous pit 150 meters deep the dull rumble of molten lava gave the impression of fiery power, and of the role of heat as creator and destroyer within our globe.

We set up our two tents close to the edge of the crater, on a solidified platform, where the wind incessantly brought to us sulphur smells. The night is cold and the porters have disappeared. They are entombed in a long subterranean gallery. By moonshine we reach the margin of the inner crater by way of plains covered with sulphur in ebullition. The spectacle is Dante-esque: here are glowing lavas in fusion bursting through the midst of black surfaces, and active eruption cones growling and emitting jets of flame and whirls of vapor.

Early in the morning we extracted our blacks from under the lava plain (the underground gallery where they lived had only a small opening) and we climbed down into the inferno for a depth of 100 meters. Surrounded by steam and sulphur we found the walking troublesome on this lava, that may break in underfoot at any moment. We approached within a few meters one of the active cones where fused lava was boiling; strong gushes of sulphur gas prevented any long stay.

The edges of the vents, yellow with crystals of sulphur, made contrast with the red of the boiling lava; on the interior crust of these little craters from two to twenty meters in diameter, and ten in number, there are clinging long tresses of hair (filamentous lava) which are agitated by the currents of hot air. After visiting several of these cones, and dodging the lava spatter and the dense clouds of sulphur vapor that they disgorged, we finally reached the base of the central island by walking across hot lava surfaces. The island is of massive rock 80 meters high.

After studying the map, I undertook the first ascent of the craggy height and in 20 minutes reached the summit. The only difficulty was a climb through a chimney for a height of four meters. The summit is covered with volcanic gravel surrounding a shallow funnel. The panoramic view was extensive.

Toward the north on the middle platform, could be seen the active region with its cracks, chimneys and cones spouting lava, lava which poured incessantly through subterranean tunnels into the big pit in the southwestern part of the crater. The bottom of this pit forms a lower platform. The level of the bottom of this large pit, 750 meters across, was in January 1932 at elevation 2,767 meters, in January 1933, 2,810 meters, and in June 1933, 2,828 meters. This regular elevation gives a measure of the amount of lava that has poured into this lower pit from the active area amounting to about twenty million cubic meters per year. At this rate the lower pit will be filled with lava about September 1934, and the level of the middle platform will be built up in from 3 to 4 years to elevation 2,904 meters, corresponding to the height of the active sources; unless a flank eruption of Nyamlagira drains the crater and again lowers the level of the bottommost flow.

The last eruption of Nyamlagira in 1912 was by way of the new subsidiary volcano Rumoka, situated 20 kilometers south-southwest from the main dome. Another eruption in about the same direction came from the Singiro vent erroneously called Nahimbi, 6.5 kilometers from Rumoka and about 15 kilometers from Nyamlagira. Between these two outbreaks there was another in 1905 from the volcano Kanamaharagi, 11 kilometers east of Nyamlagira, and about 13.5 kilometers N.N.E. from Niragongo.

From 1901 to 1912 there were four eruptions. From 1912 to 1933 external outbreaks have not occurred, but the level of the crateral lava within Nyamlagira has always risen. It is possible to calculate almost exactly the time when the lava level will reach the elevation (2,952 meters) of the upper platform, which is also the level of the overflow of this great volcano; but usually a breach occurs elsewhere.

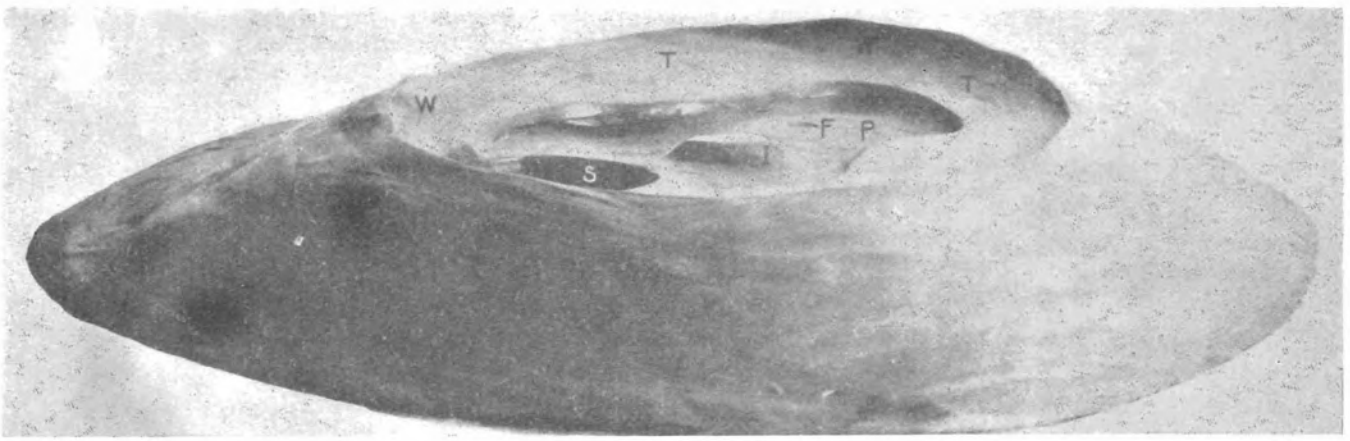
The study of the two active volcanoes of Albert National Park is part of the programme of the Belgian Scientific Institution. Such study will be of great interest to the geologists.

Hawaiian Volcano Observatory Report for April 1938

VOLCANOLOGY

Slides at Halemaumau pit were erratic with the greatest cancentration in numbers during the first and third weeks. The slides undoubtedly were responsible far many of the tremors reported during those periods. Seismic activity showed a slight increase toward the latter half of the manth. Occurrence af earthquakes indicating distance of origin Mauna Laa as well as Kilauea shows that movement is taking place at both volcanaes. At Kilauea tilt and angle measurements would suggest that lawering of the crater floor is continuing. A summary of data for the Kilauea station for April 1938 follaws:

Week Ending	Seismicity	Slides	Crack Openings	Local Tremors and Quakes
April 10	13.50	21	9.0 mm.	50
" 17	8.50	1	6.0 mm.	28
" 24	11.75	23	—0.5 mm.	35
May 1	12.25	11	4.5 mm.	43



Photograph of madel of summit af Nyamlagira as viewed from southwest. (W, main outer crater-wall; T, inner terrace; P, lava pit; F, fountain-basin; I, island; S, sink-hole.)

Faur of the quakes were af proper distance far Mauna Loa northeast rift, five may have originated deep under Mauna Loa elsewhere, a shock April 15 was felt strongly at Kapapala and a feeble earthquake April 12 was located twenty miles fram Kilauea. The sixteen earthquakes remaining originated under or near Kilauea crater.

Frequency of Events by Weeks

The first week produced slides at Uwekahuna, very slight tilt at the Observatory, more pronounced tilt at Halemaumau. The second week had less sliding and crack opening, and increased tilt at the Observatory. The third week showed increase of earthquakes and slides, unusual closing of the Halemaumau rim cracks and notable change of direction of tilting at the Observatory and at Halemaumau west. The fourth week produced additional slides and less tilting.

Slides at Halemaumau

The recorded slides from the wall of Halemaumau were:

April 4, 9:25 a.m., W wall.
April 4, 11:25 a.m., NW wall.
April 4, 11:44 a.m., NW wall.
April 4, 12:27 p.m., NW wall.
April 4, 1:27 p.m., NW wall.
April 4, 1:30 p.m., N wall.
April 4, 5:00 p.m., large dust cloud from NNE rim.
April 7, 7:45 a.m., W wall.
April 7, 8:05 a.m., W wall.
April 7, 8:10 a.m., NW wall.
April 7, 8:15 a.m., W wall.
April 7, 8:24 a.m., W wall.
April 7, 8:40 a.m., W wall.
April 7, 10:16 a.m., W wall.
April 7, 10:25 a.m., W wall.
April 7, 11:00 a.m., W wall.
April 7, 11:40 a.m., W wall.
April 17, 12:17 p.m., small slide NW wall, naise heard at Uwekahuna.
April 21, 12:45 p.m., dust over W rim.
April 23, 9:15 a.m., dust clouds NW.
April 23, 11:10 a.m., dust clouds NW.
April 23, 11:12 a.m., dust clouds NW.
April 23, 11:15 a.m., dust clouds NW.
April 24, 9:00 a.m., dust from W rim.
April 24, 9:10 a.m., dust from W rim.
April 24, 9:18 a.m., dust from W rim.
April 24, 9:31 a.m., dust from W rim.
April 24, 10:05 a.m., dust from W rim.
April 24, 10:12 a.m., dust from W rim.
April 24, 10:16 a.m., dust from W rim.
April 24, 10:31 a.m. dust from W rim.
April 24, 11:02 a.m., dust from W rim.
April 24, 11:08 a.m., dust from W rim.
April 24, 11:23 a.m., dust from W rim.
April 24, 12:09 p.m., dust from W rim.
April 24, 12:15 p.m., dust from W rim.
April 24, 12:23 p.m., dust from W rim.
April 24, 12:25 p.m., slides from N rim.
April 24, 2:00 p.m., slides from N rim.
April 24, 3:06 p.m., slides from N rim.
April 24, 3:12 p.m., slides from N rim.
April 25, 11:02 a.m., slide from N or NW walls.
April 25, 11:05 a.m., slide from N or NW walls.
April 25, 12:25 p.m., slide from N or NW walls.
April 25, 1:16 p.m., slide from N or NW walls.
April 25, 1:25 p.m., slide from N or NW walls.
April 25, 2:28 p.m., slide from N or NW walls.
April 28, 1:45 p.m., slide from W rim.
April 29, 10:50 a.m., moderate slide from N rim near hot crack.
April 29, 2:30 p.m., slide from W rim.
May 1, 12:25 p.m., slide from N rim.

Measurement of Halemaumau Rim Cracks

Weekly measurements of rim crack locations around Halemaumau resulted during April in aggregate movement as follows:

Week ending forenoon of:

April 9, 28 locations, 13 opened, 1 closed, opening 9.0 mm.
April 15, 28 locations, 11 opened, 3 closed, opening 6.0 mm.
April 22, 28 locations, 7 opened, 5 closed, closing 0.5 mm.
April 29, 28 locations, 8 opened, 1 closed, opening 4.5 mm.

T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant* Earthquakes	Weekly† Seismicity
April 10	46	4	0	0	13.50
April 17	24	3	1	0	8.50
April 24	25	8	1	1	11.75
May 1	37	6	0	0	12.25

* Including teleseisms or earthquakes of over 5000 km from Kilauea.

† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

April 7, 8:28 pm, very feeble, 2.2 miles deep, Kilauea Crater, near NE rim of Halemaumou. 19° 24.9′ N; 155° 17.0′ W.

April 9, 3:00 am, very feeble, probably originated in area about 1.0 mile NE of Kilauea NE crater rim.

April 10, 7:04 pm, very feeble, of shallow origin near Byron Ledge. 19° 24.6′ N; 155° 15.4′ W.

April 10, 7:05 pm, very feeble, of shallow origin near W portion of Kilauea Iki. 19° 24.9′ N; 155° 15.3′ W.

April 12, 8:48 am, a feeble earthquake registered. It was probably of Mauna Loa origin although there was no record of it either at Hilo or Kealakekua. Distance from the Observatory was 20.0 miles.

April 15, 2:36 pm, very feeble, no location but reported felt at Kapapala Ranch. Distance from the Observatory 18.0 miles.

April 16, 12:57 am, very feeble, 22.0 miles deep in vicinity of Kapapala Ranch. 19° 18.5′ N; 155° 29.5′ W.

April 19, 2:12 am, very feeble, 1.9 miles deep in NW portion of Kilauea Crater. 19° 25.4′ N; 155° 16.8′ W.

April 19, 2:56 am, very feeble, 2.6 miles deep, in vicinity of Lua Manu Crater. 19° 24.0′ N; 155° 15.5′ W.

April 19, 8:48 am, very feeble, probably originated under NW rim of Kilauea Croter.

April 19, 8:46 pm, very feeble, of Kilauea Crater origin.

April 22, 1:04 am, very feeble, of shallow origin, SE rim area of Kilauea Crater. 19° 24.1′ N; 155° 16.2′ W.

April 23, 5:51 am, feeble, of Kilauea origin.

April 23, 8:21 pm, very feeble, located at junction of SW rift with Kilauea Crater. Reported felt at CCC camp, SE rim of Kilaueo Croter and at the Kilauea Military Camp, N rim of Kilauea Crater.

April 23, 8:22 pm, very feeble, location probably same as preceding shock.

April 24, 4:54 am, very feeble, probably located in Kilauea SW rift about 20.0 miles SW of the Observatory.

April 27, 3:42 pm, very feeble, probably originated in NE portion of Kilauea Crater.

A period of continuous tremor, lasting 20 minutes, began recording at 12:59 pm, April 5.

An unidentified portion of a distant earthquake began to register at 6h 02m 24s pm, H.S.T., April 21.

Microseismic motion of the ground at the Observatory was light April 14, 15, 16, and 21; moderate April 4, 5, 10, 11, 12, 13, 22, 23, 24, 25, 26, 30; strong the remainder of the month.

Tilting of the ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau, the algebraic sum of radial tilt toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending May 1, was 1.62" S and 1.30" W.

Week Ending	Observatory	Halemaumau West Station
April 10	0.37" S 45° E	4.32" N 76° W
April 17	1.22" S 69° W	2.83" N 80° E
April 24	1.29" N 45° E	8.05" S 84° W
May 1	0.68" N 30° W	2.29" S 66° E

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
April 10	1.59" S 49° W	1.35" from
April 17	4.96" N 64° W	1.55" toward
April 24	5.96" N 44° W	0.61" toward
May 1	3.08" N 62° W	1.11" toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory April 20, indicated closing of the Halemaumau value and slight opening of the crater value compared with similar measurements of February 21. The Halmoumau measurement from SE Pit BM to NW Pit BM showed closing of 2.58" and the crater measurement from the SE Crater rim to Uwekahuna showed an opening of 0.90".

H.H.W.

THE VOLCANO LETTER

No. 459 monthly Department of the Interior National Park Service May 1938

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

ERUPTION OF NYAMLAGIRA VOLCANO 1938

(A letter from Dr. Jean Verhoogen)

Nyamlagira Volcano north of Lake Kivu in the Belgian National Park of the Congo District is a volcano of first magnitude containing lava pits in its crater similar to those of the Hawaiian volcanoes. It is characterized by dominant outflows of lava, and is distinguished as an intensely active lava producer in the midst of the interior of the great continent of Africa. It ranks with Mauna Loa and Etna, and yet is as remote from the ocean as they are near it. Its height is 3,058 meters, its position 1° 35′ S latitude, 29° 11′ E longitude. It had a voluminous eruption of lava estimated three cubic kilometers in 1894, an ash eruption from a side crater to the southwest in 1899, a lava flow in 1902 from a southern parasitic crater and it formed new mixed cones in 1904 and 1905. Other eruptions were in 1907 and 1912, the latter a flank lava flow that put out very liquid streams that reached Lake Kivu. Other activity in 1920 and 1926 shows how continuous is the release of pressure at this volcano and in 1904 there was an eruption from the bottom of the northwest corner of Lake Kivu with boiling of great surfaces of the lake accompanied by rumbling. There were possibly sixty-six eruptions in all between 1801 and 1914. (Sapper.)

From April 27 to May 26, 1935, Mr. Jean Verhoogen worked at the Hawaiian Volcano Observatory as a student sent from Belgium to prepare himself for volcanological work in the Belgian Congo. He acted as a temporary assistant at the Kilauea laboratory in order to learn the routine, and afterwards worked in graduate geological studies on California volcanoes. He published "Mount St. Helens" (Bull. Dept. Geol. Sci. Univ. Cal. 24-9-263, 1937), and took courses at both California universities; afterwards he became a teacher at Brussels.

Under date of June 12, 1938, Dr. Verhoogen writes to the Volcanologist at Hawaii National Park that he is at work on Nyamlagira volcano. When word came that a major eruption had begun the National Park Institute sent Verhoogen by airplane to Africa arriving February 1938. Dr. Verhoogen writes:

"What happened is this: you remember from Bowen's description that in September-October 1929 (N. L. Bowen, Trans. Amer. Geophys. Union 1929-30, pp. 301-307, 10 figures) the crater of this volcano consisted of a sink-hole SW, a middle platform, and an upper one, all enclosed within the walls of a caldera. The lava was issuing from tunnels in the edge of the middle platform, down the cliff margin of the sink and filling the latter.

"In 1934 the sink-hole got filled up. The lava began to pile up on the middle platform until it reached the level of the upper platform in December 1937. A few flows spread out through a gap in the caldera wall into the local 'Kau Desert' (by analogy with Kilauea, Hawaii.)

"On January 28, 1938, four fissures opened simultaneously on the SE and SW sides of the volcano, and a deluge of exceedingly fluid lava poured out. Gigantic sinking took place in the crater, and the middle platform and the sink hole appeared again. The flows from the fissures stopped quite soon.

"A new volcano was born lower down half an hour after the stoppage of the flows, on the SW side, and about a mile from Nyamlagira crater. It has been active up to June 1938 and the history is following, from up-hill down the slope.

"(a) An ever increasing number of spatter cones, all on two main lines, spitting vesicular lava in the early days of their existence, and only flames later.

"(b) A lava lake, 100 meters long, 60 meters wide, in which the lava entered from the south and disappeared all around the northern banks.

"(c) The source of a lava flow which flows down the mountain at 12 miles an hour in the open part of the channel. Total discharge has been one hundred million cubic meters from this stream (June 1938). This flow is almost entirely buried in a self-made tunnel. The construction of this tunnel was most interesting to watch.

"The intermediate lava lake on the mountain flank over the rift has had a most surprising behavior. The level sank steadily, until one day it divided up into two smaller lakes. In the southern pool, lava was fed from below the southern bank (the feeder was visible), but in the northern pool lava entered from the north. The level of the northern pool continued to lower, and as the pool got smaller and smaller, the lava which kept on entering from the same vent had to run down a bank quite a distance to the pool. Then this stream of lava solidified.

"Now there is still a circulation in the pool, lava entering apparently from below the banks. Activity on these pools consists of rising gases, folding crust, engulfment of the crust, and wild fountains which last a few minutes, so that there results a rapid sinking of the level. The level starts rising again, a crust is formed, folds appear, engulfment begins, a fountain sprouts up, and the level sinks. At the present time the whole cycle takes about 10 minutes in the southern pool, and is very irregular in the northern pool. It suggests more a geyser action than anything else.

"I have with me an optical pyrometer which works wonders, as it allows measurement in inaccessible spots. A number of measurements has shown that the lava is just as hot in the stream half a mile below its source as it is in the hottest fountain.

"I have taken still pictures, movie films and color films. The attempt to collect gases with vacuum tubes was only partially successful, as the tubes broke in transport, and the fusible tips failed to fuse. I think I have one air-free sample.

"I am expecting a spectograph. The spatter cones keep on day and night heaving huge yellow flames, almost sufficient to read by: I have not seen blue flames."

This is a perfect description of the Halemaumau activities of 1917-19, the masking and heat-holding effects of lava tunnels, the rift eruption of Kau Desert 1919-20, and the concealing of vent cracks as soon as lava covers them and forms concentric banks.

A translation showing what preceded the 1928 eruption was printed in the April Volcano Letter.

T. A. JAGGAR.

Hawaiian Volcano Observatory Report for May 1938

VOLCANOLOGY

The measurements at Halemaumau pit showed nothing exceptional until the forenoon of May 28. On that day, beginning about 6:00 a.m., almost continuous quaking developed with several moderate shocks that were generally felt. On that same day it was discovered that one large crack and numerous small ones were developing in an East-West direction, athwart the Chain-of-Craters road between Pauahi and Aloi pits, east rift of Kilauea Volcano.

The nature of the development appeared to be block faulting with downthrow to the south and there is possibly some graben faulting. This motion along the eastern rift belt of Kilauea mountain implies extension westward of the active cracks of 1924 at Kapoho, 1922 at Makaopuhi and 1923 in the upland west of Makaopuhi. A hot spot on the cracks which is killing the verdure indicates the presence of active lava below.

Diminishing seismic activity continued to the end of the month and a seismoscope was placed near the Chain-of-Craters road. Halemaumau showed no sign of breaking out.

Location of the earthquakes indicates that their epicenters were partly some five to six miles from the Observatory and a few of them were as close as two miles distant. These distances correspond to the southeast rim of Kilauea, and to Pauahi pit or slightly beyond.

The following are the local weekly data for the month at the Observatory and Halemaumau:

Week Ending	Seismicity	Slides	Crack Openings	Local Tremors and Quakes
May 8	10.50	3	2.5 mm.	36
May 15	11.75	5	5.5 mm.	40
May 22	8.75	0	3.0 mm.	27
May 29	247.75	8	4.0 mm.	726

Shocks capable of being felt occurred on May 5, of Kilauea origin, and also of May 28 to 30 as indicated above. Shocks of Mauna Loa origin occurred May 17, felt at Kapapala and Pahala. The last three weeks of the month were notable for strong distant earthquakes six in number located near Mexico, Papua, Borneo, Japan, the Philippines, and Oregon. This world-wide sympathy in time, with a similar seismic activity of down-breaking fault blocks of Kilauea, occurring a month before the summer solstice season of 1938, is worthy of close attention.

It should be noted that the accumulated tilt for the year always tending southward at the Observatory, and the tendency of levelling surveys to show the south bench marks of the Kilauea rim low with reference to the Halemaumau rim, and much evidence of crater angles closing, all tend to agree with downsinking of fault blocks. It should be noted that whenever the levelling (see October and December Volcano letters 1937) reports relative elevation of Spit bench mark (a southern rim bench of Kilauea crater) and the northwest Pit bench mark at Halemaumau, the statement that the crater floor has lowered may mean that the southern rim bench has been raised. And the statement that the Halemaumau rim is higher, may mean that the Spit bench mark is relatively lower. The northwest station on the Halemaumau rim is on the Mauna Loa side of the rift belt; Spit bench mark is on the side of Hilina Pali fault blocks. If one of the fault blocks adjoins Kilauea crater, its movement downwards might produce a relative tilt to the northwest between Spit bench mark and the western rim of Halemaumau. There has been a notable amount of northwest tilting lately in the Halemaumau southeast station. The spell of downfaulting with road cracks and earthquakes at the Chain-of-Craters rift belt is confirmatory of a trend noticed for years past, suggesting southwesterly tilt at the Observatory, and general lowering of the southern side of Kilauea crater and its floor.

Sequence of Events by Weeks

The first week produced westerly tilt at all stations and otherwise nothing exceptional. Second week showed increase of slides, quakes and opening of cracks and the Halemaumau tilt increased to the northwest. The third week was quiet, but the Observatory tilt increased to the southwest. The fourth week was the time of excessive earthquakes and numerous slides. Crack openings were moderate, Observatory tilt was away from the crater, Halemaumau west station tilted east, and Halemaumau southeast station tilted north; the resultant for these two was exceptional tilt toward the pit.

Slides at Halemaumau

The recorded slides from the wall of the Pit were:

May 2, 3:00 p.m., slide from W rim sent up dust cloud.
May 7, 9:35 a.m., dust rose at N wall.
May 8, 3:43 p.m., slide from N rim.
May 9, 10:25 a.m., N rim.
May 11, 5:40 p.m., large dust cloud N rim.
May 12, 9:52 a.m., rocks dribbled continuously from N wall.
May 12, 11:30 a.m., dust from N wall.
May 15, 12:30 p.m., N rim.
May 25, 9:45 a.m., N rim.
May 25, 9:55 a.m., N rim.
May 27, 10:36 a.m., N rim.
May 27, 10:46 a.m., W wall.
May 27, 1:15 p.m., N rim.
May 28, 1:33 p.m., N rim.
May 28, 1:40 p.m., N rim.
May 29, 4:55 p.m., N wall.

Measurement of Halemaumau Rim Cracks

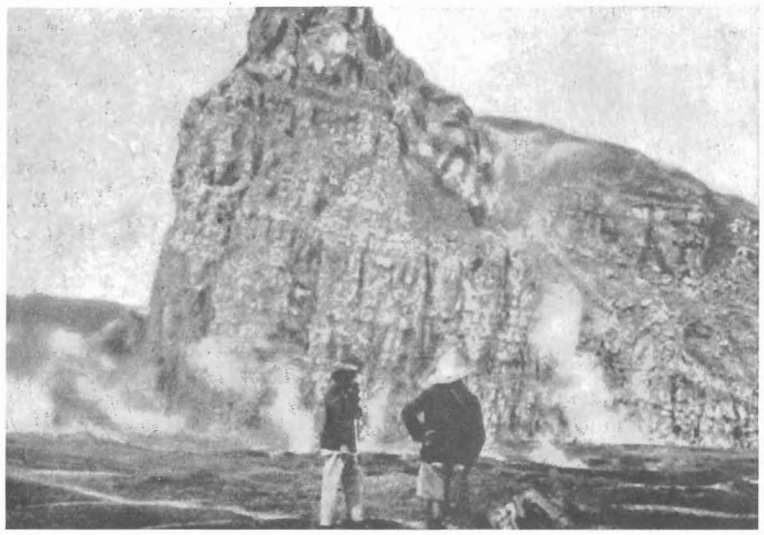
Weekly measurement of rim crack locations around Halemaumau pit resulted during May in aggregate movement as follows:

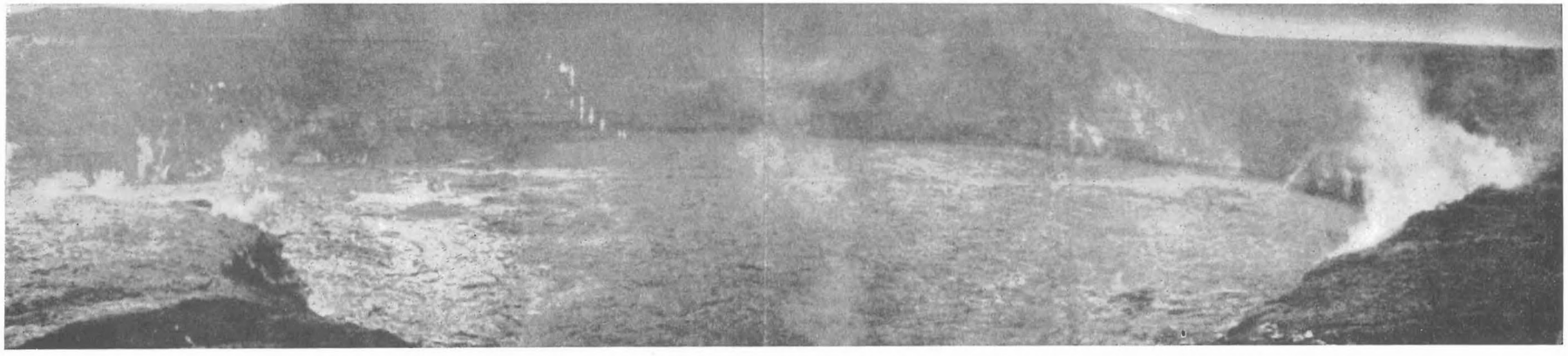
Week ending forenoon of:
May 6, 28 locations, 6 opened, 2 closed, opening 2.5 mm.
May 13, 28 locations, 9 opened, 1 closed, opening 5.5 mm.
May 20, 28 locations, 7 opened, 2 closed, opening 3.0 mm.
May 27, 28 locations, 5 opened, 0 closed, opening 4.0 mm.

Chain-of-Craters Crisis

The continuous tremor that began at 6:05 a.m. May 28 and continued until 1:00 p.m. the same day marked an outbreak of seismic motion that included numerous felt earthquakes. This unusually heavy swarm of tremors and earthquakes at the Hawaiian Volcano Observatory was accompanied by visible evidence of breaking and shearing of the ground along the Chain-of-Craters road near Pauahi crater. It was remarkable that this entire seismic spasm continuing into June was localized and shallow, and even the moderate felt earthquakes of Kilauea were not felt at all in Hilo and Pahala. While some of the shocks had epicenters near Devil's Throat, slides at that overhanging pit were not reported until June. The appearance of the tremor on the seismograph record was similar to that which appears during lava movement. Recent discovery of a new hot area in the forest near Kokoolau crater makes the







Pahoehoe lava on middle platform, central crag, and southern sinkhole of Nyamlagira Crater in 1933. (Philippson).

Puna rift belt a possible location for rising lava that has been recovering its pressure since 1924. Kokoolau is a mile toward Kilauea from Devil's Throat, and the new vapors have killed the vegetation within the last year or two. The combination of events probably represents both crustal adjustments and underground lava rising.

On the evening of May 28 a large crack across the Chain-of-Craters road was reported. At least eleven sets of new cracks had developed across the road between Pauahi and Aloi pits with general direction East-West. Seventeen individual cracks were counted on the evening of May 29.

The largest break in the asphalt paving of the road near Pauahi crater had caused the pavement to cave in in a chasm widest toward the west and narrowing half-way across the road to a three-inch crack extending on in the country rock beyond. There is evidence in the bushes away from the road of an old chasm in the rock. The cracks cross the road obliquely in plan. The widest part of the big hole in the road was five to six feet across. A hump in the paving near the Devil's Throat was higher than before as tangential compression had there been at work. This hump has been growing since the road was built some years ago, and its increase, as well as the development of the Kokoolau hot area indicates that the movements of the present crisis are accelerations of a process long continued.

The evidence for shallow depth of these earthquakes, and the correspondence of the distance of epicenters with the crack area of the Chain-of-Craters, and the location of some of the shocks much closer to Kilauea, as well as the strength of the vertical record, make it certain that we have good correspondence here between deformation of the land and epicentral distance. If an outbreak of Halemaumau follows, the expectancy will agree with the outcome. T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Moderate Earthquakes	Distant† Earthquakes	Weekly* Seismicity
May 8	32	3	1	0	0	0	10.50
May 15	33	7	0	0	0	2	11.75
May 22	21	5	1	0	0	3	8.75
May 29	593	107	9	14	3	1	247.75

* Including teleseisms or earthquakes over 5000 km from Kilauea.

† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

May 5, 11:38 am, very feeble, 18 miles deep under area 15 miles east of Summit Crater of Mauna Loa and seven miles NW of Kilauea Crater. Reported felt at Kapapala Ranch. 19° 27.0' N; 155° 21.5' W.

May 5, 3:17 pm, feeble, 1.5 miles deep in SE rim area of Kilauea Crater. 19° 24.5' N; 155° 15.6' W.

May 6, 8:15 am, very feeble, 1.3 miles deep and 0.4 mile SE of Keanakakoi. 19° 23.9' N; 155° 14.4' W.

May 6, 8:18 am, very feeble, 1.7 miles deep in Kilauea Crater 1.5 miles SW of the observatory. 19° 24.7' N; 155° 16.3' W.

May 9, 2:30 am, very feeble, 0.9 miles deep near Puhimau Crater. 19° 23.6' N; 155° 14.9' W.

May 10, 3:50 pm, very feeble, 22.0 miles deep and 10.0 miles N of summit of Mauna Kea. 19° 57.5' N; 155° 27.0' W.

May 10, 10:05 pm, very feeble, 1.8 miles deep in Kilauea Crater 1.0 mile SW of the observatory. 19° 25.2' N; 155° 16.1' W. Reported felt at CCC camp NE rim of Kilauea Crater.

May 14, 3:47 am, very feeble, probably originated in Kilauea SW rift about 13.0 miles SW of the Crater.

May 15, 9:16 am, very feeble, probably of Kilauea Crater origin.

May 15, 12:44 pm, very feeble, 0.6 mile deep in SE rim area of Kilauea Crater near Keanakakoi. 19° 24.3' N; 155° 16.1' W.

May 16, 3:35 am, feeble, 11.0 miles deep in Hilina-Kapukapu Fault system. 4.0 miles south of Makaopuhi Crater. Reported felt rather strongly in Pahala and at Kapapala.

May 16, 4:36 am, very feeble, of Kilauea Crater origin.

May 17, 2:13 am, very feeble, 27.0 miles deep under Mauna Loa summit Crater. Reported felt at Kapapala Ranch and at Pahala. 19° 27.5' N; 155° 33.5' W.

May 20, 8:18 pm, very feeble, probably originated near Kokoolau Crater.

May 23, 11:33 am, very feeble, 3.2 miles under Kilauea Crater. 19° 25.1' N; 155° 16.4' W.

May 23, 11:46 am, feeble, of shallow origin near SE rim of Kilauea Crater in vicinity of Keonakakoi. 19" 24.3' N; 155° 15.9' W.

May 23, 11:50 am, very feeble, of Kilauea Crater origin.

May 23, 1:25 pm, very feeble, 1.8 miles deep in Kilauea Crater 1.0 mile SW of the observatory. 19° 25.2' N; 155° 16.1' W.

May 24, 3:15 am, very feeble, probably originated in Chain-of-Craters rift near Devil's Throat.

May 28-29: beginning at 6:05 am, May 28, a period of continuous tremor lasting 414 minutes began to record at the Volcano Observatory and ended at about 1:00 pm the same day. Within that period of 7 hours there occurred 3 moderate, 12 slight, 7 feeble and 66 very feeble earthquakes for a total of 88 disturbances excluding the tremor. The greatest concentration of these was between 6:00 and 9:00 am, during which period the tremor reached its greatest intensity and there were 3 moderate, 7 slight, 4 feeble and 52 very feeble shocks. Seismic activity continued abnormally high the remainder of the week. For the entire day, May 28, there were 3 moderate, 12 slight, 7 feeble, 85 very feeble earthquakes and 499 minutes of tremor. There was considerable decrease in activity on May 29 although seismic activity was high. On that day there occurred 2 slight, 1 feeble, 16 very feeble earthquakes and 84 tremors.

Moderate earthquakes:

May 28, 6:32 am, distance from observatory 4.0 miles.
May 28, 6:52 am, distance from observatory 4.0 miles.
May 28, 6:57 am, distance from observatory 5.0 miles.

Slight earthquakes:

May 28, 6:22 am, distance from observatory 4.3 miles.
May 28, 6:33 am, distance from observatory ? miles.
May 28, 6:34 am, distance from observatory 5.0 miles.
May 28, 6:47 am, distance from observatory ? miles.
May 28, 7:26 am, distance from observatory 2.4 miles.
May 28, 8:13 am, distance from observatory 3.8 miles.
May 28, 8:21 am, distance from observatory 5.0 miles.
May 28, 9:32 am, distance from observatory 4.6 miles.
May 28, 9:38 am, distance from observatory 3.5 miles.
May 28, 10:21 am, distance from observatory 2.7 miles.
May 28, 11:07 am, distance from observatory 3.8 miles.

May 28, 11:46 am, distance from observatory, 3.2 miles.
May 29, 9:48 am, distance from observatory 4.0 miles.
May 29, 6:32 pm, distance from observatory ? miles.
Feeble earthquakes:

May 28, 6:07, 6:19, 6:32, 6:52, 8:05, 11:42 am, 12:46 pm; May 29, 10:01 pm with distances averaging about same values as slight and moderate shocks.

The 101 very feeble earthquakes were of similar origin with the exception of one that registered May 28, 7:32 pm, which apparently originated under summit crater of Mauna Loa and May 29, 12:55 pm which indicated a distance of 18.3 miles.

Residents of the Hawaii National Park and at Kilauea Military Camp were generally owakened by the first maderate shock of 6:32 am, May 28. Houses creaked, doors and windows rattled, dogs barked, pheasants squawked and hanging objects swoyed. A few articles on shelves were overturned. The Bosch-Omori and vertical seismographs at the observatory and the Hawaiian type seismograph at the SE rim of Halemaumau were dismantled. Slight earthquakes and the tremar perceptably shaok the ground until after the moderate shocks of 6:52 and 6:58 respectively. Although these disturbonces were registered on the Hilo and Kono seismographs, the recordings were of a minor nature and the shocks were felt only a few miles from Kilauea crater.

The evening of May 28, new cracks in the Chain-of-Craters rood SE of Kilaueo crater were discavered. Eleven groups of them crossed the road between Pauahi ond Aloi croters. Near Pauahi crater and where the most northerly of the cracks crossed the road, a section of the road caved in. The cracks ran roughly in an E-W direction.

General locations of this series of eorthquokes fell within an area extending from Kilauea Crater to Alealea Crater along the Chain-of-Craters rift. Develapment of the road cracks was undoubtedly associated with these eorth disturbonces and the relationship was very close.

The maderate earthquakes of May 28 indicated greater successive distonces from the observotory. The location af that of 6:32 am was 1.9 miles deep in the Choin-of-Craters orea near Kakoolau Crater. 19° 23.3' N; 155° 14.6' W. The maderate shock of 6:52 am, probably originated near Devil's Throat and the one of 6:58 am, neor Pauohi Croter. The earlier quakes seemed to be closer to Kilauea Crater thon the later ones as though same sub-surface disturbance was from the Kiloueo Croter, southeostward.

A hump in the road neor Devil's Throot was noticeobly increased in relative height.

Depths of the earthquakes of this series ranged from shallow ones near the surfoce to two and one half miles.

A portion of the preliminary woves of a teleseism begon to register at Kilauea at 4h 37m 38s am, May 11; from news reports, it was located off W coast of Mexico 16° 8 N; 100° 7 W. The preliminary waves of a second teleseism began recording at 5h 19m 24s am, location in vicinity of East Papua, adjoining New Britain, 4,350 miles from Kilauea; 5° S; 147° E. At 6h 51m 05s am, May 19, the preliminary waves of a teleseism began to register, distance 5,750 miles, located 0.5° N, 119° E, near Borneo. May 22, 8h 58m 32s pm, the preliminary waves of an earthquake strongly felt in Japan began registering at the observatory. It was 3,815 miles from this station. At 10h 04m 01.0s pm, the same day the preliminary waves of a quake felt in Manila reached Kilauea; it was 5,500 miles distant. A portion of a teleseism whose reported location was in Oregon, U.S.A., began registering at Kilauea 12h 57m 51s pm, May 27. All time is Hawaiian standord.

Microseismic motion of the ground at the Observatory was moderate May 3, 13, 14, 18, 19, 20, 22, 23, 24, 27, 28 and strong the remainder of the month. H.H.W.

Tilting of the ground

The following tables show tilt by weeks as recorded by the observatory seismogroph and at Halemaumau, the olgebraic sum of radial tilt toward or away from the pit.

At the observatory the totol accumulated tilt for the year ending May 29 was 3.5" S and 5.7" West.

Week Ending	Observatory	Halemaumau West Station
Moy 8	0.90" S 72° W	3.19" S 43° W
May 15	0.52" S 73° W	4.38" W
May 22	1.10" S 62° W	2.44" S 67° W
May 29	0.74" N 43° E	4.98" N 73° E

Week Ending	Halemaumau Southeost Stotion	Halemaumau Resultant
May 8	6.22" S 85° W	0.98" toword
May 15	7.11" N 59° W	2.16" toward
May 22	6.25" N 30° W	4.38" toward
May 29	6.09" N 3° W	9.01" toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the observotory Moy 18, indicated slight opening af the Halemaumau value and closing of the crater volue compared with similar measurements of April 20. The Halemaumau measurements from the SE Pit BM to NW Pit BM showed opening af 0.08" ond the croter meosurement fram the SE Croter Rim to Uwekahuna showed closing of 1.74". H.H.W.

Errata:

"The Moui Eorthquoke of Jonuory 22, 1938," by H. H. Woesche, Asst. Geologist at the Howaiion Volcono Observatory; Volcano Letter No. 457, March 1938, page 4, column 2, under Bosch-Omori should be iE, 10:03:22.7 pm and iN 10:03:23.7 pm (Dismantled). H.H.W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at variaus places on the Islond of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provisian.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis-Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcame, and if suitable, will be published with due acknowledgment.

THE VOLCANO LETTER

No. 460 monthly Department of the Interior National Park Service June 1938

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

PLANNED PROGRAM FOR THE HAWAIIAN VOLCANO RESEARCH ASSOCIATION

By T. A. JAGGAR

The following statement on the subject of financing technical publication of the records of the Hawaiian Volcano Observatory was presented April 1, 1938, to a group of business leaders of Hawaiian industry in Honolulu at the call of the Board of Directors of the Hawaiian Volcano Research Association. The meeting was held in the Board of Directors' room of the Hawaiian Sugar Planters' Association.

The Hawaiian Volcano Observatory under the Whitney fund of Massachusetts Institute of Technology was proposed in 1909 with a view to continuous record of Kilauea and Mauna Loa volcanoes. It aimed at an engineering science of volcanic phenomena of all kinds, in order to increase safety of life and property.

The Research Association was founded to safeguard the precious records for Hawaiian use. The financing was by $5 members and voluntary contribution of donors from year to year. It was supplemented by government.

In 1933 the government cut its appropriation. This was the fourth severe crisis that had to be met. As before the Research Association and the University saved the Volcano Observatory. This was followed by an extraordinary scientific success in 1935, namely, the printed prediction of all details of a disastrous eruption of Mauna Loa. A blasting enterprise with army aid led to the eruption stopping. This had been a plan fostered by the late honored L. A. Thurston many years ago.

In 1937 another public service was inaugurated by the association, extending the national park to the whole of Mauna Loa, and surveying for barriers to defend Hilo harbor against lava flow with United States engineers as designers.

The reason for disheartening financial crises depended on the essential instability of annual congressional appropriation 5,000 miles away. The cure is to create a sponsor for technical volcanology which is permanently Hawaiian, to assist the Government.

What is technical volcanology? It is like clinical surgery. Our population is the patient. Volcanic fever or shaking is the disease. Selecting an earthquake-resistant or lava-resistant human intelligence, will make Hawaiians different from peaples of other volcanic lands. Our publications have taught foreign scientists. A Matson ship rescued the people being overwhelmed by a volcano in Papua. The British government sent to us when volcano and earthquakes were wrecking Montserrat. When Napier was demolished, New Zealand sent to Hawaii for instruments.

Volcanology has started making a volcano science publishing the results of observation. It assists soil and water geology, safety by patrols at eruptions, prediction based on history, preparedness based on organization. Hilo and Honolulu are organized.

Hawaiian volcanology has sent forth trained men: Wood at Pasadena, Finch in California and Alaska, Stearns, Powers and Wentworth in Hawaii, Perret in Martinique, Wingate, superintendent of Hawaii National Park, Wilson in Washington, Jones in oil geophysics.

Among its by products are the park itself, Uwekahuna museum and the Kilauea military camp, volcanology in California and Alaska, the Mauna Loa and Haleakala roads. In education your association has collaborated with the University of Hawaii since the college was founded. The University now helps the Association immeasurably. The Government has assisted Hawaiian volcanology liberally since 1919, under respectively weather bureau, geological survey and national parks.

Throughout all the 26 years, however, the anchor to windward that has never dragged has been the Hawaiian Volcano Research Association. Publishing an outline of observations in monthly bulletins has informed scholars what we are doing. Critical eruptions with thousands of earthquakes, and other measurements, have left voluminous records that are still not worked up. Your present director is growing old. He knows these records, notes taken by 15 former workers. They need publication as scientific memoirs during the next 10 years.

Important discovery emerges from codifying and platting the figures of old series of measurements. In 1929 we recorded times, sizes and places of 6,000 earthquakes in three weeks, North Kona was being shaken to bits. We had no time then to do more than place instruments, cheer up the ranchers, keep the recording going, and cover as much ground as possible. It is for such a crisis that we want a simple shock-recorder at every telephone exchange. I wish we had had them in Maui and Oahu on January 22, this year, 1938.

The record of 1929 contains eruptions of Kilauea in February and July, a simultaneous eruption at Tin Can island in Tonga, and the Kona earthquakes as a sign the lava of Mauna Loa was shifting northwest to a new place. The completed story is greatly needed by the British and Tongan scientists studying Samoa and New Zealand. To publish the facts of 1929 is one of many tasks lying in filing cabinets: Notes, maps, curves, photographs and seismograms.

The next eruption of Mauna Loa in December, 1933, was farther north than 1926 and wholly in the summit crater. The northern 1929 earthquake spasm informed us Pahala and Waiohinu at the south were less in danger, the Hilo direction

in greater donger. The lovo outlets hod migrated olong the crock up the south slope to the summit ever since 1868. We studied the intervals, arrived at a probable two yeors after 1933 for an outbreak still farther north threatening Hilo, and published the focts. The flow come exactly two yeors ofter 1933 with outlet five miles forther north, it threatened Hilo, and the bombing deflected it.

This episode, of our Association's 26 yeors, is only one of many critical studies made, which are of use to this territory.

Let us look at large earthquokes: A frocture that broke open Hualolai volcano in 1800; o quake that ripped open o huge crack at Pohalo in 1823; a jalt and lova flow in Puno in 1840 a terrific one with two lovo flows including Mauna Loa in 1868. It suggests migration in the direction of Kahala and Maui.

Next a bad earthquake in Hilo in 1887; the 1929 series of shocks at Puuwaowaa; the Januory, 1938, a crash at Maui affecting Honolulu. What about the great fracture still farther northwest ocross the north side of Molokai? Projected westward it hits Diomond Head on the map, and Diamond Head is Hanolulu city.

In oll, we find o series of big eorthquake sposms, extending through a century, from the Kilauea-Mauno Loa axis to the Haleokola-Kahoolowe axis. Will the Molokai-Diomond Head axis move? It is worth study.

We hove many unstudied records. We need to learn everything possible about cycles and intervals, and obout building codes and fire safety. Mr. Stearns is perfectly sound in recolling the Haleakola eruption of the Kaupa gap obout 1750. It is merely asking, ore our records, that cost us $260,000, warth preserving in permanent form before they are mere scrap poper?

The superintendent of schools, ofter the recent eorthquake in Honolulu, wrote me osking whot to do in cose of severe earthquakes for reconstruction or discipline, in second class school buildings. I told him of California, New Zealand and Japan experiences, and referred him to the authorities.

The nationol guord officer asked me to criticize a written out problem of discipline and organization for Hilo. The terrific destruction of hospitols, roods, cliffs, drug stores, banks, water supply ond docks in Napier, New Zealond, was the model. I sketched and put in print the plan of orgonizotion.

The Chamber of Commerce, during the fright of 1935 when lovo was pouring down Woiluku volley obove Hilo, asked what Hilo should do in case of o quicker flow from o nearer vent straight toword the harbor. We consulted engineers, studied the contour maps, examined precedents and costs, and the borrier plan was the answer. Incidentolly, it turned out that such o flow is very probable.

The Association has no sufficient money in the next 10 years to print the records the society has filed. The immediate need is to publish technicol results under our own imprint before the present director is incapacitated.

The notional park does not publish technical volcanology. It is not economy to spend $260,000 through a quarter century for precious records, and leave them to fire and cockroaches.

The volconologist is no more a prophet of evil thon on army officer. They both have expensive jobs over lorge areas making war against evils.

The one has popular government money, the other is unknown. Hawaii has taken the leod to moke seismic strategy known.

A famous scientist was asked by a lady, "What use is it?" He replied, "What use is a baby?" In the 19th century we had leaf hoppers, now we have parasites; then smallpox and plagues, now vaccination and quarantine; then floods and storms, now control and resistant construction; then slums ond overgrown roads, now welfare and cantoneering. It took a century to persuade people to use common sense sciences.

Volconology is a common sense science. There was earthquoke, lavo and tidal wove destruction, now there is earthquake proof construction, oir bombing and seismic foretelling of woves. Then there was city congestion ond panic, now city planning and educotion. Then there was resistless lava filling, now constructed borriers as plonned. Then there was disaster ond deoth, now preporedness organiaztion.

The Government offers us the plan of o $125,000 reinforced concrete building for the new volcano observatory at Kilouea, with large lobarotories, library, exhibit rooms, auditorium, map room and safe storage.

A group of generous local danors has given o sum of money for beginning the publication of monagraphs.

Summarizing this question of publishing valuable scientific orchives of the Territory of Hawaii, there is needed:

1. Fifteen thousand dollars a year for the next 10 years.
2. To get the $125,000 government laboratory proposed.
3. To complete publications in technical form.
4. To appaint a scientific board to aversee publication.
5. To shift current work and routine publication gradually to Hawaii Nationol Park, with the consent of the park service.
6. To allow the volcanologist to edit finished reports as his chief remaining work.
7. To present this program to the Secretary of the Interior, from the Hawaiian Volcano Research Association, as representing the contributors who have accumulated these records.

Hawaiian Volcano Observatory Report for June 1938

VOLCANOLOGY

The crisis of downfaulting of benches south of Chain-of-Craters that began ot the end of May continued into the first week of June, but died away completely to o quiet spell at the end of the third week, or just at the time of solstice. New cracks were discovered on the trails extending north and south from Choin-of-Craters rood and obout June 5 caving in of the Devil's Throat was discavered and rock falls into that pit continued for a week. It was evident that the breakage crossing the line of the Chain-of-Craters on cracks trending ENE about Pouahi Crater were now being supplemented by the breakage northeostward along the mapped cracks that lie to the southwest of the Devil's Throat. The month of June developed no sign of Halemaumau activity.

The following ore the locol weekly data for the month ot the Observatory at Halemaumau:

Week Ending	Seismicity	Slides	Crack Openings	Local Tremors and Quakes
June 5	65.00	3	3.5 mm.	195
" 12	24.50	12	2.0 mm.	80
" 19	8.00	1	3.0 mm.	24
" 25	15.00	0	0.5 mm. closed	48

Sequence of Events by Weeks

The first week produced notable reduction in the volue of seismicity, the second week further reduction and increase of slides, the third week notable diminution of both, and the fourth week the ordinary increased frequency of local tremors and the registration of one distant earthquake, that would be expected after solstice.

Slides at Halemaumau

The recorded slides from the wall of the Pit were:
May 31, 10:00 a.m., 12:20 p.m., 12:29 p.m., dust cloud NE.
June 6, 11:20 a.m., 5:30 p.m., N rim.

June 8, 9:20 a.m., N rim.
June 9, 8:45 a.m., 8:50 a.m., 3:15 p.m., N rim.
June 10, 9:55 a.m., 10:45 a.m., 10:58 a.m., N rim.
June 12, 12:35 p.m., 1:25 p.m., 1:40 p.m., N rim.
June 17, 5:20 p.m., N rim.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim cracks located around Halemaumau pit resulted during June in aggregate movement as follows:

Week ending forenoon of:
June 3, 28 locations, 7 opened, 6 closed, opening 3.5 mm.
June 10, 28 locations, 8 opened, 5 closed, opening 2.0 mm.
June 17, 28 locations, 5 opened, 2 closed, opening 3.0 mm.
June 24, 28 locations, 2 opened, 3 closed, closing .05 mm.

Chain-of-Craters Crisis

During the week ending June 5 new cracks were discovered on the road to Ainahou Ranch leading south from Pauohi Crater; these were extensions of the cracks which had fractured the Chain-of-Craters road. Eight distinct groups of cracks were counted on the Ainahou road and one on the road leading toword Puu Huluhulu about two hundred yords from the main road leading east. All the older cracks showed some evidence of opening and in some coses down-faulting to the south was pronounced.

On June 6 cracking of the ground around Devil's Throat was discovered and there was evidence of slides from the rim of this pit within the post twenty-four hours. Most of the slides had occurred at the east and south rim, at 2:30 p.m. June 6 rocks were heard falling in Devil's Throat, and cracks were noticed in the masonry wall on its southwest side. Some new cracks were seen on the opposite side and it was evident that the circle of the pit was under stress on all sides. Rock falls continued in this pit during the remainder of the week, and the area was closed to visitors. T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Distant*	Weekly† Seismicity
June 5.....	158	31	3	2	1	1	65.00
June 12.....	68	9	3	0	0	2	24.50
June 19.....	18	5	1	0	0	1	8.00
June 26.....	40	6	2	0	0	2	15.00
July 3.....	43	10	1	1	0	0	18.75

* Including teleseisms of earthquakes over 5000 km. from Kilauea.
† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of depth of focus has been made.

May 30, 1:43 am, slight, 1.3 miles deep in SE portion of Kilauea Crater, 0.6 mile E of Pit Seismograph. 19° 24.4′ N; 155° 16.5′ W.

May 30, 11:52 am, very feeble, of shallow origin in rifts 1.2 miles SW of Pauahi Crater. 19° 21.6′ N; 155° 14.5′ W.

May 30, 8:54 pm, very feeble, probably originated in Kilauea SW rift about 15 miles from the crater.

May 31, 1:13 am, very feeble, probably of shallow origin, vicinity of Hiiaka crater.

May 31, 1:19 am, very feeble, of shallow origin in rifts 0.5 mile SW of Pauahi crater. 19° 22.0′ N; 155° 14.0′ W.

May 31, 4:53 am, very feeble, 1.3 miles deep under SE rim of Kilauea crater. 19° 24.5′ N; 155° 15.8′ W.

May 31, 5:58 am, feeble, originated at junction of Lele o Kalihipaa and Kalanaokuaiki Palis, 1.7 miles SW of Pauahi crater. 19° 21.4′ N; 155° 14.8′ W.

May 31, 2:16 pm, very feeble, of shallow origin, vicinity of Hilina Pali. 19° 18.8′ N; 155° 16.3′ W.

June 1, 10:27 am, feeble, 3.0 miles deep in area immediately S of Kilauea Iki. 19° 24.8′ N; 155° 15.2′ W.

June 1, 10:38 am, moderate, 7.0 miles deep in Hilina Pali area about 3.0 miles N of Apua Point. 19° 18.2′ N; 155° 11.5′ W. Dismantled seismographs at observatory and SE rim of Halemaumau.

June 1, 8:03 pm, very feeble, probably originated in vicinity of Pauahi crater.

June 2, 3:25 am, very feeble, 1.0 mile deep in Kilauea crater, SE rim cracks 0.4 mile W of Keanokakoi. 19° 24.2′ N; 155° 16.4′ W.

June 2, 4:42 am, very feeble, 12.0 miles deep, Mauna Loa NE rift 4.5 miles NE of Puu Ulaulo. 19° 34.5′ N; 155° 24.5′ W.

June 2, 8:24 am, very feeble, 4.3 miles deep, N rim area of Kilauea crater. 19° 26.1′ N; 155° 16.7′ W.

June 2, 3:33 pm, slight, 15.0 miles deep, Kilauea SW rift near Kooe, 3.5 miles SW of Kilauea crater. 19° 21.7′ N; 155° 19.5′ W.

June 2, 8:55 pm, very feeble, of shallow origin under Byron Ledge, E rim of Kilauea crater. 19° 24.6′ N; 155° 15.7′ W.

June 2, 10:10 pm, very feeble, 1.8 miles deep under NE portion of Kilauea crater. 19° 25.2′ N; 155° 16.2′ W.

June 4, 2:48 am, very feeble, 0.7 mile deep, SE rim of Kilauea crater. 19° 24.3′ N; 155° 15.9′ W.

June 4, 7:57 pm, very feeble, probably originated in Kilauea crater, near N rim of Halemaumau.

June 4, 9:46 pm, very feeble, 0.8 mile deep, NE portion of Kilauea crater, 0.9 mile S by E of Volcano observatory. 19° 25.2′ N; 155° 14.8′ W.

June 5, 1:18 am, very feeble, of shallow origin, near center of Kilauea crater.

June 5, 1:47 am, feeble, 1.0 mile deep near center of Kilauea crater, 0.6 mile NE of Pit seismograph. 19° 24.7′ N; 155° 16.7′ W. Reported felt by mony in Hawaii National Park.

June 6, 1:14 am, feeble, probably originated in cracks about 1.0 mile W of Hiiaka crater. Reported felt by many in Hawaii National Park.

June 6, 7:46 am, very feeble, probably originated in Chain-of-Craters area, vicinity of Hiiaka and Devil's Throat.

June 6, 11:53 am, very feeble, probably originated in rifts, 1.0 mile W of Pauahi crater.

June 7, 11:59 pm, very feeble, 1.7 miles deep under Byron Ledge, E rim of Kilauea crater. 19° 24.9′ N; 155° 15.6′ W.

June 8, 12:07 am, very feeble, 1.8 miles deep in E portion of Kilauea crater. 19° 24.8′ N; 155° 15.9′ W.

June 8, 5:39 am, feeble, of shallow origin in fault blocks along NE rim of Kilauea crater. 19° 25.7′ N; 155° 15.8′ W. Felt by several around National Park Headquarters area.

June 8, 8:32 pm, very feeble, thought to have originated in NE portion of Kilauea crater.

June 9, 7:17 am, very feeble, of shallow origin, SE rim area of Kilauea crater. 19° 24.3′ N; 155° 15.8′ W. Reported felt by few in the National Park.

June 10, 12:27 am, very feeble, 1.1 miles deep in E central

portion of Kilauea crater. 19° 24.8′ N; 155° 16.2′ W.

June 10, 12:51 am, feeble, 1.4 miles deep, E portion of Kilauea crater near Byron Ledge. 19° 25.0′ N; 155° 15.8′ W. Reported felt at new CCC Camp and by residents along NE rim of Kilauea crater.

June 12, 3:39 pm, very feeble, of shallow origin in Kilauea crater about 1.2 miles NE of Pit seismograph. 19° 25.0′ N; 155° 16.7′ W.

June 14, 12:13 am, 1.5 miles deep in NE portion of Kilauea crater. 19° 25.4′ N; 155° 15.9′ W.

June 17, 5:18 am, very feeble, 0.5 mile deep, E portion of Kilauea crater. 19° 24.8′ N; 155° 15.8′ W.

June 17, 7:34 pm, very feeble, probably of shallow origin in NE portion of Kilauea crater.

June 18, 6:26 am, feeble, 1.1 miles deep, in N portion of Kilauea crater. 19° 25.5′ N; 155° 15.4′ W.

June 19, 12:55 pm, very feeble, 1.3 miles deep near center of Kilauea crater (NE rim area of Halemaumau) 19° 25.0′ N; 155° 16.8′ W.

June 19, 6:59 pm, very feeble, probably originated in NE portion of Kilauea crater.

June 20, 10:01 am, very feeble, 1.0 mile deep in N portion of Kilauea crater about 1.0 mile NE of Uwekahuna. 19° 25.9′ N; 155° 16.6′ W.

June 20, 5:22 pm, very feeble, 2.2 miles deep, Chain-of-Craters, near Pauahi crater. 19° 22.4′ N; 155° 13.7′ W.

June 23, 5:46 am, feeble, 1.2 miles deep E portion of Kilauea crater. 19° 24.8′ N; 155° 16.0′ W. Reported felt at new CCC camp and at the observatory.

June 23, 5:53 am, very feeble, of shallow origin near center of Kilauea crater, 1.0 mile NE of Pit seismograph. 19° 24.9′ N; 155° 16.4′ W.

June 26, 1:45 am, feeble, 1.8 miles deep in E portion of Kilauea crater. 19° 24.8′ N; 155° 16.0′ W.

June 27, 1:58 pm, very feeble, 0.8 mile deep, E rim area of Kilauea crater. 19° 24.8′ N; 155° 15.9′ W.

June 27, 3:23 pm, very feeble, of Kilauea crater origin.

June 28, 12:30 pm, very feeble, probably of shallow origin in Kilauea crater near E rim of Halemaumau.

June 30, 11:42 pm, very feeble, 19.0 miles deep under Mauna Loa, 3.0 miles NE by N of Summit crater. 19° 32.2′ N; 155° 33.8′ W.

July 2, 1:29 pm, very feeble, 21.0 miles deep, Mauna Loa NE rift, 9.0 miles NE of Puu Ulaula. 19° 35.5′ N; 155° 20.2′ W. Reported felt strongly at Kapapala Ranch.

July 2, 2:20 pm, slight, 8.0 miles deep in Chain-of-Craters rift 6.0 miles SE of the Valcano observatory. 19° 23.0′ N; 155° 11.5′ W. Reported felt at Kapapala and in National Park area.

July 2, 3:16 pm, feeble, 10.0 miles deep, in Kilauea SW rift 6.0 miles SW of the crater. 19° 22.0′ N; 155° 22.2′ W.

Distant Earthquakes

May 30, "P" waves at 4h 09m 03s am, located 3660 miles from Kilauea. 20° 4′ S; 169° 4′ E in the Solomon Island area.

June 8, "S" waves at 9h 7m 25s am, origin in the Malluca Sea, Dutch East Indies, 5550 miles from Kilauea. 3° 1′ S; 125° 7′ E.

June 9, "P" waves, 11 h 35 m 22s pm, originated off NE coast of Formosa, 5000 miles from Kilauea. 25° 2′ N; 124° 6′ E.

June 15, "P" waves, 3h 56m 22s pm, off the SW tip of Kyushu Japan along E border of China Sea. 29° 2′ N; 127° 7′ E. Distance 4750 miles.

June 20, unidentified portion began to register at 3h 50m 04s am.

June 23, "P" waves at 2h 34m 43s am, located in the vicinity of New Hebrides, 3615 miles from this station. 19° 1′ S; 168° 9′ E.

Hawaiian standard time used in above reports.

Microseismic motion of the ground at the observatory light June 10, 12, 14 to 25 and June 30 to July 3; moderate May 30, June 2 to 6, June 9, 11, 13 and 26 to 29, dates inclusive. It was strong May 31, June 1, 7 and 8. H.H.W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the observatory seismograph and at Halemaumau, the algebraic sum of radial tilt toward or away from the Pit.

At the observatory the total accumulated tilt for the year ending July 3 was 3.76" S and 6.42" W.

Week Ending	Observatory	Halemaumau West Station
June 5	0.75" S 42° W	6.20" S 16° W
June 12	0.16" S 46° E	8.02" N 68° W
June 19	0.67" N 27° E	4.44" W
June 26	0.54" N 12° W	4.32" S 78° W
July 3	0.62" N 10° W	2.18" S 81° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
June 5	7.91" S 27° E	9.56" from
June 12	1.65" N 69° W	5.85" from
June 19	6.54" N 35° W	1.85" toward
June 26	10.11" N 85° W	2.33" toward
July 3	4.28" N 55° W	1.80" toward

Crater Angles

Measurement of horizontal angles across Kilauea crater from the observatory June 17, indicated closing of both the Halemaumau value and the total crater value. The Halemaumau measurement from the SE Pit BM to NW Pit BM showed closing of 0.84" and the crater measurement from the SE crater Rim to Uwekahuna showed closing of 1.66".

H.H.W.



THE VOLCANO LETTER

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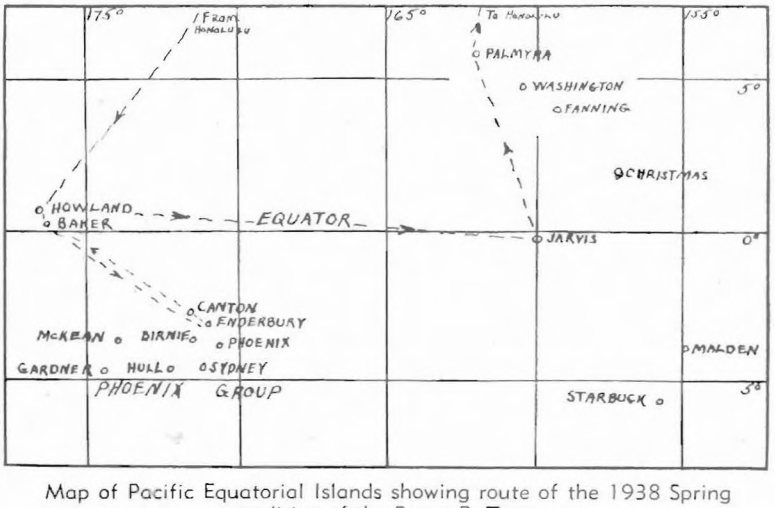
Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Map of Pacific Equatorial Islands showing route of the 1938 Spring expedition of the Roger B. Taney.

AN EQUATORIAL CRUISE

By Hugh H. Waesche, Assistant Geologist

For some years the Department of the Interior of the United States government has sponsored and maintained colonists on the tiny Pacific Equatorial Islands, Howland, Baker and Jarvis. Reference to the accompanying map will show their location to other islands. These pin-points of coral sand are not suitable for sustaining human life as they are practically of desert climate. This has necessitated regular trips to the Islands to deliver supplies to, and replacements in, the colonizing personnel. The colonists who are young Hawaiian men are transferred from island to island and are not allowed to remain away from their homes in Hawaii for more than nine consecutive months at a time. Transportation to and from the islands is part of the regular duties of the U. S. Coast Guard. The Cutter, "Roger B. Taney," makes about three trips per year to these Islands, usually late autumn, early spring and mid-summer.

Mr. E. G. Wingate, superintendent of Hawaii National Park, conceived the idea of some member of the Observatory staff making one of these trips to make general observations, the main issue being the practicability of establishing seismograph stations as an aid in seismological studies of the mid-Pacific areas. Selected for this reconnaissance were Messrs. S. H. Lamb, Park Naturalist, and Hugh H. Waesche, Assistant Geologist of the Hawaiian Volcano Observatory. Mr. Lamb was to make natural history studies of fauna and flora, and Mr. Waesche was to set up instruments for seismometric studies.

There was no opportunity to construct a conventional seismograph. The alternative was to take shock recorders of the mercury cup, annunciator type, developed during the past year by Dr. T. A. Jaggar for use on the Island of Hawaii. These instruments are of little value for recording distant earthquakes but have been of value in studies of local shocks. They are relatively sensitive and will readily indicate the very feeble earthquakes which are not generally felt here in Hawaii. These shock recorders register only maximum intensity for any particular shock giving no indication of phase. They are designed for use by people who have no technical training whatever. Registration of any earthquake is accomplished by annunciators which show a number from one to six, depending on the intensity of the earthquake. Once an earthquake has recorded, the value remains until reset to zero manually, by the observer. If a number of such seismoscopes were well distributed over an area, they should show relative increases of intensity toward the epicenter from all directions with diminishing values in the opposite directions. As no seismologists or otherwise scientifically trained men were among the colonists of the Equatorial Islands the shock recorders were apparently the most desirable; also they were easily portable and could be set up in any given locality with only a screw driver and a pair of pliers in a few minutes. No record paper was necessary, with the other complications which go with recording devices either on smoked paper or by photographic means. All that was necessary was a solid base and daily observation. These were assured.

Two of the shock recorders were available so were crated and prepared for shipment to Honolulu. No definite locality was predetermined for their placement. They were to be placed on the most desirable islands with regard to location and per-

sonnel. Tentatively chosen were Howland and Jarvis if landing were easy; they are widely separated giving a desirable variation of location. On arrival in Honolulu the instruments were put aboard the Cutter and preparations made for the expedition.

The "Taney" sailed from Honolulu at 5:00 p.m. Sunday, February 16, 1938. After four rather uneventful days the party arrived off Howland Island. At 7:00 a.m., March 4, a change in the colony personnel was made but no supplies were taken ashore. That afternoon a landing was made through heavy surf at nearby Baker. Originally Howland Island had been considered as the probable location of one of the shock recorders. However, the day before arrival there, Mr. Black announced that a colony was to be established on Canton Island in the Phoenix Group and suggested that one of the shock recorders be placed on it as the greatest number of more technically skilled colonists were to be there, and that both a shelter and concrete base for the instrument would be found, left by the eclipse expedition the preceding year.



Landing supplies at Enderbury.

Howland Island is located about forty miles north of the Equator and about one hundred miles west of the 175th meridian. Baker Island is about thirty-five miles S. by E. of Howland and the two might well be considered together. They are similar in appearance, geology, and climate. Both are of coral, shells, and lithothamnia and might well have been atolls or parts of atolls formerly although there is no water in their interiors at present. In the vast Pacific Ocean, both are mere specks of land. Howland Island is elongated in shape in a more or less N-S direction with a length of about three and one half miles and a maximum width of about 1.1 miles. Maximum elevation about mean sea level is about ten feet. Baker Island is smaller than Howland, not so elongated, and has a maximum elevation of about fifteen feet. They are saucer-shaped with high ridges of coral sand and debris along the shore line and the low points near, or only slightly above sea level toward their interiors. No evidence of rocks other than of coral or marine organic life were noticed on this trip nor have been reported by any previous visitors. Along the beach are coral sands of varying texture and rather massive reef rock and coral conglomerate near the water's edge. Inland, the sand was of fine texture with accumulations of bird guano in all low or basin areas. As in some other Pacific Islands this guano had been previously worked for commercial use.

The climate of the two islands is quite uniform. This is true of the temperature in particular which probably does not vary greatly from a minimum of about 78° to a maximum of 94° F. daily. Precipitation is light, mostly falling at night or in the early morning before daybreak. Sun pouring on the brilliant white coral sand is reflected as heat. The rising hot air causes rain-producing clouds approaching the islands either to break up or dissipate. Many observers report that clouds moving from the east with the prevailing winds will separate on reaching the edge of the island and pass to the north and south. As would be expected, vegetation is scant. Christophersen reports Boerhaavia and Portulaca as abundant in open spaces. A few clumps of Cordia were reported also on Howland. Attempts are being made to develop a growth of coconut palms brought with soil from Palmyra, but the results so for have not been promising.

Gas-operated lighthouses have been constructed by the colonists on both Howland and Baker. They are automatic and will operate for six months or more without attention. They are about twenty-five feet in height. The lighthouse at Howland has a diorite or similar dark igneous block above the doorway inscribed "Amelia Earhart, 1937" and is a memorial to that flyer who was lost while enroute to tiny Howland Island from New Zealand.

After brief stops at Baker and Howland Islands the "Taney" headed in a southeasterly direction, crossing the Equator about 6:30 p.m. Friday, March 4. On Saturday morning ceremonies were held on deck for benefit of those who had never crossed the "Line" before. King Neptune and Court saw to it that all "pollywogs" became "shellbacks."

Enderbury Island was sighted early the morning of Sunday the 6th. Like Howland and Baker, bright coral sand which reflected the sun's rays with great intensity was the first thing to impress the visitor. It was in strong contrast to the surrounding blue sea. Work of unloading supplies for the new colony to be established was started immediately. Food and water, the latter in old oil drums, were taken ashore. The food was taken through the surf in ship's boats. The water was floated ashore in the drums. This was accomplished by removing one gallon of water from each drug, lashing four to six of them together and then towing them from ship to island. The fresh water in the drums also added to their buoyancy.

Except for thousands of booby (gannet) and frigate (man-o'-war) birds, Enderbury was uninhabited. There were also in evidence the red-tailed tropic bird and several varieties of terns including the very beautiful "love-bird". The latter are snow-white and hover in pairs over the heads of intruders. They seem as though carved from exceptionally white porcelain. The "Taney" remained throughout the day, but sailed for Canton after sundown, leaving a camp, complete supplies and four Hawaiian colonists behind.

Enderbury Island is similar to Howland. It is a coral island about three miles long and one mile wide. It, too, is saucer-shaped with a decided depression toward its center. The low areas are partially filled with soft muddy materials which are principally bird guano. Around one of the muddy areas were several small coconut palms. At the southeastern end of the island were many large angular blocks of rock. From the ship these seemed dark and even looked as though they might be igneous rocks. Close observation showed them to be coral conglomerates evidently tossed upon the beach by wave action.

Enderbury is located about three degrees below the Equator and about one hundred and seventy-one degrees west. Canton Island, the most northerly of the Phoenix group, is about forty-three miles to the northwest.

A party from the "Taney" landed on Canton about 9:00 a.m. Monday, March 7. The American colonists began immediately to put up a temporary camp and to land supplies. As had been anticipated by Mr. Black, an old building with a concrete floor had been left by the Eclipse Expedition of 1937 (see National Geographic Magazine, June 1938). That afternoon a shock recorder was brought ashore and placed in oper-

ation. It was oriented to record earth waves only in a N-S direction. At the Hawaiian Volcano Observatory these shock recorders vibrate with slight motion of the pen continuously. This is probably caused by the microseismic motion of the ground. Vibration of the same nature was observed at Canton. In Hawaii wave motion of the sea on the NE shore of the Island is a suspected cause. This view might be even more readily acceptable on Canton where the motion of the sea acts only on a very narrow strip of land.

Canton is a typical coral atoll. A strip of coral sand and coral conglomerate, 150 feet to a third of a mile in width, almost completely enclosing a shallow coral-bottomed lagoon about nine miles long and three miles wide. The distance along the atoll around the lagoon is reputed to be about twenty-seven miles. To the southwest of the lagoon is a channel connecting it with the open sea. The channel is deep enough for small boats and if deepened could be utilized by larger craft. At



View at Canton Island. Shock recorder located in long low building at right.

various times of the day strong currents move in the channel so that it is used only at times when these are not dangerous. The channel may be as much as a quarter of a mile wide. It is well filled with large sharks which seem to prefer that locality to any other.

The atoll has two beaches, one to the open sea and one to the lagoon. Exploration of the area around the western lip of the channel revealed only coral sand, fragments and conglomerate. What appeared to be a peculiar rounded earthen mound about a mile and a half from camp turned out to be only a kou tree about twenty feet high which afforded a nesting place for a multitude of birds. The beach to the open sea along the southeast portion is broken by the presence of large quantities of angular slabs of coral conglomerate similar to the ones observed on Enderbury. On the lagoon side the beach is smooth, made up of coral sand and small shell fragments. Tide and waves in the lagoon have had a sorting effect, as various shells and sizes of sand show definite zones of stratification. Low areas lie inland between the beaches, and they as on the other islands contain deposits of guano. Also, one part of Canton rises some twenty feet above sea level.

The climate is mild, has steady easterly winds and a temperature maximum in the daytime of between 85° and 90° F. Rainfall is scant, but enough for several groves of coconut palms to have obtained a good start.

Monday night, March 7, 1938, the "Taney" returned to Enderbury. It remained there until noon Tuesday, completing final arrangements for the party left behind, and then returned to Canton, arriving there at 4:00 p.m. On Tuesday the shock recorder was again checked and it was moved to a more desirable location in the same building, and oriented for E-W movement instead of N-S as previously set up. Final instructions were given to an army sergeant who was to observe the instrument periodically. No registration occurred the two days the writer was at Canton. Apparently none has occurred since. It is not like a volcanic region where local shocks would be expected. A seismograph for recording of distant earthquakes located on Canton should produce some interesting results.

Wednesday evening, March 9, the "Taney" sailed for Howland and Baker Islands, arriving at the former at 8:30 a.m. Friday. By 1:00 p.m. landing of supplies and replacement of colonists had been completed and the ship left for Baker, which was reached at 4:30 p.m. Supplies were landed there and then at 8:20 p.m. the "Taney" again sailed for Howland to transfer a colonist to that island from Baker. Early Saturday morning, March 12, the "Taney" headed east for Jarvis Island nearly one thousand miles away. It was reached early the morning of March 15.

Jarvis is another isolated, saucer-shaped coral island. It is small, having a land area of 1.7 miles. It is about one mile wide and two miles long. The location is 160° W. longitude, 00° 23' S latitude. Jarvis is probably higher above sea level than any of the other islands visited. The beach slopes steeply up from the sea to a rim twenty feet or more above. This rim encircles the entire island. Toward the interior there is a gentle slope which produces the saucer effect. The lowest portion of the depression is in places slightly below sea level, and over most of the area is probably between this low and an elevation of ten feet. As was true of the other islands, the interior depressions are collecting spots for bird guano. The beach is made up of coral sand, and shell fragments of other marine organisms. Along most of the north and east shores there is a bench along the lower portion of the seaward slope. The bench is made up of stratified calcareous conglomerates which have been formed by cementation and consolidation of beach deposits. They are made up of corals and corallines and remains of other marine organisms. Above the conglomerate along the northeast shore are flat, roughly circular coral rocks tossed up by the waves and lying at low angles. Wentworth calls these "coral shingles." They were undoubtedly formed by wave action which was responsible both for their shape and location.

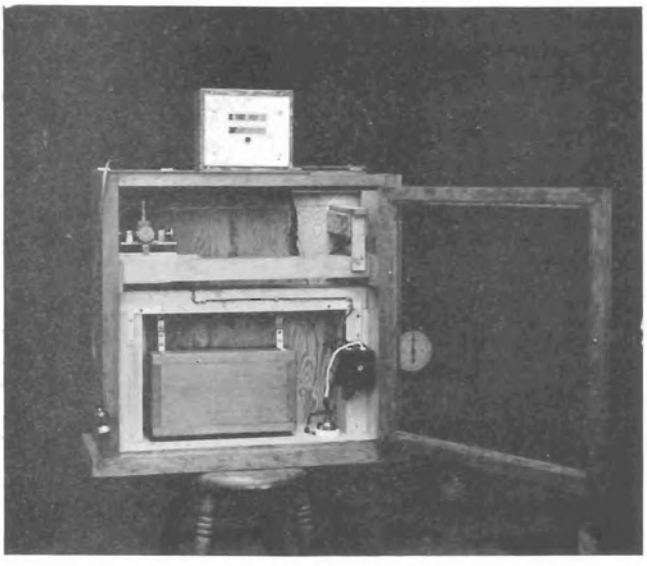
The second shock recorder was taken ashore at Jarvis and set up for operation. The only concrete base available was the floor of the lighthouse. This was considered desirable at first, but Mr. Edgecombe thought that it would be dangerous to place an electrical recording device which produced open sparks so near the gas supply. As an alternate the recorder was set up temporarily in the living quarters of the colonists. This proved very unsatisfactory as the moving of the people around the house caused a great deal of disturbance to the instrument. It was finally decided that the instrument be left in the house as set up but with the current shut off until the colonists stationed at Jarvis could build a concrete base and small shelter nearby. This has been done with the shock recorder oriented to record motion in a N-S direction, at right angles to the one left on Canton.

Explorations of the west and northwest beaches of Jarvis were made and the interesting remains of the barkentine "Amaranth" wrecked in 1913 were examined. It was apparently loaded with coal as pebbles of the black material are well distributed along the adjoining beach. These pebbles are well rounded and water worn.

The "Taney" left Jarvis the same day and sailed for its last stop of the trip, Palmyra Island, where it arrived in the early morning of Thursday, March 17. The day was very stormy with heavy rainfall. The small tree-covered islets composing Pal-

myra were visible only rarely during the day. Crew members fishing off the stern caught several black-finned sharks and a few red snappers. The sky cleared after sundown. Many "booby" birds and terns hovered about the ship throughout the day and several "boobies" flew aboard after dark attracted by the lights.

It had been agreed that there would be a landing party the next day regardless of weather conditions. Conditions were much more favorable on the morning of March 18, so that two of the ship's boats were sent as near the island as feasible. Two small boats with outboard motors were also towed in and with the party were landed on Home Island. From Home Island the party went across the large western lagoon to Cooper Island on the north side. After exploration there the boats returned across the lagoon to the south side, landing in the vicinity of



Type of shock recorder left on Canton and Jarvis Islands.

Paradise Islet. Lunch was eaten on the south side of that island. Soon after noon rain squalls began and occurred at intervals the remainder of the afternoon. A number of pictures were obtained in the morning but weather conditions prevented photographic work later in the day. Most of the afternoon was utilized in making underwater observations of marine life in the channels around Home and Paradise Islets and on the coral shelf to the west of the group.

Palmyra Island, otherwise known as Samarang or Palmoore, is located in the north Pacific Ocean 960 miles S. by W. of the city of Honolulu, Hawaii. Latitude 5° 53' North, longitude 162° 05' W. The island is a regular atoll, well covered with vegetation wherein it differs from other equatorial islands such as Jarvis and Howland. Altogether, Palmyra consists of a group of some fifty-two islets all of which are projections above the ocean surface from one underlying mass of coral growth and debris occupying a space of five and two-thirds miles in an east-west direction and one and one-half miles in the north-south direction. Including the entire extension of reef under water the length is nearly eight miles, east-west. The atoll encloses three large lagoons and one small one. All the larger lagoons have depths of at least twenty fathoms and the large western lagoon has a depth of 28 fathoms. In one of the lagoons are several small islets which are exposed at low tide. The greatest elevation is located on Eastern Islet and is about six feet above sea level. The U. S. Hydrographic Chart gives a maximum elevation of the trees as 91 feet above sea level and these may be observed from a ship 15-20 miles at sea. The largest islet is 46 acres in area and the smallest is reputed to be 0.47 acres.

An extensive coral flat extends to the westward of the islet for about three miles from the shore line where the depth is 6-7 fathoms at high tide. More or less cylindrical coral heads rise from the shelf nearly to the water's surface and are often five feet or more in diameter. Their number increases toward the island proper where the water becomes very shallow and a person can readily walk on the coral bottom. Boat landings can only be made in this vicinity at high tide, and it is the only portion of the island group where one may go ashore safely. At low tide no boats can pass over the coral shelf nearer than one mile from the shore.

Heavy surf of white-foamed breakers continuously roars against the reef from the open sea, to the north, east and south. They are never more than a few hundred feet from shore. This condition is to be expected as Palmyra is in the trade wind area of prevailing northeast and southeast winds the year around. This also accounts for the western side or lee side being the only safe landing point.

On the lagoon side the islets are bordered by strips of white coral sand which may extend inward in the form of spits. At high tide this sand is covered by about ten inches of water; at low tide it is often exposed and dry with never over an inch or two of water. The islets are separated by narrow channels through which flows considerable current at high tide. At low tide the channels are often blocked or the current obstructed by sand bars on the lagoon side. They deepen seaward. It is possible to walk between most of the islands as the water in the channels is seldom more than waist deep. The bottom is sandy toward the lagoon and becomes more rugged with new coral growth toward the sea. This is a natural gradation typical of atolls in general.

The weather at Palmyra is probably rather uniform. No visits to the island have apparently been of length sufficient to make accurate observations. The dense vegetative cover of the island indicates ample rainfall. Determinations for short periods indicate a rainfall of at least one hundred inches per year and probably as much as one hundred and fifty inches per year. All visitors report rain at Palmyra and heavy rainfall occurred the two days of this visit. Daily and yearly temperature range is probably not great. Rock reports a high of 90° during the day and a low of 78° during the night. Tropic islands completely surrounded by ocean and far from other land masses are likely to have a mild and equitable climate.

Palmyra is near no existing commercial ocean traffic lane. It is reached only by privately owned vessels capable of making long ocean voyages or by government vessels of the Coast Guard or Navy. Some people of the Hawaiian Islands visit the island annually in privately owned ships.

The map of Palmyra shows that the group is open at the western end and closed with a point at the eastern end. Prevailing winds and ocean currents from a general easterly direction are probably responsible for this condition as this fits in with the general rule. According to such a rule the coral growth should be most favored on the current side and along the northern and southern tip extremities of the western end of the island where the seaward current carrying the greatest quantities of coral food is likely to flow by and eddy backward, greatly retarded in speed. Corals and calcareous algae are sensitive marine organisms demanding close adjustment of temperature, depth, aeration, condition of water and amount of sandy material present. As a result coral growth would be accelerated on the windward, and less on the more protected, portions of the island. This is borne out by the facts illustrated by the reef extension to the westward and the diminishing of coral growth inward from the sea in the inter-island channels. Coral growth is greatly retarded in the lagoons and over the

entire area surrounded by the islets, where sand and debris brought in from the sea is deposited, destroying the living coral.

During the approach of high tide and for considerable time afterward there is much scouring action in the channels which keeps their seaward end very clean. The slowing of the current in passing through the channels causes deposition of the sand to build fans and shoals into the lagoon. Presumably this process continued over a long period would cause the filling up and elimination of the lagoon, which would go through a brackish marsh stage before attaining that end. After the lagoon had been filled by debris in this manner it seems likely that eventually wave action building up the resulting shore line would produce the elongated saucer type of coral island so common in the South Pacific. Probably because of the open west end on the lee side offering less resistance to the flow of water, the current return to the ocean at low tide seemed to be



Typical colonists on Jarvis Island.

less through channels than at high tide inflow. This also would tend to increase the chance of eventual elimination of the channels by building up from the sea. The heavy surf on the seaward side of the island prevents accumulation of sand or small debris in spits or bars. The outer beaches are of sand and some of coarse gravel and Tridacna shells.

Some coral grows in the inner lagoons contributing to the building processes but is much less vigorous than that on the outer portions of the island, as debris accumulation in the interior is more plentiful and food less available. The inner beaches are formed of fine coral and shell-fragment sand which at some localities become a fine mud quite soft, and often ankle deep. Heavy rains wash great quantities of bird guano into these mud flats. Beach water-lines fluctuate widely between high and low tide over these areas because of their very low angle of deposition. No evidence points to former sea levels above the present ocean level. The inner portions of the various islets are made up of coarse detrital materials with a few composed of calcareous sandstones and conglomerates. The islands to the east are apparently the youngest, and no doubt other islands may develop even farther eastward superseding the existing line of growth.

In order to make proper tide connections the return to the ship was made at 4:00 p.m. Stormy weather was again in evidence on the morning of March 19th. One squall about 8:00 a.m. with a wind velocity of over 60 miles per hour tore away a large portion of the "Taney's" awning. It was thought that weather conditions would not improve so the ship weighed anchor and set a course for Honolulu. The ship arrived at that port at 6:00 p.m., March 21, ending a most interesting cruise of 23 days.

References

1. Christophersen, E.; Vegetation of Pacific Equatorial Islands, Bernice P. Bishop Museum Bulletin 44, Whippoorwill Expedition Publication Number 2, 1927.
2. Emory, Kenneth P.; Archaeology of the Pacific Equatorial Islands, Bernice P. Bishop Museum Bulletin 123, Whippoorwill Expedition, Publication Number 4, 1937.
3. Rock, Joseph F.; Palmyra Island, Honolulu Star-Bulletin, 1916.
4. Wentworth, Chester K.; Bernice P. Bishop Museum, B., Occasional Papers, Volume IX, Number 15, Whippoorwill Expedition, Publication Number 15, Whippoorwill Expedition, Publication Number 3, 1931.
5. Gardner, Irvine C.; Crusoes of Canton Island, The National Geographic Magazine, Vol. LXXIII, Number 6, pp. 749-766, June 1938.

Hawaiian Volcano Observatory Report for July 1938

VOLCANOLOGY

With the exception of the last two weeks of July rock slides from the north and east rim walls of Halemaumau were numerous during the month. The excessive sliding of the first fortnight along with several earthquakes indicating origins of about Halemaumau distance (2 miles) and the occurrence of higher seismicity after the sliding stopped, justifies the inquiry whether the recent fault movements southeast are extending themselves to the Kilauea block. Fuming from the southeast solfatara on the floor has continued. Seismic activity has been ordinary with most of the disturbances indicating Kilauea origins. Three felt earthquakes July 2 were of Mauna Loa origin. The Kona seismograph recorded only five small disturbances, indicating that there is only minor activity taking place under Mauna Loa and Hualalai. Kilauea seems to be currently the most active volcanic center on Hawaii. Two rather feebly recorded distant earthquakes were registered during the week ending July 24.

Observations from time to time of the cracks in the vicinity of Pauahi crater have been made and slight earth movements there are continuing, with a tendency shown both on the ground and by seismic distances for the fault movements to extend themselves northwestward. The hump in the road near Devil's Throat has increased in height. The large crack near Pauahi pit increased in width with increased downthrow to the southeast. The large crack near Aloi pit has widened. Systematic measuring of these cracks is provided for.

Temperature measurements at the hot area near Kokoolau pit have been made with highest readings about 85° C. The area does not appear to have increased its dimensions.

The Chief Ranger reported the discovery Friday, July 15, on an inspection trip to patrol the telephone line, along the trail up Mauna Loa northeast of the summit, that new cracks about four inches wide broke the surface of the trail at three places. The first one encountered was about 1.5 miles above Puu Ulaula resthouse at elevation 10,800 feet approximately; the other two were in the vicinity of 12,000 feet elevation, or about opposite and to the east of the main cone source of the 1935 flow. This is important as suggesting a breakage on the rift belt of Mauna Loa farther east than the fracture of 1935. It is worthy of note that earthquakes near Puu Ulaula shook Mauna Loa after the middle of January 1938, when the startling earthquake of Maui and Honolulu occurred: and that ten days before the earthquake crisis at Chain-of-Craters began, a deep earthquake occurred under Mauna Loa summit crater. These two Mauna Loa seismic events may be correlated with the new cracks.

The following are the local weekly data for the month of July at the Observatory and Halemaumau.

Week Ending	Seismicity	Slides	Crack Openings	Local Tremors and Quakes
July 3	18.75	30	7.0 mm.	55
" 10	10.25	15	0.5 mm.	17
" 17	18.25	28	0.0 mm.	50
" 24	23.25	3	3.5 mm.	67
" 31	20.00	3	0.5 mm. closed	60

One slight and two very feeble earthquakes were felt at Kapapala Ranch July 2. One very feeble earthquake July 13 was felt in Kilauea National Park.

Sequence of Events by Weeks

The first week was notable for many Halemaumau slides and Mauna Loa earthquakes. Slides continued the second week but tremors were less frequent. During the third week slips of rock from the wall of Halemaumau were numerous around the northern and eastern rims and seismic activity increased both at Kilauea and Mauna Loa. For the fourth week numbers of slides decreased to a low figure but earthquakes and tremors increased in number. The fifth week showed Halemaumau very quiet with reference to both slides and crack movements but seismicity remained high; many shocks were of Kilauea origin, a few showed Mauna Loa distance and one seismogram indicated Hualalai.

Slides at Halemaumau

The recorded slides from the wall of the Pit were:

July 1, 8:58 a.m. to 12:58 p.m., 13 slides N and NE.

July 2, 9:32 a.m. to 2:47 p.m., 14 slides N and NE.

July 3, 10:08 a.m., 1:03 p.m., 1:40 p.m., slides from northern walls.

July 4, 1:05 p.m., small slide from new crack high up N wall; rocks dribbled down SW and N walls for a half hour.

July 5, 12:57 p.m., slide N rim.

July 6, 9:33 a.m., 3:29 p.m., 3:37 p.m., 3:41 p.m., N rim.

July 7, 10:49 a.m., 11:19 a.m., N rim.

July 9, 9:45 a.m., 10:00 a.m., 10:45 a.m., 1:07 p.m., 1:30 p.m., 2:50 p.m., northern walls.

July 11, 9:00 a.m., 9:28 a.m., 9:35 a.m., 10:10 a.m., 10:11 a.m., 11:03 a.m., 11:11 a.m., slides from N, NE or E walls.

July 11, 6:47 p.m., dust clouds N rim, indicated large slide.

July 13, 8:50 a.m. to 12:05 p.m., 18 slides from N, NE and E walls.

July 15, 10:00 a.m., N rim.

July 17, 10:40 a.m., 1:13 p.m., northern wall slide.

July 18, 3:43 p.m., NE rim.

July 20, 9:45 a.m., N rim.

July 28, 9:10 a.m., NE rim.

July 28, 9:50 a.m., 10:05 a.m., N rim.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations around Halemaumau pit resulted during July in aggregate movement as follows:

Week ending forenoon of:

July 1, 28 locations, 11 opened, 1 closed, opening 7.0 mm.
July 8, 28 locations, 2 opened, 3 closed, opening 0.5 mm.
July 15, 28 locations, 5 opened, 5 closed, opening 0.0 mm.
July 22, 28 locations, 4 opened, 1 closed, opening 3.5 mm.
July 29, 28 locations, 3 opened, 4 closed, closing 0.5 mm.

T.A.J.



SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant* Earthquakes	Weekly† Seismicity
July 10	35	3	0	0	10.25
July 17	33	14	3	0	18.25
July 24	45	20	2	2	23.25
July 31	42	17	1	0	20.50

* Including teleseisms or earthquakes of over 5000 km from Kilauea.

† For local seismicity definition see Volcano Letter 371.



Frigate birds, found on all islands except Palmyra.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of depth of focus has been made.

July 4, 2:13 pm, very feeble, probably originated near Pauahi crater.

July 7, 1:56 pm, very feeble, 0.4 mile deep in E portion of Kilauea crater. 19° 24.7′ N; 155° 16.0′ W.

July 12, 9:58 am, very feeble, of shallow origin, Kilauea SE crater rim. 19° 24.2′ N; 155° 16.3′W.

July 13, 10:45 am, feeble, 0.9 mile deep, Kilauea crater, 1.2 miles E of Halemaumau. 19° 24.6′ N; 155° 15.7′ W.

July 15, 4:12 am, feeble, location same as preceding.

July 15, 4:58 am, very feeble, 0.6 mile deep in Kilauea crater rim area near Kilauea Iki. 19° 25.1′ N; 155° 15.4′ W.

July 15, 5:34 am, very feeble, probably originated in Chain of Craters rift near Lua Manu.

July 15, 5:56 am, feeble, 1.6 miles deep in NW portion of Kilauea crater. 19° 25.7′ N; 155° 16.7′ W.

July 15, 11:04 pm, very feeble, probably originated in Chain of Craters rift near Lua Manu.

July 16, 6:52 am, very feeble, 1.4 miles deep, E rim of Kilauea crater, 19° 24.9′ N; 155° 15.7′ W.

July 17, 8:49 pm, very feeble, of shallow origin, NW rim area of Kilauea crater, 1.1 miles SW of the Observatory. 19° 25.2′ N; 155° 16.2′ W.

July 17, 10:51 pm, very feeble, 0.7 mile deep in Kilauea crater, 1.1 miles SW of the Observatory. 19° 25.2′ N; 155° 16.2′ W.

July 18, 4:37 am, very feeble, 1.0 mile deep, Waldron Ledge, NE rim of Kilauea crater. 19° 25.4′ N; 155° 15.5′ W.

July 19, 12:36 am, feeble, of shallow origin (0.3 mile), Kilauea crater, 0.4 mile E by N of pit seismograph. 19° 24.4′ N; 155° 16.3′ W.

July 19, 3:58 am, very feeble, of shallow origin 0.5 mile SE of pit seismograph. 19° 24.1′ N; 155° 16.6′ W.

July 21, 2:36 pm, very feeble, 0.6 mile deep SE rim, Kilauea crater, 1.6 miles E of pit seismograph. 19° 24.2′ N; 155° 15.5′ W.

July 22, 4:29 am, very feeble, 1.7 miles deep, Kilauea crater, 1.2 miles NE of pit seismograph. 19° 25.1′ N; 155° 16.4′ W.

July 22, 4:42 am, very feeble, 0.7 mile deep near Puhimau crater. 19° 24.0′ N; 155° 15.3′ W.

July 22, 5:02 am, very feeble, 0.8 mile deep, NE rim Kilauea crater (Byron Ledge), near Kilauea Iki. 19° 25.2′ N; 155° 15.6′ W.

July 22, 5:49 pm, very feeble, of shallow origin E rim of Kilauea crater. 19° 24.6′ N; 155° 15.7′ W. Felt in National Park residential area.

July 22, 7:32 pm, very feeble, 1.0 mile deep under N portion of Halemaumau. 19° 24.8′ N; 155° 17.2′ W.

July 23, 9:38 am, very feeble, probably originated in vicinity of Kilauea Iki.

July 23, 4:06 pm, very feeble, of Kilauea crater origin.

July 23, 10:09 pm, very feeble, probably originated in N central portion of Kilauea crater.

July 24, 12:54 am, very feeble, probably of Kilauea crater origin.

July 24, 5:20 am, very feeble, probably originated in Chain of Craters near Puhimau.

July 24, 7:51 pm, feeble, of shallow origin (0.6 mile) in SE rim area of Kilauea crater. 19° 24.5′ N; 155° 16.1′ W.

July 25, 7:16 am, very feeble, of Kilauea crater origin.

July 25, 9:31 am, very feeble, 1.5 miles deep, NW rim of Kilauea crater 0.5 mile NE of Uwekahuna. 19° 25.7′ N; 155° 17.1′ W.

July 28, 7:50 am, very feeble, probably originated in Mauna Loa NE rift in vicinity of Puu Ulaula.

July 30, 11:36 am, very feeble, 1.4 miles deep in NE portion of Kilauea crater, 1.4 miles NE of pit seismograph. 19° 25.2′ N; 155° 16.1′ W.

July 30, 9:43 pm, very feeble, 1.7 miles deep, 1.6 miles SE of pit seismograph in vicinity of Puhimau. 19° 23.6′ N; 155° 15.8′ W.

July 30, 9:50 pm, feeble, 0.7 mile deep Kilauea crater, 1.0 mile NE of pit seismograph. 19° 24.9′ N; 155° 16.3′ W.

July 31, 2:54 am, very feeble, 1.5 miles deep, E portion of Kilauea crater. 19° 24.8′ N; 155° 15.9′ W.

July 31, 8:27 am, very feeble, of Kilauea crater origin.

July 31, 8:45 am, very feeble, 2.0 miles deep N central portion of Kilauea crater. 19° 15.1′ N; 155° 16.4′ W.

At 11:49 am, July 9, 22 minutes of continuous tremor began to register.

Distant Earthquakes:

July 21, unidentified portion began recording at the Observatory at 9h 37m 24s pm, H.S.T.

July 24, unidentified portion, 3h 00m 30s am, H. S. T.

Microseismic motion of the ground at the Observatory was light July 4-8, 13, 14, 19-25; moderate July 9, 11, 12, 15-18, 26-31 and strong July 10.

Tilting of the Ground:

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau, the algebraic sum toward or away from the pit.

At the Observatory the total accumulated tilt for the year ending July 31 was 1.85″ S and 6.30″ W.

Week Ending	Observatory	Halemaumau West Station
July 10	0.61″ N 26° E	5.00″ N 75° W
July 17	0.56″ N 35° W	4.71″ S 75° W
July 24	0.87″ N 14° W	4.47″ S 85° W
July 31	0.85″ N 50° E	4.83″ S 65° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
July 10	4.73″ S 55° E	9.14″ from
July 17	12.70″ N 22° W	7.38″ toward
July 24	5.60″ N 37° W	1.03″ toward
July 31	3.24″ S 47° E	7.71 from

Crater Angles:

Measurement of horizontal angles across Kilauea crater from the Observatory July 21 indicated closing of both the Halemaumau value and the total crater value. The Halemaumau measurement from the SE pit BM to NW pit BM showed closing of 0.83″ and the crater measurement from the SE crater rim to Uwekahuna showed closing of 0.84″.

H.H.W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis-Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

THE VOLCANO LETTER

No. 462 Department of the Interior National Park Service August-December, 1938

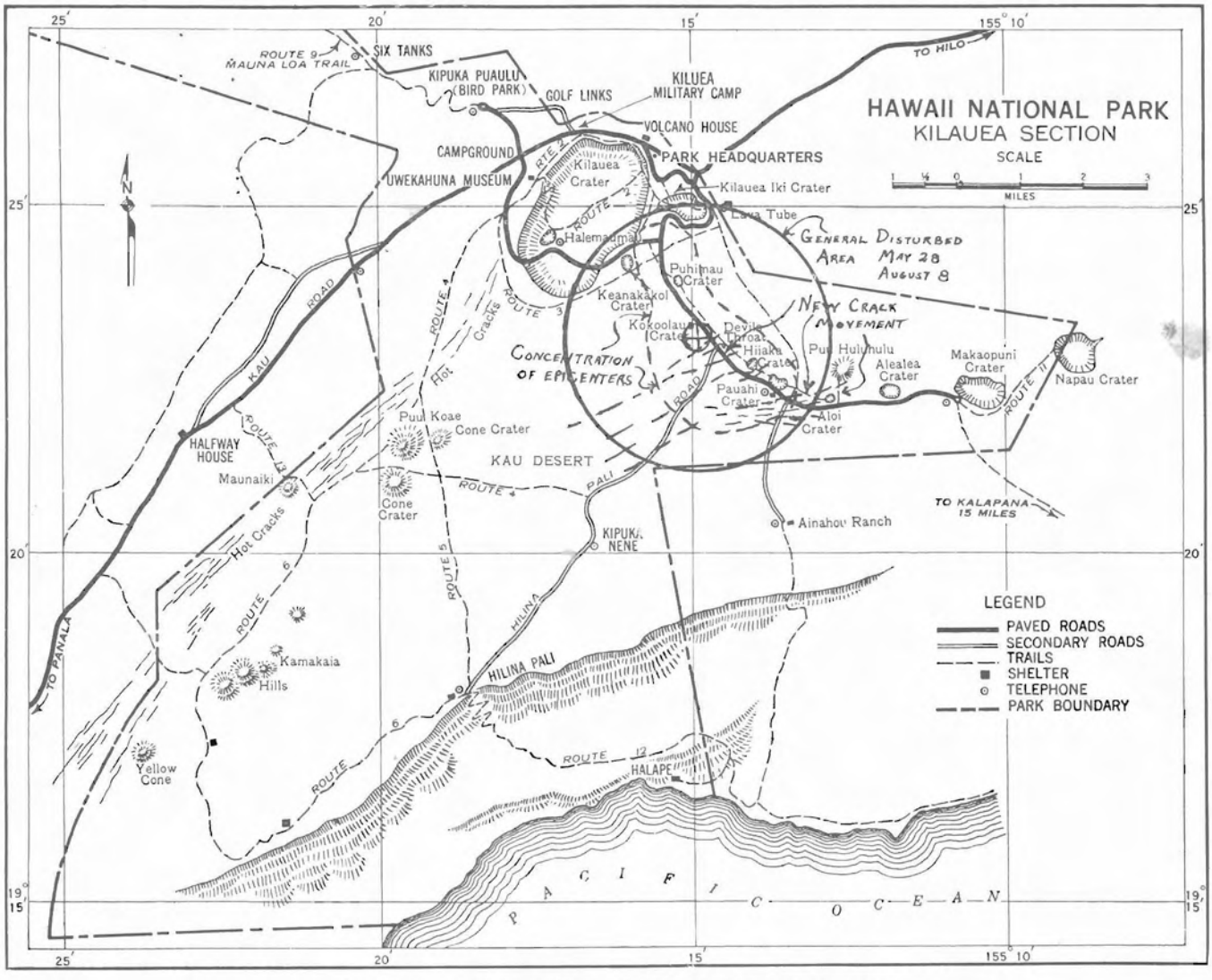
Edward G. Wingate Superintendent
Hawaii National Park

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

NOTICE CONCERNING PUBLICATIONS

This number of the Volcano Letter completes the 1938 series, and is published by the University of Hawaii. Hereafter the Letter will be published as a quarterly and will be sent out from the publication office of the University of Hawaii. Members of the Hawaii Volcano Research Association will receive it without cost.

The Third Special Report of the Hawaiian Volcano Observatory has been published by the Hawaiian Volcano Research Association: Ash Formations of the Island of Hawaii, Chester K. Wentworth, 1938, pp. 183; and is ready for distribution upon application to the Secretary, 320 Jas. Campbell Bldg., Honolulu, T. H. $3.00 per copy, postage free.



Map of disturbed area, Chain-of-Craters. Hot vapor killing vegetation is between Kokoolau and Keanakakoi.

Hawaiian Volcano Observatory Report for August-December 1938

VOLCANOLOGY

AUGUST 1938

During this month there was another disturbance of the fault blocks making new crack movement along Chain-of-Craters road similar to the one of May 28, 1938. There were felt earthquakes the forenoon of August 8, the road hump near Devil's Throat increased in elevation, eight new cracks were found between Devil's Throat and Hiiaka pit, and a large number of local shocks were registered instrumentally during the second week of the month. They were not felt in Hilo, but eleven shocks August 8-10 were from Mauna Loa. There were slides in Devil's Throat and Pauahi pit.

Opening of cracks in the road near Devil's Throat amounted to 2.5 and 4.00 mm. between August 10 and 12. The third week two Devil's Throat cracks opened 7.5 mm., and of three cracks between Pauahi and Aloi pits two opened 8.5 mm. The fourth week, of seven cracks marked along the Chain-of-Craters road, one at Devil's Throat opened 1.0 mm., another a half mile east of Pauahi opened 16.0 mm., and one near Aloi closed 14.5 mm. A heavy slide from the west rim of Pauahi crater occurred August 26. Kilauea quakes had decreased in number after August 14 and all but two of the measured shocks showed Mauna Loa distances.

The following are the local data for August:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
August 7	0	0.0 mm.	26
" 14	5	7.0 mm.	454
" 21	0	1.0 mm.	24
" 28	0	5.0 mm.	11

SEPTEMBER, 1938

Slides September 3 at the north wall of Kilauea crater made a new talus there. The week ending September 5 showed some recurrence of movement along Chain-of-Craters rift with settlement of the rim of Pauahi pit, and a new crack at Devil's Throat. On September 26 the large road crack near Pauahi crater caved in farther under the impact of a car.

Inspection of northeast rift of Mauna Loa September 15 showed recent disturbance of the new cracks at 11,000 feet elevation, and the 1935 cone was fuming and depositing sulphur.

The following are the local data for September:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
September 4		1.5 mm.	11
" 11	5	2.5 mm.	11
" 18	2	0.5 mm. closing	9
" 25	1	7.5 mm.	11
October 2	0	5.5 mm. closing	12

OCTOBER 1938

The first week of the month produced no earthquakes and few tremors although there was increase of slides at Halemaumau. During the second week there were no slides and only two small earthquakes. The third week was seismically the quietest of the year to date. The last week produced an earthquake at 6:12 p.m. October 27 on the southwest rift of Mauna Loa that cracked a concrete floor in the village of Naalehu.

The following are the local data for October:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
October 9	24	2.5 mm.	12
" 16	0	5.5 mm.	13
" 23	1	0.5 mm.	6
" 30	0	2.5 mm.	12

NOVEMBER 1938

The month was notable in the Pacific area in producing eleven distant earthquakes, and the local field here was extraordinary in developing large numbers of small slides from the Halemaumau wall, and also some avalanches from the northern corner of Kilauea crater. It is remarkable that the measured local earthquakes of the fortnight ending November 27 were dominantly from sources in the island not within Kilauea Volcano, although there were great numbers of Halemaumau slides.

The following are the local data for November:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
November 6	3 (Kilauea)	0.0 mm.	33
" 13	1 (Halemaumau)	4.5 mm.	10
" 20	23 "	4.0 mm.	24
" 27	93 "	3.5 mm.	30

DECEMBER 1938

The first week showed slides in some of the pits of Chain-of-Craters, and also on the Puna cliffs towards the sea. There was one day of slides in Halemaumau. During the third week some motion occurred along the Chain-of-Craters.

Inspection of Mauna Loa northeast rift December 9-10 showed the upper cone of 1935 steaming and smelling of sulphur dioxide and hydrogen sulphide; parts of the bright yellow sulphur coatings had the orange tinge of either iron or selenium.

The following are the local data for December:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
December 4	7	4.5 mm.	38
" 11	0	1.0 mm.	8
" 18	3	3.5 mm.	17
" 25	0	2.0 mm.	14

T.A.J.

SEISMOLOGY AND GROUND MEASUREMENTS

Earthquakes

AUGUST 1938

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Moderate Earthquakes	Distant† Earthquakes	Weekly* Seismicity
Aug. 7	17	9	0	0	0	0	8.75
Aug. 14	1,014	184	56	36	3	0	482.50
Aug. 21	17	6	1	0	0	0	8.25
Aug. 28	10	1	0	0	0	0	3.00

† Including teleseisms or earthquakes of over 5000 km from Kilauea.

* For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

August 2, 8:51 am, very feeble, probably originated near center of Kilauea Crater.

August 2, 9:17 am, very feeble, probably originated in NE portion of Kilauea Crater.

August 3, 9:53 am, very feeble, probably originated near center of Kilauea Crater.

August 4, 9:50 pm, very feeble, same as preceding.

August 5, 8:59 pm, very feeble, 0.9 mile deep under Byron Ledge. 19° 25.5′ N; 155° 15.5′ W.

August 6, 2:59 am, very feeble, 12.0 miles deep under Mauna Kea about 5.0 miles S of Summit. 19° 45.5′ N; 155° 27.0′ W.

During the week, August 7-14 inclusive, 454 local seismic disturbances were recorded on the seismographs of the Hawaiian Volcano Observatory. Between midnight August 7 and 2:10 am August 8, there were three tremors and one very feeble earthquake. At 2:14 am, 840 minutes of continuous tremor began to register, ending at 4:38 pm August 8. During the remainder of the day there were 74 tremors, 184 very feeble, 56 feeble, 36 slight and 3 moderate earthquakes.

The moderate earthquakes were:

5:12 am, 1.3 miles deep, 0.4 miles SW of Hiiaka Crater.

9:44 am, thought to have originated in the vicinity of Devil's Throat.

11:41 am, probably originated in cracks about 0.6 mile W of Kokoolau Crater.

It may be noted that the three were successively closer to Kilauea Crater, indicating distances from the Observatory of 4.7, 3.5 and 3.2 miles respectively.

These and associated shocks were felt by most residents of Hawaii National Park. Those asleep were awakened by the early disturbances. The swarm of earthquakes began after the continuous tremor. The shocks were not felt at any great distance from Kilauea Crater.

For the week there are the following data:

Date	Disturbances	Minutes of Tremor*	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Moderate Earthquakes
Aug. 8	323	917	166	45	31	3
Aug. 9	83	60	11	8	4	....
Aug. 10	22	16	4	1	1	....
Aug. 11	10	8	2	....	....	....
Aug. 12	6	6	....	....	....	....
Aug. 13	8	5	1	2	....	....
Aug. 14	2	2	....	....	....	....
Totals	454	1,014	184	56	36	3

* —840 continuous and 77 spasmodic.

Focal distances of the shocks were between 0.5 and 6.0 miles from the Observatory. The circle on the accompanying map shows the general area of disturbance. The majority of the shocks were located by determinations derived from a study of seismograms from the Observatory, Pit and Uwekahuna seismographs. The epicenters thus determined fell within the irregular area inside the circle on the map. The center of the circle (+) was apparently the center of greatest disturbance and was determined by averaging all the S-P values from the three stations mentioned above. The earthquakes were most strongly felt within the areas indicated. The fact that they were not felt at any great distance (probably not over 7.0 miles) from their source indicates they were local to the Kilauea Crater area, particularly in the Chain-of-Craters to the SE and were of shallow origin. By graphic methods of determination depth of focus was in no case more than two miles. Most were less than 1.0 mile and in many cases appeared to have been less than 0.5 mile. A substantial number indicated depths of 1.5 to 1.8 miles.

Accompanying the earthquakes there was apparently considerable movement of probably preexisting cracks between Kokoolau and Hiiaka Craters. The cracks which had shown movement during May disturbances apparently changed slightly. The latter were located between Pauahi and Aloi Craters. Concentric cracks around Devil's Throat increased and more rockfalls from the rim occurred. Slides also occurred in Pauahi. The hump in the Chain-of-Craters road near Devil's Throat increased in height and the road surface was considerably fractured. Other cracks opened 10 feet north. Three sets of cracks in the road developed to the S of Devil's Throat, i.e., between Devil's Throat and Hiiaka and on the S rim of Hiiaka. Many shocks originated in Kilauea Crater.

One slight shock felt at Kapapala Ranch at 9:45 am, August 8, was apparently located 15.0 miles deep in the Hilina Fault system 7.5 miles SW of the Observatory. 19° 19.0′ N; 155° 15.0′ W.

Another (very feeble) from same general locality registered at 5:53 pm. A third (very feeble) located in Hilina Fault System near the junction with the SW rift 8.0 miles deep occurred at 1:24 am, August 10. 19° 16.0′ N; 155° 19.5′ W.

Other August earthquakes were:

August 15, 6:46 am, very feeble, originated 8.0 miles deep in Kilauea SW rift, 13.0 miles from Halemaumau. 19° 14.5′ N; 155° 24.0′ W.

August 15, 6:14 pm, very feeble, 2.0 miles deep, SE portion of Kilauea Crater. 19° 24.7′ N; 155° 26.1′ W.

August 16, 7:43 pm, feeble, 25.0 miles deep under Mauna Loa, about 20.0 miles W of Kilauea Crater. 19° 25.0′ N; 155° 34.0′ W. Strongly felt in Pahala and at Kapapala Ranch.

August 20, 3:12 pm, very feeble, 2.0 miles deep, Kalanaokoai Pali, 2.0 miles WSW of Pauahi Crater.

August 20, 5:06 pm, very feeble, 14.0 miles deep, Mauna Loa NE rift about 3.0 miles E of Puu Ulaula. 19° 32.5′ N; 155° 26.0′ W.

August 22, 1:19 am, very feeble, 15.0 miles deep, Mauna Loa SW rift, 14.0 miles SW of summit. 19° 18.5′ N; 155° 43.5′ W.

Microseismic motion of the ground at the Observatory was light August 1-8; moderate August 9-13, 18, 24-28 and strong August 14-17, 19-23 inclusive.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the observatory seismograph and at Halemaumau, the algebraic sum toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending August 28 was 1.49″ S and 6.6″ W.

Week Ending	Observatory	Halemaumau West Station
August 7	0.40″ N 15° W	3.19″ N 75° W
August 14	1.20″ N 42° E	8.08″ N 60° W
August 21	0.32″ S 59° W	4.17″ N 69° W
August 28	0.12″ N 68° E	1.61″ S 50° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
August 7	8.42″ N 54° W	5.15″ toward
August 14	10.69″ N 39° W	4.13″ toward
August 21	7.06″ N 72° W	4.01″ from
August 28	2.79″ N 72° W	1.09″ toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory August 10 and 22, indicated slight opening of the Halemaumau value and closing of the total Crater value compared with similar measurements July 21. Between July 21 and August 10, the Halemaumau measurement from SE Pit BM to NW Pit BM showed closing of 0.26″ and between August 10 and 22, opening of 0.59″. Total opening 0.33″. Between July 21 and August 10 the Crater measurement from SE rim station to Uwekahuna showed opening of 0.67″ and between August 10 and 22, closing of 1.01″. Total closing 0.34″.

H.H.W.

Earthquakes

SEPTEMBER 1938

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant* Earthquakes	Weekly† Seismicity
September 4	7	3	1	1	4.25
September 11	10	1	0	0	3.00
September 18	6	3	0	0	3.00
September 25	8	3	0	0	3.50
October 2	9	3	0	0	3.75

* Including teleseisms or earthquakes of over 5000 km from Kilauea.

† For local seismicity definition see Volcano Letter 371.



New hump in road near Devil's Throat, May and August 1938.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

August 29, 2:30 pm, very feeble, 10.0 miles deep. Mauna Loa NE rift 4.0 miles NE of center of summit crater. 19° 30.5′ N; 155° 32.2′ W.

September 2, 2:53 am, feeble, 13.0 miles deep, Kilauea SW rift, 8.0 miles SW of Halemaumau. 19° 20.0′ N; 155° 23.0′ W. Reported felt at Kapalapala and Pahala.

September 2, 4:09 am, very feeble, 17.0 miles deep, Mauna Loa NE rift, 7.0 miles NE of summit crater. 19° 31.5′ N; 155° 29.0′ W. Reported felt at Kapalapala Ranch.

September 3, 7:13 am, very feeble, probably originated about 4.6 miles S of Pit seismograph station in Kalanaokuaiki.

September 9, 6:58 am, very feeble, probably located in Kilauea SW rift near Pahala.

September 14, 5:38 pm, very feeble, 1.6 miles deep in vicinity of Puu Huluhulu, Chain-of-Craters rift. 19° 22.7′ N; 155° 12.6′ W.

September 16, 2:42 pm, very feeble, 1.8 miles deep in Kalanaokuaiki fault, 1.8 miles E of Puu Ohale. 19° 21.2′ N; 155° 15.2′ W.

September 21, 6:17 pm, very feeble, probably originated in Kilauea SW rift about 11.0 miles SW of Halemaumau.

September 24, 1:49 pm, very feeble, 11.0 miles deep, 3.0 miles N of Halfway House between Kilauea and Mauna Loa. 19° 21.4′ N; 155° 25.2′ W.

October 1, 9:04 pm, very feeble, 2.8 miles deep, near center of Kilauea Crater. 19° 25.1′ N; 155° 16.4′ W.

Distant Earthquakes

"P" waves began recording at Kilauea at 1h 30m 33s am, H.S.T., August 30. Distance from the Observatory estimated at 4,400 miles.

Microseismic motion of the ground at the Observatory was light September 3, moderate August 29, 31, September 1, 2, 4, 5, 10-15 and strong August 30, September 6-9, 16-30 and October 1 and 2.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau, the algebraic sum toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending October 2, was 0.73" S and 5.36" W.

Week Ending	Observatory	Halemaumau West Station
September 4	0.72" N 65° E	2.38" N 41° W
September 11	0.70" N 24° E	3.73" N 45° W
September 18	0.84" N 39° E	6.05" N 80° W
September 25	0.70" N 24° E	2.00" N 20° W
October 2	0.75" S 4° W	1.85" S 61° W

Week ending	Halemaumau Southeast Station	Halemaumau Resultant
September 4	4.57" S 16° E	5.41" from
September 11	10.40" N 39° W	7.99" toward
September 18	5.64" N 4° E	1.43" from
September 25	14.42" N 31° W	13.49" toward
October 2	8.88" N 63° W	6.30" toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory, September 7 and 22, indicated closing of the Halemaumau value and closing of the total Crater value compared with similar measurements August 22. Between August 22 and September 7, the Halemaumau measurement from SE Pit BM to NW Pit BM showed closing of 2.66" and between September 7 and September 22, closing of 0.58". Total closing 3.24". Between August 22 and September 7 the Crater measurement from SE rim station to Uwekehuna showed closing of 0.66" and between September 7 and 22 closing of 0.67". Total closing 1.33".

Levelling at Kilauea

Since December 9, 1937 three sets of levels have been run in Kilauea Crater from the S pit BM, SE rim area of Kilauea Crater and the NW pit BM on the NW rim of Halemaumau. The first run, February 8, 1938 showed a relative lowering of NW pit BM with reference to S pit BM of 6.7 centimeters within the preceding two-month period. Similar measurements July 24, indicated a raising of the NW pit BM of 4.6 centimeters since February 8 and from July 24 to September 15, a raising of 0.5 centimeter. As in the February run, the last two are with reference to the S pit BM. It is possible that the movement indicated February 8, may have been a raising of S pit with reference to NW pit and in the last two cases S pit may have lowered. The latter movement seems quite plausible in view of recent visible earth movements along Chain-of-Craters road where cracks indicate apparent downward movements to the south. These measurements give only relative changes between two stations with no reference in either case to changes relative to sea-level.

H.H.W.

OCTOBER 1938

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble	Slight	Distant*	Weekly† Seismicity
October 9.....	12	0	0	0	3.00
October 16.....	11	2	0	0	3.75
October 23.....	5	1	0	2	1.75
October 30.....	7	3	2	0	7.25

* Including teleseisms or earthquakes of over 5000 km from Kilauea.

† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

October 10, 11:52 am, very feeble, 4.7 miles deep, NW rim area of Kilauea Crater about 0.5 mile N of Uwekahuna, 19° 25.7′ N; 155° 17.4′ W.

October 13, 5:09 am, very feeble, 33.0 miles deep, Hualalai-Puu Waawaa area. 19° 47.0′ N; 155° 52.7′ W.

October 19, 7:25 am, very feeble, 15.0 miles deep in Chain-of-Craters area 4.0 miles SE of the Observatory, 19° 23.4′ N; 155° 13.6′ W.

October 25, 12:18 pm, slight, 16.0 miles deep, near Glenwood, 18.5 miles SSW of Hilo. 19° 27.8′ N; 155° 09.5′ W. Reported felt by many in Hilo and by a few in Hawaii National Park.

October 26, 9:38 am, very feeble, 2.6 miles deep in Chain-of-Craters, vicinity of Aloi and Puu Huluhulu. 19° 22.1′ N; 155° 12.6′ W.

October 27, 6:11 pm, slight, 15.0 miles deep under Hualalai. 19° 42.0′ N; 155° 50.2′ W. Reported felt by many in Kona and at Naalehu.

October 29, 7:07 am, very feeble, of Mauna Loa origin.

October 30, 2:46 am, very feeble, probably originated south of Kilauea Crater in cracks near Puu Ohale.

Distant Earthquakes

"P" waves began recording at Kilauea at 4h 01m 58s pm, H.S.T., October 19. Probably originated about 5500 miles from the Observatory.

Unidentified portion began registering at 1h 10m 56s am, H.S.T., October 20.

Microseismic motion of the ground at the Observatory was light October 13, 14, 15; moderate October 12, 16, 17, and strong the remainder of the month.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau, the algebraic sum toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending October 30, was 0.52" N and 4.74" W.

Week Ending	Observatory	Halemaumau West Station
October 9	1.22" N 40° E	5.00" S 43° W
October 16	0.12" W	2.68" N 18° W
October 23	0.15" S	4.53" S 83° W
October 30	1.24" N 19° E	5.96" N 73° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
October 9	4.96" N 63° W	0.64" toward
October 16	2.92 S 20° W	2.22" from
October 23	10.27" S 40° W	6.90" from
October 30	4.44" N 47° W	1.13" from

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory, October 11 and 25, indicated little change in the Halemaumau value but closing of the Crater value compared with similar measurements September 22. Between September 22 and October 11, the Halemaumau measurement from SE pit BM to NW pit BM showed closing of 0.43" and between October 11 and 25, opening of 0.50". Total opening 0.07". Between September 22 and October 11, the Crater measurement from SE rim station to Uwekahuna showed closing of 1.66" and between October 11 and October 25, closing of 0.50". Total closing 2.17".

H.H.W.

NOVEMBER 1938

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Distant*	Weekly† Seismicity
November 6.....	26	6	1	4	10.50
November 13.....	31	2	1	4	9.75
November 20.....	18	7	1	2	9.00
November 27.....	24	6	0	1	9.00

* Including teleseisms or earthquakes of over 5000 km from Kilauea.

† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

October 31, 1:05 pm, very feeble, 20.0 miles deep, Hualalai, 5.0 miles SE of summit. 19° 39.2′ N; 155° 47.7′ W. Reported felt at Puu Waawaa ranch house.

November 2, 12:14 am, very feeble, probable origin, E portion of Kilauea Crater.

November 3, 12:53 pm, very feeble, probable origin, Hilina Fault system about 4.0 miles SE of Makaopuhi.

November 4, 7:40 am, very feeble, 2.8 miles deep in N portion of Kilauea Crater. 19° 25.6′ N; 155° 16.6′ W.

November 5, 10:37 am, very feeble, 1.7 miles deep, 0.5 mile NE of Hiiaka Crater. 19° 23.0′ N; 155° 13.6′ W.

November 5, 10:27 pm, feeble, 2.0 miles deep, 0.4 mile W of Kokoolau. 19° 23.2′ N; 155° 15.2′ W.

November 7, 6:15 am, feeble, 25.0 miles deep, 4.0 miles W of summit of Hualalai. 19° 42.8′ N; 155° 56.0′ W. Reported felt in Kona district.

November 9, 12:01 am, very feeble, probably originated in NE rim area of Kilauea Crater.

November 12, 9:37 pm, very feeble, probably originated in NE rim area of Kilauea Crater.

November 14, 12:17 am, very feeble, probably originated under Halemaumau, Kilauea Crater.

November 18, 2:29 am, very feeble, 28.0 miles deep, 10

miles W by S of summit of Mauna Kea, 14 miles E by N of Puu Waawaa. 19° 47.8′ N; 155° 38.0′ W.

November 18, 3:48 am, very feeble, 3.8 miles deep, 0.8 mile S of Pauahi Crater. 19° 21.7′ N; 155° 13.4′ W.

November 20, 5:31 pm, feeble, 13.0 miles deep in Hilina-Kapukapu fault system, 4.0 miles S by W of Makaopuhi. 19° 19.0′ N; 155° 12.0′ W. Reported felt by several persons in Hawaii National Park Headquarters area.

November 20, 6:08 pm, very feeble, probably originated in Hilina fault system about 3.0 miles SE of Kamakaia Hills.

November 21, 11:13 pm, very feeble, probably originated near Kokoolau, Chain-of-Craters.

November 22, 10:48 am, very feeble, of Mauna Loa origin, NE rift.

November 27, 9:21 am, very feeble, of Kilauea Crater origin, vicinity of Holemaumau.

Four minutes of continuous tremor registered November 10, beginning at 10:33 am. The tremor was superimposed on a portion of a teleseism. At Halemaumau it was equivalent in size to a feeble shock so probably originated in Kilauea Crater near Halemaumau.

Three minutes of tremor registered November 16 beginning at 4:09 pm.

Teleseisms

November 4, 10h 23m 20s pm, "P" waves, distance from Kilauea 3775 miles.

November 5, 12h 30m 05s am, "P" waves, distance 4025 miles. Located in Northern Japan where some damage resulted. Alsa reported felt in Tokyo.

November 5, 10h, 33m 41s pm, "P" waves, distance 3880 miles.

November 6, 11h 18m 37s am, "P" waves, distance 3550 miles.

November 8, 11h 13m 18s pm, unidentified portion.

November 10, 9h 55m 42s am, "P" waves, distance 2485 miles. Apparent location was near Shumagin Islands off S coast of Alaska. U.S.C. & G.S. location of origin was 55° N; 159° S. Seismographic registration of this shock was unusually strong throughout the world. Maximum waves dismantled Bosch-Omori seismograph ot the Hawaiian Volcano Observatory at 10:07 am. Small tidal wave was observed in Hawaiian Islands between 3:00 and 3:30 pm. Reported felt over large portion of Alaska but no damage reported.

November 10, 2h 34m 49s pm, "P" waves, distance 3370 miles.

November 13, 12h 49m 42s pm, unidentified portion.

November 14, 1h 46m 09s am, unidentified portion.

November 16, 5h 31m 37s pm, "P" waves, distance 2420 miles. According to news dispatches, originated Aleutian Islands, Alaska, at approximately same locality as earthquake of November 10.

November 21, 2h 54m 02s pm, "P" waves, distance 3725 miles.

Time used above is Hawaiian Standard, 10h 30m behind G.C.T.

Microseismic motion of the ground at the observatory was moderate December 17, 18, 19 and 26 and was strong the remainder of the month.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau, the algebraic sum toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending November 27 was 1.1″ S and 4.43″ M.

Week Ending	Observatory	Halemaumau West Station
November 6	0.92″ S 20° E	2.68″ S 75° W
November 13	1.13″ N 80° E	4.17″ N 40° W
November 20	0.40″ S 47° W	6.05″ S 77° W
November 27	0.93″ N 35° E	3.33″ S 55° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
November 6	3.30″ S 80° W	1.08″ from
November 13	3.24″ N 5° W	0.97″ from
November 20	2.91″ N 71° W	3.68″ from
November 27	3.89″ N 55° W	0.73″ toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory, November 23, indicated closing of the Halemaumau value and opening of the Crater value compared with similar measurements made October 25. During that period the angle between SE pit BM and NW pit BM closed 1.58″ and the angle between SE rim Station and Uwekahuna opened 1.48″. H.H.W.

DECEMBER 1938

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Distant*	Weekly† Seismicity
December 4.....	23	11	4	1	15.25
December 11.....	6	2	0	0	2.50
December 18.....	20	6	0	0	8.00
December 25.....	21	2	0	0	6.25
January 1.....	9	5	0	0	4.75

* Including teleseisms or earthquakes of over 5000 km from Kilauea.

† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

November 28, 2.03 pm, very feeble, 1.8 miles deep, 1.0 mile west of Puhimau and 0.6 mile south of Keanakakoi in Chain-of-Craters, 19° 23.7′ N; 155° 15.9′ west.

November 29, 5:43 am, feeble, 4.0 miles deep in SW portion of Kilauea Crater immediately W of Halemaumau. 19° 24.7′ N; 155° 17.6′ W. Reported felt in Hawaii Nationol Park.

November 29, 9:59 am, very feeble, probably originated in Chain-of-Craters area near Kokoolau.

November 29, 10:18 am, very feeble, of Kilauea Crater origin.

November 29, 10:19 am, feeble, of Kilauea origin. Reported felt in national park residential area.

November 30, 4:17 am, very feeble, probably originated in Kilauea SW rift about 2.0 miles from Halemaumou.

November 30, 2:05 p.m., very feeble, of shallow origin in Chain-of-Craters near Puhimau and Kokoolau. 19° 23.4′ N; 155° 15.2′ W.

November 30, 3:08 pm, feeble, 3.2 miles deep, Chain-of-Craters, 1.0 mile N of Hiiaka. 19° 23.5′ N; 155° 14.1′ W. Reported felt in national park residential area.

November 30, 3:13 pm, very feeble, 1.2 miles deep, 0.8 mile E of Keanakakoi, 19° 24.2′ N; 155° 15.2′ W.

November 30, 8:57 pm, feeble, 4.0 miles deep, 1.4 miles W of Pauahi Crater. 19° 22.3′ N; 155° 14.8′ W. Reported felt in Hawaii National Park residential area and at CCC camp.

December 1, 4:32 pm, very feeble, location approximately same as preceding shock.

December 2, 6:53 pm, very feeble, 8.0 miles deep, Mauna Loa NE rift 3.5 miles SW of Puu Ulaula. 19° 30.7′ N; 155° 31.0′ W.

December 2, 9:27 pm, very feeble, same general locality as preceding shock. 19° 31.5′ N; 155° 31.0′ W.

December 4, 4:32 am, very feeble, originated in Mauna Loa NE rift near Puu Kulua.

December 4, 7:34 am, very feeble, 2.2 miles deep in Chain-of-Craters near Hiiaka and Pauahi craters. 19° 22.7′ N; 155° 13.3′ W.

December 8, 11:09 pm, very feeble, of comparatively shallow origin, Mauna Loa NE rift, vicinity of Pohaka Hanalei. 19° 30.0′ N; 155° 33.6′ W.

December 10, 7:59 pm, very feeble, 12.0 miles deep under N slope of Mauna Loa about 5.0 miles N of Puu Ulaula. 19° 36.5′ N; 155° 26.8′ W.

December 13, 7:26 am, very feeble, E slope of Mauna Loa, 5.0 miles E of summit crater. 19° 28.3′ N; 155° 31.0′ W.

December 13, 10:11 am, very feeble, 8.0 miles deep under coast line S of Hilina Pali and 4.0 miles W of Keahou Point. 19° 16.5′ N; 155° 18.0′ W. Reported felt in Hilo.

December 14, 12:13 am, very feeble, in Hilina Fault system, 4.5 miles SE of Makaopuhi.

December 16, 1:18 pm, very feeble, of shallow origin near Devil's Throat. 19° 22.9′ N; 155° 14.5′ W.

December 16, 1:27 pm, very feeble, possibly 35.0 miles deep, under E slope of Mauna Loa. 19° 26.5′ N; 155° 32.0′ W.

December 17, 1:31 pm, very feeble, originated in Kilauea Crater, probably under Halemaumau.

December 19, 5:24 pm, very feeble, probably originated in Kilauea SW rift near Junction with Hilina Fault system.

December 20, 12:51 pm, very feeble, originated in Kilauea Crater near E rim of Halemaumau.

December 23, 7:18 am, a tremor which registered as feeble on Mauna Loa seismograph and originated in Mauna Loa NE rift.

December 26, 6:23 pm, very feeble, probably originated in area 3.2 miles E of Kilauea Iki.

December 27, 6:33 am, originated in Kilauea crater under Halemaumau.

December 28, 3:12 am, very feeble, 1.2 miles deep, Chain-of-Craters, 0.9 mile east of Keanakakoi. 19° 24.7′ N; 155° 15.2′ W.

Continuous tremor:

10 minutes, beginning at 3:45 pm, December 15.

10 minutes, beginning at 7:22 pm, December 19.

Teleseisms

Unidentified portion began to register at the Observatory 4h 17m 28s pm, HST, November 29. Located in Japan, E coast of Honshu. 37° 5′ N; 141° 3′ W.

Microseismic motion of the ground at the Observatory was moderate December 9 and 10 and strong the remainder of the period between November 28 and January 1 inclusive. Stormy weather prevailed at sea contemporaneously.

Tilting of the Ground

The following tables show tilt by weeks, as recorded by the Observatory seismograph and at Halamaumau, the algebraic sum toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending January 1, 1939, was 0.86″ S and 6.82″ W.

Week Ending	Observatory	Halemaumau West Station
December 4	1.12″ S 68° W	7.36″ N 71° W
December 11	0.80″ E	6.00″ S 76° W
December 18	1.10″ N 12° W	0.42″ N
December 25	2.17″ S 30° W	3.22″ S 57° W
January 1	0.80″ N 66° W	3.43″ S 60° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
December 4	2.08″ N 34° W	4.76″ from
December 11	7.08″ N 12° W	0.92″ toward
December 18	3.97″ N 41° E	0.81″ toward
December 25	8.10″ S 49° W	3.32″ from
January 1	10.05″ N 49° E	2.32″ from

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory, December 29, indicated opening of both the Halamaumau and the crater values compared with similar measurements of November 23. Between November 23 and December 13 the Halemaumau measurement from SE pit BM to NW pit BM showed opening of 0.35″ and between December 13 and 29, opening of 0.57″. Total opening of 0.92″. Between November 23 and December 13, the crater measurement from SE rim station to Uwekahuna showed closing of 1.07″ and between December 13 and 29, opening of 1.51″. Total opening 0.44″. H.H.W.

THE VOLCANO LETTER

No. 463 Department of the Interior National Park Service January-March, 1939

Edward G. Wingate Superintendent
Hawaii National Park

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
in cooperation with
UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, is leased and operated by the United States Government, Department of the Interior, National Park Service.

The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** maintain outside seismograph stations and supplement the work of the government with research associates, instrumental plants and special investigations.

The **Volcano Letter,** a quarterly record of the Hawaiian volcano laboratories, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the above establishments.

Hawaiian Volcano Observatory Report for January-March 1939

VOLCANOLOGY

January 1939

Until the last week, the month of January was locally quiet at the Hawaiian volcanoes. A feeble earthquake was sharply felt January 15, and there was a notable increase of spasmodic tremors during the last fortnight of the month. These originated under Mauna Loa and Hualalai. Distant destructive earthquakes of large size from Chile and the Solomon Islands were registered January 24 and January 29.

A moderate slide December 30, 1938 from about 300 feet below the north rim of Halemaumau occurred 10:07 a.m. On January 14 rock slides from the east and northwest walls occurred about 1:40 p.m. Slides became more numerous from the western walls of Halemaumau on January 25, ten being counted between 9:55 a.m. and 11:53 a.m.

On the morning of January 17 with nearly calm air much fume hung over Halemaumau originating mostly at the southeast solfatara at the edge of the floor.

Opening of the measured cracks around Halemaumau rim increased somewhat during the month along with the seismicity and the slides. For the week ending January 1, cracks across Chain-of-Craters road near Devil's Throat closed 2.0 mm. The next change noted there was opening of these cracks 1.5 mm. as measured January 20, and again by a like amount January 27. (See map Volcano Letter 462.)

The following are the local data for January:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
January 1	1	0.5 mm.	14
" 8	0	1.5 mm.	32
" 15	1	3.0 mm.	16
" 22	0	3.0 mm.	60
" 29	10	3.0 mm.	45

February 1939

The general conditions in Halemaumau pit as observed February 22 showed a small hole on the southeastern floor of the pit to be steaming near a long white stained crack. Fume above this eastern wall crack had lately been conspicuous. Stain was evident on the 1932 cone southwest, and along the canoe sill at the base of the northeast wall. Margin of the floor was sulphurous in several places. Slides had made a new scar on the south wall February 6 and February 16, and that wall kept scaling off during the last half of the month. The break made a wide white scrape up the entire height of the wall, on the east side of the upright southwestern rift cavern.

Kilauea was quiet the first week of February in contrast to volcanic disturbances in Central America and South America and a reported eruption of Asama in Japan February 3. The second week produced heavy rainfall February 9-10 resulting in clouds of vapor over Halemaumau.

A noisy rock slide fell from the southeast wall of Halemaumau 11:55 a.m. February 6. Rock slides increased during the third week and were noted February 16 at northeast rim 9:25 a.m.; February 17 north wall 7:55 a.m. and west wall 8:53 a.m.; February 18 northeast and north rims 11:00 a.m.; February 19 west wall 10:01 a.m. and northeast rim 10:08 a.m. This was the period when fresh scars and dust streaks were produced on the southeast wall. Two rock slides at the north wall occurred February 21, 9:18 a.m. and 12:10 p.m.

Measurements February 11 showed the new road cracks in the vicinity of Devil's Throat to have opened 2.0 mm., one near Hiiaka pit closed 0.5 mm., and the cracks beyond Pauahi pit were stationary. On February 17 the cracks near Devil's Throat had closed 1.0 mm.; one near Hiiaka closed 0.5 mm.; and one beyond Pauahi closed 0.5 mm. The excessive opening of Halemaumau rim cracks during the week ending February

26 was accompanied by openings of cracks near Devil's Throat 0.5 mm.; Hiiaka 0.5 mm.; and a large crack at Pauahi 1.0 mm.

The following are the local data for February:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
February 5	0	0.0 mm.	17
" 12	1	1.0 mm.	32
" 19	6	5.0 mm.	27
" 26	2	8.5 mm.	15

March 1939

The most distinctive event of March 1939 was excessive rainfall at the beginning of the month. This produced clouds of vapor from the floor of Halemaumau. Precipitation exceeded 19 inches in Hilo in one day, March 2, at Kilauea Crater the rain gauge registered 11.02 inches, and for the week ending March 5, 17.54 inches. The flood was disastrous in Hilo, and the level of water in Olaa Mill well rose three feet above the flood level of 1938 so as to require removal of machinery.

Sharp tilting of the Observatory ground westward March 2 may have been caused by the loading of floor of Kilauea Crater with rain. This was followed by remarkable increase of rim crack openings at Halemaumau for the week ending March 12. Fifteen of twenty-eight crack locations showed opening, one closed, resulting in aggregate opening 17.5 mm. The greater part of this value was contributed by cracks east and southeast. Increased rate of opening of the rim cracks about spring equinox has been noted each year since 1933, generally with accompaniment of rock slides. The strong opening of cracks continued for the remainder of the month.

Observations at Makaopuhi pit March 21, in the Chain-of-Craters, showed that sulphur deposition and fuming are in progress at a hot spot halfway up the crater wall, and a small rock slide was observed at the north rim. On March 29 vapor was observed rising from the talus on the east side of Alealea Crater probably stimulated by deeper penetration of the recent rain.

The cracks near Devil's Throat had opened 2.0 mm. March 3 and 1.5 mm. March 10. The cracks near Hiiaka pit and Pauahi pit had opened 0.5 mm. March 10. Inspection March 21 indicated that new cracks across the road are developing near Devil's Throat, a small portion of the southwest rim of this pit has recently fallen, cracks to the northwest have increased and humps in the road pavement are growing higher near Pauahi and near the Ainahou road. Temperature measurement at the hot area in ohia forest near Kokoolau Crater showed no change and there is no encroachment of solfataric action on the surrounding forest.

Rock slides in Halemaumau were observed at northeast wall March 3, 10:15 a.m. and 10:28 a.m. Two small slides from the north wall occurred at 10:20 and 10:30 a.m. March 6. Slides increased March 27 and were observed 11:51 a.m., northwest wall; March 30, 7:36 a.m., northeast wall and 11:07 a.m. northwest wall; March 31, 8:58 a.m. northeast wall; April 1, northeast rim 11:50 a.m. and 1:30 p.m.

The following are the local data for March:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
March 5	2	4.5 mm.	13
" 12	2	17.5 mm.	17
" 19	0	13.5 mm.	32
" 26	0	10.0 mm	24
April 2	6	13.5 mm.	28

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

	Minutes of Tremor	Very Feeble	Feeble	Slight	Distant*	Weekly† Seismicity
Jan. 8	28	4	0	0	0	9.00
" 15	12	3	1	0	0	5.50
" 22	55	4	0	1	1	17.75
" 29	80	1	0	0	2	20.50
Feb. 5	15	2	0	0	1	4.75
" 12	28	4	0	0	1	9.00
" 19	32	4	1	0	0	11.00
" 26	11	4	0	0	0	4.75
Mar. 5	11	2	0	0	0	3.75
" 12	16	1	0	0	0	4.50
" 19	24	5	2	1	0	12.50
" 26	18	4	2	0	1	8.50
Apr. 2	23	5	0	0	0	8.25

* Including teleseisms or earthquakes over 5000 km. from Kilauea.
† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of depth of focus has been made.

January 2, 8:45 am, very feeble, 8.0 miles deep off seacoast 5.0 miles south of Ahua Point. 19° 11.0′ N; 155° 12.7′ W.

January 4, 8:40 am, very feeble, 2.5 miles deep, Kanaokuaiki Pali about 1.5 miles east of Puu Ohale. 19° 21.2′ N; 155° 15.4′ W.

January 7, 5:15 am, very feeble, 7.0 miles deep NE rift of Mauna Loa. 19° 31.5′ N; 155° 33.0′ W.

January 10, 9:41 pm, very feeble, 2.6 miles deep near Hiiaka and Pauahi Craters. 19° 21.3′ N; 155° 13.9′ W.

January 13, 12:01 am, very feeble, 18.0 miles deep in vicinity of Puu Kulua, Mauna Loa NE rift. 19° 34.0′ N; 155° 26.3′ W.

January 14, 10:46 am, very feeble, 1.2 miles deep, 0.7 mile SW of Ahua Kamokukolau. 19° 22.7′ N; 155° 16.7′ W.

January 15, 3:30 pm, feeble, of shallow origin in Kilauea Crater near Halemaumau. 19° 24.5′ N; 155° 16.3′ W. Reported felt by many persons in Hawaii National Park residential area and by a few in Hilo.

January 16, 1:10 am, very feeble, about 13.0 miles deep in Mauna Loa NE rift, in the vicinity of Puu Ulaula. 19° 33.0′ N; 155° 27.0′ W.

January 17, 4:35 pm, very feeble, about 6.0 miles deep under area about 3.0 miles SE of Puu Ulaula, Mauna Loa NE rift. 19° 31.7′ N; 155° 25.8′ W.

January 17, 8:19 pm, very feeble, 13.0 miles deep in Kilauea SW rift about 9.0 miles from Halemaumau. 19° 20.6′ N; 155° 24.5′ W.

January 19, 2:58 pm, slight, 16.0 miles deep under Hualalai. 19° 41.6′ N; 155° 52.0′ W. Reported strongly felt by many persons in Kona and Kohala districts and slightly by some in Hilo and Kau districts.

January 25, 11:42 am, very feeble, probably originated in Chain-of-Craters SE of Kilauea Crater.

February 2, 9:56 pm, very feeble, originated in Mauna Loa NE rift near Summit Crater. 19° 30.0′ N; 155° 32.0′ W.

February 5, 1:57 pm, very feeble, probably originated about 5.0 miles W by N of Pahala. (3.0 miles NW of Kula mountain.)

February 9, 7:45 am, very feeble, 0.9 mile deep at Chain-of-Craters near Pauahi and Hiiaka Craters.

February 10, 9:56 am, very feeble, 3.3 miles deep in same general area as preceding quake. 19° 21.3′ N; 155° 13.9′ W.

February 10, 3:46 pm, very feeble, 10.0 miles deep in Mauna Loa NE rift near Puu Ulaula. 19° 33.0′ N; 155° 27.0′ W.

February 13, 7:17 pm, very feeble, probably originated in area between Devil's Throat and Ahua Kamokukolau.

February 16, 9:26 am, very feeble, probably originated under NE edge of Kilauea Crater floor.

February 17, 6:05 am, very feeble, 25.0 miles deep, 8.0 miles E of Kulani cone. 19° 34.3′ N; 155° 13.3′ W. Reported felt in Hilo.

February 17, 6:36 pm, feeble, 4.0 miles deep under N rim of Kilauea Iki. 19° 25.8′ N; 155° 14.7′ W.

February 18, 4:36 pm, very feeble, probably located in Chain-of-Craters near Kokoolau.

February 21, 2:26 pm, very feeble, 2.7 miles deep in area N of Kilauea Iki. 19° 25.8′ N; 155° 14.5′ W.

February 23, 12:52 pm, very feeble, 5.0 miles deep in Hilina fault system 3.0 miles S of Makaopuhi. 19° 19.2′ N; 155° 11.0′ W.

February 26, 7:53 am, very feeble, originated under N portion of Halemaumau.

February 26, 6:11 pm, very feeble, probably originated in Kohala area about 4.0 miles N of Kawaihae. 20° 5′ N; 155° 50.0′ W.

March 4, 3:18 am, very feeble, originated in NE portion of Kilauea Crater.

March 5, 1:11 am, very feeble, 15.0 miles deep in Mauna Loa NE rift, 7.0 miles NW of Kulani Cone. 19° 35.4′ N; 155° 21.6′ W.

March 8, 10:33 am, very feeble, 22.0 miles deep in Mauna Loa NE rift near Pukauahi Cone. 19° 33.0′ N; 155° 31.2′ W.

March 13, 9:28 pm, very feeble, 10.0 miles deep under E slope of Mauna Loa, 2.5 miles SE of Mauna Loa seismograph. 19° 27.5′ N; 155° 21.2′ W.

March 14, 6:08 am, very feeble, 2.0 miles deep near Kipuka Puaulu. 19° 26.8′ N; 155° 18.7′ W.

March 14, 9:54 am, slight, 2.3 miles under Halemaumau, Kilauea Crater. 19° 24.6′ N; 155° 17.2′ W.

March 14, 10:56 am, feeble, probably originated in area between Makaopuhi Crater and Hilina Pali.

March 14, 12:10 pm, feeble, of shallow origin in area about 0.8 mile W of Devil's Throat. 19° 22.7′ N; 155° 14.9′ W.

March 20, 12:13 am, very feeble, probably originated in Hilina Pali area about 6.00 miles SE of Makaopuhi.

March 21, 8:47 am, very feeble, of shallow origin in area immediately E of Kilauea Iki. 19° 24.7′ N; 155° 13.6′ W.

March 22, 5:46 am, 40.0 miles deep Mauna Loa NE rift, 8 miles from Summit Crater. 19° 33.0′ N; 155° 30.0′ W.

March 22, 10:57 pm, feeble, 10.0 miles deep Mauna Loa NE rift, 13.0 miles from Hilo. 19° 38.0′ N; 155° 16.0′ W. Reported generally felt in Hilo.

March 24, 8:59 pm, very feeble, 9.0 miles deep in Kau desert area about 2.0 miles S of Puu Ohale. 19° 20.7′ N; 155° 15.0′ W.

March 25, 11:02 pm, very feeble, probably originated in Chain-of-Craters between Devil's Throat and Puhimau Crater.

March 28, 5:36 am, very feeble, 20.0 miles deep, Mauna Loa NE rift near Puu Kulua. 19° 35.2′ N; 155° 26.0′ W.

March 29, 9:47 am, very feeble, of Kilauea Crater origin.

March 30, 9:35 pm, very feeble, originated in NE portion of Kilauea Crater.

Continuous Tremor

Thirty-seven minutes beginning at 8:30 am, January 27. Eleven minutes beginning at 2:02 am, February 18.

Teleseisms

January 18, 11:53 pm, H.S.T., beginning of unidentified portion.

January 24, 5h 15m 41s pm, H.S.T., "P" waves began to register. Shock originated in Chile and was of very destructive nature resulting in estimated loss of over 20,000 human lives, distance from Kilauea 6,435 miles.

January 29, 3h 57m 57s pm, H.S.T., "P" waves began to register. Shock originated in Solomon Islands. Distance from Kilauea 3,800 miles.

February 2, 7h 05m 37s pm, H.S.T., "P" waves began to register. Distance from Kilauea, 3,795 miles.

February 7, 8:26 pm, unidentified portion began recording. No reports have been received concerning this quake either by press or from other stations.

February 24, 4:01 am, unidentified portion.

Microseismic Motion

Microseismic motion of the ground at the Observatory was moderate January 15-21 inclusive and January 29, 30, and 31. It was strong the remainder of the month.

For February it was light on the 20th, 21st, and 25th; moderate on the 12th, 22nd-24th, 26th-28th, and strong the remainder of the month.

During March it was strong 3-5, 17-19, and moderate the remaining dates. All dates inclusive.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the observatory seismograph and the one at Halemaumau; the algebraic sum toward or away from the pit.

At the Observatory the total accumulated tilt for the year ending January 29, 1939 was 1.15" S and 5.93" W.

For the year ending February 26, it was 1.00" S. and 1.73" W.

For the year ending April 2, it was 3.08" S and 4.85" W.

Table of Tilt

Week Ending	Observatory	Halemaumau West Station
Jan. 8	0.43" S 54° E	3.22" S 64° E
" 15	0.55" S 11° E	3.52" S 42° W
" 22	0.91" S 19° W	4.77" N 15° W
" 29	0.97" S 35° W	2.62" N 30° E
Feb. 5	2.00" S 28° W	2.92" N 85° W
" 12	0.77" S 12° W	1.49" S 60° W
" 19	0.25" N 16° W	1.49" N
" 26	0.00" 0	1.64" N 25° W
Mar. 5	1.81" N 26° W	2.89" N 20° E
" 12	0.62" S 29° W	2.59" S 60° W
" 19	3.20" S 43° W	3.61" S 34° W
" 26	1.30" S 51° W	1.49" N 39° W
Apr. 2	1.03" S 30° W	1.49" N 61° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
Jan. 8	2.53" N 85° W	4.30" toward
" 15	1.65" N 70° W	1.23" from
" 22	2.95" S 35° W	1.56" from
" 29	4.54" S 34° E	1.98" toward
Feb. 5	1.13" N 44° E	2.67" from
" 12	4.28" N 59° W	2.55" toward
" 19	2.56" N 87° W	1.62" toward
" 26	2.49" N 25° W	1.81" toward
Mar. 5	4.05" N 37° W	5.08" toward
" 12	3.30" N 15° W	0.70" toward
" 19	1.07" N 31° W	2.17" toward
" 26	4.21" N 81° W	2.03" toward
Apr. 2	1.20" S 9° W	2.00" from H. H. W.

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory January 21, indicated closing of both the Halemaumau and the crater values compared with similar measurements of December 29. The Halemaumau angle between the pit seismograph and the NW pit BM closed 0.50". The crater angle between the SE crater rim station and Uwekahuna closed 1.58".

Angle values determined on February 15, indicated opening across Halemaumau and closing across the crater. Between January 21 and February 15, the Halemaumau value increased 0.83", and the crater value decreased 1.15".

During March two determinations were made of the angles. These were March 13 and 30. On the first of these two runs, the Halemaumau angle closed 2.25" and the crater angle closed 0.25". Between March 13 and March 30 the Halemaumau angle again decreased (0.59") and the crater angle opened by an amount of 2.24". Total change for the month, Halemaumau angle closed 2.84" and the crater angle opened 2.00".

During the first three months of 1939 the Halemaumau angle has decreased 2.51" and crater angle has decreased 0.84".

These changes agree favorably with current tilt toward Halemaumau.

H. H. W.

Levelling at Kilauea

Since January 1, 1939 two sets of levels have been run over the usual circuit on the floor of Kilauea Crater between the Spit BM on the SE crater rim and the NW Pit BM. The line of levels follows the S-SW-W, rims of Halemaumau.

These determinations were made January 30 and March 21. In both cases the NW Pit showed relative lowering with reference to Spit BM. On the first run, this value amounted to 14.0 millimeters and on the second run, a similar value of 15.0 millimeters. These determinations are in accord with both tilt and horizontal angle determinations.

Since the lava inflow at Halemaumau in September, 1934 the NW Pit BM has showed a total relative lowering with respect to the Spit BM of 0.429 meters or 1.41 feet.

H. H. W.

Chain of Craters, Crack Openings*

At 6:00 am, May 28, 1938 a series of earthquakes of various intensities began to register on the seismographs of the Hawaiian Volcano Observatory. Many were strongly felt in the National Park Headquarters area. Within the ensuing 24-hour period well over 100 earthquakes were recorded as well as several hours of continuous tremor in the early stages of the disturbance. Accompanying this seismic activity were visible ground movements along pre-existing cracks in the Chain-of-Craters between Pauahi and Aloi, roughly four miles SE of Kilauea Crater. Definite evidence of these movements was produced by shattering of the hard surface of the Chain-of-Craters road at approximately 11 different localities. Slides occurred in Pauahi. The largest crack developed near Pauahi where a large section of the roadway was destroyed by caving. A few days later seismic conditions had returned to normal.

On the morning of August 8 at 2:14 o'clock, a similar crisis began. More earthquakes were recorded in the following 24 hours than had occurred in the corresponding period in May. Over 200 earthquakes occurred on August 8 alone. This time there were a number of shocks from Kilauea Crater, several from Hilina Pali and others at various points along the Chain-of-Craters but mostly concentrated near Kokoolau and Devil's Throat. Again visible evidence of the general area of disturbance was indicated by cracks across the Chain-of-Craters road; three groups near Devil's Throat and one near Hiiaka (SW rim). The cracks between Pauahi and Hiiaka showed no appreciable changes.

On August 10 seven representative cracks were chosen for measurement and numbered successively from the large crack (hump) near Devil's Throat to the last large crack near Aloi.

The list is as follows:

No. 101—At the "hump" about 1000 feet W of Devil's Throat.

No. 102—At W side of junction of Chain-of-Craters road with the Hilina Pali road.

No. 103—Near S rim of Hiiaka.

No. 104—Large crack near S rim of Pauahi.

No. 105—About 1000 feet SE of the Chain-of-Craters road and Ainahou Ranch road junction.

No. 106—About 50 feet SE of No. 105.

No. 107—About 750 feet W of W rim of Aloi Crater.

Table of crack measurements on Chain-of-Craters road. (Values in centimeters except No. 104 which is in feet, inches and sixteenths.)

Date	101	102	103	104	105	106	107
August 10	402.05	62.85	101.60	17'8- 8/16"	87.00	88.45	41.00
September 2	402.65	63.90	101.45	17'8-12/16"	87.10	88.60	40.90
October 7	402.80	64.00	101.40	17'8-14/16"	87.15	88.65	40.75
November 4	402.95	64.10	101.40	17'8-15/16"	87.20	88.65	40.65
December 2	403.00	64.10	101.45	17'9.0"	87.15	88.65	40.60
January 6	403.30	64.20	101.45	17'9.0"	87.05	88.65	40.50
February 3	403.45	64.25	101.45	17'9.0"	87.05	88.65	40.45
March 3	403.65	64.30	101.40	17'9- 1/16"	87.10	88.65	40.40
March 31	403.70	64.40	101.35	17'9- 1/16"	87.15	88.65	40.40
Total change in mm.	+16.5	+15.5	—2.5	+10.0	+1.5	+2.0	—6.0
	plus (+)=open			minus (—)=close			

The indications from the above figures are that the greatest amount of movement has been and continues near Devil's Throat with next highest rates of change at Pauahi and Alai respectively.

These measurements are to be continued and will be reported regularly.

H. H. W.

* See Volcano Letter 462, August-December 1938 for map and description.

THE VOLCANO LETTER

No. 464 Department of the Interior National Park Service April-June, 1939

Edward G. Wingate Superintendent
Hawaii National Park

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
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TIME CONTROL FOR SEISMOGRAPHS OPERATED BY THE HAWAIIAN VOLCANO OBSERVATORY

HUGH H. WAESCHE, Asst. Geologist

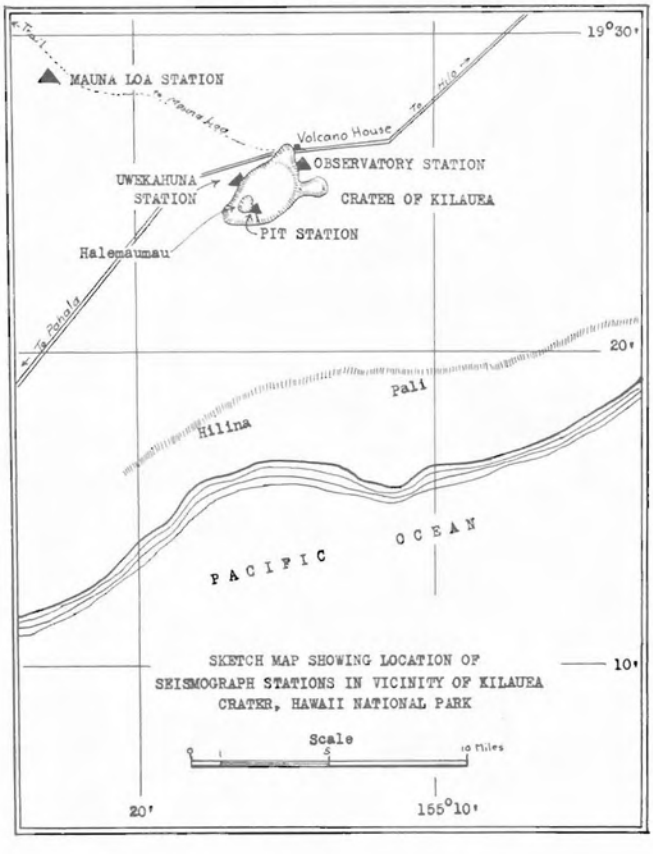
A major problem concerning the operation of any group of seismograph stations is the time control. This is important for widely separated stations but becomes of increasing value for studying travel times between stations separated by distances from one mile to several hundred miles where time errors of tenths of seconds may produce relatively large error in determining earthquake focii.

At Kilauea, seismographs are located at the Observatory, NE rim, Uwekahuna, NW rim and at the SE rim of Halemaumau (see map). At the Observatory there are three instruments, the Bosch-Omori, a vertical component and a low magnification instrument of special design. The entire group has always had a common time control, originating from a pendulum clock (Howard) equipped with electrical contacts for closing the circuit on the fifty-ninth second and breaking on the sixtieth second of every minute and closing for ten seconds during the first minute of each hour. Proper correction of clock is maintained by comparison with radio time signals from NPM and NPG daily at 4:30 pm, H.S.T.

The writing pens are lifted off the smoked drums by a solenoid supported in front of and slightly above each needle. This system has been the most satisfactory method found for indicating the time on the smoked paper. It is true that occasionally important phases are missed in an earthquake but this occurs far more rarely than might be suspected and indicates the time in a reliable manner. The Bosch-Omori low magnification and Uwekahuna recording drums have minutes 50 millimeters in length; all the other records have minute lengths of 30 millimeters.

Individual time clocks were installed at Halemaumau and Uwekahuna as well as in the outlying stations at Hilo and Kealakekua. A station using the same system was installed on Mauna Loa in October, 1938. The latter is located about 10.0 miles NW of the Observatory. None of these stations had radio sets for time corrections and were unattended except for daily visits to change the recording drums.

In 1931 Mr. A. E. Jones began studies of travel times in

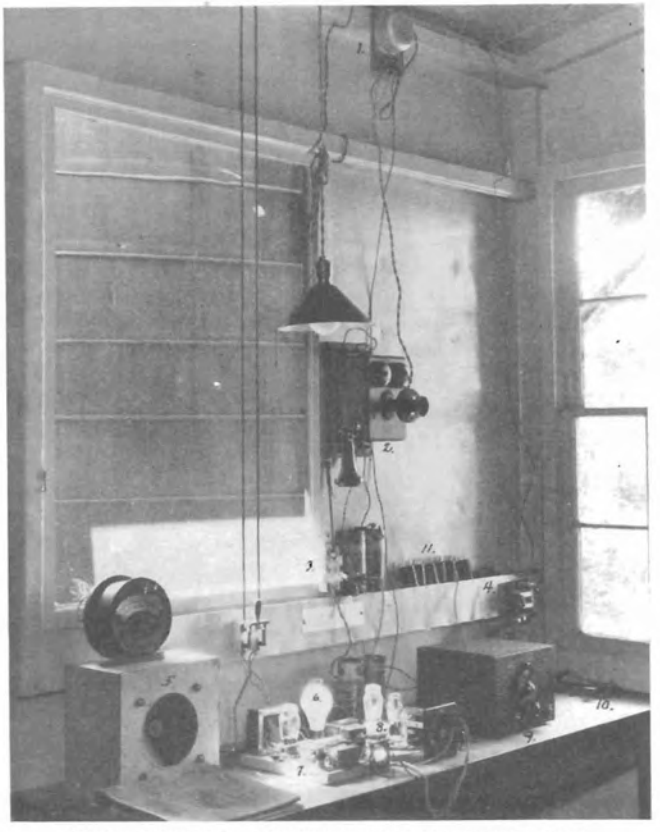


the Hawaiian Islands. Before this, travel times developed by Omori for local shocks in Japan had been used. Mr. Jones found that the Omori travel times did not agree with the seismic facts in Hawaii so immediately set to work developing a set of travel times for the Island. He succeeded in doing this very ingeniously as described in his paper "Hawaiian Travel Times", published in the Bulletin of the Seismological Society of America in January, 1935. During these studies, time comparisons between the Pit and Uwekahuna clocks were made with the clock at the Observatory using a stop watch carried between stations daily. Time corrections at Hilo and Kona were made by listening to the time tone and then as nearly as possible synchronizing this by manual operation of a key which transmitted a signal over the mutual telephone lines to those stations. Lags and other errors of the personal equation as well as unreliability of time clocks in the outlying stations made the system only partially successful and by 1937 all attempts at time control have been given up other than for S-P determinations based on the known speed and dimensions of the recording drum and at the Observatory where close watch could be kept on clocks and radio.

As more earthquakes were recorded, however, there came the conviction that good, reliable time control with all the stations exactly correlated with the clock at the Observatory was a necessity. There was still considerable doubt as to the speed of the compressional and transverse waves from various parts of the Island and earthquakes with good preliminaries at all stations still did not give satisfactory solutions when locations were attempted. Consequently, various plans were considered, varying from radio control from the central station to direct wire connections. Little was done because of the expense of the necessary equipment.

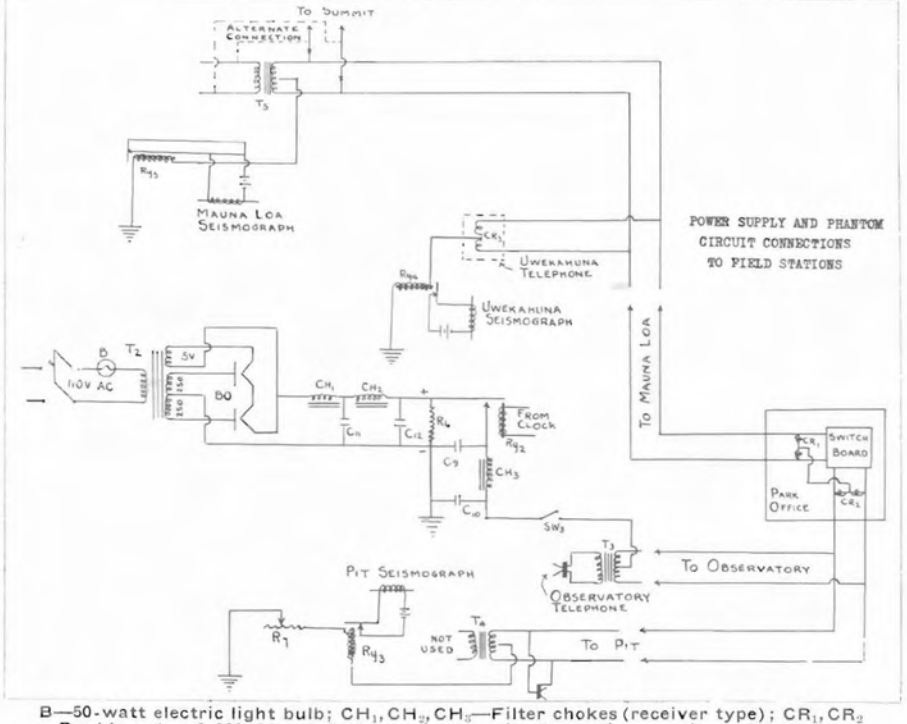
The first step was made in December, 1936, when a sensitive relay and vacuum tube amplifier to operate it were added to the regular short wave receiver then in service. About the same time a rectifier was added to the set, thus utilizing the Hilo power, 110 volts A.C. Previously batteries had been used but had proved expensive. The radio-operated sensitive relay closed the same circuit operated by the time clock and thus indicated the position of true time with reference to the nearest minute. Every day time was checked at 4:30 pm, by an operator tuning the set to the 12,885 kc frequency of NPG or NPM. This was highly successful and probably gave a time correction at the Observatory well under 0.5 sec. for all the instruments operated in that building.

About one year after the relay was installed, the 10,000-ohm coil winding burned out. A new 5,000-ohm coil was wound and operation resumed with little change in the sensitivity of the relay. In attempting to make some mechanical changes in the relay during April of this year, the coil was injured beyond repair. Rather than rewind the relay and take chances on its burning out again, a new relay was constructed, using two 1,250-ohm telephone ringer coils in series. This relay proved sensitive enough (closes on about 0.5 milliamps) and has the added

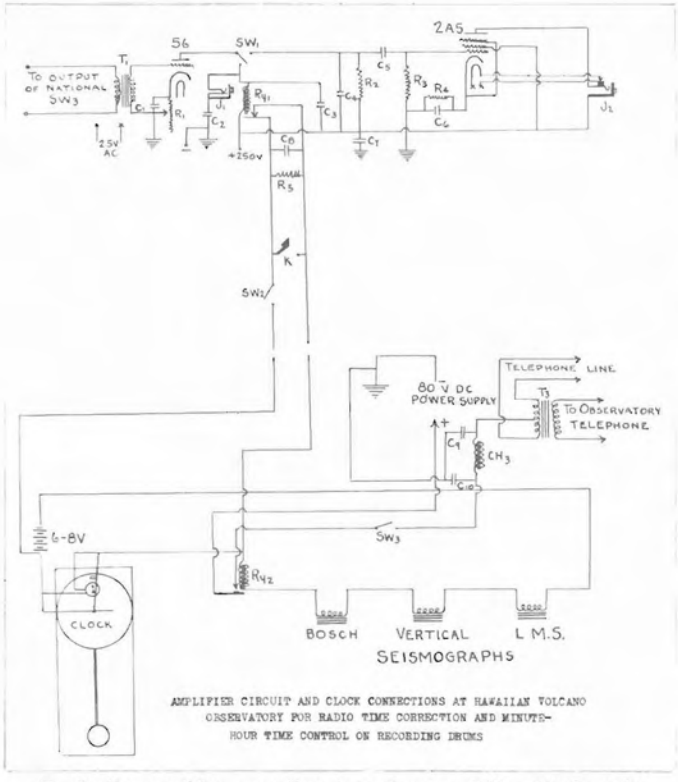


TIME CONTROL STATION AT THE HAWAIIAN VOLCANO OBSERVATORY

1. Observatory repeating coil; 2. Test telephone set; 3. Anne-mometer switch; 4. Sensitive time relay connected to radio receiver; 5. Loud speaker; 6. 50-watt ballast bulb in series with power transformer; 7. Power unit and rectifier for operation of time control system; 8. Power and amplifier unit for radio receiver; 9. National SW3 radio receiver; 10. Key for manual control of circuits; 11. Wave band coils for radio receiver.



B—50-watt electric light bulb; CH_1, CH_2, CH_3—Filter chokes (receiver type); CR_1, CR_2—Double sets of 800-Ohm telephone ringer coil; CR_3—Ringer coil on Uwekahuna telephone; T_2—Power transformer 250-250 secondary and 5 V for rectifier; T_3, T_4, T_5—Repeating coils; Ry_2—Relay of low resistance in Observatory circuit; Ry_3, Ry_4, Ry_5—1250-Ohm relays at seismograph stations; SW_3—Single pole, single throw switch for cutting off phantom circuit; $C_9, C_{10}, C_{11}, C_{12}$—8 mfd filter condensers; R_6—50,000-Ohm bleeder resistor; R_7—5000-Ohm wire wound variable impedence (not found necessary).



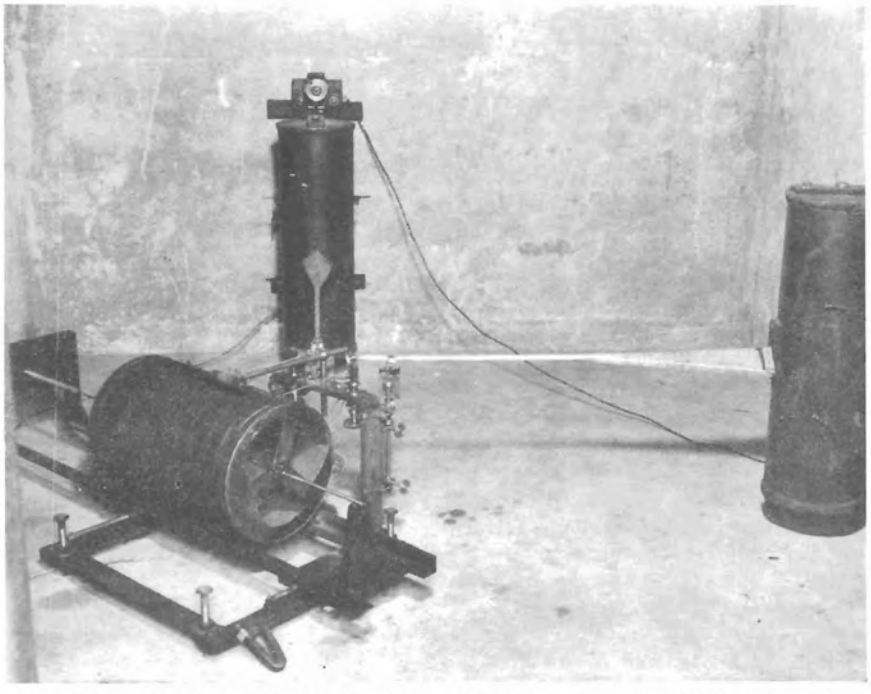
AMPLIFIER CIRCUIT AND CLOCK CONNECTIONS AT HAWAIIAN VOLCANO OBSERVATORY FOR RADIO TIME CORRECTION AND MINUTE-HOUR TIME CONTROL ON RECORDING DRUMS

T—Audio-amplifier, coupling transformer; SW_1—Single pole double throw toggle switch; J_1, J_2—Jacks for connecting speaker; C_1—4 mfd; C_2—0.2 mfd; C_3—0.1 mfd; C_4—0.002 mfd; C_5—0.1 mfd; C_6—10 mfd; C_7—0.25 mfd, relay sparking filter; C_8—0.5 mfd; R_1—50,000-Ohm potentiometer DC component control; R_2—30,000-Ohm 1 watt carbon; R_3—75,000-Ohm 1 watt carbon; R_4—300-Ohm 2 watt carbon; R_5—500-Ohm 1 watt carbon relay sparking filter; Ry_1—Home-made relay 2500-Ohm; K—Key for manual operation; SW_2—Single pole single throw switch to disconnect amplifier from clock; SW_3—Single pole single throw switch to disconnect power from telephone line; C_9, C_{10}—8 mfd electrolytic filter condenser; Ry_2—Relay operated by clock circuit, closes time circuit to other stations; T_3—Repeating coil.

advantage of having readily replaceable coils of which there always are some in stock as the Hawaii National Park keeps a supply for replacement purposes in their telephones.

The U. S. National Park Service, for purposes of protection and convenience, operates its own telephones and necessary lines in the Park. There is a small exchange at Park Headquarters through which are connected three trunk lines, all of which are metallic, that is, two wire and ungrounded. One line is connected to the Observatory and also serves the southern part of the Park, including Halemaumau. A second line serves the Park employee, residential area and the third line serves Uwekahuna Museum, the Hotel, Military Camp and the Mauna Loa line extending to the summit. For some time these lines had been thought of as potential connecting links between the seismograph stations with direct time control from the Observatory clock. A plan was evolved using center tapped resistors across the line, one at the Observatory and one at the Pit seismograph station. This would produce a phantom circuit on the metallic line with a ground return. A relay was to be activated by the clock simultaneously with the Observatory seismographs. The contact circuit of the relay would then be made to send a direct current of sufficient voltage over the phantom circuit to operate a relay at the Pit station. Theoretically this circuit would not interfere with the telephone circuits as the current on the metallic line would be balanced and moving in the same direction over the lines. Before trying this arrangement Mr. L. W. Branch, local manager of the Mutual Telephone Company, was consulted. His opinion was that such a circuit would be effective but recommended the use of standard telephone repeating coils instead.

In December two of the repeating coils were purchased from the telephone company. One of these was placed in the Observatory and the other was placed at the Pit and connected as indicated in the accompanying diagram. Ninety volts of "B" battery were the source of power. The trial was successful in that the time was transmitted and synchronized with the Observatory. However, it was discovered that each time the circuit was closed or opened, an unbearably strong popping noise was heard on all phones on that line or others connected through the switch-board. A filter circuit consisting of the conventional 8 mfd condenser—filter choke and 8 mfd of condenser inserted in the phantom alleviated the situation so that the phones were usable; but this did not completely clear up the situation. The lines were undoubtedly either unbalanced or one wire was grounded. Furthermore, the batteries soon become exhausted. As batteries were short-lived and therefore impractical a power pact similar to those used regularly on radios was constructed. This was connected to the regular 110-volt A.C. power. The transformer was that from an old radio receiver and an 80 rectifier tube was used. A 50-watt electric light bulb was hooked in series with the primary of the transformer as an indicating device and safety precaution in case any of the circuits should become shorted. The flash of this bulb every minute showed that the circuit was operating and continuous bright glow of the bulb showed that something was wrong with the circuit. When the high voltage power was idling and only the filament current for the rectifier



MAUNA LOA SEISMOGRAPH STATION SHOWING LARGE DRUM FOR 48-HOUR CONTINUOUS OPERATION. N-S COMPONENT TO RIGHT; E-W TO LEFT.

tube was being drawn, only a dull red glow showed from the bulb in the darkness.

For about three months the test circuit operated consistently but the disturbance to the phones, though not bad, continued. Finally the relay at the Pit stopped. Current tests showed that the line drew 150 milliamperes. It was evident that at least one line was shorted. A careful check showed that the short was at a place near the Pit station, where insulation had been worn from a wire running through a portion of the line which had been put in a pipe below ground. Correction of this fault cleared the telephones of all noise and the relay responded vigorously. The trial circuit was then a complete success and the Pit station was considered permanently time-coupled to the Observatory.

The problem was now to add the Mauna Loa and Uwekahuna stations to the circuit. This could be done by putting repeating coils at the switch-board terminals of the Observatory-Pit line and the Mauna Loa line. A repeating coil with one side of the transformer burned out was available in the Park. Cost of more transformers made them impractical. The burned out transformer was placed at the Pit and the good side used. The transformer from there was transferred to the Mauna Loa station. To offset the lack of repeating coils at the switchboard two sets of two 800-ohm ringer coils were used. One set was connected across the Mauna Loa line and the other set across the Observatory line. The two coils in each set were connected in series. This connecting wire was equivalent to a center tap so a jumper was connected from the link on one pair of coils to the link on the other. This made a phantom circuit path for the time signal whether the two lines were directly connected through the switchboard or not. Effective resistance across the metallic line was that of two telephones at 1,600 ohms each, but offered only a total of 800 ohms in the timing circuit. The relays at the Pit and on Mauna Loa had 150-ohm coils. They were replaced by 1,250-ohm telephone ringer coils. This made them much more sensitive and reduced current consumption materially and even allowed for considerable current loss through line leakage in wet weather or from other causes.

A third relay patterned after the one at the Pit was installed at Uwekahuna. No more repeating coils were available so the phantom circuit was tapped from the connecting link between the two ringer coils on the regular Uwekahuna telephone. This was found to be a satisfactory arrangement with the relays responding consistently and without interfering in any way with the telephone service.

With the telephone lines clear all three relays in the circuit operating and a 50-watt bulb in series with the power transformer primary, the current drawn is 60 milliamperes at about 80 volts.

The results have been very gratifying. The only interruption was caused by an accidental short on the line to Mauna Loa by linemen placing a grounded cable against a guy wire which in turn was bent across a service line. When this short was in existence, the Mauna Loa and Uwekahuna relays responded only when the switchboard was connected through from 4:00 pm to 8:00 am, daily. A few days before the short was discovered, all the relays were out of operation. Since this trouble was cleared up the circuit has performed perfectly.

No careful studies have been made of the results on the seismograms yet, but preliminary observations indicate that the arrangement is extremely worthwhile and gives direct time correlation for the entire circuit. Extra work involved in making time corrections has been eliminated and the uncertainty of S-P values has been corrected.

The remaining problem now is to obtain accurate time correlation for the Hilo and Kona stations. Specially designed semi-automatic radios have been requested and it is hoped they will be available in the near future. There will be much value and satisfaction to a completely coordinated set of seismograph stations. When this is accomplished accurate travel times for the area may be determined and possibly more knowledge obtained of the underground structure in Hawaii.

Hawaiian Volcano Observatory Report for April-June 1939

VOLCANOLOGY

April 1939

The Volcanic Observatory recorded a cold and rainy April, with low seismicity and some Halemaumau slides. A rock slide from the northwest wall of Halemaumau occurred at 9:50 a.m. April 5 and several unusually large newly fallen boulders were seen at the foot of the northeast talus at 10:00 a.m. April 7. On April 16 a slide from the southwest rim at 9:32 a.m. continued for about five minutes. It left a mark on the Pit wall and produced tremor at the Halemaumau seismograph. Marks on the Pit walls indicated other slides.

Crack measurements at the twenty-eight marked localities around Halemaumau showed decline from the measurements of March during the first week of April, there was increase of opening the second week, and thereafter the crack movement notably declined and for the whole month there was strong decrease of crack-opening.

Mauna Loa was visited by the northeast trail April 20, and no visible changes in the conditions of that volcano were observed.

Of the sixty-six shocks and tremors registered on the seismographs for April, fifteen were located by seismometric method, and of these eleven were under Kilauea mountain, three were Mauna Loa and one was Hualalai.

The following are the local data for April:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
April 9	2	6.0 mm.	19
" 16	1	10.5 mm.	16
" 23	0	3.0 mm.	18
" 30	0	2.5 mm.	13

May 1939

The month of May appears to have been strongly seismic and volcanic all over the world with press reports of a destructive earthquake in Japan and of increase of volcanic activity in Alaska, Costa Rica, Italy and Java. Hawaii showed steady increase of numbers of earthquakes reaching a peak of seismic activity May 31 with three strongish shocks near Hilina Pali and Kilauea. Exceptionally strong tides with high waves altered the black sand beach at Kaimu May 19 and 20, measured cracks near Chain-of-Craters road both opened and closed, relative height of the road humps on this road increased, and slides occurred at Makaopuhi, Devil's Throat and Hilina Pali.

Rock slides occurred in Halemaumau at northwest rim 8:47 a.m. and 9:02 a.m. May 3. At 12:47 p.m. May 11 a slide fell from the northwest wall. The strongish earthquake of 10:27 a.m. May 15 was accompanied by slides from the northern and western walls 10:28 a.m. and 10:29 a.m. Sliding at northwest wall occurred 11:23 a.m. May 15. Along

with earthquakes approximately fifteen slides occurred in Halemaumau as follows:

May 23, southwest wall, 2:14 and 2.31 p.m. ;
24, northeast and northwest rims 1:11 p.m. and north rim 2:30 and 5:50 p.m.;
26, north wall, 8:17, 8:20, 8:40 a.m. and 4:29 p.m.;
27, northwest rim, 2:20 and 2:40 p.m.;
28, northern rim, 8:38, 8:59, 10:15 and 11:05 a.m.

At Makaopuhi Crater a scar indicating fresh slide from the north rim was seen on May 5, and the Devil's Throat continues to fracture and break away along the west and north rims. Several slides from the cliffs in the Hilina Pali region occurred about 2:05 p.m. May 18.

Of one hundred eighty-four seismic disturbances twenty-three indicated place of origin. Of these, six were from Kilauea, six from Hilina Pali and six from Mauna Loa. One each was from Hualalai and Chain-of-Craters. One was near Honolulu, one west of Maui and one from Mountain View.

The following are the local data for May:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
May 7	2	7.5 mm.	12
" 14	1	3.5 mm.	38
" 21	3	13.0 mm.	39
" 28	15	8.5 mm.	95

June 1939

After the second week of June the seismic activity dwindled. The maximum of the different types of activity, including seismic frequency, was the second week of June, but the greatest intensity of quaking had been at the end of May. A strongish shock occurred June 12 and another June 19, both fairly deep under Kilauea; a peculiar shock June 24 was like a blast, of shallow origin under the northeast rim of Kilauea crater. Of late, Veniaminof has been active on the Alaskan peninsula, Poas and Irazu volcanoes in Costa Rica, Vesuvius excited some press report, and so did Krakatoa. Eleven distant earthquakes have been registered from New Caledonia, northeastern Asia, Solomon Islands, Lower California, Aleutian Islands, Tonga Islands, and a near shock about ninety miles from us.

Rock slides at Halemaumau were reported June 7, north wall, 12:53 p.m.; June 8, northern walls, 12:53 p.m.; and from northwest wall on June 9; June 14 a slide wth large boulders from high up west wall 3:25 p.m. Dust clouds indicated slides at northwest wall June 12, 1:36 p.m.; June 16, 2:12 and 2:13 p.m. A slide from northwest wall was reported June 26 11:15 a.m.

That the working of the fault benches southeast of Kilauea is a distributed movement was shown by discovery June 12 of a fresh landslip on Pali Lele O Kalihipaa four miles south of the center of Kilauea.

Of a total of three hundred thirty-seven local seismic disturbances in June, thirty-one had their centers located, of which twenty-two were under Kilauea, five along Chain-of-Craters, three at Hilina Pali and one between Kilauea and Hilo. It is remarkable that Mauna Loa and Hualalai were not heard from. There was some seismic activity near Maui.

The following are the local data for June.

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
June 4	0	8.5 mm.	36
" 11	3	10.5 mm.	124
" 18	8	4.5 mm.	88
" 25	0	4.0 mm.	58
July 2	1	5.5 mm.	31

T. A. J.

SEISMOLOGICAL AND GEODETIC DATA

Earthquakes

Date	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Distant*	Weekly Seismicity†
April 9	16	3	0	0	0	1	5.50
" 16	11	3	0	2	0	0	8.25
" 23	15	3	0	0	0	3	5.25
" 30	10	3	0	0	0	1	4.00
May 7	11	1	0	0	0	1	3.25
" 14	35	2	0	1	0	1	11.75
" 21	34	4	0	0	1	0	14.50
" 28	85	7	0	1	2	0	33.75
June 4	28	5	0	1	2	1	17.50
" 11	102	21	1	0	0	2	37.00
" 18	72	12	1	2	1	0	33.00
" 25	49	6	0	2	1	0	23.25
July 2	30	0	0	0	1	0	11.50

* Including teleseisms or earthquakes over 5000 km from Kilauea.
† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

April 4, 9:03 pm, very feeble, probably originated near center of Kilauea Crater.

April 5, 3:04 am, very feeble, 3.0 miles deep, Kilauea near W rim of Halemaumau (SW rift). 19° 24.6'N; 155° 17.8' W.

April 6, 9:09 pm, very feeble, Mauna Loa NE rift near Puu Ulaula.

April 12, 4:18 am, slight, 18.0 miles deep NE slope of Kilauea about midway between the crater and Glenwood. 19° 27.0' N; 155° 14.0' W. Reported felt in Hilo, Olaa and Hawaii National Park.

April 13, 2:53 pm, very feeble, probably originated in Twin Craters area E rim of Kilauea Crater.

April 15, 9:48 pm, slight, felt by many persons in Hawaii National Park. Located 1.3 miles deep in Kilauea Crater, NE rim of Halemaumau. 19° 25.0' N; 155° 16.9' W.

April 16, 6:14 pm, very feeble, probably originated in Hilina fault system S of Makaopuhi Crater.

April 16, 10.57 pm, very feeble, probably of shallow origin near center of Kilauea Crater.

April 17, 1:08 pm, very feeble, of Kilauea Crater origin, near center.

A shock was reported felt in Hilo at 10:24 pm, April 17. This corresponded with the registration time of a tremor at the Observatory. It apparently originated 13.0 miles from Hilo in the NE rift of Mauna Loa.

April 20, 6:42 am, very feeble, Kilauea Crater near NE rim of Halemaumau.

April 20, 8:49 am, very feeble, NE portion of Kilauea Crater.

April 24, 2.51 pm, very feeble, Kilauea SW rift about 18.0 miles from Kilauea near sea.

April 25, 2:21 am, very feeble, 22.0 miles deep under Hualalai area. 19° 41.5' N; 155° 46.0' W.

April 29, 9:57 pm, very feeble, Mauna Loa NE rift, 5.0 miles deep and 5.0 miles NE of the summit crater. 19° 31.6' N; 155° 26.0' W.

May 1, 5:15 pm, very feeble, originated under Halemaumau.

May 8, 7:03 am., slight, probably originated in Hilina fault system about 20.0 miles deep and 4.0 miles S of Makaopuhi Crater.

May 11, 7:51 am, very feeble, probably originated 7.0 miles under Kilauea Crater.

May 13, a tremor at the Observatory recording at 3.32 pm corresponded with time of an earthquake reported felt in Honolulu.

May 14, 5:37 am, very feeble, of Kilauea Crater or Chain-of-Craters origin.

May 15, 10:28 am, moderate to strong, strongly felt over entire Island of Hawaii with exception of Kohala district. Probably most strongly felt in Hilo where there was slight damage to some masonry structures and plaster work. Also quite strongly felt in Hawaii National Park. Located 10.0 miles deep, 2.5 miles E of Makaopuhi Crater. 19° 22.0′ N; 155° 08.0′ W.

May 18, 8:48 pm, very feeble, 10.0 miles deep in Hilina Pali area, 4.0 miles S of Makaopuhi. 19° 19.0′ N; 155° 9.0′ W.

May 20, 2:05 am, very feeble, Kilauea Crater near NE rim of Halemaumau.

May 20, 10:18 am, very feeble, probable origin, Hilina fault system about 4.0 miles S of Puu Huluhulu.

May 23, 2:14 pm, moderate to strong, felt over entire Island of Hawaii and registered on University of Hawaii seismograph at 2h 16m 03s pm. All instruments at the Observatory except the strong motion seismograph were dismantled. Subsidiary stations at Hilo, Kona on Mauna Loa and around Kilauea Crater likewise were dismantled. Source of origin was apparently 7.5 miles NW of Kilauea Crater from a depth of 12.0 miles. 19° 28.5′ N; 155° 22.0′ W.

May 24, 12:59 pm, moderate to strong. Similar to quake of preceding day in that it was felt throughout Island of Hawaii and dismantled all seismographs except strong motion instrument at the Observatory. Registered at Unversity of Hawaii, Honolulu, "S" wave at 01h 00m 29s pm. Location 15.0 miles deep, 2.5 miles SE of Observatory, E rim of Kilauea Crater. 19° 25.0′ N; 155° 14.0′ W.

May 24, 1:09 pm, slight, probably same epicenter as preceding but possibly 5.0 miles deeper.

May 25, 3:39 am, very feeble, probably originated in Hilina fault system.

May 25, 8:54 am, very feeble, probable epicenter same as moderate shock of May 23, 2:14 pm.

May 26, 10:40 pm, very feeble, probable origin, Hualalai.

May 27, 4:29 pm, very feeble, probable origin, about 5.0 miles from Summit Crater, Mauna Loa, NE rift, about 8.0 miles deep.

May 28, 3:48 am, very feeble, probable origin, about 15.0 miles under Mauna Loa Summit Crater.

May 28, 6:34 am, very feeble, probable origin, Mauna Loa SW rift, 15.0 miles under area near 1907 source cones.

May 29, 7:15 pm, very feeble, registered on Honolulu seismograph "P" wave at 07h 15m 09s pm. Reported widely felt on Oahu and on Maui. Located 20-30 miles deep, 90.0 miles S of Lanai, 19° 30′ N; 156° 50′ W.

May 29, 11:45 pm, very feeble, probable origin, Chain-of-Craters near Devil's Throat.

May 31, 3:10 pm, moderate to strong, 11.0 miles deep in Hilina fault system, 8.0 miles S of Kilauea iki. Dismantled seismographs at Observatory and Pit but no others. 19° 18.5′ N; 155° 14.5′ W. This shock was peculiar in that there were no reports of it being felt. Members of the Observatory staff were conscious that earthquake was taking place through a special electric signal system, yet experienced no sensation of earth motion.

May 31, 8:38 pm, slight, felt in Hilo and Hawaii National Park, 12.0 miles deep, Mauna Loa NE rift, 13.0 miles SW of Hilo. 19° 37.5′ N; 155° 15.5′ W.

May 31, 8:51 pm, moderate to strong, reported felt throughout Kau and Hilo districts as well as other parts of Island of Hawaii but was particularly strong in Hawaii National Park and moderately so in Hilo. Location of source of origin, 11.0 miles deep, area 4.0 miles W of Mountain View. 19° 34.0′ N; 155° 10.5′ W.

June 2, 11:38 am, very feeble; Hilina fault system near SW rift was probable origin.

June 5, 2:06 am, very feeble, probable origin, under Kapoho area about 7.0 miles E of Pahoa, E extremity of Island.

June 5, 7:01 pm, very feeble, probably originated under sea floor off SE coast of Hawaii near Kalapana.

June 6, 4:07 pm, very feeble, 4.0 miles deep in Kilauea SW rift at Crater Junction. 19° 24.1′ N; 155° 18.0′ W.

June 7, 1:34 pm, very feeble, origin similar to that of moderate quake of 3:10 pm, May 31.

June 7, 10:47 pm, very feeble, NE portion of Kilauea Crater.

June 8, 10:45 pm, very feeble, 1.1 miles deep, 1.0 mile W of Puhimau Crater. 19° 23.6′ N; 155° 15.9′ W.

June 9, 2:25 am, very feeble, 3.0 miles deep, 0.5 mile NW of Pit seismograph station, Kilauea Crater. 19° 24.8′ N; 155° 17.1′ W.

June 9, 9:29 am, very feeble, probably of relatively deep origin, Hilina Fault system, 10.0 miles SE of Observatory.

June 9, 2:06 pm, very feeble, of shallow origin, cracks 0.7 mile N of Puu Ohale. 19° 21.9′ N; 155° 16.7′ W.

June 10, 5.41 am, very feeble, 1.1 miles deep, E rim of Kilauea Crater in vicinity of Kilauea iki. 19° 25.0′ N; 155° 15.6′ W. Felt slightly by a few persons in Hawaii National Park.

June 10, 10:10 am, very feeble, about 3.0 miles deep, 1.0 mile SW of Kamokukolau. 19° 22.5′ N; 155° 16.9′ W.

June 10, 8:51 am, feeble, 3.0 miles deep, about 0.5 mile W of Ahua Kamokukolau. 19° 23.0′ N; 155° 16.6′ W.

June 11, 11:18 am, very feeble, probable origin deep under Hilina fault system about 8.0 miles S of Observatory.

June 11, 10:45 pm, very feeble, 2.5 miles deep, about 2.1 miles W of center of Halemaumau. 19° 24.6′ N; 155° 19.0′ W.

June 12, 1:11 am, moderate to strong, 13.0 miles deep in Kau Desert area near Koae and Puu Ohale. Felt generally on the Island of Hawaii but apparently with greatest intensity in Hilo and Hawaii National Park areas. Dismantled Observatory, Pit and Mauna Loa seismographs.

June 12, 5.47 pm, feeble, 3.7 miles deep, 2.0 miles W of Pit seismograph under SW rim, Kilauea Crater. 19° 24.4′ N; 155° 18.5′ W.

June 12, 6:26 pm, very feeble, of shallow origin (0.5 mile ±), approximately 0.5 mile N of Uwekahuna. 19° 26.0′ N; 155° 17.4′ W.

June 13, 10:47 pm, very feeble, probably originated near SE rim of Kilauea Crater.

June 14, 1:04 am, slight, approximately 2.0 miles deep, Kilauea Crater between SE rim of Halemaumau and SE rim of Crater. 19° 24.5′ N; 155° 17.8′ W.

June 14, 2:06 am, very feeble, probably originated near SE rim of Kilauea Crater.

June 14, 6:27 am, very feeble, 2.3 miles deep, Kilauea SW rift near Cone Peak. 19° 23.7' N; 155° 18.5' W.

June 14, 10:02 am, slight, 2.1 miles deep, S rim of Kilauea Crater, 1.3 miles SE of Center of Halemaumau. 19° 23.6' N; 155° 16.5' W.

June 15, 3:18 pm, very feeble, 15.0 miles deep, S rim area of Kilauea Crater. 19° 23.5' N; 155° 15.5' W.

June 15, 5:46 pm, very feeble, probably originated near Kilauea iki.

June 16, 11:35 am, very feeble, Kilauea Crater origin near Halemaumau.

June 18, 5:12 pm, very feeble, of shallow origin near NE portion of Halemaumau.

June 19, 4:49 am, moderate, 15.0 miles deep in area E of Kilauea Crater approximately 2.0 miles SE of Observatory. 19° 25.3' N; 155° 15.0' W. Felt in Hilo and Hawaii National Park, where many persons were awakened. Dismantled E-W component of Bosch seismograph at Observatory and both components at Pit.

June 20, 4:10 am, very feeble, of shallow origin, Kilauea Crater near SE portion of Halemaumau.

June 20, 3:01 pm, slight, 13.0 miles deep, Puna rift near Makaopuhi. 19° 22.0' N; 155° 10.0' W.

June 24, 2:04 pm, slight, Bosch seismogram at Observatory indicated no S-P phase interval but began abruptly with "M" phase. In immediate vicinity of this station (Hawaii National Park headquarters) the shock was reported felt as a sudden vibration similar to that produced by nearby blasting. Many persons thought it actually was a heavy blast. On this evidence it was assumed the quake originated in the faulted area NE rim of Kilauea Crater. Examination of the Pit and Uwekahuna seismograms confirmed this assumption and the point of origin was so placed and considered of shallow origin. 19° 25.8' N; 155° 16.6' W.

July 1, 12:20 am, moderate, 11.0 miles deep, Chain-of-Craters near Puu Huluhulu and Alealea Crater. 19° 23.0' N; 155° 11.5' W. Reported felt by many persons in Hilo, where a large number were awakened. In Hawaii National Park the shock was reported felt as a prolonged and persistent swaying motion lasting 15 ± seconds. Here, too, a number of persons were awakened. E-W component of Bosch seismograph was dismantled as was the same component at Halemaumau.

Teleseisms

April 5, "P" waves began recording at 6h 21m 58s am, 3,755 miles from Kilauea. Reports from the Jesuit Seismological Association place the origin in the vicinity of New Caledonia. 27° S; 167° E.

April 17, unidentified portion at 8h 16m 33s pm.

April 20, "eP" at 6h 08m 17s pm, distance 3,630 miles. Jesuit Seismological Association reports 500 km deep, NE Asia. 48.6° N; 138° E.

April 21, "eP?" at 9h 42m 35s am, no distance determined and no reports from other localities received.

April 29, "eP" at 4h 34m 49s pm, distance 3,730 miles. Reports from U. S. C. and G. S. give origin as 11° S; 158° E. Solomon Islands.

May 2, "eS?", 3h 01m 26s am, U. S. C. and G. S. report—off coast of Lower California as place of origin. 29.5° N; 113.8° W.

May 9, "ePr?" at 9h 21m 27.0s pm, U. S. C. and G. S. location given as Aleutian Islands. 41° N; 179° W.

June 1, "iP" at 5h 15m 10s pm, no distance, no reports.

June 8, "eP" at 10h 24m 31s am, U. S. C. and G. S. reported location between Samoa and Tongas. 15° S; 173° W.

June 11, "eP?" at 5h 01m 13s ± am, no distance, no location reported.

On June 16, at 4:20 am, a tremor registered on the Observatory seismograph having the appearance of a near shock. Kona seismograms indicated a distance of 66 miles; the Mauna Loa seismograph indicated a distance of 93.0 miles.

Microseismic Motion

April

Light—10, 11, 13, 14, and 25.
Moderate—9, 12, 15, 16, 19, 21-24, 26-28.
Strong—3-8, 17, 18, 20, 29, 30.

May

Light—2, 6, 7, 19, 20.
Moderate—3-5, 8-13, 16-18, 21-31.
Strong—1, 14, 15.

June

Light—2-9, 13-16, 18, 21-30 inclusive.
Moderate—1, 10, 11, 12, 17, 19, 20.
Strong—None.

Time used throughout is Hawaiian Standard, 10h 30m slower than G. C. T.

Tilting of the Ground

The following tables show tilt by weeks recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum toward or away from the Pit as indicated by tilt stations on the W and SE rims respectively.

At the Observatory the total accumulated tilt for the year ending April 30, was 4.0" S and 5.35" W.

For the year ending May 28, it was 3.92" S and 4.75" W.

For the year ending July 2, it was 3.75" S and 2.6" W.

Table of Tilt

Week Ending	Observatory	Halemaumau West Station
April 9	1.61" S 83° W	1.85" N 5° E
" 16	0.93" N 72° E	3.73" N 87° W
" 23	0.25" N 83° E	1.49" S
" 30	0.47" S 60° W	2.53" W
May 7	0.45" N 22° E	6.11" N 69° W
" 14	2.19" S 61° W	7.09" S 79° W
" 21	0.92" N 73° E	11.62" S 64° W
" 28	0.31" N 25° E	15.44" N 41° W
June 4	0.43" N 19° E	3.37" S 85° W
" 11	0.48" N 36° E	3.99" W
" 18	0.17" N 45° E	11.18" N 72° W
" 25	0.88" N 11° E	4.41" S 50° E
July 2	0.42" N 21° E	11.62" N 48° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
April 9	6.48" N 63° W	5.97" toward
" 16	15.91" W	5.82" toward
" 23	15.31" W	9.09" toward
" 30	6.12" N 41° W	3.63" toward
May 9	4.99" N	1.62" from
" 14	5.67" N 21° E	3.93" from
" 21	12.15" N 40° E	7.96" from
" 28	16.20" N 86° W	1.59" toward
June 4	16.85" S 74° E	17.04" from
" 11	8.42" N 37° W	4.41" toward
" 18	1.72" S 41° W	10.46" from
" 25	2.75" N 11° W	4.75" toward
July 2	6.45" S 89° W	8.38" from

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory, April 15, indicated closing of both the Halemaumau and the Crater values compared with similar measurements of March 30. The Halemaumau angles between the Pit seismograph and the NW Pit BM closed 0.91". The crater angle between the SE crater rim station and Uwekahuna closed 1.16".

During May two determinations were made of the same angles. These were May 6 and 26. On May 6 the Halemaumau angle had opened 1.59" and the Crater angle had closed 1.17". Between May 6 and 26 the Halemaumau angle closed 0.34" and the Crater angle opened 0.75". Total change for the month, Halemaumau angle opened 1.25" and the Crater angle closed 0.42".

Angle values determined June 17 indicated closing of the Halemaumau and closing of the Crater angle. Halemaumau value decreased 3.33". Crater value decreased 0.38".

Total change at Halemaumau, March 30 to June 17, 2.99", closing; across Crater 1.16" closing.

Chain-of-Craters Road Cracks

Date	101	102	103	104	105	106	107
April 28	403.70	64.40	101.35	17'19/8	87.15	88.60	40.35
June 2	404.00	64.40	101.45	X	87.20	88.60	39.75
June 30	404.35	64.50	101.45	X	87.25	88.75	39.70
Total change in mm.	+ 6.5	+ 1.0	+ 1.0	——	+ 1.0	+ 1.5	—6.5

Plus (+) = open. Minus (—) = close.

In 104, near Pauahi was temporarily discontinued. Large size makes it difficult to measure but determinations will be resumed in near future.

There was no change between March 30 of last report and April 28 of this report.

It is obvious that these cracks were greatly accelerated in their openings during the month of May, when seismic activity likewise increased. Cracks around Halemaumau showed relatively large increase in same period. This demonstrates the probability that the cracks around Halemaumau, although greatly activated by gravity, are also moved by volcanic changes, i.e., seismic changes.

H. H. W.

THE VOLCANO LETTER

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Edward G. Wingate, Superintendent
Hawaii National Park

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

EXPEDITION TO LAVA-BOMBING SITE

T. A. JAGGAR

This expedition to the north slope of Mauna Loa was conducted by the volcanologist of Hawaii National Park in cooperation with the Territorial Department of Forestry and Agriculture. The scientific members of the party were T. A. Jaggar, L. W. Bryan and H. H. Waesche. Cordial assistance came from Parker Ranch through Joseph Ignacio, who prepared trail and camp ground at 7,000 feet elevation on the north slope of Mauna Loa. The objects were to photograph the exact spots where bombs fell to deflect the 1935 lava flow, to delimit the flow area, to note the bomb effects, to map some older flows and to start a campaign to study more closely Mauna Loa on its danger slope above Hilo.



Fig. 1—Bomb crater with upstanding edges and pahoehoe ring and torrent of released lava; Target 2, elevation 8,200 feet. Arrow shows crater. Photo by Jaggar.

Camp was made August 30, 1939; the Bryan party studied the middle of the flow September 1 and the source region at 8,900 feet September 2. The Jaggar party joined them, and mapped and photographed the bomb craters September 3 and 6, taking color and monochromatic pictures. On September 5 a study was made of the 1899 flow about 8,000 feet, and on September 7-8 a heavy black aa flow in contact with the 1935 flow on its east side was found to be very fresh and to check perfectly in age and position with the western 1880 flow, **never hitherto mapped,** but described succinctly by Coan, Baker and Hitchcock as sweeping from Puka Uahi twelve miles towards Mauna Kea the first week of November 1880. This becomes of very great importance in studying the source of the 1935 Humuula flow that was bombed, for the 1935 outburst was between this relatively recent flow and the 1843 flow and was guided by the depression between them. The contact between the aa lavas of this 1880 branch and 1935 was found, 1935 red and free from vegetation, 1880 black with some lichens and with large concretionary "snow-ball" boulders on its surface (Figure 8).

The exploration of the bomb craters was started by Forester Bryan and carried forward by Dr. Jaggar, Mr. Waesche and Ranger Jess, so that most of the twenty demolition bombs dropped by the army squadrons were accounted for in the mile of lava-source cracks and tunnels between Target A and Target B. (See Volcano Letter 442.) Fragments of shrapnel, rusty red, were found in profusion; several of the "pointer" bombs of black powder and sand were discovered; one large "dud" bomb was found with end torn off and several hundred pounds of TNT exposed (Figure 3); and pieces of casing, vanes, covers and detonator tubes were picked up (Figure 6). The pointer bomb casings contained Hilo beach sand. The TNT was lighted and burned, first piecemeal, then as a whole with a newspaper fuse, while the party retreated down the mountain. After twenty-five minutes of flame and black smoke, the remains of the explosive were detonated by the fire perhaps reaching the war-head mechanism, and a quarry blast ended the perform-



Fig. 2—Bomb crater in old lava; near Target 1, elevation 8,800 feet. Photo by Stearns.

ance. The place was revisited and photographed by Mr. Jess, who found a 3-foot depression, and fragments 100 feet away.

About sixteen of the bomb-holes were identified, one a perfect oval one hundred feet long by forty feet wide, crowned by a ring of upturned fragments of the rim, the interior a pit forty feet deep to a lava tunnel below. Liquid lova had splashed up and out in great sheets and gushes of molten glass. Seventy-five per cent of the holes found had exposed liquid lava. Four holes were off the stream line and in pairs, making bomb craters of broken rock (Figure 2), circular soucers twenty feet across and six feet deep.

In one case melted glass clung to shell fragments. In another a winged bomb had plunged through a thin crust, possibly into liquid lava (Figure 4), and was intact, its nose exposed protruding down into a tunnel below. Great blobs of glassy lava lay on the surface of pahoehoe silvery tongues, where explosions had flung them high. Rivers of liquid lava had escaped from some of the deep tunnel punctures, where the explosion had opened the tube. Other places had halos fifty or sixty feet wide, platforms of black glass, around an immense circular hole, where the bomb had released an artesian well of lava. The edge of the hole was scalloped like a tiara (Figure 4). The upper Target A was thickly strewn with pieces of rusty steel, from a quarter-inch to ten inches across, thin and thick, terribly jagged shrapnel torn from the big 600-pound shells like so much pasteboard.

The source region one mile below its upper limit had been studied by Jaggar and Waesche on foot in March 1936. They had found the lower bomb-craters, recognized the slabs and upwellings, but had not found any iron fragments. The actual source at Target A is a channel twenty feet across bordered by a bank of froth lava, meandering slightly, and lined



Fig. 3—Demolition bomb fragments with protruding TNT; near Target 1. Photo by Waesche.



Fig. 4—Pointer bomb of black powder near Tarket 1 with nose in cavern beneath; and Forester L. W. Bryan. Photo by Jaggar.

by a glassy pahoehoe floor, with windows revealing frozen streams and tunnel beneath. This channel begins abruptly at a ten-foot inclined shaft and transverse cracks. Up the mountain is a hill or flow-front of pasty-mixed lava of non-identifiable age. Down the mountain the torrent flowed in the channel, sometimes on the surface, sometimes deep in a tube. Mostly the margins are silver pahoehoe, but aa patches occur. Farther down a gush of pahoehoe begins and spreads in a fan. This is repeated five times in three miles. Underneath all this is a flow of aa. Down at Humuula the pahoehoe gushes unite at a river bending into a lake. They bend around the front of two large feather-shaped deltas of the aa of mid-December, 1935.

A striking feature of the bombed area was the existence upstream from some bomb-holes (Figure 5), of tunnel-openings where pudgy, pasty, stiff semi-aa lava welled up as a heap or pudding. The smashing of the tunnel had cooled the oncoming liquid so that it dammed itself. This confirmed the theory that the bombing solidified the tunnel lava back into the heart of the mountain. With twelve river hits out of sixteen, and liquid flung up hundreds of feet, there can be no question whatever that the bombing stopped the flow. The tunnels farther down the hillslope from the artificial damming were full of liquid which poured on for a week. But the bombardment of the river targets had cooled, dammed, solidified and freed from gas an enormous volume of slag, which froze where it lay, and the

very smallness of the natural vents proves how large was the artificial effect of this human achievement. The whole flow was in a single pipe, and the collective bomb craters were much bigger than that pipe. The pipe was a natural sewer tunnel twenty to forty feet underground and ten to fifteen feet across. A single one of sixteen bomb punctures was eighty feet across and forty feet deep to the roofed-over flow. No slag-stream full of gas could take such a bombardment, flinging up its substance, with several tons of high explosive, distributed along a mile of stream-way, and fail to thicken and solidify.

The source stream of the Humuula flow when active, at elevation 8,900 feet, glowed and steamed in a line of vents that were pahoehoe where the lava emerged, and this heap was visited by Ranger G. E. Olson, Philips and Ignacio November 25, 1935, as is shown by the photograph, Figure 7. An air photograph by Dod at the same period shows that the line of vapors ended abruptly against older dark lava uphill. This was the lower glow-spot, Figure 5, Volcano Letter 429, and the upper limit of bombed stream, Volcano Letter 442 frontispiece. The conclusion is that this channel and tunnel was a crack in the mountain that vomited out the Humuula flow of 1935, and that the dark lava uphill is part of the cold 1880 torrent. The line of vapors and glows ended against this older lava, and the crack beneath emerged downhill from it but did not break it.

The event was on December 27, 1935, when the front of the lava flow was pushing toward Hilo a mile a day, twelve miles from the city, and fifteen miles downhill from this source tunnel. The United States Army Air Corps all day long bombed the two targets of the source tunnel from the air. The next day the front slowed down, and five days later it stopped.

This camping trip of a week shows that the scientists can live in the high lava of Mauna Loa in comfort, that the danger



Fig. 5.—Pasty lava plug welled up, as result of bomb damming, in main stream tunnel; Mauna Kea in distance; Target 1. Photo by Jaggar.



Fig. 6—Miscellaneous fragments of bombs and vanes collected. Photo by Cunningham.

slope above Hilo can be critically studied with new markers and air photographs, and with the proposed barriers for deflection of the most rapid flows that may rush to the sea near Hilo, we can eventually, if supported with men and trails and additional upper Mauna Loa lands in the Park, make the inhabitants of this fair land take pride in their defense against volcanoes.

Hawaiian Volcano Observatory Report for July-September 1939

VOLCANOLOGY

July 1939

Halemaumau had few rock slides, but the month showed uneasy working of fault blocks on Chain of Craters, and at Hilina Cliff south of Kilauea fresh avalanche scars were found July 13. A strongish shock July 14 originated there five miles underground. Three slides on Hilina Cliff July 25 occurred about 4:20 p.m. A slide from the northwest wall of Halemaumau July 30, 11:30 a.m., made a cloud of dust.

The cracks parallel to Halemaumau rim, of which 28 are measured weekly, showed aggregate closing for the first and third weeks of July, a condition not recorded since October, 1938. It is of interest that Chain of Craters measured fault cracks, four miles southeast, also closed for these weeks.

Sulphur fume was reported July 7 on Mauna Loa trail as an odor one mile below 1935 cone. Fuming in Halemaumau bottom has decreased, but was observed at the stain southeast the second week, and on July 28.

Messrs. Bullard, Schulz and others camped at Mokauweoweo rest house, summit of Mauna Loa, July 20-21. Abundant fumes were found on the crater floor, heat was rising from the summit part of 1935 rift northeast, and sulphur was being deposited in cavities on southwest flank of 1935 cone at 11,000 feet.

The numbers of local and distant seismic disturbances recently, by months, have been:

	Local	Distant
April	66	5
May	184	3
June	337	3
July	203	3
August	287	2
September	101	1

The swarm of June-July is evident, but the July disturbances were mostly tremors. Sixteen Kilauea shocks and five from Mauna Loa were located for July, two of the latter 35 miles deep. A distant earthquake of July 6, 3,550 miles away, was reported as 550 km. deep between Fiji and Tonga.

Of the 203 shocks and tremors of local origin registered on the seismographs for July, 21 were located by seismometric method, and, of these, 10 were under Kilauea crater, 5 were under Mauna Loa, 3 under Kilauea rifts, and 3 at the Hilina Cliffs.

The following are the local data for July:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
July 9	0	3.0 mm. closed	40
" 16	0	7.5 mm. opened	56
" 23	0	2.0 mm. closed	70
" 30	1	3.5 mm. opened	37

August 1939

The month at Kilauea crater exhibited some movement in the Hilina-Chain of Craters fault blocks which border the Kilauea rift on the southeast. (See map Volcano Letter 462.) A roadside crack at the edge of Aloi pit opened 2 feet in an hour of the early afternoon August 2, and extended 20 feet in depth. The motion did not continue.

The next event was a swarm of earthquakes about August 17, several of them felt, centering at the Hilina Pali fault system, including greatly increased frequency of very feeble movements and tremors.

A remarkable feature of this period, enduring for two weeks, was cumulative closing instead of opening, of the 27 concentric rim cracks around Halemaumau edge which are measured once a week. On the week ended August 18, of the rim cracks 19 closed, 8 were unchanged, and none opened, with aggregate closing of 15 millimeters. Along Chain of Craters, also, the measured cracks showed temporary closing of 8.5 millimeters. As these measurements were made the day after the Hilina disturbances, and the following week showed restorative opening of cracks, it appears that the fault movements caused this unusual compression normal to the fault planes, and both Halemaumau and the Chain of Craters took the squeeze, as both are on the major Kilauea rift.

Of two distant earthquakes both in New Hebrides region, 3,270 and 3,500 miles away, August 11 and 17, the second coincided in date with the moderate local earthquakes, preceding them by about six hours.

Slides in August were observed as follows:

August 2, 10:20 a.m., at north wall of Pauahi Pit;
" 2, 10:00 a.m., west wall Halemaumau, small;
" 6, Kilauea Iki scars north wall;
" 15, north wall Halemaumau, 11:19 a.m.;
" 17, scars in Pauahi crater.
" 20, north wall Halemaumau, 3:17 p.m.;
" 27, dust streaks north and west walls Halemaumau.

Of the 287 local shocks and tremors counted on the seismograms for August, 20 were located, and of these 7 were from Hilina Cliffs, 6 from Kilauea crater, 3 from Mauna Loa, 1 each from Kilauea southwest rift, Kona, Kohala and Hualalai.

The following are the local data for August:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
August 6	1	2.5 mm. opened	57
" 13	0	1.5 mm. closed	50
" 20	2	15.0 mm. closed	86
" 27	0	11.0 mm. opened	52
Sept. 3	0	5.0 mm. opened	42

September 1939

For six weeks following August 20 the decline in local earthquake frequency, and in numbers of tremors that determine technical seismicity, was steady and progressive. There were some feeble earthquakes felt that preceded equinox. Nothing volcanic was remarkable. An earthquake near Kamchatka under Bering Sea occurred September 8, 2,800 miles from Kilauea station.

Slides in September were observed as follows:

September 8, 12:40 and 12:59 p.m., northwest wall Halemaumau;
" 29, 10:33 a.m., north rim Halemaumau;
" 29, fresh fall of debris in road crack Pauahi Pit.

There was gradual movement detectable along the fractured rim of Devil's Throat, and humps in the road increased slightly between Hiiaka and Aloi pits. Blue fume is notably less at Halemaumau. Gas collections were made by Dr. Ballard of the University of Hawaii in Mokuaweoweo September 14. The three members of the expedition felt a sharp earthquake on the Mauna Loa crater floor at 10:07 a.m. of that date. This registered as a tremor at Kilauea seismographs.



Fig. 7—Pahoehoe steaming heap with glow-hole in foreground, November 25, 1935, at 8,900 feet elevation, Humuula. Photo by Olson.

Of the 101 local shocks and tremors recorded in September, 16 were located, and of these 6 were from Kilauea crater, 4 from Mauna Loa, 3 from Kilauea rifts, 2 from Hualalai, and 1 from Hilina Cliff region.

The following are the local data for September:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
September 10	2	2.0 mm. opened	39
" 17	0	1.5 mm. opened	28
" 24	0	3.0 mm. opened	19
October 1	1	2.0 mm. opened	15

T. A. J.



Fig. 8—Concretion balls on supposed 1880 lava. Photo by Jaggar.

SEISMOLOGICAL AND GEODETIC DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Distant*	Weekly Seismicity†
July 9....	34	4	1	1	0	1	13.50
" 16....	48	7	0	0	1	0	19.50
" 23....	66	4	0	0	0	2	18.50
" 30....	33	4	0	0	0	0	10.25
August 6....	50	6	1	0	0	0	17.00
" 13....	46	2	2	0	0	1	14.50
" 20....	66	16	1	1	2	1	35.50
" 27....	50	2	0	0	0	0	13.50
September 3....	36	5	1	0	0	0	12.50
" 10....	35	3	1	0	0	1	11.25
" 17....	22	4	2	0	0	0	9.50
" 24....	16	3	0	0	0	0	5.50
October 1....	13	2	0	0	0	0	4.25

* Including teleseisms or earthquakes over 5,000 km from Kilauea.
† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the station operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

July 5, 12:20 am, slight, 12.0 miles deep in Hilina Pali area 2.5 miles S of Makaopulii 19° 20.2′ N., 155° 10.2′ W. Felt slightly in Hilo and by a few persons in Hawaii National Park.

July 7, 5:46 pm, very feeble, probably originated in SE rim area of Kilauea Crater.

July 7, 7:23 pm, very feeble, probably originated in SE rim area of Kilauea Crater.

July 7, 8:04 pm, feeble, probably originated in E rim area of Kilauea Crater.

July 8, 3:32 pm, very feeble, probably originated Kilauea SE rift near Kalapana.

July 11, 5:51 pm, very feeble, of Kilauea Crater origin.

July 12, 11:30 pm, very feeble, of Kilauea Crater origin.

July 14, 3:51 am, moderate to strong, 5.0 miles deep, Hilina fault system about 5.0 miles SE of Makaopuhi. 19° 19.5′ N; 155° 07.0′ W. All instruments at the Observatory were dismantled with the exception of the strong motion seismograph. The quake was generally felt on the island with the greatest internicity centered in the Kau-Puna area. Most sleepers were awakened in Hawaii National Park and in Hilo. Reported unusually strong at Pahoa.

July 15, 9:46 pm, very feeble, of shallow origin in Kilauea Crater E of Halemaumau.

July 16, 7:14 am, very feeble, about 35.0 miles deep, Mauna Loa NE rift, 13.0 miles NE of Summit Crater. 19° 33.5′ N; 155° 25.5′ W.

July 16, 3:57 pm, very feeble, probable origin Hilina Fault system about 3.5 miles S of Makaopuhi Crater.

July 19, 11:38 am, very feeble, 1.5 miles deep, Chain of Craters, near Puhimau. 19° 23.6′ N; 155° 14.9′ W.

July 19, 10:15 pm, very feeble, 1.4 miles deep, 1.3 miles W of Hiiaka Crater. 19° 22.6′ N; 155° 15.1′ W.

July 21, 9:04 pm, very feeble, Mauna Loa NE rift about 12 miles SW of Hilo.

July 25, 11:00 am, very feeble, originated about 1.7 miles NW of Volcano Observatory, 4.2 miles deep. 19° 26.9′ N; 155° 16.3′ W.

July 25, 11:45 am, very feeble, 35.0 miles deep, Mauna Loa NE rift, 16.0 miles NE of Summit Crater.

July 27, 2:02 am, very feeble, 23.0 miles deep on W slope of Mauna Loa, 14.0 miles W by S of Mauna Loa Summit Crater. 19° 26.0′ N; 155° 48.0′ W.

July 28, 5:12 pm, very feeble, probably originated in Kilauea Crater 1.3 miles SW of Observatory.

July 31, 8:58 am, very feeble, of shallow origin Mauna Loa NE rift 16 miles from Summit Crater.

July 31, 8:18 pm, very feeble, probably originated in Kilauea Crater near Halemaumau.

July 31, 8:21 pm, very feeble, of shallow origin, Kilauea Crater rim area near Kilauea Iki. 19° 25.1′ N; 155° 15.3′ W. Reported felt by few persons in Hawaii National Park and dismantled NS component of Pit seismograph.

August 4, 3:16 pm, very feeble, of shallow origin near S rim of Keanakakoi Crater. 19° 24.1′ N; 155° 16.0′ W.

August 4, 11:56 pm, very feeble, 2.2 miles deep, 4.0 miles NW of the Observatory. 19° 28.5′ N; 155° 18.8′ W.

August 5, 1:46 pm, very feeble, 8.0 miles deep, 5.0 miles SW of Kailua. 19° 31.0′ N; 156° 02.0′ W. Reported felt at Holualoa and Hookena.

August 6, 5:09 pm, very feeble, origin was 40.0 miles under Hualalai. 19° 41.5′ N; 155° 35′ W.

August 7, 7:19 am, very feeble, probably originated under N rim area of Kilauea Crater.

August 8, 4:32 am, feeble, originated in Hilina Fault system, 3.0 miles N of Apua Point, 6.0 miles deep. 19° 18.0′ N; 155° 11.5′ W. Reported felt in Hilo.

August 8, 6:50 am, feeble, 10.0 miles deep in Hilina Fault system 4.0 miles S of Makaopuhi. 19° 19.0′ N; 155° 10.0′ W. Reported felt in Hilo.

August 11, 6:39 pm, very feeble, probably originated in Kilauea SW rift near sea coast.

August 15, 2:52 pm, very feeble, probably originated in Mauna Loa NE rift.

August 16, 10:29 am, very feeble, originated in area between Makaopuhi and Hilina Fault.

August 16, 2:20 pm, very feeble, originated near Uwekahuna, NW rim, Kilauea Crater. 19° 25.5′ N; 155° 17.6′ W.

August 16, 2:40 pm, very feeble, Mauna Loa NE rift about 5.0 miles SW of Puu Ulaula.

August 17, 5:57 am, moderate, 8.0 miles deep in Hilina Fault system, 4.5 miles SE of Makaopuhi. 19° 19.5′ N; 155° 06.5′ W. Unusual in that it was not reported felt.

August 17, 6:18 am, moderate, 4.0 miles deep in Hilina Fault system, 4.0 miles ESE of Makaopuhi. 19° 21.5′ N; 155° 07.0′ W. Not reported felt.

August 17, 6:58 am, very feeble, probably in Hilina Fault system, about 15.0 miles deep and N of Keahou Point.

August 17, 11:51 pm, slight, probably of shallow origin in Hilina Fault system 3.5 miles S of Puu Ohale.

August 18, 9:03 pm, very feeble, probably originated under NE portion of Mauna Loa Summit Crater.

August 20, 10:01 am, very feeble, 12.0 miles deep, 3.0 miles W of Kulani Cone near NE rift of Mauna Loa. 19° 31.7′ N; 155° 21.0′ W.

August 27, 4:19 pm, very feeble, NE rim area of Kilauea Crater.

August 28, 6:21 pm, very feeble, probably originated in Kohala district.

September 3, 6:17 am, very feeble, Mauna Loa Summit Crater origin.

September 3, 6:54 am, very feeble, of shallow origin in Chain of Craters near Kokoolau and Devil's Throat. 19° 23.0′ N.; 155° 14.7′ W.

September 3, 8:10 pm, feeble, 7.0 miles deep, Mauna Loa NE rift, 3.0 miles SE of Puu Ulaula. 19° 30.0′ N; 155° 26.0′ W. Reported felt at Kilauea Military Camp accompanied by mild roaring noise.

September 4, 12:28 am, very feeble, 5.0 miles deep, Mauna Loa NE rift near Pukauahi Crater. 19° 31.5′ N; 155° 31.0′ W.

September 7, 1:32 am, feeble, 15.0 miles deep, Hualalai Volcano. 19° 41.0′ N; 155° 51.0′ W. Reported strongly felt at Puu Waawaa.

September 7, 10:46 am, very feeble, 4.0 miles deep under Waldron Ledge, NE rim Kilauea Crater. 19° 24.4′ N; 155° 15.4′ W.

September 8, 1:39 pm, very feeble, NE portion of Kilauea Crater.

September 13, 6:49 am, feeble, 9.0 miles deep Kilauea SW rift, 6.0 miles from the Observatory. 19° 24.0′ N; 155° 20.0′ W.

September 13, 4:20 pm, feeble, 13.0 miles deep Hilina Pali about 4.0 miles N of Apua Point. 19° 18.0′ N; 155° 10.0′ W.

September 14, 10:07 am, a tremor, reported felt on Mauna Loa.

September 14, 12:10 pm, very feeble, probably originated from relatively great depth under Hualalai.

September 15, 6:13 pm, very feeble, NW rim of Kilauea Crater, 0.6 mile N of Uwekahuna. 19° 25.9′ N; 155° 17.5′ W.

September 17, 3:33 am, very feeble, of shallow depth, Kilauea Crater near Halemaumau.

September 20, 10:41 am, very feeble, about 2.5 miles deep in Kilauea Crater near Halemaumau.

September 27, 11:24 am, very feeble, Kilauea SW rift.

September 28, 9:11 am, very feeble, probably from SW portion of Kilauea Crater.

Teleseisms

July 6, "P" waves began recording at 12h 18m 54.0s pm. This was reported by the Jesuit Seismological Society as a deep earthquake (550 km) which originated in the area between the Fiji and Tonga groups of the S. Pacific. 24° S; 18° W. Distance from Kilauea approximately 3,550 miles.

July 17, unidentified portion at 5h 11m 36s pm. No reports received.

July 23, 5h 03m am, unidentified portion.

August 11, "P" waves, 3h 46m 11s pm, J. S. A. location in vicinity of New Hebrides 13° S; 169° E. Distance from Kilauea, 3,270 miles.

August 17, surface (L) waves at 12:10 am, U. S. C. and G. S. location 18° S; 168° E in New Hebrides area. Distance from Kilauea, 3,500 miles.

September 8, 1h 42m 19s am, "P" waves began. U. S. C. and G. S. location near Kamchatka in Bering Sea. 51° N; 175° E. 2,800 miles from Kilauea.

Microseismic Motion

July

Light—5, 7-9, 18-21, 24-29, 31.
Moderate—3, 4, 6, 10-12, 15, 17, 22, 23, 30.
Strong—13, 14, 16.

August

Light—3-6, 8-10, 12-15, 19, 21-31.
Moderate—1, 2, 7, 11, 16-18.
Strong—20.

September

Light—1-3, 5-12, 18, 27-29.
Moderate—4, 13-17, 20, 23, 24, 26, 30.
Strong—19, 21, 22, 25.
Time used throughout is Hawaiian Standard, 10h 30m slower than G. C. T.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum toward or away from the Pit as indicated by tilt stations on the W and SE rims respectively.

At the Observatory the total accumulated tilt for the year ending July 30, was 2.05" S and 4.0" W.

For the year ending August 27, it was 1.53" S and 3.43" W.

For the year ending October 1, it was 1.24" S and 3.20" W.

Table of Tilt

Week Ending	Observatory	Halemaumau West Station
July 9	0.50" N 20° E	6.97" S 26° W
" 16	0.97" N 26° E	3.13" S 23° W
" 23	0.66" N 21° W	2.98" N 79° W
" 30	1.05" N 20° W	5.72" N 60° W
August 6	0.88" N 51° W	5.63" N 66° W
" 13	2.05" N 63° E	6.82" N 9° E
" 20	0.27" N 89° E	3.03" N 80° W
" 27	0.48" N 33° E	2.15" N 69° W
Sept. 3	1.00" N 10° E	4.65" N 80° W
" 10	1.34" N 50° E	1.58" S 60° W
" 17	0.35" N 42° E	1.97" S 27° E
" 24	0.30" S 3° W	0.00
October 1	0.50" N 86° E	2.68" N 30° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
July 9	4.92" N 79° E	7.15" from
" 16	3.34" N 31° W	1.91" toward
" 23	4.86" N 17° W	1.71" toward
" 30	7.71" N 44° E	3.62" from
August 6	2.43" N 69° W	4.31" from
" 13	3.63" N 39° W	5.36" toward
" 20	11.99" N 50° W	8.83" toward
" 27	0.78" N 66° E	2.10" from
Sept. 3	3.11" N 38° E	3.66" from
" 10	10.37" S 81° W	3.52" toward
" 17	10.89" S 69° W	3.66" toward
" 24	8.29" S 44° W	1.45" from
October 1	12.02" N 75° W	8.20" toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory were made twice during the month of July. On July 7, these measurements indicated opening of 0.58" for the Halemaumau value and closing of 0.61" for the Crater value compared with similar measurements of June 17. Between July 7 and July 29, the Halemaumau value showed closing of 2.73" and the Crater value showed opening of 1.58". Total, June 17 to July 29: Pit closed 2.25" and Crater opened 0.97". The Halemaumau value is measured between the seismograph station on the SE rim and the NW Pit bench mark. The Crater value is measured between a station on the SE rim of Kilauea Crater and the Uwekahuna station.

Angle values August 17, indicated opening of the Halemaumau value of 4.42" and closing of the Crater angle of 2.75".

Two measurements were made during September. On September 12, the Halemaumau angle had closed 0.17" and the Crater angle had closed 0.25". Between September 12 and September 27, Halemaumau value closed 2.41" and Crater value opened 2.41". Total change August 17 to September 27, Halemaumau closed 2.58" and the Crater opened 2.16".

Total change at Halemaumau, June 17 to September 27: Halemaumau closed 0.41" and the Crater opened 0.38".

Spirit Levelling around Halemaumau

Between August 25 and 30, a line of levels on Kilauea Crater floor was run for a complete circuit around Halemaumau. Comparison with a similar run made March 20-21, 1939 shows that the NW Pit BM had lowered since that period 4.4 centimeters relative to the Spit B. M.

Chain of Craters Road Cracks

Date	101	102	103	104	105	106	107
July 28	404.40 cm.	64.45	101.45	17'19⅛"	87.30	88.70	39.60
Sept. 1	404.45	64.50	101.55	17'19⅛"	87.35	88.80	39.55
Sept. 29	404.65	64.55	101.55	17'19⅛"	87.30	88.75	39.65
Total change in mm. since June 30..	+3.0 mm.	+0.5	+1.0		+0.5		

Plus (+) = open. Minus (—) = close.

New cracks developed in the side of the road nearest Aloi Crater and on its S rim. One crack was parallel to the road and the other was across the road surface. Measurement of these two cracks was started August 2, 1939. They were designated 108 and 109 respectively. On September 29 No. 108 had opened from 102.55 cm to 102.70 cm, a total of 1.5 millimeters. No. 109 remained unchanged at 97.70 cm.

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
in cooperation with
UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, is leased and operated by the United States Government, Department of the Interior, National Park Service.

The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** maintain outside seismograph stations and supplement the work of the government with research associates, instrumental plants and special investigations.

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THE VOLCANO LETTER

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Edward G. Wingate, Superintendent
Hawaii National Park

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

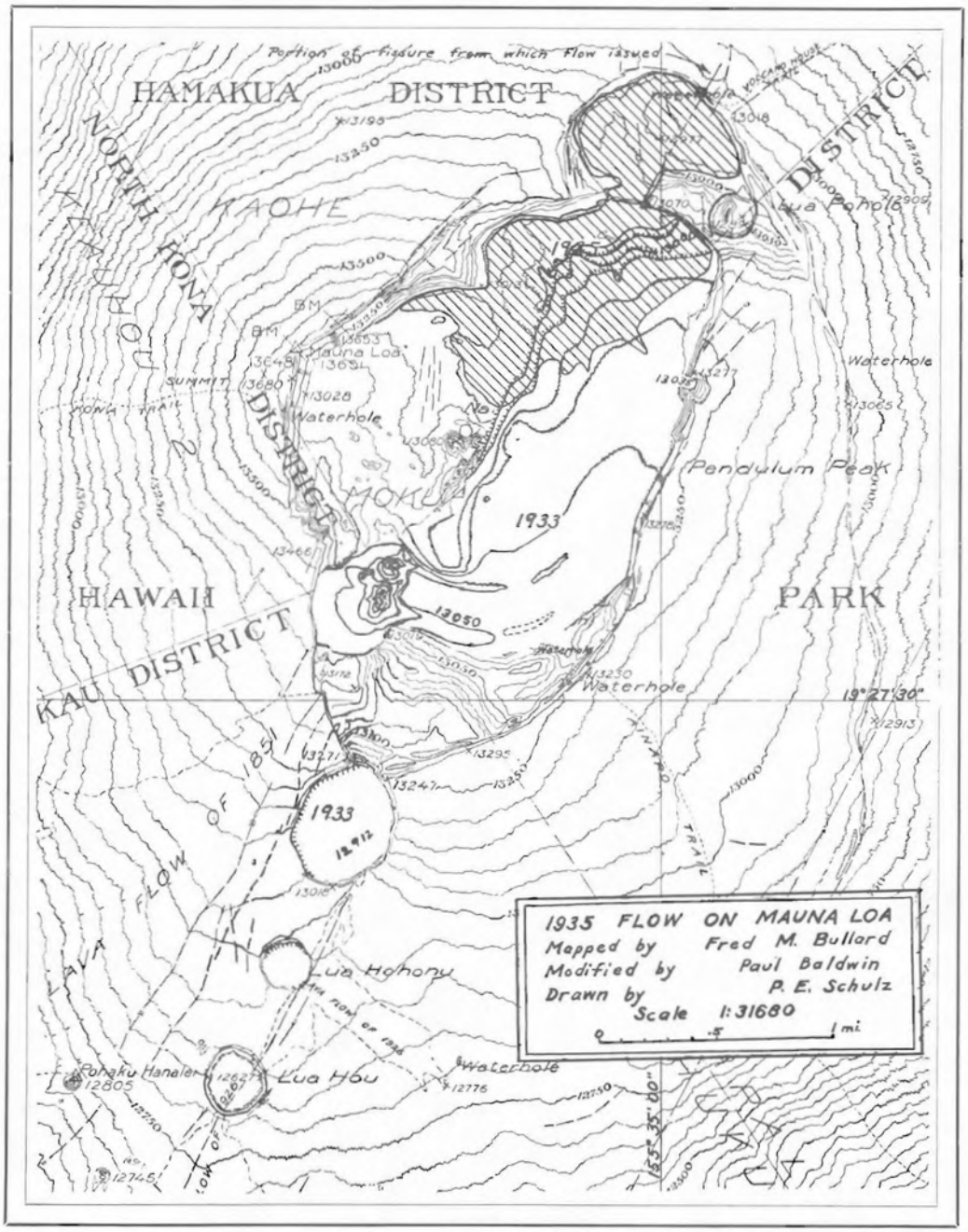

Figure 1

1935 LAVA IN MOKUAWEOWEO CRATER

By HUGH H. WAESCHE, Assistant Geologist

In the evening of November 21, 1935 about 6:30 p.m., Hawaiian Time, Mauna Loa began on eruption which was to lost well over six weeks and which was to exhibit oll phases of activity common to Mauna Loa eruptions. The major portion of the activity was a spectoculor outflow with large streams of lavo descending the north slope of the mountain into the saddle between Mauna Loa and Mauno Kea.

Just what occurred in the eorly hours of the eruption is vague. It was a cloudy evening and the activity was not visible from the Observatory until about 10:00 p.m. At that time a minimum of 8 fountains were playing olong the northeast slope af the mountain from the summit crater to a point about five miles along the rift. Apparently the NE rift had cracked open over this distance. By 2:00 a.m. oll of the upper fountoins had diminished slightly and the octivity was concentrating at the two lowest fountains near the 12,000 foot elevation. At approximotely 6:00 a.m., Lt. Carl Truesdole of the United States Army Air Corps flew over the Crater of Mokuaweoweo and reported some activity there still in progress. By 10:00 a.m. when the writer flew over the area af activity with Lt. Campbell all activity in the Summit Crater had ceased. The two fountains at 12,000 feet continued for approximately ten days. The remainder of the time, lava issued from what oppeared to be a rift hidden by old lava flows on the north flank of the mountain. At most the crater activity lasted hardly more than twelve hours.

Later when National Park rangers went to the summit af Mauna Loa, they found thot the fissure indicated on the map (near top) had opened within 100 feet of the rest house and that lava had poured into the crater and down the northeast slope in great quantities from it. The lava was a brownish-black, frothy type of pahoehoe indicating that it had probably been highly charged with gases. The Volcano House Trail was covered and eliminated for about three-quarters of a mile. (For photographs see Volcano Letter No. 445, March 1937.) It is possible that the fissure extended southwest toward the center of Mokuaweoeo in the general direction of the 1903 and 1914 cones but was covered by lava pouring into the main crater from the higher elevation bay to the northeast.



Fig. 2—Dr. Jaggar on an exploration of a Mauna Loa rift. Pit in 1881 pahoehoe dome northwest of Puu Ulaula. (October 4)

The attention of olmost everyone had been concentroted on the flows resulting from this eruption so consequently the croter hod received little attention. In 1934 Mr. A. E. Jones had made a detailed map showing the extent of the 1933 crater flow.* Dr. Jaggar has described that eruption. Mr. E. G. Wingate had mapped the 1926 flow. It was desirable thot the series be completed, therefore on July 18, 1939, Dr. Fred M. Bullard, professor of geology at the University of Texas ond temporarily employed by the National Park Service ot the Volcano Observatory, made the trip to the summit. Using a United States Geological Survey preliminory sheet of the area as a base, he mode a Brunton Compass survey of the crater inflow which is indicated by the hatched area toward top of map. The work was done July 19, 20, and 21. Mr. Paul Baldwin, temporary National Park ranger, repeated the work of Dr. Bullard obout three weeks later. His map was identical to Bullard's with the addition of the tongues and other slight modification of the southeast edge of the flow.

Apparently the 1935 lava covered a sizeable portion of the 1933 flow as indicated by the dotted boundaries of the latter flow as mapped by Jones.

The 1935 flow is little more than a veneer over pre-existing flows and has changed the contour of the crater little. It may attain a thickness of 5 feet in a few spots particularly where it adjoins the 1933 flow which in some places is aa in choracter.

* The Volcano Letter No. 309, September 1936.

Hawaiian Volcano Observatory Report for October-December, 1939

VOLCANOLOGY

October 1939

October had no special volcanic events. For the first week seismic activity increased and northeast tilting of the ground at the observatory was marked but normal for this time of year. The second week this tilt increased as well as the number of earthquakes; one of these was sharply felt on the floor of Mokuaweoweo, the summit crater of Mauna Loa, at 2:27 p.m. October 11, and on the same day at 3:42 p.m. a shock resembling a powder blast was felt at Kilauea. On the 15th a rock slide at 10:32 a.m. sent a dust cloud up the north wall of Halemaumau. The third week held a similar seismicity and thin fume rose from the southeast marginal crack of Halemaumau floor; the northwest solfatara had dimmed in color and ceased to fume. During the last week things quieted down and the measured rim cracks which changed closed instead of opening, just as in July-August.

Distant earthquakes were registered October 3 and October 16, the last located near the New Hebrides. The local shocks were distributed between Mauna Loa and Kilauea with the last most abundant, and one shock of October 19 was from Hualalai or beyond thot mountain.

Exploration of NE Rift of Mauna Loa

Dr. Jaggar, with Mrs. Jaggar and Ranger Jess, camped at Puu Ulaula, 10,000 feet elevation, northeast rest house of Mauna Loa October 2-5, to identify lava flows with those seen in Humuula trip of September, (Volcano Letter No. 465) to collect specimens for spectrograph tests, and to take photographs in Kodachrome and monochrome. Some of the latter are reproduced here. (Figures 2, 3, 4, 5, 6, 7.)

Puu Ulaula is old shell pahoehoe and cinder (Figure 5) with other old cones northeast of it, over the rift line here trending ENE and bifurcating to the NE. Southeast from the hills lying a mile WSW, extends the Kapapala aa flow of November 1880, entirely distinct from the pahoehoe black flow and cones (Figures 3, 6, 7) of 1881 which originate above and to the west of Puu Ulaula and trend NE, dominated by the large square-topped black cone of 1881 at elevation 9,617 feet lying a mile and a half NE of the Rest House, (from summit of which photographs 6 and 7 were taken). The aa lava of 1880 is distinct from the later 1881 source basalt: the former has a red porridge-like surface (Figure 4), its pahoehoe being bronzy and frequently frothed on the surface to coarse brassy pumice.

The 1899 lava is black pahoehoe all around the cone Puka Uahi and overriding the 1880 flows. Just northeast under the 1880 floods are the red and bright-colored cones of 1855 with surfaces of fine-grained brassy pumice a half inch thick. The black, smooth torrent of 1899 flowed off to the north from Puka Uahi, and was explored far to the north in September trip. On the engraved Humuula sheet U.S.G.S. the northeast Hilo flow is misnamed 1880 and the southeast Kapapala flow is misnamed 1881: these names should be exchanged. To all appearances it is possible to ride on the 1899 pahoehoe to Humuula by the routes explored in September.

The black floods of the 1881 Hilo-flow NW of Puu Ulaula are like the Kilauea floor lavas, and extraordinarily like the smooth piles of Mauna Iki in Kau Desert. Figure 2 shows the rim and cavernous overhang of a circular pit 60 feet across, with tumble of debris of collapse, that was in 1881 a lava lake on top of a pahoehoe dome. This was a source-heap over a crack of the NE Mauna Loa rift belt, a half-mile WNW from Puu Ulaula rest house. In the background of the photograph is one of the older cones of possibly 1855 cinder. The general view up the rift belt from the top of the 1881 black cone (elevation 9,617 feet) includes this slag heap near the skyline (Figure 6). The floods of pahoehoe from it fill the picture. The near line of conelets curving to the right, is the 1880-81 rupture. This pahoehoe is the later phase of 1881 that pressed forward in tunnels seven months to Hilo. Among the distant cones on the right is Puka Uahi (11,068 feet). In the early months of the 1880-81, floods of lava that pushed towards Mauna Kea from the Puka Uahi region, and towards the Hilo slope, were all stirred to become aa in the lower lands and some of these came from the Black Cone line of vents. The plexus of cones around Puka Uahi were sources of 1855, 1880, 1881 and 1899.

Before leaving the 1881 Black Cone, let us look at a photograph from its summit to the northeast, Figure 7. This is towards Puu Oo ranch lands, in the extreme distance across the sag of the upper Wailuku drainage above Hilo. In the foreground the open gash of the rift is bordered by pumice cones and aa lava. On the left appears the 1881 pahoehoe which sweeps to the right across the distant lands.

Outside the extreme right of the picture is the source of the aa of 1852 which gushed from a vent only 8,500 feet above the sea, but as always, with pahoehoe at its source and down its middle stream for three miles. Its flowing was short lived, so it never sent its vitreous lava to Hilo by the tunnel method. If its rushing torrent of liquid aa, 13 miles long between elevations 8,300 feet and 3,300 feet, had not been preceded by the emission of great volumes higher up the mountain twice, respectively 6 months, and 3 days, before the lowest Hilo outburst, this 1852 flow would have been in Hilo harbor in a week. The duration of the Hilo flow including decadence was 17 days, February 20 to March 8, the front stopping 12 miles from Hilo shore. As in all the outflows there was an extension of the crack up to the summit, this gushed from summit downwards with tremendous power February 17-18 for forty hours, and these upper 1852 floods are quite unidentified on the landscape of today.

The extension of the mapped crack from its cone at 8,420 feet elevation, takes us past the south side of Puu Ulaula, where a flood of black lava with phenocrysts of feldspar makes a sharkskin type of pahoehoe. This is overlapped by the 1880 Kapapala flow and is shown on the right in Figure 4. It may be part of the upper floods of 1852. A line of conelets heads almost due east from Puu Ulaula to Kulua and Puu Kipu, showing how cracks radiate from Puu Ulaula, as an important subsidiary dome on the ENE rift.

The map of all these features is Humuula Sheet, 1930, County of Hawaii, United States Geological Survey. Any later eruption may bury the lava of any former one. The concretion-ball aa lava supposed 1880 (Figure 8, Volcano Letter 465) discovered in September at elevation 7,000 feet, 4½ miles SSW from Humuula sheep station, came from near Puka Uahi, and its source pahoehoe is obscure in that vicinity until some petrogenic distinction, chemical or mineralogic, is discovered characteristic of date or age. Progressively later date means stage of internal alteration of magma. Age means stage of external weathering. In order to map thoroughly all these flows and recount their histories, specimens for comparison are being collected.

Microscopical petrography is not enough when a single flow may differ more in samples from source to front than two flow specimens of separated ages differ from each other. For this



Fig. 3—Cascades of 1881 pahoehoe along line of cones, north of Puu Ulaula. (October 4)

reason it is proposed to submit samples of known different years to arc vaporization in spectrograph for possible qualitative or quantitative differences in elements, and also to test for hydration and some other analytic distinctions, that may be characteristic of year of emission, apart from chemical or crystal differences exhibited within a single eruption. If discovered, this would mean secular magmatic change throughout a century, and identity of year could be established for two flows reaching different fronts, if both had the same characteristic of a specific date.



Fig. 4—The 1880 flow near source, aa in foreground, on Kapapala side of rift, south of Puu Ulaula, looking north. (October 5)

The color pictures that were taken of the interior brilliant ochre glazes of 1855 ond 1935 vents showed brick red, bronzy green, orange and coffee-colored surfaces within cracks and pits. Similor colors mark the pumices. Here ore gas-fluxing phenomena. Vent basalt can be gas-melted to recrystallization and reglazing like the glazing of pottery. The recrystollization within Hawoiian basalt stalactities, by gas melting, of augite and feldspor shelled over by hematite and magnetite, as described by Edword Dana ("Characteristics of Volcanoes," J. D. Dana, p. 339. The quotation from Brigham of water origin is totally erroneous.) shows that cavern linings remelted by gas heat demonstrate the power of gas fluxing to recrystallize the lava's own substance in a gas-filled chamber. The small droplets on the stalactites and glozes show they were very liquid. The small bubbles on the pumiceaus skin of gassy source lavas agoin show intense liquidity; these by their rainbow tints produce the brass color mentioned.

Geologists do not realize that gas-reactions approoching 1500° C., in enarmaus volumes of suddenly released carbon gases and hydrogen, make the high-energy phase of the dike-rupture colled "o volcanic outbreak". This foaming incandescence and its gas, freed in confinement (pits and caverns), ore melting agents. The gas-tight shell over a flowing lava stream can increase the temperature af that stream, by confining its reacting gases; and those gases can glaze and recrystallize the under-surface of the shell. If such a gas-melt were re-digested by rising lava, we would have a feldspar-augite-iron oxide concentrate assimilated by normal basalt.

Now imagine the inbreak (irruption) of an intrusion in a foreign rock doing the same thing, and gas-fluxing that rock. The rock might be highly siliceous or calcareous. The deep chamber of rupture would be gas-tight and confine the vesiculate foam, but the rise of temperature would be great ond the melting assimilation by basalt would proceed to whatever andesitic crystallinity the final gas-free magma achieved. Just as in the beautiful aggregates of feldspar crystals synthesized in Mauna Loa glazes and stalactites, totally different in grouping, and somewhat in chemical composition, from the lava, so where gas-fluxing melts to dripping a quartzite or shale, it is easy for anyone who has seen in Hawaii glowing caverns, red hot fuming and Mauna Loa fountains, to envisage the evolution of hybrid magmas from pre-existing solid phases when attacked by olivine-basalt glass in process of gas effervescence. There is a field for experiment in solution of gases in such glass, pressure release from solution, and in gas-fluxing various rocks to a glaze.

The following are the local data for October:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
October 8	0	3.0 mm. opened	22
" 15	1	2.0 mm. opened	33
" 22	0	2.5 mm. opened	44
" 29	0	6.5 mm. closed	19



Fig. 5—Summit of Puu Ulaula, showing flag, wind gauge, and azimuth plate. (October 5)

November 1939

The month of November was notable for steady decline of the seismic index. The first week showed a slight increase over the end of the preceding month in seismic activity of both Mauna Loa and Kilauea. Fresh rocks on the floor of Makaopuhi Crater indicated there had been small slides from the southwest wall. There was a return to the opening of Halemaumau rim cracks, whereas the previous week had been extraordinary in that none had opened. Tilting af the ground at the Observatory was away from the crater. A slight shock November 3 and a feeble one November 4 were of Kilauea origin but not reported felt.

The second week produced a moderate rock slide sending up dust at the north



Fig. 6—Looking up rift from 1881 Black Cone; Puu Ulaula on left skyline.

wall of Halemaumau 10:22 a.m. November 10. There was one feeble earthquake under Kilauea Volcano and felt there. Tilting of the ground at the Observatory was away from the crater.

The third week recorded one rock slide Halemaumau north rim 10:20 a.m., November 14. Earthquakes were very feeble. The rim cracks resumed excessive closing. Tilting of the ground continued NNE.

The fourth week showed excessive microseismic activity along with a storm at sea causing waves to wash over Hilo breakwater. Seismic activity was locally very small though earthquakes were reported all over the world. Observatory tilt was still away from the crater.

The following are the local data for November:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
November 5	0	8.0 mm. opened	25
" 12	1	4.0 mm. opened	21
" 19	1	1.5 mm. closed	19
" 26	0	2.0 mm. opened	13

December 1939

The month of December was seismically quiet and, in accordance with the habit of the last five years, the solstice week about December 21 was particularly peaceful. This is the more remarkable in that during the active years of the last two cycles December has been the eruption month. Seismic activity increased at the beginning of the month and Observatory tilt changed to the crater direction. The second week fume was noted in Halemaumau probably from the solfatara along SE edge of floor. On December 8 at 10:35 a.m. rocks were heard falling at Halemaumau wall NW. Distances of earthquakes indicated Hualalai, Mauna Loa and Kilauea. Tilting was resumed away from Kilauea Crater. The third week produced a moderate slide at 2:55 p.m. December 12 making noise and sending out dust at Halemaumau NW wall and two other slides from the rim N and NE occurred at 3:25 and 3:29 p.m. A very feeble earthquake under Halemaumau completely dismantled the seismograph there, was felt at Uwekahuna but registered as very feeble. Observatory tilt was towards the crater.

The fourth week with earthquakes reported from Costa Rica, Manila, London, Kamchatka and the Celebes nothing happened at the Observatory except registration of some distant shocks and a feeble earthquake near noon December 23 indicating origin 15 miles deep under Mauna Loa northeast rift with epicenter eight miles from Mokuaweoweo. Sources at this locality command close attention because of the menace to Hilo. Observatory tilt was away from the crater. The end of the year produced outbreaks of disastrous earthquakes in Turkey. Some fume could be seen over Halemaumau on calm humid days, rim cracks closed and Observatory tilt was inward.

The following are the local data for December:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
December 3	0	3.5 mm. opened	26
" 10	1	0.5 mm. opened	18
" 17	3	0.5 mm. closed	33
" 24	0	5.5 mm. opened	18
" 31	0	0.5 mm. closed	20

Change of Annual Tilt

A significant change of importance is indicated by the following table showing in seconds the amount of tilt and its direction at the Observatory, NE rim of Kilauea Crater, for the year preceding the date indicated respectively in north-south azimuth and east-west azimuth at the seismographs.

January 29, 1939	S 1.15 seconds	W 5.93 seconds
February 26, 1939	S 1.0 "	W 1.73 "
April 2, 1939	S 3.08 "	W 4.85 "
April 30, 1939	S 4.0 "	W 5.35 "
May 28, 1939	S 3.92 "	W 4.75 "
July 2, 1939	S 3.75 "	W 2.60 "
July 30, 1939	S 2.05 "	W 4.00 "
August 27, 1939	S 1.53 "	W 3.43 "
October 1, 1939	S 1.24 "	W 3.20 "
October 29, 1939	S 1.15 "	W 1.48 "
December 3, 1939	N 2.20 "	W 1.56 "
December 31,1939	N 1.70 "	W 1.35 "



Fig. 7—From summit of 1881 Black Cone looking toward Puu Oo ranch lands.

This record of tilt south and west, or toward Kilauea Crater at the top of the NE wall of that crater, throughout the year 1939 as representative of the preceding twelvemonth for the end of each month, was also characteristic of many preceding years, checked by levels and readings of horizontal angles towards Kilauea and Halemaumau that hove all agreed in indicating since the explosive eruption of 1924 that the general trend has been downward and inward. Individual Halemaumau eruptions have produced temporary tiltings awoy from the crater, but the annual record for repeated monthly summaries has appeored to imply that the ground around Halemaumau pit was continuing to lower as it did in 1924, but in less angular amount.

Beginning with the record of December 3, 1939 the north-south component suddenly shows a change from the preceding month of o totol of 3.35 seconds from the record of October 29, and this substantial northerly tilt for the year preceding the date of record is retained on December 31 as nearly two seconds to the north or away from Halemaumau. When a record of this kind is a resultant of accumuloted change for an entire year it is much more significant of a change of habit in underground workings of the volcano than the mere tilt from one month to the next. It should be remembered that the spring and summer of 1938 produced first a big earthquake in Maui and then a visible rupture along Chain-of-Craters, east rift of Kilauea in May, with renewal of movement there in August 1938 and some seismic sequences of the same disturbance in 1939. As the average interval for Kilauea outbreaks in this century was about a year and a half up to 1934, it appears that an eruption was omitted in 1936, and was about due in 1938. This Chain-of-Craters disturbance may have been the equivalent of that eruption, absorbed in subterranean intrusion, and representative of the return of lava from the seaward direction to the east, where there was submarine outflow in 1924. This submarine outflow as o fundamental disturber of the mountain, producing intense subsidence, may have continued that subsidence by sluggish flow until the backing up of the lava achieved the 1938 intrusion. Meantime the succession of gushes on the Halemaumau bottom may have been offshoots from Mauna Loa. If now the change in tilt at the Observatory means a resumption of swelling and elevation of Kilauea Crater, the lava that returns to Halemaumau about 1940 may have enduring characteristics more like the Kilauea activity of aforetime.—T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Distant*	Weekly Seismicity†
Oct. 8	19	3	0	0	0	1	6.25
" 15	27	3	3	0	0	0	11.25
" 22	39	5	0	0	0	1	12.25
" 29	17	2	0	0	0	0	5.25
Nov. 5	16	7	1	1	0	0	10.50
" 12	17	3	1	0	0	0	6.75
" 19	12	7	0	0	0	0	6.50
" 26	11	2	0	0	0	0	3.75
Dec. 3	22	4	0	0	0	0	8.00
" 10	11	7	0	0	0	0	6.25
" 17	30	3	0	0	0	1	9.00
" 24	12	4	2	0	0	2	6.00
" 31	19	1	0	0	0	1	5.25

* Including teleseisms or earthquakes over 5,000 km from Kilauea.
† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the islond of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of depth of focus hos been made.

October 3, 4:12 p.m., very feeble, probably originated Mauna Loa NE rift neor summit crater.

October 5, 5:52 p.m., very feeble, probably originated in area south of Kilauea Crater neor junctian of Poli Lele o Kalinipaa ond Pali Kalanaokuaiki.

October 8, 10:35 a.m., very feeble, originated in vicinity of NE rim of Kilauea Crater.

October 11, 1:11 a.m., feeble, probably originated in Hilina Fault system about 4.0 miles southeast of Makaopuhi.

October 11, 2:27 p.m., feeble, 8.0 miles deep, Mauna Loa NE rift about 3.0 miles SW of Puu Ulaula. 19° 30.5′ N; 155° 29.0′ W. Reported sharply felt at Mauna Loa resthouse.

October 11, 3:42 p.m., feeble, 0.8 mile deep, east portion of Kilauea Crater. 19° 24.7′ N; 155° 16.0′ W. Reported felt in Hawaii National Park.

October 14, 3:55 p.m., very feeble, originated near eost central portion of Kilauea Crater.

October 15, 4:38 a.m., very feeble, originated 22.0 miles under Mauna Loa summit crater, 19° 28.5′ N; 155° 36.0′ W.

October 15, 11:03 a.m., very feeble, east central portian of Kilauea Crater.

October 16, 10:25 a.m., very feeble, of Kilauea Crater origin.

October 16, 1:35 p.m., very feeble, of Kilauea Crater origin.

October 17, 6:33 a.m., very feeble, probably originated in Chain-of-Craters near Puhimau.

October 19, 7:33 p.m., very feeble, under west slope of Hualalai, 5.0 miles NNW of Kailua, 19° 42.0′ N; 156° 01.0′ W.

October 26, 6:18 p.m., very feeble, probably originated in Mauna Loa NE rift about 10.0 miles SW of Hilo.

October 29, 12:02 a.m., very feeble, about 7.0 miles deep, Mauna Loa NE rift, 19° 35.5′ N; 155° 23.0′ W.

November 1, 2:38 p.m., very feeble, of shallow origin about 0.6 mile west of Kokoolau Crater, 19° 23.2′ N; 155° 16.0′ W.

November 3, 12:15 a.m., very feeble, probably originated in Hilina Fault system, near Laeapuki.

November 3, 3:38 p.m., slight, 3.0 miles deep in the vicinity of Cone Peak along Kilauea SW rift. 19° 23.5′ N; 155° 18.3′ W.

November 4, 3:07 a.m., feeble, probably of same origin as preceding shock.

November 4, 3:54 p.m., a tremor at the Observatory recorded on Mauna Loa as a feeble shock probably originating in the NE rift.

November 4, 10:58 p.m., very feeble, 25.0 miles deep under Mauna Loa 8.0 miles NW of Pahala. 19° 17.5′ N; 155° 34.0′ W. Reported felt in Pahala.

November 7, 5:34 a.m., very feeble, 2.7 miles deep, 1.4 miles east of Puu O Hale in Kalanaokuaiki Pali near junction with Pali Lele O Kalihipaa. 19° 21.4′ N; 155° 15.4′ W.

November 8, 11:23 p.m., very feeble, of shallow origin east central portion of Kilauea Crater. 19° 25.0′ N; 155° 16.0′ W.

November 10, 7:06 a.m., feeble, of shallow origin east rim of Kilauea Crater under SW portion of Kilauea Iki. 19° 25.0′ N; 155° 15.0′ W.

November 10, 11:06 a.m., very feeble, probably of same origin as preceding quake.

November 13, 1:02 a.m., very feeble, of Kilauea origin.

November 13, 1:59 p.m., very feeble, of shallow origin east central portion of Kilauea Crater.

November 14, 7:55 a.m., very feeble, from Mauna Loa NE rift about four miles from Summit Crater.

November 14, 9:56 a.m., very feeble, of Kilauea origin, probably Hilina Fault system south of Makaopuhi Crater.

November 19, 3:21 a.m., very feeble, of relatively shallow origin under Summit Crater of Mauna Loa.

November 19, 6:08 a.m., very feeble, of Mauna Loa NE rift near Summit Crater.

November 19, 7:23 a.m., very feeble, of shallow origin, SE rim of Halemaumau in Kilauea Crater.

November 20, 4:29 p.m., very feeble, 7.0 miles deep, Mauna Loa NE rift about 5.0 miles from Summit Crater. 19° 31.0′ N; 155° 31.5′ W.

November 24, 5:34 a.m., very feeble, from Hilina Fault Zone, 5.0 miles west of Kalapana.

November 27, 10:30 p.m., very feeble, of shallow origin, Kilauea Crater, 1.0 mile NE of Pit seismograph.

December 1, 12:35 p.m., very feeble, probably originated in Mauna Loa NE rift.

December 2, 8:48 a.m., very feeble, 0.8 mile deep, 1.0 mile SSE of Halemaumau. 19° 23.5′ N; 155° 16.6′ W.

December 3, 5:21 a.m., very feeble, 18.0 miles deep under Mauna Loa Summit Crater. 19° 31.0′ N; 155° 32.5′ W.

December 5, 6:29 a.m., very feeble, probably originated under ocean floor to SE of Island of Hawaii.

December 6, 10:56 p.m., very feeble, of shallow origin Mauna Loa NE rift 5.0 miles from center of Summit Crater.

December 8, 12:18 a.m., very feeble, probably originated under sea floor to SE of Island of Hawaii.

December 8, 3:49 a.m., very feeble, of shallow origin, NE rim of Mauna Loa Summit Crater. 19° 30.0′ N; 155° 34.3′ W.

December 8, 11:54 p.m., very feeble, from Chain-of-Craters near Devil's Throat.

December 10, 2:24 p.m., very feeble, of shallow origin 1.0 mile SE of Pit seismograph. 19° 23.8′ N; 155° 16.3′ W.

December 13, 1:56 a.m., very feeble, probably originated under sea floor about 23 miles west of Hualalai.

December 17, 2:48 p.m., very feeble, of shallow origin, south rim of Kilauea Crater, 1.0 mile south by east of Pit seismograph. 19° 23.5′ N; 155° 16.8′ W. Dismantled both components of Pit seismograph and reported felt in residential area of Hawaii National Park.

December 19, 1:11 p.m., very feeble, of shallow origin, Kilauea Crater.

December 21, 8:15 a.m., very feeble, about 20.0 miles deep and 12.0 miles south of Mauna Loa Summit Crater, 8.0 miles NW of Pahala. 19° 17.5′ N; 155° 34.0′ W.

December 22, 5:36 a.m., feeble, 9.0 miles deep, 8.0 miles SE of Summit Crater of Mauna Loa. 19° 24.4′ N; 155° 29.0′ W. Reported strongly felt at Kapapala Ranch House.

December 23, 12:06 p.m., feeble, 15.0 miles deep, Mauna Loa NE rift, 8.0 miles from Summit Crater. 19° 32.0′ N; 155° 29.0′ W.

December 23, 10:54 p.m., very feeble, 1.7 miles deep, 0.7 mile SE by south of Pit seismograph. 19° 23.8′ N; 155° 16.4′ W.

December 26, 8:50 p.m., very feeble, Kilauea SW rift near junction with Hilina Pali. 10.0 miles deep. 19° 15.5′ N; 155° 23.0′ W.

December 13, 8 minutes of continuous tremor began recording 6:02 a.m.

Teleseisms

October 3, 3h 18m 40.0s, a.m., "P" waves? Distance undetermined.

October 17, 8h 01m, p.m., located in New Hebrides area. Reported to have originated at a depth of 100 km. Distance from Kilauea, about 3,500 miles. Epicenter 16° S; 168° E, by U.S.C. and G.S.

December 16, 12h 25m 48s, a.m., "P" waves. Distance undetermined.

December 21, 10h 42m 55s, a.m., "P" waves. Distance from Kilauea approximately 5,505 miles, probably originated in Celebes.

December 21, 6h 25m 13s, p.m., "P" waves. Distance from Kilauea, approximately 4,625 miles. No reports received on location.

December 26, 2h 16m, p.m., surface waves. Distance undetermined; origin the disaster near Erzerum in Asiatic Turkey.

Microseismic Motion

October

Light—6, 8, 11, 14.
Moderate—1, 4, 5, 7, 9, 10, 12, 13, 15-20, 27.
Strong—2, 3, 21-26, 28-31.

November

Light—
Moderate—4-9, 20.
Strong—1-3, 10-19, 21-30.

December

Light—
Moderate—14, 20.
Strong—1-13, 15-19, 21-31.

Time used throughout is Hawaiian Standard, 10h 30m slower than Greenwich Time.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum toward or away from the Pit as indicated by tilt stations on the W and SE rims respectively.

At the Observatory the total accumulated tilt for the year ending October 29, was 1.15" S and 1.48" W.

December 3, 2:20" N and 1.56" W.

December 31, 1.70" N and 1.35" W.

Table of Tilt

Week Ending	Observatory	Halemaumau West Station
October 8	1.85" N 45° E	4.47" S 60° W
" 15	1.45" N 52° E	5.16" N 15° W
" 22	0.50" S 58° W	0.00 ——
" 29	0.77" N 79° E	2.98" W
November 5	1.43" N 35° E	3.81" N 53° W
" 12	0.56" N 30° E	4.41" N 74° W
" 19	0.74" N 11° E	0.00 ——
" 26	0.00 ——	0.00 ——
December 3	0.60" N 53° W	0.00 ——
" 10	0.27" W	3.13" S 55° W
" 17	0.27" S 6° E	5.99" S 30° E
" 24	0.21" N 67° E	4.47" N
" 31	1.17" S 48° W	0.00 ——

Week Ending	Halemaumou Southeast Station	Halemaumau Resultant
October 8	4.86" S 50° E	8.55" from
" 15	9.23" N 47° E	0.09" toward
" 22	4.96" N 67° E	0.97" from
" 29	15.10" N 83° W	6.90" toward
November 5	3.79" N 25° E	0.90" from
" 12	1.94" S 65° E	5.64" from
" 19	3.60" N 30° W	4.86" toward
" 26	14.45" S 30° E	4.25" from
December 3	0.00 ——	No change
" 10	4.76" N 30° W	1.86" toward
" 17	6.58" S 17° W	1.52" from
" 24	6.48" N 30° W	6.93" toward
" 31	6.48" S 30° E	6.48" from

Crater Angles

Measurements of horizontal angles across Kilauea Crater from the Observatory were made October 10 and 26, November 15 and December 7 and 19. On October 10 the measurements indicated opening of 1.16" for the Halemaumau value and opening of 0.92" for the Crater value, compared with similar measurements made on September 27. Between October 10 and October 26 the Halemaumau angle remained unchanged and the crater angle closed 2.08". Total, September 27 to October 26, Pit opened 1.16" and Crater closed 1.16". The Halemaumau volue is measured between the seismograph station on the SE rim and the NW Pit bench mark. The crater value is measured between a station on the SE rim of Kilauea Crater and the Uwekahuna Station.

Angles November 15 had changed by the Halemaumau value opening 0.59" and the Crater value opening 0.24" compared with October 26 determinations.

Two more angle determinations were made during December. On December 7, the Halemaumau angle had opened 0.16" and the Crater angle had opened 1.09" since November 15. Between December 7 and 19, the Pit angle closed 1.25" and the Crater angle remained unchanged. Total change November 15 to December 19; Halemaumau angle closed 1.09" and the Crater angle opened 1.09".

For the period September 27 to December 19, both ongles showed on increase. The Halemaumau value increased 0.66" and the Crater value increased 0.17".

Chain-of-Craters Road Cracks

Date	101	102	103	104	105	106	107
October 27	404.65	64.55	101.50	17'9⅛"	87.30	88.75	39.55
November 24	404.60	64.60	101.50	same	87.35	88.75	39.60
December 29	404.55	64.60	101.55	same	87.35	88.75	39.50
Total change in mm. since September 29	—1.0	+0.5	.....	.....	+0.5	.....	—1.5

The two cracks which opened at the road edge of Aloi Crater rim during August showed no changes in the past three months.

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
in cooperation with
UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, is leased and operated by the United States Government, Department of the Interior, National Park Service.

The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** maintain outside seismograph stations and supplement the work of the government with research associates, instrumental plants and special investigations.

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Edward G. Wingate, Superintendent
Hawaii National Park

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

TILT CHANGES AT KILAUEA

By HUGH H. WAESCHE,
Asst. Geologist

Tilt has been defined by T. A. Jaggar and R. H. Finch as "a change in the angular relation between a portion of the earth's surface and the plumb line". This change is measured on "tilt-sensitive" seismographs or on instruments often called clinoscopes built exclusively for tilt measurement. Usually they are pendulum devices. Horizontal pendulums of several seconds period are particularly tilt sensitive. At Kilauea the Bosch-Omori seismograph located on the NE rim of Kilauea Crater is the principal instrument used for tilt determinations. In addition there are two clinoscopes, one on the southeast rim and the other on the west rim of Halemaumau. For other tilt studies, values are also obtained from the Mauna Loa, Hilo and Pit seismographs. The Bosch-Omori seismograph consists of two components N-S and E-W, recording on a single drum. A fixed pen is made to record a reference line each time a new, smoked paper record is started. Daily measurements from this line to the second line of the regular seismograph recording, in millimeters, give the migration of the recording pens caused by ground tilt. The drums are changed each morning and evening usually at 8:00 a.m. and 8:00 p.m., thus two tilt readings per day are obtained although it has been found necessary to use only one, which is the evening reading. The Bosch-Omori seismograph at the Observatory with a static magnification of about 115 and a period of seven seconds is sensitive enough to record a depression of 1 centimeter in 16 kilometers or 0.4 inch in 10 miles. For reference, 1 second of arc is equivalent to 0.272 inches depression or elevation at a distance of 1 mile. Charts derived from measurements of tilt changes recorded by the Bosch-Omori seismograph at the Observatory are the only ones discussed in this article.

Early studies of volcanic eruptions and earthquakes in Japan drew attention to ground tilt as a factor of great importance preceding, during and after the respective disturbances. Pioneers in tilt studies in that country were the late Professor Omori and Director Emeritus Akitune Imamura his successor at the Imperial University in Tokyo. In 1930, Dr. Imamura[1] discussed at length, "Topographical Changes Accompanying Earthquakes or Volcanic eruptions". In that publication he deals in some detail with fourteen earthquakes between the Tosa earthquakes of the year 684 A.D. and the Formosa earthquake of 1906 A.D. where evidences of ground tilt have occurred but where no instrumental check was available. Tilt changes of twelve other earthquakes between 1891 and 1927 were checked by precise levelling. In addition, tilt changes associated with the volcanic eruption of Usu in 1910 and the Sakurajima eruption of 1914 are described. One of the principal conclusions drawn was that with all earthquakes and all volcanic eruptions there occur topographic changes (with emphasis on ground tilt) whether they are observed or not. Conclusions of that nature only served to emphasize the importance of tilt studies and development of instruments for determining tilt as a source of data supplementing other geophysical investigations. Such data might be of great value in predicting future earthquakes or volcanic eruptions and are particularly important from that point of view in Japan and California as well as other localities subject to sudden terrestrial changes. The Japanese seismologists have developed a wide variety of tilt measuring devices and are obtaining data in quantity from both volcanic and seismic areas with most attention probably centered on the Tokyo area, scene of the very destructive Kwanto Earthquake of September 1923. Results have proven instructive and gratifying and undoubtedly, as more knowledge is gained, will play an important role in predictions both volcanic and seismic.

In California, ground tilt is being carefully studied by the staff of Pasadena Seismological Laboratory of the Carnegie Institution, the seismological laboratory of the University of California and the United States Coast and Geodetic Survey. These groups are especially interested in tilt associated with the great earthquake-making faults of the west coast as an indicator of the approach of potential, property and life damaging earthquakes.

In Hawaii, H. O. Wood first noticed pronounced ground tilt at the Observatory with the establishment of the seismographs on the NE rim of Kilauea Crater in 1913. However, tilt was not given an important place in the study of Hawaiian Volcanoes until 1917 when Romberg and Jaggar began the systematic recording and studying of daily and seasonal tilt changes and their relationship to Kilauea and Mauna Loa. Their work has been carried on and is now considered one of the more important studies in volcanic research.

Apparently Hawaii, Japan and California are the only places in the world where tilt studies have been a serious part of the

[1] "Publications of the Earthquake Investigation Committee in Foreign Languages, No. 25."

volcanic and seismic research program. Interest in this phase of earth movement is gaining rapidly though as its importance is more generally realized. The positive results obtained are of great value in volcanologic studies.

In order that the ground tilt might be better visualized, results of the daily readings are plotted on coordinate paper lined ten to the inch. One millimeter change on the seismogram is plotted to 1/10 inch so that 1 inch on the paper is equal to 1.21 seconds of arc. The latter value is determined from the constants of the seismograph. An arbitrary numerical value was assigned to the starting point and all tilt has been plotted on this base since. The E-W migrations of the seismograph pen are plotted as abscissa and the N-S as the ordinates. During the 27 years of measurement, it has been found that tilt on the NE rim of Kilauea Crater, considered as the path of the top of a vertical rod describes an annual loop of from 5 to 20 seconds of rotational arc with the loop elongated in a NNE-SSW direction, the greater axis usually being about twice the length of the shorter one. In the course of producing the major loop many minor ones occur and both, almost without exception, progress in a clockwise direction. In general, tilt is southwesterly during the warmer summer and fall months and northeasterly during the cooler late winter and spring months. Jaggar and Finch[2] have shown that seasonal temperature changes and tilt at Kilauea are correlated; at the same time loading due to rainfall is not related. A direct relation to lava eruption, confirming tilt changes was shown by precise levelling results by R. M. Wilson in 1921 and 1927.[3] Lava movements apparently affect tilt directly. This is shown in irregularities of the annual curve and in accumulated tilt from year to year. Accumulated tilt may be thought of as relative average change of position or migration of the annual loop, or relative displacement at corresponding periods of successive years.

Three types of tilt graphs are regularly plotted at the Hawaii Volcano Observatory. One is simply a daily curve derived from lines connecting points plotted as described. This produces a rather irregular diagram at times confusing. In order to straighten out and smooth the annual curve a system of overlapping 7-day means is used for the second type. This makes any plotted point a 7-day average. The next value to be plotted is obtained by subtracting the seismogram measurement of the first date used in the average summation and then adding the value succeeding the seventh measured. As tilt moves the seismograph pens beyond normal registration range, the instrument is adjusted to realign the recording pens and proper corrections added or subtracted from the last measured tilt value depending on direction of adjustment. The third system used two separate graphs for N-S and E-W components, representing direction in one plane only. In this system the dates are on the abscissa and amount of tilt in millimeters, ordinates. Millimeter graph paper is used with the millimeter divisions used for days and millimeters of tilt as measured on the seismograph record. The advantage of this type of graph is that it shows the marked excess of N-S tilt compared with that of the E or W.

The center of Halemaumau is S 50° W and the center of

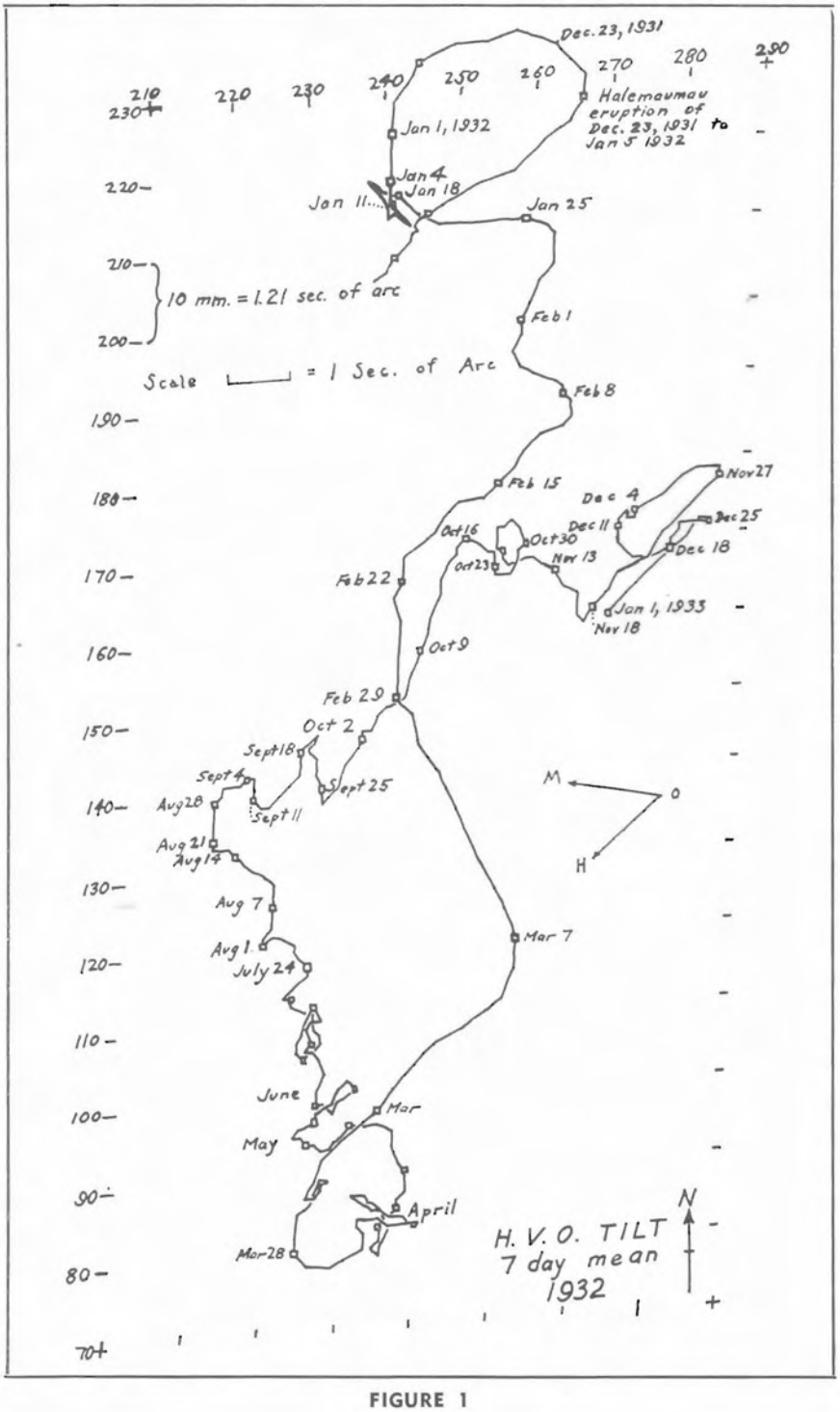


FIGURE 1

[2] Tilt Records for Thirteen years at the Hawaiian Volcano Observatory; Bulletin of the Seismological Society of America, Vol. 19, No. 1, March 1929.

[3] Ground Surface Movements at Kilauea Volcano, University of Hawaii Research Publications, Number 10, 1935.

Kilauea Crater is S 40° W from the Observatory. The longer axes of the annual loops average S 30° W. The figures suggest that factors other than concentric tumescence around either Halemaumau or Kilauea influence the direction of tilt at the Observatory. The factors may be topographic and/or structural. It seems likely that the area S of the Observatory is made up of a series of fault blocks stepped downward toward the sea and roughly paralleling the Hilina Fault system and the Mauna Loa rift system. If this is true there would be the SW Kilauea rift as indicated by the fractures in the SW Crater wall and dykes in Halemaumau, and another rift running to the east through Kilauea Iki. The Keanakakoi-Chain of Craters rift would be echelon connecting the Kilauea Crater with the Hilina Pali toward Puna. Such a fault block system might easily explain the lack of E-W tilt on the NE Kilauea Crater rim, which would tip more to its N than E with reference to the direction of greatest ease of ground movement.

The accompanying charts are copies of original plats which have been made at the Observatory. Figure 1 shows the Bosch-Omori, 7-day mean, tilt path for 1932. The yearly loop was very irregular. Apparently during 1931 the lava-gas pressure under Kilauea Crater had forced the tilt well to the N and E. This effect continued until December 23 when Halemaumau inflow began. As the eruption continued, pressure was released resulting in the westerly and southerly tilt lasting until January 18. After that easterly tilt of 2 seconds of arc occurred presumably because some pressure built up after the vent had sealed off. During the sealing period, probably January 4 to 18, irregularities which may have been sympathetic to resulting pressure changes in the crater occurred. The pressure release as a result of the eruption allowed considerable southerly tilt to occur. However, reference to figure 2 shows that the more easterly accumulated tilt of 1932 was a forerunner of the building up of pressure under Mauna Loa preceding the eruption of the summit crater December 2 to 18, 1933 almost due west of the Observatory. Simultaneously Kilauea Crater was no doubt adding to the increased easterly tilt.

In Figure 2, south and easterly tilt began building up about October 29, 1933. A maximum was reached about November 26. On December 2, Mauna Loa erupted at the summit crater. Tilt showed sympathetic reactions between December 3 and December 24. The "jog" in the line, December 17, corresponds to the sealing off and end of the eruption December 18. Tilt continued west and north until December 24 when it moved east and north, possibly because of increases of pressure under Kilauea resulting from termination of the Mauna Loa activity. It is of interest to note that 1933-tilt ended to the N and W of its starting point—indicating that tilt had accumulated to the N from Kilauea pressure and probably had altered to the W as a result of pressure release from Mauna Loa.

Figure 3 is a continuation of the 1933 chart (Fig. 2). Starting with January 7, the general progress of

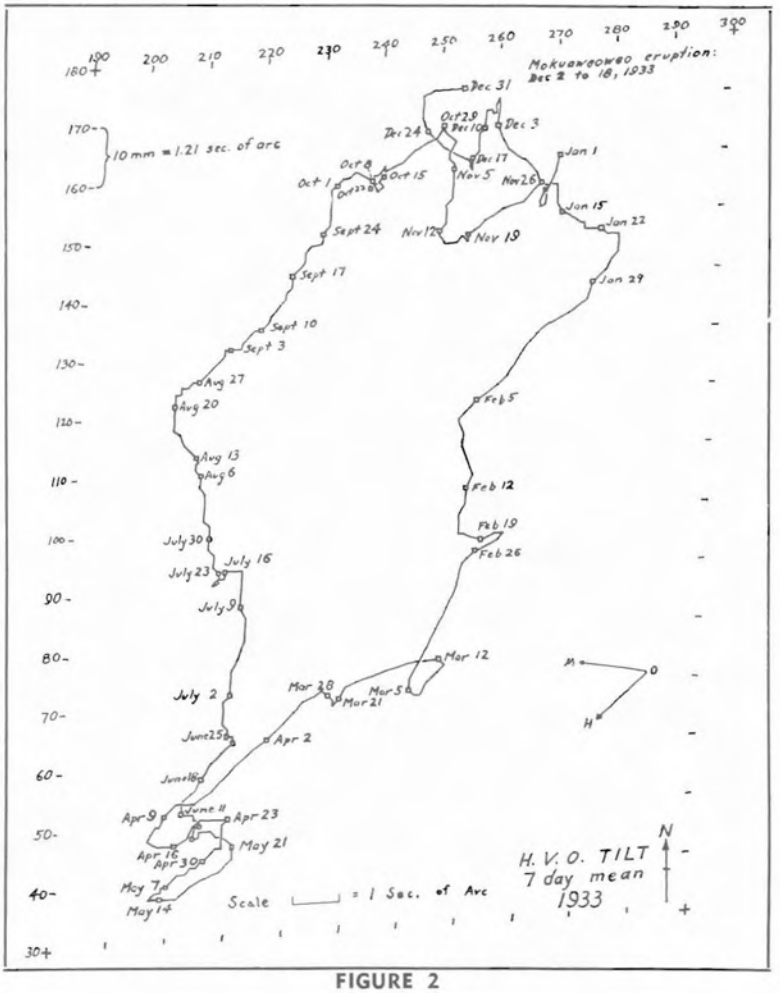


FIGURE 2

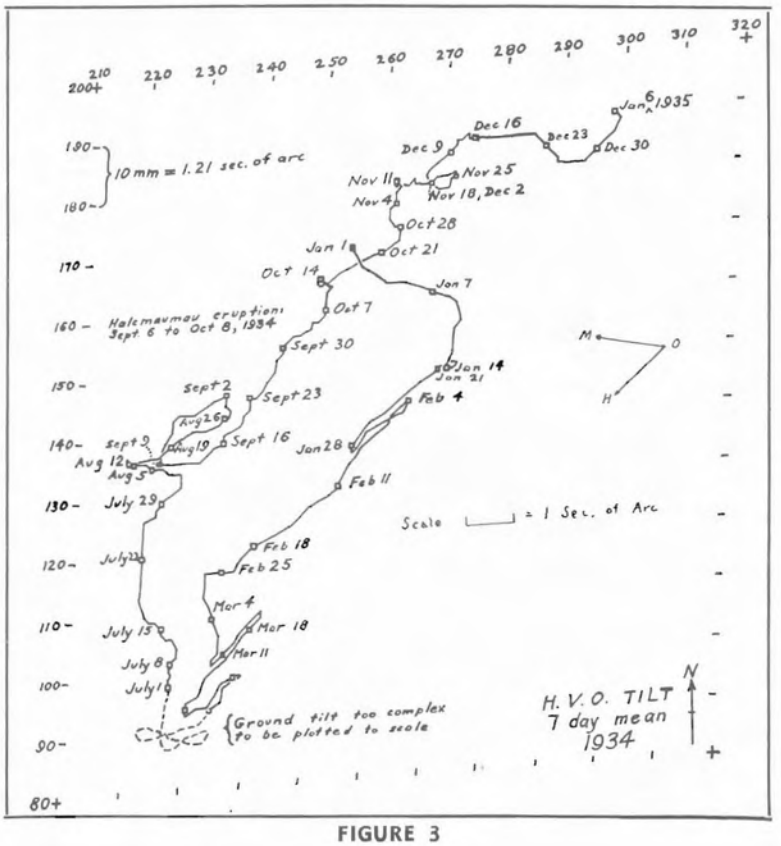


FIGURE 3

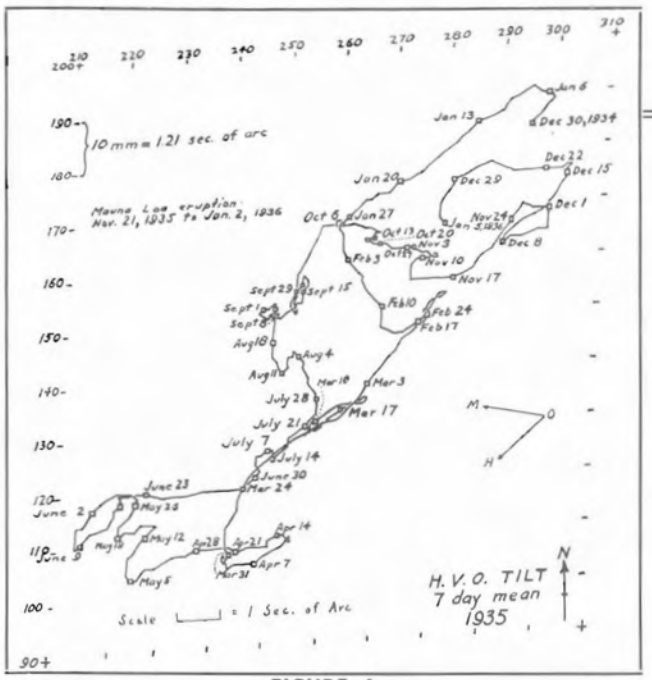


FIGURE 4

the annual loop is to the south and west in normal fashion. The interesting point however is that the southwesterly tilt ceased about five and one half seconds from the low of 1933 and moved steadily north until August 5 when irregularities began to occur. Halemaumau began erupting in the early morning hours of September 6. Tilting to the SW followed until September 9 when recovery started and the normal trend continued in a northeasterly direction until January 6, 1935. At that time the ground on the NE rim of Kilauea had tilted approximately three seconds of arc northeast of its position at the same date the preceding two years. In other words, in 1933 and 1934 tilt had accumulated to the north and east.

Figure 4, 1935 continues from the preceding chart and marks the last tilt-eruption curve. This curve is highly irregular. In June, some two seconds of arc had again accumulated to the northeast over a similar period in the preceding year. On October 6, southeasterly tilt began, continuing until November 17 when Mauna Loa summit crater and N E rift began an eruption which continued until January 2, 1936. The tilt

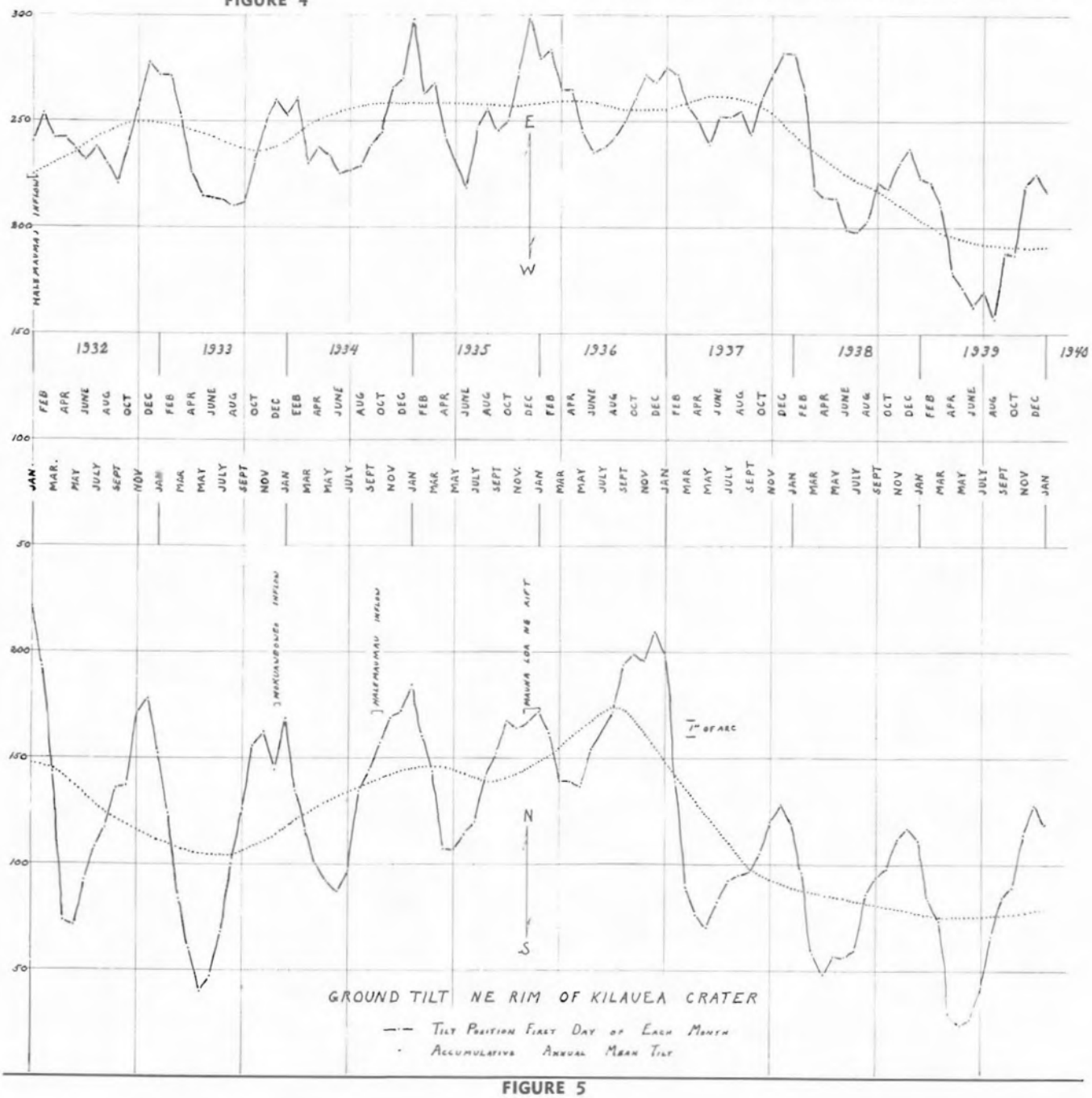


FIGURE 5

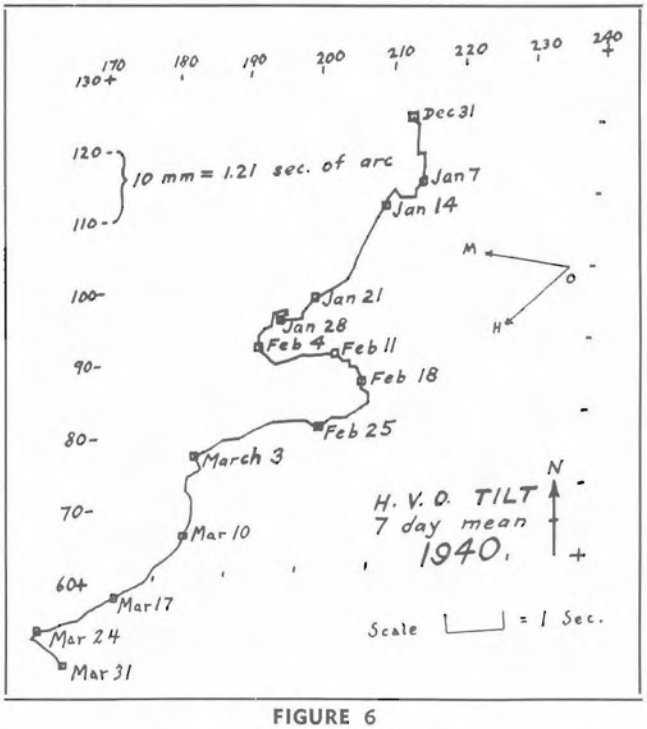


FIGURE 6

recovered most of its northerly trend which would be normal for Kilauea and then moved rapidly to the west December 22 to December 29, during the decline of the Mauna Loa eruption. It is striking that northerly tilt did not recover as it had done in preceding years. Possibly sympathetic pressure under Kilauea had been reduced with the Mauna Loa eruption.

Reference to Figure 5 will show relations which followed. Accumulated tilt increased in 1936 and then steadily receded during 1937 and 1938 but began to recover during the last six months of 1939. By December 1939, northerly tilt had recovered beyond that of the same period in 1937 although easterly tilt had not so recovered. The dotted line marking mean annual tilt indicates a definite recovery corresponding roughly with the peaks. Furthermore, the plotted 7-day mean loops of 1937, 1938 and 1939 were open and relatively regular.

Figure 6 shows the tilt for the first quarter of 1940. On March 31, 1940 the tilt position was 2.6 seconds N and 1.37" W of the same relative position for preceding year. Northerly tilt has recovered much but easterly tilt has lost. However, the strong northerly trend in contrast to condition of three preceding years may be strongly significant of volcanic changes to come.

Figure 7 illustrates the appearance of the tilt curve plotted on a daily basis rather than as a smoothed curve. Sharp irregularities are diurnal in nature and may be related to temperature changes between day and night. It covers the same period as Figure 6.

In the smooth curves, dates of tilt changes do not correspond exactly to visible or other volcanic changes as they are affected by possible sudden changes three days before or after the date concerned which are of course not clearly shown because of the smoothing by overlapping means.

The most interesting chart of the entire group is Figure 8 which gives a general picture of tilt changes at the NE rim of Kilauea Crater from 1913 to the end of 1939. In this case average monthly tilt has been determined and these values plotted as overlapping means in groups of five in the same manner that the daily Bosch-Omori tilt was plotted by 7-day means. The relative position of each month is represented by a square and in order to simplify the resulting maze, each yearly trace is given a different design. During a large portion of each of the two years, 1916 and 1917, tilt records either were not kept or were lost. That period is indicated by a dotted line using an X for each month rather than a square. The major loop progresses counter-clockwise but all others are of normal clockwise movement. That part of the plat from 1913 to 1931 inclusive was worked up and plotted by Dr. H. A. Powers, the remainder by the author.

Changes in ground tilt represented by Figure 8 bear a direct relation to volcanic activity during the same period. A direct relation also was found to exist between the tilt and ground surface changes determined by surveys of precise levels and triangulation in 1912, 1921 and 1927 as described by R. M. Wilson.

Reference to Figure 8 shows that there was strong easterly tilt from July 1913 to July 1918 with only slight westerly recession in 1919. Mauna Loa summit crater erupted in 1914; the SW rift was active in 1916 and in 1919 it produced the Alika flow. The flows were progressively bigger. From March to August 1919 there was considerable westerly tilt. This continued until August 1924 when marked easterly tilt developed. In 1926 the Hoopoloa flow from the SW rift of Mauna Loa occurred. In 1928 and 1929 there was recession to the west again but recovery to the east was resumed in 1930 which continued until 1936. During that period there occurred the Mauna Loa summit eruption of 1933 and the NE rift eruption of 1935-36. Westward tilt followed in 1937, 1938 and 1939. Relative E-W position at the beginning of 1940 is about the same as 1914 and 1926 indicating that pressure conditions from Mauna Loa as affecting tilt at Kilauea at no period have been less than at present and on this basis do not alter its eruptive possibilities, compared with the years referred to.

The proximity of Kilauea makes its effects on the Observatory tilt more striking. It should and apparently does affect the NE Crater rim tilt more in the N-S direction than in the E-W direction. In 1913, 1914, 1915, 1916 and 1917 there was pronounced annual fall tilt. Lava rising occurred simulta-

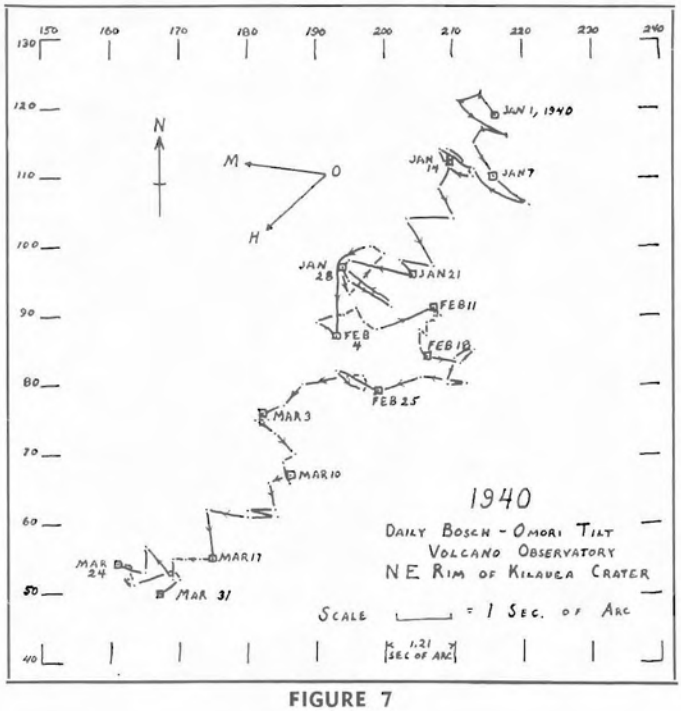
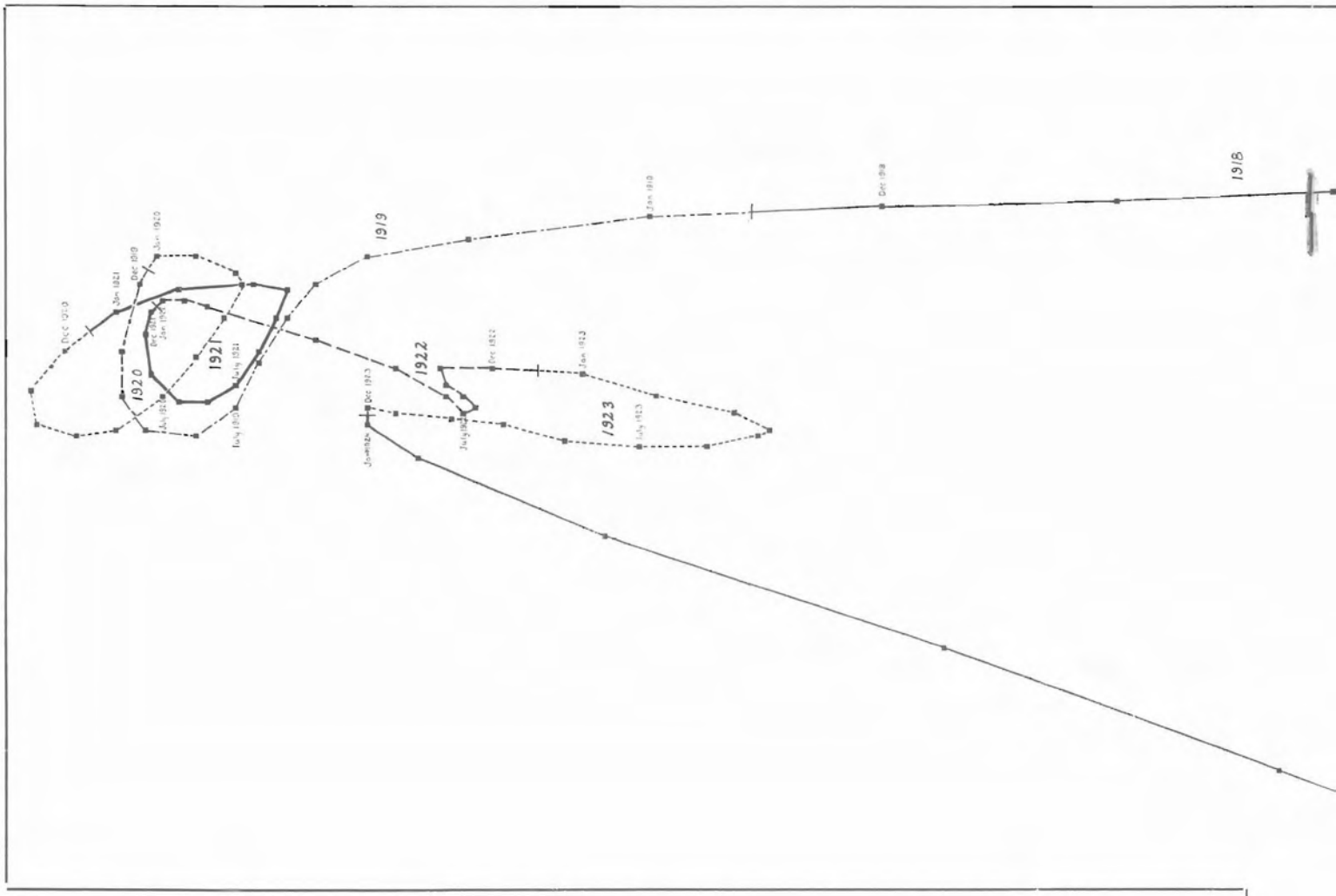


FIGURE 7



neously in Halemaumau and this in turn was apparently sympathetic to increases of pressure under Mauna Loa. Beginning in 1918 the Mauna Loa influence is submerged by the great changes taking place within the Kilauea dome reflected by rising lava in Halemaumau and fifty-three seconds of northerly tilt between May and January of that year. Strong northerly tilt continued until August 1919 culminating simultaneously with Halemaumau lava overflow. In 1920 outflows occurred in the Kau Desert and Halemaumau overflows occurred again in 1921. After this there was lava recession with outflow in vicinity of Makaopuhi during 1922 and 1923. Southerly tilt was marked during those two years. However, in the fall of 1923 there was recovery of north tilt with an accompanying rise in lava in Halemaumau. This was followed by strong southerly tilt of eighty-one seconds between January and July, 1924. In May 1924, lava in Halemaumau receded to unknown depths and activity reached a culmination during that month by steam blast explosion and finally collapse of Halemaumau and to some extent the entire dome of Kilauea. After this, Kilauea Crater was only periodically active with Halemaumau inflows which occurred in July 1924, July 1927, January 1928, February and July 1929, November-December 1930, December-January 1931-32 and September-October 1934. Southerly accumulative tilt continued during 1925 and 1926 but recovered in 1927 to the north. Southerly tilt again occurred for 1928 and 1929 with little change during 1930-31. Slight southerly tilt accumulated during 1932, 1933 and then recovered in 1934 to a point north of the two preceding years. Halemaumau inflow of September, 1934 was the last Kilauea extensive activity to date. Northerly tilt continued during 1935 and 1936. During 1937, 1938 and 1939 southerly tilt steadily accumulated and, with the exception of the Chain-of-Craters seismic crisis of May and July 1938, Kilauea has had its quietest period of the current cycle of events. However, 1939 ended with accumulated tilt again to the north and the first three months of 1940 have borne out the suggestion that a new cycle of northerly tilt may have started and with it the possibility of a coming change in volcanic activity somewhere in the Hawaiian system of eruptive vents.

R. M. Wilson's work has confirmed the major changes described. Precise levels were run from Hilo to Kilauea in 1912, 1921 and 1927. These showed that apparently between 1912 and 1921 the Volcano House B. M. was elevated about two feet and between 1921 and 1927 it was lowered about 3.5 feet. Comparison with Figure 8 shows that the values coincide with tilt changes both in time and relative amounts.

Levels have been run periodically around the SW rim of Halemaumau from the Spit B. M. on the SE Crater rim to a B. M. on the NW rim of Halemaumau. Since 1934 there had been relative lowering of the NW Pit B. M. of 2.02 feet by April 1940. If it is assumed that the Spit has remained more or less stationary, then the Crater floor of Kilauea has settled, and accumulated tilt should be to the south. All other evidence confirms this condition.

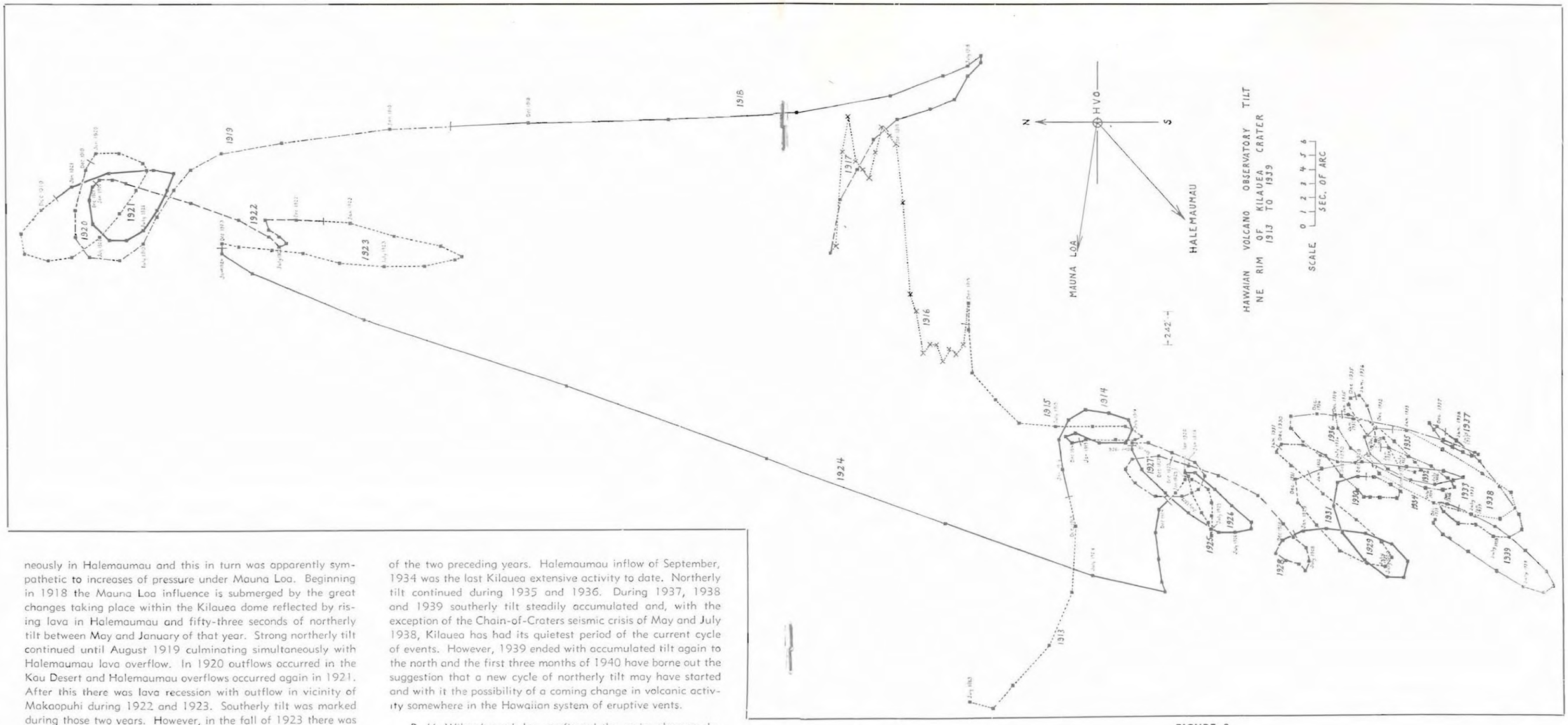


FIGURE 8

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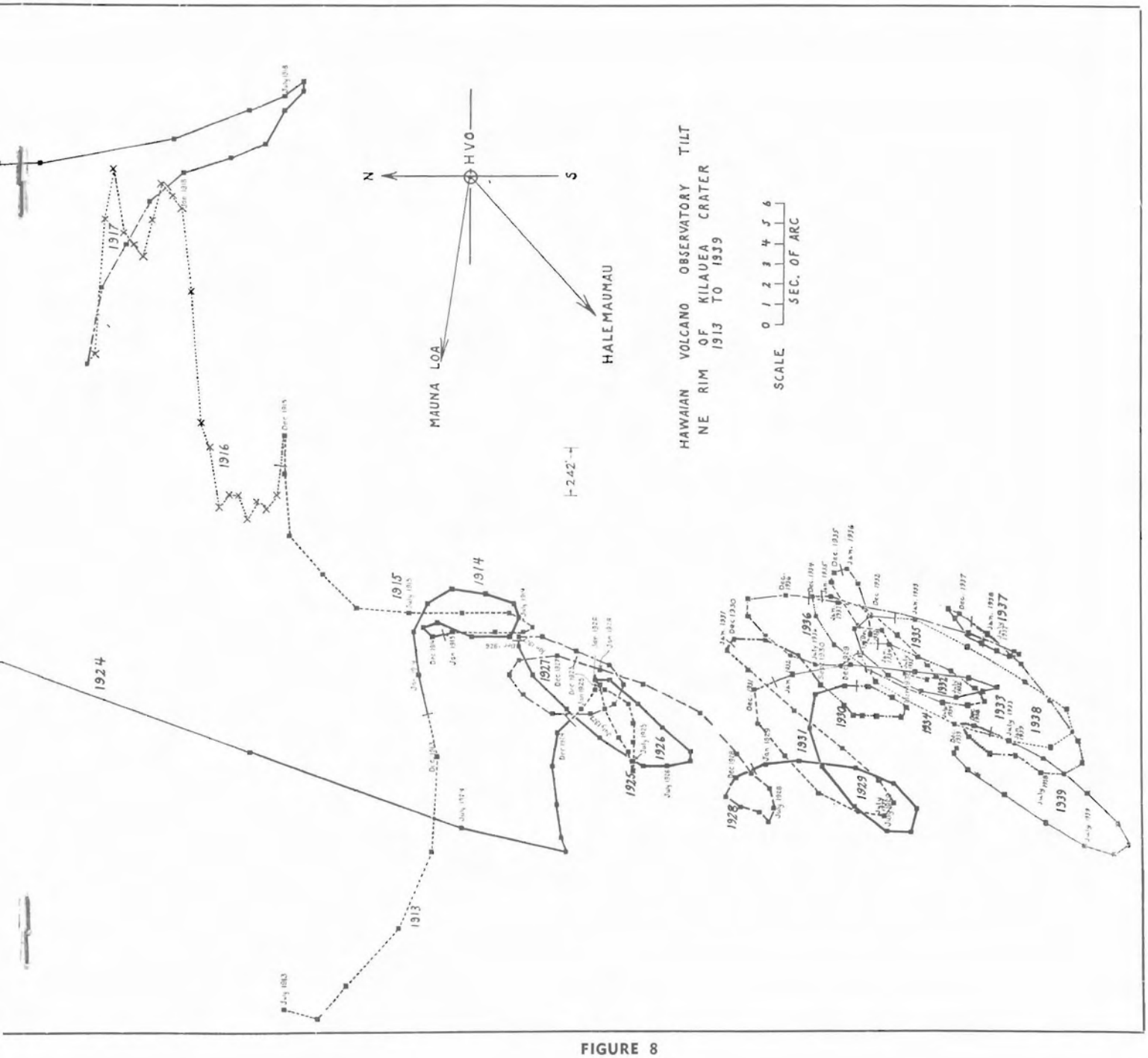

FIGURE 8

From the facts here illustrated and discussed it seems obvious that ground tilt is an extremely revealing as well as important factor in volcanic studies. More instruments should be developed. Dr. Willard H. Eller of the University of Hawaii Physics Department, in cooperation with the Volcano Observatory, is working on the problem and several new instruments have been developed which are promising. The need is for a self recording "tiltmeter" little affected by temperature which will give a clear picture of ground movement in any direction. Such instruments well placed and in sufficient numbers would not only be useful in determining changes in lava movements but would also be of help in straightening out the complicated structural relations of the Hawaiian Volcanoes.

In acknowledgment, the author wishes to thank Mr. P. E. Schulz of Hawaii National Park for tracings made of charts Nos. 1, 3, 4 and 6 and used for reproductions here illustrated, and to Dr. H. A. Powers and Mr. A. E. Jones for figures and computations on earlier charts.

Hawaiian Volcano Observatory Report for January-March 1940

VOLCANOLOGY

January 1940

The month of January began with still less seismicity than December but the third and fourth weeks produced excess of disturbances on the Mauna Loa seismograph, and the half of these recorded at Kilauea were mostly of Mauna Loa origin (29 out of 31 shocks third week). Nothing is known to have happened at the craters, and the island was going through a period of excessive drouth with very light southerly winds and calms. Humps in the Chain-of-Craters road were increasing in number between Devil's Throat and Aloi pit.

The following are the local data for January:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
January 7	2	4.0 mm. closed	11
" 14	0	2.0 mm. opened	18
" 21	0	2.5 mm. opened	31
" 28	0	4.0 mm. closed	26

Two rock slides from the southeast rim of Halemaumau down the interior wall were indicated by dust clouds seen from the Uwekahuna Museum January 4 at 9:45 a.m. and 9:57 a.m.

February 1940

The month of February was without unusual volcanic events. The drouth continued and the burning down of Volcano House February 6 produced danger to the wooden Observatory a few hundred feet away. A peculiar tremor on the seismograph was recorded between 6:15 a.m. and 7:10 a.m. while the fire was at its height, possibly correlated with flame pulsations of the conflagration as well as related traffic movement.

The first week of the month at Mauna Loa seismograph continued to show more very feeble earthquakes than the one at Kilauea but this peculiarity was declining. Of the feeble and very feeble earthquakes of the month, 31 in number, only 10 were from distances corresponding to Mauna Loa or beyond, the others chiefly Kilauea shocks.

No slides were reported at Halemaumau. Inspection February 17 showed a thin blue haze reflecting sunlight between 10:00 a.m. and noon. For the first time a bright orange-yellow spot was observed on the floor between the center and the southeast rim wall, making a faint plume of fume, with yellow-lined cracks adjacent. Presumably sulphur was being deposited.

The following are the local data for February:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
February 4	0	2.5 mm.	43
" 11	0	3.0 mm.	42
" 18	0	2.0 mm.	50
" 25	0	2.5 mm.	34

March 1940

The month of March produced notable increase in Mauna Loa earthquakes, solfataric stains were increasing on the Halemaumau floor and some feeble earthquakes were felt during the month. Of 26 feeble and very feeble local earthquakes registered during the month 13 were from Mauna Loa distances and two were reported felt.

In Halemaumau on March 1 there was faintly visible fume and much white and yellow stain along the southeast edge of the pit floor. The solfatara at the base of the west wall is apparently dead. Accompanying a felt earthquake at 9:47 a.m. March 2 rocks fell from the WNW wall of Halemaumau and there was a scar of recent sliding at the south. A moderate slide sent up a dust cloud lasting 10 minutes at NE wall of Halemaumau 5:28 p.m. March 4. The end of the month produced a few rock slides and the fuming and yellow spots were still in evidence at the southeast in Halemaumau. Observation at Devil's Throat March 30 showed fresh rocks on the floor from the west wall.

The Mauna Loa seismograph showed a spell of seismic activity more intense than that at Kilauea for forty-eight hours between noon March 8 and noon March 10. Approximately 40 seismic disturbances were registered, whereas Kilauea recorded only 23. All but two at Kilauea were tremors, whereas Mauna Loa registered 15 as very feeble earthquakes. Apparently Mauna Loa was in local agitation under the northeast rift, and Mauna Loa was again focus of swarms of small earthquakes at the end of the month. This was precursory to the outbreak of Mauna Loa of April 7, and these interesting demonstrations of how differently two seismographs behaved only 9.4 miles (15 km.) apart show how desirable are multiple instruments of simple design over a uniform net of locations, recording time and intensity at a central station.

The following are the local data for March:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
March 3	1	1.0 mm. opened	52
" 10	1	2.5 mm. closed	45
" 17	0	5.5 mm. opened	22
" 24	0	0.5 mm. closed	24
" 31	few	7.0 mm. opened	26

Change of Annual Tilt

Referring to the notable change of tilt at the end of each month for the year next preceding, tabulated in page 5 of Volcano Letter No. 466, it is of interest to exhibit a general continuance of tilt to the west and north at the Observatory northeast rim of Kilauea Crater, for the year preceding the date indicated, respectively in north-south azimuth and east-west azimuth at the Bosch-Omori seismograph.

January 28, 1940	S 0.88 seconds	W 3.27 seconds
February 25, 1940	N 0.97 seconds	W 1.34 seconds
March 31, 1940	N 2.6 seconds	W 1.37 seconds

All of this is in contrast to a strongly southwesterly tilt of over 5 seconds between May and July 1939, this changing to an aggregate of about 3 seconds of northwesterly tilt between December 1, 1939 and March 31, 1940.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Distant*	Weekly Seismicity†
January 7....	11	0	0	0	0	2	2.75
" 14....	17	1	0	0	0	0	5.25
" 21....	23	7	1	0	0	1	9.75
" 28....	22	4	0	0	0	0	7.50
February 4....	31	12	0	0	0	0	13.75
" 11....	31	11	0	0	0	4	13.25
" 18....	41	8	1	0	0	0	15.25
" 25....	34	0	0	0	0	2	8.50
March 3....	46	5	1	0	0	0	15.00
" 10....	38	6	1	0	0	0	13.50
" 17....	19	2	1	0	0	0	6.75
" 24....	19	1	4	0	0	0	7.75
" 31....	21	5	0	0	0	1	7.75

* Including teleseisms or earthquakes over 5000 km. from Kilauea.
† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible a determination of depth of focus has been made.

January 9, 7:47 pm, very feeble, probably originated in Kilauea SW rift about 8.0 miles SW of Halemaumau.

January 16, 11:06 pm, feeble, of shallow origin Mauna Loa summit crater, 19° 28.0' N; 155° 37.5' W.

January 16, 11:08 pm, very feeble, same location as preceding quake.

January 16, 11:32 pm, very feeble, 9.0 miles deep in area 4.5 miles W of Kilauea crater (Kaoiki Pali). 19° 25.2' N; 155° 20.5' W.

January 16, 11:45 pm, very feeble, probably originated in Kilauea SW rift.

January 17, 10:50 am, probably of Hualalai origin.

January 20, 12:34 am, very feeble, probably originated in Hilina Fault about 3.5 miles SW of Kamakaia Hills.

January 28, 1:06 am, very feeble, 2.3 miles deep, Kilauea SW rift, 0.8 mile NE of Cone Peak. 19° 23.9' N; 155° 17.9' W.

January 28, 6:18 pm, very feeble, Mauna Loa NE rift about 6.5 miles NE of Puu Ulaula.

January 28, 9:14 pm, very feeble, Mauna Loa NE rift about 3.0 miles NE of Pohaka Hanalei.

January 29, 8:06 am, very feeble, probably originated under N slope of Mauna Loa.

January 30, 1:11 am, very feeble, Mauna Loa NE rift about 3.0 miles NE of Pohaka Hanalei.

January 30, 11:32 am, very feeble, 1.1 miles deep, SE rim area of Halemaumau. 19° 24.4 ' N; 155° 16.6' W.

January 30, 1:54 pm, very feeble, Mauna Loa NE rift 6.0 miles NE of Puu Ulaula.

January 31, 2:19 am, very feeble, 1.1 miles deep, near SW rim junction of Kilauea Crater with SW rift. 19° 23.9' N: 155° 17.6' W.

February 2, 12:29 am, very feeble, of shallow origin, SE rim of Halemaumau. 19° 24.5' N; 155° 16.9' W.

February 2, 9:14 am, very feeble, from central portion of Kilauea Crater.

February 3, 12:49 pm, very feeble, probably originated in vicinity of Ahua Kamokukolau.

February 5, 7:50 pm, very feeble, E rim area of Kilauea Crater near Byron Ledge.

February 7, 11:43 am, very feeble, of shallow origin, Mauna Loa NE rift 5.0 miles SW of Puu Ulaula. 19° 31.0' N; 155° 31.0' W.

February 8, 7:19 am, very feeble, 11.0 miles deep, near junction of Hilina Pali fault with Kilauea SW rift. 19° 15.0' N; 155° 21.5' W.

February 8, 10:42 am, very feeble, of shallow origin, Kilauea Crater 0.9 mile NE of center of Halemaumau. 19° 24.9' N; 155° 16.4' W.

February 9, 7:42 am, very feeble, probably originated in Chain-of-Craters near Puhimau.

February 9, 10:47 pm, very feeble, probably originated under E rim of Kilauea Crater.

February 10, 4:44 am, very feeble, originated under Halemaumau not over 0.3 mile in depth and near SE rim. 19° 24.3' N; 155° 17.2' W.

February 12, 11:18 pm, very feeble, NE rim area of Kilauea Crater.

February 14, 8:54 pm, very feeble, NE portion of Kilauea Crater.

February 15, 3:03 am, very feeble, 11.0 miles deep near junction of Hilina Fault with SW rift of Kilauea. 19° 13.5' N; 155° 21.5' W.

February 16, 9:12 am, very feeble, probably originated 13.0 miles from the Observatory in the Kilauea SW rift.

February 16, 4:09 pm, very feeble, 2.3 miles deep under NE rim of Kilauea.

February 17, 7:03 am, feeble, 4.2 miles deep in rifts 0.9 mile S of Ahua Kamokukolau. 19° 22.2' N; 155° 15.9' W.

February 28, 10:38 am, very feeble, probably originated in Kilauea SW rift.

March 1, 1:58 am, very feeble, 12.0 miles deep, Mauna Loa NE rift, 8.0 miles NE Puu Ulaula and 18.0 miles SW of Hilo. 19° 36.0' N; 155° 22.0' W.

March 2, 9:47 am, feeble, of shallow origin SE rim area of Kilauea Crater. 19° 23.8' N; 155° 16.5' W. Dismantled N.S. component of Pit seismograph and reported sharply felt on SW rim of Halemaumau.

March 2, 10:20 am, very feeble, some origin as preceding quake.

March 4, 8:15 pm, very feeble, probably originated under SW end of Mauna Loa summit crater.

March 8, 10:40 pm, very feeble, Mauna Loa NE rift.

March 9, 4:00 pm, Mauna Loa summit crater.

March 10, 4:06 pm, feeble, 17.0 miles deep, Mauna Loa NE rift about 4.0 miles NE of Puu Ulaula. 19° 34.0' N; 155° 24.5' W. Reported felt at Uwekahuna.

March 11, 11:43 pm, feeble, of shallow origin under Byron Ledge, E rim of Kilauea crater. 19° 24.8' N; 155° 15.7' W.

March 14, 11:26 am, very feeble, probably originated in cracks 0.8 mile NE of Puu Ohale.

March 18, 3:27 am, very feeble, 18.0 miles deep under Hualalai. 19° 40.0' N; 155° 48.0' W.

March 20, 7:46 pm, feeble, 11.0 miles deep, Hilina Pali, 4.0 miles S SE of Makaopuhi. 19° 19.0' N; 155° 09.0' W.

March 21, 11:11 pm, very feeble, probably originated under Mauna Kea area.

March 22, 3:23 am, very feeble, probably originated in Hilina Pali.

March 26, 12:45 am, very feeble, NE slope of Mauna Loa, 4.0 miles SW of Hilo seismograph.

March 27, 7:27 am, very feeble, 18.0 miles deep under Mauna Loa summit crater. 19° 28.0' N; 155° 37.0' W.

March 27, 5:54 pm, very feeble, Mauna Loa NE rift near Mauna Loa seismograph station.

March 27, 6:50 pm, very feeble, of shallow origin, Kilauea Crater, 0.4 mile E of east rim of Halemaumau. 19° 24.5' N; 155° 16.5' W.

March 28, 2:31 am, very feeble, 18.0 miles deep, Mauna Loa NE rift, 2.0 miles SW of Puu Ulaula. 19° 31.0' N; 155° 29.0' W.

Teleseisms

January 2, 1h 06m 34s am, unidentified portion registered. Location by U.S.C. and G.S. Vicinity of Easter Island. 31° S; 108° W.

January 6, 3h 42m 51s am, "P" waves registered. 3775 miles from Kilauea in vicinity of New Hebrides and Loyalty Islands. 22° S; 170° E.

January 16, 2h 54m 18s pm, "P" waves registered. 3700 miles from Kilauea in vicinity of Marianas Trough. 17° N; 148° E.

February 7, 6h 53m 37s am, "P" waves. 2810 miles from Kilauea in the Aleutian Islands. 52° N; 174.5° E.

February 8, 1h 09m pm, unidentified portion. No information concerning point of origin obtained.

February 11, 9h 59m 17s pm, "P" waves. 3115 miles from Kilauea in vicinity of Tonga Trough. 22.6° S; 177.5° W.

February 11, 10h 53m 04s pm, unidentified portion recorded. Originated in Aleutian Trough. 54° N; 160° W.

February 19, 3h 56m 56s pm, "P" waves. 3250 miles from Kilauea in Solomon Islands. 12° S; 167° E.

February 24, 1h 40m 54s, am, "P" waves.

March 27, 2h 18m am, unidentified portion.

Microseismic Motion

January

Moderate—1, 13, 14, 17, 31.

Strong—2 to 12, 15, 16, 18 to 30.

February

Light—1, 2.

Moderate—3, 8, 9, 12, 13, 17 to 19, 26.

Strong—4 to 7, 10, 11, 14 to 16, 20 to 25, 27 to 29.

March

Light—

Moderate—8, 11 to 13, 21, 22, 30.

Strong—1 to 7, 9, 10, 14 to 20, 23 to 29, 31.

Time used throughout is Hawaiian Standard, 10h 30m slower than G. C. T.

Tilting of the Ground

The following tables show tilt by weeks as recorded on the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau, the algebraic sum toward or away from the Pit as indicated by stations on the W and SE rims respectively.

At the Observatory the total accumulated tilt for the year ending January 28, was 0.88" S and 3.27" W.

For the year ending February 25, was 0.97" N and 1.34" W.

For the year ending March 31, was 2.6" N and 1.37" W.

Table of Tilt

Week Ending	Observatory	Halemaumau West Station
January 7	1.12" S 10° E	0.00
" 14	0.77" S 56° W	0.00
" 21	1.94" S 37° W	0.00
" 28	0.73" S 59° W	1.58" N 71° W
February 4	0.63" S 39° W	4.23" N
" 11	1.34" S 88° E	0.98" N 79° W
" 18	0.66" S 45° E	1.37" N 16° E
" 25	1.09" S 44° W	1.72" S 20° W
March 3	2.15" S 76° W	0.00
" 10	1.41" S 8° W	1.19" S 71° W
" 17	1.68" S 48° W	2.38" N 56° E
" 24	1.46" S 66° W	1.04" N 49° W
" 31	0.77" S 39° E	0.51" S 72° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
January 7	12.77" S 36° E	12.79" from
" 14	6.48" S 80° W	4.86" toward
" 21	3.89" S 39° W	0.98" from
" 28	3.82" N 68° W	1.59" toward
February 4	0.74" S 70° W	1.95" toward
" 11	3.43" S 55° E	4.13" from
" 18	0.00	0.60" toward
" 25	0.00	0.89" from
March 3	3.24" S 34° E	3.40" from
" 10	3.24" N 34° W	2.21" toward
" 17	10.37" S 8° E	7.14" from
" 24	2.20" S 68° W	0.11" from
" 31	3.82" N 10° E	1.99" toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory was made once during the month of January. On January 11, the measurement indicated closing of 0.42" for the Halemaumau value and closing of 0.41" for the Crater value compared with similar measurements of December 19.

Angle values February 8, indicated closing of 0.08" for Halemaumau and opening of 1.41" for the Crater. February 28, Halemaumau angle had closed 2.19" and Crater angle had opened 2.06". Change January 11 to February 28, closing of 2.17" for Halemaumau and opening of 2.45" for Kilauea Crater.

Angle values March 16, indicated opening of 2.00" for Halemaumau and closing of 1.39" for the Crater. March 28, Halemaumau angle had opened 0.26" and Crater angle had opened 1.59". Change February 28 to March 28, Halemaumau opened 2.26" and Crater closed 1.56".

Total change December 19 to March 28. Halemaumau angle from Pit seismograph to NW Pit BM, closed 0.33"; Crater angle from SE rim station to Uwekahuna opened 1.50".

Spirit Levelling Around Halemaumau

On February 9, a line of levels was run from the Spit B.M., SE rim of Kilauea Crater to the NW Pit B.M., on the NW rim of Halemaumau. Compared with a similar run made August 30, 1939, the NW Pit B.M., had lowered 0.067 meters with reference to Spit. This relative lowering, since July 2, 1934 has amounted to 0.697 meters or 2.26 feet.

Chain-of-Craters Road Cracks

Date	101	102	103	104	105	106	107
Jan. 26	404.70	64.60	101.55	17'9"-⅛	87.35	88.75	39.50
Feb. 23	404.85	64.60	101.55	same	87.30	88.75	39.50
Mar. 29	404.80	64.65	101.55	same	87.35	88.65	39.50
Total change in mm. since Dec. 29, '39	+2.5	+0.5	.....	.....	.....	—1.0	.....

The rim crack at Pauahi at edge of Chain-of-Craters road closed 2.5 millimeters between December 29, 1939 and March 29, 1940.

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
in cooperation with
UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, is leased and operated by the United States Government, Department of the Interior, National Park Service.

The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** maintain outside seismograph stations and supplement the work of the government with research associates, instrumental plants and special investigations.

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Edward G. Wingate, Superintendent
Hawaii National Park

University of Hawaii
T. A. Jaggar, Geophysicist

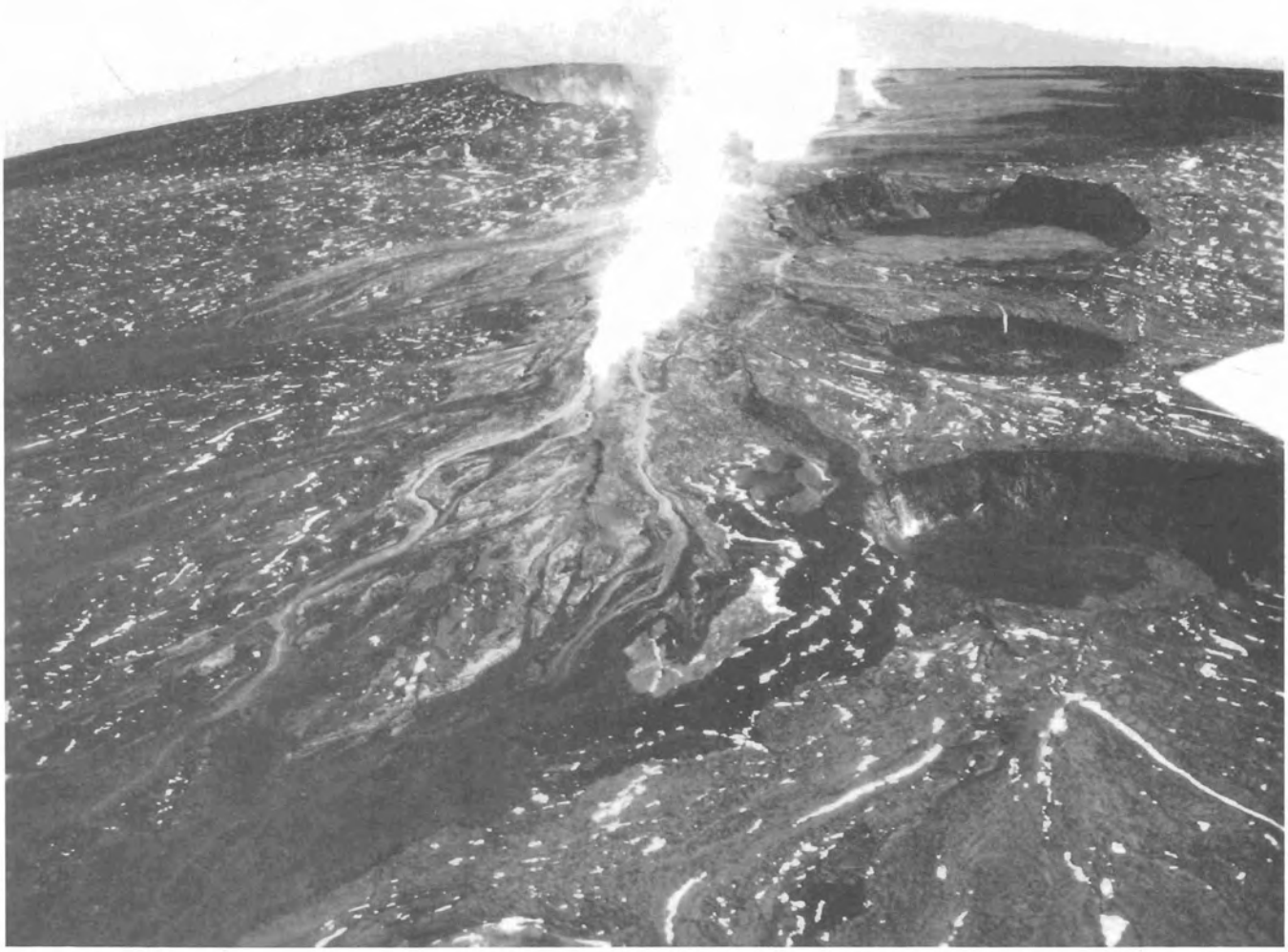

Fig. 1.—Mauna Loa summit crater eruption of 1940. Flows and fountains along southwest rift, the morning of April 8. Photo by 18th Air Base Photo Laboratory, A.C., Wheeler Field, T. H.

MAUNA LOA SUMMIT CRATER ERUPTION 1940

By HUGH H. WAESCHE
Acting Principal Scientist

Historical Background

With very little immediate warning, Mauna Loa became active with a summit crater outbreak during the late evening hours of April 7, 1940. That event was not unexpected as numerous data had indicated the possibility of volcanic activity and only a few weeks before, Dr. T. A. Jaggar had publicly stated that Mauna Loa should produce activity, probably in the summit crater, about May 1, 1940. This statement was based principally on known periodicity of Mauna Loa outflows and on average lengths of periods between eruptions during the current century compared with corresponding similarity of events in the nineteenth century. The first eruption of Mauna Loa reported observed was that of 1832; the next, and well observed, was the northeast rift flow of 1843. The similarity of conditions during the 1843 eruption and that of 1935 is striking. Both issued from the same approximate elevations and were accompanied by minor activity in Mokuaweoweo at the outbreak. Bath were active with fountains in the vicinity of twelve thousand feet for a week or ten days and later produced voluminous flows from much lower elevations on the northern flank of Mauna Loa. The course of the 1935 flow would undoubtedly have been that of 1843 if it had not been interfered with and diverted by the earlier flow. The parallel was carried over by the recent 1940 summit eruption. The 1843 outbreak was followed 6 years and 4 months later by a Mokuaweoweo outflow; the one of 1940 followed the 1935 activity in 4 years and 5 months. Like 1849, the activity of 1940 was remarkably free of seismic effects which are normally expected before and with any eruption. The 1935 eruption is thought to have been stopped by bombing. If this is true the inactive period which followed may have been shortened accordingly to keep the parallelism, and also may have allowed a more rapid build-up of lava pressure under the mountain. If, on the other hand, average periodicity of eruption for Mauna Loa is considered, it will be observed that that alone was sufficient for expected activity at approximately the time it occurred. Seismic activity and tilt also suggested coming volcanic changes.

Since 1899 there have been 9 Mauna Loa eruptions. Of these 4 have been purely summit activity while the other 5 have been flank outflows accompanied for the first few hours by activity in Mokuaweoweo. Eruptions of this century and their respective sources are as follows:

1899—July 4, summit 4 days, northeast rift 19 days
1903—October 6, summit 2 months
1907—January 9, summit short, southwest rift 15 days
1914—November 25, summit 6 weeks
1916—May 19, southwest rift 2 weeks
1919—September 29, summit short, southwest rift 6 weeks
1926—April 10, summit short, southwest rift 2 weeks
1933—December 2, summit 17 days
1935—November 21, summit short, northeast rift 42 days
1940—April 7, summit 19 weeks

Tilt Change Diagrams Volcano Letter 467

The millimeter divisions of original chart make non-rectangular coordinate lines at side and top of some of the figures by the angular amount the seismograph booms were permanently set oblique to the N-S and E-W azimuths.

Study of this list shows that with the exception of the 1916-1926 eruptions, summit eruptions have alternated with flank outflows. In general the same relations seems to have existed during the nineteenth century and this may be accepted as the normal succession although by no means an iron-clad rule.

The average period of quiescence between eruptions since 1899 has been 4 years, 6 months with a maximum interval of 7 years and 10 months between 1907 and 1914 and a minimum between 1914 and 1916 of one year and 6 months. If the average interval had occurred between 1935 and 1940, the latter eruption would have begun, probably late in May. Actually it came nearly two months ahead. The 4 years and 3 months-period between 1899 and 1903 was very close to the average and the 1935-40 interval. Another interesting relation is the time interval between a summit eruption and a rift flow. The average is 25 months, with the shortest, 16 months between 1914 and 1916 and the longest, 37 months between 1903 and 1907. The 25-month average for this century is close to the 28-month average value from 1849 to the present. This suggests that the time interval between summit and flank eruptions of the same volcanic episode stays fairly constant within close limits.

Seismic Events

Although there was a remarkable absence of seismic phenomena associated with the 1940 period of activity, there was no lack of earthquakes in the 12-month period which preceded the outbreak. All eruptions are preceded by premonitory seismic disturbances and also are succeeded by after effects of a similar nature. It is difficult to distinguish where earthquakes associated with one eruption end, and those of the next begin. Then too, there are other shocks which probably have no direct relation to the subterranean lava movements.

In 1935 premonitory earthquakes of the Mauna Loa eruption, which came in November, probably began with the strong shock which caused some damage in Hilo, June 28, at 9:00 a.m. It was located in the Mauna Loa northeast rift about 10 miles from Hilo. Mauna Loa shocks increased in number and reached a climax on the night of September 30-October 1 when 1 strong (11:58 p.m. strongest recorded at Observatory in over 5 years), 3 moderate, 2 slight, 3 feeble and 20 very feeble earthquakes registered within a period of 12 hours from 10:00 p.m. to 10:00 a.m. They originated at points scattered throughout the Mauna Loa rift system from Hoopuloa to Hilo. At 1:11 a.m., November 21, a moderate earthquake originating at a point 5.0 miles from the summit crater in Mauna Loa northeast rift marked the locality from which, 17 hours later, floods of lava were to issue. With the outbreak there were 2 slight, 2 feeble, 2 very feeble earthquakes and then a period of 3,198 minutes of tremor. During that eruption there were almost no earthquakes. One hundred twenty-five earthquakes, from very feeble to strong, had been located in 1935, and of these 23 were of Mauna Loa origin with 4 locations in southwest rift, 9 near Mokuaweoweo and the remainder from the northeast rift. In 1936, after the Mauna Loa eruption, there were no notable earthquakes of Mauna Loa origin and about the normal number from Kilauea.

The figures for the years 1935 to 1939 inclusive are tabulated as follows:

Year	Total Locations	Mauna Loa Total	Mokua-weoweo	SW Rift	NE Rift
1935	125	23	9	4	10
1936	195	10	3	1	0
1937	257	20	4	1	15
1938	386	32	6	2	24
1939	217	47	14	1	32
1940, to June 30.....	106	20	9	0	11
Jan. 1 to Mar. 31.....	50	16	7	0	9

These figures fit in very well with the known volcanic developments; 1935 was the year succeeding the last Kilauea outflow.

The Observatory seismographs are located on the northeast rim of Kilauea Crater and show the very large excess of recorded Kilauea earthquakes over those from Mauna Loa. That also explains the increase of total locations of epicenters in successive years from the low of 1935 (Kilauea in repose following the 1934 eruption) to the high of 1938 which was the year of the Kilauea Chain of Craters crisis in May and August. The approaching Mauna Loa activity probably explains the slower decline in seismic activity after 1938 compared with the rise preceding that year. The Mauna Loa column is clear-cut in its significance; 1935 relatively high wtih Mauna Loa in eruption, then a low in 1936 with repose of lava movement. Starting in 1937, Mauna Loa seismic disturbances steadily increased with their highest increment (last figure in column 6) between January and April, 1940. In the first half of 1940 there were 20 Mauna Loa earthquakes located with 16 of these in the first quarter. Thus for the first quarter of 1940 the Mauna Loa earthquake rate at the Observatory was an increase in ratio over 1939 of 64 to 47. During the period of activity following the release of initial energy there were only 4 located Mauna Loa shocks by the end of the second quarter. The remaining three columns are identified with the sites of eruption and outflow. The 1935 northeast rift activity was the first from that source since 1899. That 1899 eruption high on the slope (12,500±) was the last of the nineteenth century series which had successively sealed the northeast rift from the vicinity of Kulani Cone. It was followed by 1907, 1916, 1919, and 1926 flows, successively higher on the Mauna Loa southwest rift effectively sealing that section which was the only part of the rift open after 1899. Many more earthquakes occurred to the southwest than to the northeast in those years and they were still plentiful through 1933. Four earthquakes in 1935 were



Fig. 2.—Fountains and rift in Mokuaweoweo the morning of April 8. Note small fountain to the north of Na Puu Waenakonu, left center; 1914 cone in right foreground, later center of activity. Photo by 18th Air Base Photo Laboratory, A.C., Wheeler Field, T. H.

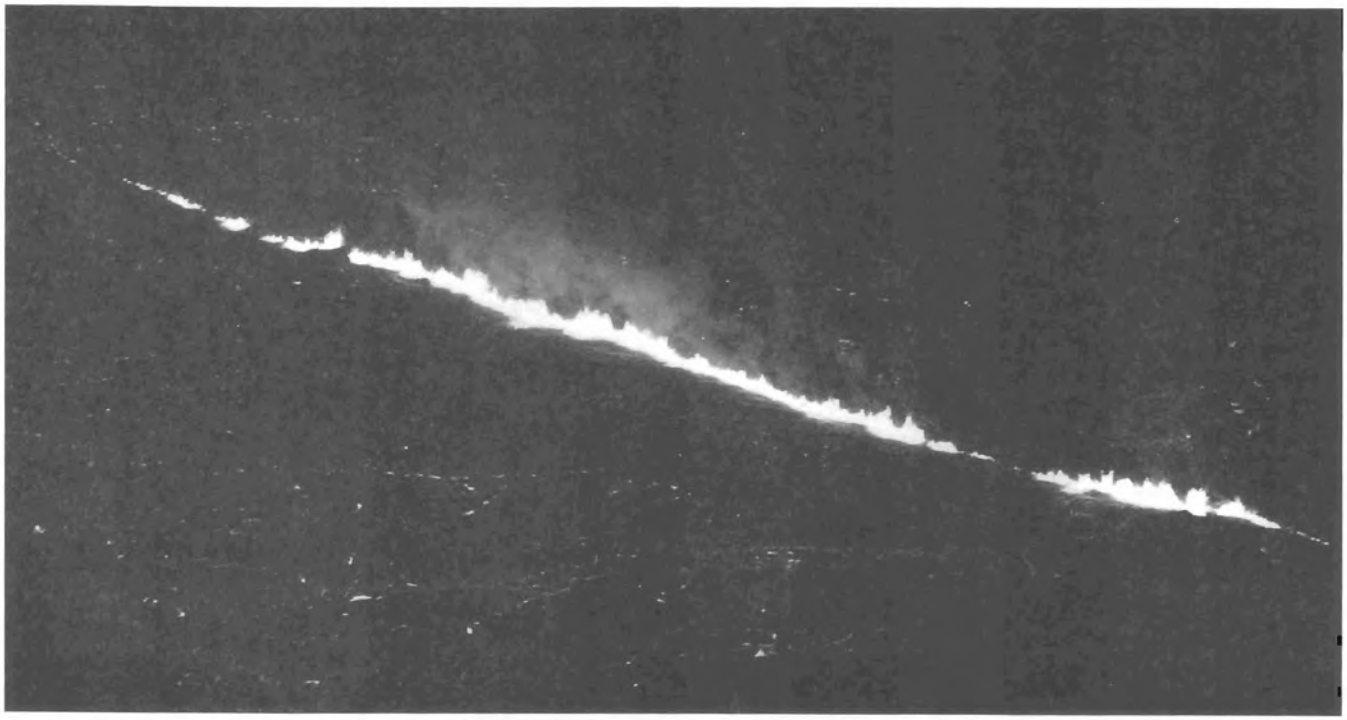

Fig. 3.—Air photograph, showing fountains along rift in Mauna Loa about 4:30 a.m. April 8. Fountains at right foreground start at base of south lunate platform. Note Na Puu Waenakonu, left center. Photo by 18th Air Base Photo Laboratory, A.C., Wheeler Field, T. H.

located in the southwest rift including a very heavy shock the night of September 30-October 1. Intrusion at least was probably going on then in the southwest rift. After that year there were almost no southwest rift earthquakes and this was borne out by the Kona seismograph at Kealakekua.

By far the greater proportion of the earthquakes from Mauna Loa originated in the northeast rift which is probably "open" and "working." Theory here fits with fact. The "liveness" of the Mauna Loa northeast rift was confirmed by the registration in January and March, 1940, of earthquake swarms on the Mauna Loa seismograph, which is located at an elevation of about seven thousand feet and 6 miles southeast of Puu Uloula on the northeast rift. In 48 hours, January 16-18, more than 60 seismic disturbances registered. They were of tremor or very feeble classification, most of which did not register at the Observatory. Distances indicated were such as to give locations along the rift toward the summit crater. The Volcano Weekly Report No. 1462 of the week ending Jonuary 28 says, "The Mauna Loa seismograph has continued to show more earth disturbances than the seismographs at the Observatary . . . . Evidence still points to some movement along the Mauna Loa northeast rift. Between noon, March 8 and the same time March 10 (48 hours), 40 seismic disturbances registered on Mauna Loa compared with 23 at Kilauea. Fifteen of these were very feeble earthquakes."

Seismic activity is usually more intense before pending eruptions and with the possible exception of the one of 1849 the current activity has probably the lowest record of seismic disturbance before and during the activity. The strong earthquake of January 22, 1938, felt throughout the Island group, as well as registered all over the world, may well have been the beginning of the Chain of Craters crisis at Kilauea during the summer of 1938 and the beginning of the summit eruption of 1940 on Mauna Loa. In any case, such earthquakes, located a hundred or more miles from the Observatory and under the sea floor to the north and west of Hawaii have been usual rather than unusual in the past history of Hawaii and its volcanoes. In 1912 there were 2, and one each in 1913 and 1914. The last preceded the 1914 eruption by 3 months. In 1916 (Mauna Loa year) there were 3 earthquakes; 2 in 1918; 3 in 1919 (Mauna Loa year); one in 1923; one in 1926 (which preceded Mauna Loa eruption by 3 weeks); and, in 1927 there were 2 (1929 was Hualalai earthquake year).

Unless the relatively heavy earthquake shocks of May, June, and July, 1939, may be similarly classed there were no unusual seismic events leading up to the 1940 eruption other than an increase in numbers. It is possible that the heavy seismic activity (intensity not quantity) of 1935 so shattered the northeast rift and summit cracks that the lava could later rise and flow along them without producing any great amount of crustal disturbance. Also the 1935 eruption may have been artificially halted leaving the magma column well up in the volcanic system ready to break through at the slightest increase of pressure.

Activity on Mauna Loa was first observed as bright glow from summit fountains of lava the evening of April 7, 1940, at about 11:30 p.m. On the seismograph, the usual harmonic type of tremor began at 10:59 p.m. and continued until 4:00 a.m., April 8; this latter time corresponded with a visible diminishing of glow and fume. The tremor was interrupted by very feeble earthquakes at 11:09, 11:21, 11:35 and 11:38 p.m. Apparently these were felt by no one. Other than o feeble earthquake at 12:07 p.m., May 17, felt widely on the Island of Hawaii and a slight to moderate one at 5:32 p.m., June 11, also reported felt, there was no other seismic disturbance of importance that could have been said to originate under Mauna Loa. Practically no shocks were reported by observers stationed near the scene of activity. Probably indirectly connected with the summit eruption was the strong earthquake, felt throughout the Island group and of world-wide registration which recorded at 11:57 p.m., June 16. The Pasadena seismological

laboratory classified this shock as grade 7, a major earthquake. It was followed by many after shocks of various intensities.

Tilt

The possibility of some volcanic change either at Kilauea or Mauna Loa was suggested by the fact that the annual Observatory ground tilt of Kilauea showed accumulation to the north for the first time since 1936 in December, 1939. This northerly accumulation was increased during the first three months and all southerly tilt ceased in April as usual. However, there were erratic changes from normal westerly tilt to easterly tilt in February and March when there should be almost exclusively westerly tilt and a relatively smooth curve when plotted.

Outbreak

Between 11:30 p.m. and midnight April 7, residents of the Hawaii National Park heard a great amount of squawking by pheasants in nearby groves of ohias and ferns. This peculiarity is usually significant of earth disturbances and in this case indicated that the seismic effects of the Mauna Loa outbreak were detected by the birds but in no case seem to have affected any humans. A roar like the sound of a distant automobile motor was distinctly heard about 11:45 p.m. by one resident who dismissed the sound as that. Telephone communications from the Kona section of the Island to the Park superintendent announced that Mauna Loa was in eruption. That occurred at or about 12:10 a.m., April 8. At 12:30 a.m. a bright orange red glow, illuminating the entire western sky, was visible from the National Park residential area. From the Volcano Observatory a clear view of the glow from fountains, fume column and red reflection from nearby clouds, was obtainable. Extent of the fountaining area appeared to be from the northeast rim of the summit crater to a point well over the summit curve to the southwest. Measurements by transit from the Observatory bench mark indicated that activity was from the north bay of Mokuaweoweo to a point in the region west of Lua Hohonu, the second pit crater to the southwest. A more accurate location could not be determined from that point; however, airplane pictures made of the summit about 4:30 a.m., April 8, showed fountains extending along a crack from about the center of the main crater, southwestward across the south lunate platform, through the southwest rim and along old rifts toward Kahuku, a total distance of about three and one half miles. Terminals were approximately 1903 cones (Na Puu Waenakonu) at north, and cracks west of Lua Hohonu. The line of the rift was S 23° W and was in direct line of connection between cones of 1903, and those of 1914 and 1926. It seems likely that the wider glowing expanse measured by transit from the Observatory included fresh lava flows which may have flowed over the northern half of Mokuaweoweo with great rapidity in the first few hours of activity when the lava is always most fluid. If there were fountains in the northern half of the Crater, no pictures show them. However, soldiers who left the north rim at 2:30 p.m., April 8, reported fountains in the north bay with lava rising rapidly and at that time within five feet of the rest house on the northeast brink of the north bay. In spite of this it is doubtful if deep-seated fountains actually developed north of the center of Mokuaweoweo.

At 1:15 a.m., the light from 6 main fountaining areas was readily discernible with their accompanying columns of fume. Smaller fountains and fume columns were interspersed with the larger ones. Most intense glow seemed toward north with others slightly less toward center of body of glowing region; to the south light was fainter and fume thinner. At 2:00 a.m., 8 fountaining areas were visible but by 4:00 a.m., they had dwindled to 4 with largest still at center and to north. Fume columns were still faintly visible to south.

During these first few hours, pahoehoe lava streams covered practically the entire floor of Mokuaweoweo with the

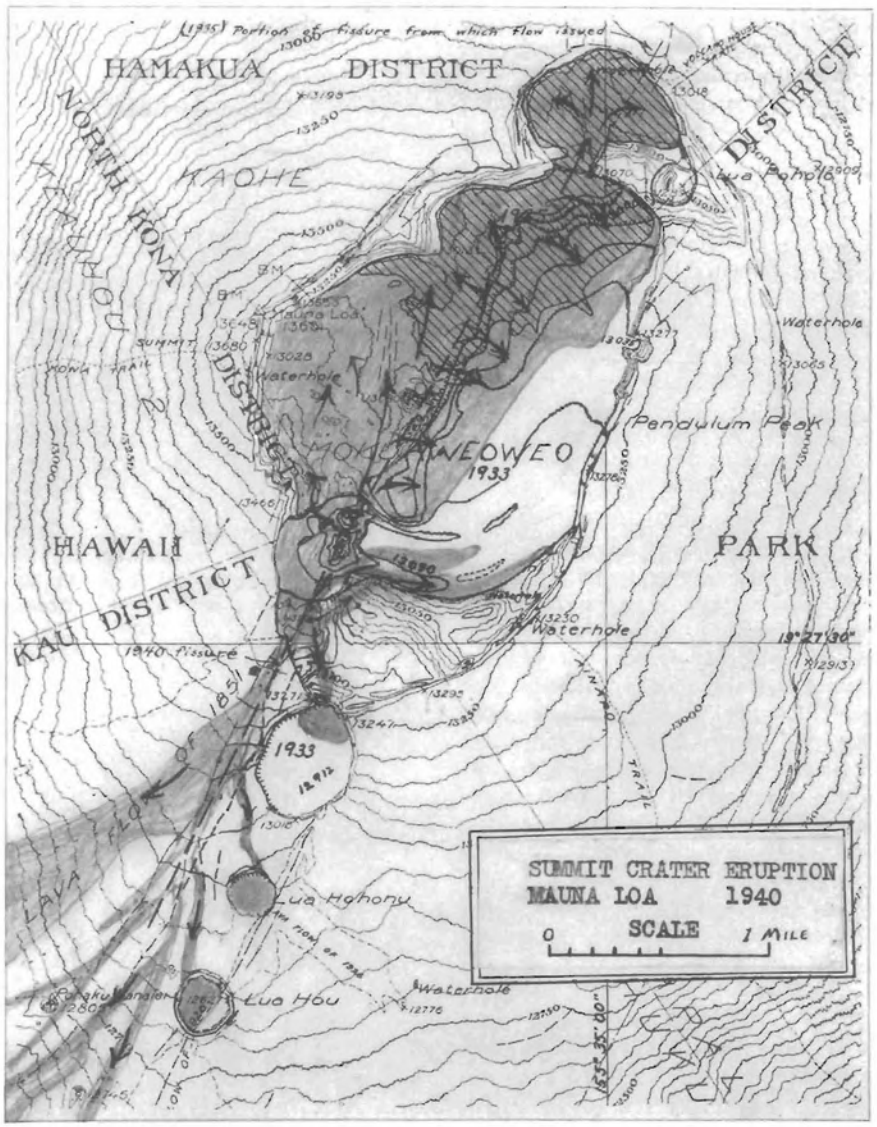

Fig. 4.—Map of Mokuaweoweo, 1940. Shaded areas show approximate extent of lava flows during the first twenty-four hours of activity. Arrows indicate direction of flow. Hatched area to north is 1935 lava. Light area to southeast is 1933 aa, extensively covered by later flows during May and June. Base map, U. S. Geological Survey, preliminary sheet of 1926.

exception of the southeast portion which was partially filled with 1933 aa preventing extension there of the new flows. One flow, however, which originated at the fountains on the south lunate platform, moved north to cascade into the main crater and then turned eastward across the 1933 aa nearly reaching the east well of the Crater before the source fountains ceased and stopped its further progress. Another flow from same source cascaded into the first pit crater to the southwest. Undoubtedly all of these flows were extremely fluid, highly gas-charged, and covered the floor of Mokuaweoweo with extreme rapidity as is characteristic of the early hours of all eruptions.

To the southwest of the Crater, on the outer slope of Mauna Loa, pahoehoe streams turned into aa further down the slope and cascaded from the rift into all three of the pit craters with the greater part of the activity taking place in the vicinity of Lua Hohonu. Greatest extent of this flow seems to have been about four miles.

At 9:00 a.m., April 8, a large column of fume was visible over Mauna Loa summit rising vertically from two areas to a great height, possibly ten to fifteen thousand feet above summit where it bent sharply to the east and extended in a long broad zone to the horizon southeast of Kilauea. The fume was of the usual bluish tint in reflected light and amber in direct light. The denser of the two contributing fume columns was to the south in contrast to relative values of preceding night. This confirms the air picture which showed the most active fountains near the center of the crater although the first party to reach the summit found the activity concentrated in the southwest portion where it remained for the rest of the eruption. The main fountaining apparently changed from the region of the northeast 1903 canes to the vicinity of the 1914 cones within the first 18 hours, just as the extra-crateral fountaining did from southwest to the 1914 cones.

A party from the National Park went to the summit the first day. On the way up a fume column of whitish-amber color was plainly visible. Its rate of emission was variable with some puffs being given off with a great amount of energy. At Puu Ulaula rest house a rumbling noise came from the direction of the activity resembling the pounding of surf on a distant shore. The morning after the outbreak, Pele's hair was found distributed over the entire southern portion of the island, including the vegetable gardens northeast of Kilauea.

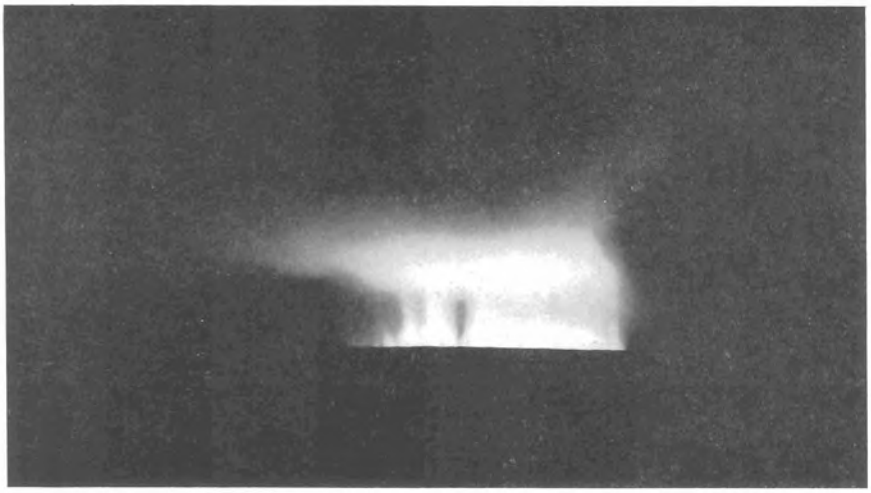

Fig. 5.—Mauna Loa eruption from northeast rim of Kilauea Crater, 12:30 a.m., April 8. Photo by Mollenhoff.



Fig. 6.—Fountains and flows, 11:30 a.m., April 9; 1914 cone right, 1933 to left. Photo by Mollenhoff.



Fig. 7.—Fountains from west rim, 3:00 p.m., April 11. Photo by Jess.



Fig. 8.—High fountaining (600 feet ±) from rim of north bay, 8:30 a.m., April 16. Photo by Jess.



Fig. 9.—Pressure ridge in gap to north bay looking south, 3:50 p.m., April 4. Photo by Waesche.



Fig. 10.—Detail of pressure ridge, 4:00 p.m., April 24. Photo by Waesche.

Initial Crater Phase

By the time the first party had reached the summit crater at 6:10 p.m., April 8, all activity had become concentrated in a series of fountains toward the southwest end of Mokuaweoweo between the 1903 cones and the south lunate platform. Their exact position could not be identified at first as they were observed end on. The north bay had been partially filled with black pahoehoe which had reached a level about 10 or 15 feet below the rest house ledge. This already had cooled enough to slump downward 5 to 10 feet by shrinkage and probably by some runoff of liquid lava below the surface. Where the crust had fractured, glowing cracks and caverns were produced; faint bluish fumes hung over the entire crater. There was no conclusive evidence that fountains had been active in the north bay. A tongue of pahoehoe had moved along a crack toward the pit crater Lua Poholo but had stopped on its rim. Pele's hair was seen floating in large quantities in the air.

There was now only one fume column and the fountains at its base were extremely active, of orange red color and were playing two to three hundred feet above the crater floor throwing out liquid, lava spatter but apparently few cinders; there had been practically no cone building at this stage. Heat waves caused all objects in the crater to appear to waver considerably and the glowing flow fronts moving north and west looked like many small fountains. Much snow clung in patches to the crater walls.

On the morning of April 9, there was little apparent change. Observations from the west rim showed the main fountaining concentrated in a portion of the rift about 1,400 feet long with its northern extremity between the 1914 and 1933 source cones. A crack in the crater floor was plainly visible extending from the fuming 1903 cones south-southwest to a point on the rim near the first south pit crater. At the main fountaining area there were 6 jets or centers of activity with the most energetic to the north. The largest jets played to heights of 300 feet and relative intensity remained almost constant. To the south of the main fountain there were 5 smaller, independent fountaining areas of diminishing size. The largest may have been 50 feet in height. Other fountains which had been active on the south lunate platform were producing fume only. The 5 smaller fountains between the main fountaining area and the south lunate platform apparently stopped after this date

as they were not mentioned in later reports, although the jets of the large fountaining area continued and even increased in size during later periods of the eruption.

Two main lava flows issued from the large fountain; one from its south side flowed west and a second from the north side to the north. They were producing pahoehoe. Near the fountain the two streams were extremely fluid and flowed with rapidity. Although the front of the flow was dark and black, the remainder was of a light bronze color. These flows were covering black pahoehoe of an earlier stage of the 1940 eruption, probably first night outpourings contemporaneous with lava of the north boy. The pahoehoe fronts advanced in a normal manner by the projection of advancing arms and toes. No gas vents similar to those seen at the 1935 eruption were noticed. Occasionolly bright flashes of lava issued from the flanks, near the base of the old cones.

During the afternoon of April 9, the north lava flow front advanced to within a half mile of the north bay. Movement along the front was plainly visible from the rest house and by the morning of the tenth had advanced to within a quarter of a mile of the north bay. However, the low gradient of the crater floor and the increased distance from the cones had resulted in a slowing down of the flow's advance; accompanying this was the beginning of the next phase of crater activity, the formation of pressure ridges, dome building and cone development at the vents. By 8:30 a.m., April 10, the front of the flow moving to the north had increased from about five feet in thickness to 10 or 20 feet.

Pressure Ridges and High Fountains

Continual observation of eruption progress was meanwhile being made and there was an unbroken line of daily reports throughout the continuously visible activity.

By 6:00 p.m., April 11, the pahoehoe front had reached the gap between the main crater and the north bay. There the general shape of the crater was such that the forward movement of the lava for the next few days was deflected with a curved front to the east. This slowed down the actual flow front to a standstill where it had a chance to cool and form a resistant dam to farther advances into the north bay. Meanwhile, great volumes of liquid lava were pouring northward behind this front and as a result enormous horizontal pressures were produced between the hydraulic effect of the liquid lava and the crater walls. Great sections of the floor in the northern end of the main crater were ruptured, slipped over lower layers, and piled into ridges sometimes 50 feet in height. Blocks of dense lava 15 or 20 feet across and several feet thick were stacked in heaps and along ridges like molehills. In places where the uppermost crust of the crater floor had slid over lower layers lava had been ground to a pink rock flour. A chaotic condition over the greater portion of the crater was the result and this made most of the area nearly inaccessible. This type of activity continued through April 19, when most of the flow to the north ceased along with a general decrease in activity.

The fountains continued with little change through noon, April 12. Most energetic portion of the fountain was at north end of a series of 8 jets, and played to heights of 300 feet, throwing out molten spatter. By 2:30 p.m., there was a notable increase with ejecta from the north jet going to heights of 500 feet. During the remainder of the afternoon the intensity increased until at 6:00 p.m., spatter, pumice and cinders were being thrown to heights of 600 feet. From then on through April 19, this type of activity, pulsating in character, was a daily occurrence with the fountains reaching a low, liquid lava stage in the morning and then gradually reaching a climax in the late afternoon. The high fountains produced much pumice accompanied by increased cone construction; the low fountain periods produced almost exclusively liquid spatter. The cone had developed to a height of about 175 feet and was still most active at the north jet.

On April 15, 11:00 a.m., from an airplane, one large jet was seen to be active with 4 smaller ones of diminishing intensity to southwest. The large fountain had built up a cone which had by now almost completely covered the 1914 and 1933 cones. Fountains were pulsating considerably and producing pumice. These pulsations apparently became more erratic and at greater intervals with the passing of the next few days.

Period of Crateral Flow and Cone building

After April 19, there was a rapid decline in fountain activity and almost no lava movement until on April 23 only a faint fume column was visible and a report of "no glow visible" at the cinder cone was received from the observer at the summit. The afternoon of April 24, a party made its woy one mile into the main crater. From there much fume was visible at the cone but no incandescent material was in evidence. However, many hot, glowing cracks were encountered in northeast portion of crater and in most cases the glow was at least 5 feet below the surface. Aa was found, confirming the earlier reports of that type of flow being produced at north bay gap and in northeast portion of main crater where it was forced through frozen pahoehoe crust April 20 and 21.

At 6:30 p.m., April 24, glow from the cone indicated activity was continuing in spite of apparent lull of preceding day and pasty lava spatter "sloshed" from the mouth of the vent and splashed fluidly down the cone slopes. On the morning of the twenty-fifth, observations from the west rim of Mokuaweoweo showed considerable activity at the portion of the cone to south in contrast to the previous greatest intensity point to the north. Lava was agitated in the mouth of vent and from time to time



Fig. 11.—Cone as seen from west rim, 8:30 a.m., April 25. Note pressure ridges in foreground. Photo by Hagerlund.

splashed over the north rim. The vent to the north subsided entirely within the next few days and all activity became centered in the more southerly one. A small pahoehoe flow issued from the west flank of the cone through the cinders and fanned out toward the west wall. Every five to ten minutes lava was thrown from the vent with greater than average violence and accompanied by booming, explosive noises. The 1903 cones had been almost buried by 1940 lava. This general type of activity continued with little change until May 9, adding cinders and spatter to the cone and gradually increasing lava accumulations on the crater floor to the north and west. The fountains rarely played more than 50 feet above the cone summit.

Beginning May 9, explosions occurred within the vent of varying intensities, some quite violent, and general activity appeared to increase with the fountains at times playing to heights of 100 feet above the cone crest. A new flow developed from the north base of the cone May 11. This type of activity continued with unusually heavy explosions May 13, at 12:30 a.m., and May 15, at 4:30 p.m., both of which ruptured and altered the shape of the cinder cone. On May 25, the cone apparently split open near the center of its ridge to form a transverse east-west rift. Three lava streams issued as a result, flowing east, west and south with great rapidity. The east stream coalesced with the south flow and nearly inundated a small spatter cone formed during earlier stages of eruption, about one quarter of a mile to the southwest. The west flow then swung south to join the other two and a new flow developed to the north which at 5:00 p.m. was rapidly advancing. On May 26 most of the flow was to the east with tongues of pahoehoe advancing across the 1933 aa and at several points contacting the east wall. This type of activity continued with flows constantly spreading to east and north of the center of activity and the fountain playing with little change. During May 27, 28, and 29 there was much puddling of lava to east and north, forming a large lake near the center of the crater. The contributing lava stream cascaded down the east slope of the high portion of the cone. On June 5, a flow was moving over 1933 aa toward the east wall; the fountain increased in height and appeared to be producing more pumiceous material. At 6:00 p.m. new flows developed to east and west, and east rim of cone partially foundered; a small spatter cone developed several hundred feet to east of main vent. At this time fume increased considerably and a dense column was visible from Kilauea daily.

A large rounded lava dome, like Mauna Iki in Kau Desert, had formed around and under the cone by May 8. It measured possibly 75 to 85 feet above the average crater floor and was surmounted by the still active cinder cone which was about 190 feet in height with the greatest length south-southwest-north-northeast, at its base, about 1400 feet. With flows moving east, north and at times to the west and with almost continuous fountaining to heights of 50 to 100 feet there was little change until June 19, when there began periods of intermittent quiet and renewed activity which continued the remainder of the month of June.

Areal Extent and Volume

Between April 7 and June 30, the almost continuous outpouring of lava within the summit crater of Mauna Loa resulted in an enormous volume of filling over practically the entire crater floor. The greatest fill was in the vicinity of the center of activity to the southwest. Next in order were the west and north portions of the crater followed by the north bay and finally the east portion, probably far below the other areas in quantity because of the presence of the higher 1933 fill. If the greatest fill was 90 feet apart from cone and zero taken as the minimum, it would be reasonably safe to say that the fill of 1940 had an average depth of 45 feet for all of Mokuaweoweo. Forty-five feet are equivalent to approximately 14 meters. The area of Mokuaweoweo is about thirty-two million square meters. Then the total volume of new lava in Mokuaweoweo should be about four hundred and forty-eight million cubic meters. The 1933 eruption was estimated to have produced sixty-eight million cubic meters. The 1940 figures do not include the flows in the pits to the southwest or along the rift.

Kilauea Reaction

Throughout the Mauna Loa eruption, Kilauea showed little or no sympathetic effects. Crack openings increased somewhat but were not abnormal. Levelling showed Kilauea floor to be still lowering relative to Spit B M. It has shown no appreciable changes since.

Conclusion

The Mauna Loa eruption of 1940 was expected and its location in the summit crater was normal based on observations of previous eruptions. Earthquakes show the northeast rift still to be restless and the southwest rift to be quiet. Mauna Loa summit eruptions are invariably followed by flank eruptions. They usually come within 2 years, occasionally less than one, and at other times at periods os great as 3 years. It is not altogether impossible that alternation of flows might take place and that the next outflow may be on the Kona side. It seems more likely it will be on the Hilo side and there is no doubt but what a flow will come in the not too distant future.

The 1940 Mauna Loa eruption was the longest duration of summit crater activity of any such since 1873-74.

The author is indebted to the National Park summit observers for their daily reports, which contributed much of the data here used, and to Dr. T. A. Jaggar for his helpful comments and criticism.

References used:

T. A. JAGGAR, "History of Mauna Loa," *Paradise of the Pacific*, Vol. 46, No. 2, February 1934.

WILLIAM T. BRIGHAM, "The Volcanoes of Kilauea and Mauna Loa," *Memoirs of the B. P. Bishop Museum*, Vol. II, No. 4, 1909.

The Volcano Letter, 1935-1940.

Hawaiian Volcano Observatory Report for April-June 1940

VOLCANOLOGY

April 1940

In April an eruption of the summit crater of Mauna Loa began about 11:00 p.m. April 7 and continued throughout the month. The number of earthquakes was unusually small for a time of lava eruption. Nothing notable happened at Kilauea. The Observatory staff and the Park rangers visited the summit camp of Mokuaweaweo in relays, so that this was the best observed Mauna Loa source in action on record.

The outbreak fulfills expectations in that Mauna Loa intervals have been somewhat over four years average for this century, and the last eruption ended in January, 1936. The lack of earthquakes resembles the 1849 summit eruption. This followed 1843 which like 1935 had flowed in the Humuula saddle. The partial outflows of 1940 south of Mokuaweoweo, just where 1851 erupted, strongly suggests that the next decade will have voluminous outflow at the north, like the decade that followed 1851. That also was a time of no mention of earthquakes, and as the 1940 eruption proved to be a long one in the summit crater like 1849, the danger of a Hilo outflow within the next few years is considerable. There is every reason to acquire the whole summit region of Mauna Loa for the National Park and to build there stations for scientific observation.

Army airplane photographs by Brig. Gen. W. F. Frank, Capt. M. W. Kaye, Col. G. W. Fitzgerald's party and others were in port taken the first night and morning, developed and printed in Honolulu, and delivered at the Volcano Observatory at 6 p.m. the same day. The Park telephone to the summit and Puu Ulaula camps kept the Observatory in constant touch with the activities as never before. Color photographs both in motion and still, some of them by the Park staff, are among the most remarkable that were ever taken of Hawaiian activity. Ranger Olson and party spent the night at the actual fountains inside Mokuaweoweo Crater April 17-18, and their experiences almost duplicated the descriptions of the several active cones of October, 1919 as published in Observatory Bulletin. On April 12 Dr. S. S. Ballard collected gases at the summit, for analysis at the University of Hawaii, returning to Honolulu April 14. As the summit crater camp had been threatened by rising lava the first day it was torn down with a view to rebuilding it later on the east margin.

The eruption is fully reported in Hugh H. Waesche's article herewith. It began along the rift from the plateau of the 1851 source west of the south pits of Mokuaweoweo, with first seismic record 10:59 p.m. April 7, and extended its crack through the 1914 and 1903 cone (Puu Waenakonu) regions of the main crater. Intensity declined throughout the month with floods of lava into the main bowl. Streams of pahoehoe the first night flowed southwest from the upland into Kahuku and South Kona, turning into aa further down. Streams also cascaded into the southern pits. Flows outside of the crater stopped within half a day. Inside the crater torrents of frothy pahoehoe flowed around all the cones, but mostly at the west.

There was from a distant view the usual broad band of lighted fume the first night, dwindling until April 18, when the fume was seen best in afternoon light with the sun behind it. At the end of April, glow and fume were visible chiefly at the summit station. There the fountain April 17-21 occasionally jetted up 700-900 feet through vents, becoming clogged along a fissure line of seven jets heaping up a ridge of basaltic pumice, from about the 1914 cone position southward. The concentrated building of a dome inside the crater centered between the 1914 and 1933 cones in the southwestern part of Mokuaweoweo sink. The old cones were buried under the new accumulations. The April eruption closely resembled that of 1933, but did most of its filling on the west side of the crater, whereas the December, 1933 eruption had been to the east. The first pahoehoe fills of the north bay, and the central crater became ruptured by aa lava rising up cracks, making pressure ridges so as to leave a chaotic floor. At the end of April there were fountains 50 feet high. Absence of felt earthquakes at the Mauna Loa camps was remarkable.

There was continuous tremor at the beginning of the Mauna Loa eruption lasting five hours. A feeble shock, felt as a jolt like blasting, occurred at Kilauea Crater April 16 and a slight shock also felt near Kilauea occurred April 21; a deeper shock April 26 was located under the Kilauea-Puna rift near the east point of the island.

The following are the local data for April, counting tremor spasms as single seismic disturbances:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
April 7	0	1.5 mm. closed	24
" 14	0	2.0 mm. "	26
" 21	3	1.5 mm. opened	16
" 28	several	8.0 mm. "	11

May 1940

Throughout the month the eruption of the summit crater of Mauna Loa built up a large heap of pahoehoe lava in the southwest part of the main bowl of Mokuaweoweo, so that from a side channel in the top of the heap a cascade overflowed the 1933 lava at the east side of the floor. This process continued into June. Nothing notable happened at Kilauea. Parties of rangers and workers built a trail from the end of the northeast trail around the northeast side of the crater to the flat plateau of the Wilkes Camp of 1840 where it is planned to rebuild the summit resthouse.

There was a seeming lull in the activity the middle of May, with only slight visibility of fume and no glow as seen from Kilauea. There was marked revival at the end of the month with glow at night plainly visible, and fume column showing at times the amber or cinnamon color of the early days. After two months of activity the fountain source produced more heavy pahoehoe and less pumice, and the pahoehoe was now burying part of the earlier pumice beds, and part of the pressure ridges and aa that welled up cracks, but still leaving the Mokuaweoweo floor very rough.

There was said to be increased heat and fume coming up the cracks in such early surfaces of the eruption as the fill of the north bay near the older resthouse location. This suggested that intrusive lava was penetrating under the earlier crater fillings, as in the case of Halemaumau in October, 1934, when also the fountaining of the cone center became pulsatory with gushing at intervals. The local seismic index of only 4 to 5 at Kilauea for each week was remarkably small for a period of continuing eruption. The measured earthquakes in National Park station were mostly at Mauna Loa distances, and nothing happened to suggest any change at Halemaumau.

A feeble earthquake May 17 was strongly felt at Kapapolo

Ranch and feebly felt at Hilo. There was continuous tremor for six minutes the evening of May 21, but there is no reason to correlate these later spasms with Mauna Loa. The Mauna Loa seismograph on east flank of mountain did not show them. This quarter was a time of many distant earthquakes, especially the month of May, with disturbances in the Philippines, Aleutian Islands, Imperial Valley of California, Peru, and northwest Canada, all of these around the Pacific Ocean.

The following are the local data for May, counting tremor spasms as single seismic disturbances:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
May 5	1	2.5 mm. closed	17
" 12	0	3.5 mm. "	14
" 19	0	0.5 mm. opened	15
" 26	0	2.5 mm. "	15

June 1940

The month of June found the Mauna Loa summit eruption continuing with the large slag heap growing in Mokuaweoweo Crater, and the tendency to alternation between gushes and intrusions increasing. Nothing notable happened at Kilauea. Observers lived at the summit of Mauna Loa continuously. A new feature of great importance, which has happened before in connection with eruptions of the Hawaiian volcanic system, was a strong and perhaps relatively deep earthquake on June 16, followed by many aftershocks for a fortnight, and centering about the ocean deep northwest of Maui and about 185 miles east of Honolulu.

It happens that in this general vicinity there is a deep trench of 3,000 fathoms bordering the southwest side of a large triangular plateau in the ocean bottom 170 nautical miles long, containing a high peak rising 8,000 feet above it, 240 miles northeast of Honolulu. The deep trench is between this seemingly submerged island and Maui, and it is in this trench 75 miles north of Ookala that the disturbances occurred which generated these earthquakes. The earthquake of June 16 was strong and profound enough to register on the seismographs of Pasadena as a teleseism.

From past experience there seems to be good reason to connect such earthquakes as this with the reactions of magma pressing upward under the larger Hawaiian ridge, in some way related to the clogging effects of the cooling and restraining plug that was solidifying in the Mauna Loa crater and bringing the eruption to a close after three months of outpouring. There is here matter for a seismological study worthy of extended investigation.

Mauna Loa in June showed a succession of lulls followed by outbursts at or near the top of the new inner dome of floor in Mokuaweoweo Crater. Apparently the lowerings were times of intrusion, as on May 27-29, when glow-cracks developed even as far away from the center as the north bay. Then at the cone center May 29 the liquid lava came up with fountaining, and overflows of the inner dome occurred, mostly to the east. The alternations were, down June 1-4, up after June 5, down June 10-12, up June 13-16, down June 17-24, up June 25-26, down June 27-July 2, and up July 3-5.

The duration of the gushes decreased from four days to two days; the duration of the intrusive spells increased from two days to eight days. The intervals between gushes increased from five to twelve days between the end of May and June 25: the intervals between intrusive spells increased from five to ten days in the same period. There was a pronounced quake felt in Kona during the low level following June 10, and the large earthquake northeast of Maui of June 16-17 near midnight was felt even in Honolulu and accompanied the quiescence of Mauna Loa lava that began June 17.

The gushing spells were accompanied by rupture and caving in of the summit craterlet, followed by fountains spurting 50 to 100 feet above the top of the dome, along with strong glow and fume as seen from Kilauea, and cascading torrents of lava to both west and east sides of the Mokuaweoweo floor, but mostly to the east. The structure built up stands more than 300 feet above the floor of 1939, it surmounts in height the east wall of Mokuaweoweo, and the recurrence of heat and glow was marked under the floor of the north bay of the greater crater during June, suggesting intrusive confinement of gas.

The following are the local data for June, counting tremor spasms as minutes of duration:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
June 2	0	0.0 mm. opened	15
" 9	1	1.5 mm. closed	10
" 16	0	2.5 mm. opened	10
" 23	0	1.0 mm. closed	119
" 30	0	1.0 mm. opened	25

Felt earthquakes occurred June 11, June 16, June 17 twice, and tremor spasms were notably small the first half of June, the 144 minutes of tremor indicated being recorded during the fortnight of aftershocks following the large earthquake.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Distant*	Weekly Seismicity†
April 7	76	8	0	0	0	1	23.50
" 14	260	5	0	0	0	0	67.50
" 21	9	4	2	1	0	1	8.25
" 28	6	4	1	0	0	0	4.50
May 5	14	3	0	0	0	0	5.00
" 12	12	2	0	0	0	0	4.00
" 19	12	2	1	0	0	2	5.00
" 26	19	1	0	0	0	3	5.25
June 2	12	3	0	0	0	2	4.50
" 9	9	1	0	0	0	1	2.75
" 16	7	2	0	0	1	0	9.75
" 23	99	16	1	2	1	1	40.75
" 30	20	4	1	0	0	0	7.00

* Including teleseisms or earthquakes over 5,000 km from Kilauea.
† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

April 3, 2:49 pm, very feeble, originated under NE rim of Kilauea Crater.

April 4, 4:29 pm, very feeble, 8.0 miles deep, Hilina Fault, 3.6 miles S of Puoialua. 19° 19.0′ N; 155° 09.2′ W.

April 4, 11:08 pm, very feeble, 6.0 miles deep, Mauna Loa NE rift 5.0 miles NE of Puu Ulaula. 19° 34.0′ N; 155° 24.0′ W.

April 4, 11:24 pm, very feeble, 0.9 mile deep, SE portion of Halemaumou. 19° 24.5′ N; 155° 17.0′ W.

April 7, 11:09 pm, very feeble, of shallow origin, Mauna Loa summit crater. Associated with outbreak of eruption. Others followed at 11:21 pm, 11:35 pm and 11:38 pm.

April 10, 2:00 pm, very feeble, from Mokuaweoweo.

April 11, 2:33 pm, very feeble, 10.0 miles deep, Mauna Loa NE rift, vicinity of Puu Ulaula. 19° 32.0′ N; 155° 28.6′ W.

April 14, 12:46 am, very feeble, of shallow origin, 0.5 mile E of Ahua Kamakukolau. 19° 22.9′ N; 155° 15.6′ W.

April 14, 8:10 pm, very feeble, same source as preceding.

April 15, 12:00 noon, feeble, 4.2 miles deep, vicinity of Cone Peak, Kilauea SW rift. 19° 23.6′ N; 155° 18.4′ W.

April 16, 6:06 am, very feeble, 0.6 mile deep, SE portion of Kilauea Crater 0.6 mile E of Pit Seismograph. 19° 24.3′ N; 155° 16.4′ W.

April 16, 8:51 am, very feeble, from E rim of Kilauea Crater (Byron Ledge).

April 16, 4:53 pm, feeble, of shallow origin, NE rim of Kilauea Crater, 19° 15.6′ N; 155° 15.9′ W. Felt by residents in Hawaii National Park headquarters area as a sharp hump similar to heavy blasting.

April 20, 5:06 pm, very feeble, of shallow origin in cracks between Kokoolau Crater and Ahua Kamokukolau.

April 21, 1:06 am, slight, 0.4 mile deep, Kilauea Crater, 0.9 mile E of center of Halemaumau. 19° 14.5′ N; 155° 16.3′ W. Felt by few persons in Hawaii National Park. Dismantled Pit seismograph.

April 21, 12:32 pm, very feeble, from vicinity of Puhimau and Kokoolau Craters.

April 22, 11:01 pm, very feeble, 5.0 miles deep, 6.0 miles S of Pahoa, Kilauea Puna rift. 19° 25.0′ N; 154° 57.0′ W.

April 23, 1:16 am, very feeble, 12.0 miles deep, Kilauea SW rift, 6.6 miles SW of Pit seismograph. 19° 21.0′ N; 155° 22.0′ W.

April 23, 9:38 am, very feeble, Kilauea Crater, 0.7 mile, NE of Pit seismograph.

April 26, 11:56 am, feeble, probably 15.0 miles deep, Kilauea-Puna rift near Cape Kumukahi.

May 5, 10:13 am, very feeble, probably originated off coast of Hawaii in vicinity of Laupahoehoe. Reported felt at Paauhau.

May 5, 8:47 pm, very feeble, about 15.0 miles deep off coast of Hawaii, 4.0 miles NE of Ninole. 19° 58.0′ N; 155° 07.0′ W. Reported felt at Paauhau.

May 10, 12:37 pm, very feeble, 2-5 miles deep under Mokuaweoweo, summit crater of Mauna Loa. 19° 28.0′ N; 155° 35.5′ W.

May 17, 5:41 am, very feeble, of shallow origin, 5 miles off seacoast near Punalulu. 19° 04.5′ N; 155° 29.5′ W. Reported felt at Pahala and Kapapala Ranch.

May 17, 12:06 pm, feeble, of relatively shallow origin, under Mauna Loa summit crater. 19° 28.0′ N; 155° 35.0′ W. Reported felt at Kapapala Ranch and Hilo.

May 18, 10:56 am, very feeble, origin probably same as preceding.

May 26, 3:32 am, very feeble, probably originated in E central portion of Kilauea Crater.

May 27, 2:10 am, very feeble, of Halemaumau origin.

May 27, 2:49 am, very feeble, originated in NE portion of Kilauea Crater.

May 28, 11:12 pm, very feeble, 10 miles deep, Kilauea SW rift. 2.0 miles NW of Koae Cone. 19° 22.8′ N; 155° 19.5′ W.

June 11, 5:32 pm, slight to moderate, 18.0 miles deep, Mauna Loa. 19° 26.8′ N; 155° 31.6′ W. Felt in Kona at Hookena and Kealakekua and at Hawaii National Park.

June 13, 11:18 pm, very feeble, Mauna Loa NE rift near Pukauahi Crater.

June 16, origin time 11h 56m 49s pm, a strong earthquake was felt throughout Hawaiian group and particularly Hawaii, Maui and Oahu. No damage reported. Reported as major earthquake of grade 7 by seismological laboratory of California Institute of Technology at Pasadena. All seismographs in Territory dismantled with exception of strong motion instrument at Hawaiian Volcano Observatory. Awakened most sleepers on islands referred to. Most people report roaring noise preceding felt portion. Dogs howled, pheasants squawked and loose objects in or attached to buildings rattled violently. Location as worked out in cooperation with Lt. E. O. Heaton of the U. S. Coast and Geodetic Survey in Honolulu was: depth probably normal; epicenter 21.0° N. latitude; 155.3° W longitude. This would place epicenter approximately 85 miles N of Hilo and 185 miles E of Honolulu.

The main shock was followed by many after shocks chronologically arranged as follows:

June 17, 12:14 am, slight
12:38 am, very feeble
12:40 am, very feeble
3:28 am, very feeble
7:47 am, moderate; felt; Hawaii, Maui, Oahu.
11:20 am, very feeble
11:28 am, very feeble
12:13 pm, very feeble
12:39 pm, slight; felt; Hawaii, Maui, Oahu.
3:47 pm, very feeble
4:27 pm, very feeble
5:04 pm, very feeble
June 18, 11:52 am, very feeble
June 19, 12:20 pm, very feeble
June 23, 1:14 am, very feeble
June 26, 8:44 am, very feeble
10:15 am, very feeble
10:21 am, very feeble
June 28, 7:54 pm, feeble

All of the above were apparently located within an area bounded by lats. 20° 45′ to 21° 15′ N and longs. 155° 0′ to 155° 3′ W. This area would be centered approximately 75.0 miles N of Ookala, NE coast of the Island of Hawaii.

June 17, 1:48 am, very feeble, 1.3 miles deep under cracks, 0.8 mile SE of Ahua Kamokukolau. 19° 22.5′ N; 155° 15.5′ W.

June 19, 1:54 pm, feeble, originated under seacoast area S of Kilauea crater near Keahou landing.

June 19, 4:35 pm, very feeble, of shallow origin Mauna Loa summit crater.

June 21, 6:46 am, very feeble, of shallow origin SE rim area of Halemaumau 19° 24.4′ N; 155° 16.9′ W.

June 21, 7:45 pm, very feeble, 0.6 mile deep, 1.1 mile S of Pit seismograph. 19° 23.5′ N; 155° 16.7′ W.

June 25, 1:33 am, very feeble, originated near center of Kilauea crater to NE of Halemaumau.

Teleseisms:

April 1, 1h 00m 08.0s am, "P" waves. Probably originated in the vicinity of the Philippines.

April 15, 7h 45m 28.0s pm, "P" waves. 2,710 miles from Kilauea in region of Aleutian Islands. 52.6° N; 173.8° W.

May 18, 6h 14m 08.0s pm, "P" waves, probably originated about 2,575 miles from Kilauea; Imperial Valley disaster of California.

May 19, 4h 56m 26s am, "P" waves, distance about 3,200 miles.

May 21, 8h 26m 55s am, "P" waves, distance undetermined.

May 24, 6h 16m 24s am, "P" waves, probably originated near Peru, abaut 5,645 miles distant.

May 24, 12h 10m 31s pm, unidentified portion.

May 27, 11h 22m pm, "P" waves, location of point of origin undetermined.

May 30, 6h 53m pm, unidentified portion.

June 5, 12h 40m am, "P" waves, from NW Canada; 68° N; 138° W.

June 22, 1h 18m 49s am, "P" waves, distance about 5,500 miles.

Continuous tremor:

April 7, 10:59 pm to midnight, 61 minutes and April 8, midnight to 4.00 am, 240 minutes with visible outflow of lava Mauna Loa summit crater; total 301 minutes. May 21, 7:06 pm, 6 minutes of tremor. June 1, 11:20 pm, 3 minutes and 11:52 pm, 4 minutes.

Microseismic Motion:

April:

Light—28, 30.
Moderate—15, 16, 19 to 27, 29.
Strong—1 to 14, 17, 18.

May:

Light—5 to 7, 15 to 30.
Moderate—2, 3, 11, 13, 14, 31.
Strong—1, 2, 8 to 10, 12.

June:

Light—1, 2, 5 to 10, 12, 13, 15 to 18, 21, 23, 28, 29.
Moderate—3, 4, 11, 14, 19, 20, 22, 25, 26, 30.
Strong—24, 27.

Tilting of the Ground:

The following tables show tilt by weeks as recorded on the Observatory seismograph NE rim of Kilauea Crater and at Halemaumau, the algebraic sum toward or away from the Pit as indicated by stations on the W and SE rims respectively.

At the Observatory the total accumulated tilt for the year ending April 28 was 2.58″ N and 0.53″ E.

For the year ending May 26, 3.20″ N and 0.90″ E.

For the year ending June 30, 4.90″ N and 0.33″ E.

Table of Tilt

Week ending	Observatory	Halemaumau West Station
April 7	0.78″ S 13° W	0.00″
" 14	0.73″ S 67° W	1.64″ N 7° E
" 21	0.95″ N 71° E	1.91″ S 20° W
" 28	0.24″ N 81° E	0.54″ N 70° E
May 5	0.52″ N 77° W	0.54″ S 70° W
" 12	1.27″ S 75° W	0.00
" 19	0.74″ N 57° E	0.00
" 26	0.77″ N 58° E	0.00
June 2	0.93″ N 20° W	0.00
" 9	0.73″ N 85° W	0.00
" 16	1.82″ N 35° E	0.00
" 23	0.90″ N 45° E	3.58″ S 60° E
" 30	0.88″ N 4° E	0.00

Week ending	Southeast Station	Halemaumau Resultant
April 7	1.59″ N 25° W	1.42″ toward
" 14	4.92″ S 25° E	4.25″ from
" 21	4.92″ N 25° W	3.81″ toward
" 28	0.00	0.45″ toward
May 5	2.49″ S 68° W	1.59″ from
" 12	3.24″ S 20° E	2.03″ from
" 19	6.71″ N 6° W	5.23″ toward
" 26	2.33″ N 20° E	1.89″ toward
June 2	0.00	0.00
" 9	2.33″ N 70° W	1.79″ toward
" 16	1.39″ N 60° E	0.17″ from
" 23	2.17″ N 9° E	4.44″ toward
" 30	2.17″ S 72° E	1.62″ from

Crater angles

Measurement of horizontol angles across Kilauea Crater from the Observatory was made April 11. At that time the measurement indicated closing of 0.17" for the Halemaumau value and closing of 1.51" for the Crater value compared with similar meosurements made March 28.

Determinations of May 14, indicated closing of 0.42" for Halemaumau and opening of 1.26" for the Crater. Between May 14 and May 29, Holemaumau angle closed 1.08" and Crater angle closed 2.25". Total change April 11 to May 29, Holemaumau angle closed 1.50" and Crater angle closed 0.99".

Final measurements of the quarter was made June 20. May 29 to June 20, Halemaumau angle showed no change and the Crater angle opened 1.25".

Total change March 28 through June 20, Halemaumau angle (Pit seis. to NW Pit BM) closed 1.65" and the Crater angle (SE Crater rim to Uwekahuna) closed 1.25".

Chain-of-Craters Road Cracks

Of the seven principal Chain-of-Craters Road Cracks normally measured, only two have shown any appreciable changes between March 29 and June 28. Numbers 101 and 102, both near Devil's Throat showed increases (openings) of 1.0 millimeter each during thot period.

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
in cooperation with
UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Government, Department of the Interior, National Park Service.

The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** maintain outside seismograph stations and supplement the work of the government with research associates, instrumental plants and special investigations. Dr. T. A. Jaggar is their geophysicist resident in the National Park.

The **Volcano Letter,** a quarterly record of the Hawaiian volcano laboratories and published by the University of Hawaii, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the above establishments.



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Hawaii National Park
Edward G. Wingate, Superintendent
R. H. Finch, Volcanologist

University of Hawaii
T. A. Jaggar, Geophysicist

A CHEMICAL STUDY OF KILAUEA SOLFATARIC GASES, 1938-40

By STANLEY S. BALLARD and JOHN H. PAYNE*

The current research project on the collection and analysis of volcanic gases was begun in the fall of 1935. It was the first project under the new cooperative agreement between the University of Hawaii and the Hawaii National Park. Many collections of solfataric gases have been made at Kilauea, and two at Mauna Loa, but as yet there has been no suitable opportunity to collect primary volcanic gases from either vent. A report on the first stages of the investigation appeared in The Volcano Letter[1] over two years ago. Since that article was written, a number of improvements have been made both in the technique of collection and in the method of analysis employed. Also, since September, 1938, we have attempted to make monthly gas collections at the Sulphur Banks wells, or "Kilauea Solfatara," and 23 collections were made in the succeeding two-year period.

There is a dual purpose in making regular analyses of the Sulphur Banks gases. The first is to accumulate a long-time record of the constitution of the gases of a well-established solfatara. This has never been done in America, and its importance has recently been given recognition by the Geological Society of America, which is aiding our project with a research grant from the Penrose fund. The second purpose involves the search for variations in the gases that might correlate with periods of volcanic activity. If such a correlation can be found, another method of prediction will be available and supplementary to the cyclic, seismic and tilt methods that have been used for so many years in Hawaii. Fluctuations in the sulphur dioxide content of the exhalations were indeed noted, but we have not as yet been able to correlate these with any of the volcanic phenomena at Kilauea. However, just prior to the 1940 eruption of Mauna Loa, hydrogen sulphide was noted for the first time at the Sulphur Banks.[2]

From September, 1938, to August, 1939, gas was collected by the "vertical wet" method described elsewhere.[1] This setup is pictured on page 2 of The Volcano Letter, No. 453 (November, 1937). The objection to this method was that when two or three tubes were collected in succession on the same day, considerable variation was found from tube to tube. One tube was used in determining sulphur dioxide, and the remaining one or two tubes in determining the sulphur dioxide plus carbon dioxide total. In view of the possible variation between the tubes of a given collection, this introduced considerable doubt as to the reliability of the results. Also, the collections of May, June, and July, 1939, seemed to be of progressively poorer quality. Therefore a new method of making collections was introduced in September, 1939. As shown in Figs. 1 and 2, three tubes were mounted in series, and the gas reached them only after being drawn through a long copper coil which was immersed in an ice bath. Because of the high thermal conductivity of copper, practically all steam was condensed before the gas left the upper end of the coil, and any condensate that might have been drawn through the coil was trapped in a flask mounted between the coil and the tubes. The gas finally collected in the three tubes was free from condensate, and if care was taken in making the collection, gas samples from the three tubes were of uniform composition.

The analytical methods described previously[1] involved the determination of all constituents by the absorption pipette method. It was realized in the spring of 1938, however, that this method was giving incorrect results, since the absorbent for sulphur dioxide also absorbed large percentages of the much more abundant carbon dioxide. The results of the analyses as previously reported[1, 3] were hence in error. During the summer of 1938 we introduced the present analytical method in which the sulphur dioxide is determined gravimetrically by precipitation as barium sulphate; the sulphur dioxide plus carbon dioxide total is determined by absorption in caustic potash solution; and, the carbon dioxide is computed by difference. The only other regular constituent is air; oxygen is determined by absorption in alkaline pyrogallol and the residuum is regarded as

* Research Associates in Geophysics and Geochemistry, respectively, Hawaii National Park.

nitrogen. Spectroscopic tests[1] confirmed the identity of the nitrogen and failed to show any other gases in the residuum except traces of argon. Combustibles have been sought in every analysis by the combustion pipette method but have never been detected. The volume percentages of the chief constituents, air, sulphur dioxide, and carbon dioxide in the various samples, are presented in Table I. Two or three 250-cubic-centimeter tubes of gas were collected an each date, but because of the analyticol methods employed, only a single set of percentages was obtained in some cases. It is seen that the proportion of air varies widely, between zero and 40 per cent. It seems to us that this gives an indication of the quolity of the collection, and that in satisfactory collections the air content should be one per cent or less. The wide variation of sulphur dioxide, from 0.5 to 18 per cent, is much too large to be occasioned by possible analytical errors. Figure 3 is a graph showing the fluctuation of the sulphur dioxide during the two-year period starting September, 1938. The percentage of sulphur dioxide showed a sudden rise to approximotely 15 per cent in the Januory, 1939, collection. This high value remained fairly constant for a period of five months, after which it dropped to the previous lower value of about 2 per cent. A second increase occurred in October, 1939, but lasted for only o month. There appears to be no regularity about this variation, and the wirters have not been able to find any correlation between it and any of the volcanic or meteorological phenomena measured regularly at the Hawaiian Volcano Observatory.

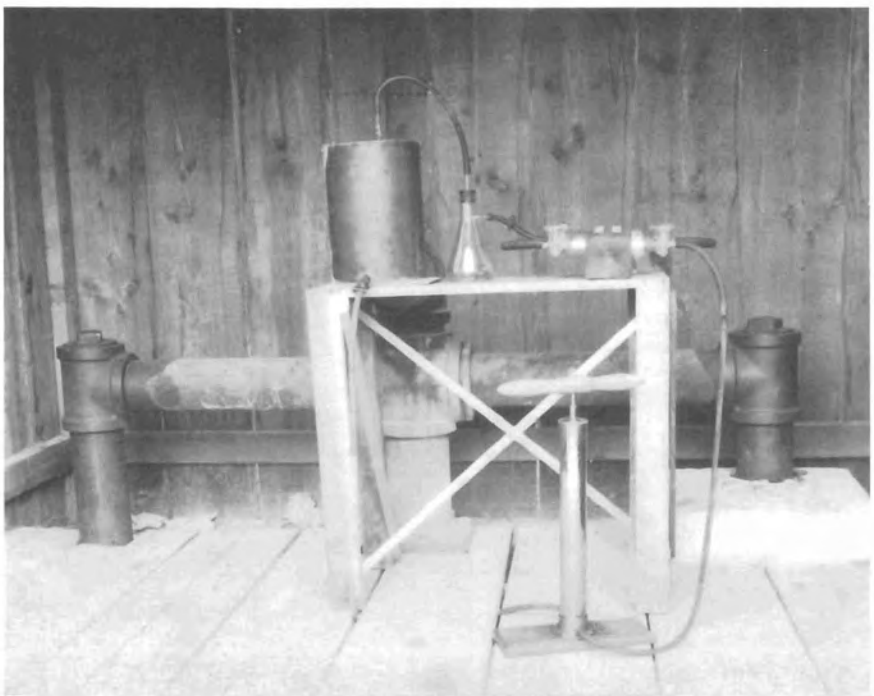

Fig. 1.—Gas collecting setup used at Sulphur Banks wells from September, 1939, to September, 1940. Photo by Fagerlund.

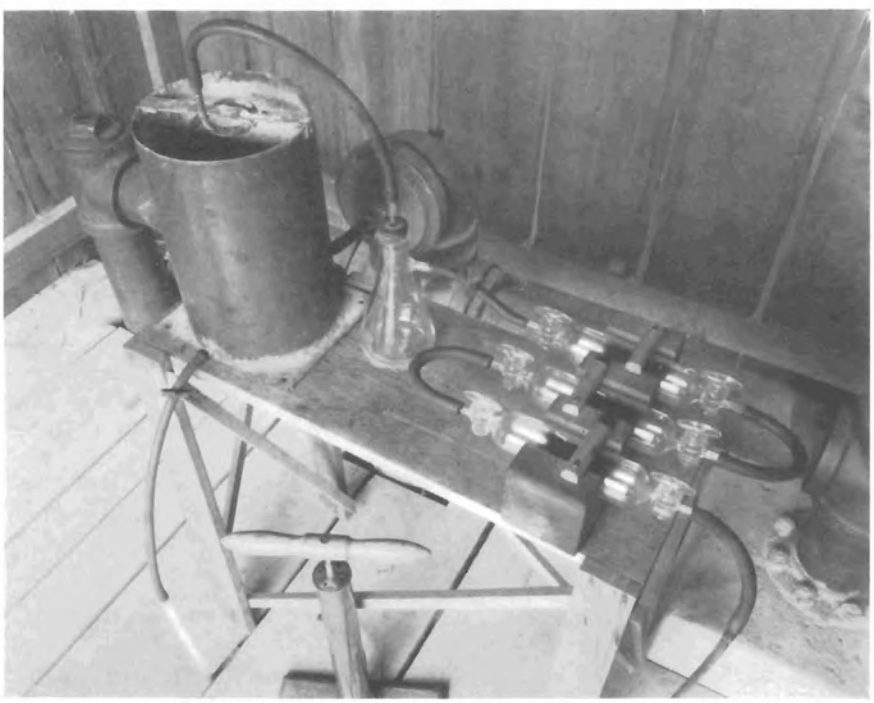

Fig. 2.—Top view of apparatus shown in Fig. 1. When gas is being collected, the copper coil is cooled by filling the brass drum with ice and water. Photo by Fagerlund.

In the collection of March 14, 1940, hydrogen sulphide appeared for the first time. It was easily detected qualitatively by odor, by the darkening of lead acetate paper, and by the formation of yellow cadmium sulphide when the gas was passed into cadmium sulphate solution. There was not sufficient hydrogen sulphide to make its quantitative determination possible. On April 7, 1940, volcanic activity broke out at the summit of Mauna Loa. Samples of gas collected at Kilauea an April 11 and on April 21 contained hydrogen sulphide, but none was found in the collections of May 10 and June 18, even though Mauna Loa was still erupting, although with greatly lessened activity.

The appearance of hydrogen sulphide in the Kilauea solfataric gases just prior to Mauna Loa activity may have been a premonitory sign. If so, this appears to afford an exceedingly valuable methad of forecasting volcanic outbreaks. Furthermore, its occurrence suggests a close relationship between solfataric activity and primary volcanism.

The only previous analyses of these gases were made by Brun[4] and by Allen[5]. Brun's analyses were only partial. Allen determined the steam content to be 96.2 per cent. He found 0.1 per cent sulphur dioxide, traces of sulphur vapor and of

hydrochloric acid, and 3.7 per cent of "fixed gases." It appears from our analyses that Allen's "fixed gases" consisted of air or carbon dioxide or both. We have not as yet determined the steam content of these exhalations.

Further improvements were made in the collection methods in September, 1940. We are also starting to investigate different analytical methods, including especially the possibility of determining sulphur dioxide by the thermal conductivity method.

Many of the gas collections were made by members of the Park staff; we wish to acknowledge particularly the assistance of H. H. Waesche and P. E. Schulz in this regard. Thanks are due L. M. Foster for assistance in making the analyses.

TABLE 1.
SUMMARIZED ANALYSES OF KILAUEA SOLFATARIC GASES

Date of Collection	Per Cent Air	Per Cent SO_2	Per Cent CO_2	SO_2:CO_2 Ratio
Sept. 17, 1938	1.4	1.4	97.2	1:69
Sept. 17, 1938	2.9	2.0	95.1	1:48
Oct. 20, 1938†	.....	.....	.....	.....
Nov. 22, 1938	0.8	2.3	96.9	1:42
Nov. 22, 1938	33	.....	.....	.....
Jan. 3, 1939	1.1	14.3	84.6	1:5.9
Feb. 8, 1939	36.9	13.9	49.2	1:3.5
Mar. 14, 1939	1.1	13.8	85.1	1:6.2
Apr. 15, 1939	1.2	14.2	84.6	1:6.0
May 15, 1939	20.0	16.7	63.3	1:3.8
June 20, 1939	32.8	10.6	56.6	1:5.3
July 21, 1939†	.....	.....	.....	.....
Sept. 11, 1939	9.0	1.8	89.2	1:50
Sept. 11, 1939	9.4	1.8	88.8	1:49
Sept. 11, 1939	7.8	1.8	90.4	1:50
Oct. 13, 1939	9.9	16.5	73.6	1:4.5
Oct. 13, 1939	1.6	17.7	80.7	1:4.6
Nov. 17, 1939	8.8	16.6	74.6	1:4.5
Nov. 17, 1939	2.2	17.8	80.0	1:4.5
Dec. 15, 1939	18.4	0.6	81.0	1:135
Dec. 15, 1939	40.0	0.4	59.6	1:149
Dec. 15, 1939	38.8	0.9	60.3	1:67
Jan. 15, 1940	1.3	1.7	97.0	1:57
Jan. 15, 1940	1.1	1.7	97.2	1:57
Jan. 15, 1940	1.1	1.7	97.2	1:57
Feb. 12, 1940	1.3	1.0	97.7	1:98
Feb. 12, 1940	1.2	1.0	97.8	1:98
Feb. 12, 1940	1.1	1.0	97.9	1:98
Mar. 14, 1940	6.5	1.5*	92.0	1:61
Mar. 14, 1940	0.0	1.6*	98.4	1:61
Mar. 14, 1940	0.9	1.6*	97.5	1:61
Apr. 11, 1940	0.6	1.4*	98.0	1:70
Apr. 11, 1940	0.6	1.4*	98.0	1:70
Apr. 21, 1940	1.0	1.2*	97.8	1:81
Apr. 21, 1940	10.3	1.1*	88.6	1:81
May 10, 1940	0.3	1.2	98.5	1:82
May 10, 1940	0.6	1.2	98.2	1:82
June 18, 1940	16.8	0.45	82.7	1:185
June 18, 1940	0.7	0.54	98.8	1:185
June 18, 1940	3.2	0.53	96.3	1:185
July 17, 1940	1.0	3.0	96.0	1:32
July 17, 1940	10.5	2.7	86.8	1:32
Aug. 10, 1940	1.2	0.44	98.4	1:223
Aug. 10, 1940	0.0	0.45	99.5	1:221
Aug. 10, 1940	1.8	0.43	97.8	1:227

† Poor collection; not analyzed. * H_2S present also; H_2S calculated as SO_2.

REFERENCES

[1] Ballard, Stanley S., "The Volcanic Gas Problem," *The Volcano Letter* No. 455 (January, 1938), 1-5.

[2] Payne, John H. and Ballard, Stanley S., "The Incidence of Hydrogen Sulphide at Kilauea Solfatara Preceding the 1940 Mauna Loa Volcanic Activity," *Science*, Vol. 92 (1940), 218-219.

[3] Ballard, Stanley S., "Constitution of the Solfataric Gases at Kilauea Volcano, Hawaii," *Physical Review*, Vol. 54 (1938), 236.

[4] Brun, A., *Recherches sur l'exhalaison volcanique* (A. Hermann, Paris, 1911), p. 251.

[5] Allen, E. T., "Preliminary Tests of the Gases at Sulphur Banks, Hawaii," *Bulletin of the Hawaiian Volcano Observatory*, Vol. 10 (1922), 89-93.

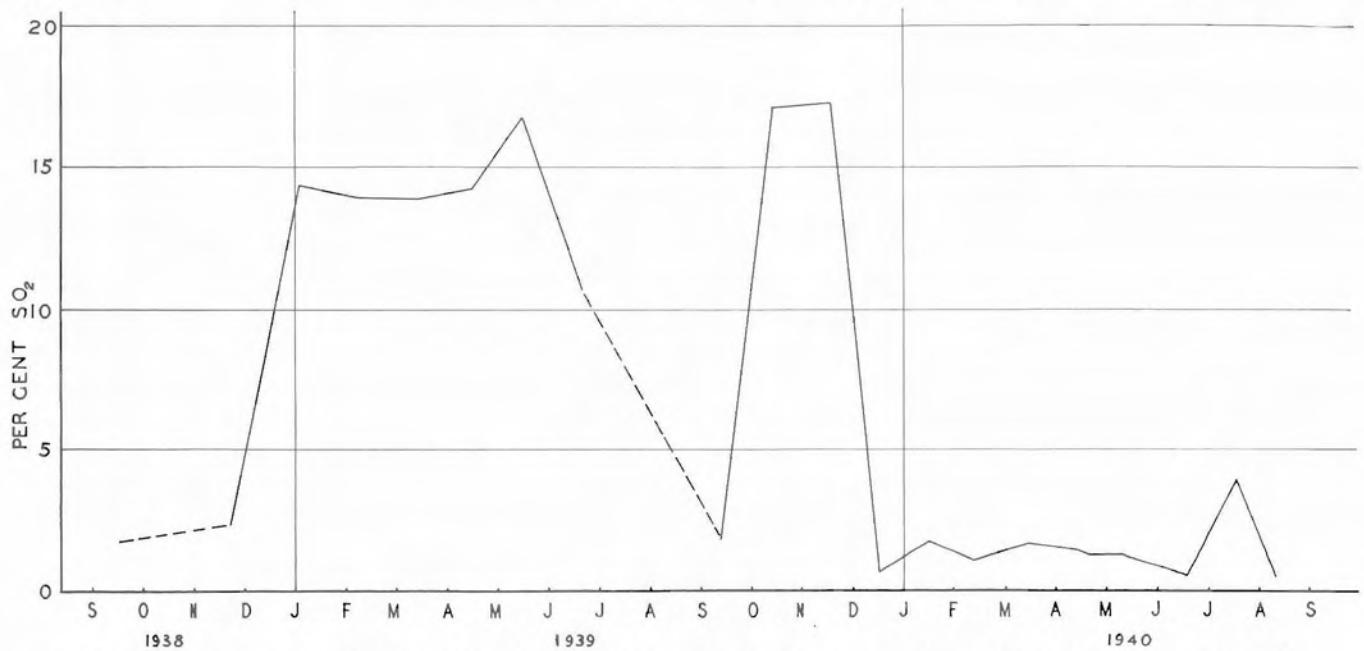

Fig. 3.—Variation of percentage of sulphur dioxide in Kilauea Sulphur Banks gases, September, 1938, to September, 1940.

Hawaiian Volcano Observatory Report for July-September 1940

VOLCANOLOGY

July 1940

The Mauna Loa eruption at the summit crater waned to a seeming standstill with decreasing intervals and decreasing activities. Observation of it by Park employees continued, and nothing new happened at Kilauea.

The alternations between activity and quiet in Mokuaweoweo, the summit crater of Mauna Loa, to which the outflow of lava was confined, were as follows:

Quiet	00 a.m.	July 1	to	8:30 a.m.	July 4
Active	8:30 a.m.	July 4	to	8:00 a.m.	July 10
Quiet	8:00 a.m.	July 10	to	6:00 p.m.	July 18
Active	6:00 p.m.	July 18	to	9:30 a.m.	July 21
Quiet	9:30 a.m.	July 21	to	9:15 a.m.	July 23
Active	9:15 a.m.	July 23	to	8:00 a.m.	July 24
Quiet	8:00 a.m.	July 24	to	4:15 p.m.	July 26
Active	4:15 p.m.	July 26	to	6:00 p.m.	July 26
Quiet	6:00 p.m.	July 26	to	12:00 noon	July 27

Only activity after 12:00 noon July 27 was feeble glow the nights of July 27 and July 28 followed by quiet thereafter.

The duration of active spells in sequence according to this table appears to be 24, 64, 23, 2, 36 hours.

The duration of quiet spells appears to be 202, 48, 56, 18, 36-plus hours.

The activity was from the vent in the top of the new inner summit lava cone of Mokuaweoweo southwest of the center of the crater, with fume from internal fountains rising from that vent all the time, and outflows from the cone as indicated. After July 4, flows within Mokuaweoweo streamed to the north, east, west and south from fountains 50 to 75 feet high. On July 8, there was one fountain at the cone center, two in a lake northwest of the cone. On July 18, a fountain in the cone vent shot up 150 feet, and made a strong roar at midnight July 18-19. The fountain was again 150 feet high July 23 at 12:55 p.m., and a strong flow poured into the lake north of the cone in Mokuaweoweo. On July 26, at 5:00 p.m., flowing lava was seen in a crack at the northeast base of the inner Mokuaweoweo cone.

The only slide at Halemaumau reported for July was at 6:34 p.m., July 3, when thin dust rose above the northern half of the pit. There was unusual closing of rim cracks around Halemaumau in the first and last weeks of the month. An important near shock felt from Honolulu to Hawaii at 4:48 p.m., July 15, was located under the sea floor 90 miles east of Maui like the one a month before; there were four other shocks located in this vicinity during the quarter-year.

The following are the local data for July, counting tremor spasms as seismic disturbance for each minute of duration:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
July 7	1	2.5 mm. closed	28
" 14	0	2.5 mm. opened	26
" 21	0	3.5 mm. opened	57
" 28	0	6.5 mm. closed	50

August 1940

After 18 days of seeming quiet, Mauna Loa resumed gushing of lava through the summit inner cone of Mokuaweoweo crater during the afternoon of August 15 about 5:00-6:00 p.m. At 9:30 p.m. the same date, a strong fume column, colored bright red with reflected light of the fountain, rose several thousand feet above the Mauna Loa summit. On August 16, a fume column hung over Mauna Loa throughout the day and red glow was faintly visible through clouds in the evening. This kind of activity continued, but declined August 17-18, and observers at the summit rest camp reported one large fountain in the inner cone and a north flow during the evening on the Mokuaweoweo floor. The fume column was less dense August 18 and a pulsating glow was visible over Mauna Loa as seen from Kilauea. This period of activity came to an end during the night August 18-19, some fume was seen at 7:00 a.m., August 21, and no further lava activity was observed.

Rocks were heard falling from the northeast, east and southeast walls of Halemaumau 10:00 to 11:00 a.m., August 25 and a period of continuous tremor lasted five minutes after 6:19 p.m., August 21. During the last week of the month rocks fell at Halemaumau frequently, and a larger slide at the northeast wall occurred at 3:35 p.m., August 31.

A sharp increase in local seismic activity followed the cessation of lava gushing at Mokuaweoweo. Another moderate earthquake was felt slightly in Hawaii National Park at 10:15 p.m., September 1, originating 117 miles from the Observatory with center probably at the sea-floor east of Maui like the felt, stronger shocks of June 16 and July 15. A very feeble shock from a similar distance occurred August 27.

The following are the local data for August:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
Aug. 4	0	2.5 mm. opened	33
" 11	0	2.5 mm. opened	25
" 18	0	3.0 mm. opened	28
" 25	3	1.0 mm. opened	19
Sept. 1	6	0.5 mm. opened	45

September 1940

During the first week of the month Mauna Loa and Kilauea were quiet, two earthquake shocks were felt and all but one of the feeble shocks were under Kilauea. Tilting of the ground away from the crater became pronounced at the Kilauea Observatory in August and September.

The second week indicated concentrations of seismic activity in the Chain-of-Craters where the highway has shown some increased movement. The third week produced earthquake shock from various distances, and the same may be said of the fourth week, with no notable changes at the crater of Kilauea.

The following are the local data for September:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings	Seismic Disturbances
Sept. 8	0	0.0 mm.	45
" 15	0	5.0 mm. opened	21
" 22	0	0.5 mm. opened	19
" 29	0	0.5 mm. opened	21

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Distant*	Weekly Seismicity†
July 7	25	1	2	0	0	1	8.75
" 14	21	5	0	0	0	1	7.75
" 21	52	4	0	0	1	0	18.75
" 28	42	6	2	0	0	1	15.25
Aug. 4	32	1	0	0	0	1	8.50
" 11	20	3	1	1	0	0	10.50
" 18	24	4	0	0	0	0	8.00
" 25	19	0	0	0	0	2	4.75
Sept. 1	35	9	0	0	1	0	17.25
" 8	32	10	3	0	0	0	16.00
" 15	14	5	2	0	0	1	8.00
" 22	11	7	1	0	0	2	7.25
" 29	16	4	0	1	0	0	8.00

* Including teleseisms or earthquakes over 5,000 km from Kilauea.
† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

July 1, 4:23 pm, very feeble, probably originated in E central portion of Kilauea Crater.

July 4, 3:55 pm, feeble, probably originated 40.0 miles NE of Hilo.

July 6, 2:54 am, feeble, 1.8 miles deep in area between Devil's Throat and Puu Ohale. 19° 22.0′ N; 155° 15.4′ W.

July 9, 7:30 pm, very feeble, probably originated off NE coast of Hawaii about 12 miles E of Ookala.

July 12, 10:14 am, very feeble, Mauna Loa NE rift near Puu Kulua.

July 14, 12:39 am, very feeble, associated with earthquake of 4:48 pm, July 15, and others listed as follows:

July 14, 10:40 pm, very feeble.

July 15, 9:13 pm, very feeble (reported felt in Hamakua at Paauhau and on Maui at Ulupalakua).

July 16, 3:48 pm, very feeble.

August 16, 11:27 pm, very feeble.

August 27, 2:35 pm, very feeble.

September 20, 10:29 am, very feeble.

All of these originated in area under the sea floor about 80 miles N of Hilo bounded as follows: 20° 45′ to 21° .00′ N and 155° to 155° 15′ E.

July 15, 4:48 pm, moderate, probably of normal depth located 65.0 miles N of Laupahoehoe and about 90 miles E of Kahului, Maui. 20° 54′ N; 155° 08.0′ N. Felt generally over all the Islands with the exception of Kauai.

July 19, 7:42 am, very feeble, off sea coast in vicinity of Kawaihae Bay. Reported felt in Kahala.

July 24, 10:50 am, very feeble, of shallow origin, NW rim area of Kilauea Crater 0.6 mile NE of Uwekahuna. 19° 25.6′ N; 155° 17.0′ W.

July 26, 3:49 am, very feeble, Hilina Fault zone S of Puaialua.

July 26, 4:24 am, feeble, 8.0 miles deep, Hilina Fault system, 4.0 miles SSE of Puu Ohale. 19° 18.5′ N; 155° 14.6′ W.

July 26, 4:26 am, very feeble, Hilina Fault, same general locality as preceding.

July 26, 5:34 am, very feeble, Hilina Fault, 3.0 miles NW of Apua point. 19° 17.0′ N; 155° 15.0′ W.

July 26, 11:52 am, feeble, located 11.0 miles deep off sea coast S of Hilina Fault near Apua Point. 19° 16.3′ N; 155° 09.0′ W.

August 1, 1:49 pm, very feeble, 6.0 miles deep on E slope of Mauna Loa, 5.0 miles E of the Pit Crater, Lua Hohonu. 19° 27.0′ N; 155° 31.6′ W.

August 5, 3:27 am, slight, 0.4 mile deep, NE rim of Kilauea Crater near the National Park Headquarters. 19° 25.7′ N; 155° 15.5′ W. Most persons in immediate vicinity of epicenter were awakened by this earthquake.

August 5, 7:31 am, feeble, of shallow origin near junction of Byron and Waldron Ledges, NE rim of Kilauea Crater. 19° 25.5′ N; 155° 15.5′ W. Reported felt in Hawaii National Park.

August 7, 5:51 am, very feeble, Mauna Loa summit crater.

August 10, 1:44 pm, very feeble, 3.0 miles deep near center of Kilauea Crater. 19° 25.2′ N; 155° 16.5′ W.

August 10, 5:34 pm, very feeble, 12.0 miles deep under S coast of Hawaii 9.0 miles E of Pahala. 19° 12.0′ N; 155° 20.6′ W.

August 12, 10:04 pm, very feeble, probably originated in vicinity of Pahala or adjoining sea coast area.

August 14, 2:32 pm, very feeble, 25.0 miles deep, Hualalai, 8.0 miles E of summit. 19° 40.0′ N; 155° 45.0′ W.

August 30, 5:02 am, very feeble, NE portion of Kilauea Crater.

August 30, 1:09 pm, very feeble, 2.4 miles deep under SW rim of Kilauea Crater 0.6 mile W of center of Halemaumau. 19° 24.6′ N; 155° 17.8′ W.

August 30, 5:33 pm, very feeble, of shallow origin, Byron Ledge. 19° 24.6′ N; 155° 15.7′ W.

August 30, 6:35 pm, very feeble, 0.4 mile deep, E portion of Kilauea Crater near Kilauea Iki gap. 19° 24.8′ N; 155° 15.8′ W.

August 31, 6:18 pm, very feeble, of shallow origin, area near junction of Hilina Fault and SW rift (Kilauea). 19° 17.5′ N; 155° 21.0′ W.

September 1, 4:53 am, very feeble, probably originated SE rim area of Kilauea Crater.

September 1, 3:02 pm, very feeble, located 0.5 mile deep under E rim of Halemaumau. 19° 24.5′ N; 155° 16.7′ W.

September 1, 10:15 pm, moderate, 90.0 miles NNW of Hilo. 21° 00.0′ N; 155° 16.0′ W. Reported felt generally on Island of Hawaii.

September 2, 1:43 am, very feeble, of shallow origin near center of Kilauea Crater. 19° 24.7′ N; 155° 16.6′ W.

September 2, 5:12 pm, feeble, 13.0 miles deep, Hilina Fault, 3.0 miles N by E of Keahou Point. 19° 18.5′ N; 155° 13.3′ W.

September 4, 4:02 am, very feeble, originated in rift zone about 1.5 mile W of Devil's Throat.

September 4, 11:48 am, very feeble, Hilina Fault, 4.0 miles SE of Kamakaia Hills.

September 4, 10:44 pm, very feeble, 1.3 miles NE of Puu Ohale.

September 5, 1:07 am, very feeble, Chain-of-Craters near Pauahi.

September 5, 3:11 am, very feeble, Mauna Loa NE rift between Pukauahi Crater and Puu Ulaula.

September 5, 10:09 am, feeble, 0.8 mile deep, 0.4 mile N of Puhimau Crater (Chain-of-Craters). 19° 24.1′ N; 155° 15.1′ W.

September 6, 9:09 am, very feeble, Kilauea NE crater rim.

September 6, 2:01 pm, very feeble, 3.5 miles NW of Hawaiian Volcano Observatory.

September 6, 10:24 pm, feeble, SE rim of Kilauea Crater, of shallow origin, 0.6 mile SE of Pit seismograph. 19° 24.0′ N; 155° 16.5′ W.

September 9, 10:09 am, very feeble, S rim area of Kilauea Crater about 0.7 mile S of Pit seismograph.

September 10, 3:03 pm, very feeble, 1.7 miles deep, 1.4 miles NE of Puu Ohale. 19° 21.6′ N; 155° 16.0′ W.

September 12, 9:59 am, very feeble, 1.3 miles deep, Kilauea SE crater rim near Keanakakoi. 19° 24.3′ N; 155° 15.8′ W.

September 12, 10:07 am, very feeble, of shallow origin, Kilauea E crater rim (Byron Ledge). 19° 24.9′ N; 155° 15.9′ W.

September 12, 4:31 pm, feeble, 1.5 miles deep, 3.5 miles NW of Volcano Observatory. 19° 28.4′ N; 155° 17.6′ W. Reported felt in Hawaii National Park.

September 14, 5:25 pm, feeble, 5.0 miles deep, SW rim of Kilauea Crater at junction with SW rift. 19° 24.0′ N; 155° 17.8′ W.

September 16, 6:06 am, very feeble, of Halemaumau origin.

September 17, 9:35 pm, very feeble, of Halemaumau origin.

September 18, 3:24 am, very feeble, S portion of Kilauea Crater.

September 21, 5:18 pm, feeble, 12.0 miles deep, Hilina Fault, 4.0 miles SE of Kamakaia Hills. 19° 17.7′ N; 155° 18.5′ W.

September 24, 12:56 pm, very feeble, 5.0 miles deep, E slope of Mauna Loa, 7.0 miles SE by S of Mokuaweoweo. 19° 23.0′ N; 155° 32.0′ W.

September 26, 6:14 pm, very feeble, probably same general location as preceding.

September 26, 6:47 pm, slight, of Kilauea origin.

September 27, 12:21 am, very feeble, 3.0 miles deep near center of Kilauea Crater. 19° 25.1′ N; 155° 16.4′ W.

September 27, 11:14 am, very feeble, of shallow origin, Halemaumau. 19° 24.5′ N; 155° 17.2′ W.

Continuous Tremor:

July 17, 9:28 to 9:50 pm, 22 minutes.

August 21, 6:20 to 6:25 pm, 5 minutes.

August 26, 9:34 to 9:52 am, 18 minutes.

Teleseisms

July 2, 8h 56m am, unidentified portion.

July 13, 7h 30m 16s pm, "P" waves, distance 2,620 miles. Located in Aleutian Island region, 52.7° N; 177.6° W. Reported by Jesuit Seismological Association.

July 27, 3h 12m 40s am, "P" waves. 13.7° N; 91.3° W. Honduras.

August 1, 4h 48m 32s am, "P" waves, distance 4,165 miles; Island of Hokkaido, northernmost of Japan group, 44.0° N; 139.6° E.

August 20, 8h 54m 30s am, unidentified portion.

August 21, 5h 04m 04s pm, "P" waves, distance 2,285 miles.

September 12, 2h 56m 51s am, "P" waves, distance 4,060 miles.

September 19, 8h 14m 05s am, "P" waves, distance 3,525 miles.

September 22, 12h 33m 00s am, "P" waves, distance 4,700 miles.

All time H.S.T. (10h 30m slower than Greenwich).

Microseismic Motion

July:

Light: 2, 3, 24, 26, 27, 29.

Moderate: 1, 5, 6, 8, 10 to 14, 16 to 18, 22, 23, 25, 28, 30, 31.

Strong: 4, 7, 9, 15, 19 to 21.

August:

Light: 2 to 5, 12 to 14, 18, 19, 23, 25 to 27.

Moderate: 1, 8, 10, 11, 15 to 17, 20 to 22, 24, 28 to 31.

Strong: 6, 7, 9.

September:

Light: 17 to 20.

Moderate: 2 to 5, 11 to 16, 21, 22, 28, 29.

Strong: 1, 6 to 10, 23 to 27, 30.

All dates inclusive.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau, the algebraic sum toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending July 28, 1940, was 5.50" N and 1.21" W.

For the year ending September 1, it was 7.22" N. and 1.1" E.

For the year ending September 29, it was 7.05" N and 2.18" E.

Table of Tilt

Week ending	Observatory	Halemaumau West Station
July 7	1.08" N 8° W	0.00
" 14	1.55" N 13° W	0.54" N 75° E
" 21	0.63" N 8° W	0.45" S 70° E
" 28	0.33" N 47° W	0.00
Aug. 4	1.67" N 57° E	1.79" N 42° E
" 11	1.21" N 56° E	Aug. 5 to 15 repairs made to cellar
" 18	1.23" N 26° E	0.00
" 25	1.23" N 3° E	2.98" N
Sept. 1	0.94" N 54° E	1.31" S 87° E
" 8	0.48" N 86° E	0.00
" 15	0.22" N	1.43" N 9° E
" 22	0.61" S 71° E	0.00
" 29	1.60" N 60° E	7.21" N 58° W

Week ending	Halemaumau Southeast Station	Halemaumau Resultant
July 7	0.00	0.00
" 14	3.98" N 71° W	3.69" toward
" 21	4.92" S 49° E	4.40" from
" 28	3.34" W	1.46" toward
Aug. 4	1.45" N 60 ° E	0.91" toward
" 11	3.24" S 31° E	3.24" from
" 18	3.82" S 40° W	0.81" from
" 25	6.48" S 20° E	6.01" from
Sept. 1	4.86" N 20° W	4.69" toward
" 8	3.24" N 20° W	4.72" toward
" 15	3.63" N 38° E	1.11" toward
" 22	5.99" S 11° W	4.05" from
" 29	0.00	5.81" from

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory June 20 indicated closing of the Halemaumau value and opening of the Crater value compared with similar measurements May 29. The Halemaumau angle between the Pit seismograph station and the NW Pit BM decreased 2.50" and the crater angle between the SE rim station and Uwekahuna increased 1.75".

Angle determinations August 7, showed that the Halemaumau value decreased 1.65" and the Crater value increased 0.85" between that date and June 20.

On September 4, the Halemaumau angle had increased 1.81" and the Crater angle had increased 0.23".

Total Halemaumau change, June 20 to September 4: 0.16" increase; Crater: 1.0" increase.

Levelling at Kilauea

The level circuit on Kilauea Crater floor from the Spit BM on the S Crater rim to the NW Halemaumau rim BM was run September 18, 1940. Compared with determinations of April 18, there was only 5.0 millimeters lowering of the NW Pit BM relative to the Spit BM.

The Crater floor has been apparently settling since the 1934 Kilauea eruption and with the exception of a short period during the 1935 Mauna Loa eruption this is the first run in the last 5 years that such a slight change has occurred. It would seem that Kilauea Crater floor had reached a more stable condition or that lava pressure has increased under Kilauea since April 18.

Chain-of-Craters Crack Measurements

June 28 to October 4: 101—increased 2.0 millimeters; there were no changes in the others during this period.

At Devil's Throat, one crack on the SE rim increased 4.0 millimeters.

It appears that the only measurable movement in the Chain-of-Craters region is taking place in the vicinity of Devil's Throat (No. 101 is about one-quarter of a mile to the NW).

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
in cooperation with
UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Government, Department of the Interior, National Park Service.

The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** maintain outside seismograph stations and supplement the work of the government with research associates, instrumental plants and special investigations. Dr. T. A. Jaggar is their geophysicist resident in the National Park.

The **Volcano Letter,** a quarterly record of the Hawaiian volcano laboratories and published by the University of Hawaii, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the above establishments.



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Hawaii National Park
Edward G. Wingate, Superintendent
R. H. Finch, Volcanologist

University of Hawaii
T. A. Jaggar, Geophysicist

ENGULFMENT AT KILAUEA VOLCANO

By R. H. FINCH

The amount of engulfment at the time of the explosive eruption at Kilauea in 1924 was computed by T. A. Jaggar[1] and the writer. T. A. Jaggar in the same bulletin (p. 119), discussed the volume of Kilauea Crater fill for the first century of its recorded history.

In this paper the computations have been extended to include the volume of engulfment at the time of each major collapse, as in 1823, 1832, 1840, 1868, 1886, 1891, 1894, 1916, 1919, and 1922. In most cases the collapse occurred at the time of a Kilauea lava flow at a lower elevation, or immediately followed the cessation of a Mauna Loa outbreak. It is suspected that if we had more complete data on subterranean and submarine lava flows, the correlation between flow and collapse would be nearly one hundred per cent. There were other years with rapid drop in the lava column, notably in 1849, 1855, 1871, 1879, and 1913, but the volumes involved for the most part were not large.

In attempting to compute the volume relations for 1823, the first recorded collapse at Kilauea, we quickly found that the accounts as given by Ellis,[2] Brigham,[3] Dana,[4] and Hitchcock[5] gave widely varying values for the depth of the crater.

Ellis, the first to give a written account of Kilauea, in August, 1823, observed a black ledge about 400 feet below the crater rim and 300-400 feet above the main floor. He wrote, "It was evident that the large crater had been recently filled with liquid lava up to the black ledge, and had, by some subterranean canal, emptied itself into the sea or upon the lower land on the shore." There had been a lava flow from the southwest rift of Kilauea near sea level shortly prior to his visit.

Edward Loomis, in a letter published by Brigham (p. 42), indicates there were several small pits in 1824 with a depth of 200-300 feet which probably had been full of molten lava in 1823. The total depth of Kilauea, referred to Uwekahuna, in 1824 must have been about 1,315 feet. If the computations for volume of engulfment were made for 1824 instead of 1823, the value would be changed by only a small percentage. Loomis made the depth of the main floor 600 feet below the rim where he descended. Malden's depth figures, as given by Dana, are 1,300 feet (p. 51) and 1,700 feet (p. 127). Let us set the various estimates and measurements in tabular form, in order to arrive at a probable figure for the depth of the crater.

Authority	Elevation of rim at place of estimate	Elevation of crater floor	Elevation of black ledge
Ellis, 1823.....	3800 feet	3000 feet	3400 feet
Loomis, 1824	3625 "	3025 "	3325 "
Chamberlin, 1824	.....	3000 "	.....
Malden, 1825	4090? "	2790 "	3190 "
Bingham, 1830 ..	4000? "	3000 "	3400 "
Alexander, 1833..	4000? "	2000 "	Not mentioned
Douglas, 1834	4090 "	2975 "	3375 "
Wilkes, 1840	4000? "	3010 "	3350 "

Ellis made an attempt to check his estimate, first with a string 100 feet long and then with one 230 feet in length. He commented that the string of 100-feet "did not appear to reach near half way to the black ledge of lava." Loomis made his estimate at the lowest point on the rim where the dimensions were small, and, knowing that he measured the width of the black ledge, one can assume that his estimate is not seriously in error. Dana found serious errors in Malden's computation and it may well be that there was an error in his base line. Subsequent careful measurements are in close agreement with the Loomis estimate.

Goodrich estimated that by 1832 the black ledge had been covered with 50 feet of new lava. Subtracting this 50 feet from the Douglas elevation of the black ledge in 1834 gives 3,325 feet, the same as the Loomis estimate. It should be noted that this value differs from the Ellis estimate by only 75 feet. It should not be assumed that the black ledge was an exact level surface around the pit, though judging from the sketches and from the type of activity in 1832 and probably in 1823, the ledge had quite uniform height. By 1840 there was a conical mound around Halemaumau 100 feet above the general floor. The total depth of the crater as given by Malden may be

[1] T. A. Jaggar, "Volume Relations of the Explosive Eruption 1924," *Bulletin of Hawaiian Volcano Observatory*, December 1924, p. 117.
[2] William Ellis, *Journal* (Reprinted Honolulu, 1917), pp. 177-189.
[3] William T. Brigham, "The Volcanoes Kilauea and Mauna Loa," *Memoirs Bernice P. Bishop Museum*, Honolulu, 1909.
[4] J. D. Dana, *Characteristics of Volcanoes*, New York, 1891.
[5] C. H. Hitchcock, *Hawaii and Its Volcanoes*, Honolulu, 1911.

brought into closer agreement with most of the others if we assume that his figures are for one of the several pits in the crater floor at that time.

An interesting item gleaned from the Ellis account is the report of a chasm across the black ledge apparently where the Puna rift cuts the crater wall.

The average drop of the crater floor in 1823 must have been close to 400 feet. As a convenience in computing the area involved, it was divided into two parts: the northern and wider portion with an area of 40,750,000 sq. ft., and the narrow southern portion with an area of 2,550,000 sq. ft., or a total of 43,300,000 sq. ft. With a drop of 400 ft. the volume engulfed would be 17,320,000,000 cu. ft.

The estimates of the depth of the crater in 1832 vary from 2,000 feet (unsupported) to 1100 feet. The area affected by this collapse was but little less than in 1832, or 41,430,000 sq. ft. With a drop of 450 feet, that means an engulfment of 18,640,000,000 cu. ft.

An observation by Goodrich (Dana, p. 55) indicates that the collapse of 1832 may well have occurred in the latter part of July. This would make it coincide with the cessation of the 1832 outbreak of Mauna Loa.

The collapse of 1840 left an inner pit much smaller than that of 1823 or 1832. The estimate of average depth involved for this year is rendered somewhat uncertain by the considerable relief of the crater floor. The total area of collapse was about 22,120,000 sq. ft. With an average drop of 350 feet, the amount engulfed would be 7,752,000,000 cu. ft.

After the drop of 1868, there was considerable difference in level of the crater floor with the most profound sinking at Halemaumau. This was to be expected because, since 1840, the principal seat of activity was at Halemaumau. The great pit had the outline of an inverted frustum of a cone, with an upper diameter of 2,000 feet, and a lower one of 1,500 feet. It was 500 feet deep. This gives the collapse at Halemaumau of 650,000,000 cu. ft. The sunken portion of the crater, less Halemaumau, had an area of 30,000,000 sq. ft. An average drop over this area of 200 feet would mean a volume of 6,000,000,000 cu. ft. The total engulfed in 1868 then was 6,650,000,000 cu. ft.

The collapse in 1886 left a triangular area with sides about 3,350 feet long. There was a sink near the center of the depression 590 feet deep, but it was only 600 feet across and affected the total volume but slightly. The average drop of about 250 feet over an area of 5,600,000 sq. ft. represents a volume of 1,400,000,000 cu. ft. In addition to the above, there may have been some down-warping as indicated by a pronounced crack that opened near the northern end of the crater.

Since 1868 the source of volcanic activity has become quite centralized in the southern end of the crater at Halemaumau, or its immediate vicinity. In 1891 the collapse was confined to Halemaumau. The estimates of the depth of Halemaumau after the collapse of 1891 vary from 500 to 700 feet. The diameter of the pit was 2,500 feet. The average of the computed values of the volume evacuated was 1,200,000,000 cu. ft.

In 1894 the volume represented in the formation of two benches on the rim of the collapsed pit was about 30,000,000 cu. ft. The pit itself had a diameter in one direction of 900 feet and 1,000 feet in the other. After the initial drop in 1894, there was considerable movement at the bottom with some slight infilling. The estimates of depth clustered around 500 feet. The average based on different estimates and measurements and various methods of calculating makes the 1894 engulfment 300,000,000 cu. ft.

The collapse of 1916 left a void that may be thought of as a frustum of a cone with diameters of 1,100 and 375 feet. The drop in level was 400 feet. These figures give the volume displacement in 1916 as 260,000,000 cu. ft.

The 1919 collapse left a void 1,200 feet in diameter at the top and about 200 feet at the bottom, 591 feet below. At a depth of 275 feet, the diameter was 1,060 feet. The void created by a shelf at the north rim was 600,000 cu. ft. The volume of the main pit, computed as upper and lower frusta of cones, was 353,500,000 cu. ft. This gives for 1919 a total of 354,100,000 cu. ft.

Early in May, 1922, the lava was within about 50 feet of the rim of Halemaumau, while crags stood nearly 50 feet above the rim. By the last of the month there was a void 861 feet deep with a width at the rim of 2,000 feet in a NE-SW direction, and 1,485 feet in a NW-SE direction. This void comprised 750,000,000 cu. ft.

A summation of the computations is shown in the following table:

Volume Engulfed by Principal Collapses in Kilauea

Year	Volume in Cu. Ft.
1823	17,320,000,000
1832	18,640,000,000
1840	7,752,000,000
1868	6,650,000,000
1886	1,400,000,000
1891	1,200,000,000
1894	300,000,000
1916	260,000,000
1919	354,100,000
1922	750,000,000
1924	7,120,000,000
Total	61,746,100,000

After each collapse the crater floor was raised by inflows and in some periods, at least, by marked tumescence. During the period under discussion the total filling exceeded the total engulfment.

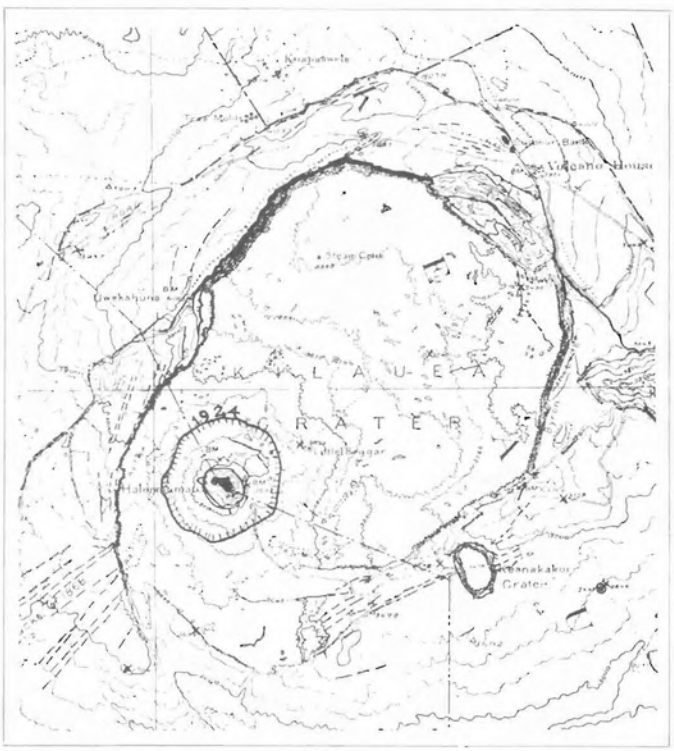

Fig. 1.—Map of Kilauea Crater, 1912 to 1924; enlargement of Halemaumau by engulfment.

Hawaiian Volcano Observatory Report for October-December, 1940

VOLCANOLOGY

October 1940

No glow was visible in the summit crater of Mauna Loa when it was visited on October 14-16, though there was heavy fuming at the 1940 source cone. A portion of the summit of this cone had collapsed.

Kilauea was quiet throughout the month though rock slides were observed on October 18, 29, and 30.

Tilting to the northeast accumulated more than the seasonal normal.

Exceptionally strong microseisms were recorded on October 18 at a time of unusually high waves on Hawaiian shores.

November 1940

There was increase of rock slides from Halemaumau, particularly from the western wall, otherwise Kilauea was quiet in November. Faint bluish fume was noticed over Halemaumau on November 8 and 29.

No activity was observed on Mauna Loa.

December 1940

During the second week of December there was increase in seismicity. The majority of the shakes originated near Kilauea. Rock slides were frequent during the month. A slide at noon December 4 made a large dust cloud.

Tilt for December was to the east. For the year ended December 31, 1940, there was an accumulation of ENE tilt. This tilt indicates that a volcanic low may have been reached in 1939.

The following are the local data for October, November, and December.

Week Ending	Halemaumau Slides	Halemaumau Crack Openings (Millimeters)	Seismic Disturbances
Oct. 6	0	1.0 opened	15
" 13	0	1.0 "	7
" 20	0	2.5 closed	14
" 27	1	5.5 opened	37
Nov. 3	4	4.0 "	13
" 10	2	3.0 "	8
" 17	2	0.5 closed	0
" 24	1	0.5 "	14
Dec. 1	10	6.0 opened	21
" 8	4	3.0 "	32
" 15	1	2.5 "	25
" 22	3	0.5 "	12
" 29	1	3.5 "	10

R. H. F.

Errata

Volcano Letter No. 467, January-March 1940, "Tilt Changes at Kilauea," p. 2, second paragraph, ninth line, should read: During the 27 years of measurement, it has been found that the tilt on the NE rim of Kilauea Crater, considered as the path of the top of a vertical rod, describes an annual clockwise loop of from 5 to 10 seconds of rotational arc with the loop elongated in a NNE-SSW direction, the greater axis being about twice the length of the shorter one. In the course of producing the major loop many minor ones occur and the latter almost without exception progress in a counter-clockwise direction. In general tilt is **northeasterly** during the warmer summer and fall months and **southwesterly** during the cooler late winter and spring months.

Volcano Letter No. 469, July-September 1940, p. 7, Table of Tilt, Halemaumau resultant Sept. 29: change "5.81" from" to "2.48" from." H.H.W.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Distant*	Weekly Seismicity†
Oct. 6	14	1	0	0	0	1	4.00
" 13	5	1	1	0	0	0	2.75
" 20	13	1	0	0	0	0	3.75
" 27	34	1	1	1	0	1	12.00
Nov. 3	10	2	1	0	0	0	4.50
" 10	6	2	0	0	0	0	2.50
" 17	20	0	0	0	0	1	5.00
" 24	11	3	0	0	0	0	4.25
Dec. 1	19	2	0	0	0	0	5.75
" 8	30	2	0	0	0	0	8.50
" 15	16	8	1	0	0	0	9.00
" 22	7	5	0	0	0	1	4.25
" 29	8	2	0	0	0	1	3.00

* Including teleseisms or earthquakes over 5,000 km from Kilauea.
† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and, whenever possible, a determination of depth of focus has been made.

October 7, 5:19 am, feeble, of shallow origin, NE rim of Kilauea Crater not over 0.5 mile from the Observatory. 19° 25.6' N; 155° 15.8' W.

October 11, 11:34 am, very feeble, Mauna Loa NE rift near Pukauahi Crater.

October 16, 3:03 pm, very feeble, probably originated in Mauna Loa NE rift about 5 miles SW of Hilo.

October 22, 3:17 am, feeble, of Kilauea origin, Hilina Fault zone 3.5 miles SE of Kamakaia Hills.

October 26, 7:57 pm, slight, 5.0 miles deep, E slope of Mauna Loa, 7.5 miles E of Pohaka Hanalei. 19° 31.0' N; 155° 26.5' W. Reported felt in Hawaii National Park and sharply felt by many persons at Pohala.

October 28, 9:27 pm, feeble, 15.0 miles deep, in the vicinity of Hilina Fault about midway between Puu Ohale and Keahou Landing. 19° 20.0' N; 155° 16.0' W. Reported felt by a few persons in Hilo.

November 3, 4:36 am, very feeble, probably originated in Kilauea SW rift about 15 miles from the Observatory.

November 4, 11:03 am, very feeble, Hilina Fault, 3.5 miles SW of Kamakaia Hills.

November 6, 5:54 am, very feeble, Hilina Fault system, 5.0 miles deep, 7.0 miles SW of Makaopuhi. 19° 19.5' N; 155° 05.0' W.

November 18, 6:35 am, very feeble, of shallow origin, SE portion of Kilauea Crater, 0.7 mile SE of Pit seismograph. 19° 23.9' N; 155° 16.4' W.

November 22, 5:33 am, very feeble, Mauna Loa NE rift, about 5 miles NE of Mokuaweoweo.

November 24, 11:26 am, very feeble, Hilina Fault system, SE of Makaopuhi.

November 25, 7:34 am, very feeble, 2.0 miles deep, central portion of Kilauea Crater. 19° 25.0' N; 155° 16.7' W.

November 30, 9:52 am, very feeble, of shallow origin under Mauna Loa summit crater.

December 8, 5:48 am, very feeble, Kilauea Puna rift SE of Makaopuhi.

December 9, 1:21 am, very feeble, 1.3 miles deep S rim of Kilauea Crater. 19° 23.8' N; 155° 17.1' W.

December 9, 8:27 am, very feeble, 1.7 miles deep S rim of Kilauea Crater. 19° 24.1' N; 155° 17.2' W.

December 9, 1:24 pm, very feeble, 0.7 mile deep, Kilauea Crater near E rim of Halemaumau. 19° 24.5' N; 155° 16.7' W. Dismantled Pit seismograph.

December 9, 5:05 pm, S rim of Kilauea Crater near Halemaumau.

December 9, 7:35 pm, very feeble, Kilauea SW rift 1.0 mile SW of Halemaumau.

December 11, 9:02 am, feeble, 0.6 mile deep, Kilauea SW rift, 0.3 mile NE of Cone Peak. 19° 24.0' N; 155° 18.4' W.

December 12, 9:52 am, very feeble, 12.0 miles deep, 12 miles NE by N of the Observatory. 19° 30.0' N; 155° 13.0' W.

December 15, 3:26 pm, very feeble, 40 miles ± deep under Mauna Kea. 19° 49.0' N; 155° 29.0' W.

December 19, 1:00 pm, very feeble, of shallow origin, Mauna Loa NE rift near Mokuaweoweo. 19° 31.0' N; 155° 32.0' W.

December 20, 2:48 am, very feeble, 18.0 miles deep, Hilina Fault system, N of Apua Point. 19° 18.3' N; 155° 11.5' W.

December 20, 3:26 am, very feeble, 15.0 miles deep, 8.0 miles S of Kilauea Crater in Hilina Fault system. 19° 18.0' N; 155° 16.5' W.

A number of disturbances, which registered on the Observatory seismograph as tremors, reported elsewhere as follows:

November 8, 5:54 pm, very feeble on Mauna Loa seismograph.

November 12, 1:53 pm, very feeble on Mauna Loa seismograph.

November 16, 8:17 pm, very feeble on Mauna Loa seismograph.

November 25, 4:59 pm, feeble on Mauna Loa seismograph.

November 27, 10:12 pm, reported felt at Paauhau.

December 9, 6:51 am, reported felt at Hookena.

Teleseisms

October 3, 10:08 pm, unidentified portion. Originated in Chile. 19° S; 67° W.

October 26, 7h 37m 40s pm, surface waves. Originated in Central America region. 9.9° N; 84.4° W.

November 16, 5:42 pm, unidentified portion.

December 22, 2:20 am, unidentified portion.

December 28, "P" waves at 6h 17m 15s am. Originated 3,775 miles from Kilauea.

Microseismic Motion

October:

Light: .....
Moderate: 3 to 5, 7, 8, 15, 23, 24.
Strong: 1, 2, 6, 9 to 14, 16 to 22, 25 to 31.

November:

Light: .....
Moderate: 16, 17.
Strong: 1 to 15, 18 to 30.

December:

Light: .....
Moderate: 18, 27 to 31.
Strong: 1 to 17, 19 to 26.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau, the algebraic sum toward or away from the Pit.

At the Observatory, the total accumulated tilt for the year ending on each of the following dates was:

October 27—8.23" N and 3.60" E.
December 1—5.60" N and 5.30" E.
December 29—7.83" N and 9.90" E.

Table of Tilt

Week ending	Observatory	Halemaumau West Station
Oct. 6	1.11" N 75° E	1.91" N 81° E
" 13	0.75" N 32° E	0.00 .....
" 20	1.17" N 49° E	1.40" S 11° E
" 27	2.44" N 43° E	2.26" N 42° E
Nov. 3	1.53" N 62° E	1.91" S 84° E
" 10	0.46" S 3° W	1.40" N 9° E
" 17	1.05" N 30° E	1.40" S 9° W
" 24	2.04" S 6° E	1.40" N 9° E
Dec. 1	1.27" N 39° E	2.18" N 79° W
" 8	1.70" N 86° E	0.00 .....
" 15	1.24" S 43° W	0.00 .....
" 22	1.76" N 4° E	0.00 .....
" 29	3.20" N 75° E	0.00 .....

Week ending	Halemaumau Southeast Station	Pit Resultant
Oct. 6	3.24" S 19° E	1.29" from
" 13	3.73" N 45° W	3.73" toward
" 20	1.62" N 76° E	0.50" from
" 27	1.56" S 17° E	0.18" toward
Nov. 3	3.30" N 20° W	6.48" toward
" 10	6.45" S 19° E	5.86" from
" 17	4.89" N 19° W	4.25" toward
" 24	9.98" S 7° E	8.30" from
Dec. 1	3.24" N 17° W	1.15" toward
" 8	7.35" N 10° E	5.19" toward
" 15	2.20" N 65° W	1.46" from
" 22	1.72" N 21° W	4.36" toward
" 29	6.38" N 23° E	2.75" from H. H. W.

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory October 1, 1940, indicated closing of both the Halemaumau and the Crater values compared with similar measurements made September 4. The amount of closing of the Halemaumau angle, between the Pit seismograph station and the NW Pit BM, was 0.32" and the crater angle, between the SE rim station and Uwekahuna, was 2.16".

Between October 1 and October 24, the Halemaumau angle opened 0.49" and the crater angle closed 0.92".

October 24 to November 12: Halemaumau angle opened 0.52" and the crater angle opened 3.33".

November 12 to November 29: Halemaumau angle opened 0.08" and the crater angle closed 0.92".

November 29 to December 19: Halemaumau angle closed 0.66" and the crater angle opened 0.69".

Net Halemaumau change, October 1 to December 19: 0.33" open; crater change: 2.16" open. H. H. W.

Chain-of-Craters Crack Measurements

On the Chain-of-Craters Road there have been no appreciable changes in cracks except at No. 108, S rim of Aloi Crater. This crack has opened as follows:

October 4 ..... 97.30
October 25 ..... 97.35
November 29 ..... 97.40
December 27 ..... 97.75

Total opening .... 4.5 millimeters

Crack No. 2, N rim of Devil's Throat opened a total of 2.0 millimeters in the same period. H. H. W.

Time used throughout this report is Hawaiian Standard time, 10h 30m slower than Greenwich.

THE VOLCANO LETTER

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Hawaii National Park
Edward G. Wingate, Superintendent
R. H. Finch, Volcanologist

University of Hawaii
T. A. Jaggar, Geophysicist

THE FILLING IN OF KILAUEA CRATER

By R. H. FINCH

The net result of the first century of the recorded history of Kilauea Volcano, despite numerous breakdowns, has been a gradual filling of the crater. To facilitate computations of the volume of the uneven filling from 1823 to the present, the areas between convenient contours on the 1922 edition of the Kilauea Crater advance sheet of the U.S. Geological Survey were determined by planimeter. The collapse of 1823 left a comparatively narrow, black ledge around the inner margin of Kilauea Crater. This ledge, 3,400 feet above sea level, was taken as a base. The volume computed from this base plus the amount of the collapse in 1823 would give the total fill since the first recorded visit to Kilauea (in 1823) to the present time. The planimeter measurements indicate that the volumes given in Volcano Letter No. 470 for the collapses in 1823 and 1832 should be increased by about 10 per cent.

The amount of filling can be computed for only a few of the many periods of inflow and tumescence because of lack of adequate data. The volume for the period between 1823 and 1832 would be, to a close approximation, the amount engulfed in 1823 plus a layer 50 feet deep over the entire crater. Just prior to the collapse of 1832, the lava stood 50 feet higher than the black ledge of 1823. The total fill for the period then was about 23,850,000,000 cu. ft. The filling must have taken place within eight years as the lava was at as low a level in 1824 as in 1823, or perhaps a little lower. This would make the average per year about 3,000,000,000 cu. ft. The maximum rate of filling is not readily determinable and was quite likely much higher than the average.

Between 1840 and 1846 a large percentage of the increase in elevation of the crater floor was due to tumescence. However the ratio of the volume due to tumescence to that of inflow cannot readily be determined. In some places a canal or moat that separated the interior platform from the black ledge was 200 feet deep. Because the inner crater was

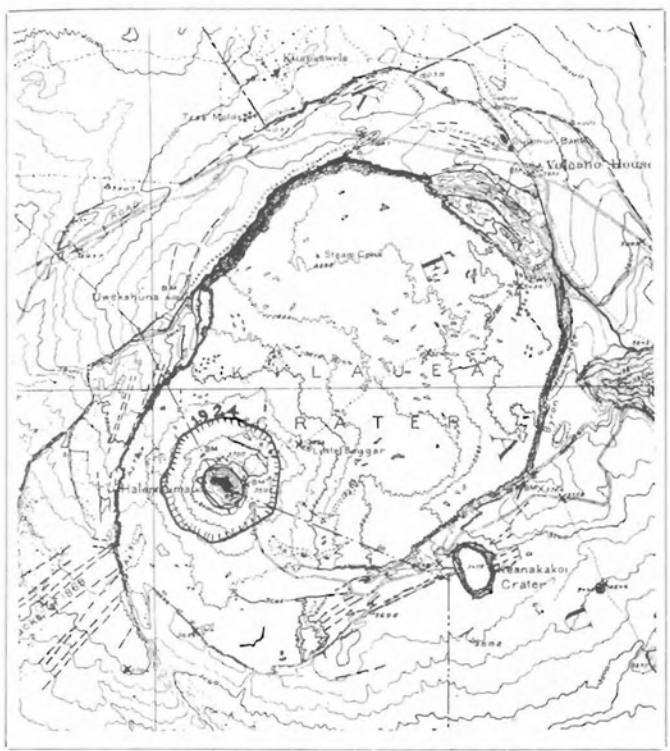
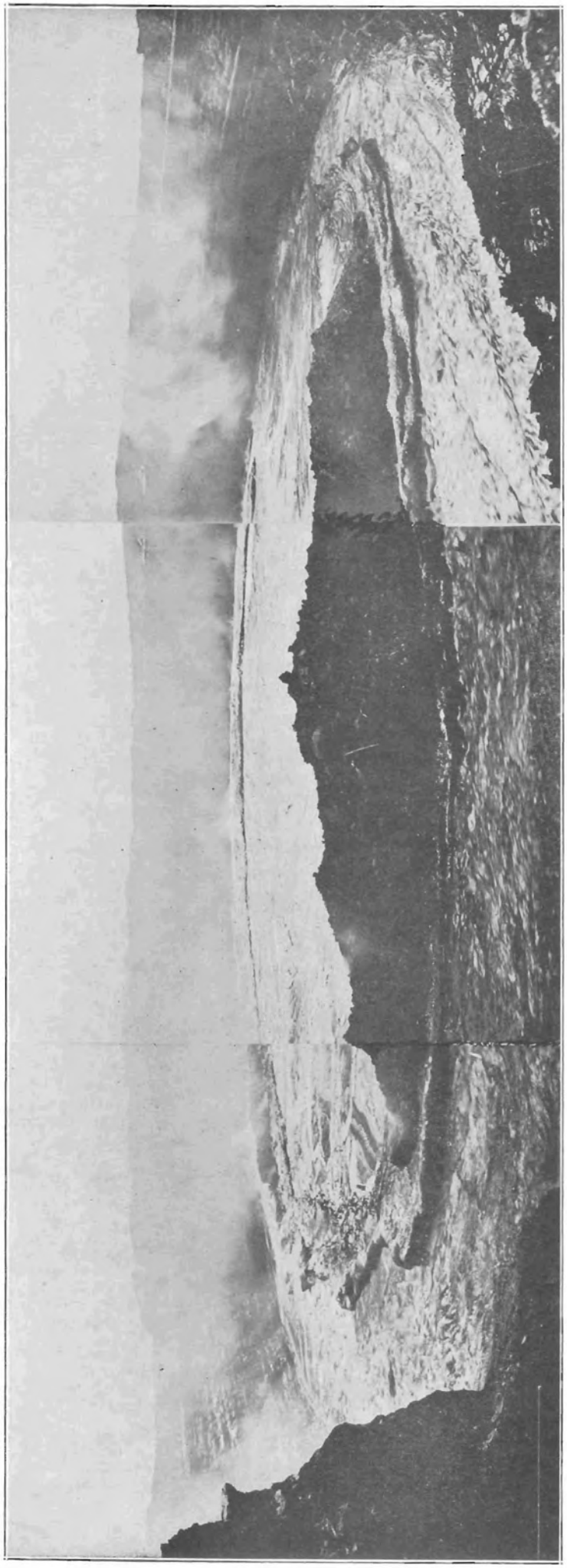


Fig. 1—Map of Kilauea, 1912 to 1924.



funnel-shaped, gaps were left between the resulting interior platform and the walls of the black ledge when the floor was bodily elevated. These gaps were the canals observed in 1844 and 1846 by Titus Coan and Prof. C. S. Lyman. The 200-foot depth of the canal does not necessarily mean that the platform was elevated uniformly through that range. The interior basin may have been elevated much less. Then too, the accumulation of talus blocks around the margin of the lower floor prior to the uplift would have been an important factor in making the margin the highest part of the elevated platform.

Brigham,[1] referring to Lyman's explanation of the canals of 1846, states, "The rise of a cylinder of lava a mile in diameter some 200 feet would be remarkable, but with an overflowing bowl of lava more than a thousand feet in diameter in its very midst the phenomenon would be incomprehensible." But that is exactly what did happen, as correctly explained by Lyman whose visit to Kilauea wos ot about the end of the tumescing period.

A similar phenomenon was the subject of daily measurements by the Hawaiian Volcano Observatory in 1919. Immediately after the collapse of November 28, 1919, it was noted that the bottom of Halemaumau (see map Fig. 1) was being elevated as a unit. In the lava lake was a ring-shaped island surfaced in many places with talus blocks as shown in Fig. 2. This island mantained its identity while the lava column rose vertically 450 feet in 17 days. The upper half of Fig. 3 shows the plan of Halemaumau at the end of the uplift, and the lower half, a section, illustrates the nature of the island and the relation of the superficial lava lakes to the more plastic portions of the lava column. The fact that lava lakes are but comparatively shallow depressions in a pasty plug was not known to Brigham when he wrote.

Tumescing accompanied many, if not all, periods of rapid rise and inflow, but in most cases was not as pronounced as that between 1840 and 1846. The ascensive force of the lava affects not only the more mobile portions of the lava column, but the entire region surrounding Kilauea Crater.[2]

Sometime in 1846 it was observed that the surface of Kilauea was nearly back to its position before the collapse of 1840. This would make the fill of six years about equal to the amount engulfed in 1840, or 7,750,000,000 cu. ft. The averoge per year would be 1,290,000,000 cu. ft.

Dividing the total fill of several years by the number of years obviously does not give a true rate.

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[1]William T. Brigham, **Volcanoes Kilauea and Mauna Loa,** p. 60.
[2]T. A. Jaggar and R. H. Finch, **Tilt Records for Thirteen Years at the Hawaiian Volcano Observatory,** p. 43.

Fig. 2—Halemaumau on Dec. 16, 1919, after a rapid rise from a depth of 591 feet. Photo by T. A. Jaggar.

Observations as to the time of beginning and ending of activity are lacking, and also, in some of the longer periods, one or more years may have been periods of inactivity or even recession. Nevertheless, it is a rough measure of activity. In 1919 the rise took place within 17 days, and the average rate fill for this period if continued for an entire year would have amounted to 2.2 cu. mi.

The 1922 map of Kilauea Crater is substantially correct for 1941 save for the 1924 enlargement of Halemaumau and the subsequent inflows. The least elevation change since 1823, unless it be near the southwest rim of Kilauea, is just below Byron's Ledge. There the present surface is but 100 feet above the back ledge of that year. The greatest depth of fill was a little more than 700 feet, at the rim of Halemaumau.

The total fill between 1823 and 1924 was 70,280,000,000 cu. ft. If we subtract the amount engulfed in 1924, 7,120,-000,000 cu. ft., from this total we will have the net fill up to the time of the inflow of July, 1924, or 63,160,000,000 cu. ft. To this net, however, must be added the total volume of the several inflows into Halemaumau from 1924 to 1934. These inflows have lessened the depth of Halemaumau from 1,335 feet below the rim in 1924 to its present depth of 770 feet. Part of the elevation of the Halemaumau floor has been due to the accumulation of landslides from the walls. It is thought that about 800,000,000 cu. ft. was due to inflows. The net fill between 1823 and 1941 then, is 63,960,000,000 cu. ft. The gross filling between 1823 and 1941 would be the above total plus the amount of engulfments from 1832 to 1922 inclusive, or 101,266,000,000 cu. ft.

The history of Kilauea shows that there has been a diminution in size of the volcanic conduit under the crater floor. In 1823 and 1832 nearly the entire crater floor responded to volcanic pressure changes. Between 1840 and 1846, half the crater floor was bodily elevated indicating plastic material under that much of the crater. Most of the inflows of that period, however, came from the site of Halemaumau, and the canal near the southwest end of the crater was obliterated before there were any appreciable flows in the remainder of the canal. The breakdowns of 1868, 1886, and 1891 showed that the mobile portion of the crater got progressively smaller until from 1891 on, it was confined to Halemaumau and the immediate vicinity. That a mobile lava column still exists under Kilauea is indicated by an accumulation of 17 seconds of northeast tilt at the Hawaiian Volcano Observatory since 1939. Northeast tilt at the Observatory means an increase in elevation of Kilauea mountain.

What happened at Kilauea for many years after the explosive eruption of 1790 is not known, but at least by 1823, 33 years afterwards, there was intense activity over the entire crater. The interval of inactivity after 1790 may have been much less than 33 years, for native accounts given in 1823 said that there had been many lava flows but no explosion since 1790.

If Kilauea continues to be periodic in its activity and repeats the conditions following 1790, the 1924 explosion should be followed by a very active Halemaumau in or before the latter part of this decade.

Hawaiian Volcano Observatory Report for January-March, 1941

VOLCANOLOGY

January 1941

An unusual feature of the month was the continuation of northerly tilt until the last week of the month. Seasonal southwesterly tilt normally sets in about the first of the year. The tearing down of a part of the Hawaiian Volcano Observatory should, apparently, have been effective in increasing the normal southwest tilt.

There were no reports of unusual activity on Mauna Loa and surface activity at Kilauea was confined to rock slides from Halemaumau walls which were frequent January 20-22.

February 1941

A light fume column was visible over Mokuaweoweo at 5:15 pm, February 11. On the morning of March 12, Navy aviators reported heavy fume from the same place.

During the two weeks ended February 16 there was a slight southeast tilt instead of the normal southwest tilt for this time of year. The amount was slight but the actual figures do not tell the whole story. To produce an easterly tilt in February it would appear that some deep-seated pressure change, call-

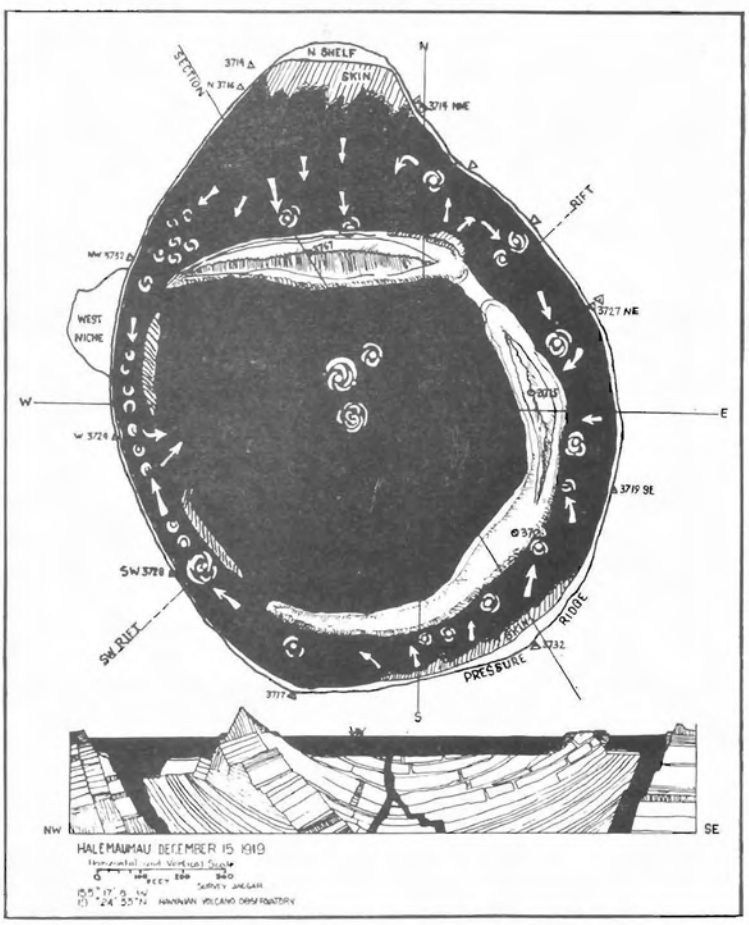

Fig. 3—Plan and section across Halemaumau, Dec. 15, 1919, showing the relation of lava lakes to the viscous and solid material below. From Volcano Observatory records by T. A. Jaggar.

ing for an easterly tilt, must first exceed the seasonal westerly tilt before it can become manifest.

Landslides from Halemaumau have a tendency to occur in groups and this was shown by several on February 17 and 21.

March 1941

Tilting of the ground at the Observatory continued to be erratic in March. In the first ten days the tilt was to the northeast and during the last week it was to the northwest. This means that there will be but little seasonal tilt to the southwest during the first four months of the year. Under normal conditions such a tilt would justify a prediction of volcanic activity but current work on the new hotel adjacent to the seismograph cellar may be affecting the records.

The 1940 Mauna Loa eruption cone was observed to be fuming on March 25.

Some of the local data for January, February, and March are as follows:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings (Millimeters)	Seismic Disturbances
Jan. 5	0	2.5 opening	10
" 12	1	0.5 "	5
" 19	2	0.0	15
" 26	15	2.0 opening	18
Feb. 2	3	1.0 closing	7
" 9	0	3.5 "	15
" 16	1	6.0 opening	11
" 23	4	0.5 closing	21
Mar. 2	0	2.0 opening	7
" 9	0	6.5 "	7
" 16	0	1.5 "	5
" 23	0	0.5 "	7
" 30	0	5.0 "	11

R. H. F.

SEISMOLOGICAL DATA

Earthquakes

Date	Minutes of Tremor	Very Feeble	Feeble	Slight	Distant*	Weekly Seismicity†
January 5	10	0	0	0	0	2.50
" 12	5	0	0	0	0	1.25
" 19	12	2	1	1	1	7.00
" 26	10	8	0	0	0	6.50
February 2	7	0	0	0	0	1.75
" 9	12	1	2	0	1	5.50
" 16	9	1	1	0	0	3.75
" 23	17	3	0	1	0	7.75
March 2	2	5	0	0	0	3.00
" 9	3	4	0	0	0	2.75
" 16	4	1	0	0	0	1.50
" 23	6	1	0	0	0	2.00
" 30	5	6	0	0	0	4.25

* Including teleseisms or earthquakes over 5000 km from Kilauea.
† For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of depth of focus has been made.

January 15, 7:45 am, very feeble, 0.8 mile deep, Chain of Craters between Kokoolau and Devil's Throat. 19° 23.0' N; 155° 14.6' W.

January 17, 7:30 am, slight, 14.0 miles deep under W slope of Hualalai near seacoast at Kaiwi Point. 19° 40.3' N; 156° 03.5' W. Reported felt at Naalehu, Kailua, Hookena, Hilo, and strongly felt by everyone at Puuwaawaa.

January 18, 9:34 am, feeble, probably originated about 15 miles N of Papaaloa, in general area of earthquakes of summer of 1940 which originated in same region.

January 19, 6:20 pm, very feeble, 11.0 miles deep under E slope of Mauna Loa, 17 miles W of Kilauea Crater. 19° 25.5' N; 155° 27.8' W.

January 20, 11:01 pm, very feeble, 4.0 miles deep, 1.7 miles SSE of Volcano Observatory; 0.3 mile S of S rim of Kilauea Iki.

January 21, 2:15 am, very feeble, probably originated SW rift of Kilauea near Hilina Fault.

January 21, 7:24 pm, very feeble, 10.0 miles deep, Mauna Loa NE rift near Puu Ulaula. 19° 33.0' N; 155° 28.0' W.

January 22, 3:26 am, very feeble, of shallow origin, Mauna Loa summit crater.

January 25, 3:56 am, very feeble, 15.0 miles deep, 4.0 miles NNW Kailua, W slope of Hualalai on seacoast. 19° 41.0' N; 156° 01.0' W. Reported felt at Kailua and Kealakekua.

January 26, 8:42 am, very feeble, 3.5 miles NE Puu Kulua, Mauna Loa NE rift.

February 3, 2:08 pm, feeble, 14.0 miles deep, E slope Mauna Loa, 5.1 miles W of W rim of Kilauea Crater. 19° 25.0' N; 155° 20.0' W. Reported felt by many persons in Pahala.

February 8, 9:19 am, feeble, located about 37.0 miles N of Hilo under sea floor; 24 miles NE of Ookala. 20° 10.2' N; 155° 0.00' W.

February 11, 9:56 pm, feeble, 60 miles N by E of Hilo. 20° 34.0' N; 154° 49.0' W.

February 13, 12:05 pm, very feeble, Kilauea Puna rift area in general vicinity of Kalapana.

February 18, 11:53 am, slight, 30 miles deep, 14 miles E of summit of Hualalai. 19° 41.0' N; 155° 39.0' W.

February 20, 12:48 am, very feeble, probably originated 8.5 miles SW of Kilauea Crater in vicinity of Kamakaia Hills.

March 1, 12:16 pm, very feeble, Mauna Loa summit crater.

March 1, 3:46 pm, very feeble, Mauna Loa NE rift, 15.0 miles from Hilo.

March 4, 12:37 am, very feeble, Hilina Fault 7.0 miles W of Kalapana.

March 6, 4:28 pm, very feeble, located at base of NE rim of Kilauea Crater and of shallow origin. Sharply felt at Volcano Observatory.

March 8, 9:14 am, very feeble, Kilauea SW rift near junction with Hilina Fault.

March 13, 12:49 pm, very feeble, Hilina Fault N of Apua Point.

March 22, 5:54 pm, very feeble, located under NE rim of Kilauea Crater.

March 25, 5:57 pm, very feeble, probably originated in the vicinity of Punaluu.

March 30, 0:54 pm, very feeble, located on the SW rift of Kilauea, 0.6 mile beyond the SW rim and 0.6 mile NE of Cone Peak. 1.6 miles deep. 19° 24.1' N; 155° 18.3' W.

March 30, 3:42 pm, very feeble, located 20 miles north of Hilo and 8 miles off shore of Laupahoehoe. Depth 20 miles. 20° 00.8' N; 155° 07.3' W.

March 30, 6:54 pm, same location as earthquake of 3:42 pm.

March 30, 9:23 pm, same location as earthquake of 3:42 pm.

March 30, 11:48 pm, same location as earthquake of 3:42 pm.

H. H. Waesche

Teleseisms

January 13, 6h 08m 03s am, probable distance from Kilauea, 3,480 miles.

February 8, 11h 18m 49s am, distance not readily determined, probably 4,540 miles.

Microseismic Motion

January

Light: 1, 4, 5, 8, 9, 15, 16.
Moderate: 3, 6, 7, 10, 14, 17, 19, 25.
Strong: 2, 11 to 13, 18, 20 to 24, 26 to 31.

February

Light: 17 to 22.
Moderate: 6, 7, 14 to 16, 23 to 25.
Strong: 1 to 5, 8 to 13, 26 to 28.

March

Light: 13, 21 to 23.
Moderate: 2 to 4, 6, 12, 18 to 20, 24.
Strong: 1, 5, 7 to 11, 14 to 17, 25 to 31.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau, the algebraic sum toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending on each of the following dates was:

January 26 - 12.22" N and 11.16" E.
March 2 - 10.20" N and 12.64" E.
March 30 - 12.58" N and 10.41" E.

Table of Tilt

Week Ending	Observatory	Halemaumau West Station
January 5	0.95" W	0.00 - - -
" 12	1.49" N 6° W	2.77" N 64° W
" 19	1.80" N 76° W	1.61" S 10° E
" 26	0.77" S 21° W	1.31" N 28° E
February 2	0.91" S 14° W	2.90" S 28° E
" 9	1.82" S 72° E	3.19" S 22° W
" 16	0.73" S 13° E	5.42" N 38° E
" 23	3.44" S 24° W	1.31" S 10° W
March 2	1.88" N 45° E	2.26" S 55° W
" 9	5.53" N 18° E	0.00 - - -
" 16	4.63" S 54° W	2.32" S 6° W
" 23	5.81" S 19° W	1.37" N 21° W
" 30	2.17" N 19° W	0.44° S 16" E

Week Ending	Halemaumau Southeast Station	Pit Resultant
January 5	6.48" S 29° W	2.75" from
" 12	7.87" N 19° E	3.31" toward
" 19	13.93" S 15° E	12.98" from
" 26	3.24" N 31° W	3.28" toward
February 2	3.24" S 30° E	2.24" from
" 9	14.58" N 30° W	13.84" toward
" 16	13.71" S 61° E	8.74" from
" 23	5.83" N 78° W	3.91" toward
March 2	2.85" N 45° E	1.45" from
" 9	5.77" N 30° E	2.27" toward
" 16	3.40" S 2° E	3.37" from
" 23	5.93" S 7° W	4.82" from
" 30	5.93" N 7° E	4.52" toward

H. H. Waesche and P. E. Schulz

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory, January 14, 1941, indicating closing of the Halemaumau value and opening of the Crater value compared with similar measurements made December 19. The amount of closing of the Halemaumau angle was 1.51" and of opening of the Crater value was 1.09".

Between January 14 and January 30, the Halemaumau angle closed 1.24" and the Crater angle closed 1.26".

Between January 30 and February 17, the Halemaumau angle opened 1.16" and the Crater angle opened 0.09".

Between February 17 and March 4, the Halemaumau angle closed 1.57" and the Crater angle closed 2.17".

Net Halemaumau change December 19 to March 4: Halemaumau 2.16" closed; Crater 2.25" closed.

H. H. Waesche

Kilauea Crater Floor Levels.

A level circuit was run from Spit B.M., S rim of Kilauea Crater, to NW Pit B.M., Jonuary 16, 1941. There was no relative change in elevation between these two stations compared with a similar run made September 18, 1940.

Chain-of-Craters Crack Measurements

On the Chain-of-Craters road there have been no appreciable changes in meosured cracks except at #108, S rim of Aloi Crater. This crack has opened as follows:

December	27	measurement was	97.75 cm
January	31	" "	98.25
Februory	28	" "	98.70
March	28	" "	98.90
Total opening			1.15 cm

Devil's Throat rim cracks indicoted only slight chonges.

H. H. Woesche

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
in cooperation with
UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record of volcanoes in the Hawaiian Islonds and around the Pacific Ocean. Its equipment at Kilauea Volcano, Howaii Island, has been transferred to the United States Government, Department of the Interior, National Pork Service.

The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** mointain outside seismograph stations and supplement the work of the government with research associotes, instrumental plants and special investigations. Dr. T. A. Jaggar is their geophysicist resident in the National Park.

The **Volcano Letter,** o quarterly record of the Hawaiian volcano laboratories and published by the University of Hawaii, is issued by outhority of the Department of the Interior and supplied to a restricted membership and exchange list of the obove establishments.

THE VOLCANO LETTER

No. 472 **Department of Interior** **National Park Service** **April-June 1941**

• The Volcano Letter, a quarterly record of the Hawaiian volcano laboratories, published by the University of Hawaii, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the Hawaiian Volcano Research Association and the University of Hawaii.

• The Hawaiian Volcano Research Association was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, is leased and operated by the United States Government, Department of the Interior, National Park Service.

• The University of Hawaii (T. A. Jaggar, geophysicist) cooperates in maintaining a research laboratory at Hawaii National Park (Edward G. Wingate, superintendent, R. H. Finch, volcanologist). The Association and the University maintain outside seismograph stations and supplement the work of the government with research associates, instrumental plants, and special investigations.

CALDERAS AND THEIR ORIGIN, BY WILLIAMS

Review by R. H. FINCH

Calderas and their Origin, by Dr. Howell Williams, [Bulletin of the Department of Geological Sciences, University of California, Vol. 25, No. 6, 107 pages, 1941], offers geologists a thought-provoking and comprehensive discussion on caldera and crater formation. "Calderas are large volcanic depressions, more or less circular or cirque-like in form, the diameters of which are many times greater than those of the included vent or vents, no matter what the steepness of the walls or form of the floor." A crater is limited to "a constructive apparatus from which ejecta escape to build up positive land forms." It follows then that "calderas are almost invariably large volcanic basins produced by engulfment."

He lists six classes of calderas: 1, explosion calderas; 2, collapse calderas; 3, erasion calderas; 4, volcanic graben; 5, volcanic rents or fissure troughs; and 6, major volcano-tectanic depressions. Erosion calderas are probably included for the sake of completeness as they result from modification of other forms. It will be noted that some form of collapse is present in all classes except for the "rare and relatively small explosion calderas."

Uniformity in names such as Dr. Williams proposes would make for clarity, but it will be some time before all volcanologists will cease to use the word crater in the sense of depressions in the surface of the earth caused by volcanic processes. In some ways it would be more in keeping with the ordinary meaning of caldera if the proposed definitions of caldera and crater were interchanged. At Kilauea it is easy to think of Halemaumau as a cauldron in Kilauea crater.

It is gratifying to see proper recognition given to the splendid work of the geologists of the Dutch East Indies, especially Stehn, van Bemmelen, van den Bosch, and Neumann van Padang. The above are included under the term field volcanologists. This would imply that the other class would be library volcanologists. Williams' interest in calderas was aroused by a visit to Kilauea and subsequently he did extensive work on the Brokeoff caldera in California, the Newberry and Crater Lake calderas in Oregon. He also spent considerable time at the calderas in New Zealand, Dutch East Indies, and Japan.

One of the effects of the paper will be to lay forever the idea that explosions by themselves are competent to account for large calderas. In each case discussed, the volume of coarse lithic debris about the rim is strikingly insufficient to account for the material removed. It is surprising that so slight attention has been paid to the scarcity of the old lithic material around each volcano "that blew its head off," for this scarcity was recognized at Santorin by Fouque published in 1879, and by Diller at Crater Lake published in 1902. Van den Bosch is quoted as saying that it is the scarcity of such lithis debris that "explodes the explosion hypothesis."

That small craters may be due to explosions is accepted. Three examples of known small calderas produced by explosion, Rotomahana in New Zealand, Bondai-san in Japan, and Chaos Crags in California are described.

Before discussing 20 illustrative examples of collapse calderas about whose origin there is but little doubt, three calderas doubtfully ascribed to explosion are discussed. They are the Valles caldera in New Mexico, Aniakachak in Alaska, and Mount Multnomah in Oregon. The Valles caldera with diameters of 17 and 18 miles is "probably the largest caldera in the world." The discussion on these three calderas convinces one that Williams was quite conservative in labelling them "doubtfully ascribed to explosion."

These large calderas, often with rim volcanoes, suggest to the reviewer that the great volcanic arcs, such as the Aleutian, mark portions of ancient subsidence basins with rim volcanoes that were many hundreds of miles in diameter.

Krakatau is taken as the type where engulfment follows repeated and usually short-lived explosions of pumice and juvenile ash. An excellent review of the history of Krakatau is given. On page 262 listing some of the possible causes of the activity there, is the statement that the magma prior to 1883 may have been "potentially explosive owing to a high content of dissolved gases, perhaps absorbed from the walls of the reservoir." The mechanism of such an absorption introduces grave difficulties aside from the relatively small volume of gases available from such a source. Escher's gas-caring hypothesis is inadequate to account for the formation of large calderas and comes in for just criticism.

On page 256 occurs the statement that the earlier small explosions of Krakatau of May 20 "were chiefly of vulcanian type —— whereas the culminating explosions were of pelean type, the overwhelming mass of pumice being deposited with great rapidity as glowing avalanches (nuees ardentes)." This seems to be overworking the term nuees ardentes which by many means a more or less downward component of a pumice-charged explosion and not merely a glowing cloud. Ver Beek and Dana long ago assumed that the caldera at Krakatau was produced by engulfment and to this most of the later workers there, Stehn, van Bemmelen, van den Bosch, Neumann van Padang, Reck, and Williams, agree.

The next caldera discussed is Santorin caldera of Greece. The pioneer studies of Fouque have in the main been verified by the comprehensive work of Neumann van Padang and Reck. Fouque's calculation indicated that the ratio of pumice to old lithic material was about 99 to 1.

Eight pages are devoted to the history of Crater Lake which is in fact but a resume of his monograph on that subject which will appear shortly. The arguments that Crater Lake is due

to engulfment should convince the most skeptical of the explosion school. The ancestral cone of Crater Lake is ossumed to have hod a small crater atop its summit at a height of about 12,000 feet. It would seem that a height of about 10,000 feet could account for the glaciotion. The extra 2,000 feet in height would increase the total snowfall but slightly. The top may have been made up of at least two peaks. Such o difference in the originol height would decreose the amount of material that disoppeared from 17 cu. mi. to about 12 cu. mi. The estimate of the volume of the old lava in the ejecta is not over 2 cu. mi. Hence whether the amount engulfed was 12 or 17 cu. mi. affects his orgument not at oll. It is exceedingly hard to follow, however, the argument that the "frothy magma was expelled in so great a volume that instead of being thrown high above the cone it rose but a short distance and falling bock on the slopes of the mountain rushed headlong in a series of glowing clouds (nuees ardentes)." The distributian of the pumice indicates that wind may have been an importont factor in some of the blasts. The "prodigious speed" with which "the avalanches raced down the canyons and spread out on the encircling lowlands for distances as great as 35 miles" may be questioned. Apparently prodigious velocities of translotion were not attoined in the nuees ardentes (horizontal blasts) at Mt. Pele, Soufriere or Lassen. The velocity of the explosian avalanche at Bandai-san was 48 miles an hour.

The four great calderos of Kyusu, Japan, that lie along a north-south line are next token up. Of the numerous calderas to be found in Japan these four receive special treatment because of the greatness of their size and because Aso is the only one well known outside af Japan. The smallest of these, Kikai, has on area of 230 km². Each has a "central cone," though active vent might be a more appropriate term; Sakurajima, for instance, is at the southern rim of the Aira caldera. The subsidence following the 1914 eruption of Sakurajima is nearly symmetrical about the Aira caldera instead of the Sakurajimo cone.

Other cases described under the Krakatau type are Lago di Bolseno in Italy, Mount Gambier in Australia and the Knebel See in Iceland.

Next discussed are calderas whose collopses are occasioned by the lowering of the magma level in the central conduit by dike intrusion injection at depth or lateral outflow at low levels. Kilauea is taken as the type volcano. If explosions accompany the formation of this type, they are phreatic. Sondberg's contention that the walls af Kilauea represent the sides of the originol conduit that has progressively grown smoller until it has reached the very small dimensions of Halemaumau is refuted. In defense of Sandberg's idea, however, it should be remembered that nearly the entire crater was active in 1823 and 1832, not, of course, over a conduit of that size but over a network of feeding fissures. Following a collapse in 1840 involving about one squore mile, the collapsed area rose bodily in some portions at least 200 feet. Since 1891 the active conduit has been restricted to Halemaumau. The sinking of the lovo column in 1919 is attributed to the opening of a lateral fissure. Why not ottribute it to a withdrawal into the depths? If there can be deep-seated pressure increase under a volcano, then why not deep-seated decrease?

Stearns is followed in his belief that Mokuaweoweo is the result of the coalescing of small pit craters fluxed and stopped along the rift zone. However, arguments such as one or more peripheral crocks—not parallel to the rift zone—con be produced pointing to a more widespread collapse at Mokuaweoweo.

Other calderas of the Kilauea type discussed are Nyamlagera in Africo, Batoer on Bali, Medorika in the Kurile Islands, Nemrut Golu in Turkey, and Newberry caldera in Oregan.

Kotmoi is put in a class by itself. The discussion of the volconoes up to Kotmai suggests thot there is a unity in the broader aspects of volcanism. General considerations make one question Fenner's rapid assimilation theory as an explanation of Katmai's activity. This theory is considered a possibility though Fenner himself raised four serious objectians to it.

The discussion of cryptovolcanic calderas is especially interesting as indicating that vestiges of volcanism may still be found in regions long free from orogenic disturbances and quite deeply mantled with sedimentary deposits. Why subterranean explosions are thought to be a necessary accompaniment af such formations is not clear. A decrease of pressure, probably following an increase, and withdrawal of magma into the depth or dike intrusions could account for most of such depressions. The wide distribution of cryptovolcanic calderas is evidenced by the examples offered: Bosumtwi and Nebiewale of the Gold Coast of Africa, the Pretoria Salt Pan af South Africa, the Steinheim Basin and Rieskessel in Germany, and one each in Indiana, Illinois, Kentucky, Ohio, Tennessee, and Utah.

Glen Coe, Scotland, is taken as the type where a caldera results from the collapse af a large cylindrical block along ring fractures. Other calderas described with distinct ring fracture features are those of Ossipee, New Hampshire; Silverton, Colorado; and Buell-Park, New Mexico.

Stromboli is the type for the volcanic sector graben. The sector collapse here has progressed to the northwest producing a series of terrace-like benches. The Somma-vesuvius system is included in this type. As the Vesuvian cone has been built up near the lower western wall of the Somma caldera formed at the time of the 79 A. D. eruption one wonders why it is placed in this group.

Volcanic rents or fissure troughs ore depressions formed on volcanic cones by horizontal movement. Crescentic troughs on several volcanoes of Java appeor to be of this origin.

Some very large depressions related to areal eruptions from extensive fissure systems are classed as major volcano-tectonic depressions. Examples in Sumatra and New Zealand are cited. Such crustal collapses in regions without a large central vent edifice are on a vast scale and not readily apparent as such.

After the discussion of specific volcanoes, 16 pages are devoted to a review af the different theories that have been advanced to account for crater and caldera formations. Serious objections are found to all theories except explosion for small calderas and engulfment for large ones.

This caldera paper is an essential part of the library of every student of volcanoes. No single paper excels it in giving so comprehensive a view of the development of volcanic structures.

Hawaiian Volcano Observatory Report for April-June, 1941.

VOLCANOLOGY

April 1941

There was no visible activity at the Hawaiian Volcanoes during April. A glow was reported over the northeast slope of Mauna Loa the evening of April 1st. It is doubtful if it was of volcanic origin as the moon set at about the time and in the direction of the reported light. There were several earthquakes centering at Kilauea during the last 10 days of the month.

May 1941

Landslides were frequent at Halemaumau during the first half of the month. Pronounced southerly tilting that started on March 10, 1941 continued through April and May.

It appears that many of the Kilauea earthquakes occur at origins deeper than was common at times when molten lava was present as some of the feeble Kilauea shakes are reported as perceptible in Hilo.

June 1941

The 1940 cone in Mokuaweoweo continues to fume quite noticeably. Sulphate and sulphurous deposits are locally conspicuous on last year's lavas.

At Kilauea southwest tilt continued throughout the month. The short period irregularities in the tilt curve and the total accumulated tilt in April, May, and June were greater than common for the past several years. In fact the tilt charts for these months and March resemble those obtained prior to 1924 when there was molten lava in Halemaumau.

Some of the local data for April, May, and June are as follows:

Week Ended	Halemaumau Slides	Halemaumau Crack Openings (Millimeters)	Seismic Disturbances
April 6	1	2.0 closing	13
" 13	0	2.0 opening	9
" 20	3	0.5 "	37
" 27	2	4.0 closing	49
May 4	1	0.5 "	27
" 11	3	1.0 opening	13
" 18	0	0.5 closing	15
" 25	1	1.0 "	28
June 1	0	2.5 opening	14
" 8	2	0.5 "	13
" 15	0	0.0	4
" 22	0	2.5 opening	11
" 29	0	0.5 closing	10

R. H. F.

VOLCANIC ACTIVITY IN THE MARIANAS ISLANDS

An observer reports that on the night of March 28-29, 1941, while passing between the two northernmost islands of the Marianas, fire was observed shooting out of the top and lava flowing down from the volcano on Uracas Island. When first sighted the eruption of this volcano appeared as a bright clear light due to apparent refraction, but later, when closer, it appeared bright near the top and dull red farther down the mountain. It was visible about 40 miles at night. (Hydrographic Bulletin July 2, 1941)

April-June, 1941

SEISMOLOGICAL DATA By P. E. Schulz

Earthquakes

Date	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
April 6	10	3	0	0	0	4.00	1
" 13	9	0	0	0	0	2.25	0
" 20	30	5	0	1	1	15.00	1
" 27	38	10	1	0	0	15.50	0
May 4	21	6	0	0	0	8.25	0
" 11	10	2	1	0	0	4.50	1
" 18	13	2	0	0	0	4.25	2
" 25	19	9	0	0	0	9.25	0
June 1	13	1	0	0	0	3.75	0
" 8	8	5	0	0	0	4.50	1
" 15	2	2	0	0	0	1.50	0
" 22	10	1	0	0	0	3.00	0
" 29	5	2	3	0	0	5.25	1

* For local seismicity definition see Volcano Letter No. 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory of Hawaii National Park on the island of Hawaii. A new station was established May 22 on Haleokala, Maui, but no disturbances were recorded there during the quarter. Kilauea earthquakes were located by means of the main seismograph station located at the Observatory and the subsidiary stations on Uwekahuna Bluff and near the SE rim of Halemaumau. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began recording at the time indicated, and wherever possible a determination of depth of focus has been made.

The number preceding each earthquake date is the serial number of the quake for the current year.

30. April 3, 10:25 am, very feeble, Mauna Loa NE rift near Puu Ulaula.

31. April 6, 5:22 am, very feeble, Mauna Loa NE rift 15 miles from Hilo Bay, depth 20 miles, 19° 38.1' N, 155° 19.3' W.

32. April 6, 5:51 am, very feeble, Mauna Loa NE rift, 19 miles from Hilo Bay, depth 18 miles, 19° 35.5' N, 155° 20.3' W. Reported felt by a few persons in bed at "29 miles," 1.5 miles east of the Observatory.

33. April 20, 1:17 am, very feeble, of Kilauea origin, probably some location as No. 34.

34. April 20, 1:34 am, very feeble, 0.4 mile east of Cone Peak on the Kilauea SW rift, 2.3 miles deep, 19° 23.7' N, 155° 18.3' W.

35. April 20, 2:40 am, slight, location same as No. 34.

36. April 20, 3:33 am, very feeble, location some as No. 34.

37. April 20, 3:51 am, very feeble, Kilauea SW rift, 0.9 mile from Cone Peak at 3,729 foot B. M.

38. April 20, 4:47 am, very feeble, location probably same as No. 37.

39. April 20, 10:46 am, moderate, 0.3 mile sauth of Keanakakoi Crater, depth 1.0 mile, 19° 23.9' N, 155° 16.0' W. Generally felt in the Kilauea area, Kau, and Kano, and by some persons in Hilo.

40. April 22, 6:04 am, very feeble, origin undeterminable.

41. April 24, 7:09 pm, very feeble, central portion of Kilauea Crater.

42. April 25, 2:23 pm, very feeble, location same as No. 41.

43. April 25, 7:36 pm, very feeble, location same as No. 41.

44. April 26, 8:17 am, very feeble, east flank of Mauna Loa about 8.5 miles north of the Volcano Observatory.

45. April 26, 4:10 pm, feeble, Kilauea Crater, 0.9 mile NE of the center of Halemaumau, depth 0.9 mile, 19° 25.1' N, 155° 16.9' W.

46. April 26, 7:13 pm, very feeble, probably Mauna Loa NE rift midway between Hilo and Makuoweoweo. Reported felt by a few persons in Hilo.

47. April 27, 3:08 am, very feeble, SE rim of Kilauea Crater, 1.6 miles deep, 19° 24.4' N, 155° 16.1' W.

48. April 27, 4:47 am, very feeble, SE rim of Kilauea Crater, 0.9 mile deep, 19° 24.4' N, 155° 16.1' W.

49. April 27, 7:16 am, very feeble, center of Kilauea Crater, 1.0 mile deep, 19° 25.0' N, 155° 16.3' W.

50. April 27, 9:12 am, very feeble, probably north of Kilauea Iki.

51. April 28, 1:04 am, very feeble, origin undeterminable.

52. April 29, 7:08 am, very feeble, Kilauea Crater at the 3,646 B. M. just west of Halemaumau, depth 1.0 mile, 19° 24.7' N, 155° 16.8' W.

53. April 30, 10:20 am, very feeble, south rim of Halemaumau, depth 0.8 mile, 19° 24.2' N, 155° 17.2' W.

54. May 1, 9:03 am, very feeble, Kaoiki Pali 2.2 miles SW of the Halfway House on the Momalahoa Highway, depth normal, 19° 20.2' N, 155° 24.3' W.

55. May 1, 8:43 pm, very feeble, probably of Kilouea Crater origin depth fairly great.

56. May 2, 10:53 am, very feeble, adjacent to the Mauna Loa NE rift zone 1.0 mile west of Kiipu Cone, depth normal, 19° 33.3' N, 155° 20.0' W.

57. May 6, 1:46 am, very feeble, Mauna Loa NE rift, 2.5 miles from Mokuaweoweo Crater, depth 7.5 miles, 19° 31.6' N, 155° 31.5' W.

58. May 9, 4:34 am, feeble, east flank of Mauna Loa

half way between Mokuaweaweo and Kilauea Craters, depth about 28 miles, 19° 27.5′ N, 155° 27.6′ W.

59. May 9, 3:23 pm, very feeble, central Mokuaweoweo Crater, depth 15 miles, 19° 29.0′ N, 155° 36.3′ W.

60. May 12, 5:10 am, very feeble, of Kilauea origin, exact locality undeterminable.

61. May 13, 3:47 am, very feeble, about 50 miles from the Observatory, off the SE shore of Hawaii probably on the extension of the Puna rift.

62. May 20, 3:10 am, very feeble, NE rim area of Kilauea Crater.

63. May 21, 8:20 pm, very feeble, junction of the SW rift with the SW rim of Kilauea Crater, depth 1.0 mile, 19° 24.1′ N, 155° 17.7′ W.

64. May 22, 1:59 pm, very feeble, Uwekahuna Bluff of Kilauea Crater, depth 5.0 miles, 19° 25.2′ N, 155° 17.4′ W.

65. May 22, 2:49 pm, very feeble, Kilauea Crater 0.3 mile NE of Halemaumau, depth 2.7 miles, 19° 24.9′ N, 155° 16.8′ W.

66. May 23, 8:25 am, very feeble, of Halemaumau origin, depth shallow.

67. May 23, 9:45 pm, very feeble, 0.8 mile SW of Kilauea Crater, depth 0.8 mile, 19° 24.1′ N, 155° 18.3′ W. Felt by a few persons at "29 miles" and at Hilo.

68. May 24, 11:10 am, very feeble, probably in the north portion of Kilauea Crater.

69. May 24, 6:46 pm, very feeble, east flank of Mauna Loa in the Keawe Wai region.

70. May 25, 6:30 pm, very feeble, 1.4 miles ESE of the Observatory, depth 4.0 miles, 19° 25.8′ N, 155° 14.9′ W. Felt by a very few persons in Hilo.

71. May 26, 1:49 am, very feeble, south of Holemaumau, depth 0.7 mile deep, 19° 24.5′ N, 155° 17.3′ W.

72. June 3, 5:35 pm, very feeble, center of Holemaumau, depth 1.0 mile, 19° 24.5′ N, 155° 17.0′ W.

73. June 4, 7:36 am, very feeble, south of Holemaumau.

74. June 4, 3:18 pm, very feeble, probably near summit of Mauna Loa.

75. June 5, 4:40 pm, very feeble, of Kilauea origin, location undeterminable.

76. June 8, 6:39 pm, very feeble, Mauna Loa NE rift 3 miles SW of Hilo Bay, depth 13.0 miles, 19° 42.7′ N, 155° 07.5′ W. Felt by a few persons in Hilo.

77. June 12, 9:59 pm, very feeble, 10 miles NE of Cape Kunakaki, 17 miles deep, 19° 39.2′ N, 155° 42.5′ W.

78. June 14, 1:33 pm, very feeble, east flank of Mauna Loa probably half way between Mokuaweoweo and Kilauea Craters.

79. June 16, 8:34 pm, very feeble, probably Mauna Loa NE rift in the Puu Kulua area.

80. June 24, 11:22 am, very feeble, of Kilauea origin, exact location undeterminable.

81. June 25, 2:35 am, feeble, SE flank of Mauna Loa, 7.7 miles WNW of the Observatory, depth 2.1 miles, 19° 28.9′ N, 155° 21.6′ W.

82. June 25, 10:54 pm, very feeble, Cone Peak on the Kilauea SW rift, depth 1.3 miles, 19° 23.7′ N, 155° 18.6′ W.

83. June 29, 6:48 am, feeble, Mauna Loa NE rift zone 4.5 miles NE of Puu Ulaula, depth 8.0 miles, 19° 34.5′ N, 155° 26.1′ W. Felt by a few persons at "29 miles."

84. June 29, 8:25 am, feeble, Mauna Loa NE rift 2.0 miles SW of Puu Ulaula, depth 7 miles, 19° 31.7′ N, 155° 26.3′ W.

Teleseisms

April 1, 00h 27m 43s distance undetermined
April 14, 08h 47m 30s distance approximately 3,600 miles
May 7, 11h 59m 05s distance undetermined
May 13, 5h 41m 51s distance 1,750 miles
May 16, 4h 03m 38s distance 5,955 miles
June 8, 8h 00m ?s low amplitude, distance doubtful

Microseismic Motion

	April	May	June
Light	None	2, 14, 19, 24, 26, 27, 29-31	1-3, 7-9, 11, 14-18, 21-26, 29, 30
Moderate	2, 12, 13, 15, 19, 20, 22-25, 28-30	11-13, 15-18 20-23, 25, 28	4-6, 10, 12, 13, 19, 20, 27, 28
Strong	1, 3-11, 14, 16-18, 21, 26, 27	1, 3-10	None

Tilting of the Ground Surface

Several changes have been made in this section of the Seismological Report, which appears at the bottom of this page. It is believed that the changes are justified in that (1) the original data are less manipulated, and (2) the same method is now applied to all 3 tilt stations.

At the Observatory the total accumulated tilt for year ending

April 30: 10.65"N and 10.65"E
May 31: 2.54"N and 10.41"E
June 30: 4.96"S and 7.87"E

MISCELLANEOUS DATA By P. E. Schulz

Crater Angles, Horizontal	Halemaumau Angle	Kilauea Crater Angle
March 4 to April 17	+0.1"	+2.0"
April 17 to May 6	−1.0"	−1.9"
May 6 to June 27	+2.2"	+3.0"
Net Change March 4 to June 27	+1.3"	+3.1"

Kilauea Crack Measurements

During the quarter 3 Halemoumau rim cracks opened 1.0 millimeter each, and 2 opened 1.5 millimeters each; 2 closed 1.0 millimeter each and one closed 1.5 millimeters.

No appreciable changes occurred in the Devil's Throat cracks. Of the remaining Chain of Craters road cracks only #108 parallel to the rim of Alai Crater changed; it opened 1.0 millimeter. Since January 1, 1940, crack #108 has opened 12.5 millimeters.

Week Ending	NE Rim Kilauea Crater			Halemaumau West Station			Halemaumau SE Station		
	Total Amount	Direction	Tilt to (+) or from (−) Halemaumau	Total Amount	Direction	Tilt to (+) or from (−) Halemaumau	Total Amount	Direction	Tilt to (+) or from (−) Halemoumau
April 6	1.61"	S67°W	+1.50"	2.68"	S52°E	+2.00"	2.27"	S13°E	−2.11"
" 13	0.46"	N37°E	−0.44"	1.64"	N7°W	−0.09"	3.73"	S86°E	−2.40"
" 20	2.09"	S21°W	+1.84"	1.49"	S12°W	−0.39"	5.18"	N78°W	+3.92"
" 27	2.61"	S62°E	−0.97"	3.58"	N51°E	+2.92"	0.00"	—	0.00"
May 4	0.52"	N76°W	+0.31"	0.75"	S63°E	+0.67"	2.43"	N79°E	−1.00"
" 11	0.99"	S59°E	−0.33"	6.56"	S17°W	−2.50"	4.54"	N22°W	+4.41"
" 18	2.23"	S12°W	+1.77"	4.62"	N29°E	+2.65"	3.40"	S4°E	−2.88"
" 25	6.22"	S01°E	+3.92"	1.49"	N38°E	+1.01"	3.73"	S9°W	−2.59"
June 1	2.50"	N29°W	−0.52"	1.49"	S45°E	+1.01"	4.54"	N10°W	+4.02"
" 8	3.30"	S04°W	+2.31"	1.49"	N45°W	−1.01"	8.10"	S13°E	−7.39"
" 15	0.65"	W	+0.48"	1.79"	S18°W	−0.72"	8.10"	N13°W	+7.39"
" 22	0.64"	S40°E	+0.12"	1.79"	N72°E	+1.70"	3.40"	S59°E	−3.05"
" 29	0.57"	S65°W	+0.36"	0.75"	N43°W	−0.48"	3.40"	N59°W	+3.05"
	Net tilt toward (+) 10.35"			Net tilt toward (+) 6.77"			Net tilt toward (+) 1.37"		

THE VOLCANO LETTER

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TILT RECORDINGS AT THE HAWAIIAN VOLCANO OBSERVATORY AND THEIR CONVERSION TO SECONDS OF ARC

By P. E. SCHULZ

The measuring ond plotting of ground tilt is on important factor in volcanologic studies at the Hawaiian Volcano Observatory. The status of this work is summarized in "Tilt Changes ot Kilauea" by H. H. Waesche, Volcono Letter No. 467, January-March 1940.

The purpose of the present article is to show the relationship of the undamped period of the Bosch-Omori seismograph to the conversion factor for stylus displacement to seconds of ground tilt, and the order of mognitude of error in tilt determination which results from the tilting of the instrument itself unless proper corrections are mode.

The curve in Fig. 1 was computed for the Bosch-Omori seismograph from the formula developed in "Tilt Records for Thirteen Years at the Hawaiian Volcono Observatory" by T. A. Jaggor and R. H. Finch, Bulletin of the Seismological Society of Americo, Vol. 19, No. 1, March 1929 which is:

$$\phi = \frac{4\pi^2 L}{g\, T_o^2} \times \frac{D\, s}{A\, l} = \frac{4\pi^2 \times 2.5}{978.236\, T_o^2} \times \frac{1.0 \times .86}{102 \times 24.5} \times 206265$$

where ϕ is the tilt in seconds, L is the reduced length of the pendulum, D is the displacement of the stylus, s and l are the short ond long sides of the pivoted stylus (magnifying arm) respectively, and A is the length of the seismograph boom. The right hand member of the equation is multiplied by 206265 so that the result will be in seconds.

The undamped period of 7.70 seconds of the Bosch-Omori seismograph at Kilouea seems to approach the ideal, for at this value the instrument is a sensitive 2-component tiltmeter whose styli are displaced one centimeter for each 1.21 seconds of tilt, and yet the instrument responds reodily to microseisms, tremors, and local earthquakes. It follows that the registry of teleseisms is not all that could be desired, but the registering of teleseisms is a relatively unimportant part of the work of the Observatory.

Changes in the height of the magnifying lever above the recording drum, which occur from occasional instrumental maintenance, result in slight changes in magnifying lever-stylus length l. In the equation given above for the Bosch-Omori seismograph, however, changes of as much as 5 millimeters in this value do not appreciably alter the conversion factor ϕ.

Tilting of the ground itself, however, may be of sufficient magnitude to change the angle i (between the plumb line and the line joining the 2 suspension points) of the pendulum enough to cause appreciable changes in the undamped period of the instrument, and hence in the conversion factor. This condition exists at Kilauea. The 2 largest tilt-change components for short periods are those of 53 seconds to the narth May 1918 to January 1919, and 81 seconds to the south December 1923 to July 1924. Had the north-south pendulum period been 7.70 seconds at the outset of each, it would have increased or decreased 0.06 and 0.09 seconds respectively depending on whether the pendulum was hung on the south side or the north side of the support. (The Bosch-Omori instrument at the Observatory has its masses suspended on the south and west sides of the supports). From Fig. 1 the conversion factor changes corresponding to 0.06 and 0.09 are 0.03 and 0.04. The net north-south tilting of the ground between the extremes of 1920 and 1939 was 110.0 seconds and the net east-west tilting between the extremes of 1913 and 1918 was 46.4 seconds. The 110.0-second tilt on a 7.70 seconds seismograph period basis causes a change in period of 0.12 seconds with a factor change, from Fig. 1, of 0.06. The 46.4-second tilt results in 0.04-second period increase or decrease in the east-west pendulum with a 0.02 factor change. The approximate averoge annuol range of ground tilt on the northeast rim of Kilauea Crater is 15 seconds north-south and 5 seconds east-west. Even the largest of these figures results in only a 0.02 second period change which does not oppreciobly affect the conversion factor.

The north-south component of the Bosch-Omori seismograph was reoriented July 1, 1941 by rotating it clockwise 7½ degrees into a true east-west position. Since the true tilt varies with cosine of the orientation angle it follows that measured north-south tilt volues were 99 percent of the true north-south tilt values before the reorientation.

The writer is indebted to Mr. R. H. Finch for suggesting the consideration of this subject.

Hawaiian Volcano Observatory Report for July-September, 1941

VOLCANOLOGY

July 1941

The 1940 cone in Mokuaweoweo was observed to be fuming strongly during the latter part of the month. The solfataric deposits on the 1940 lava showed a noticeable increase.

Two earthquakes that occurred on July 8 had their origin at the junction of Waldron and Byron ledges. This would indicate a slight sinking at the northern end of Kilauea Crater. There is evidence in several places that the crater floor has sunk slightly with reference to the crater walls since 1924.

August 1941.

During August, as for the three preceding months, a majority of the earthquakes recorded on the seismographs at the Observatory originated on the northeast slope of Mauna Loa. The rim cracks around Halemaumau showed a distinct opening during the last week of the month. The normal northeast tilt that did not set in until early in July, about two months later than common, continued through most of August.

September 1941

During the first two weeks in September earthquakes of Kilauea origin predominated. An earthquake on September 25 with origin on the east flank of Mauna Loa, about 15 miles from the Observatory, did considerable damage at Kapapala and Pahala. It was strongly felt all over the island of Hawaii and as far northwest as Oahu. The main shaking merged into a continuous tremor that continued for 45 minutes, quite similar in this respect to the shake of September 14, 1919, with about the same indicated origin.—R.H.F.

July-September, 1941
SEISMOLOGICAL DATA by P. E. Schulz

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
July 6	6	1	0	0	0	2.00	0
" 13	5	4	0	2	0	7.25	0
" 20	8	4	1	0	0	5.00	0
" 27	11	2	0	0	0	3.75	1
Aug. 3	11	12	1	0	0	9.75	2
" 10	9	5	1	0	0	5.75	0
" 17	7	4	0	0	0	3.75	0
" 24	9	2	0	0	0	2.75	0
" 31	16	4	0	0	0	6.00	0
Sept. 7	9	10	0	0	0	7.25	1
" 14	15	6	0	0	0	7.25	1
" 21	10	6	0	0	0	5.50	0
" 28	75	5	3	0	1	28.25	0

*For local seismicity definition see Volcano Letter No. 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory of Hawaii National Park on the islands of Hawaii and Maui. Kilauea earthquakes were located by means of the main seismograph station located at the Observatory and the subsidiary stations on Uwekahuna Bluff and near the SE rim of Halemaumau. The more distant shocks were located with the aid of seismograms from Hilo, Kealakekua, and Haleakala (Maui). The disturbances began recording at the Hawaiian Standard time indicated, and wherever possible, a determination of depth of focus has been made and is given relative to a horizontal plane of 4000 feet elevation passing approximately through the Observatory.

Building construction at the Observatory causing occasional disruptions such as stoppage of the master clock, of the automatic relay circuit, of the seismographs, and of the reception of the radio time signal has rendered the earthquake times given below inaccurate after August 5, 1941.

The number preceding each earthquake date is the serial number of the quake for the current year.

85. July 2, 01:11, very feeble, Mauna Loa NE rift, 1 mile NE of Puu Ulaula, depth 4.8 miles.

86. July 8, 10:14, slight, felt by many persons at Kilauea, NE rim of Kilauea Crater at the junction of Waldron's and Byron's Ledges, depth 0.7 mile.

87. July 8, 20:02, slight, felt generally in the Kilauea area, stronger than No. 86. Location and depth the same.

88. July 9, 15:25, very feeble, NE rim of Kilauea Crater near the Observatory.

89. July 9, 17:53, very feeble, probably on the Mauna Loa NE rift 19 or 20 miles from Hilo.

90. July 11, 21:30, very feeble, probably Mauna Loa NE rift near Hilo, of deep origin.

91. July 12, 17:46, very feeble, SW rim of Kilauea Crater 0.5 mile from the center of Halemaumau, depth 1.0 mile.

92. July 14, 02:40, very feeble, Hilina Pali fault zone about 4 miles south of Kamakaia Hills.

93. July 16, 04:25, very feeble, generally felt in Kona, just north of Akahipuu an the west Hualaloi slope, depth 18.5 miles.

94. July 17, 05:16, very feeble, central portion of Kilauea, of shallow origin.

95. July 18, 05:21, very feeble, Mauna Loa 1.0 mile NE of Kiipu Cone, depth 6 miles.

96. July 19, 07:44, feeble, Mauna Loa NE rift, 20 miles from Hilo, felt by few persons in Hilo, depth 8 miles.

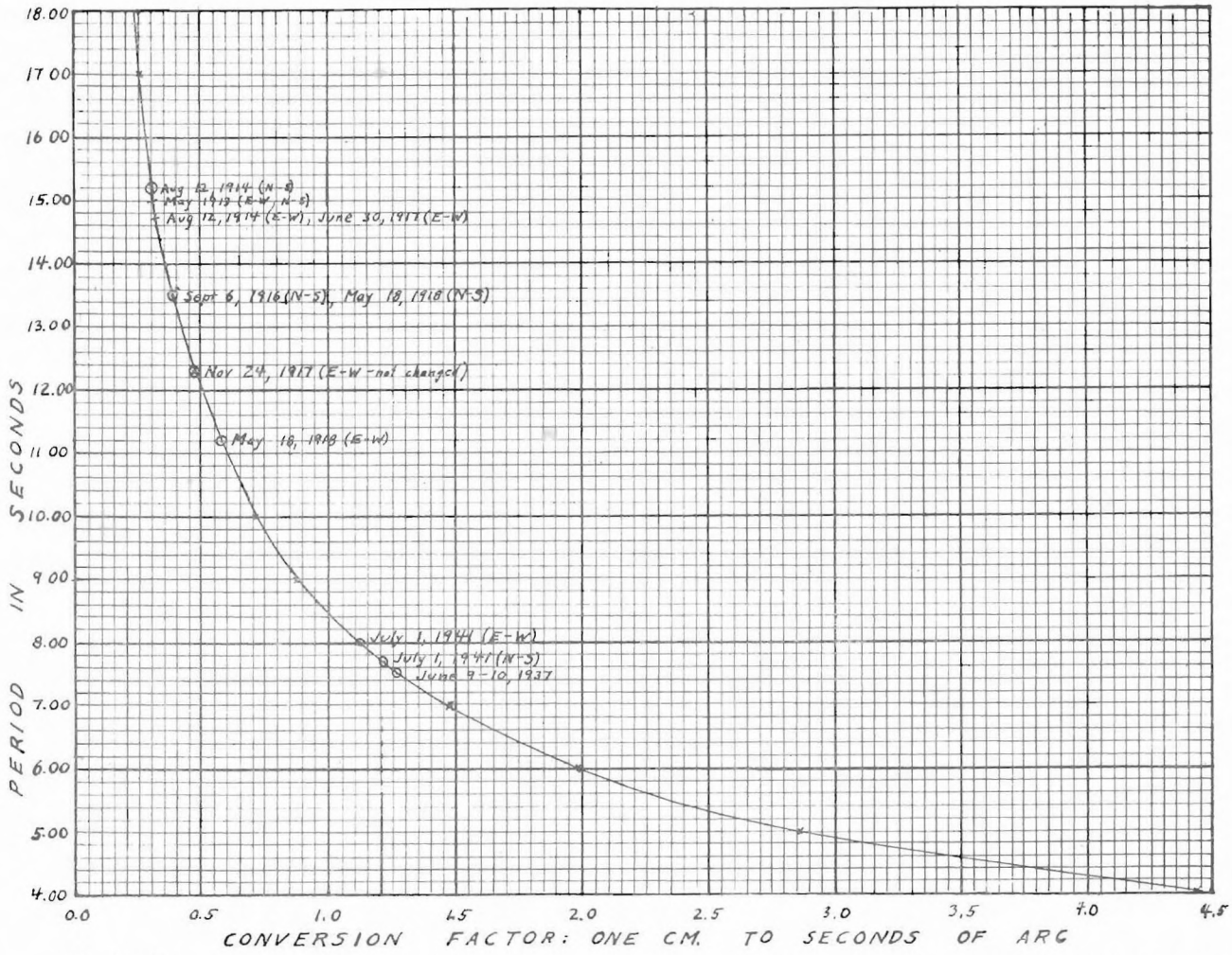

Fig. 1. Curve computed for the Bosch-Omori Seismograph pen arm displacement resulting from tilting of the ground.

97. July 21, 13:20, very feeble, Mauna Loa NE rift, 4 or 5 miles of Puu Ulaula, depth about 8 miles.

98. July 25, 13:31, very feeble, Kaoiki fault, 3.3 miles west of 3913 BM, Kilauea SW rim, depth 2.7 miles.

99. July 28, 03:07, very feeble, 1.1 miles ENE of Puu Ohale, depth 2 miles.

100. July 28, 07:31, very feeble, summit of Mauna Loa, 1.2 miles west of Mokuaweoweo, depth about 15 miles.

101. July 28, 08:32, very feeble, Mauna Loa, probably in the summit area, depth moderate.

102. July 30, 17:14, very feeble, Kilauea Crater area, of shallow origin.

103. August 1, 05:50, very feeble, Hilina Pali fault system, 3.0 miles NW of Apua Point, felt by a few persons in Hilo, depth 9 miles.

104. Aug. 2, 07:56, very feeble, Kilauea Crater, 0.2 mile west of Byron's Ledge, depth 1.0 mile.

105. Aug. 2, 10:30, very feeble, east flank of Mauna Loa, 5.3 miles NW of Uwekahuna, felt by a few persons at "29 miles," 1 mile east of the Observatory, depth 4.3 miles.

106. Aug 2. 13:21, very feeble, of Halemaumau origin, shallow depth.

107. Aug. 2, 20:09, very feeble, SW rim of Kilouea Croter, shallow depth.

108. Aug. 3, 11:16, very feeble, Puna rift, 0.1 mile NW of Devil's Throat, depth 1.5 miles.

109. Aug. 3, 12:43, very feeble, Puna rift, 0.1 mile east of Kokoolou Crater, depth 1.4 miles.

110. Aug. 3, 21:00, very feeble, probably along the Puna Rift near Kilauea Crater.

111. Aug. 3, 23:29, feeble, Puna rift, 0.2 mile north of Kokoolau Crater, depth 1.5 miles.

112. Aug. 4, 01:28, feeble, Puna rift, Kokoolau Croter, of shallow depth.

113. Aug. 4, 01:31, very feeble, Kilauea Crater probably near Byron's Ledge, shallow depth.

114. Aug. 5, 11:14, very feeble, probably Mauna Loo NE rift 4 or 5 miles NE of Puu Ulaula.

115. Aug 6, 17:15, very feeble, of Kilauea origin, possibly near the NW rim of the Crater.

116. Aug. 8, 22:28, very feeble, probably Mauna Loo NE rift area about 5 miles NE of Puu Ulaula.

117. Aug. 10, 09:32, very feeble, summit of Mauna Loa, 1.2 miles NE of Mokuaweoweo Crater, depth 12 miles.

118. Aug. 12, 22:40, very feeble, Mauna Loa NE rift, 8.0 miles NE of Puu Ulaula, depth 6 miles.

119. Aug. 14, 03:09, very feeble, Kilauea east flank 4.0 miles WSW of Pahoa, depth 16 miles.

120. Aug. 15, 17:?, very feeble, Mauna Loa NE rift probably about 6 miles NE of Puu Ulaula.

121. Aug. 17, 00:02, very feeble, Mauna Loa NE rift, Pukauahi Crater, depth 6 miles.

122. Aug. 22, 09:36, very feeble, Kilauea Crater, originated in the Halemaumau area at shallow depth.

123. Aug. 22, 11:04, very feeble, same as No. 122.

124. Aug. 27, 16:10, very feeble, probably in the vicinity of Hilea.

125. Aug. 28, 04:37, very feeble, Hilo 2.3 miles NW of the center, depth about 20 miles, felt by a few persons.

126. Aug. 30, 04:17, very feeble, Kilauea Crater, probably east central portion, of shallow depth.

127. Aug. 30, 17:56, very feeble, Kealakekua Bay, felt by a few persons in Kona, depth probably about 4 miles.

128. Sept. 1, 03:59, very feeble, Kilauea Crater central portion, felt by a few persons at Kilauea and "29 miles," of shallow depth.

129. Sept. 2, 01:10, very feeble, SE rim of Kilauea Crater, depth 0.8 mile.

130. Sept. 2, 10:08, very feeble, central Kilauea Crater, of shallow origin.

131. Sept. 2, 23:47, very feeble, probably 21 miles N of Hilo, depth 10 or 12 miles.

132. Sept. 5, 14:59, very feeble, 2.6 miles W of Uwekahuna near Kaoiki Pali, depth probably 10 miles.

133. Sept. 5, 21:26, very feeble, probably Puna rift near Heiheiahulu Crater.

134. Sept. 6, 18:34, very feeble, SE rim of Kilauea Crater 0.3 mile from Byron's Ledge junction, depth 3.5 miles.

135. Sept. 7, 03:20, very feeble, Kilauea Crater 0.2 mile SW of Halemaumau, depth 1.0 mile.

136. Sept. 7, 14:41, very feeble, pali NW of Kaoiki fault 3.9 miles west of Uwekahuna, depth 3.4 miles.

137. Sept. 7, 19:26, very feeble, Kilauea Crater, 0.2 mile south of 3646 BM, depth 0.8 mile.

138 Sept. 8, 09:20, very feeble, probably east central portion of Kilauea Crater.

139. Sept. 8, 16:25, very feeble, east rim of Keanakoi Crater, depth 2.7 miles.

140. Sept. 8, 17:29, very feeble, NE portion of Kilauea Croter.

141. Sept. 9, 08:35, very feeble, 0.2 mile SE of Kilouea Croter near Keanokakoi, depth 1.5 miles.

142. Sept. 11, 15:17, very feeble, Kau Desert, 0.4 mile north of Cone Peak, depth 6.8 miles.

143. Sept. 14, 11:57, very feeble, probably NE central portion of Kilauea Crater.

144. Sept. 15, 01:48, very feeble, 2.0 miles east of the Observatory.

145. Sept. 16, 01:51, very feeble, 2.0 miles west of the south end of Pauahi Crater, depth 2 miles.

146. Sept. 18, 12:24, very feeble, probably of Halemaumau origin.

147. Sept. 19, 00.04, very feeble, SW portion of Mokuoweoweo Croter, depth 19 miles.

148. Sept. 19, 19:13, very feeble, NE portion Kilauea Crater.

149. Sept. 21, 16:42, very feeble, 0.3 mile SW of the center of Halemaumou, depth 1.7 miles.

150. Sept. 25, 02:07, very feeble, center of Kilauea Crater, depth 1.5 miles.

151. Sept. 25, 07:18, moderate to strong, SE flank of Mauna Loa 4.0 miles north of Kapapala Ranch House, depth 7.0 miles. Felt sharply over the whole island of Hawaii and by some persons in Honolulu. Dismantled all seismographs on the island of Hawaii (low magnification instrument not in operation) and at Haleakala on Maui. Several thousand dollars worth of damage done at Pahala where safes were moved over 1 inch northward, plaster cracked, pipes were sprung, roadfills cracked and some shoulders failed, furniture overthrown and dishes were broken in homes, pharmaceuticals at the Pahala hospital, chemicals in the Pahala Sugar Laboratories and package goods in stores were thrown from shelves. Some persons were injured in flight from houses. At Kapapala Ranch two windows and many dishes were broken, several stone walls were partially thrown down. No disturbance of the sea was reported observed at Punaluu. At Kealakekua a few books were thrown from shelves but no damage was reported. Boulders were shaken loose from steep slopes at the head of Wood Valley and on Hilina Pali. Numerous slides from Halemaumau's walls caused great dust clouds, but no damage was reported in the Kilauea area. Hilo also was strongly shaken but with only slight effect; an old earthquake crack in one building reopened. Residents in the Pahala and Kapapala area were agreed that this earthquake was stronger than any since 1929 and many claimed it was the strongest in 30 to 50 years.

152. Sept. 25, 07:30, feeble, approximately same location as No. 151, but probably deeper, sharply felt at Pahala and Kapapala.

153. Sept. 25, 07:43, feeble, probably near Ainapo, depth perhaps 20 miles, sharply felt at Pahala and Kapapala.

154. Sept. 25, 08:28, very feeble, 2.0 miles NE of Kapapala Ranch house, depth 7.0 miles, felt generally at Pahala and Kapapala.

155. Sept. 25, 09:51, very feeble, Kilauea Crater, probably of shallow Halemaumau origin.

156. Sept. 25, 10:54, very feeble, same as No. 155.

157. Sept. 25, 13:25, very feeble, SE flank of Mauna Loa, 4.0 miles NNW of Kapapala Ranch house, depth 7.0 miles, felt by many persons at Kapapala and Pahala.

158. Sept. 28, 14:11, feeble, Mauna Loa NE rift near Puu Ulaula, depth of the order of 20 miles; felt by some persons in Hilo and at "29 miles."

159. Sept. 30, 11:32, very feeble, Kilauea Kau rift 0.6 mile SE of Cone Peak, depth 2.3 miles.

160. Sept. 30, 11:32, feeble, Kilauea SE rim just SW of Keanakakoi Crater, depth 3.7 miles.

161. Sept. 30, 12:28, slight, Kilauea Kau rift, 1.2 miles SW of Cone Peak, depth 2.0 miles.

Teleseisms: Hawaii Standard time of first wave arrival used; J. S. A. data gives time of origin in Greenwich Time.

July 26, 09: 41 (?), unidentified phase; J. S. A. provisional data 20: 11: 21, 19°.1 N, 142°.2 E.

July 29, 15: 29, weak, undetermined, short period; J. S. A. data 01: 51: 28, 60°.7 N, 149°.5 W, shallow.

Aug. 2, 01: 21, distance 3775 miles; J. S. A. data 11: 41: 25, 30°.3 S, 177°.8 W possibly fairly deep.

Sept. 4, 00: 01, undetermined, recorded at Pasadena.

Sept. 13, 08: 03, undetermined.

Microseismic Motion

	July	August	September
Light	1—31	1—31	1-4, 7-30
Moderate	None	None	5, 6
Strong	None	None	None

Crater Angles, Horizontal: Measured from the 3974-foot bench mark on the NE rim of Kilauea Crater. Between June 27 and July 22, the Halemaumau angle closed 0.5" while the Kilauea Crater angle opened 3.5". Additional measurements were prevented by construction and weather conditions.

Kilauea Crater Levels

A level circuit was run from the SE crater rim to the Spit BM. From thence it was run via the Pit Seismograph counter clockwise around Halemaumau in a complete circuit. The results show an appreciable decrease in elevation of points adjacent to Halemaumau with respect to the Spit BM. Between January 16 and August 14-25, the level changes were:

South side crack #43	— 0.060 meter	(.1969 feet)
NW Pit BM	— 0.035 meter	(.1148 feet)
West Tilt Station	— 0.032 meter	(.1050 feet)
Pit Side Crack #40	— 0.029 meter	(.0952 feet)
Pit Seismograph BM	— 0.031 meter	(.1017 feet)

Crack Changes

On Friday of each week, 28 stations on rim cracks around Halemaumau were measured. During the quarter, there was a general increase in both the number of and amount of crack changes, especially in the case of openings. The total of 41 measured crack openings for the quarter amounted to 34.5 millimeters. Of these the least weekly opening was measured on July 25 and August 1, when in each instance only one crack opened 0.5 millimeter. Largest crack openings were recorded August 29, when 7 cracks opened 4.0 millimeters and September 26, when 7 cracks opened 13.5 millimeters. The largest opening unquestionably resulted from the earthquake of September 25. The total of 38 measured crack closings during the quarter amounted to 21.5 millimeters. July 4 revealed no closing; greatest closing was recorded September 26, when 8 cracks closed 6.5 millimeters.

Monthly measurements of 9 Chain of Craters cracks also showed progressive openings: July 25, none opened, and 3 closed 1.5 millimeters, on August 29, 3 opened 4.5 millimeters, and none closed, and on September 26, 6 opened 5.5 millimeters, and one closed 2.0 millimeters.

The Aloi rim crack showed a uniform rate of opening during the entire quarter save the last week in September when an opening of 7.0 millimeters was recorded due no doubt to the earthquake of September 25. The total opening of this one crack for the quarter was 15.5 millimeters.

The 5 rim cracks around Devil's Throat showed no appreciable change.

Tilt

The following tables give a summary of the tilting of the ground as measured at 3 stations on the summit of Kilauea Volcano. The ** sign indicates approximation only because of loss of tilt records from September 14 to 28 resulting from reconstruction in the seismograph cellar.

Week Ending	Tilt NE Rim Kilauea Crater			Tilt Halemaumau West Station			Tilt Halemaumau SE Station		
	Total Amount	Direction	Tilt to (+) or from (—) Halemaumau	Total Amount	Direction	Tilt to (+) or from (—) Halemaumau	Total Amount	Direction	Tilt to (+) or from (—) Halemaumau
July 6	1.67"	S11°W	+1.32"	3.10"	N29°E	+1.79"	1.61"	S60°E	—1.46"
" 13	1.28"	N48°W	+0.16"	1.49"	S45°W	—1.19"	3.56"	N39°W	+3.56"
" 20	1.21"	N12°W	—0.59"	1.49"	N45°E	+1.19"	4.99"	S86°E	—3.24"
" 27	2.47"	N39°W	—0.08"	0.00"	—	0.00"	23.98"	S15°E	—22.49"
Aug. 3	2.42"	N3°W	—1.46"	3.93"	S38°E	+2.18"	19.12"	S1?°E	—17.30"
" 10	6.57"	S9°E	+3.47"	1.97"	N35°W	—0.98"	9.56"	N10°W	+8.59"
" 17	1.78"	S86°E	—1.28"	0.00"	—	0.00"	5.38"	N43°W	+5.38"
" 24	1.21"	N38°W	—0.04"	0.00"	—	0.00"	1.65"	N18°W	+1.59"
" 31	2.53"	N32°W	—0.41"	0.00"	—	0.00"	6.93"	N15°E	+4.47"
Sept. 7	2.93"	S55°W	+2.93"	3.22"	N26°E	+1.70"	3.11"	N9°W	+2.85"
" 14	1.91"	N86°E	—1.52"	1.37"	S44°E	+0.86"	1.91"	S64°E	—1.75"
" 21	Tilt undeterminable			1.58"	S49°W	—1.28"	0.00"	—	0.00"
" 28	Tilt undeterminable			8.46"	N88°E	+8.46"	25.69"	N35°W	+25.69"
Quarter Ending Sept. 28	Net tilt toward (+)12.03"**			Net tilt toward (+)12.73"			Net tilt toward (+)5.89"		

NE Rim Kilauea Crater

Year Ending	Total Amount	Direction	Tillt to (+) or from (—) Halemaumau	Net N-S Tilt	Net E-W Tilt
July 31	8.75"	S46°E	—2.11"	6.17"S	6.29"E
Aug. 30	11.95"	S16°E	+5.07"	11.50"S	3.27"E
Sept. 30	12.62"**	S 3°W**	+8.76"**	12.58"S**	0.73"W**

THE VOLCANO LETTER

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Hawaii National Park
Edward G. Wingate, Superintendent
R. H. Finch, Volcanologist

University of Hawaii
T. A. Jaggar, Geophysicist

LAVA FLOWS IN EASTERN PUNA

By GORDON A. MACDONALD
Associate Geologist, U. S. Geological Survey*

Introduction. Only once since the beginning of written records in Hawaii have lava flows inundated part of eastern Puna. That once was in 1840. But there is ample evidence that in geologically recent times Puna has often been the site of eruption of cinder cones and extensive lava flows. More than sixty cinder and spatter cones dot the east rift zone of Kilauea volcano from the end of the Chain of Craters Road to Cape Kumukahi. Some are 150 to 200 feet high and half a mile or more in diameter, and others are mere hillocks. It is probable that all of the surface lavas throughout this region should be considered geologically Recent, but many of them are of such late date that it is surprising not to find more mention of them in native tradition. Few references to prehistoric lava flows have been preserved by the Hawaiian chroniclers however, perhaps because eruptions were so commonplace.

Much of the northeastern slope of Kilauea between the towns of Olaa and Pahoa is covered by flows of pahoehoe basalt that cannot be more than a few hundred years old. Not only are they nearly devoid of any soil or ash cover, but the vegetation which covers them is often scant and is of the type composed largely of small ahia trees and abundant staghorn fern which characterizes the younger lava flows, such as those of 1793 (?) and 1840. Through these younger lavas protrude **kipukas**, or "islands" of older rock, covered by several inches of ashy soil and the tree-fern jungle which typifies the more mature forests of Puna. Although these late lavas must certainly have been erupted within the time of residence of the present Hawaiian people, who are believed to have arrived in the islands about 1100 A.D.,[1] no mention of them is found in native tradition.

Traditional prehistoric eruptions. A few eruptions recorded by tradition before the arrival of the missionaries in 1820 may be mentioned. The dates are, of course, uncertain. The earliest is an eruption near Kapoho, probably between 1340 and 1380 A.D.[2] This eruption is incorporated in a legend which relates how Pele, goddess of volcanoes, attended in disguise a great **holua**, or sliding contest, held near Kapoho by Kahawali, the chief of the neighborhood. Challenging Kahawali to a race, Pele was badly beaten. She then asked the chief to lend her his sledge so that she might try again. When he refused, the angry goddess stamped upon the earth, and there burst forth showers of heated rocks. Realizing too late the identity of his competitor, the chief fled panic-stricken to Puu Kukii and then northward to the coast, pursued all the way by Pele's magmatic missiles. A crack trending N 60° E, which still exists between Kapoho and Koae, is said to have opened up before him, but he crossed it by laying down his spear for a bridge. Not until he had paddled far out to sea did he escape.

Translating this story into terms of the modern volcanologist, a flank eruption of Kilauea appears to have commenced with the opening of a fissure and the ejection of cinders at Kaholua o Kahawali (Kahawali's holua-slide). As the fissure opened farther and farther down the flank of the mountain the eruption progressively shifted farther seaward, building the line of small cinder and spatter cones which terminates at Kapoho.

Another eruption is said to have occurred near Kaimu in the reign of Alapai, probably between 1730 and 1754.[3] This eruption probably produced the fresh-appearing aa flow crossed by the Pahoa-Kalapana road a mile north of Kaimu. At this altitude the lava is covered only by lichens and moss, and appears as fresh as the 1922 lava in Napau Crater. But farther mountainward, in regions of greater rainfall, it supports thick vegetation, although not much more than the 1793 (?) and 1840 lavas.

Eruption of 1793 (?). When William Ellis, in 1823, questioned the natives about early eruptions of Kilauea, part of the meager information he elicited was mention of an eruption thirty years or so before.[4] The eruption was said to have produced voluminous lava flows contiguous to the cones of Honuaula, Puulena, and Kaliu, along the east rift zone of Kilauea, 3½ to 7 miles southwest of Kapoho. The boundaries of this lava flow as shown in the accompanying figure were mostly mapped by the topographers of the U. S. Geological Survey in 1922 (Kalapana quadrangle), but it was labeled "Lava flow of 1840." However, the distribution of the lava fits so well the traditional description of the 1793 (?) flow that there can be little doubt that it originated at that time. The lava differs in composition from the adjacent flow which reached Nanawale Bay in 1840, and moreover the map prepared by Commodore Wilkes only a few months after the 1840 eruption does not show the 1840 lava approaching within a mile of the line of

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[1] Buck, P. H., **Vikings of the Sunrise**, p. 252, New York, 1938.

[2] Ellis, William, **A Narrative of a Tour Through Hawaii, or Owhyhee**, pp. 219-223, Honolulu, 1917.
Hitchcock, C. H., **Hawaii and Its Volcanoes**, pp. 164-165, Honolulu, 1911.

[3] Hitchcock, **op. cit.**, p. 164.

[4] Ellis, **op. cit.**, pp. 214, 218.

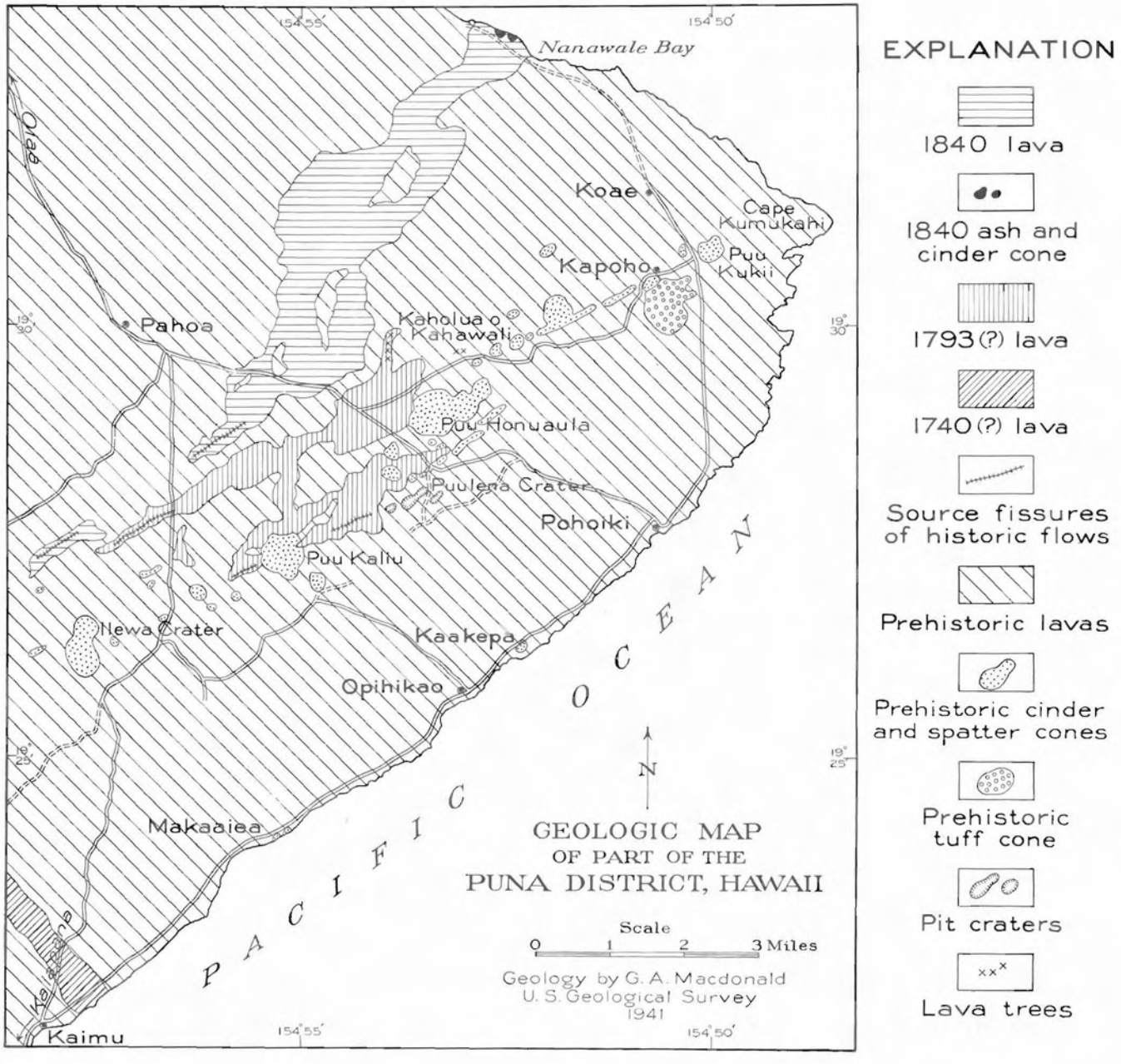
cinder cones.[5] The 1793 (?) lava issued from fissure vents and is largely pahoehoe. Lava trees are well preserved along the narrow northern tongue of the flow north of the Pahoa-Kapoho road and northwest of Puu Honuaula.

Eruption of 1840. The only large eruption which has occurred in eastern Puna since the advent of white men in Hawaii is that of 1840. The eruption was not witnessed by white men, but the region was traversed shortly afterward by Father Coan, who for 40 years was the faithful chronicler of Hawaiian volcanoes, and by Commodore Wilkes, Dr. Pickering, James D. Dana, and other members of the United States Exploring Expeditian. The outbreak commenced with the appearance of lavas in Alae Crater, a pit crater near the Chain of Craters Road, on May 30.[6] The lava level rose about 300 feet in the pit crater but fell again when new eruptions appeared on the flanks of the lava cone Kane Nui o Hamo, and north and west of Napau Crater. The spatter left at the "high water mark" in Alae Crater was examined soon afterward by Dr. Pickering. Cracking continued along the east rift zone toward Kapoho, fissures a few inches to 10 or 12 feet wide being opened, but no lava reached the surface. Finally, on June 1, the principal flow commenced near the present Pahoa-Kalapana road. Three days later it reached the sea at Nanawale Bay, and it continued to flow into the sea for three weeks, building out the shore line about a quarter of a mile.

Where the lava encountered sea water, violent steam explasions resulted, and the liquid lava was hurled into the air as by a giant atomizer, to be drifted inland by the wind or heaped into small hills of glassy sand on the fresh lava at the edge of the water. Three of these hills were built, ranging in height from 150 to 250 feet, but because of their unconsolidated nature and their exposure to the full impact of the ocean waves and the nearly constant northeast trade winds, they were rapidly eroded away. There are now only two of them left, and the highest is only 78 feet high.

Coan[7] tells of a man who went to watch the 1840 flow and, wishing to take no chances, stopped some distance away on

[5] Wilkes, Charles, **Narrative of the U. S. Exploring Expedition, 1838-1842**, vol. 4, p. 110, 1845.
[6] Coan, Titus, **Missionary Herald**, vol. 37, p. 283, 1841.
[7] **Op. cit.**



open lava, whence he had a good view of the moving stream. He was therefore considerably startled suddenly to find the lava crust rising beneath his feet. Escaping from his dangerous position, he looked back and saw that where he had stood the crust had been buckled up to a height of 15 or 20 feet, and that liquid lava was escaping through crevices. This man appears to have had the unusual experience of standing on an actively developing tumulus.

Hawaiian Volcano Observatory Report for October - December 1941

VOLCANOLOGY

October 1941

Conspicuous fuming at Mokuaweoweo was noted early in the month. The majority of the October earthquakes were of Kilauea origin. The widely felt earthquake of October 25 had its origin near Waimea well down the northwestern slope of Mauna Kea. It was deep seated and may well have originated along the fundamental NW-SE rift of the Hawaiian ridge.

November 1941

As the month progressed it was found that the earthquakes of October 25 and November 8 were premonitory of the swarm of shakes that started at Waimea on the north slope of Mauna Kea on November 13. The shaking was more or less continuous, and by December 7 over 2,000 quakes had been recorded on the Mauna Loa seismograph, the instrument nearest the epicenter. No cracks were observed at the surface in the epicentral area. The characteristics of the shaking indicated that the focus extended into a region with an appreciable degree of mobility. This is not surprising when one considers that the quakes originated 27 miles below the surface.

December 1941

Immediately following the Waimea shakes, which ceased on December 8, there commenced a seismic lull that continued through the rest of December. There are some reasons for thinking that such a seismic lull indicates a high or increasing lava pressure under Hawaiian volcanoes.

SEISMOLOGY

Earthquakes October - December 1941

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseism
Oct. 5	20	1	1	1	0	8.50	0
12	7	4	0	0	0	3.75	0
19	14	0	0	0	0	3.50	0
26	4	1	2	0	0	3.50	0
Nov. 2	13	8	5	3	0	18.75	0
9	5	2	0	0	0	2.25	0
16	52	13	1	1	1	25.50	0
23	68	16	4	1	1	35.00	0
30	40	4	0	0	0	12.00	1
Dec. 7	373	2	0	0	0	94.25	1
14	49	2	0	0	0	12.75	0
21	9	2	0	0	0	2.75	0
28	5	0	1	0	0	2.25	0

* For definition of local seismicity see Volcano Letter No. 371.

The data of the following local disturbances was determined from six seismograph stations operated on the islands of Hawaii and Maui by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard. Distances are from Observatory.

The number preceding each earthquake date is the serial number of the quake for the current year.

162. October 7, 14:29, very feeble, distance 14 miles.

163. October 8, 05:24, very feeble, distance 16 miles NE slope, Mauna Loa.

164. October 10, 11:22, very feeble, distance 3 miles SW of Kilauea.

165. October 12, 08:07, very feeble, distance 4 miles SW of Kilauea.

166. October 20, 00:47, very feeble, N slope of Mauna Kea.

167. October 20, 00:51, feeble, near Mokuaweoweo.

168. October 25, 08:54, feeble, N slope of Mauna Kea near Waimea, generally felt on island of Hawaii.

169. October 28, 01:46, very feeble, distance 4 miles.

170. October 28, 08:06, slight, NE rift of Mauna Loa.

171. October 28, 08:07, very feeble, beginning in No. 170.

172. October 28, 08:15, feeble, distance 9 miles.

173-176. October 28, four very feeble shakes during forenoon.

177. October 29, 05:10, very feeble, distance 7 miles.

178. October 29, 08:54, very feeble.

179. October 29, 09:42, feeble, distance 7 miles.

180. October 29, 11:30, very feeble.

181. October 30, 08:31, very feeble.

182. October 30, 18:00, slight, distance 7 miles.

183. October 31, 11:51, slight, distance 7 miles.

184. November 2, 00:20, feeble, P uncertain.

185. November 8, 13:20, very feeble, distance 58 miles.

186. November 9, 05:44, very feeble, distance 16 miles NE slope of Mauna Loa, felt in Hilo.

187. November 11, 02:41, very feeble, distance 16 miles, felt locally.

188. November 13, 20:07, feeble, distance 52 miles, felt in Waimea.

189-196. November 14, 00:51-17:34, eight very feeble shakes, distance 58 miles, felt plainly at Waimea and lightly at widely scattered points on island of Hawaii, depth 27 miles.

197. November 15, 06:53, slight, distance 52 miles, 27 miles deep near Waimea, Hilo instrument dismantled.

198. November 15, 13:27, very feeble, felt in Waimea.

199. November 15, 18:37, feeble, distance 52 miles, felt generally in northern part island of Hawaii.

200. November 16, 02:31, feeble, distance 52 miles, near Waimea, depth 27 miles.

201. November 16, 02:35, very feeble.

202. November 16, 09:41, moderate, origin near Waimea 52 miles away and 27 miles deep, generally felt over island of Hawaii, some slight damage, instruments dismantled.

203-207. November 17, five very feeble shakes originating near Waimea.

208. November 18, 02:56, moderate-strong, strongly felt on entire island and to a lesser degree on Maui, near Waimea, slight damage, 27 miles deep.

209-210. November 18, two very feeble shakes, origin near Waimea.

211. November 18, 10:30, feeble, generally felt over island.

212. November 18, 10:33, feeble, generally felt over island.

213-216. November 18, four very feeble shakes with origin near Waimea.

217. November 19, 07:43, feeble, distance 52 miles, widely felt.

218-219. November 19, two very feeble shakes, origin near Waimea.

220. November 22, 10:04, feeble, near Waimea.

221-222. November 22, two very feeble Waimea shakes.

223. November 22, 21:23, slight, near Waimea, generally felt on island of Hawaii and by a few persons on Maui.

224. November 22, 22:12, very feeble, felt in Waimea.

225. November 24, 18:02, very feeble.

226-228. November 30, three very feeble Waimea shakes.

229. December 4, 09:30, very feeble, distance 52 miles, near Waimea.

230. December 6, 09:44, very feeble, distance 4 miles.

231. December 13, 23:15, very feeble.

232. December 18, 13:00, very feeble.

233. December 20, 15:30, very feeble.

234. December 24, 09:54, feeble, distance 5 miles.

235. December 30, 14:22, feeble, distance 5 miles.

Teleseisms

December 5, 10:29, distance 4,700 miles.

Microseismic Motion

Microseisms were light throughout the quarter.

Crack Changes

Crack movement around Halemaumau and along the Chain of Craters for the quarter was slight. Opening of the crack predominated over closing but most cracks remained unchanged.

Tilting of the Ground

The southeast Halemaumau station showed a slight accumulation of northerly tilt during the quarter. The accumulation of tilt at the west Halemaumau station was very slight to the ENE.

Table of tilt at Observatory on NE rim of Kilauea.

Week Ending		Amount of Tilt	Direction of Tilt
October	5	1.54"	N 51° E
	12	2.43"	N 69° E
	19	3.41"	N 18° E
	26	5.28"	N 66° E
November	2	1.64"	S 39° E
	9	3.52"	N 8° E
	16	4.32"	N 17° E
	23	0.30"	S 45° W
	30	1.70"	S 82° E
December	7	2.28"	N 32° E
	14	1.70"	S 82° W
	21	4.54"	S 34° E
	28	3.52"	S 49° W

R. H. F.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
in cooperation with
UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Government, Department of the Interior, National Park Service.

The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** maintain outside seismograph stations and supplement the work of the government with research associates, instrumental plants and special investigation. Dr. T. A. Jaggar is their geophysicist resident in the National Park.

The **Volcano Letter,** a quarterly record of the Hawaiian volcano laboratories and published by the University of Hawaii, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the above establishments.

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THE PHYSICAL PLANT—HAWAIIAN VOLCANO OBSERVATORY

BY P. E. SCHULZ

A new physical set-up is resulting in a material improvement at the Volcano Observatory, Hawaii National Park. The tearing down of the old Observatory buildings on the brink of the northeast rim of Kilauea crater was completed in September. The first unit of the Hawaiian Volcano Observatory was built in 1912 by the Hawaiian Volcano Research Association. Additions were made thereto from time to time in subsequent years. The old structures have been razed to make their site available for the new hotel in Hawaii National Park—the Volcano House. The seismograph cellar, however, remains, and a reinforced concrete slab has been emplaced over it. The slab is covered with about 18 inches of soil. This covering coupled with the location over steam cracks results in a nearly constant temperature cellar. The diurnal variation seldom exceeds 1°F. There the Bosch-Omori seismograph will continue to function in situ as the nucleus of the instruments of the Observatory.

During the wrecking operations and construction, tilt records (pen wanderings with respect to reference lines on seismograms) were lost or useless for 2 weeks in September, 1941, but only 3 days' seismograms were lost. The latter break in record was reasonably well filled by the records from outlying stations. The low magnification and vertical component instruments were taken out of service August 17, 1941. The former will be reinstalled in the old seismograph cellar.

The new quarters of the Hawaiian Volcano Observatory are in the Volcano Observatory and Naturalist Building, which is nearing completion, approximately 610 feet east-northeast of the old site. It will be provided with fireproof rooms for the storage of the official records of the Observatory and with ample office, machine shop, drafting, and library space. A seismograph cellar is also provided, and here the vertical component seismograph has been installed. A simple 2-component horizontal pendulum-type tilt meter is also being installed. This cellar is also built over a steam crack and but slight diurnal and seasonal temperature variations are indicated. In the near future a Hawaiian-type seismograph will be added, possibly to be replaced ultimately with a high magnification instrument.

The new physical set-up is a step forward. The most important implication may be the operation of seismographs and tilt meters in the area about 640 feet from the sheer, 220-foot cliff of Kilauea crater, at the base of which fault blocks and talus descend another 250 feet to the crater floor, and the concurrent maintenance of additional seismographs on the old site only about 30 feet from the cliff. It is expected that there will be a difference in the daily and seasonal tilt, and in the character and amplitude of local earthquakes as recorded in the two locations.

Hawaiian Volcano Observatory Report for January-March, 1942

VOLCANOLOGY

January

The seismic lull that started on December 8, 1941 continued through the month of January. More earthquakes were recorded on Mauna Loa than at Kilauea. There was no surface manifestation of volcanic activity at any Hawaiian volcano during January.

February

The history of Mauna Loa indicates that a flank eruption can be expected during 1942. An earthquake on February 8 on the northeast rift 8 miles southwest of Hilo with a depth of 30 miles was the first definite premonitory symptom in 1942 of such an eruption. A subsurface splitting progressed up the northeast rift, the foci of the earthquakes became progressively shallower. A series of earthquakes on February 21 near the source of the 1852 flow had a depth of 5 miles.

An earthquake at 00:09 February 18 which originated 8 miles under the northern end of Kilauea crater may well have been directly connected with the growing uneasiness of the Mauna Loa-Kilauea system. Coincidental with the occurrence of this shake there commenced a slight northerly tilt at the Observatory that continued until the last of March. It should be borne in mind that before there can be a northerly tilt at this time of year the pressure increase must first be sufficient to overcome the normal southerly tilt.

March

The progressive cracking along the northeast rift of Mauna Loa continued in March, first showing epicenters high up on the northeast rift, then under Mokuaweoweo, and finally on March 21 some distance down the southwest slope. When earthquakes were resumed along the northeast rift on March 28, it seemed safe to predict that Mauna Loa would soon erupt from this rift. Such a forecast was written but not published, owing to war conditions.

Tilt records for March continued and strengthened the indications that Kilauea was reacting sympathetically to Mauna Loa's preparation for an outbreak. The E-W tilt curve for March was marked by pronounced irregularities, which is what might be expected to accompany an increase of internal pressure. Records show that irregularities are more prominent when Halemaumau is active than in times of quiet. The northerly tilt, however, was insufficient to indicate that a breaking of the Halemaumau seal could be expected.—R.H.F.

SEISMOLOGY

Earthquake Data, January-March, 1942

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
Jan.	4	3	1	1	0	0	2.25	0
	11	18	1	2	0	0	7.00	0
	18	6	3	0	0	0	3.00	0
	25	6	0	0	1	0	3.50	1
Feb.	1	8	3	0	0	0	3.50	0
	8	5	1	0	1	0	3.75	0
	15	6	0	0	0	0	1.50	0
	22	14	4	2	3	3	22.50	0
Mar.	1	11	3	0	0	0	4.25	0
	8	11	2	0	1	0	5.00	0
	15	8	4	1	1	0	7.00	0
	22	17	5	2	2	1	15.75	1
	29	7	1	0	1	0	4.25	0

*For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard. Distances are from the Observatory.

The number preceding each earthquake date is the serial number of the quake for the current year.

1. January 2, 13:13, very feeble, felt in Kona.
2. January 9, 13:35, feeble, distance 25 miles.
3. January 9, 14:20, feeble, distance 3 miles, felt locally.
4. January 10, 15:20, very feeble, distance 2 miles.
5. January 12, 15:45, very feeble.
6. January 15, 17:36, very feeble, distance 4 miles.
7. January 18, 05:39, very feeble, distance 17 miles.
8. January 25, 06:13, slight, distance 16 miles, plainly felt locally, broke a few dishes at Kilauea Military Camp.
9. January 26, 22:17, very feeble.
10. January 28, 09:21, very feeble, distance 14 miles.
11. January 29, 09:38, very feeble, northeast rift of Mauna Loa.
12. February 8, 17:48, slight, 8 miles SW of Hilo, 30 miles deep, felt locally, Hilo instruments dismantled.
13. February 8, 19:56, very feeble, same location as No. 12.
14. February 18, 11:09, moderate, 8 miles deep, under northern end of Kilauea crater, awakened many people, dismantled local and Mauna Loa seismographs.
15. February 21, 08:11, moderate, distance 15 miles on NE rift of Mauna Loa, 5 miles deep, all island seismographs dismantled, widely felt.
16. February 21, 08:14, moderate, same as No. 15, only one seismograph recording at beginning.
17. February 21, 08:36, slight, same location as Nos. 15 and 16, E-W dismantled.
18. February 21, 10:01, very feeble.
19. February 21, 20:15, very feeble.
20. February 21, 20:32, feeble, distance 15 miles.
21. February 21, 22:28, very feeble.
22. February 22, 04:12, feeble, distance 14 miles.
23. February 22, 14:47, slight, distance 16 miles.
24. February 22, 15:05, slight, distance 15 miles.
25. February 23, 22:31, very feeble.
26. February 24, 15:34, very feeble.
27. February 26, 14:11, very feeble.
28. March 5, 12:46, very feeble, felt at Kapapala.
29. March 5, 13:14, very feeble.
30. March 7, 06:41, slight, under northern end of Mokuaweoweo.
31. March 13, 21:20, very feeble.
32. March 15, 09:35, slight, E-W dismantled, near southern end of Mokuaweoweo.
33. March 15, 11:00, very feeble.
34. March 15, 12:24, very feeble, southwest of Mokuaweoweo.
35. March 15, 12:39, very feeble.
36. March 15, 23:43, feeble, southwest rift of Mauna Loa, felt in Kona.
37. March 16, 07:08, feeble, near southern end of Mokuaweoweo, felt in Kona.
38. March 16, 21:57, slight, E-W dismantled, near southern end of Mokuaweoweo, felt in Kona.
39. March 18, 11:21, very feeble, SW rift of Mauna Loa.
40. March 18, 15:16, very feeble, northern end of Mokuaweoweo.
41. March 19, 00:17, slight, E-W dismantled, near Mokuaweoweo.
42. March 20, 01:34, very feeble.
43. March 20, 23:05, moderate, dismantled instruments, widely felt, stopped clocks in South Kona, on SW rift of Mauna Loa.
44. March 21, 01:34, very feeble.
45. March 21, 20:14, feeble, SW rift of Mauna Loa, felt in South Kona.
46. March 25, 09:14, very feeble.
47. March 28, 21:55, slight, NE rift of Mauna Loa, felt locally and in Hilo.

Teleseisms

January 19, 20:00, slight.
March 19, 01:46, slight.

Microseismic Motion

Microseisms were very light throughout the quarter.

Tilting of the ground

The southeast Halemaumau station showed a slight NNW tilt for the quarter, while the tilt at the west station was slight to the ENE.

Table of Tilt at Observatory on NE rim of Kilauea

	Week Ended	Amount of tilt	Direction of tilt
January	4	1.21″	S 45° W
	11	1.69″	E
	18	2.06″	N 32° W
	25	1.81″	S 71° E
February	1	2.81″	S 31° W
	8	4.48″	S 80° W
	15	1.60″	S 13° E
	22	2.78″	N 62° W
March	1	1.94″	N 86° E
	8	1.10″	N 41° E
	15	2.42″	N 71° W
	22	4.96″	E
	29	6.41″	N 87° W

Crack Measurements

During the quarter 21 Halemaumau cracks opened an average of 4.2 millimeters, 7 remained unchanged, and no crack showed a closing. Of the 13 cracks that were measured along the Chain of Craters Road, 7 opened an average of 26.2 millimeters, one closed 1 millimeter, and 6 remained unchanged. R.H.F.

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Hawaii National Park
Edward G. Wingate, Superintendent
R. H. Finch, Volcanologist

University of Hawaii
T. A. Jaggar, Geophysicist

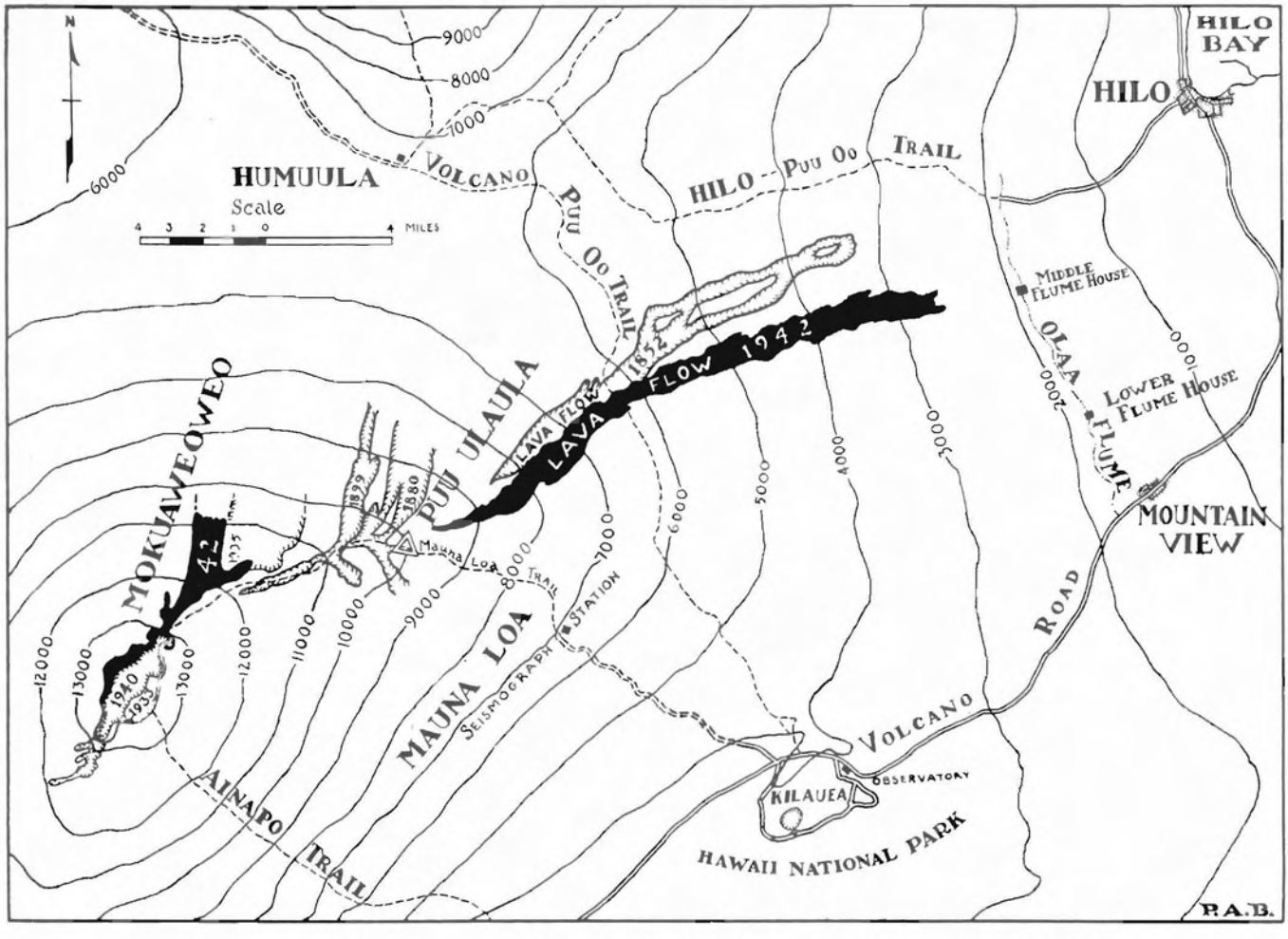

Fig. 1—The northeast slope of Mauna Loa, showing the approximate location of the 1942 flows.

THE 1942 ERUPTION OF MAUNA LOA

By R. H. FINCH

The expected eruption of Mauna Loa began on April 26, 1942 when a line of fountains appeared in the northern part of Mokuaweoweo and for a short distance down the northeastern rift. The summit of Mauna Loa was obscured by clouds at the beginning of the outbreak, though the recording of continuous tremor on the seismographs indicated that it began a little after 5:00 P.M., daylight-saving time, (4:00 P.M., H.S.T.).

The events leading up to the eruption were of especial interest, as they made it possible to predict both the approximate time and place of the outbreak. The history of Mauna Loa teaches us that it is periodic in its activity. After reviewing the historical record, Dr. T. A. Jaggar wrote in 1937 that a lava flow from the northeast rift of Mauna Loa could be expected anytime from 1942 on. The summit eruption of 1940 made 1942 a year with very definite prospects for a flank eruption. Such a historical background gave one complete confidence that an eruption was imminent when seismological evidence pointed to the same conclusion.

Possibly the seismic prelude to the 1942 eruption may be thought of as starting with the seismic crisis near Waimea in November and December, 1941, when about 2,000 earthquakes with depth of focus of about 27 miles occurred. Such shakes indicate an adjustment along the southeastern part of the fundamental Hawaiian rift, though the records were insufficient to show conclusively whether the shaking accompanied an increase or decrease in pressure. Most of the evidence, however, indicated a pressure increase.

On February 8, 1942, an earthquake occurred 8 miles southwest of Hilo, with an indicated depth of 30 miles. The origin was 37 miles southeast of the Waimea shakes and underneath the extension of the northeast rift of Mauna Loa. There was a progressive movement of the epicenters of the earthquakes up the northeast rift after this date, and on February 21 a series of shakes with depth of origin of about 5 miles originated nearly under the source of the 1852 lava flow or about where the 1942 flank eruption was to break out later. During February, 50 earthquakes were recorded at Kilauea, while 143 were recorded on the Mauna Loa seismograph. The preponderance of Mauna Loa shakes was about the same in March, or 57 at Kilauea, and 136 at Mauna Loa.

After February 21 the epicenters of the earthquakes continued to progress along and up the Mauna Loa rift from northeast to southwest. The northern end of Mokuaweoweo was reached on March 7. A shake on March 20 that originated 5 miles southwest of and across Mokuaweoweo was widely felt over the island of Hawaii. It was especially strong along the Kona coast, where some clocks were stopped and objects thrown from shelves. This shake marked the end of progressive cracking and when earthquakes were resumed along the northeast rift on March 28, it seemed safe to assume that an eruption of Mauna Loa could be expected anytime and that it would occur along the northeast rift. Owing to war conditions, a forecast was not made public, though one was included in the March report of the Observatory to Park Superintendent Edward G. Wingate. Press reports in February and March had called attention to the growing uneasiness of Mauna Loa.

The nature of the splitting action or movement that produced the shakes when the earthquakes were progressing from the northeast to southwest is not clear. A wedging force, applied at a depth of 5 miles or more, from below upward seems indicated. The splitting action down the mountain just preceding a flank eruption produces shallow foci earthquakes and cracks that reach the surface. In many cases the depth of this cracking may well be less than 10,000 feet. The depth of foci of earthquakes and the fact that summit activity nearly always precedes a flank eruption indicate that the ascent of lava at Mauna Loa is restricted to the feeding conduits under Mokuaweoweo.

From observations made after the eruptions, in August, Dr. G. A. Macdonald of the U. S. Geological Survey reports that summit activity originated along a fissure that started near the large bend in the northwestern wall of Mokuaweoweo. After roughly following the northwest wall of the main crater, the fissure crossed the North Bay and extended down the northeast rift for about 2 miles. Within Mokuaweoweo the fissures were, for the most part, well up on the crater wall though they came down to the floor in places. There were several lava cascades into Mokuaweoweo from wall cracks 200 to 300 feet above the crater floor. New lava made an appreciable fill near the western edge of the main crater and covered over half of the North Bay. From the crack outside the crater, a lava flow poured northward for several miles. The upper part of the upper 1935 lava flow was largely buried and the cone of that year entirely surrounded (fig. 1).

By early morning of April 27 the summit activity was about over, and splitting down the rift was in progress as evidenced by numerous perceptible earthquakes. According to G. O. Fagerlund and B. J. Loucks of the Hawaii National Park staff, who arrived at Puu Ulaula at 8:40 A.M. after spending the night on the trail, earthquakes were so frequent that sleep was impossible.

At 3:34 P.M. a vent opened at about 12,000 feet that emitted great quantities of fume. Coincident with the opening of this vent, earthquakes diminished as though the escape of gas had released the pressure to a stage below that necessary for continuance of splitting. The shaking had noticeably increased by 9:00 P.M. and reached a climax at 10:41 P.M. with an earthquake of alarming

proportions. The Mauna Loa seismograph (see map, fig. 1), which is but 6 miles from the epicenter of this shake, suffered considerable damage.

At 4:40 A.M., April 28, lava made its appearance along a crack three-fourths of a mile long, extending from an elevation of 9,500 feet to 9,100 feet. By 9:00 A.M. the upper 500 feet of the fountaining chain was sealing off after having built up a low spatter rampart. By 1:40 P.M. activity had nearly ceased along the next 500-foot stretch, and fountaining was becoming concentrated near the lower end. The lower fountains ejected frothy slag as well as pumice (fig. 2). From the ground it appeared as though there were a distinct northerly bend in the live rift near the lower end. An airplane view by the Army Air Corps indicates that there were two nearly parallel cracks 20 to 30 feet apart, from which lava issued. The lava river from the upper northern crack in joining that from the lower one produced the illusion of a sharp bend.

Airplane observations at 9:30 A.M., April 28, showed that the front of the lava river which issued from the lower end of the fountaining area was obscured by clouds below the Puu Oo trail. This meant a progress of over 6 miles in 5 hours.

As the 1942 flow was partly on top of and moving parallel to the 1852 flow, and thus heading in the general direction of Hilo, its progress was watched with considerable apprehension. Observations of the front of the flow were difficult, owing to its location in a dense jungle and to its being obscured by clouds most of the time. Transit observations by Park Engineer A. L. Jess at 8:00 P.M., April 30, indicated that the front of the flow was at an elevation of 3,500 feet and had progressed nearly 2 miles in the preceding 12 hours.

On May 1, sites for bombing, with a view of diverting lava rivers into new channels and thus making two or more short flows instead of one long one, were selected by A. L. Jess and the writer while flying over the flow in a United States Army airplane. A secondary source,

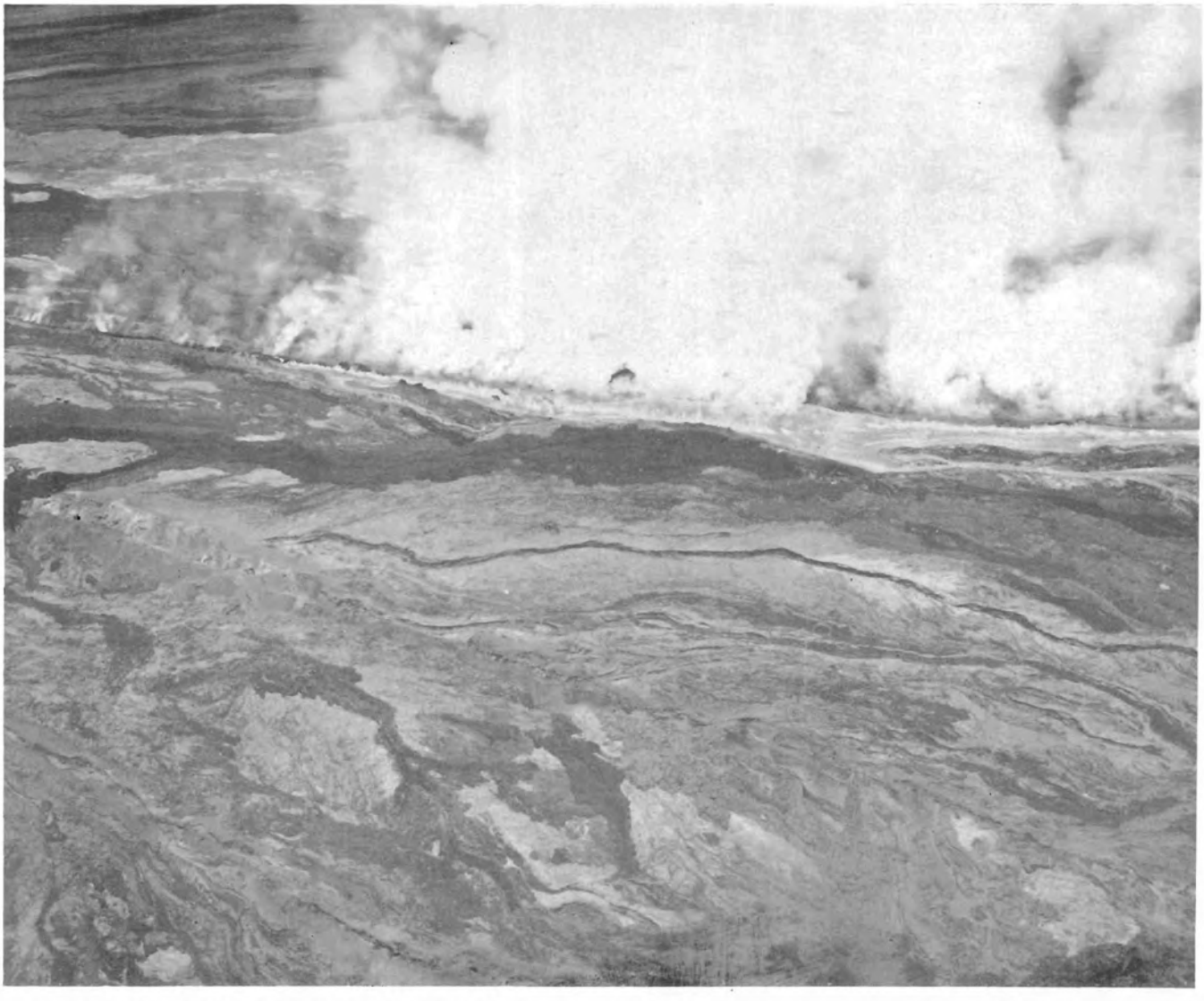

Fig. 2—Looking across the northeast rift of Mauna Loa, April 28, toward the source of the 1942 flank eruption. Though taken early after the outbreak, lava fountains have ceased in the upper 1,000 feet of the fissure. Photo by Base Photo Lab., A. A. F.—A. P. O. No. 953.

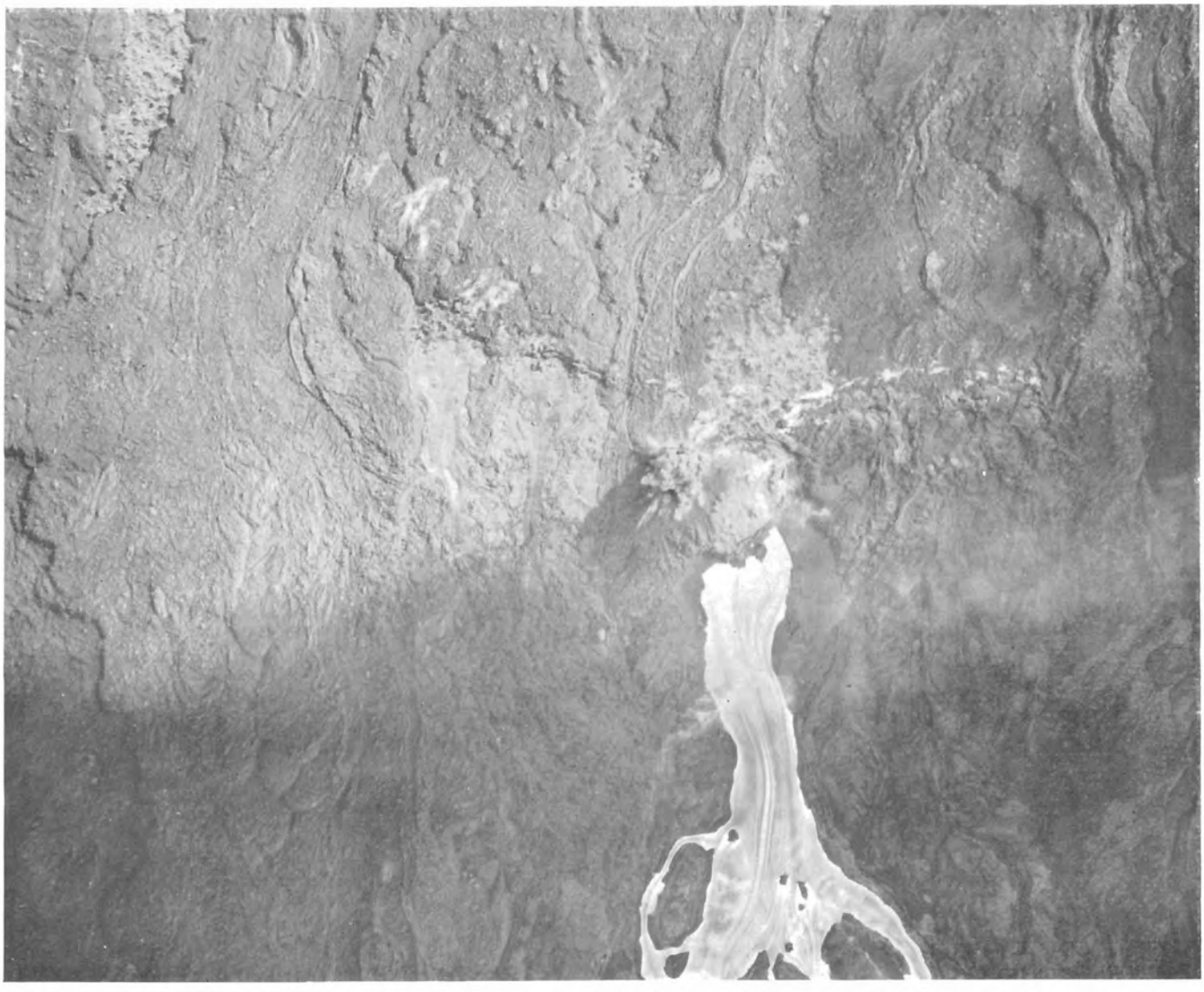

Fig. 3—Lower source 2½ miles below source cone of flow on Mauna Loa, May 1, 1942, with bomb exploding beside it. Photo by Base Photo Lab., A. A. F.—A. P. O. No. 953.

which was suspected on April 30 on account of a noticeably bright spot in the flow area, was found to be in a patch of old reddish-brown lava about 2½ miles below the source cone. A lava river with approximately the same volume as the one from the main source quietly poured out of what appeared to be an old lava tube. There was no fountaining at this source, though fume was issuing from some small cracks aligned at right angles to the northeast rift. Dr. Macdonald examined this area in August and found that there had been three vents along one of these cracks from which lava had issued. The lava emerged from a pahoehoe flow which was overlain by old aa lava. Possibly the crack over which the source cone was located cut across an old tube, and after a little more than a day the tube had become sufficiently heated to allow lava to flow through it. Bombs were dropped alongside this source (fig. 3).

The streams from the 2 sources divided, and for some distance there were 4 or more parallel lava rivers. The 4 rivers came together lower down and continued as pahoehoe for about a mile before becoming an aa stream. This mile of channel seemed to offer the best place for a diversion experiment. Places near the two sources offered other favorable locations. Before a return trip could be made, however, the lower place was obscured by clouds. Several 600-pound bombs were dropped at the upper places during the afternoon of May 1 and on the morning of May 2. At least one stream was diverted, but it returned to its old channel a short distance below. Molten lava cools so rapidly that a diversion lasting but a minute or two is not without appreciable effects on the front of a flow.

Airplane observations by A. L. Jess on the morning of May 2 showed that the front of the flow had widened greatly in the preceding 24 hours and was about 3,000 feet across. The thickness of the front averaged about 25 feet (fig. 4).

On May 1, P. E. Schulz reached the flow by going in from the Kaumana Road to the 1880-81 flow and following up this flow for 3 or 4 miles, thence by more or less following a contour he came to the active front about 1½ miles south of the 1852 flow. Explosions were frequent many

feet back from the edges of the flow. They are caused by the gases resulting from distillation of vegetal matter becoming mixed with air in underground chambers and then ignited. Mr. Schulz reports that they produced billowing black clouds that reached heights of over 500 feet and that the larger explosions produced craters 10 feet across and 2 feet deep. The front of the flow was advancing 300 to 500 feet an hour.

According to observations made by Dr. Macdonald on May 2, the upper 2,000 feet of the active fissure was mainly a fume producer. Blue flames were observed at two localities in the lower part of the inactive fissure. The flame at the lower of these two vents—just above the source cone—was more or less continuous for several days. The extreme upper end of the source cone continuously emitted large volumes of fume. Occasionally, however, pumice was ejected explosively. At other times spindle and ribbon bombs were hurled out. The fume smelled principally of sulphur dioxide. The odor of boric acid was detected over the upper part of the fissure and in the steam from several places in the flow. The main bulk of the fountains averaged nearly 200 feet high, with occasional jets reaching 400 feet.

Nearly all observers noticed fluctuations in fountaining activity. Park Superintendent Wingate at 6:00 P.M., May 3, estimated that the fountains averaged about 100 feet in height, with occasional maxima of about 190 feet. He observed a noticeable increase in activity at 11:00 P.M., which reached a maximum about 2:00 A.M., May 4, when the height of the fountains averaged 140 feet, with occasional jets at least 100 feet higher. The writer on May 5, noticed high fountains in the late afternoon and early evening, a minimum at 11:00 P.M. to 3:00 A.M., May 6, and a noticeable increase in height starting about 5:00 A.M. By 6:00 A.M. the tips of the fountains were reaching heights in excess of 400 feet. It should be noticed that these estimates of height are largely just opposite of what one might expect from the relative visual effects of daylight and darkness. Coincident with the decrease in fountaining, there was an increase in the temperature

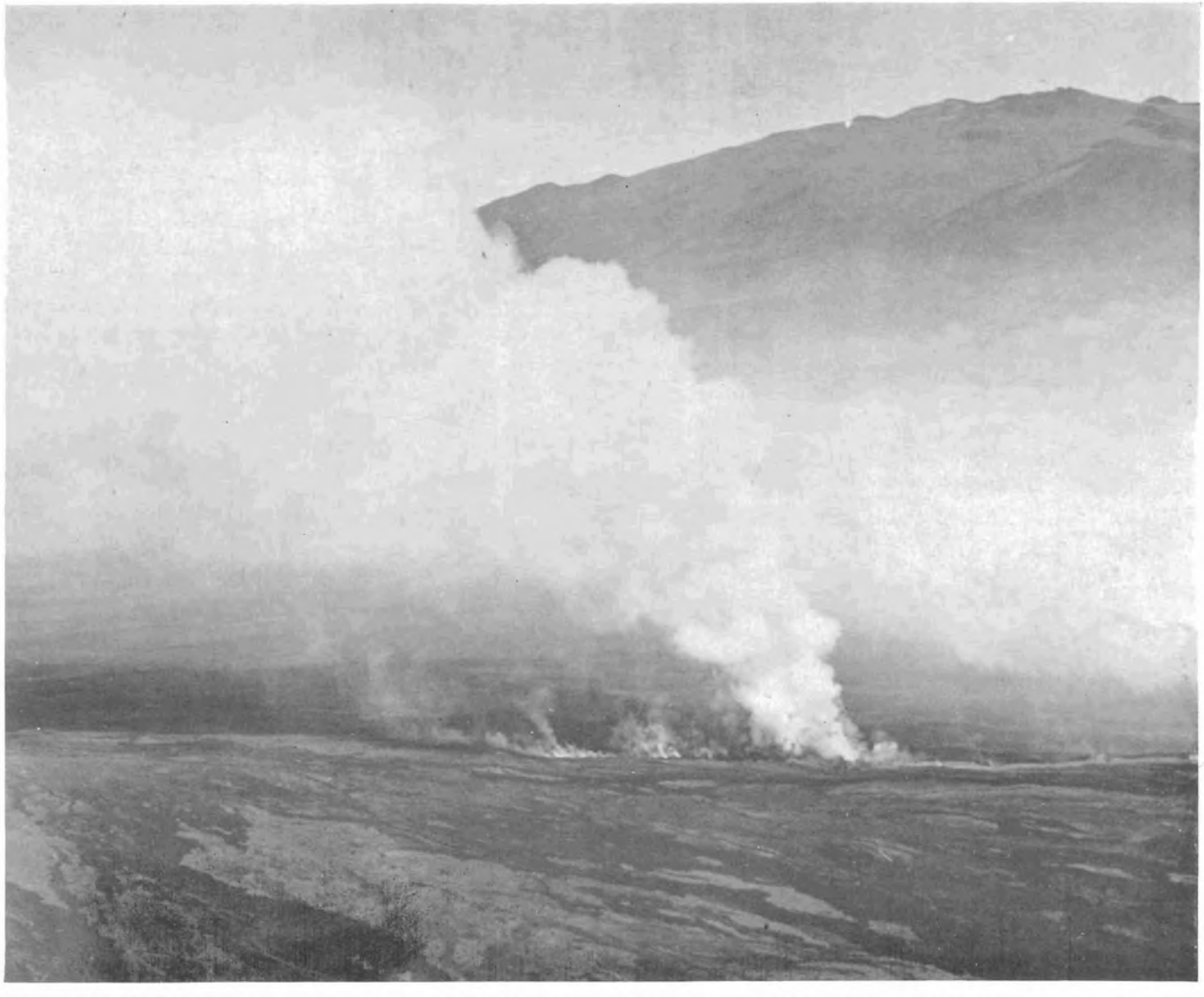

Fig. 4—Northeast slope of Mauna Loa and distant Mauna Kea, showing cone source of 1942 lava flow and live channel, about May 2. Photo by Signal Corps, U.S.A.



Fig. 5—Motion picture photograph close to north side of s ource cone, at about 9,000 feet elevation. Sudden gushing 600-foot fountains jetting southwestward with intense overflow, 1942 eruption of Mauna Loa, 9:00 P.M., May 4. Photo by Lt. Commander F. B. Herman, U.S.N.R.

of the lava river, as evidenced by the decrease in the amount of black skin on the lava and a general increase in brightness. It appeared that the material falling back from the fountains produced a distinct cooling in the lava pool.

The elongated source cone was built up to a height of about 75 feet by deposits of frothy slag and pumice, with the former predominating. This does not necessarily mean that the volume of ejected slag exceeds that of the pumice, for the area around the cone to a distance of about 2,000 feet is mantled with pumice.

During the evening of May 4, Merrill Carlsmith and F. B. Herman witnessed the breaching of the cone in two places, each of which produced large lava rivers (fig. 5). The new river on the northwest side soon reached the old channel, while the one on the southeast side flowed parallel to the old channel and reached a distance of about 6 miles before lateral flows from it, and cooling, stopped forward progress.

The natural diversion accomplished what was expected could be done by further bombing had such a step been necessary, and may have been a backing-up of the May 1 bombing. Progress at the lower front of the flow practically ceased on May 5 at an elevation of 2,750 feet, or a little less than 3¼ miles west of the middle flume house of the Olaa Sugar Company.

The breach on May 4 reached a little over half way down the cone rampart, or low enough for the surging of the lava in the fountaining pool to make a continuous discharge for over a day. If the breaching of the cone had been effected by direct bombing, it might have reached to its base and produced a more voluminous flow. It would appear that the rampart of a source cone offers a favorable place for diversion by bombing.

From May 5 on until activity ceased on May 10, lava outpourings were confined to flows 5 miles or less in length on top of or alongside of the first flows. Glow could be seen in the source rift for several days after May 10. Considerable blue fume was still being emitted from the source area and some distance below it on May 22. Smoke, largely of vegetal origin, was observed over the lower regions of the flow during the latter part of June.

The length of the flank eruption flow was about 17 miles. The area covered with new lava was roughly 5 square miles. An accurate estimate of the volume of the flow is difficult to make without a reasonably good map. Rough calculations, however, indicate that it exceeded 2,000,000,000 cubic feet.

The author is indebted to nearly all members of the Hawaii National Park staff for notes and observations, though but few are mentioned in the text. Of the many others to whom I am indebted for details of the outbreak, especial mention should be made of Dr. G. A. Macdonald of the U. S. Geological Survey. He not only allowed the use of his excellent notes but also read and discussed the manuscript while it was being prepared.

Hawaiian Volcano Observatory Report for April-June, 1942

VOLCANOLOGY

April

That seismicity is often low during the few weeks just preceding a Mauna Loa eruption was again demonstrated in 1942. The premonitory shakes in 1940 preceded the outbreak by 4 weeks. The premonitory shakings in 1942 occurred in Febuary and March. The interval between the earthquakes and the appearance of the lava at the surface accounts for the rather common statement that "Mauna Loa erupted with but little or no seismic warning."

The seismograph not only records the premonitory symptoms of Mauna Loa eruptions but usually accurately times the start of the outbreak. Continuous tremor that began to be recorded a few minutes after 5:00 P.M., April 26, showed that the outbreak began over an hour before it was visible from Kilauea.

Activity at Kilauea was limited to the landslides at Halemaumau caused by several of the stronger Mauna Loa shakes.

May

By May 5, the intensity of the continuous tremor accompanying the Mauna Loa eruption and the rate of outpouring of lava had decreased appreciably. The continuous tremor was recorded on the Mauna Loa seismograph until May 9. The flow stopped during the forenoon of May 10. Considerable fume continued to issue from the source cone and from many places in the flow until the last of the month.

Kilauea continued inactive.

June

Rumors of activity at several places on the recent Mauna Loa flow were common throughout the month. Local adjustments in the 1942 flow, which is over 40 feet thick in many places, may have been the basis of some of the reports, but most were based on local fuming, smoke from vegetal fires at the edges of the flow, or steam clouds following rainstorms. Early in the month smoke from the lower reaches of the flow was sufficient to produce a thin pall of fume over the upper northeast flank of the mountain.

The 1940 cone in Mokuaweoweo was emitting considerable fume on June 30. Local adjustments in the northeast Mauna Loa rift on June 13, 14, and 15, resulted in 92 tremors being recorded on the Mauna Loa seismograph.

Halemaumau remained quiet, though 19 Kilauea tremors were recorded on the Observatory seismograph on June 20 and 21.

R.H.F.

SEISMOLOGY

Earthquake Data, April-June, 1942

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
Apr.	5	8	0	0	0	0	4.50	0
	12	14	1	0	0	0	4.00	1
	19	8	11	1	0	0	4.50	0
	26	277	3	0	0	1	72.75	0
May	3	509	23	12	9	1	164.25	0
	10	6	3	0	0	0	3.00	0
	17	9	0	1	0	0	3.25	1
	24	9	1	0	0	0	2.75	0
	31	7	1	0	0	0	2.25	0
June	7	2	1	1	0	0	1.50	0
	14	10	0	0	0	0	2.50	0
	21	20	1	0	1	0	6.50	0
	28	14	2	0	0	0	4.50	0

*For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard. Distances are from the Observatory.

The number preceding each earthquake date is the serial number of the quake for the current year.

48. April 8, 14:23, very feeble, near Mokuaweoweo.

49. April 14, 12:31, feeble, under Kilauea.

50. April 14, 22:11, very feeble.

51. April 19, 22:23, very feeble, Kilauea shake.

April 26, 16:05, start of continuous tremor that continued for 270 minutes, and beginning of summit eruption of Mauna Loa.

52-54. April 26, three very feeble shakes at 20:03, 22:39, and 22:50.

55. April 26, 23:41, moderate, felt locally and Hilo, instruments dismantled, upper NE rift of Mauna Loa, vertical indicates shallow focus.

56. April 27, 00:01, slight, origin same as No. 55.

57. April 27, 04:21, slight, origin same as No. 55.

58. April 27, 08:49, slight, E-W dismantled, upper NE rift of Mauna Loa.

59. April 27, 09:52, slight, near Mokuaweoweo.

60-62. April 27, three very feeble shakes, 10:04 to 10:41.

63. April 27, 11:53, slight, above Puu Ulaula.

64-69. April 27, six very feeble shakes, 11:59 to 13:57.

70. April 27, 14:12, slight, record confused.

71. April 27, 14:15, feeble.

72. April 27, 14:23, slight.

73. April 27, 16:44, slight.

74-78. April 27, five feeble shakes, 16:30 to 21:17.

79. April 27, 21:43, moderate, instruments dismantled, pronounced at Puu Ulaula.

80-87. April 27, eight feeble shakes, 22:01 to 23:50.

88. April 28, 01:45, very feeble, Mauna Loa flank eruption started 1½ miles below Puu Ulaula about this time.

89. April 28, 10:30, feeble.

90. April 29, 06:15, feeble, origin near source of flank outbreak.

91. April 29, 11:10, slight.

92. April 29, 23:14, very feeble.

93. April 30, 02:39, very feeble.

94. April 30, 07:43, slight, flank eruption source.

May 1, eleven shakes recorded on Mauna Loa seismograph but not at Kilauea.

95. May 2, 04:02, very feeble.

96. May 2, 18:00, very feeble.

97. May 2, 19:00, very feeble.

98-100. May 3, three very feeble shakes, 14:41 to 21:43.

101. May 4, 00:26, very feeble, felt at source.

102. May 4, 01:46, very feeble, continuous tremor greatly diminished though prominent on Mauna Loa instrument until 23:00.

103. May 4, 23:54, very feeble.

104. May 14, 22:40, feeble.

105. May 19, 01:34, very feeble NE rift Mauna Loa.

106. May 27, 14:45, very feeble.

107. June 1, 03:45, feeble Kilauea shake accompanied by a rumble.

108. June 18, 08:05, slight, E slope of Mauna Loa.

109. June 21, 05:54, very feeble.

110. June 24, 16:40, very feeble.

111. June 26, 17:10, very feeble.

112. June 30, 19:05, very feeble.

Teleseisms

April 8, 05:26, slight.

May 13, 16:45, moderate.

Microseismic Motion

Microseisms were present, though slight, throughout the quarter.

Tilting of the Ground

The southeast Halemaumau station showed a distinct southeast tilt early in April but practically no movement during the remainder of the quarter. At the west station there has been but little tilt for the past six months.

Tilt

Table of Tilt at Observatory on NE Rim of Kilauea

Week Ended		Amount of tilt	Direction of tilt
April	5	5.44″	S 67° E
	12	1.94″	S 82° W
	19	1.88″	N 66° W
	23	0.64″	S 13° W
May	3	2.48″	S 81° W
	10	3.39″	N 70° E
	17	1.91″	S 26° W
	24	1.33″	S 29° W
	31	1.82″	N 37° W
June	7	0.36″	N 45° W
	14	2.31″	N 87° W
	21	1.45″	N 21° W
	28	1.03″	N 21° W

Crack Measurements

Crack movement around Halemaumau was distinctly less during April-June than during the preceding 3 months, 16 cracks opened an average of 2.8 millimeters, 11 remained unchanged, and one closed 0.5 millimeters. Movement of the cracks along the Chain of Craters Road was very slight, with the majority showing a slight closing tendency. At the Devils Throat one crack opened 1.5 millimeters, and the others remained unchanged.

R.H.F.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
in cooperation with
UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Government, Department of the Interior, National Park Service.

The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** maintain outside seismograph stations and supplement the work of the government with research associates, instrumental plants and special investigation. Dr. T. A. Jaggar is their geophysicist resident in the National Park.

The **Volcano Letter**, a quarterly record of the Hawaiian volcano laboratories and published by the University of Hawaii, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the above establishments.

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Hawaii National Park
Edward G. Wingate, Superintendent
R. H. Finch, Volcanologist

University of Hawaii
T. A. Jaggar, Geophysicist

THE DUG WELL AT OLAA MILL

By GEORGE DUNCAN

The Olaa Sugar Company recently sank a well shaft 10 feet in diameter in the mill grounds, where the elevation is 220 feet above sea level. Such a shaft gives a detailed exposure of the geologic structure in this part of Puna, where cliffs or other good exposures are lacking, as well as information on the amount of mobile ground water in the vicinity of the conduits of Hawaiian volcanoes.

The author acknowledges his indebtedness to Dr. G. A. Macdonald of the United States Geological Survey and R. H. Finch, Volcanologist, Hawaii National Park, for aid in preparing this article, particularly those parts dealing with geologic interpretation.

The well is located on the northeastern slope of Mauna Loa 3½ miles from the ocean, a little to the north of the Kilauea-Mauna Loa contact. It is thought that most of the lavas exposed in the well are of Mauna Loa origin, though some may be from Kilauea, as in this vicinity there must be some interfingering of Kilauea and Mauna Loa lavas.

The log of the well by Dr. Macdonald, describing each layer, is shown in Table 1.

TABLE 1.

LOG OF OLAA WELL—1941

(On file in Honolulu office of U. S. Geological Survey)

By G. A. Macdonald

Depth	Description
Feet	
0–23	Aa clinker, containing scattered olivine phenocrysts up to 2 mm. across in an aphanitic ground mass.
23–47	Medium-gray sparingly vesicular to dense aa, with moderately abundant phenocrysts of olivine up to 3 mm. long. (Contains hypersthene.)
47–54	Reddened aa clinker, with moderately abundant olivine phenocrysts up to 3 mm. long.
54–56	Fine powdery red ash.
56–61	Moderately vesicular dark-gray pahoehoe with a few small phenocrysts of olivine less than 1 mm. across.
61–64	Dark-gray sparingly to moderately vesicular pahoehoe with a few olivine phenocrysts less than 1 mm. across and scattered phenocrysts up to 1½ mm. long.
Feet	
64–66	Dense to sparingly vesicular light-gray pahoehoe, dikytaxitic, essentially nonporphyritic but with a few olivine phenocrysts less than ½ mm. across.
66-70	Highly to moderately vesicular medium-gray pahoehoe with a few phenocrysts of feldspar up to 1½ mm. long and a very few of olivine less than 1 mm.
70-73	Dark-gray moderately vesicular pahoehoe with a few phenocrysts of feldspar up to 1 mm. or a little more in length. The flow shows a reddened ropy top.
73–81	Dark-gray moderately vesicular pahoehoe, essentially nonporphyritic, but with a few small phenocrysts of olivine and feldspar.

Depth	Description
Feet	
81–88	Moderately to highly vesicular dark-gray pahoehoe, nonporphyritic, approaching clinker in places. Shows ropy flow surfaces.
88–92	Light-gray sparingly to moderately vesicular pahoehoe; some vesicles are as large as 2 mm. across, containing a few phenocrysts of feldspar and olivine up to 1½ mm. Many of the vesicles are lined with platy feldspar crystals.
92–97	Sparingly vesicular to dense light-gray pahoehoe containing scattered small phenocrysts of olivine and feldspar up to 1½ mm. in diameter. (Probably same as above.)
97–107	Moderately vesicular dark-gray pahoehoe with a few phenocrysts of feldspar up to ½ mm. long.
107–115	Sparingly vesicular dark-gray pahoehoe with scattered phenocrysts of feldspar and a few of olivine up to 1 mm. in diameter. (May be same as above.)
115–120	Reddened aa clinker, aphanitic and nonporphyritic.
120–139	Dense to sparingly vesicular medium-gray basalt with a few phenocrysts of olivine up to 1 mm. and feldspar up to 2 mm. across.
139–150	Reddened aa clinker with scattered phenocrysts of feldspar up to 2 mm. Caved badly in shaft.
150–206	Dense medium-gray aa with scattered phenocrysts of feldspar up to 1½ mm. Shows good columnar jointing.
206–217	Aa clinker.

The first 23 feet was composed of aa clinkers so loose that a cement retaining wall was necessary. Retaining walls were also necessary for the ash layer at 54-56 feet and for the clinkery portions of aa flows at 115-120 and 139-150 feet. The massive portion of the aa layer, 150-206 feet, caused real difficulty. It was so abrasive that the best of drills was completely worn out in penetrating 8 to 14 inches of rock.

The ash layer at 54 feet was the only one encountered. The thinness of this layer and the absence of others indicate that this part of the Puna district geologically is comparatively young.

The water in the older drilled wells in the same grounds stands about 17 feet above sea level. Such a level is about what is to be expected, as the normal ground-water-level gradient in regions of moderate to heavy rainfall is about 4 feet for each mile of distance from the shore. At the distance of 3½ miles from the shore, the normal elevation of the ground-water level then would be 14 feet. As the Olaa Mill is located in a region of about 200 inches of rainfall a year, a level averaging a little higher than 14 feet is what is to be expected.

A chamber for housing pumps and motors with a floor 17 feet above sea level was excavated in the massive part of the thick aa flow (150-206 feet, Table 1). After the chamber was excavated and lined with cement, work was commenced to deepen a hole for the sump. The water level was found at 14 feet above sea level. Pumps were installed, and by removing 7,000,000 gallons per day the level of the water was kept at about 6 feet above sea level. A tunnel, the bottom of which was at an elevation of 3¼ feet, was excavated in a northwest direction for about 35 feet in the aa clinker. In view of the fact that pumping was keeping the water at least 8 feet below the normal and that there was a rapid inflow into the tunnel, it appeared too hazardous to continue the excavation. Very rapid rises in the water level that were measured later justified such a belief.

The rise of the water level in the well shows a good correlation with heavy rains. The interval between a heavy rain and the peak of the water level is about 3 days. However, a rain occurring after a dry spell of appreciable length is not followed by a rise in the water level, though it may decrease the rate of lowering. The water of such a rain is used up in saturating the ground. For local rains the rise is very rapid, and the interval a little less than 3 days. For rains higher up the mountain slope the rise is more gradual, and the interval a little more than 3 days. The range of the fluctuation of the water level is considerable. In April 1938 the water reached a height of 22.7 feet and flooded some of the machinery, though most items had been removed before the water reached them. A false floor was installed 6½ feet above the original one. In March 1939 a level of 25.86 feet was reached. Following a dry spell in 1940, the lowest level recorded—13 feet above sea level—was observed. Generally the water level stands at an altitude of about 17 feet.

No evidence of volcanic heat was found anywhere in the shaft. The temperature of the water is constant at 66°F., and the salt content at 0.85 grains per gallon.

No water ran into the shaft even during the heaviest rainfalls. After the shaft was completed and the adit to the pump chamber commenced, there was no sign of water from the sides. This circumstance shows that for 217 feet below the surface there is no impervious ash layer and that the descent of the rainwater is essentially vertical.

The well produces from the lens of fresh water which, owing to its lesser specific gravity, floats on top of the salt ocean water beneath it.

Hawaiian Volcano Observatory Report for July-September, 1942

VOLCANOLOGY

July

Smoke was reported from the 1942 Mauna Loa flow on July 17. This appears to be the last observation of smoke over the flow, though fume continues to be emitted from the source cone.

A landslide from the north rim of Halemaumau on July 16 produced a conspicuous dust cloud.

August

Fume was noticed from the source cones of both 1940 and 1942. More earthquakes were recorded at Kilauea than at Mauna Loa. This relation of earthquake frequency will probably continue for most months until Mauna Loa shows signs of preparing for another eruption.

September

A rainstorm about the middle of the month produced pronounced steam clouds over the lower half of the 1942 Mauna Loa lava flow. The general rise of the steam indicated that nearly all portions of the flow were still hot.

A swarm of Kilauea earthquakes that occurred during the last few days of September may be taken as evidence of subterranean activity. The climax was reached on September 27, when 28 local seismic disturbances were recorded. The tilt curves for July, August, and September indicated that such a swarm of earthquakes was not a premonitory symptom of impending activity.

The September earthquakes caused several landslides from the walls of Halemaumau and one from the southwest wall of Kilauea.

R.H.F.

SEISMOLOGY

Earthquake Data, July-September 1942

Week Ended	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
July 5	6	2	0	0	0	2.50	0
12	8	4	0	1	0	5.75	0
19	5	1	0	0	0	1.75	0
26	7	0	0	0	0	1.75	1
Aug. 2	20	2	0	0	0	6.00	0
9	15	0	0	0	0	3.75	1
16	8	3	0	0	0	3.50	0
23	4	0	0	0	0	1.00	0
30	8	1	1	0	0	3.50	1
Sept. 6	11	2	0	0	0	3.25	0
13	12	2	0	1	0	6.00	1
20	17	3	1	0	0	6.75	0
27	22	6	1	2	0	13.50	0

*For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard. Distances are from the Observatory.

The number preceding each earthquake date is the serial number of the quake for the current year.

113. July 3, 17:50, very feeble.

114. July 8, 5:15, very feeble, distance 3 miles.

115-117. July 8, 17:27 to 22:33, 3 very feeble shakes.

118. July 9, 3:00, slight, E-W component dismantled, felt locally and strongly in Kohala, in ocean north of Kohala.

119. July 19, 23:30, very feeble, felt at Kapapala.

120. July 29, 06:45, very feeble, Kilauea shake.

121. August 2, 23:05, very feeble, NE rift of Kilauea.

122-123. August 10, 10:35, very feeble, twin shakes.

124. August 15, 06:37, very feeble.

125. August 27, 02:38, very feeble, NW of Mauna Kea.

126. August 27, 10:25, feeble near Mokuaweoweo.

127. September 4, 00:48, very feeble.

128. September 6, 05:20, very feeble.

129. September 9, 21:37, very feeble, Kilauea shake.

130. September 11, 16:50, very feeble, felt in Kohala.

131. September 12, 10:25, slight, Kilauea shake.

132. September 18, 01:51, feeble, felt locally, Kilauea shake.

133. September 19, 09:56, very feeble, distance 2 miles.

134. September 20, 13:31, very feeble.

135. September 20, 14:26, very feeble, Kilauea shake.

136. September 26, 16:55, very feeble, Kilauea shake.

137. September 27, 01:41, feeble, felt locally, distance 2 miles.

138. September 27, 02:57, slight, felt locally.

139-141. September 27, 11:33-13:15, 3 very feeble shakes.

142. September 27, 17:36, slight, felt locally, accompanied by rumble, distance 3 miles.

143-144. September 27, 18:46-19:17, 2 very feeble shakes.

145. September 28, 14:15, feeble, felt locally, distance 3 miles.

146. September 30, 10:20, very feeble.

147. September 30, 10:21, feeble, felt locally.

148. September 30, 10:21, slight, felt locally, E-W dismantled. Accompanied by a landslide from NE wall of Halemaumau.

Teleseisms

July 25, 05:00, slight.
August 6, 13:01, slight, Guatemala.
August 24, 14:36, slight, Peru.
September 8, 15:05, slight.

Microseismic Motion

Microseisms were slight though noticeable throughout the quarter.

Tilting of the Ground

A conspicuous feature was the strong ESE tilt at the Observatory from July 1-10. The E-W tilt curve, which usually is in agreement with the seasonal temperature curve, did not change from westerly to easterly until September 26. Except for the southerly tilt in the first decade of July, tilt in the N-S direction was quite uniformly to the north, or normal for this season of the year.

There were but negligible changes in direction and amount in the tilt at the two stations near the rim of Halemaumau.

Table of Tilt at Observatory on NE Rim of Kilauea

Week Ended		Amount of tilt	Direction of tilt
July	5	2.12″	N 66° E
	12	9.20″	S 46° E
	19	1.04″	N 35° E
	26	0.36″	S
Aug.	2	1.45″	N 45° W
	9	0.71″	S 31° E
	16	0.92″	N 66° W
	23	1.23″	N 11° W
	30	0.12″	N 45° E
Sept.	6	1.04″	N 70° W
	13	0.60″	N 36° E
	20	0.24″	S 45° E
	27	0.71″	N 31° W

Crack Measurements

Crack movement during the quarter was slight. There was no change along the Chain of Craters Road or at the Devil's Throat. At Halemaumau movement was confined to 2 cracks which showed openings of 1 millimeter each.

R.H.F.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
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The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** maintain outside seismograph stations and supplement the work of the government with research associates, instrumental plants and special investigations. Dr. T. A. Jaggar is their geophysicist resident in the National Park.

The **Volcano Letter**, a quarterly record of the Hawaiian volcano laboratories and published by the University of Hawaii, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the above establishments.

THE VOLCANO LETTER

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Hawaii National Park
Edward G. Wingate, Superintendent
R. H. Finch, Volcanologist

University of Hawaii
T. A. Jaggar, Geophysicist

THE SURFACE ASH DEPOSITS AT KILAUEA VOLCANO

BY R. H. FINCH

The object of this paper is to show that there have been eight, perhaps nine, explosive periods in the geologically recent history of Kilauea. The older ash beds exposed in the walls of the crater and good evidence that at least a portion of the Pahala[1] ash had its origin at Kilauea indicate that explosive eruptions at Kilauea have been rather common through a considerable portion of its history.

A study of the ash deposits indicates that there have been more magmatic than phreatic explosions and that the magmatic explosions were in most cases larger than the phreatic. (A magmatic explosion is one that has fluid or essential material in the ejecta; a phreatic explosion is one without contemporaneous molten lava.)

The area surrounding Kilauea crater is covered with ash to an appreciable depth. At the northeast rim the depth is as much as 6 feet in places; at the southwest end of the crater, depths of 35 feet may be found. The greater depth at the southwest is owing to the prevailing northeast trade winds. A cave-in at an old lava tube half a mile southwest of the Kilauea rim reveals a thickness there of 20 feet of ash (fig. 1). The total depth of the ash deposited can not be determined, as appreciable quantities of most layers were removed by the wind before the next succeeding layer was laid down. The southwest side of the crater is especially susceptible to wind erosion, as it is in the Kau Desert. The deposits on the northeast side are in a region of about 100 inches annual rainfall and are much less subject to wind erosion. At the northeast the terrain is relatively flat and stream erosion has been very slight. At the southwest rim of Kilauea, 5 inches of the ash of that year was still in place one year after the small explosions of 1924. Within a few years it was reduced to a barely discernible trace.

Stone[2] found evidence of at least four carbonaceous or soil layers in the ash around the northern rim. Stearns[3] reports six different vegetal horizons. The six different vegetal horizons in the ash would mean, of course, that there had been seven different explosive periods.

One erosional unconformity is distinct at many places in the ash at the southwest side of Kilauea. If sufficient time had elapsed between explosive eruptions for vegetation and soil layers to develop at the northeastern end of the crater, it seemed that more unconformities could be found at the southwest side. Some time was spent in looking for such unconformities at places favorable for the development of small streams.

Stone[4] reported an ash bed at least 3 feet thick in an open fissure near Cone Peak (fig. 1) that is separated from the surface ash by 12 feet of lava flow. Stearns[5] surmised from discrepancies in the thickness of the ash near Cone Peak that some of the basal layers of ash in this vicinity had been buried by lava flows. On the same page Stearns also mentions a line of driblet cones along a fissure concentric to and 0.7 mile southwest of the Kilauea rim (fig. 1). He found a lava flow from the fissure interbedded in ash. A little study of Figure 1 shows that the drainage pattern has been interrupted by the opening of the crack. As the drainage pattern is in the ash, it is obvious that the fissure opened after at least one ash layer was laid down.

Figure 2 shows a lava flow interbedded in ash in the wall of the fissure. There is a thickness of 132 inches of ash under the flow, and 34 inches over it. At some places near the crack, 10 feet of ash is still in place, though

[1] For a discussion of the Pahala ash which forms the yellow soil layer especially noticeable in the vicinity of Pahala, see Stone and Stearns, references 2 and 3 respectively.

[2] Stone, John B. "The Product and Structure of Kilauea." Bishop Museum Bulletin No. 33, 1926, p. 34.

[3] Stearns, H. T. "Geology and Water Resources of the Kau District, Hawaii." U. S. Geological Survey Water Supply Paper No. 616, 1930, p. 151.

[4] Stone, John B., loc. cit., p. 34.

[5] Stearns, H. T., loc. cit., p. 150.

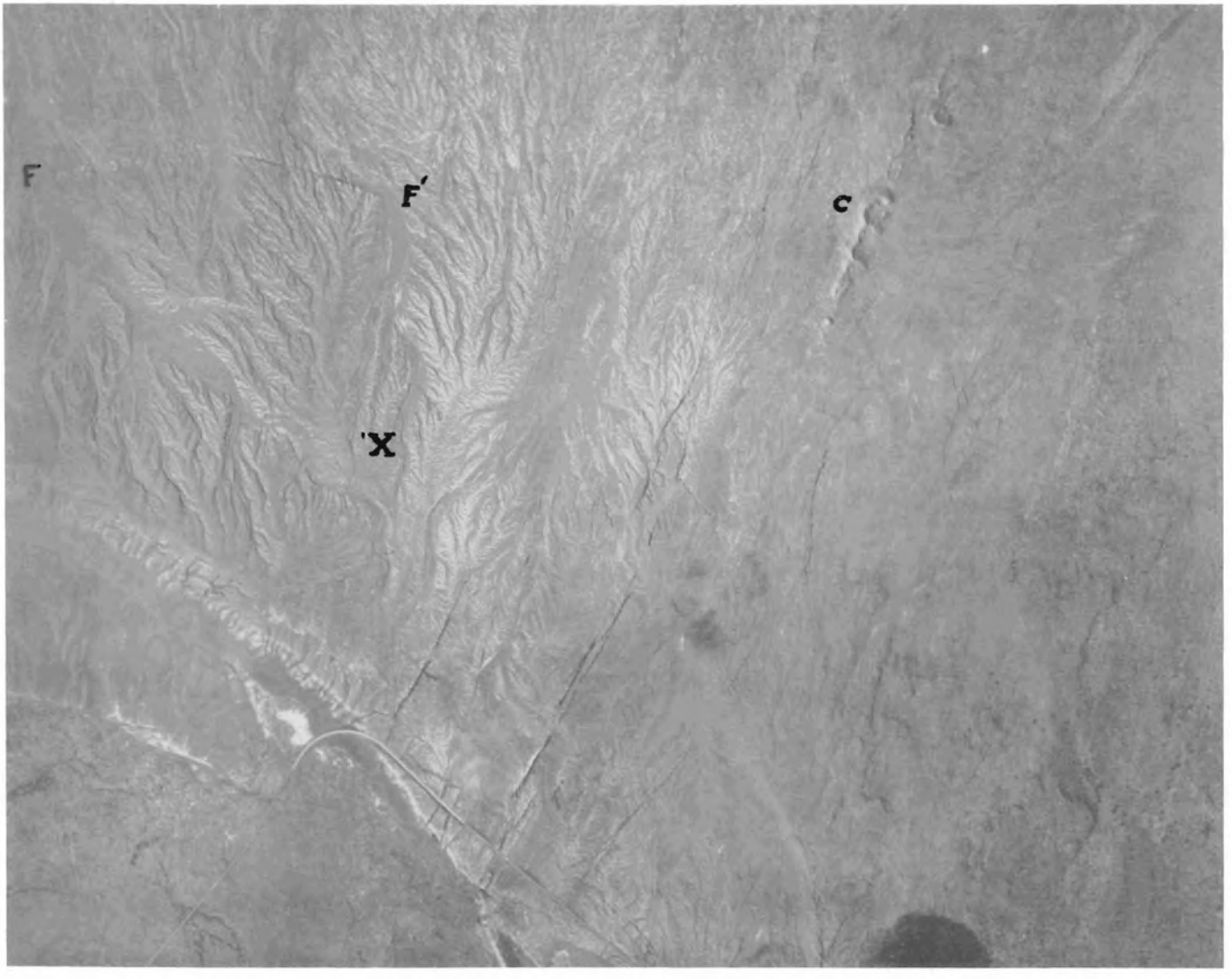

Figure 1. The Kau Desert southwest of Kilauea Crater. X marks the breakdown in an old lava tube where the ash is 20 feet thick. FF' is the concentric fissure, with lava flows interbedded in the ash. C is Cone Peak. Note the numerous cracks in the southwest rift zone. (Photo by Base Photo Laboratory, A.C.)

generally the depth is much less. The fact that the ash section containing the flow is thicker than at many places nearer the crater is what is to be expected when one considers that the lava may have protected the covered layers from wind erosion for an appreciable time interval. There were several different lava flows from this fissure, all probably contemporaneous. It is not certain whether these lava flows occurred during the interval that produced the pronounced unconformity shown in the ash beds near the southwest rim, but such may well be the case.

The basal layer of the ash series is a thin, discontinuous, gray, clayey ash readily discernible only at the northern rim. This is not surprising, as any such ash deposited at the southwest, which is in a desert area, would quickly be removed by the wind. Before the next true explosion occurred there must have been a magnificent display of fire fountains, as the country for several miles around the northern part of the crater is covered with a very light pumice—the "thread-lace scoria" of Dana. The basal layer at the southwest is a somewhat indurated bed of yellow, glassy ash. Indications of an unconformity in this layer suggest that it is the product of two explosive periods. Above this layer is another glassy layer with an appreciable percentage of conspicuous pumice fragments. It is probably the product of but one explosive period. Above the pumice charged layer is another one of rather fine glassy texture, in which there is a distinct unconformity; hence it is the product of two different eruptive periods. A rather coarse, gravelly layer is the topmost member. It has heretofore been considered the product of the 1790 explosions, with traces from 1924. Suggestions of unconformities in this layer indicate that the basal portions may have been ejected prior to 1790. Although most of the products of the 1790 eruption are composed of old lithic material, the fact that it contains bombs causes it to be classed either as a magmatic or a mixed explosion. The products of the 1924 eruption contain nothing but old lithic material; hence it was a phreatic explosion.

There are indications, then, of nine different explosive periods in the recent history of Kilauea. The possibility of there having been explosions, the records of which are lost, with intensities comparable to those of 1924, must also be considered. If the floor of Kilauea crater should again be covered by lava flows, but precious little field evidence of there having been an eruption in 1924 would remain.

Sweeping statements that explosions at Hawaiian volcanoes are of the phreatic type are hazardous. Of the last nine indicated explosive eruptions at Kilauea, at least six appear to have been of the magmatic type.



Figure 2. Lava flow, LL', interbedded in ash at the fissure shown in Figure 1. (Photo by G. O. Fagerlund, Hawaii National Park.)

Hawaiian Volcano Observatory Report for October-December, 1942

VOLCANOLOGY

October

There was no visible activity at Hawaiian volcanoes in October. During the first few days of the month there were several small aftershocks from the swarm of Kilauea shakes of September 27. During the remainder of the month, Mauna Loa shakes predominated. The only felt earthquake occurred at 12:43 p.m., October 11. It originated on Mauna Loa and was strong enough to dismantle both the Mauna Loa and Kilauea seismographs.

November

Hawaiian volcanoes continued inactive in November. Forty-five seismic disturbances were recorded at Kilauea, while 56 were registered on the Mauna Loa seismograph.

Strong winds on November 13 raised conspicuous dust clouds on the southwestern floor of Kilauea Crater and in the Kau Desert, although the material of the clouds—ash from the explosive eruption in 1924—was deposited over 18 years before.

December

Observations at Mokuaweoweo on December 17 showed that some fume was escaping from the 1942 vents.

Forty-four earthquakes occurred on December 21. They originated about 2 miles east of Napau Crater along the Puna rift of Kilauea. With a shallow focus 11 miles from Halemaumau, it is believed that they have no special volcanic significance. They probably resulted from local and superficial adjustments along the Puna rift.

R.H.F.

SEISMOLOGY

Earthquake Data, October-December 1942

Week ended		Minutes of tremor	Very feeble shakes	Feeble	Slight	Local seismicity*	Teleseisms
Oct.	4	34	1	3	1	13.00	0
	11	22	2	0	1	8.50	0
	18	11	1	0	0	3.25	0
	25	3	0	0	0	0.75	1
Nov.	1	6	0	1	0	2.00	0
	8	5	1	1	0	2.75	0
	15	8	0	0	0	2.00	1
	22	11	0	0	0	2.75	0
	29	17	2	1	0	6.25	0
Dec.	6	4	2	1	1	4.50	0
	13	11	0	0	0	2.75	1
	20	7	0	0	0	1.75	0
	27	76	10	4	4	36.00	0

*For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard. The number preceding each earthquake date is the serial number of the quake for the current year.

149. October 1, 06:04, very feeble, NE rift Mauna Loa.

150. October 5, 23:47, very feeble.

151. October 6, 13:33, very feeble, Kilauea shake.

152. October 11, 11:43, slight, E-W dismantled, both components dismantled, Mauna Loa, northern end of Mokuaweoweo.

153. October 16, 09:21, very feeble.

154. October 29, 22:30, Kilauea shake.

155. November 5, 12:56, feeble.

156. November 8, 00:47, very feeble, SW slope Mauna Loa.

157. November 25, 01:54, feeble, felt locally.

158. November 25, 10:20, very feeble, Kilauea shake.

159. November 26, 03:59, very feeble.

160. December 1, 17:03, very feeble.

161. December 4, 18:28, very feeble, Kilauea shake.

162. December 5, 07:07, very feeble, Kilauea shake.

163. December 6, 12:08, slight, felt from Hilo to S. Kona, in Kahuku near source 1868 flow.

164. December 21, 05:28, slight, instruments dismantled, felt locally and in Hilo, 2 miles east of Napau Crater.

165. December 21, 06:50, feeble, felt locally, same origin as No. 164.

166. December 21, 07:47, feeble, same as No. 164.

167-176. December 21, record confused, 7 very feeble and 3 slight shakes.

177. December 21, 23:57, feeble, same as No. 164.

178. December 22, 07:45, very feeble.

179. December 24, 15:15, feeble, Kilauea Crater.

180. December 26, 10:41, very feeble.

181. December 29, 16:33, very feeble.

Teleseisms

October 21, 06:09, slight, southern California.

November 10, 01:30, moderate, Indian Ocean.

December 9, 12:10, slight.

Microseismic Motion

Microseisms were present, though uniformly slight through October-November.

Tilting of the Ground

There were some slight variations in the direction of tilt, though as a whole there was a slight and rather uniform tilt to the northeast. The direction and amount was normal for this season of the year. The tilt stations at Halemaumau showed almost no movement from October to December, inclusive.

Table of Tilt at Observatory on NE Rim of Kilauea

Week ended		Amount of tilt	Direction of tilt
Oct.	4	1.11″	N 13° E
	11	0.97″	N 29° E
	18	0.17″	S 45° E
	25	0.27″	N 63° W
Nov.	1	0.98″	N 83° E
	8	1.21″	N 45° W
	15	1.95″	N 30° E
	22	0.80″	S 34° E
	29	0.12″	N
Dec.	6	0.39″	N 19° E
	13	0.54″	S 63° E
	20	0.63″	N 45° E
	27	0.63″	N 45° E

Crack Measurements

In October there was no appreciable movement in the cracks around Halemaumau or along the Chain of Craters Road. In November many of the cracks immediately adjacent to the rim of Halemaumau opened slightly, while those farther back and along the Chain of Craters Road showed no movement. Many of the cracks at both places opened slightly in December.

R.H.F.

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THE VOLCANO LETTER

No. 479 **Department of Interior** **National Park Service** **January-March 1943**

PUBLISHED BY THE UNIVERSITY OF HAWAII

HAWAII NATIONAL PARK: Edward G. Wingate, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist



LAVA SURGINGS IN HALEMAUMAU AND THE EXPLOSIVE ERUPTIONS IN 1924

By R. H. FINCH

The object of this paper is to show a possible relation between fluctuations in the lava column of Halemaumau and the steam blast eruptions in 1924, as well as to point out the limitations in the quantity of heat and amount of water available for such steam blasts.

A remarkable series of fluctuations in the height of the molten lava in Halemaumau commenced in December 1923 and continued until the lava disappeared on February 21, 1924. The fluctuations suddenly began near the culmination of the steady rise in the lava column that followed the collapse accompanying the small lava flow near Makaopuhi in August 1923. There were short-period fluctuations of approximately 6 to 8 hours, superposed on fluctuations with a period of almost exactly 1 week. The amplitude of the short-period fluctuations was about the same as that of the week-period fluctuations, often amounting to over 60 feet.[1] The general rise in the lava level continued until January 21. Until that date the risings usually exceeded the sinkings. After January 21, however, there was a gradual lowering and the sinkings usually exceeded the rises. This last relation continued until the lava disappeared from view on February 21.

After the disappearance of molten lava in February, harmonic tremor and the smoky condition of the pit, through which glow was occasionally visible, indicated that the lava column remained rather high and nearly stationary until the time of rapid subsidence in the latter part of April. The pasty lava that was revealed at the beginning of this subsidence strengthened such indications.

Previous to the disappearance of the lava, the area of the lava lake that was fluctuating through a range of 50 to 60 feet was about 40 acres. This meant that a large amount of molten lava was involved. In one half-hour period observed, over 10,000,000 cubic feet of lava poured into the lake basin. Some of the withdrawals were even more rapid. If, as seems probable, the total area in cross section of the feeding conduits was small compared to the lava lake, then surgings with similar volume, when confined to the conduits, would mean large vertical ranges. Even if much smaller volumes of lava were involved, the vertical range might well have been much larger than the observed 50 to 60 feet when the upper ends of the conduits terminated in a lake basin.

The possibility of large vertical ranges in the lava surgings being established, indications for such surgings are now required. Harmonic tremor[2]—seismic indications of underground movement of molten lava—furnishes just such evidence. This type of tremor diminished on the seismograms of the Hawaiian Volcano Observatory just before the lava disappeared in February and then was barely visible until April 29, when there was a noticeable increase. Coincidental with the increase in harmonic tremor, a strong southwest tilt and a marked subsidence in the lava column began. Lava drainage into the Puna rift[3,4] may have begun about this time.

A distinct increase in harmonic tremor started on May 7,

[1] Bulletin, Hawaiian Volcano Observatory, December 1923, January 1924, and February 1924.

[2] Jaggar, T. A. "Seismometric Investigation of the Hawaiian Lava Column." Seismological Society of America Bulletin, December 1920, page 267.

[3] Jaggar, T. A., and Finch, R. H. "The explosive eruption of Kilauea in Hawaii 1924." American Journal of Science, November 1924, page 358.

[4] Jaggar, T. A. "Kilauea's Lost Lava Flow." Paradise of the Pacific, Vol. 46, No. 6.

just 4 days prior to the onset of the explosions. This type of tremor was moderate to strong until May 17 and slight through the remainder of the explosive period. The maximum in explosive intensity was reached on May 17 to 18, though earthquakes increased in frequency after this date, reaching a maximum on May 24. There is evidence, then, of lava surging prior to and during the explosive period. If the amplitude of the harmonic tremor is an indication of the amplitude of the surgings, the range of movement of the lava column preceding and during the explosions may have exceeded those during the preceding winter.

Dr. T. A. Jaggar has demonstrated that the explosions in May 1924 must have had their origin in steam blasts.[5] The following discussion attempts to indicate in a more detailed way a possible mechanism and the periodicity of the steam blasts. The potency of volcanic heat in producing steam blasts is easily recognized. A cubic foot of water at a pressure of 1 atmosphere and a temperature of 1,700° F. would yield over 5,000 cubic feet of steam, or, if confined, produce a pressure of over 80,000 pounds per square inch. If one considers these figures only, the mechanism of volcanic steam blasts appears rather simple.

Difficulties arise, however, when one considers that with any ingress of water the hot volcano conduit system immediately produces a pressure that greatly retards, if not precludes, further entry of water. If the pressure build-up were at a moderate rate, then some seal to confine the steam before a disruptive pressure was reached would be necessary. (It would appear that landslide material could make but a poor seal, even with optimum arrangement.) If the pressure had built up rapidly, the heat supply would have had distinct limitations. It would have to come from a thin surface layer of the conduit walls and from any landslide material that fell into the conduit, say about one-eighth inch thick. The receding magma must have left appreciable areas of hot wall uncovered. A mechanism producing a very rapid generation of steam and not requiring a thorough seal, such as a "flash boiler," seems indicated.

Before proceeding with the discussion of a "flash boiler" system, a few words concerning the probable height and distribution of ground water in the vicinity of Kilauea seem desirable. For ideas on this subject, the writer acknowledges his indebtedness to Dr. G. A. Macdonald of the United States Geological Survey.

Conditions observed elsewhere in the Hawaiian Islands indicate that large amounts of ground water are trapped in compartments between dikes at relatively high levels. Dr. Macdonald believes that the ground water in some compartments near Kilauea may be as much as 1,500 feet above sea level. The normal elevation of the Ghyben-Herzberg lens of fresh water in the vicinity of Kilauea would be about 35 feet above sea level. The shape and orientation of such compartments in the vicinity of the Kilauea conduit system are probably very irregular. Evidence indicates considerable relatively high-level ground water in close juxtaposition to the volcanic conduits. As lava is a very poor conductor of heat, the horizontal temperature gradient in the conduit walls must thus have been very steep.

[5] Jaggar, T. A. Bulletin, Hawaiian Volcano Observatory, May 1924, page 35.

There can be but little doubt that an abundance of heat was available for the explosions. All that remains is to find a means whereby a considerable volume of ground water could be dropped into hot openings left empty by the receding lava.

The rapid subsidence that started on April 29 was accompanied by many earthquakes of Halemaumau origin. As previously mentioned, the retreat of the lava column was probably made up of fluctuations in which the drops exceeded the rises. The collapse of the entire floor of Halemaumau indicated a series of collapses of the walls of the feeding fissures. The downsurgings of the lava may well have timed the moment of the collapses. Sometime during this pulsating descent of the lava column, a trapped ground-water pocket was encountered, and with the shattering of the conduit walls a comparatively small amount of water gained access to the volcano system. This could account for the first small explosion on May 11. The next indicated withdrawal of lava and collapse of the conduit walls was on May 13, and explosions resulted. If the bottom of the pit was 1,000 feet below the rim, which, in turn, was 3,700 feet above sea level, and if the height of the trapped ground water was 1,500 feet above sea level, then 1,200 feet of fragmental material would have to be lifted to make an appreciable showing in the bottom of the pit. With an average specific gravity of 2 for such a plug, the pressure generated would have to exceed 1,000 pounds per square inch. Pressures of this magnitude should be developed easily. As the explosions progressed, there may have been an increase in the specific gravity of the fragmental material filling the vent because of an increase in the amount of dense material from more deep-seated walls of the conduit and a decrease in the percentage of vesicular lava from the upper walls. If, as is probable, there was a more or less progressive increase in depth of the seat of the explosions, there may not have been a striking increase in the weight of the plug, for there was a gradual increase in the depth of Halemaumau, the maximum being indicated about May 17.

In order to arrive at possible explosion pressures, let us assume probable temperatures and a possible amount of water. If, as has been assumed, most of the explosions occurred just following a downsurge in the lava column, the walls of the conduit had a temperature of about 1,700° F. Let us assume a surface area in the evacuated conduit of 6,000 square feet. An opening 50 feet long and 60 feet deep would furnish such an area. Hot fragmental material that might have fallen into the cracks would also have been an important additional source of heat. Hot volcanic gases would have been a minor contributing factor. If the explosion pressure was developed as a "flash boiler," then the heat available was confined to a layer about one-eighth inch thick in the rock surface. The volume of the rock, if one computes only the surface of the walls of the fissure, would be 62.5 cubic feet. With a specific gravity of 2.5, this volume of rock would weigh about 10,000 pounds. The number of available B.T.U.'s above 210° F. in 10,000 pounds of basalt with an initial temperature of 1,700° F. is 4,470,000, if we assume the specific heat of basalt in this temperature range to be 0.30.

If we assume a final temperature of 900° F. for the boiler system, the available heat in 10,000 pounds of basalt would amount to 2,400,000 B.T.U.'s. This amount of heat would be nearly enough to raise the temperature of 2,000 pounds of water from 66° to 210° F., evaporate it, and then superheat the steam to 900° F. Evaporation, of course, would take up most of the heat. The pressure generated by such a system with a constant volume would be over 3,000 atmospheres. Of course, there was no constant volume system, but the pressure developed must have been many times the minimum requirement of 1,000 pounds per square inch mentioned previously.

Now the question arises as to whether it is possible to inject suddenly an appreciable amount of water into an evacuated conduit. The Olaa well,[6] with a drawdown by continuous pumping of 8 feet, showed a continuous inflow of 80 gallons a second. If a void with the same capacity as that of the sump below the water surface were suddenly created, the amount rushing in during the first half second might well be several times that of any half second after pumping had been in progress for some time. Likewise the discharge during the first half second from water trapped in a dike compartment, when the wall separating it from a volcano conduit is suddenly shattered, might greatly exceed that of any subsequent half second. Furthermore, if the shattering occurred at the same time as a rapid downsurge of the lava, there might be a pressure decrease that would facilitate the inflow of water. A considerable vertical range in the shattered conduit would speed up the inflow of water, for the velocity of inflow varies roughly as the square root of the depth below the surface of the water table.

The temperature of the dust of the explosion column as it cleared the crater rim must have been nearly 900° F., for on several occasions it was observed to have a dull red glow. The expanding steam, then, in the midst of the hot dust, would have had a volume about 3,500 times that of its water equivalent when it reached atmospheric pressure and would have condensed only in the extreme upper and cooler portions of the cloud. Steam was first definitely observed in the explosion cloud on May 14, though whether it had its origin in the explosion or from steaming vents in the crater wall is not known. The amount of condensation of water vapor in the explosion clouds was never striking, in fact, not much more than might be expected from such a column of hot air with appreciable indrafts of humid air. The explosions must have been produced by relatively small amounts of steam.

Although there was no apparent regularity in timing with many of the explosions that occurred during the early part of the explosive period, the most common interval between explosions[7] was 6 to 8 hours. This interval was in accord with observations on lava fluctuations in Halemaumau. The early irregularities might be expected when one considers the possible existence of a network of feeding fissures under Halemaumau that decreased in number with increase of depth and the possibility that collapsing in the different walls may not have taken place simultaneously. Then, too, the explosion pressures themselves may have been the cause of some of the collapses and thus may have resulted in a series of explosions closely following one another. It should be noted that whether there was one feeding conduit with a diameter equal roughly to the bottom of Halemaumau or a series of feeding wells, the preceding discussion is little affected. If there were but one conduit, variation in the timing of the shattering of different portions of the conduit walls could have produced the observed effects.

Two conditions could have prevented further explosions: a lava column that had become stationary and the cessation of the shattering of the walls of the dike-inclosed compartments containing water.

Many of the explosions, perhaps all, produced air-pressure waves preceding the sound waves. This indicates that the onset of the explosions was rapid, like that of dynamite. The idea of a "flash boiler" mechanism to account for the May 1924 explosions of Kilauea does not seem incompatible with possible available heat and ground water nor with the observed facts of the explosions.

AUTHOR'S ACKNOWLEDGMENT: The author is indebted to Dr. T. A. Jaggar and Dr. G. A. Macdonald for reading and criticizing the manuscript, and to Mr. Williard M. Eller of the Hilo Electric Light Company, Ltd., for checking the computations.

COMMENTS

By T. A. JAGGAR

The foregoing discussion on a possible mechanism for comparatively shallow focus explosions is interesting.

I think of the surgings as deeper and place more emphasis on the magmatic furnace than on incandescent walls. With deeper surgings, the wall breakage with each retreat would let in fresh water from the Ghyben-Herzberg lens at the same time that magma was cascading into the evacuated chamber. The effect would be similar to the surface cascade shown in the figures in the Bulletin of the Hawaiian Volcano Observatory for August 1919.

With the Ghyben-Herzberg ground water standing at 35 feet above sea level, the bottom contact with salt water was 1,400 feet below sea level. If the lava outflow undersea was at one-fourth the depth found 40 miles off Cape Kumukahi (east point of the island) and emerged one-fourth the way down the submarine slope at an elevation of about 4,500 feet below sea level, it was 3,000 feet below the bottom of the fresh water lens.

If the rushing lava was cascading past Kilauea from a head relatively high within Mauna Loa, one cascade or rift tunnel could furnish either a continuous or intermittent furnace, such as the cascades and tunnels that were observed for days in 1919 to 1920.

Surgings and drainages would suck down air from the fissured mountain above ground-water level and so increase the

[6] Duncan, George. "The Dug Well at Olaa Mill." Volcano Letter No. 477, July-September 1942.

[7] Finch, R. H. "Seismic Sequences of the Explosive Eruption at Kilauea in May 1924." Seismological Society of America Bulletin, December 1924, page 217.

heat supply with intense gas oxidation. Cascades of retreat are nothing more than excessive convectional fountaining. Far below water level a downsurge of 10,000,000 cubic feet of lava within a half hour cannot leave a vacuum. Evacuated by steam explosions, a shatter chamber, below 1,500 feet of head of water and still lying higher than at least 3,000 feet of head of much heavier rushing lava that sends up a roaring gas furnace through the well, is likely to suck water into the chamber and make steam that pulsatingly escapes. The bulk of the magma rushes on to effervesce into the ocean. With surges of collapse a Bessemer-furnace process would be set up through the collapse debris. Flash-boiler heavings would punctuate the collapse around the deep chamber—collapses having nothing to do with faulting at the surface.

The mechanism may be thought of as a pouring torrent released through a rift tunnel. The geyser shaft was pulsating accordingly as ground water, alternately heated, blasted upward and rushed in cool. The blasts aided rupture for pumping in new water.

I think the end of the explosions resulted because of a backing up of the submarine outflow, the lava filling fracture fissures and losing pressure through satisfying the new rift-system that was generated in the first place by the tumescent stress under the whole island in surgings of 1915 to 1923. This merely makes the tumescence of the upper island extend itself eastward to the submarine island whenever the century-long cycle between steam blast eruptions shifts its surging from high under Mauna Loa to low under Kilauea or Hualalai. The 130-year period for explosions at Kilauea represents something fundamental in the volcano mechanism that cannot be satisfied with superficial relations only.

The arrangements of the 1919 to 1920 flow from Kilauea that built up Mauna Iki serve as a model of the 1924 system. The Mauna Iki flow was fed by a rift tunnel from Halemaumau through an arcade that still shows in the southwest wall. A little way down the slope from Halemaumau was a lava well, with fountaining lava and escaping gas. In 1924 the entrance arcade was somewhere in the depths under Mokuaweoweo; Halemaumau was the well over the rift tunnel; and the lava flow issued somewhere on the submarine slope east of Cape Kumukahi. With such an arrangement we get three possibilities:

(1) That the tunnel is shelled over water tight and lava tight, and the ground water outside like a tubular boiler. This is not possible, as it was recently feeding the pit and in April 1924 was in a belt of shattering.

(2) That the tunnel is a longitudinal rift torrent, open to the pit, its gases rising to the Halemaumau vents in debris; that these vents in turn are water pipes of the shatter belt under hundreds of feet of hydrodynamic head, the water surging downward as the lava fountains surge upward and downward.

(3) That the feeding vent is an independent upright dike under Kilauea, trending to Puna under the openings of 1920 (Mauna Iki), 1921 (Halemaumau), 1922-1923 (Makaopuhi), and April 1924 (Kapoho)—all sealing above and splitting wide open below to rupture a way along the under-ocean dome surface, just as the Kau Desert ruptured in December 1919 to January 1920. The water conditions were the same as (2).

Probably both (2) and (3) are true, the November 28, 1919 sympathy with the end of the Mauna Loa eruption being the beginning of the rupturing downward that fractured open the Kau Desert rifts in 1920. The upsurges of 1923 must have been dike splitting to introduce the dike fillings of the downsurges. A colossal volume of liquid had to go somewhere and come from somewhere, and neither source nor destination appeared.

All the events were a part of the same Mauna Loa-Kilauea pulse series—like 1914, 1916, 1919, 1920, 1921, 1922, and 1923—which left their output on the surface and also within the internal dikes of tumescence. Thus it is only reasonable to believe that the main vent is under Mauna Loa and deep, that the 1923 surgings were the culmination of lava lowering within Mauna Loa, and that the destination was on the same enormous submarine mountain beyond Cape Kumukahi. That Kilauea was internally robbed is proved by Wilson's shrinkage.[1]

Ground water was essential to the occurrence of any explosions at all. When the lava column, its outer armor broken, got below ground water, a phreatic accident was initiated. This means that if the 1942 flow from Mauna Loa, say, had had a head of ground water above, it would have been accompanied or followed by upper-well explosions. Just such explosions are the rule in heavily watered continental volcanoes. This would be particularly the case if the andesites were viscous and the fountaining subterranean. Ergo: Lassen, Vesuvius, Pelee, and Merapi.

[1] Wilson, R. M. "Ground Surface Movements at Kilauea Volcano, Hawaii." University of Hawaii Research Publication No. 10, 1935.

Hawaiian Volcano Observatory Report for January-March, 1943

VOLCANOLOGY

January

The beginning of 1943 found both Kilauea and Mauna Loa inactive. Heavy rains during the first week of the month caused conspicuous steam clouds over the 1942 lava flow from Mauna Loa. These clouds started rumors that Mauna Loa was in eruption. A landslide at Halemaumau raised a conspicuous dust cloud at 13:45, January 26. There was an unobserved landslide from the southwest wall of Kilauea. At Kilauea 82 seismic disturbances were recorded and at Mauna Loa 32.

February

Only one of the 83 seismic disturbances recorded at Kilauea was strong enough to be perceptible at the Observatory. On the Mauna Loa seismograph, 33 quakes were registered. There was a perceptible widening of the cracks around Halemaumau.

The thermometer shelter was moved to the new observatory grounds in 1941. The new location, slightly lower than the old, is on the windward side of the northeastern-rim steam cracks; therefore, minimum temperatures now recorded are frequently lower than those at the old location.

March

The preponderance of Kilauea shakes over those of Mauna Loa origin, exhibited in January and February, continued in March. There were 71 shakes at Kilauea and 47 at Mauna Loa. None of the quakes appeared to have any special volcanic significance, and Hawaiian volcanoes remained quiet throughout the month.

R.H.F.

SEISMOLOGY

Earthquake Data, January-March, 1943

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Local Seismicity*	Teleseisms
Jan.	3	9	1	0	0	2.75	0
	10	5	1	0	0	1.75	0
	17	9	4	0	1	6.25	0
	24	38	0	1	1	12.50	0
	31	15	2	0	0	3.75	0
Feb.	7	10	0	0	1	4.50	0
	14	29	1	0	0	7.75	0
	21	22	2	0	0	6.50	1
	28	27	1	0	0	7.25	0
Mar.	7	18	0	0	0	4.50	0
	14	14	5	2	0	8.00	0
	21	16	1	1	0	5.50	2
	28	9	0	0	1	4.25	0

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the Island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard. The number preceding each earthquake date is the serial number of the quake for the current year.

1. January 9, 20:04, very feeble, felt in S Kona.
2. January 11, 14:32, very feeble, Mauna Loa.
3. January 15, 17:41, very feeble.
4. January 16, 03:38, very feeble.
5. January 16, 04:22, very feeble, origin at Kilauea.
6. January 17, 14:08, slight, felt locally, NE rift Mauna Loa.
7. January 19, 02:48, slight, felt locally and in Hilo.
8. January 24, 03:09, feeble, felt in Pahala.
9. January 27, 19:06, very feeble, felt at Kukaiau.
10. January 30, 13:53, very feeble.
11. February 1, 22:10, slight, felt in Hilo, Mauna Loa origin.
12. February 8, 10:35, very feeble.
13. February 15, 06:30, very feeble, felt in Kohala.
14. February 16, 03:59, very feeble.
15. February 27, 07:04, very feeble.
16. March 10, 07:34, feeble, Kilauea shake.
17. March 10, 22:52, feeble, Kilauea shake.
18. March 11, 03:06, very feeble.
19. March 11, 04:11, very feeble.
20. March 11, 10:26, very feeble.
21. March 12, 19:26, very feeble.
22. March 13, 19:25, very feeble.
23. March 15, 12:06, feeble, between Mauna Loa and Mauna Kea.
24. March 16, 01:54, very feeble.
25. March 25, 13:05, slight, Mauna Loa.

TELESEISMS

February 21, 23:00, slight.
March 15, 12:30, very slight.
March 21, 10:10, very slight.

MICROSEISMIC MOTION

Microseisms were present throughout the quarter but especially noticeable on February 13 only.

TILTING OF THE GROUND

The normal southwest tilt prevailed during the quarter save for a slight north-northeast tilt during the last few days of January and the first few days of February. For the past several months the tilt stations at Halemaumau showed almost no movement.

Table of Tilt at Observatory on NE Rim of Kilauea

Week Ended		Amount	Direction
January	3	0.27″	S28° E
	10	1.46″	S42° W
	17	0.48″	S
	24	1.33″	S
	31	0.51″	S13° E
February	7	1.40″	N53° E
	14	0.74″	S80° W
	21	1.17″	N71° W
	28	1.39″	S38° W
March	7	0.57″	N45° E
	14	1.00″	S76° W
	21	0.72″	S
	28	0.84″	W

CRACK MEASUREMENTS

All cracks around Halemaumau except one showed a slight opening during the quarter. One crack along the Chain of Craters Road showed a slight opening; the other crack in this area exhibited no movement.

R.H.F.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

in cooperation with

UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Government, Department of the Interior, National Park Service.

The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** maintain outside seismograph stations and supplement the work of the government with research associates, instrumental plants and special investigation. Dr. T. A. Jaggar is their geophysicist resident in the National Park.

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THE VOLCANO LETTER

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UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

LAVA RIVERS AND THEIR CHANNELS

By R. H. FINCH

Estimates by reliable authorities of the depth of rapid-flowing lava rivers of Mauna Loa and the observed depth of the channels after flowing has ceased are often in disagreement. The discrepancy arises from the fact that the observed channel depths are too great.

Lava rivers are comparatively narrow streams flowing within well-defined banks. Where such streams flow out onto a relatively flat terrain, especially if the lava is in the aa stage, a slow-moving lava field covering a considerable area may develop. Short-lived lateral overflows often build up the banks of the channel so that frequently lava rivers are appreciably depressed within their banks. Discrepancies persist, however, even after due allowances for such depressions are made. In 1942, for instance, after the Mauna Loa flow had ceased, a channel about 16 feet deep was found where the river was estimated to have been not over 4 to 6 feet deep and depressed within its banks from 3 to 4 feet. This leaves a discrepancy of over 6 feet to be accounted for. In some cases, discrepancies are even greater.

The order of magnitude of the depth of Mauna Loa lava rivers is determined by noting the behavior of a stream at a cascade and by estimating the percentage of the large bank segments that remain visible after having broken off and fallen into the stream. Often lava rivers branch to make braided streams (fig. 1). The majority of these branches persist but a short time and thus offer opportunities to check estimates of depth. Here, estimated and measured depths are in close agreement. The shallow depth of short-lived streams might be taken as an indication that time is an all-important factor in regard to depth and that long-continued rivers erode or melt material to form a deep channel. These possibilities can be discarded, however, as such erosion cannot be appreciable. Moreover, the possibility of lava fusing the bottom of its channel to give the indicated increase in depth is very remote, because the temperature required to fuse lava does not obtain in such a river. Some other explanation must be sought. Furthermore, because lava rivers tend to crust over and the crust tends to become broken into blocks which sink into the melt, one might expect the channel to grow progressively shallower unless there is some mechanism whereby such sunken blocks are continually removed.

Dr. T. A. Jaggar made the first detailed observations on the mechanics of a Mauna Loa lava river at the Alika flow in 1919.[1] Describing the lava river, he stated: "The effect in the lava stream was as though the bottom were everywhere at shallow depth, and perhaps itself shifting downhill at a slower rate than the liquid film on top." In another paragraph he said: "After seeing the marked differentiation between the liquid lava in the channel and the evident semi-solid matter of the channel bottom and sides—the writer surmised that there were here present two kinds of magma, just as in Halemaumau. There we have the sharply differentiated lake magma and bench magma."

Irregularities in the bottom of lava rivers often manifest themselves as stationary waves at the surface. The progressive movement downstream, observed on several occasions, of some of the obstructions causing these stationary waves is a good indication of the dual nature of such streams—that is, of an upper rapid-flowing stream with low viscosity superposed on a sluggish viscous one. The closing stages of Mauna Loa lava rivers fur-

[1] Jaggar, T. A. "Activity of Mauna Loa." Bulletin, Hawaiian Volcano Observatory, October 1919, page 136.

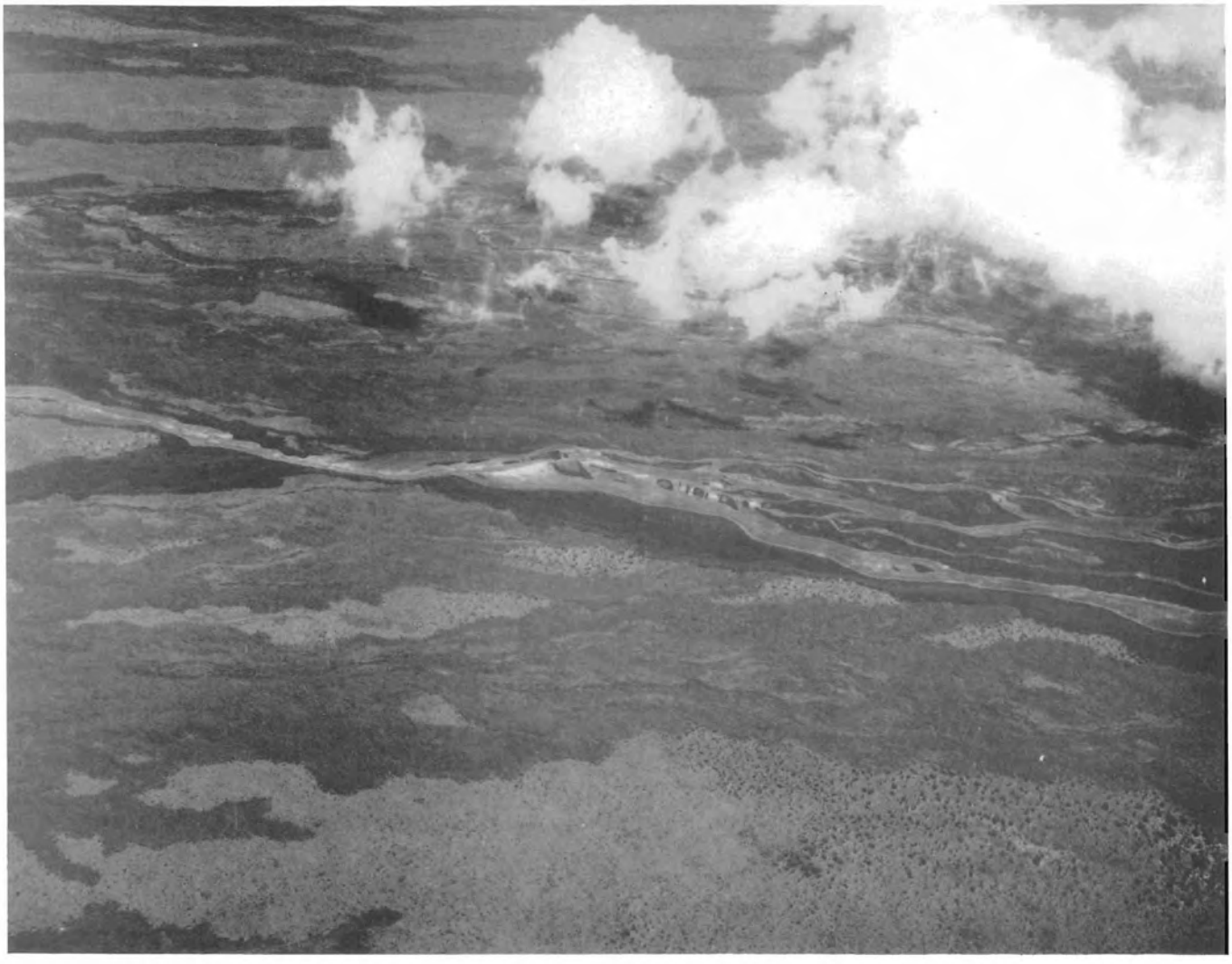

Figure 1—The 1942 Mauna Loa lava river a little below the source cone, where it divided to form a "braided" stream. These branches returned to a single channel lower down. (Photo by Base Photo Laboratory, A.A.F.—APO No. 953.)

nish further evidence on the dual nature of such streams. When diminishing activity at the source cuts off the supply, the material in the upper river quickly drains away, while the slower-moving lower stream continues for some time. Accurate timing of the cessation of the two streams would give some idea of their relative viscosities. Probably, just as perceived by resistance to sounding pipe in Halemaumau, there is gradation of viscosity from liquid vitreous foam on top of the lava rivers to semi-crystalline paste at the bottom. The flowing onward of this paste at the end of an eruption should shallow the delta region stream and deepen the upstream gorge. Exactly this occurred in 1919, 1935 and 1942.

Dr. Jaggar's observation in 1919 that the rapid-flowing Mauna Loa lava rivers are shallow and superposed on slow-moving channel material seems to be justified.

THE VISCOSITY OF MAUNA LOA LAVA FLOWS

By R. H. FINCH

The viscosity of flowing lava is constantly changing. The change is generally to a higher viscosity, because of a decrease in temperature. At the surface of a lava flow, the change is much more marked than in the interior. In pahoehoe flows, the formation of skins gives a very high viscosity for an outer layer. This outer layer, being a good insulator, helps the interior to maintain a high temperature and a relatively low viscosity. The surface granules of an aa flow likewise act as an insulator and allow this type of lava to flow to considerable distances. The rapid cooling of overflows from lava rivers and of the tongue-like extensions by which lava advances causes a rapid change in viscosity within a few seconds.

Because of these factors, one might expect to find a great range in the estimates of the viscosity of lava flows. The data for the estimates of the Alika flow were taken where it crossed the road, which is 9 miles from the source. The apparent viscosity of the lava river changed but slightly in the nine miles, although from the preceding article one might expect that the

volume of the low-viscosity surface portion of the river was relatively greater near the source than at a point 9 miles away. The figure determined by Palmer[1] may be essentially correct for a lava river near the source. Palmer gave the viscosity of the Alika flow as 15 times that of water. Whether the Palmer value is multiplied by 2, or 3, or even 10, it gives us the order of magnitude of the viscosity and is much nearer the truth than the computations of Nichols.[2] The tremendously high viscosity arrived at by Nichols—4,300,000 times that of water—was largely due to erroneous assumptions in regard to field data. For the Alika flow, he made his computations for a river channel and used a depth that was undoubtedly too great. In his computations on the 1887 flow, he had the flow moving as a unit. This, of course, was not the case.

A rough check on the errors in the Nichols' determination is provided by the data he gives on the temperature of dry melt. The formula he used gave the Alika and the 1887 flows higher viscosities than those of dry melts! Now it is well known, although often overlooked, that to reheat lava and get the same degree of mobility that it had when cooling at, say 650° C., it must be heated several hundred degrees higher. Day[3] gives the difference in temperature for lava in which movement can just be detected and the same lava reheated until it will flow under its own weight as 700° C. This is about the same temperature difference that Rittman[4] believed obtains for similar stages in Vesuvian lava. Shepherd[5] has pointed out the importance of small percentages of volatiles in melts and hence the danger of comparing the viscosity of lava flows with the viscosity of reheated devolatilized or partially devolatilized lavas.

The determinations of viscosity made by Nichols appear to be applicable to the tongue of a lava flow that has about ceased moving, but not to Mauna Loa lava rivers. His value may be too low for a moving lava field devolatilized and away from the river.

[1] Palmer, Harold S. "A Study of the Viscosity of Lava." Bulletin, Hawaiian Volcano Observatory, January 1927, page 1.
[2] Nichols, Robert L. "Viscosity of Lava." Journal of Geology, April-May 1939, page 295.
[3] Day, A. L. "Some Causes of Volcanic Activity." Franklin Institute, 1925, page 5.
[4] Rittman, A. "Oral communication." 1934.
[5] Shepherd, E. S. "The Gases in Rocks and Some Related Problems." American Journal of Science, 1938, page 311.

Hawaiian Volcano Observatory Report for April-June 1943

VOLCANOLOGY

April

April was a month of low seismicity. At Kilauea, 36 seismic disturbances were recorded and at Mauna Loa, 35. None of the shakes was perceptible in the vicinity of the Observatory. The scarcity of earthquakes and a southwest tilt that was less than normal for this season of the year may be taken as indications of rather high internal pressure in the Mauna Loa-Kilauea system. However, despite the scarcity of earthquakes and lack of much tilt, landslides from the walls of Halemaumau were rather frequent.

May

The spell of seismic quiet that marked April continued through May. At Kilauea, 29 seismic disturbances were recorded and at Mauna Loa, 26. An earthquake that originated on the eastern flank of Mauna Loa was felt slightly at widely scattered points in the eastern part of the island of Hawaii at 5:10 a.m. on April 8.

Fume in about the usual amount was observed from the center of Mokuaweoweo on May 29. Several places in the vicinity of the source cone of the 1942 Mauna Loa flow were still quite hot on May 29. The odor of free sulphur was detected at one hot spot about one-quarter mile below the cone. This spot appears to be the place from which conspicuous fume was emitted during the progress of the flow and for a week or two after the eruption ceased.

Along the northwestern edge of the flow, not far from the previously mentioned hot spot, new black aa spatter may be found on the old lava. No cone structure or spatter rampart was built up here and there is little evidence to show where the spatter came from, as the source was buried by a subsequent aa flow. The only clue is the end of a small new crack in the old lava. This crack may be taken as an indication that 1942 lava in an old tube developed sufficient pressure to disrupt the roof at this place and forcibly eject black aa spatter.

June

June is the third month with little seismic activity. At Kilauea, 22 local disturbances were recorded and at Mauna Loa, 15.

After a heavy rain during the latter part of June, the outline of the 1942 Mauna Loa flow was plainly revealed by dense steam clouds. In other words, the 1942 lava, nearly 14 months after the flow ceased, is still hot.

BLOCK LAVA IN THE 1942 FLOW FROM MAUNA LOA

A small patch of block lava may be found in the midst of aa lava near the northwestern edge of the 1942 Mauna Loa flow about one-quarter mile below the source cone.[1] This lava resembles broken brick, having none of the spiny or clinkery surface characteristic of aa. When viewed from a distance, however, its fragmental nature gives it the appearance of aa.

Block lava is distinctly different from slabby pahoehoe. The blocks were formed during the declining days of the eruption by the collapse of the walls of the lava river channel just below the source cone. An appreciable number of the blocks fell upon an aa stream, which transported them to their present position. The uniformity that exists to a greater or lesser degree in the size of the blocks is to be expected when one considers that the thickness of the different flows from which they originated was about the same. Moreover, the larger fragments would be broken during the transportation. R.H.F.

[1] For use of the term block lava, see R. H. Finch, Journal of Geology, October-November 1933, page 769.

SEISMOLOGY

Earthquake Data, April-June 1943

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Local Seismicity*	Tele-seisms
April	4	9	0	0	0	2.25	0
	11	3	0	0	0	0.75	2
	18	16	0	0	0	4.00	0
	25	7	0	0	0	1.75	0
May	2	5	0	0	0	1.25	0
	9	12	1	1	1	6.50	0
	16	11	1	0	0	3.25	0
	23	4	0	0	0	1.00	0
	30	6	1	0	0	2.00	2
June	6	4	0	0	0	1.00	0
	13	4	0	0	0	1.00	0
	20	5	0	1	1	2.75	0
	27	5	0	0	0	1.25	0

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the Island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard. The number preceding each earthquake date is the serial number of the quake for the current year.

26. May 7, 02:09, feeble, felt Kapapala to Hilo, E slope Mauna Loa.
27. May 8, 04:10, slight, generally felt eastern Hawaii, near Mokuaweoweo.
28. May 9, 02:20, very feeble.
29. May 10, 05:20, very feeble.
30. May 30, 12:53, very feeble.
31. June 14, 03:24, very feeble.
32. June 14, 21:38, slight, widely felt island of Hawaii, near Waimea.

TELESEISMS

April 5, 05:51, moderate.

April 8, 21:25, slight.

May 25, 12:50, moderate, distance 8250 km.

May 26, 00:20, slight.

MICROSEISMS

Microseisms were strong on April 10 and 11, moderate on April 28 to 30 and June 10 and 11, and slight throughout the rest of the quarter.

Tilting of the Ground

During the late winter and spring of the year, the southerly tilt was less than normal. The change to northerly tilt occurred about the middle of June. Westerly tilt, which was normal for the first five months of the year, ceased about the middle of May, and the usual easterly tilt began. There was but little movement at the tilt stations near the rim of Halemaumau during the period April to June.

Table of Tilt at Observatory on NE Rim of Kilauea

Week Ended		Amount	Direction
April	4	0.87″	S34° W
	11	1.37″	N63° W
	18	0.51″	N45° E
	25	0.39″	N71° W
May	2	0.88″	S74° W
	9	0.88″	S56° W
	16	0.51″	N45° W
	23	0.76″	S19° E
	30	0.65″	N68° E
June	6	0.60″	S37° W
	13	0.76″	S72° E
	20	0.76″	N18° W
	27	1.08″	N63° E

Crack Measurements

A majority of the cracks in the vicinity of Halemaumau showed slight openings. The opening near the south rim was appreciable in April and May. In June, one of the cracks along the Chain of Craters Road opened 6 millimeters; no movement was detected at other cracks in this vicinity. R.H.F.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

in cooperation with

UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Government, Department of the Interior, National Park Service.

The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** supplement the work of the government with research associates, instrumental plants and special investigation. Dr. T. A. Jaggar is their geophysicist resident in the National Park.

The **Volcano Letter**, a quarterly record of Hawaiian volcano laboratories and published by the University of Hawaii, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the above establishments.

THE VOLCANO LETTER

No. 481 **Department of Interior** **National Park Service** **July-September 1943**

PUBLISHED BY THE UNIVERSITY OF HAWAII

HAWAII NATIONAL PARK: Edward G. Wingate, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

WORK OF UNIVERSITY AND RESEARCH ASSOCIATION

By T. A. JAGGAR

In June, 1938, Dr. T. A. Jaggar, after reviewing twenty-six years of work at the Hawaiian Volcano Observatory, reported in Volcano Letter 460 a planned program for the Hawaiian Volcano Research Association. The plan included making secure the scientific archives, getting the new Observatory building, completing technical publications, creating a publication committee, shifting the volcanologist's work to new hands, and allowing Dr. Jaggar, as Research Associate of the University of Hawaii, to act as editor and writer with the Hawaiian Volcano Research Association collaboration. Various reports on the progress of the plan have been made. Cooperation of the three establishments, Hawaii National Park, University of Hawaii, and Hawaiian Volcano Research Association, was described in Volcano Letter 454, for December, 1937. Dr. Jaggar finished his writing of the "Volcanology" for the quarterly Observatory report of July-September, 1940. "The Physical Plant" of the Hawaiian Volcano Observatory in Hawaii National Park was reviewed by P. E. Schulz in Volcano Letter 475 of January-March, 1942. This issue of the Volcano Letter is a report by the Research Associate of the University of Hawaii on the accomplishments by the University and the Hawaiian Volcano Research Association in accordance with Dr. Jaggar's plan.

The scientific records are being worked over by both R. H. Finch, Volcanologist, and by Dr. Jaggar. The latter has sent two finished memoirs to the Geological Society of America. The new Observatory building at National Park is occupied. The publication committee in Honolulu consists of F. C. Atherton, Gregg M. Sinclair, and T. A. Jaggar. Finch writes, and Jaggar edits the quarterly Volcano Letter published by the University under authority of the National Park Service: its primary function is to maintain a continuous record of the volcano measurements. The making of duplicates of the more valuable volcano records by microfilm, photostat, and carbon copies to be kept at the University has been started.

Some publications appearing later than those listed in Volcano Letter 456 are given below:

PUBLICATIONS OF THE OBSERVATORY

Wentworth, Chester K. *Ash Formations of Hawaii*, Third Special Report of the Hawaiian Volcano Observatory. Honolulu, 1938. (Copies of this volume will be sent to anyone applying for it while the edition holds out.)

Waesche, H. H. *Maui Earthquake of 1938.* Volcano Letter 457, March, 1938.

Philippson, P. and Jaggar, T. A. *Excursion to Nyamlagira Volcano.* Volcano Letter 458, April, 1938.

Verhoogen, Jean. *Eruption of Nyamlagira 1938.* Volcano Letter 459, May, 1938.

Jaggar, T. A. *Planned Program for Hawaiian Association.* Volcano Letter 460, June, 1938.

Waesche, H. H. *An Equatorial Cruise.* Volcano Letter 461, July, 1938.

——— *Chain-of-Craters Earthquakes 1938.* Volcano Letter 462, August-December, 1938.

——— *Time-control of Seismographs.* Volcano Letter 464, April-June, 1939.

Jaggar, T. A. *Expedition to Lava-bombing Site.* Volcano Letter 465, July-September, 1939.

Waesche, H. H. *1935 Lava in Mokuaweoweo Crater.* Volcano Letter 466, October-December, 1939.

Jaggar, T. A. *Exploration NE Rift Mauna Loa.* Volcano Letter 466, October-December, 1939.

Waesche, H. H. *Tilt Changes at Kilauea.* Volcano Letter 467, January-March, 1940.

——— *Mauna Loa Summit Eruption 1940.* Volcano Letter 468, April-June, 1940.

Ballard, Stanley S. and Payne, J. H. *Chemical Study of Kilauea Gases.* Volcano Letter 469, July-September, 1940.

Finch, R. H. *Engulfment at Kilauea.* Volcano Letter 470, October-December, 1940.

——— *The Filling in of Kilauea Crater.* Volcano Letter 471, January-March, 1941.

Williams, Howell and Finch, R. H. *Calderas and Their Origin.* Volcano Letter 472, April-June, 1941.

Finch, R. H. *Volcanic Activity in the Marianas.* Volcano Letter 472, April-June, 1941.

Schulz, P. E. *Tilt Conversion to Seconds of Arc at Hawaiian Volcano Observatory.* Volcano Letter 473, July-September, 1941.

Macdonald, G. A. *Lava Flows in Eastern Puna.* Volcano Letter 474, October-December, 1941.

Schulz, P. E. *Physical Plant of Hawaiian Volcano Observatory.* Volcano Letter 475, January-March, 1942.

Finch, R. H. *The 1942 Eruption of Mauna Loa.* Volcano Letter 476, April-June, 1942.

Duncan, George. *Dug Well at Olaa Mill.* Volcano Letter 477, July-September, 1942.

Finch, R. H. *Surface Ash Deposits at Kilauea.* Volcano Letter 478, October-December, 1942.

——— and Jaggar, T. A. *Lava Surgings in Halemaumau 1924.* Volcano Letter 479, January-March, 1943.

——— *Lava Rivers and Their Channels.* Volcano Letter 480, April-June, 1943.

——— *Viscosity of Mauna Loa Flows.* Volcano Letter 480, April-June, 1943.

PUBLICATIONS IN OUTSIDE JOURNALS

Jaggar, T. A. *A Star Zenith-finder.* Trans. Amer. Geophys. Union, Wash'n. 1938. 60 Pp., illus.

Payne, J. H. and Ballard, Stanley S. *Hydrogen Sulphide at Kilauea 1940.* Science, Vol. 92, 1940. Pp. 218-219.

Ballard, Stanley S. *Solfataric Gases at Kilauea.* Phys. Rev., Vol. 54, 1938. P. 236.

Jaggar, T. A. *Magmatic Gases.* Amer. Jour. Sci., May, 1940. P. 313.

Waesche, H. H. *Ground Tilt at Kilauea Volcano.* Jour. Geol., August-September, 1942. P. 643.

Schulz, P. E. *Summit Eruption of Mauna Loa 1940.* Geol. Soc. Amer. Bul., Vol. 54, 1943. P. 739.

Macdonald, G. A. *Eruption of Mauna Loa 1942.* Amer. Jour. Sci., April, 1943. P. 241.

Eller, W. H. *A New Recording Tiltmeter.* Seis. Soc. Amer. Bul., July, 1939. P. 481.

WORK OF THE UNIVERSITY

The last lecturing to students by Dr. Jaggar was to a class of 70 in July, 1938, and to audiences of 300 persons in the Adult Education Service in March, 1939. Funds were appropriated for special geophysical research in the University by the Territorial Legislature for the biennia 1939-1941, 1941-1943, and 1943-1945, and Dr. Jaggar was appointed Research Associate in charge, to work in collaboration with University departments, the Hawaii National Park, and the Hawaiian Volcano Research Association. After December, 1941, research manuscripts were compiled (to the number of twelve by 1944) and sent to the Government. At regular intervals reports on the geophysical research, including illustrations and laboratory phases, have been made to the President of the University. Laboratory work on "Abrasion Hardness" of substances has been in progress since July, 1942, in a laboratory and shop created by the Association.

The manuscript reports include inventions used in exploration, in seismology, in mineralogy, and in volcanology, which cover a range of activities of the Hawaiian Volcano Observatory from microscope to mountain top, and under the waters of the ocean, from Alaska to New Zealand, and from Italy to Central America. The manuscripts and their illustrations are voluminous, serving in the laboratories to assemble for University use a compendium of forty years of work in geology, and bringing into system what would otherwise have been loose notes. The compendium is matter for scientific recording; publication is gradually being achieved. Samples of such publication are the papers previously listed on ash, magmatic gases, and tilting of the ground. The effort in all this work has been to aim at the principles of comparative volcanology, and not merely to give local description.

Titles of typescripts (the first fourteen written by Dr. T. A. Jaggar) that have been filed are as follows:

1. "Origin and Development of Craters." 843 pages, 93 plates. (Prepared under a grant from the Geological Society of America.)
2. "Expeditions on Certain Hawaiian Beaches." 11 pages, 1 plate.
3. "Conflagration from Earthquakes." 7 pages, 1 plate.
4. "Exploration of Alaskan Beaches." 21 pages, 1 plate.
5. "Mechanical Features of Vehicles for Exploration." 32 pages, 8 plates.
6. "Aleutian Shorelines." 117 pages, 65 plates.
7. "Volcano Explorations in Japan." 120 pages, 49 plates.
8. "Artificial Defense Against Lava-flow Damage." 139 pages, 12 plates.
9. "Expeditions to New Zealand, Tonga, Samoa, and South Sea Islands." 162 pages, 27 plates.
10. "Journals of Caribbean Earthquake Disasters." 276 pages, 36 plates.
11. "Lava Activity of Hawaii Island." 275 pages, 93 plates.
12. "Steamblast Disasters in Caribbean and Pacific." 284 pages, 39 plates. (Received as a memoir by Geological Society of America.)
13. "Volcanoes Around the Pacific." About 1200 pages, with 100 plates selected.
14. "Abrasion Hardness." About 200 pages, with miscellaneous illustrations. (Is in preliminary typescript and photostat.)
15. "Volcano Warfare," by L. W. de Vis-Norton, Secretary-Treasurer of the Hawaiian Volcano Research Association. 15 chapters, 243 pages.

Number 1 is a memoir embodying twenty-six years of experience at the Hawaiian Volcano Observatory, outlining the field of volcano science, and developing some principles of crater evolution. It assembles observations, maps, sections, diagrams, curves, photographs, reviews, and narrative histories of craters. Numbers 2, 4, and 6 deal with the physical geology of Hawaiian and Alaskan shorelines. Numbers 3 and 7 describe explorations among Japanese volcanoes and some disasters due to earthquakes adjunct to volcanic districts. Numbers 5 and 13 have chapters dealing with instrumental invention and special cross-country vehicles designed to apply power engines in exploration instead of pack animals. These publications also describe Pacific and other volcanic activities. Number 8 is a report on the history in Hawaii of an engineering attempt to protect Hilo harbor from lava-flow damage. Number 9 describes expeditions to New Zealand in 1920, Howland and Baker Islands in 1924, and Niuafoou in Tonga in 1930 by Dr. Jaggar, and to six equatorial islands of the Pacific by H. H. Waesche in 1938. It was in 1938 that an earthquake annunciator was experimented with on two of the islands, just as in New Zealand, on Niuafoou, and on Howland portable shock-recorders had been planted for testing seismicity. Number 10 is a comparative study of two earthquake disasters in the field at opposite ends of the Caribbean Sea—the Cartago shocks of Costa Rica in 1910 and the Montserrat spasms of 1933 to 1936. Number 11 is a condensation of Kilauea record books from 1909 to 1935. Number 12 is based on the author's investigation of the Pelée and Soufrière disasters in Martinique and St. Vincent in 1902, and the comparative volcanology of Kilauea, Tarawera, Sakurajima, Katmai, Taal, and Tomboro volcanoes, with especial reference to the reports of wounded persons. Number 13 is a book on twentieth century volcanology. Number 14 is unfinished and dependent on investigations in progress designed to show that physical hardness is probably a fundamental property of the association of particles measurable in terms of kinetic energy. Number 15 is Mr. Norton's book, a popular exposition of field volcano science, admirably suited to magazine publication if it can be illustrated with pen sketches by a good artist.

A sixteenth typescript of importance is a master's thesis entitled "Chemical Decomposition of Rocks at Kilauea" written by K. T. Mau in June, 1940. It includes 103 pages, 13 tables, and 8 figures. This work awaits publication: it investigates relationship between solfataric alteration and final resulting soil. Rock samples were analyzed chemically, microscopically, and spectroscopically. Natural solfatara alteration is examined with reference to decrease and increase of constituents. Decomposition by hot acid steam prolonged for six months artificially included combinations with air, carbon dioxide, and sulphur dioxide. Sulphur dioxide was proved the most active decomposing agent. Methods of analysis are described critically, and the analyses carried to 24 constituents including nickel, copper, chromium, vanadium, strontium, barium, and zirconium. The spectrographic analysis adds cobalt.

These writings are to be issued as scientific memoirs or books as the occasion to publish arises and are in part on their way into print. Other compilations dealing with field and laboratory notes on experiments with volcanoes, experimental geology, graphical position-finding by stars, simplified earthquake recorders, and Aleutian geology are in various stages of manuscript compilation.

The laboratory and offices of this work for the University are divided between 25 Hawaii Hall Annex, which is Dr. Jaggar's Honolulu office, and the Kilauea Laboratory of the University in Hawaii National Park. Dr. Jaggar's annual routine is divided between six summer months at Kilauea and the six winter months in Honolulu. The research associate's personal instruments, tools, and collections from expedition fields are in Honolulu, and the accumulated instruments and records of thirty or more years of the Volcano Observatory are at Hawaii National Park. Cordial assistance is given by the University departments and by the Hawaii National Park. The immediate cooperation of University departments of chemistry and physics at the Kilauea Laboratory was suspended in 1941.

WORK OF HAWAIIAN VOLCANO RESEARCH ASSOCIATION

In 1941, the Hawaiian Volcano Research Association assisted with materials, equipment, and labor in promoting the duplication of records for the University, and in improving the shop of the Kilauea Laboratory and the Chemical Building in Hawaii National Park when the Volcano Observatory was moved. At that time there was great disruption owing to the moving of the hotel to the old Observatory site. The Association has financed illustrations for manuscripts and preparation of collections. In 1941, Dr. Jaggar's assistant at the University was Sutejiro Sato. In 1942, the assistant was Miss Ruth Baker (Mrs. Burton Loucks) who resigned in 1943. Mr. Sato and Miss Baker typed the numerous manuscripts and did valuable work of classification and labelling, assisted in experiments and compiling, as well as in handling much material that required heavy work in the moves from building to building, and from Kilauea to Honolulu and back. The Kilauea laboratories are two buildings distinct from the new Observatory building. Formerly the property of the Research Association, they have since been rebuilt and transferred to the Park Service for the use of the University workers.

The present Board of Directors of the Hawaiian Volcano Research Association consists of: F. C. Atherton, president; W. F. Dillingham and A. L. Dean, vice-presidents; L. W. de Vis-Norton, secretary and treasurer; and C. M. Cooke, J. R. Farrington, W. F. Frear, G. M. Sinclair, W. W. Thayer, and L. P. Thurston. In 1942, there were sixty members and fourteen donors in the Association.

At that time many boxes of records and specimens from expeditions had accumulated. When the crisis of war activity called for suddenly speeded-up laboratory activity in Honolulu there was no room in which to operate. Accordingly, the Association rented a small building near the University where Dr. Jaggar, as their Scientific Director, placed and classified the collections. These included minerals and implements of his own, formerly the subjects of abrasion hardness investigation at Harvard University and the Massachusetts Institute of Technology. A shop was equipped for rebuilding instruments. Throughout 1942 and 1943 a succession of model sclerometers has been tested on specimens of glasses, minerals, woods, and metals.

A paper on the "Hardness of Hawaiian Woods" was read before the Hawaiian Academy of Science October 16, 1942, and a sclerometer was exhibited in the form of a drill-press with a steel milling tool. It was shown that the hardness of substances varied inversely as the depth of boring during a constant interval, the result having been read by micrometer indicator where the pressure and speed were kept constant.

Such model instruments, used where volume abraded under identical conditions is the end sought, are parallel to the devices employed in metal-working where "machinability" is measured. Complexity of the aggregate of particles, whether atoms, molecules, or granules in a bond, and such qualities as sharpness of tool, toughness, brittleness, and viscosity of substances, all make the investigation a prolonged puzzle. Simple indentation is used in metallurgy as a measuring device. This, however, gives inconsistent results, and is quite inapplicable to minerals, rocks, glasses, and porcelains. Progress has been made since the work on abrasion hardness of woods was made public, and it is believed that a device will be worked out that will be fundamentally sound as a physical implement.

Preparation of a manuscript in connection with the subject of abrasion has proceeded with the assembling of matter from modern reference books. It deals with the great recent extension of the grinding industry and the metallurgy of alloys and welding, a science now so important in ship and airplane construction. There is also much need for abrasion measurement of woods, plastics, earthenware, stones, and minerals. Implements are now in use that deal with wear and degradation in commerce, or with ductile or malleable flow, but the aspect in physics of mutual collision-resistance by molecules appears to have been neglected in elementary textbooks.

The results of founding the Hawaiian Volcano Research Association in 1911 were the creation of the Volcano Observatory at Kilauea, establishment of Hawaii National Park, sending forth of Pacific expeditions, extension of work to California, Alaska, and the Caribbean, and obtaining the increasing cooperation of the Federal Government, the University of Hawaii, and outside research establishments. In volcanology, there is the same need for study of the hot interior earth, including the foundation of three-quarters of the earth's surface under oceans, as there is in astronomy for the physical exploration with instruments of the hot stars of the outer universe. The importance of the Research Association's making such field study possible should be emphasized.

As accented in Volcano Letter 454, the greatest need at present is for a fireproof building for valuable records in the University grounds in Honolulu: the records are now scattered in pine buildings. On February 6, 1940, the total destruction of the hotel by fire at Hawaii National Park taught a lesson. The second need in the current situation is a lava diversion channel, constructed according to surveys which have been finished, to defend Hilo from a Mauna Loa flow: the summit eruption of November, 1943, may be the portent of a coming 1945 outflow.

The Research Association is grateful to E. G. Wingate, superintendent, Hawaii National Park, for construction improving the Kilauea laboratories of chemistry and geophysics for University use. Unfortunately, a grant for critical hydrogen study made in 1941 by the Geological Society of America was suspended by the war crisis.

Summarizing joint activities of the last five years, we report memoirs completed, many thick illustrated and bound reports put into use, laboratories extended, publications issued, physical investigations in progress of service to technology made, records duplicated, a popular book sent to a publisher, and collections of specimens from world localities assembled. These are products of the University of Hawaii and the Hawaiian Volcano Research Association. Likewise, the engineering and scientific staff of Hawaii National Park has continued steadfastly its task of accumulating records and meeting crises in the face of untold reduction of resources.

Hawaiian Volcano Observatory Report for July-September 1943

VOLCANOLOGY

July

The spell of seismic quiet that started in April continued through July. Of the 28 seismic disturbances recorded at Kilauea, 2 are classed as earthquakes and the rest as tremors. Thirty-one seismic disturbances were recorded at Mauna Loa.

Following a heavy rain during the afternoon of July 8, steam clouds were conspicuous over the 1942 flow. The outline of the clouds was so sharp that rumors of a Mauna Loa eruption were started.

August

There was less seismic activity in August than in July. At Kilauea, 21 seismic disturbances were recorded and at Mauna Loa, 26.

Several slides from the walls of Halemaumau were noticed during the first half of the month.

September

Eighteen seismic disturbances were recorded at Kilauea and 20 at Mauna Loa.

September marked the sixth consecutive month in which but very few earthquakes were recorded at the Hawaiian Volcano Observatory. This is the longest period of seismic quiet in the history of the Observatory and is probably the longest in the last 120 years.

The present 6 months period of seismic quiet occurs during the longest period without volcanic activity at Kilauea on record. Nearly 9 years have elapsed since molten lava was visible in Kilauea. For about 6½ years no fume has been visible in Halemaumau, and but very little steam has escaped.

R.H.F.

SEISMOLOGY

Earthquake Data, July-September 1943

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Local Seismicity*	Teleseisms
July	14	9	0	1	1	5.25	0
	11	9	0	0	0	2.25	1
	18	2	0	0	0	0.50	0
	25	3	0	0	0	0.75	0
August	1	5	0	0	0	1.25	1
	8	6	0	1	0	2.50	0
	15	2	1	0	0	1.00	0
	22	5	0	0	0	1.25	0
	29	5	0	0	0	1.25	0
September	5	3	0	0	0	0.75	1
	12	3	0	0	0	0.75	0
	19	6	2	0	0	2.50	4
	26	2	2	0	1	3.50	0

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours and 30 minutes slower than Greenwich. Distances are from the Observatory. The number preceding each earthquake date is the serial number for the current year.

33. July 1, 01:51, slight, felt locally and at Kapapala, near Ainapo.
34. July 3, 04:26, feeble. NE rift Mauna Loa above Puu Ulaula.
35. August 7, 12:40, Puna rift, 17 miles.
36. August 9, 02:14, very feeble.
37. September 13, 12:34, very feeble, near Mokuaweoweo.
38. September 17, 05:11, very feeble, felt Kohala.
39. September 21, 09:04, very feeble.
40. September 21, 16:17, very feeble, Kilauea crater.
41. September 21, 17:19, slight, Kilauea crater.

TELESEISMS

July 11, 15:49, slight.
July 28, 16:45, moderate, distance 7400 km.
September 13, 16:01, slight.
September 13, 17:45, slight.
September 13, 20:59, moderate, distance 5900 km.
September 19, 14:46, slight.

MICROSEISMS

Microseisms were moderate from July 6 to 9 and on July 19. During the remainder of the quarter microseisms were present though slight.

Tilting of the Ground

Westerly tilt prevailed during July and until the latter part of August when easterly tilt set in and continued through September. There was a slight and more or less continuous northerly tilt during the quarter. After having been nearly stationary for several months, the tilt instruments near the rim of Halemaumau showed some oscillations during the latter part of September.

Table of Tilt at Observatory on NE Rim of Kilauea

Week Ended		Amount	Direction
July	4	0.40″	W
	11	0.74″	N10° E
	18	1.12″	N13° E
	25	0.77″	S51° W
August	1	0.77″	N71° W
	8	0.27″	N27° W
	15	0.27″	N27° W
	22	0.48″	W
	29	0.54″	N26° E
September	5	0.17″	S45° E
	12	0.62″	N79° W
	19	1.45″	N48° E
	26	0.54″	S64° E

Crack Measurements

The majority of the cracks around Halemaumau showed no movement during July while most of those along the Chain of Craters Road closed slightly. With the exception of 1 crack which opened 3 millimeters, there was very little movement at the Halemaumau rim in August. The majority of the cracks along the Chain of Craters Road opened slightly. In September there was but very little movement either at Halemaumau rim or along the Chain of Craters Road. R.H.F.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
in cooperation with UNIVERSITY OF HAWAII

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THE VOLCANO LETTER

No. 482 **Department of Interior** **National Park Service** **October-December 1943**

PUBLISHED BY THE UNIVERSITY OF HAWAII

HAWAII NATIONAL PARK: Edward G. Wingate, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist



ACTIVITY AT MAUNA LOA IN NOVEMBER 1943

By R. H. FINCH

Conspicuous fume clouds over Mokuaweoweo and spells of continuous tremor on the seismographs indicate that there was slight activity at Mauna Loa in November 1943. The first observation of unusually heavy fume arising from Mokuaweoweo was made on October 10 by A. L. Jess from the summit of Mauna Kea. Steam always rises from the west central part of the crater. Mr. Jess made his observations at 6:45 a.m. and reported heavy fume from the southwestern part.

There had been some indications of a sustained and fairly high pressure under the Kilauea-Mauna Loa volcano system for several months. The indications were chiefly lack of southwest tilt in the spring of 1943 and extraordinarily low seismicity from April to the middle of October. Northeast tilt in the fall of 1943 was about the seasonal normal or, at least, not enough to indicate a return of lava to Kilauea. The number of seismic disturbances at Mauna Loa in October greatly exceeded those at Kilauea; they were 33 and 22, respectively. In November the corresponding numbers of seismic disturbances were 93 and 79. The majority of the November disturbances occurred on the 21st, 22nd, and 23rd. The excess of the number of Mauna Loa shakes over those from Kilauea in October and the observed fume on October 10 were definite indications of a growing uneasiness of Mauna Loa. The indications were not definite enough, however, to indicate impending activity at Mauna Loa.

Further evidence of Mauna Loa's uneasiness was the conspicuous earthquake at 5:22 p.m. (war time) November 10, in which movement of a large block in the southwestern slope of Mauna Loa was involved. Then during the morning of November 11, employees of the Puu Oo ranch on the southeastern slope of Mauna Kea observed conspicuous fume clouds over Mokuaweoweo. During the late afternoon of the same day a conspicuous fume cloud over the southern end of Mokuaweoweo was observed from Park headquarters. The fume was observed from the same place a few times on subsequent days.

Like the spells of continuous tremor, the fuming was intermittent. A National Park party was at the summit of Mauna Loa on November 19, and noticed nothing more than rather heavy steaming from the usual vents in the west central part of the crater. Tremor that continued for several minutes at a time became conspicuous on the seismographs on November 21, reached a maximum on November 22, and practically disappeared on November 23. It is interesting to note that a few reports of glow over Mauna Loa at this time were made on days of maximum spells of continuous tremor. The reports of glow would indicate that cracks heated to incandescence were exposed or else small amounts of molten lava reached the surface. The slight amplitude of the continuous tremor indicates that but a small amount of molten lava was involved, whatever the height the lava may have reached in the Mokuaweoweo conduits.

This quiet November 1943 activity brings to mind the possibility of there having been several unrecorded outbreaks in the past. If such activity had occurred when Kilauea was also active, the continuous tremor on the seismographs might well have been masked by harmonic tremor originating at Halemaumau. The continuous tremor of full-fledged Mauna Loa eruptions, having a much greater amplitude, usually overshadows the harmonic tremor from Kilauea. A conspicuous cloud developed over Mokuaweoweo in March 1921 at a time of intense activity in Halemaumau. There must have been, for a short duration, a pronounced increase in temperature of some of the cracks in the floor of Mokuaweoweo. Whether any molten lava reached the surface at that time is not known.

Apparently most, but not all, Mauna Loa summit eruptions have produced spectacular lava fountains. It is not surprising to find reports of a few outbreaks which produced little or no lava. In 1875 there was a short summit eruption in which pronounced glow was lacking. Starting in December 1887, a fume column was observed over Mokuaweoweo for more than a month. The fact that no glow was reported during this time does not necessarily mean that some short-lived glow would not have been observed had cloud conditions been favorable at the time of observation. From the Volcano House on September 10, 1907, about 8 months after the eruption of that year, a black cloud was observed over Mokuaweoweo that lasted for at least 13¼ hours. Some observers reported a glow in the cloud. At 4:00 a.m. September 11, a glow attributed to a lava flow was reported in the vicinity of Red Hill.

Fume and steam, unless dense, is more conspicuous by transmitted light than by reflected light. For instance there is a steam vent between 11,000 and 12,000 feet on the northeast slope of Mauna Loa whose presence is often plainly revealed at the Observatory by the rays of the setting sun in spring and early summer. At other times of the year the steam is seldom if ever seen. As viewed from the Observatory in June, the sun sets nearly behind the vent. Then the ascending steam is sometimes so conspicuous that it resembles lava fountains. It is interesting to note that the fume clouds of November 1943 were mainly observed by reflected light. That is, their presence was easily observed without the magnifying effect afforded by transmitted light at times of sunrise or sunset.

There is a fairly good correlation between summit eruptions and subsequent flank flows. Whether the fuming of November 1943 is to be interpreted as an added indication of a flank eruption within the next two years remains to be seen.

Hawaiian Volcano Observatory Report for October-December 1943

VOLCANOLOGY

October

The seismic lull that started in April 1943 was interrupted about the middle of October by the occurrence of several shakes, most of which were of Kilauea origin. During the month, 22 seismic disturbances were recorded at Kilauea, and 33 at Mauna Loa.

Large dust clouds from landslides were observed over Halemaumau on October 12 and 20.

November

The preponderance of Mauna Loa shakes over those of Kilauea origin in the latter part of October and the first part of November was the only authentic indication of a growing uneasiness of Mauna Loa. The interpretation of the seismograph records of the earthquake of November 10 suggests a rotational movement of a block in the southwest slope of Mauna Loa. Ninety-three seismic disturbances were recorded on Mauna Loa; 79 were recorded at Kilauea. The majority of the disturbances occurred on November 21, 22, and 23, or at the time of the maximum activity of Mauna Loa.

December

A conspicuous fume cloud was observed over Mokuaweoweo on December 19, first from Kona and later from Waimea. However, there were no signs of continuous tremor on the seismographs on this day. On December 25, steam in somewhat greater amount than usual was observed under the high western wall of Mokuaweoweo, but there was no fuming in the vicinity of the 1940 cone or elsewhere in the crater.

The number of seismic disturbances at Mauna Loa again exceeded that from Kilauea, 52 to 38, respectively.

R.H.F.

SEISMOLOGY

Earthquake Data, October-December 1943

Week Ended		Minutes of Tremor	Feeble Very	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
October	3	1	0	0	0	0	0.25	0
	10	1	0	1	0	0	1.25	0
	17	4	0	0	1	0	3.00	0
	24	4	2	0	1	0	4.00	0
	31	5	3	0	0	0	2.75	0
November	7	2	2	0	0	0	1.50	2
	14	7	2	0	0	1	5.75	0
	21	17	2	0	0	0	5.25	1
	28	59	0	0	0	0	14.75	0
December	5	9	2	1	0	0	4.25	0
	12	13	0	1	0	0	4.25	0
	19	5	2	1	0	0	3.25	0
	26	5	1	0	1	0	3.75	1

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard. Distances are from the Observatory. The number preceding each earthquake date is the serial number for the current year.

42. October 7, 08:50, feeble, Kilauea shake.
43. October 16, 02:36, slight east slope Mauna Kea, felt at Hakalau and locally.
44. October 18, 05:06, very feeble, Kilauea shake.
45. October 20, 02:07, slight, felt locally and at Hilo. Five miles deep under southern end of Kilauea crater.
46. October 22, 18:43, very feeble.
47. October 30, 18:23, very feeble, Kilauea shake.
48. October 30, 19:06, very feeble.
49. October 31, 13:28, very feeble, Kilauea shake.
50. November 4, 00:38, very feeble.
51. November 5, 15:35, very feeble.
52. November 8, 14:15, very feeble, felt in Pahala as a sharp jolt.
53. November 10, 16:18, very feeble, felt at Pahala.
54. November 10, 16:22, moderate, dismantled instruments, widely felt southern half island of Hawaii; stonewalls thrown down southwest of Pahala.
55. November 16, 23:26, very feeble.
56. November 21, 22:51, very feeble.
57. November 29, 13:45, feeble.
58. December 1, 19:52, very feeble.
59. December 3, 11:09, very feeble, lower SW rift of Mauna Loa.
60. December 7, 05:47, feeble, NE rift of Mauna Loa.
61. December 13, 19:43, very feeble.
62. December 15, 08:58, feeble, felt at Pahala.
63. December 18, 21:14, very feeble.
64. December 22, 19:50, slight, felt locally and at Hilo, southwest slope of Mauna Loa.
65. December 24, 01:51, very feeble.

TELESEISMS

November 3, 04:12, moderate, Alaska, 4550 km.
November 5, 22:15, slight, 8000 km.
November 20, 08:56, slight.
December 23, 08:45, slight, 6360 km.

MICROSEISM MOTION

Microseisms were strong on October 8, 16, December 9 to 10, and December 26 to 27, and moderate on November 18, 26, and 27. Throughout the rest of the quarter slight microseisms were recorded.

Tilting of the Ground

Normal northeast tilt prevailed during October, November, and until the middle of December except for the pronounced northwest tilt accompanying the distinct earthquake of November 10. The quake produced a permanent offset to the west in the E-W tilt curve. The sharp northerly tilt due to the quake was followed by a southerly tilt of like amount within about a day.

During 1943 there was a slight accumulation of westerly tilt due largely to the quake of November 10. The total northerly tilt for the year slightly exceeded the southerly.

Table of Tilt at Observatory on NE Rim of Kilauea

Week Ended		Amount of Tilt	Direction of Tilt
October	3	1.21″	N54° E
	10	1.02″	N45° E
	17	1.30″	N22° E
	24	0.78″	N52° E
	31	1.18″	S24° W
November	7	1.85″	N31° E
	14	3.87″	N82° W
	21	0.62″	N11° W
	28	0.48″	S
December	5	0.88″	N16° W
	12	1.48″	S81° E
	19	0.84″	S45° W
	26	0.43″	S34° E

Crack Measurements

Crack movement during the quarter was slight. Five cracks near Halemaumau opened an average of 2 millimeters. The rest of the cracks measured near Halemaumau and those along the Chain of Craters Road were stationary.

R.H.F.

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in cooperation with UNIVERSITY OF HAWAII

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THE VOLCANO LETTER

No. 483 **Department of Interior** **National Park Service** **January-March 1944**

PUBLISHED BY THE UNIVERSITY OF HAWAII

HAWAII NATIONAL PARK: Edward G. Wingate, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

HARMONIC TREMOR

By R. H. FINCH

Shortly after the seismographs were installed at the Hawaiian Volcano Observatory in 1912 it was noticed that they were recording small tremors continuously.[1] Omori had noticed similar tremors near some of the Japanese volcanoes. From their obvious connection with volcanic activity H. O. Wood called them volcanic vibrations. It was soon noticed, however, that there was no obvious connection between the outbreaks of the periodic fountain, "Old Faithful," in Halemaumau and the tremors as recorded at the Observatory 2.1 miles away. In general the tremors were most conspicuous during times of violent fountaining. The idea that such tremors are due to volcanic activity was confirmed when the seismographs that were installed in Hilo, 22 miles away, failed to record such tremors. When magmatic action totally ceased at Kilauea in 1924 the volcanic vibrations, as was to be expected, disappeared from the seismograms.

After seismograph drums with higher speed were installed at the Observatory in 1918, it was found that there were two types of tremors, one with a quite uniform period and amplitude and the other with a greater range in period and amplitude. To distinguish between the two, Dr. T. A. Jaggar in November, 1918[2] called the more rhythmic vibration "harmonic microtremor." This term was later shortened to "harmonic tremor." The less regular vibrations which often resemble miniature earthquakes were named "spasmodic tremor."[3] Austin E. Jones[4] divides spasmodic tremors into two classes and illustrates the two by idealized sketches. Mixed continuous tremor is recorded at the Observatory during Mauna Loa eruptions even though the source may be 22 miles away.

Harmonic tremor that was recorded under different conditions of the lava column at Halemaumau is shown in figure 1. In most cases the portion reproduced is typical of the tremor as recorded for days preceding and following the sample selected. *A* of figure 1 was taken when the lava lake was high and a flow was pouring on to the southwest floor of Kilauea through a tunnel the intake of which was a small distance below the Halemaumau rim. It is not likely that any of the tremors recorded were due to lava surging in this tunnel. *B* is from the record when lava was flowing at Makaopuhi and Napau craters along the Puna rift. Considering the small scale of these outbreaks and the indicated distance—over 7 miles—it seems probable that the tremors were due to lava surging in conduits under Halemaumau rather than from the seat of the outbreak. *C* shows a portion of the record in 1924 just preceding the explosive eruption of that year and at a time when no molten lava was visible. Numerous earthquakes along the Puna rift, the sinking of the lava column at Halemaumau, and harmonic tremor at this time indicated lava drainage through this rift. *D* is a portion of the record during the short-lived activity at Halemaumau starting on September 6, 1934. The especially large tremors were recorded during some of the most violent fountaining ever observed at Kilauea. Each spell of violent fountaining was usually followed by a rather quiet interval of about 30 minutes as shown by the two comparatively straight lines just below the lower large harmonic tremor. In this case there was a direct correlation between fountaining action in Halemaumau and harmonic tremor. This was due as Dr. T. A. Jaggar has explained[5] to a rather high viscosity of the lava and the inception of the fountains at the bottom of a shaft.

[1] H. O. Wood, "The Hawaiian Volcano Observatory," *Bulletin Seismological Society of America*, Vol. III, No. 1 (1913), p. 17.

[2] T. A. Jaggar, *Bulletin Hawaiian Volcano Observatory*, Vol. VI, No. 11 (Nov., 1918), p. 131.

[3] T. A. Jaggar, "Seismometric Investigations of the Hawaiian Lava Column," *Bulletin Seismological Society of America*, Vol. X, No. 4 (Dec., 1920), p. 264.

[4] Austin E. Jones, "Empirical Studies of Seismic Phenomena of Hawaii," *Bulletin Seismological Society of America*, Vol. XXVIII, No. 4 (Oct., 1938), p. 316.

[5] T. A. Jaggar, *Volcano Letter*, No. 415 (Sept., 1934).

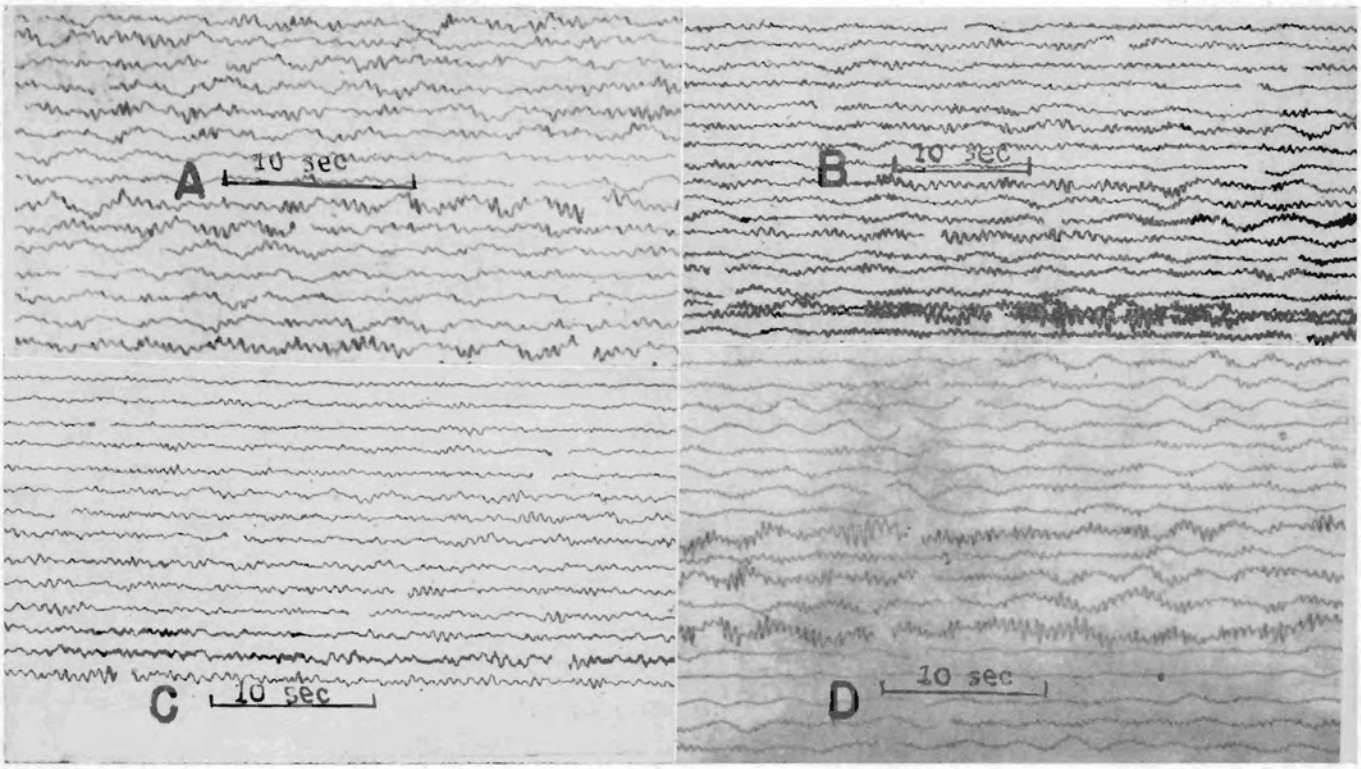

Fig. 1.—Harmonic tremor as recorded on the Bosch-Omori seismograph at Hawaiian Volcano Observatory, 2.1 miles northeast of Halemaumau. Travel from right to left. E-W component.

A. March 26, 1921—lava was high in Halemaumau and flowing in southwest part of Kilauea Crater. ×2½.
B. May 29, 1922—lava was flowing from the Puna rift. No lava was visible in Halemaumau. ×2⅓. Local earthquake is shown in second line from bottom.
C. May 8, 1924—no lava was visible in Halemaumau. Underground movement of lava in the Puna rift was suspected. ×2⅓.
D. September 30, 1934—was taken during lava activity lasting one month in 1934. The especially large tremors accompanied intermittent strong explosive fountaining. ×2½ (magnification of the seismogram, itself magnifying the earth motion about 100 times).

The absence of harmonic tremor at the time of the "False Eruption" on January 11, 1928, strengthens the belief that the small amount of lava which appeared on this date owed its appearance to being squeezed from a crusted pool of 1927 lava by a heavy landslide.

Harmonic tremor at Kilauea appears to be due to underground surging in feeding conduits below Halemaumau. If the surging is induced by the movement of very large gas bubbles in magma, then with a nearly stationary lava lake the bubbles moving through lake magma cannot set up harmonic tremor large enough to be recorded by the Observatory seismographs. When the surging takes place in a conduit of more or less restricted dimensions the solid walls of the conduit may be induced to vibrate with sufficient amplitude to be recorded. In general the tremor is larger when the magma column is falling than when rising.

Harmonic tremor affords good evidence of underground surging of lava whether magma is visible in the pit or not.

Hawaiian Volcano Observatory Report for January-March 1944

VOLCANOLOGY

January

The year opened with both Mauna Loa and Kilauea inactive. The number of Mauna Loa shakes exceeded those from Kilauea; records showed 43 and 39, respectively. The northeast rift of Mauna Loa was more active than the southwest one. The strongest shake during the month, which originated near Puu Ulaula on the NE rift of Mauna Loa on January 23, was generally felt over the southern part of the island of Hawaii.

At 2:00 p.m. on January 15, while on the road between Mauna Loa and Mauna Kea, A. L. Jess observed a distinct fume cloud with a faint yellow tinge over Mokuaweoweo.

Two landslides from the walls of Halemaumau were observed during the afternoon of January 19. Some more slides were observed during the latter part of the same week.

February

Despite the fact that the 4 perceptible earthquakes that occurred during February were of Kilauea origin, more seismic disturbances were recorded at Mauna Loa than at Kilauea; they were 41 and 33, respectively.

Clouds, lacking the characteristics of ordinary cumulus formation that frequently develops over isolated mountain peaks, were observed over Mokuaweoweo during the late afternoon of

February 7. On February 23, a white vapor cloud was visible above the radiation fog which capped Mauna Loa from 8:05 to 8:30 a.m. At other places humps in the fog marked the sites of hot spots in the crater floor.

March

While flying over Mauna Loa on March 30, Ranger Frank Hjort observed blue fume arising from Mokuaweoweo.

A total of 7 seismic disturbances was recorded in about 3 hours during the evening of March 29. Three of the shakes were strong enough to be felt locally. The series of shakes began with the strongest which dismantled the Bosch-Omori seismographs near Park Headquarters. The origin of the shakes was quite deep under the southern end of Kilauea Crater. Forty-four seismic disturbances were recorded at Kilauea and 59 at Mauna Loa.

The strong southerly wind of March 4 raised conspicuous dust clouds over the Kau Desert and adjacent cultivated fields of the Kapapala Ranch. Such winds—opposite in direction from those commonly observed transporting ash in the Kau Desert—though rare, may have been an appreciable factor in developing some soil over portions of the NE slope of Mauna Loa.

R.H.F.

SEISMOLOGY

Earthquake Data, January-March 1944

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Local Seismicity*	Teleseisms
January	2	4	0	0	0	1.00	0
	9	12	2	0	2	8.00	0
	16	8	2	0	0	3.00	0
	23	3	3	1	1	5.25	0
	30	3	1	0	0	1.25	0
February	6	0	7	0	3	9.50	0
	13	1	1	0	0	0.75	0
	20	7	0	0	0	1.75	0
	27	11	1	1	0	4.25	0
March	5	6	1	0	2	6.00	0
	12	4	1	0	0	1.50	0
	19	8	0	0	0	2.00	0
	26	8	3	0	0	4.50	0

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours and 30 minutes slower than Greenwich. The number preceding each earthquake date is the serial number of the quake for the current year.

1. January 4, 02:48, slight, northern end of Kilauea Crater.
2. January 5, 00:05, very feeble, Kilauea shake.
3. January 5, 04:47, very feeble, Kilauea shake.
4. January 7, 09:42, slight. Felt as a sharp jolt, NE end of Kilauea Crater.
5. January 10, 23:25, very feeble, SW part of Mauna Loa.
6. January 12, 20:04, very feeble, shallow focus NE rift of Mauna Loa, 12 miles SW of Hilo.
7. January 17, 01:00, very feeble, SW part of Mauna Loa.
8. January 22, 02:38, very feeble.
9. January 23, 14:40, slight, E-W dismantled, Mauna Loa instrument dismantled. Felt locally and Pahala, near Puu Ulaula.
10. January 23, 15:28, very feeble, probably same origin as No. 9.
11. January 23, 23:42, feeble, NE rift of Mauna Loa.
12. January 28, 17:23, very feeble, Mauna Loa instrument dismantled, NE rift of Mauna Loa.
13. February 1, 11:31, very feeble.
14. February 2, 19:18, very feeble, NE rift of Mauna Loa.
15. February 3, 01:02, slight, near SW end of Kilauea Crater.
16. February 3, 01:16, slight, under Kilauea Crater.
17. February 3, 01:19, very feeble, Kilauea shake.
18. February 3, 01:27, very feeble.
19. February 3, 01:28, slight, Kilauea Crater.
20. February 3, 03:37, very feeble, NE rift of Mauna Loa.
21. February 5, 21:49, very feeble, near Mokuaweoweo.
22. February 5, 23:32, very feeble.
23. February 8, 02:41, very feeble, SW rift of Mauna Loa.
24. February 22, 09:47, very feeble, near Mokuaweoweo.
25. February 27, 04:49, feeble, under Kilauea Crater.
26. February 29, 04:53, slight, E-W dismantled, underneath observatory.
27. March 3, 12:37, very feeble, E flank of Mauna Loa.
28. March 5, 09:39, slight, felt locally, NE rift of Mauna Loa.
29. March 8, 04:47, very feeble.
30. March 23, 10:36, very feeble, NE rift of Mauna Loa.
31. March 25, 10:45, very feeble.
32. March 25, 20:18, very feeble.
33. March 29, 19:54, slight, dismantled instruments, under southern end of Kilauea Crater.
34. March 29, 20:38, very feeble, same origin as No. 33.
35. March 29, 22:20, slight, probably same origin as No. 33, though initial wave was compressional in No. 35 and dilatational in No. 33.
36. March 29, 22:41, slight, similar to No. 35.
37. March 30, 00:55, very feeble.

TELESEISMS

With the exception of what appeared to be feeble long waves of two teleseisms recorded in the midst of large microseisms on March 6, no teleseisms were recorded during the quarter.

MICROSEISMS

Microseisms were strong on February 12, and March 4, moderate on February 20, March 4, and 5. Throughout the rest of the quarter microseisms were present though slight.

Tilting of the Ground

Normal southwesterly tilt started early in January and continued throughout the quarter. The direction of tilt was really south-southwest as westerly tilt was less than normal and southerly tilt above the average. In fact southerly tilt for the first three months of 1944 exceeded that for similar periods of every year since 1937. If, as seems probable, easterly tilt correlates with increase in internal pressure under Mauna Loa the less than normal westerly tilt indicates a sustained high pressure under that mountain. There were some fluctuations in the direction of tilt at the stations near the rim of Halemaumau.

Table of Tilt at Observatory on NE Rim of Kilauea

Week Ended		Amount of Tilt	Direction of Tilt
January	2	1.14″	N 58° E
	9	0.60″	N
	16	2.30″	S 25° W
	23	0.65″	S 22° W
	30	1.45″	S
February	6	0.33″	S 45° W
	13	0.53″	S 68° E
	20	1.09″	S 27° E
	27	1.74″	S 33° W
March	5	1.27″	S 17° E
	12	3.60″	S 39° W
	19	0.44″	S 34° W
	26	1.46″	S 5° W

Crack Measurements

There was a slight opening of 5 of the cracks around Halemaumau though most of those measured showed no movement. No movement was detected in the cracks at the Devil's Throat and along the Chain of Craters Road. R.H.F.

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THE VOLCANO LETTER

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HAWAII NATIONAL PARK: Edward G. Wingate, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

RADIO TRANSMISSION OF EARTHQUAKE RECORDS

By ROBERT J. STRATTON[1]
Federal Communications Commission
Radio Intelligence Division

Time control for several of the seismographs operated by the Volcano Observatory of the Hawaii National Park is obtained by a phantom circuit on Park telephone lines.[2] The location of outlying seismographs is determined by existing roads and telephone lines. This leaves a vast expanse of Mauna Loa where it is impractical to locate ordinary seismographs. If all the instruments could be made to register at one central point continuously, much travel could be avoided.

The use of radio at once suggests itself as a possible solution. The radio seismographs could be made to record on one shaft and the problem of synchronizing would be solved. Also in the case of a disturbance, records would be immediately available at the Observatory.

Radio links for the remote recording of seismographs were utilized in 1931 by Seizo Haeno.[3] He developed a short-distance, short-time scale instrument based upon the principle of frequency modulation for use in geophysical prospecting. His transmitter was a simple self-excited oscillator in which the capacity in the tank circuit was varied by the displacement of the seismograph mass. His receiver was an equally simple Tuned Radio Frequency receiver tuned off resonance and using galvanometer recording. This system was sufficiently stable for geophysical work since the recording run is normally only for a few minutes. It would not be stable, however, for continuous recording because of frequency drift.

Frequency stability could be gained by using crystal controlled transmitters. Moreover, the frequency of a crystal oscillator may be varied within limits by the use of a variable capacity across the crystal. It is proposed, therefore, that each element of the outlying Hawaiian Volcano Observatory seismographs should be equipped with a low-powered, battery-operated, crystal-controlled transmitter as shown in figure 1. Each transmitter would be far enough separated from the others in frequency so that mutual interference would be avoided. The variable "seismograph" condenser shown in figure 1 would have its rotor plates attached to the movable arm of the seismograph, while the stator plates would be attached to the seismograph frame. Any movement of the arm, however slight, would cause a corresponding change in the frequency of the oscillator. This is, of course, nothing more than frequency modulation of the rest-position carrier.

Several of the Hawaiian Volcano Observatory seismograph stations are within reach of A.C. power lines. The radio transmitters at these stations could be supplied from A.C. power in conventional ways. Some of the Hawaiian Volcano Observatory seismograph stations, both present and proposed, are in remote areas and would necessarily be battery operated. With the proper choice of frequency, tubes, and oscillator design, the use of number 6 dry cells for filament supply and 45 volt B-batteries for plate supply would be economically possible.

The continuously emitted signal would be received with a well-designed Tuned Radio Frequency receiver as shown in figure 2. As shown in the diagram, the amplified radio frequency output of this receiver is fed into a Wheatstone bridge which is

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[1] The author is indebted to Mr. Guy Omer for finishing this manuscript and drawings.—R.H.F.

[2] Waesche, H. H. "Time Controls for Seismographs Operated by the Hawaiian Volcano Observatory." *Volcano Letter* No. 464 (April-June 1939).

[3] Haeno, Seizo. "The Radio-Seismograph," *Japanese Journal of Astronomy and Geophysics*. Vol. VIII, (1931), pp. 39-50.

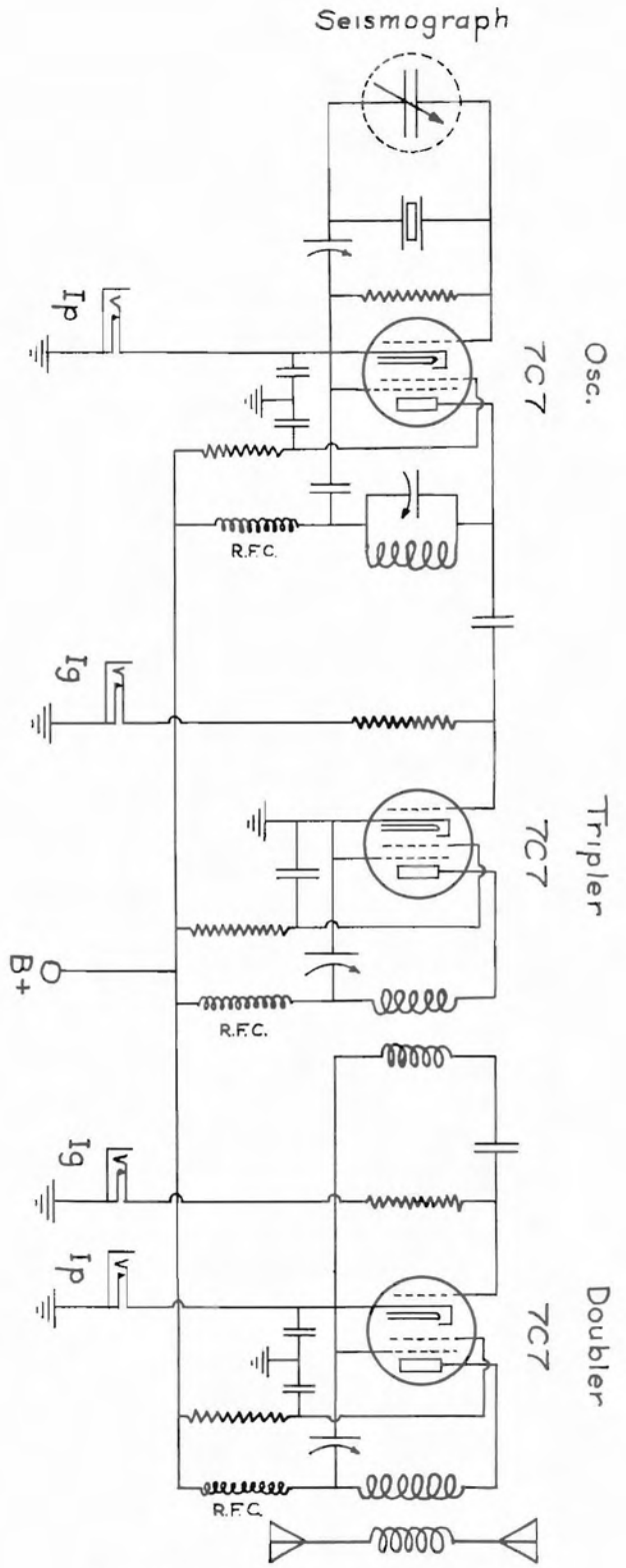

Fig. 1—Transmitter for radio seismograph.

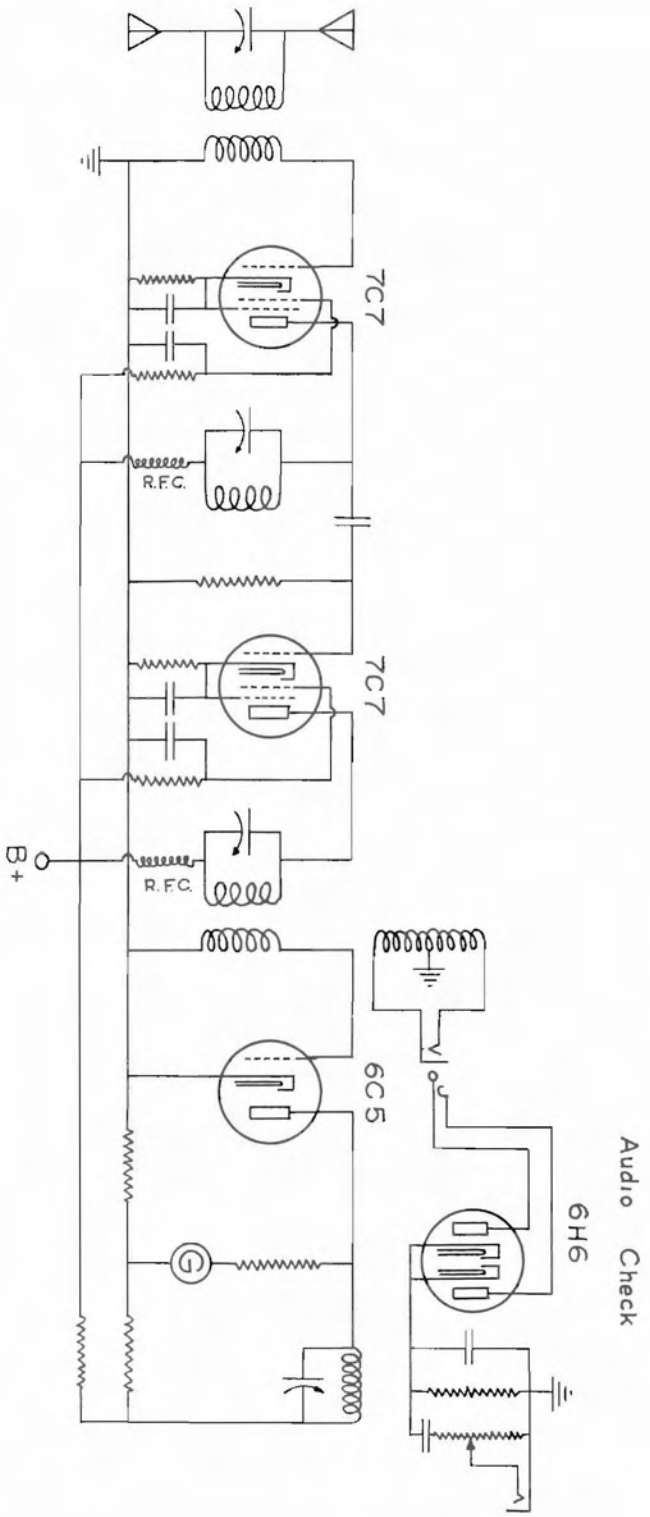

Fig. 2—Receiver for radio seismograph.

balanced at the rest-position carrier frequency. When the seismograph arm is displaced, the frequency changes, the bridge is then unbalanced, and the galvanometer is deflected. For proper operation, of course, the parallel tuned circuit in the bridge must be tuned far enough away from the rest-position frequency so that it presents a linear rising impedance over the modulation range. The actual production of the seismograph record would be by optical recording by a pin-point beam of light, reflected from the galvanometer mirror onto a continuously moving photographic film.

This system, of course, requires a separate receiver and recording chain for each transmitter. All of the receiving and recording equipment at the Observatory would be A.C. operated.

The recording of tilt is much simpler. The proposed plan for this also makes use of the principle of varying the frequency of an oscillator but with a different application. Since the change in tilt is very slight over a considerable period of time, no rapidly variable indicating instrument is necessary. For this purpose, it is proposed to use two crystal oscillators with a difference of frequency of 440 cycles per second. Only one of these oscillators will be equipped with a variable capacity as described in figure 1. The other oscillator remains constant. It then is apparent that, with the arm of the tilt instrument at center position, the two oscillators will beat against each other producing a resultant audio tone of 440 cycles. Any change in the position of the movable arm on the tilt instrument will vary the resultant tone. If the tilt is in one direction, the tone will be raised. If in the other, the tone will be lowered. The Bureau of Standards Station WWV can always be heard in this area on a frequency of either 15 mc., 10 mc., or 5 mc. depending on the time of day. This station transmits a tone standard of 440 cycles which is accurate to 0.000001 cycles per second. With this as a standard any change in the pitch of the beat of the tilt oscillators can be determined as can the direction of the tilt.

The selection of frequencies for all of these transmitters is quite important, both from the point of possible outside interference and of propagation characteristics. The latter point offers no particular difficulty for this location since all of the seismograph locations are within "line of sight" of the Observatory. Therefore, in order to avoid possible interference from extraneous signals, the use of frequencies around 50 to 60 mc. is indicated. Theoretically, no difficulty should be encountered in the use of this band of frequencies, although experiment may prove otherwise. Higher frequencies require the use of more tubes with the corresponding higher battery drain.

Owing to conditions incident to the war, it has not been possible to test the above ideas experimentally.

Hawaiian Volcano Observatory Report for April-June 1944

VOLCANOLOGY

April

Blue fume was observed over Mokuaweoweo on March 30 and again on April 1. The only other surface activity observed at Kilauea and Mauna Loa was the usual steaming. The number of steam vents as well as the amount of steam escaping at Kilauea and Mauna Loa is essentially the same as at the commencement of continuous observations in 1912.

No earthquake strong enough to be felt locally was experienced in April. Eighteen small seismic disturbances were recorded at Kilauea and 44 at Mauna Loa.

There were several small landslides from the walls of Halemaumau.

May

A conspicuous steam cloud that was observed over the lower part of the 1942 lava flow from Mauna Loa shows that the lava was still hot 2 years after it was erupted.

May continued the seismic quiet of the last several months. The Mauna Loa seismograph registered 48 seismic disturbances while the number recorded at Kilauea was 28.

June

The seismic lull that was especially noticeable in April and May continued through June. No perceptible earthquakes were recorded at the Observatory. Twenty-three seismic disturbances were recorded at Kilauea and 44 at Mauna Loa. A majority of the shakes distinct enough to show phases originated on the northeast slope of Mauna Loa at shallow depths. R.H.F.

SEISMOLOGY

Earthquake Data, April-June 1944

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Local Seismicity*	Teleseisms
April	2	8	2	0	3	10.00	0
	9	4	0	0	0	1.00	0
	16	5	0	0	0	1.25	0
	23	3	3	0	0	2.25	1
	30	2	1	0	0	1.00	0
May	7	8	0	0	0	2.00	0
	14	7	0	1	0	2.75	0
	21	1	0	0	0	0.25	0
	28	2	2	0	0	1.50	2
June	4	6	3	1	0	4.00	0
	11	6	1	0	0	2.00	0
	18	6	1	0	0	2.00	0
	25	4	1	0	0	2.00	0

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours and 30 minutes slower than Greenwich. The number preceding each earthquake date is the serial number of the quake for the current year.

38. April 19, 17 : 43, very feeble. 40 miles SE.
39. April 20, 06 : 03, very feeble. NE rift of Mauna Loa.
40. April 22, 08 : 15, very feeble. NE rift of Mauna Loa.
41. April 26, 08 : 23, very feeble.
42. May 12, 17 : 27, feeble. Deep under the northeastern rim of Kilauea crater.
43. May 23, 21 : 07, very feeble. SW flank of Mauna Loa.
44. May 28, 20 : 40, very feeble. Felt at Naalehu and Pahala. SW rift of Mauna Loa.
45. May 29, 04 : 21, feeble. Felt locally and at Pahala. East flank of Mauna Loa.
46. May 29, 04 : 27, very feeble. High up NE rift of Mauna Loa.
47. May 31, 14 : 12, very feeble.
48. June 1, 11 : 09, very feeble.
49. June 9, 12 : 01, very feeble.
50. June 16, 01 : 09, very feeble.
51. June 21, 17 : 34, very feeble. Near Puu Ulaula on NE rift of Mauna Loa.
52. June 23, 00 : 13, very feeble. NE rift of Mauna Loa.

TELESEISMS

May 23, 04 : 30, slight.
May 25, 02 : 38, moderate. 6600 km. New Ireland.
June 16, 11 : 42, slight.
June 27, 21 : 56, slight.

MICROSEISMS

Microseismic motion was quite uniformly slight throughout the quarter.

TILTING OF THE GROUND

Southerly tilt was more pronounced during the first three months of 1944 than for the corresponding period in the last several years. The total, however, was not unusual as northerly tilt set in on April 1, or over a month earlier than common.

Table of Tilt at Observatory on NE Rim of Kilauea

Week Ended		Amount of Tilt	Direction of Tilt
April	2	0.75″	S 56° W
	9	0.12″	E
	16	0.44″	N 56° W
	23	1.77″	N 16° E
	30	1.31″	S 67° W
May	7	1.36″	N 80° W
	14	0.74″	N 70° E
	21	0.74″	N 70° W
	28	0.24″	N
June	4	0.44″	N 34° W
	11	0.98″	S 30° W
	18	0.17″	N 45° W
	25	0.55″	N 64° E

CRACK MEASUREMENTS

There was but little movement of the cracks at the Devil's Throat and along the Chain of Craters Road. The cracks near Halemaumau opened slightly in April and June and were stationary during May. R.H.F.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
in cooperation with UNIVERSITY OF HAWAII

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The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** supplement the work of the government with research associates, instrumental plants and special investigation. Dr. T. A. Jaggar is their geophysicist resident in the National Park.

The **Volcano Letter**, a quarterly record of Hawaiian volcano laboratories and published by the University of Hawaii, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the above establishments.

THE VOLCANO LETTER

No. 485 **Department of Interior** **National Park Service** **July-September 1944**

PUBLISHED BY THE UNIVERSITY OF HAWAII

HAWAII NATIONAL PARK: Edward G. Wingate, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist



OUTPUT CHANGES IN KILAUEA STEAM VENTS

By GUNNAR O. FAGERLUND
Naturalist and Chief Ranger
Hawaii National Park

There is some evidence that the volume of steam from vents at the northern end of Kilauea Caldera has decreased in the last 100 years.

In 1823 Ellis[1] reported pools of water there adjacent to and on the lee side of steaming chasms. These condensation pools could exist only with much greater steam volume than there is at present. The pools subsisted during rainless periods. However, the 1790 explosion may have provided an impervious ash layer that helped in pool formation for many years.

Accompanying Kilauea activity in 1886, the steaming at Sulphur Bank fluctuated for a short period. First the steam temperature increased, then the steaming almost ceased, and finally normal temperature and volume resumed.[2] Normally the volume and temperature of the steam change little if any to correlate with Halemaumau activity.

Gordon A. Macdonald[3] states: "The distribution of altered rock and deposits of sulfur and salts, indicates that solfataric activity was once more extensive than now. Some migration of the active vents occurs."

Photographic stations have recently been established for photographing the steaming vents. Photographs taken at ten-year or greater intervals under nearly identical conditions of humidity, air temperature, and wind velocity should show whether or not the steam volume is changing.

The visibility of the vapor varies with different conditions of air temperature, humidity, and wind velocity. Actually the amount of water vapor escaping from any one vent is nearly constant. Figures 1 and 2 show visibility difference under somewhat different air conditions, but by no means do they show the maximum visibility contrast. On warm, sunny days with comparatively low humidity, some vents produce no visible vapor, while on cold damp days the same vents produce conspicuous vapor clouds. Even during a single clear day a marked contrast may be seen between early morning or evening and noon visibility of the vapor. On cold days the vapor density of the steam increases and its increased condensation forms conspicuous fog clouds. An increase in the number of hygroscopic nuclei also causes greater condensation. This fact can be demonstrated by directing tobacco smoke into steam vents where no vapor is visible. This causes a visible cloud to appear instantly. It is by this effect of nuclei that air humidity influences vapor visibility. Wind also affects visibility by dispersing and evaporating the fog.

Though air conditions affect the vapor visibility most markedly, a difference exists too when vapor is viewed in transmitted and in reflected light; this is most manifest when the sun is low. The greater visibility is in transmitted light. There is also a color difference—the vapor appearing bluish in reflected light and trending toward the red end of the spectrum in transmitted light.

The making of reliable photographic records of the vapor volume output from the steaming vents must take into account all the conditions that affect the visibility, or more precisely the photoactinicity, of the vapor. Pictures taken at intervals to show change, if any, in the actual steam volume output must

[1] ELLIS, WILLIAM. THE JOURNAL OF WILLIAM ELLIS. P. 179. Hawaiian Gazette Co., Ltd., Honolulu. 1917.

[2] BRIGHAM, WILLIAM T. THE VOLCANOES OF KILAUEA AND MAUNA LOA. Bernice P. Bishop Museum Memoirs. 2(4):162. 1909.

[3] MACDONALD, GORDON A. SOLFATARIC ALTERATION OF ROCKS AT KILAUEA VOLCANO. Am. Jour. Sc. 242(9):497. 1944.

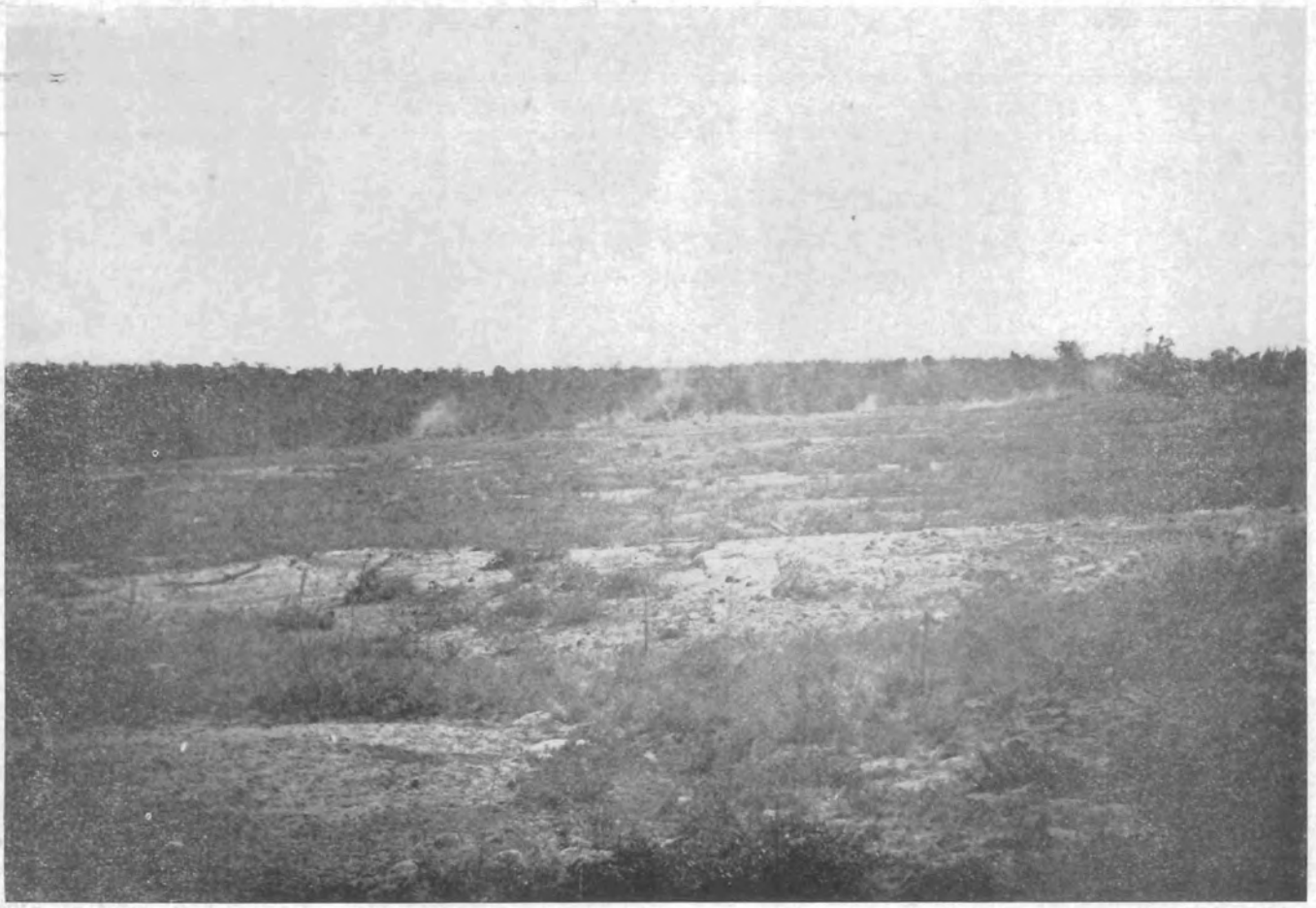

Figure 1.—Vapor issuing from vents west of Sulphur Bank. Photographed on November 19, 1944, with air temperature 62° F., humidity 68%, wind velocity 8 to 10 m.p.h. (Photographic station located on steaming flat 80 feet north of road, on line 12°49′ left from Uwekahuna to Observatory bench marks.)

be taken under nearly identical air and light conditions, with similar color sensitive film, and printed on similar paper. It would be advisable to use similar processing methods.

A factor that will affect the reliability of photographic records, and therefore should be given attention, is the pulsating manner in which the steam issues from the vents. The photographs herein were exposed as near to the instant of maximum output for the existing conditions as could be determined. The effect of the pulsating action becomes less as the distance between the vent and the camera increases. The volume of vapor recorded on a photograph encompassing considerable horizontal and vertical distances, as in the illustrations herein, would be little if at all affected by the pulsating action, except in high wind velocity.

Hawaiian Volcano Observatory Report for July-September 1944

VOLCANOLOGY

July

The seismic quiet of the last several months continued through July. No earthquakes strong enough to be perceptible at the Hawaiian Volcano Observatory were recorded though some shakes were felt at Kapapala 17 miles to the southwest. Thirty-two seismic disturbances were recorded at Kilauea and 58 at Mauna Loa.

August

A conspicuous fume cloud was observed over Mokuaweoweo from Puu Ulaula on August 12. A similar cloud was observed from the rim of Mokuaweoweo during the afternoon and evening of August 14. No glow was detected. By morning of August 15, however, nothing but the usual steaming was noted. On August 31, another conspicuous cloud was observed from the rim of Mokuaweoweo. During the fuming spell of August 12 to 14, two sharp earthquakes were felt at Puu Ulaula. The seismograph indicated that these shakes, like many that have been recorded here during the past year, occurred at very shallow foci along the upper northeast rift of Mauna Loa. Fourteen seismic disturbances were recorded at Kilauea and 56 at Mauna Loa.

September

Unusually heavy steam clouds were observed over Mokuaweoweo during the afternoons of September 11, 12, and 16. Three of the 19 earthquakes recorded at Kilauea were strong

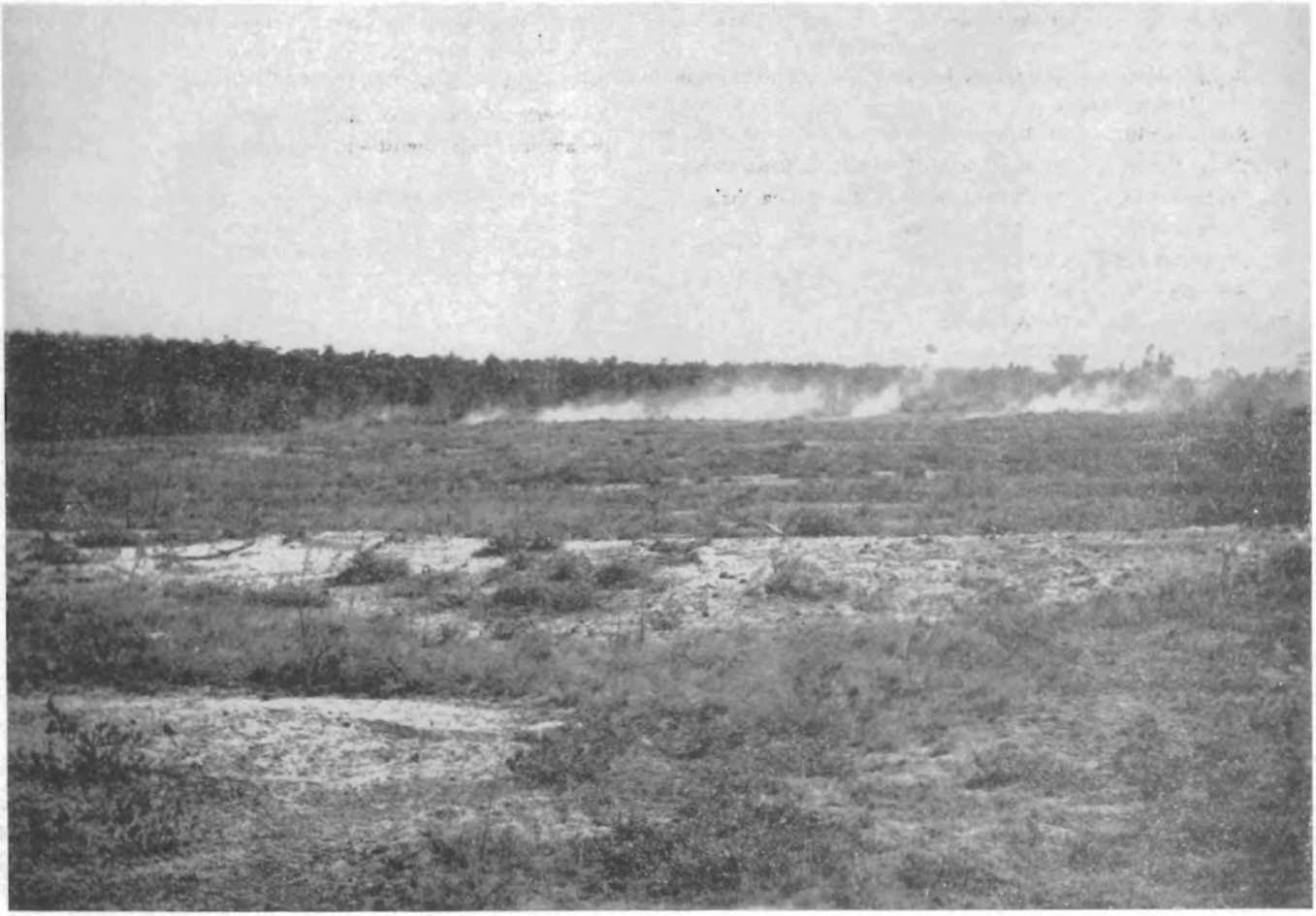

Figure 2.—Vapor issuing from same vents as in Figure 1, showing the higher visibility associated with somewhat lower temperature and higher humidity. Photographed on December 18, 1944, with air temperature 54° F., humidity 81%, wind velocity 10 to 15 m.p.h. (Photographic station the same as for Fig. 1.)

enough to be felt locally. They appear to have originated under the northern end of Kilauea crater. A majority of the 48 shakes recorded at Mauna Loa originated along the northeast rift. R.H.F.

SEISMOLOGY

Earthquake Data, July-September, 1944

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Local Seismicity*	Teleseisms
July	2	5	0	2	0	3.25	1
	9	4	1	0	0	1.50	0
	16	2	3	0	0	2.00	0
	23	5	4	0	0	3.25	2
	30	3	0	0	0	0.75	1
August	6	3	2	1	0	2.75	0
	13	0	0	1	0	1.00	1
	20	4	0	0	0	1.00	1
	27	1	2	0	0	1.25	0
September	3	1	1	0	0	0.75	1
	10	1	2	1	1	4.25	0
	17	1	0	0	0	0.25	0
	24	5	4	0	1	5.25	1

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours and 30 minutes slower than Greenwich. The number preceding each earthquake is the serial number of the quake for the current year.

53. July 1, 16:00, feeble. In hour mark.
54. July 2, 20:48, feeble. In NW Hawaii.
55. July 6, 22:23, very feeble.
56. July 14, 10:47, very feeble.
57. July 16, 01:01, very feeble.
58. July 16, 16:01, very feeble.
59. July 18, 01:01, very feeble. NE rift Mauna Loa.
60. July 20, 07:53, very feeble. Eastern slope of Mauna Loa.
61. July 22, 08:30, very feeble. NE rift of Mauna Loa.
62. July 22, 21:52, very feeble. In NW Hawaii.
63. July 31, 22:33, very feeble.
64. August 2, 00:04, very feeble. NE rift of Mauna Loa.
65. August 5, 18:53, feeble. SW slope of Mauna Loa.
66. August 7, 10:53, feeble. NE rift of Mauna Loa.
67. August 22, 06:15, very feeble. Lower NW slope of Mauna Kea.
68. August 23, 01:32, very feeble.
69. August 30, 08:47, very feeble.
70. September 4, 16:18, slight. Felt locally. Northern end of Kilauea crater.

71. September 7, 16:36, feeble. Felt locally. Northern rim of Kilauea. Accompanied by a rumble.
72. September 9, 09:14, very feeble. Near northern end of Mokuaweoweo.
73. September 10, 21:37, very feeble.
74. September 18, 00:06, slight. Felt locally. Kilauea crater.
75. September 18, 10:01, very feeble. Mauna Loa shake.
76. September 18, 19:33, very feeble.
77. September 19, 22:45, very feeble.
78. September 23, 02:52, very feeble.
79. September 29, 09:05, feeble.
80. September 29, 09:20, very feeble.
81. September 30, 18:34, very feeble.

TELESEISMS

July 19,	00:36, slight.	Off Japan.
July 20,	02:12, slight.	
July 26,	13:41, slight.	Off Aleutians.
August 9,	15:40, slight.	Off British Columbia.
August 18,	00:13, slight.	Japan.
September 3,	09:04, slight.	
September 23,	01:52, slight.	5400 km.

MICROSEISMS

Microseisms were present though slight throughout the quarter.

TILTING OF THE GROUND

Very slight westerly tilt prevailed during July and until August 20, when normal easterly tilt set in and continued through the rest of the quarter. The time of change from west to east tilt in 1944 corresponds to that of 1941, 1942, and 1943 though it is more usual for the change to occur during the spring. Northerly tilt was continuous throughout the quarter though the amount from August 4 to September 30 was less than normal.

Table of Tilt at Observatory on NE Rim of Kilauea

Week Ended		Amount of Tilt	Direction of Tilt
July	2	0.51″	N 15° E
	9	0.62″	N 79° W
	16	0.62″	N 11° E
	23	0.37″	N 45° E
	30	0.86″	N 45° W
August	6	0.74″	N 10° E
	13	0.85″	N
	20	0.65″	S 68° W
	27	0.87″	N 74° E
September	3	0.54″	N 27° E
	10	0.39″	S 71° E
	17	0.48″	W
	24	1.60″	S 81° E

CRACK MEASUREMENTS

There was practically no movement at any of the cracks measured during July and August. A majority of the cracks around Halemaumau opened slightly during September, and at the Devil's Throat and along the Chain of Craters Road a few showed a slight opening. R.H.F.

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THE VOLCANO LETTER

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HAWAII NATIONAL PARK: Edward G. Wingate, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

THE NOVEMBER-DECEMBER 1944 CRISIS AT KILAUEA

By R. H. FINCH

For over a year and a half the seismographs and tilt records have indicated a fairly high pressure under the Kilauea-Mauna Loa volcano system. In November, 1943, Mauna Loa produced several rather conspicuous fume clouds.[1] In August, 1944, fuming greater than the normal from Mokuaweoweo was observed.

It was not surprising then to find Kilauea showing definite signs of uneasiness starting with an earthquake on November 12 that originated 8 to 10 miles below the southwest rim of Halemaumau. The history of Kilauea indicates that some form of activity might be expected at any time now. In a press release dated September 13, 1943, the following statement was made: "If the present period of volcanic activity is to parallel the probable sequence following the 1790 explosive eruption, lava activity at Kilauea or Mauna Loa, or both, may be expected about the middle of this decade."

It has been over ten years since molten lava was present in Halemaumau. This is the longest period of inactivity in the recorded history of Kilauea. This is not overlooking the thirteen more or less quiet years from 1894 to 1907. During this thirteen-year period molten lava was visible for short intervals on several occasions, and considerable fume was always present. The longest period of total inactivity was the three years from July, 1924, to July, 1927. The interval between the last activity which started on September 6, 1934, and the next previous outbreak was two years and eight months or well above the average of such intervals since molten lava disappeared from Halemaumau in 1924. It is interesting to note that the 1934 outbreak was the most gaseous and lasted the longest of any of the short-lived outbreaks that have occurred since 1924. It might be expected then that a return of activity to Halemaumau will be marked by high pumice producing fountains.

On November 15, 1944, there was another earthquake with about the same epicenter as the one on November 12, but with a much more shallow focus. From November 15 until December 6 there were a few scattered Kilauea shakes with indications of a more or less progressive decrease in depth of foci. Two earthquakes on November 29 that were felt as sharp jolts at Halemaumau and recorded as feeble or slight shakes only at the Observatory twenty-two miles away were obviously of very shallow foci. The fact that the earthquakes occurred as separate shakes, often several days apart, rather than in swarms is what might be expected if molten lava were rising in the feeding conduits under Halemaumau.

At the Observatory, on the northeast rim of Kilauea, the northeast tilt was but little more than normal for this season of the year though rather definitely indicating a pressure increase under Kilauea. Beginning about the 12th of November, however, tilt instruments near Halemaumau showed a pronounced tilt; this indicated that the crater floor was doming appreciably with the maximum rise in the vicinity of the southern edge of Halemaumau. The amount of tilt during the last week in November at the Halemaumau tilt cellars is not known since the index of each instrument went completely off the scale and was stopped by horizontal braces.

[1] FINCH, R. H. ACTIVITY AT MAUNA LOA IN NOVEMBER 1943. Volcano Letter No. 482. October-December, 1943.

The focus of application of the force producing this final spurt of tilting must have been rather high to produce such marked effects near Halemaumau and so comparatively little effect at the Observatory.

The retreat of the lava column also indicates that a high level of the molten magma was reached. By the morning of December 7, both Halemaumau tilt instruments had gone completely off their scales and were resting against their frames. In this case the direction was the opposite of that during November; this indicated a sinking of the crater floor. The rapid sinking of the crater floor occurred on December 6 and 7, but a sharp southerly tilt did not start in at the Observatory until December 21. This southerly tilt continued until December 30 and amounted to 3.6 seconds of arc.

The earthquake pattern accompanying this minor 1944 crisis is rather typical. First one or two rather strong shakes of appreciable depth occurs marking the introduction of lava to the conduits under Halemaumau. (The earthquake of November 12 appears to have been of this type.) Then follow scattered lighter shakes of decreasing depth of foci accompanying the upsurge of molten lava. The spreading apart of walls of fissures and introduction of hot lava and gases reduce the tendency of seismic grating. At times of rapid recession of the lava column and appreciable subsidence of the crater floor, earthquakes are numerous. Twenty-nine earthquakes occurring between 08:30 December 6 and 13:50 December 7 accompanied the suspected 1944 recession.

The uneasiness manifested at Kilauea in the autumn of 1944 was the most conspicuous indication of fairly high internal activity that has been observed since the 1934 outbreak. It should be borne in mind that lava pressure in a volcano conduit can vary through a large range without any lava appearing at the surface. Whether molten magma reaches the surface or not depends upon, among other things, the duration of high pressure and the amount of lava involved in any particular upsurge.

Hawaiian Volcano Observatory Report for October-December 1944

VOLCANOLOGY

October

Mauna Loa and Kilauea were both quiet throughout October, Forty-eight seismic disturbances were recorded at Mauna Loa and 26 at Kilauea. Four shakes were felt at the Observatory and six were felt at Hilo. The number of distinctly Mauna Loa shakes was the smallest for the last several months.

November

For the first time in several months more earthquakes of Kilauea than of Mauna Loa origin were registered. The fact that 36 seismic disturbances were recorded at Mauna Loa and 35 at Kilauea does not show the true relative seismicity because most of the Kilauea shakes were recorded at Mauna Loa and several of the Mauna Loa shakes did not register at Kilauea. Starting with an earthquake on November 12 that was widely felt on the island of Hawaii, Kilauea showed distinct signs of uneasiness. The origin of the shake was 8 to 10 miles below the surface to the southwest of Halemaumau. On November 15, there was another Kilauea shake with about the same epicenter but with more shallow focus. A progressive decrease in depth of foci of earthquake continued until the end of the month. The tilt instruments on the crater floor indicated a distinct doming of the crater floor with the maximum rise in the vicinity of the southwest rim of Halemaumau.

December

The uneasiness of Kilauea continued until December 6. A series of earthquakes that started on this day and tilt indications of subsidence of the crater floor in the vicinity of Halemaumau clearly showed that a return of lava to the fire pit of Kilauea could not be expected.

A strong earthquake on December 27 caused Mauna Loa again to be the main center of interest. This quake as well as four others that followed within 3 days originated about 15 miles below the eastern rim of Mokuaweoweo. There was a slight migration of epicenters in a northeasterly direction in this series of shakes as though they followed along a fault block connecting southwest and northeast branches of the fundamental Hawaiian rift.

The strong earthquake of December 27 started many landslides at Halemaumau. The largest produced a roar that was audible 3 miles away, which was reminiscent of the explosions in 1924. R.H.F.

SEISMOLOGY

Earthquake Data, October-December 1944

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
October	1	0	2	1	0	0	0	02.00	0
	8	3	3	1	1	0	0	05.25	1
	15	2	0	2	0	0	0	02.50	0
	22	3	1	1	0	0	0	02.25	0
	29	3	0	1	0	0	0	01.75	0
November	5	4	2	2	0	0	0	04.00	0
	12	4	3	0	0	1	0	05.50	0
	19	6	0	1	0	1	0	05.50	1
	26	3	2	2	1	0	0	05.75	1
December	3	8	0	3	1	0	0	07.00	0
	10	15	13	2	2	0	0	18.25	1
	17	6	4	0	0	0	0	03.50	0
	24	1	2	0	0	0	0	01.25	0
	31	12	6	0	1	2	1	18.00	3

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours and 30 minutes slower than Greenwich. The number preceding each earthquake is the serial number of the quake for the current year.

82. October 2, 17:27, slight. Deep focus, near Ookala.
83. October 4, 15:22, very feeble.
84. October 6, 14:30, feeble.
85. October 6, 14:40, very feeble. Probably same origin as No. 84.
86. October 7, 14:41, very feeble.
87. October 11, 21:11, feeble. Felt locally, under Mokuaweoweo.
88. October 11, 21:12, feeble. Felt locally. Probably same origin as No. 87.
89. October 17, 13:54, feeble. Felt in Hilo, Mauna Kea.
90. October 17, 14:52, very feeble.
91. October 29, 17:17, feeble. Felt locally and in Hilo, Mauna Kea.
92. October 31, 04:26, feeble. Felt in Hilo.
93. October 31, 04:28, feeble. Felt in Hilo.
94. October 31, 04:32, very feeble.
95. November 5, 01:46, very feeble. Kilauea shake.
96. November 8, 02:16, very feeble.
97. November 8, 02:18, very feeble.
98. November 9, 08:25, very feeble.
99. November 12, 04:56, moderate. Widely felt in southern half island of Hawaii. Eight to 10 miles deep to the SW of Halemaumau. Dismantled seismograph at Hilo and Kona as well as at the Observatory.
100. November 15, 18:19, moderate. Felt locally. About same epicenter as No. 99 but with shallower focus.
101. November 15, 19:33, feeble. Felt locally. Origin at NE rim of Kilauea.
102. November 22, 22:53, slight. Under Kilauea.
103. November 23, 13:43, feeble. SW of Halemaumau.
104. November 23, 21:16, very feeble.
105. November 26, 00:48, very feeble.
106. November 26, 13:02, feeble.
107. November 28, 00:43, feeble.
108. November 29, 09:34, feeble. Felt as a sharp jolt at Halemaumau.
109. November 29, 09:36, slight. Felt as a sharp jolt at Halemaumau.
110. December 2, 00:17, feeble. Under Kilauea.
111. December 6, 07:38, very feeble. Under Kilauea.
112. December 6, 08:08, very feeble. Same as No. 111.
113. December 6, 09:47, feeble. Same as No. 112.
114. December 6, 11:51, very feeble.
115. December 6, 11:54, very feeble.
116. December 6, 19:29, very feeble. Under Kilauea.
117. December 6, 22:07, very feeble. Same as No. 116.
118. December 7, 00:58, very feeble. Same as No. 116.
119. December 7, 02:51, very feeble. Same as No. 116.
120. December 7, 05:15, very feeble.
121. December 7, 07:17, slight. Felt locally. Under Kilauea.
122. December 7, 08:46, very feeble. Accompanied by rumble audible at Halemaumau rim.
123. December 7, 11:18, very feeble.
124. December 7, 11:22, very feeble. Under Kilauea.
125. December 7, 11:39, feeble. Same as No. 124.
126. December 7, 12:50, slight. Same as No. 124.
127. December 9, 12:40, very feeble. Under Kilauea.
128. December 11, 22:01, very feeble.
129. December 15, 16:17, very feeble.
130. December 16, 15:08, very feeble. Kilauea shake.
131. December 16, 23:45, very feeble.
132. December 18, 10:38, very feeble. Kilauea shake.
133. December 21, 00:36, very feeble.
134. December 26, 09:35, very feeble. Probably Mauna Loa origin.
135. December 27, 03:42, strong. Dismantled all seismographs on island of Hawaii. Plainly felt on Oahu. Some objects toppled from shelves at places as widespread as Pepeekeo and Naalehu, stone fences were thrown down in vicinity of Hilea. Origin about 15 miles below eastern edge of Mokuaweoweo.
136. December 27, 04:21, very feeble. Same as No. 135.
137. December 27, 04:27, very feeble.
138. December 27, 05:46, slight. E-W instruments dismantled the same as by No. 135.
139. December 30, 09:21, moderate. Instruments dismantled the same as by No. 135.
140. December 31, 11:10, moderate. Instruments dismantled near Wood Valley. Twelve to 14 miles deep.
141. December 31, 19:53, very feeble.

TELESEISMS

October 5, 07:07, very slight. 4790 km.
November 16, 02:13, near Solomon Islands.
November 23, 16:26, slight.
December 6, 18:16, moderate. 3700 miles, Japan.
December 29, 12:50, slight.
December 29, 13:39, slight.
December 30, 11:47, slight.

MICROSEISMS

Microseismic motion was strong on October 12 and 13, moderate from October 14 to 20, 27 to 30, and on November 23. Throughout the rest of the quarter microseisms were present though slight.

TILTING OF THE GROUND

Northerly tilt was normal to the north in October, above the normal during the first three weeks in November, and about normal to the north until December 21, when a pronounced southerly tilt set in that continued until the end of the month. Easterly tilt was about normal in October and November. From December 6 to 26 there was a slight westerly tilt. A distinct east tilt accompanied the strong Mauna Loa earthquake of December 27, then the seasonal westerly tilt started.

Table of Tilt at Observatory on NE Rim of Kilauea

Week Ended		Amount	Direction
October	1	1.50″	N 14° E
	8	1.11″	N 40° E
	15	1.03″	S 45° E
	22	1.23″	N 11° E
	29	0.34″	N 45° E
November	5	1.75″	N 34° E
	12	0.72″	N
	19	1.45″	N 55° E
	26	0.44″	S 34° E
December	3	0.64″	N 22° W
	10	0.44″	N 34° W
	17	0.76″	N 18° W
	24	0.61″	S 11° E
	31	3.02″	S 37° E

CRACK MEASUREMENTS

During October there was no movement of consequence at any of the cracks around Halemaumau nor along the Chain of Craters Road. In November a majority of the cracks around Halemaumau showed an opening accompanying a rather rapid doming of the crater floor, though a few showed a distinct closing as is to be expected during times of such movements. There was considerable movement, both opening and closing, accompanying the rapid subsidence of the crater floor in December.

R.H.F.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

in cooperation with UNIVERSITY OF HAWAII

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THE VOLCANO LETTER

No. 487 **Department of Interior** **National Park Service** **January-March 1945**

PUBLISHED BY THE UNIVERSITY OF HAWAII

HAWAII NATIONAL PARK: Edward G. Wingate, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

ON MAGNETIC STUDIES

By GUY C. OMER, JR.

On leave of absence from the Department of Physics

University of Hawaii

While a remarkable amount of data pertaining to the internal status of the volcanoes has been collected by the seismographs of the Hawaiian Volcano Observatory, this is only one of the many possible geophysical methods that could be used. Other geophysical procedures that suggest themselves are magnetic, gravitational, and earth-current programs. The advantages of using several geophysical methods simultaneously are first, that additional data is obtained, since different effects are being measured, and second, that a very valuable cross-check is possible in the interpretation of the collated data.

A rising or falling magma column could be expected to have at least two magnetic effects. One is the local change in the permeability of the earth's crust produced by the presence of the hot magma column and the associated heating of the surrounding rock. The other is a Lenz law local field produced by eddy currents induced in the hot magma column while it is rising or falling. A change in the measured magnetic elements between two observational dates spaced a month or so apart, might well correlate with volcanic activity while the absolute value at any one date might not in itself have much significance.

The first magnetic work at Kilauea was done by J. W. Green[1] of the United States Coast and Geodetic Survey at the suggestion of Dr. T. A. Jaggar. This consisted of many magnetic measurements around Kilauea and Mauna Loa during the winter of 1913. During this time Mauna Loa was quiet and Kilauea was relatively quiet between short periods of visible activity. Many striking magnetic variations were observed, but the time available for this work was too short to allow any definite conclusions.

Magnetic observations have been made upon the volcanoes of Japan. Typical of this would be the work of Y. Kato[2] who compared regional magnetic surveys made before and after volcanic eruptions and found large and regular local changes in the magnetic elements.

It is not possible to make magnetic surveys without special instruments, so a full-fledged magnetic program cannot be immediately started at Hawaiian Volcano Observatory. However, some preliminary work has been done using instruments and data that are available. This preliminary work is of value, however, since it indicates the fruitfulness of the magnetic method and the scope and nature of an enlarged magnetic program that could be begun.

The first of this preliminary work was a crude dip survey of the entire island. The instrument used was a Swedish mining compass, which could be read to 0.2°. However, the greatest

[1] JAGGAR, JR., T. A. SPECIAL BULLETIN OF HAWAIIAN VOLCANO OBSERVATORY, p. 9, 1913.

[2] KATO, Y. SEISMIC AND VOLCANIC ACTIVITIES AND CHANGES IN THE EARTH'S MAGNETIC FIELD (three papers). Japanese Journal of Astronomy and Geophysics Vol. 10, No. 2, pp. 249-262; Vol. 12, No. 1, pp. 1-26; Vol. 12, No. 2, pp. 237-243.

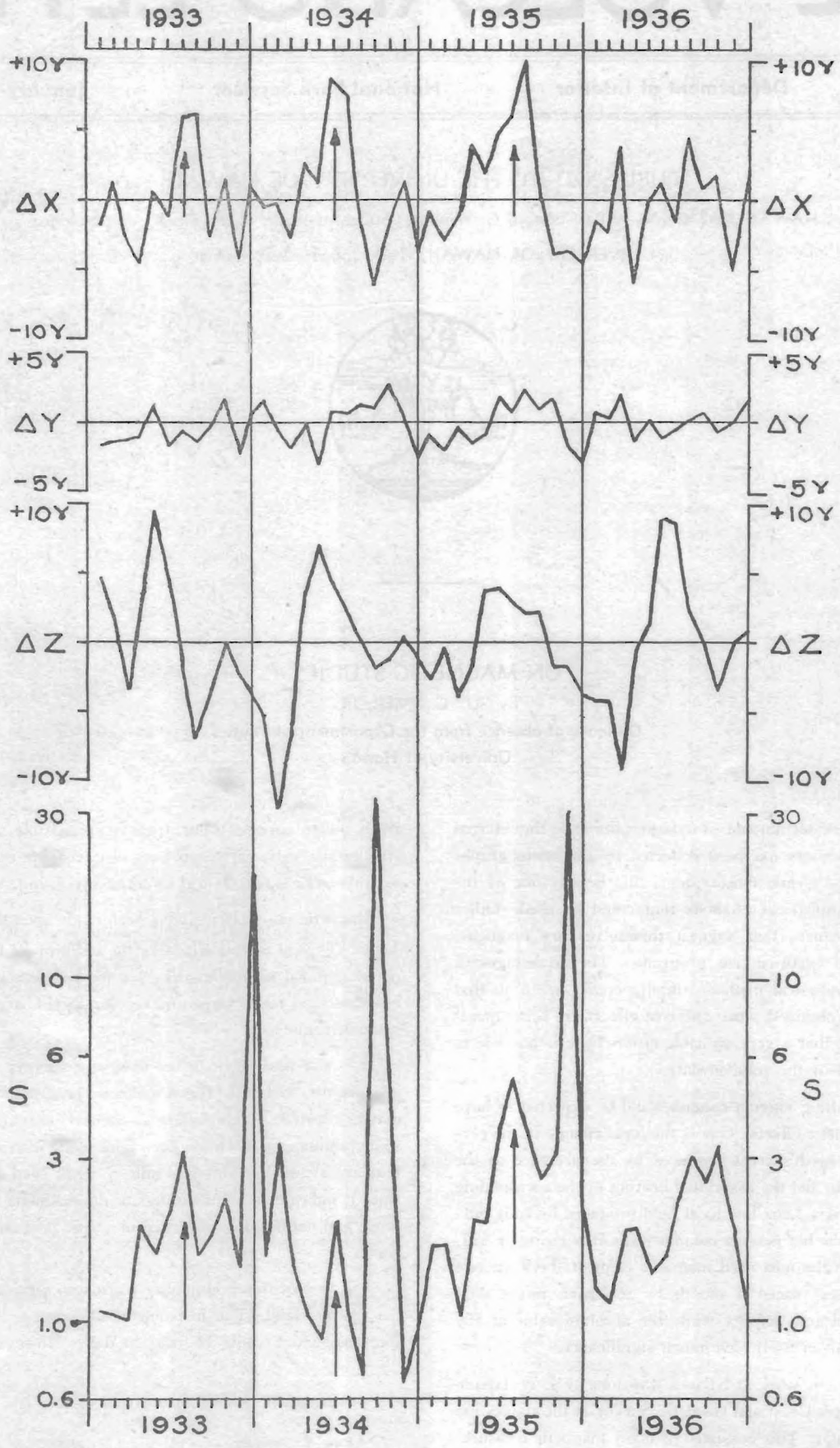

Figure 1.—Magnetic departures at Honolulu and seismicity at the Hawaiian Volcano Observatory. ΔX, ΔY, and ΔZ show the departures from the mean in gammas for the north-south, east-west, and vertical fields, respectively. *S* shows the monthly seismicity.

handicap to this survey was the extreme variation in local magnetic conditions. An attempt was made to correct this by taking an areal average, but the scatter in the data was still too great to allow the construction of a reliable iso-dip map. Nevertheless, a decrease in magnetic dip averaging between one and two degrees between the shore line and the summits of the volcanoes was definitely indicated. This is the effect to be expected if the heating of the rock under the volcano is higher in temperature than that for areas some distance from the summit caldera.

Another available source of magnetic data is the published results of the Honolulu Magnetic Observatory of the United States Coast and Geodetic Survey. While the Magnetic Observatory is about 190 miles away from the volcanoes, it is a highly sensitive station that is in continuous operation. The reduced data[3] for this station from 1933 to 1936 is plotted in Figure 1 against the monthly seismicity at Hawaiian Volcano Observatory.

The earth's magnetic field is continually varying because of a number of causes, most of which are balanced out in the published monthly means through the system of selected averaging. The remaining variations are those of secular change and any peculiar local effect. The secular change is a slow continuous varying of the magnetic field which is world-wide and of unknown cause. The secular change was eliminated from the published data by determining a smooth running mean and plotting the departures from this mean as the upper three curves of Figure 1. This should be the peculiar local effect which might correlate with volcanic activity. The unit used in plotting this magnetic data is the *gamma* which is 10^{-5} gauss. The ΔX curve shows the departures from the mean for the north-south field, the ΔY curve shows the departures from the mean for the east-west field, while the ΔZ curve shows the departures from the mean of the vertical field. This latter data is subject to the greatest instrumental inaccuracy.

Since the magnetic data plotted are monthly averages, the seismicity curve plotted is also for corresponding monthly averages, slightly adjusted in two cases to compensate for distance effects. This period included three eruptions indicated by the momentarily extremely high seismicity. These eruptions are: Mauna Loa in December, 1933; Kilauea in September, 1934; and Mauna Loa in November, 1935.

The most striking coincidence that will be noted in these curves is the high sustained positive departure in the ΔX curve which preceded each of the three eruptions by several months. The three sets of corresponding arrows on the ΔX curve and the seismicity curve indicate the probable time at which magma began to rise in the upper system of the volcano as determined by analyzing the seismic data. This occurs during the marked positive departure. A closer inspection will show the coincidence of most of the maxima and minima of these two curves. The correspondence is not one-to-one since sometimes a maximum will coincide with a maximum, and at other times a maximum will coincide with a minimum. However, a reversal of magnetic polarity is to be expected for rising and for falling magma; but a seismic maximum may occur with both.

On the other hand, there seems to be but a very slight correlation between the ΔY curve, the ΔZ curve and the seismicity. However, it must be remembered that the data plotted is only for four years and three eruptions. No definite conclusions can be drawn upon any seeming correlation over so short an epoch. The United States Coast and Geodetic Survey has just recently furnished us with the Honolulu Magnetic Observatory results from 1905 to 1943, inclusive. This data for thirty-nine years and for many eruptions of Mauna Loa and Kilauea will be handled in the same way as the data of Figure 1. From this much longer epoch the reality or the nonreality of these seeming correlations should be definitely shown.

A third possible bit of preliminary work is to determine the variation in the magnetic declination at certain selected stations around the volcanoes to the accuracy inherent in a good modern transit. This program has just been begun. The stations indicated on the map of Figure 2 have been established. Each station consists of a nonmagnetic bench mark along with a corresponding nonmagnetic azimuth mark, which fix an observing point and a fixed azimuth line. The magnetic bearing of this fixed azimuth line is read on the transit each time that the station is reoccupied. The error in resetting the transit over the bench mark and in reading the magnetic needle should not exceed 0.1° and is certainly not over 0.2° at the most.

Stations A to H inclusive were established at an average date of about February 1, 1945, and were reoccupied at an average date of about March 20, 1945. The variation found in these two readings is:

Station	Variation	
A	0.35° W	
B	0.35° W	
C	0.15° W	
D	0.00°	(Station disturbed)
E	0.15° E	
F	0.25° W	
G	0.05° E	
H	0.10° E	

The variation for some of the stations is much higher than the maximum possible error; hence the variation must be real. If this variation is plotted on the map, it will be found that the vector lines radiate out from a point which very roughly might be guessed to be on the northeast rift of Mauna Loa at about 8,000 feet. These readings coincide with a seeming period of rising magma in Mauna Loa as indicated by a seismic series which came to a climax on April 2, 1945.

No data is given for stations I and J since these were established only recently. Immediate plans are to construct a simple suspended magnet to be read optically with a telescope and scale at a fixed location each day to determine changes in declination to within a minute of arc or better.

[3] Magnetic Observatory Results at Honolulu, Hawaii, for 1933-34, MO-14, and for 1935-36, MO-19.

University of Hawaii Outline Map No. 5—Island of Hawaii

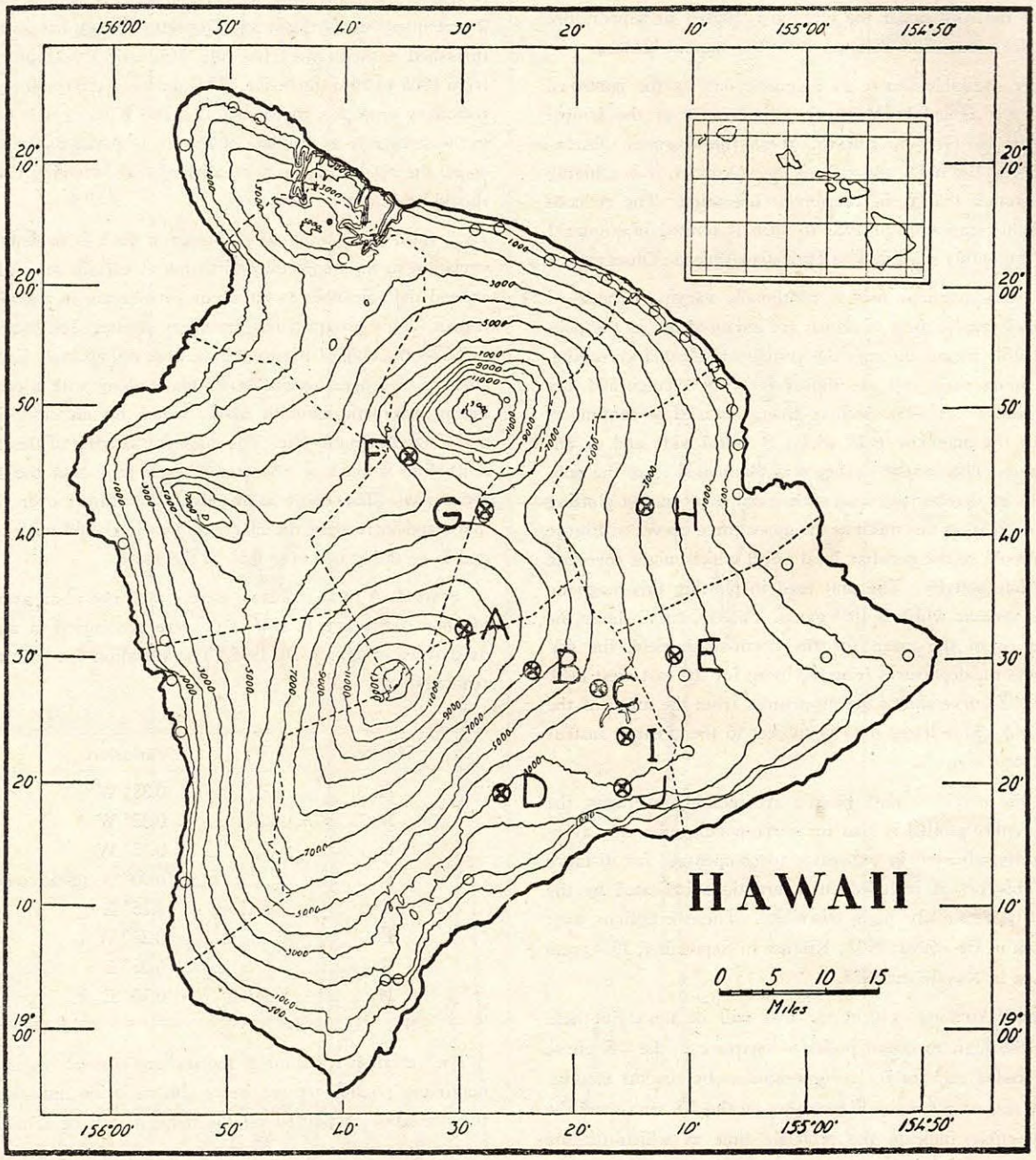

Figure 2.—Temporary declination stations.

Hawaiian Volcano Observatory Report for January-March 1945

VOLCANOLOGY

January

Following the earthquakes of the last of December, 1944, Mauna Loa continued to show signs of uneasiness with shakes on January 6 and 9 that originated near Wood Valley and in the southwestern part of Mauna Loa. Thirty earthquakes were recorded at Kilauea and 22 at Mauna Loa.

February

Several times during the last of January and the first of February distinct fume clouds were observed over Mokuaweoweo.

The tilt record gives evidence of continuing high pressure under the Kilauea-Mauna Loa volcano system. Seasonal southwesterly tilt stopped about the middle of the month and by the last of the month there was a noticeable easterly tilt. A volcanic tilt sufficiently strong to overcome the southwest tilt that is normal for this season of the year is really a positive northeast tilt.

Several landslides from the Halemaumau rim were noticed during the month. A large one on February 11 filled the pit with dust and sent up a cloud with definite outlines well above the Halemaumau rim.

Twelve seismic disturbances were recorded at Kilauea and 22 at Mauna Loa.

March

The tilt records for March show that the uneasy condition of Kilauea mentioned for February continued into March. Northerly tilt, an indication of doming at Kilauea volcano, was strong enough during the first half of the month to overcome the normal southerly tilt and show an actual accumulation to the north. The spell of uneasiness was over about the middle of the month and during the last half of the month there was about the normal accumulation of southerly tilt. An easterly tilt that set in about the middle of February continued until March 6, when the usual westerly tilt was resumed. It continued until the end of the month.

This period of uneasiness coming only two and a half months after the one of November-December, 1944, indicates that the possibility of surface manifestations of volcanic activity at Kilauea within the next year or so are rather good. The easterly tilt and the distribution of earthquakes indicate that Mauna Loa is sharing the uneasiness with Kilauea.

Forty-two seismic disturbances were recorded at Mauna Loa and 37 at Kilauea.

R.H.F.

SEISMOLOGY

Earthquake Data, January-March 1945

Week Ended	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
January 7	9	1	1	0	0	3.75	0
14	3	2	0	1	0	3.75	0
21	8	0	0	0	0	2.00	0
28	8	0	0	0	1	5.00	0
February 4	1	0	0	0	0	0.25	0
11	0	0	1	0	0	1.00	0
18	1	1	0	1	0	2.75	0
25	0	2	1	0	0	2.00	0
March 4	3	1	0	0	0	1.25	0
11	3	0	0	0	1	3.75	0
18	5	1	1	0	1	5.75	0
25	6	0	1	0	0	2.50	0

* For definition of local seismicity see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours and 30 minutes slower than Greenwich. The number preceding each earthquake is the serial number of the quake for the current year.

1. January 4, 12 : 18, very feeble.
2. January 6, 05 : 57, feeble, near Wood Valley. Felt at Kapapala and Pahala.
3. January 9, 18 : 57, slight. Felt at Pahala.
4. January 9, 19 : 08, very feeble.
5. January 11, 18 : 53, very feeble.
6. January 24, 10 : 38, moderate. Widely felt in SE half of the island. 10 to 15 miles below east rim of Kilauea.
7. February 5, 18 : 43, feeble. Felt locally. Probably at NE rift of Mauna Loa.
8. February 17, 04 : 24, very feeble.
9. February 18, 15 : 55, slight. Felt locally; E-W dismantled. Both components dismantled at Mauna Loa. About 9 miles deep near Ohaikea.
10. February 21, 02 : 00, very feeble.
11. February 23, 10 : 53, feeble. Origin about same as No. 9.

12. February 24, 18:43, very feeble. Origin probably same as No. 9.
13. February 26, 06:34, very feeble.
14. March 4, 00:00, moderate. At SW rift of Mauna Loa. Widely felt over island. Stopped clocks in South Kona.
15. March 12, 19:00, moderate. Instruments dismantled. Felt locally. In ocean off the Puna-Kau boundary.
16. March 13, 09:03, very feeble.
17. March 18, 07:54, feeble.
18. March 24, 13:33, feeble.
19. March 26, 10:04, slight. Felt locally.
20. March 26, 10:37, slight. Off coast south of Kilauea. Felt in eastern part of island.
21. March 28, 05:22, very feeble.
22. March 28, 19:58, feeble. At NE rift of Mauna Loa.
23. March 29, 18:32, very feeble.
24. March 30, 05:34, very feeble.
25. March 30, 08:31, very feeble.
26. March 31, 20:02, very feeble. Origin near Puu Keokeo. Felt in South Kona.

TELESEISMS

No teleseisms were recorded during the quarter.

MICROSEISMS

Microseisms were present though slight throughout the quarter.

TILTING OF THE GROUND

The seasonal SW tilt that started in December continued until about the middle of February when a NE tilt set in. The easterly tilt ceased on March 6 though the northerly tilt continued until March 14. During the last half of March the usual seasonal SW tilt prevailed.

Table of Tilt at Observatory on NE Rim of Kilauea

Week Ended	Amount	Direction
January 7	1.21″	S 48° W
14	0.88″	N 17° W
21	0.48″	S
28	0.62″	N 79° W
February 4	1.91″	S 26° W
11	1.46″	S 45° W
18	0.54″	N 63° E
25	0.17″	S 45° W
March 4	1.84″	N 62° E
11	1.47″	N 75° W
18	0.72″	S
25	0.71″	N 58° W

CRACK MEASUREMENTS

In January a majority of the cracks at Halemaumau rim and along the Chain of Craters Road showed a slight opening though a few showed some closing. There was considerable fluctuation in the width of these cracks in February. The net result, however, was a distinct opening in a few cracks and no change in the majority of them. In March a majority of the cracks around Halemaumau showed an opening and none showed a closing. There was no movement at any of the cracks along the Chain of Craters Road.

R.H.F.

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HAWAII NATIONAL PARK: Edward G. Wingate, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

A FLOOD-DEVELOPED CHASM OVER A BURIED FAULT

By GUNNAR O. FAGERLUND

Naturalist and Chief Ranger, Hawaii National Park

An apparent seismic movement occurred on April 8, 1945, along a concealed fault about eighteen miles southwest of Kilauea near the old belt road. A chasm approximately 325 feet long, 40 feet wide, and 20 to 40 feet deep was formed in the Pahala ash that lies 30 to 50 feet thick upon prehistoric basalt.[1] The northern end of the chasm is about 1,800 feet southwest of the benchmark at 1,856 feet elevation near Kapapala Ranch gate and about 100 feet east of the old belt road.



Figure 1.—General view of the flood-developed chasm. (Photo by G. O. Fagerlund.)

The ash lying above the section of the fault disappeared into a fissure in the underlying prehistoric lava and created the chasm (Fig. 1). Extension of the northern end of the chasm was stopped by a bridging lava flow that withstood undermining. Beyond the southern end of the chasm the ash slumped some. A block 18 feet wide and 150 feet long dropped as much as 2 feet (Fig. 2). This slump block and the topographic sag shown in the background of Figure 2 indicate the continuation of the buried fault. A wider fissure in the basalt probably accounts for the sag in the ash that was laid down upon it at this point. Another slumped section, about twelve feet long and as wide as the chasm, occurs near the southern end of the chasm and breaks its continuity.

Only the west wall of the chasm shows two lava flows, one at zero to two feet and the other at four to ten feet below the surface. Before the breakdown, the edges of these flows probably lay almost directly above the buried fault. The upper flow bridges the northern end of the chasm.

A direct seismic cause of the chasm is precluded by the absence of earthquakes at the time it was formed. However, earthquakes of former years may have fractured or weakened the ash structure.

Extraordinarily heavy rainfall occurred on April 7 and 8 of this year. The total for the storm in the vicinity of Kapapala was about twenty-five inches. The prolonged downpour caused

[1] STEARNS, HAROLD T., AND CLARK, WILLIAM O. GEOLOGY AND WATER RESOURCES OF THE KAU DISTRICT, HAWAII (INCLUDING PARTS OF KILAUEA AND MAUNA LOA VOLCANOES). Plate 1. U. S. Geological Survey Water-Supply Paper 616. 1930.

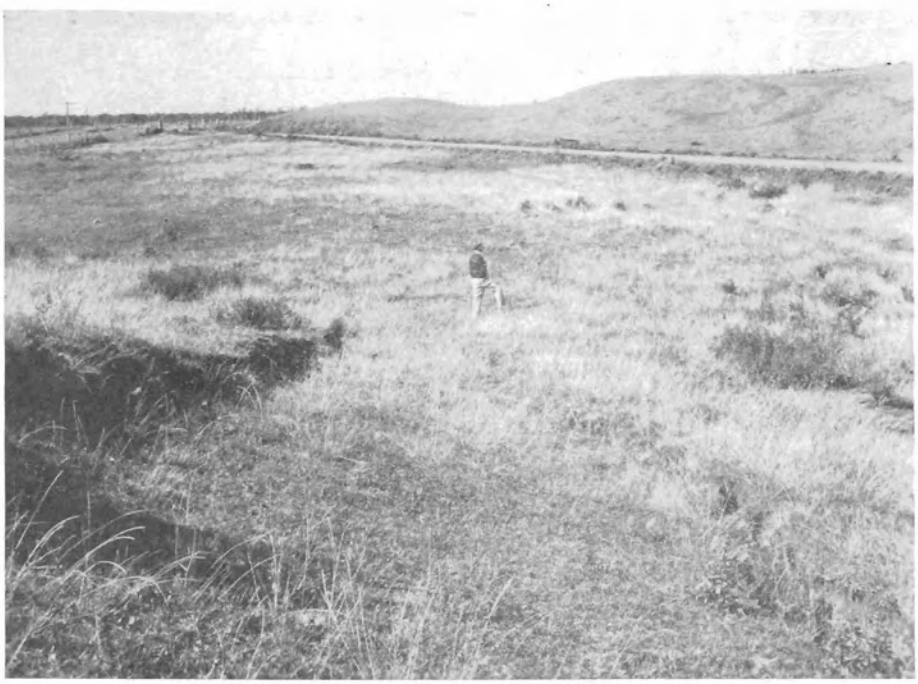

Figure 2.—Slump block near the southern end of the open chasm. The sag in the background shows extension of the buried fault. (Photo by G. O. Fagerlund.)

floods of uncommon magnitude and destructiveness. Sections of highway were washed out and fences were carried away. At Kapapala Ranch, one building was carried away and others were shifted.

Boulder-carrying floodwater moved over the area where the chasm formed. Sustained flooding probably led to seepage through the ash. Seepage may have been promoted at the fault line by earlier seismic movement there and by the edging lava flows above the fault. The seepage undermined the ash from the bottom of the bed upward in the manner of a linear swallet. This accelerating process developed into a waterfall that carried the ash into the fissure in the underlying basalt. The undermining continued until the roof collapsed.

Partial collapse followed lesser undermining near and beyond the southern extremity of the chasm, where the two slump blocks previously mentioned wedged into the ash above the fissure. Because these slumped sections formed on higher ground that was not covered by floodwater, they did not wash away, although a section of equally high ground between them collapsed completely. About twelve feet from the top of this high slumped section the presence of a water line indicates that the floodwater nearly filled the chasm for some time. Thus the length of the chasm was determined by a bridging lava flow at one end and by high ground at the other.

Figure 3 shows boulders on the edge of the chasm. Their presence indicates that the breakdown occurred after the maximum flood had passed. Floodwater, in this instance, produced a physiographic feature, viz., a chasm, of which a superficial inspection could lead one to conclude that it had been caused by seismic movement.

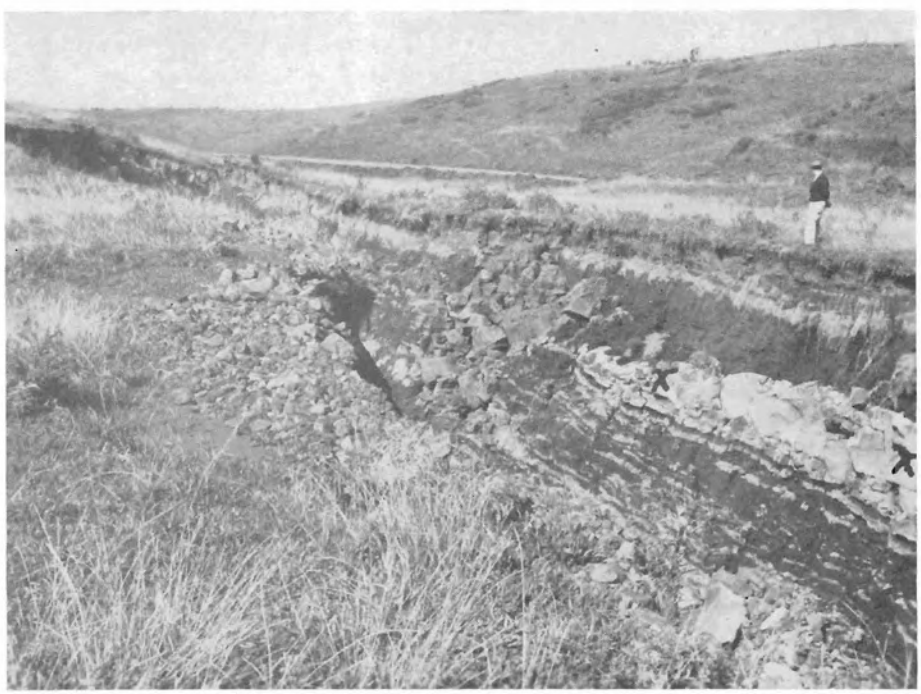

Figure 3.—The west wall of the chasm shows an interbedded lava flow from X to X. Note the fresh boulder deposit on the left rim. (Photo by G. O. Fagerlund.)

Hawaiian Volcano Observatory Report for April-June 1945

VOLCANOLOGY

April

A strong northeast tilt accompanied the torrential rains of April 7 and 8. The north tilt recovered rapidly after the rain stopped, but a slight easterly tilt continued for over a week before there was a recovery to the west. There were no signs of uneasiness at either Kilauea or Mauna Loa, though internal pressure continued high. A total of 54 seismic disturbances was recorded at Kilauea and 32 at Mauna Loa.

Several of the rim cracks at Halemaumau showed distinct openings.

May

An earthquake which occurred at 02:48 (HST) on May 19 is of especial interest. It originated at a depth of 12 to 15 miles below the surface on the east slope of Mauna Loa, about half way between Halemaumau and Mokuaweoweo. It was just strong enough to awaken light sleepers on the island of Hawaii and appears to have been only slightly less intense on Oahu. The shake produced a good record on the U. S. Coast and Geodetic Survey seismograph in Honolulu. Only one component of the horizontal seismograph at the Observatory was dismantled, though both were dismantled at the Mauna Loa station, which is about 3 miles nearer the epicenter. The widespread and rather uniform intensity suggests that the origin may have been at an even greater depth than the indicated 12 to 15 miles. At any rate, the energy of the surface waves was not much greater in the epicentral region than at places 50 miles and more away.

A total of 25 shakes was recorded at Mauna Loa and 19 at Kilauea.

June

Pressure under Kilauea and Mauna Loa changed little during June. Only two earthquakes strong enough to be felt locally were recorded. They originated along the lower southwest Kilauea rift.

Forty-one seismic disturbances were recorded at Mauna Loa and 19 at Kilauea.

R.H.F.

SEISMOLOGY

Earthquake Data, April-June 1945

Week Ended	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
April 1	12	5	1	2	0	0	10.50	0
8	18	6	2	1	1	0	14.50	0
15	4	4	2	1	0	0	7.00	0
22	5	3	1	2	0	0	7.75	0
29	3	0	0	1	0	0	2.75	0
May 6	0	1	0	0	0	0	0.50	0
13	2	0	0	0	0	0	0.50	0
20	3	2	1	1	1	0	7.75	1
27	3	0	0	0	0	0	0.75	0
June 3	3	2	0	2	0	0	5.75	0
10	2	2	0	0	0	0	1.50	0
17	3	0	0	1	0	0	2.75	0
24	2	0	0	0	0	0	0.50	1

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours and 30 minutes slower than Greenwich. The number preceding each earthquake is the serial number of the quake for the current year.

27. April 2, 00:54, very feeble.
28. April 2, 11:23, very feeble. Kilauea origin.
29. April 2, 18:37, moderate. East-west dismantled. Origin under Kilauea. Felt locally.
30. April 2, 19:51, slight. Origin under Kilauea.
31. April 3, 01:38, feeble. Kilauea shake.
32. April 3, 20:50, feeble. Kilauea shake.
33. April 4, 20:36, very feeble. Felt at Pahala.
34. April 6, 14:03, very feeble.
35. April 6, 23:52, very feeble.
36. April 8, 22:10, very feeble.
37. April 12, 21:49, feeble.
38. April 13, 04:06, slight. Kilauea shake.
39. April 13, 07:02, very feeble.
40. April 13, 18:43, very feeble.
41. April 14, 04:46, very feeble.
42. April 15, 01:35, feeble.
43. April 16, 18:52, feeble. Kilauea shake.
44. April 18, 06:41, slight. Kilauea shake.
45. April 18, 09:04, slight. Kilauea origin.
46. April 20, 16:08, very feeble. East slope of Mauna Loa.
47. April 21, 02:41, very feeble. Mauna Loa origin.
48. April 22, 18:33, very feeble.
49. April 29, 01:59, slight. Felt locally.
50. May 1, 13:33, very feeble.
51. May 19, 01:48, moderate. East-west dismantled. East slope of Mauna Loa. Generally felt on Hawaii and slightly felt on Oahu.
52. May 19, 02:05, very feeble.
53. May 19, 02:18, very feeble.
54. May 19, 03:33, feeble. Felt by a few.
55. May 19, 21:21, slight. Origin on Mauna Loa.
56. May 29, 18:45, slight. East slope of Mauna Loa, 5 miles southwest of Red Hill, 12 to 14 miles deep. Felt locally, at South Kona, and at Hilo.
57. May 30, 01:27, very feeble.
58. May 31, 15:06, slight. Five to 7 miles deep off coast south of Kilauea. Felt locally.
59. June 1, 16:13, very feeble.
60. June 7, 00:26, very feeble.
61. June 8, 04:25, very feeble. Origin in Kona.
62. June 14, 19:46, slight. Near Pahala. Felt locally and at Pahala.
63. June 27, 08:34, feeble. Kilauea shake.
64. June 27, 19:40, very feeble. Mauna Loa shake.
65. June 28, 04:08, feeble. Felt locally.
66. June 29, 16:37, feeble. Upper northeast rift of Mauna Loa.

TELESEISMS

May 19, 04:40, slight. Off northern California.
June 21, 22:58, slight.
June 27, 02:56, slight.
June 29, 19:05, slight.

MICROSEISMS

Microseisms were moderate on June 3 and 4 and unusually small throughout the rest of the quarter.

TILTING OF THE GROUND

Except for a sharp northeast tilt accompanying the unusually heavy rain of April 6 to 8, the southwest tilt that commenced in March continued until May 8. The westerly tilt, however, continued a month longer. The seasonal southwest tilt that started on June 8 continued into July.

CRACK MEASUREMENTS

In April several of the cracks around Halemaumau showed a distinct opening and none showed a closing. One crack along the Chain of Craters road opened slightly. One crack near the southwest rim of Halemaumau opened 16 mm. in May. Most of the other rim cracks also opened considerably. Only slight movement of the cracks around Halemaumau was detected in June.

R.H.F.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended	Amount	Direction
April 1	1.76″	S 73° W
8	4.96″	N 60° E
15	4.13″	S 14° E
22	0.88″	S 74° W
29	1.57″	W
May 6	0.53″	S 45° W
13	1.96″	S 68° W
20	1.57″	N 58° E
27	0.77″	N 18° E
June 3	2.17″	S 68° W
10	1.21″	N 24° E
17	0.48″	N
24	1.10″	N 40° E

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The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** supplement the work of the government with research associates, instrumental plants and special investigation. Dr. T. A. Jaggar is their geophysicist resident in the National Park.

The Volcano Letter, a quarterly record of Hawaiian volcano laboratories and published by the University of Hawaii, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the above establishments.

THE VOLCANO LETTER

No. 489 **Department of Interior** **National Park Service** **July-September 1945**

PUBLISHED BY THE UNIVERSITY OF HAWAII

HAWAII NATIONAL PARK: Edward G. Wingate, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

SUMMIT AND NORTHEAST RIFT ZONE OF MAUNA LOA

By GORDON A. MACDONALD

Associate Geologist, U. S. Geological Survey

The summit and northeast rift zone of Mauna Loa were mapped by the writer in the summer of 1942 as a part of the study of the geology and ground-water resources of the island of Hawaii made by the U. S. Geological Survey in cooperation with the Territory of Hawaii. The mapping of the vents and identifiable historic lava flows is shown in the accompanying figures. It is a pleasure to acknowledge the aid of Harvey Finch during field work in the summit area of Mauna Loa. The National Park Service permitted the use of rest houses on the mountain, and extended many other courtesies. James Y. Nitta prepared figure 2.

The topographic base used in the accompanying figures was prepared several years ago by the topographic branch of the Geological Survey. Boundaries of the historic lava flows to and including the 1926 flow which were shown on earlier topographic maps were re-examined. The delineation by E. G. Wingate and his associates of the 1926 and 1851 lava flows on the upper southwestern slopes of the mountain was found to be excellent, and the boundaries of these flows on the accompanying maps are taken from the topographic map. The flow of 1880 on the southern side of the northeast rift zone also is taken from the topographic map. But the boundaries of the flows of 1880-81 and of 1899 on the north side of the rift zone required extensive revision. In general, the area of these flows as indicated on the topographic map includes only the pahoehoe phase of the flow, the aa phase having been ignored.

Remapping of the flows of 1880-81 and 1899, and original mapping of the lavas of 1935, 1940, and 1942, was done partly on the ground and partly with the aid of aerial photographs. The source of one of the 1935 flows (A, fig. 2) was mapped on the ground by H. T. Stearns and checked with aerial photographs. The area of 1933 lava in Mokuaweoweo was shown on a map by F. M. Bullard and P. H. Baldwin,[1] and the outline of the 1940 lava in Mokuaweoweo is taken from the map by P. E. Schulz,[2] after checking in the field. There follow a few brief notes on volcanic features along the northeast rift zone and in the summit area.

A cone northeast of Puu Ulaula (C, fig. 2) gave vent to lavas rich in large crystals of olivine. It may be the source of similar lavas exposed along the trail below Puu Ulaula. The top of this cone has partly collapsed inward, possibly owing to failure of support on withdrawal of the fluid lava at the end of the eruption.

The cone with a summit altitude of 9,617 feet, and 1.4 miles N. 24° E. of Puu Ulaula (D, fig. 2), may be a source of the lava flow of 1880-81, as suggested by Jaggar.[3] The adjacent cones lie east of the flow boundary, however, and are older than the 1880 lava.

The 1899 flow issued at Pukauahi[4] and also along a fissure a mile farther west-southwest. A small tongue of lava flowed southeastward for about a mile, parallel to the Kau branch of the 1880 flow. The southeastward-flowing branch was mentioned in contemporary accounts. The northeastern branch of the 1899 flow is considerably more extensive than is shown on previous maps.

The lava flow of 1855, which lies to the north of the area shown in figure 2, cannot be traced upslope beyond the point where it is overlapped by a branch of the 1880 flow. Undoubtedly it is largely buried by the flows of 1880 and 1899, and parts of it which are not buried are indistinguishable by ordinary field methods from the many late prehistoric flows. The place of eruption is variously stated as 12,000 feet altitude, and 5 miles from Mokuaweoweo.[5] Judging from these locality descriptions and the position of the known portion of

[1] Volcano Letter 466, p. 1, 1939.

[2] SCHULZ, P. E. SOME CHARACTERISTICS OF THE SUMMIT ERUPTION OF MAUNA LOA, HAWAII, IN 1940. Geol. Soc. Amer. Bul., Vol. 54, pp. 739-746, 1943.

[3] Volcano Letter 466, p. 3, 1939.

[4] *Op. cit.*

[5] HITCHCOCK, C. H. HAWAII AND ITS VOLCANOES. Pp. 94-95, 1911.

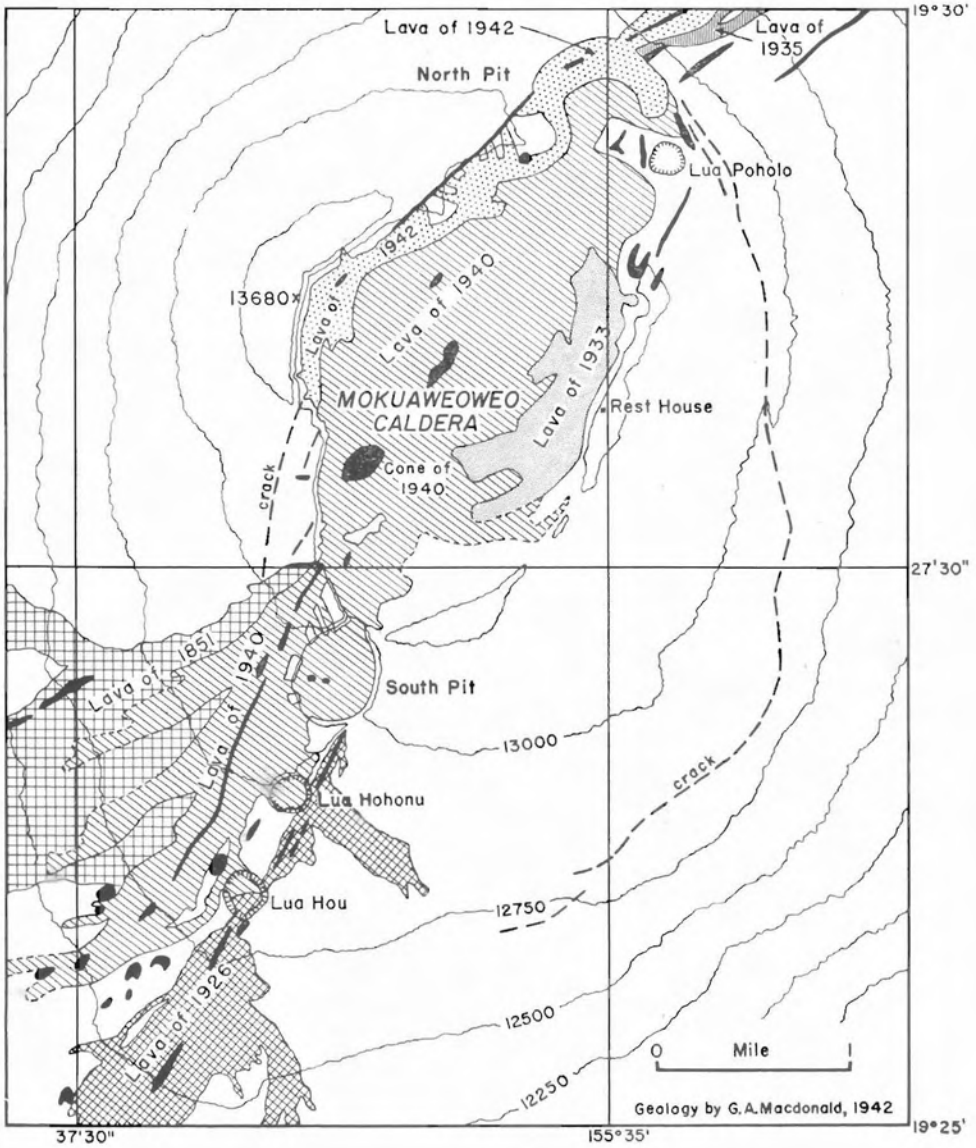

Figure 1.—Map of the summit of Mauna Loa, showing the location of vents and the areas covered by identifiable historic lava flows. Cinder and spatter cones are shown in solid black.

the flow, it probably was near Pukauahi. One possible source is a cone of unknown date west of Pukauahi (E, fig. 2). Another is a cone just south of the trail at 11,750 feet (F, fig. 2), from which the channel of a lava river leads eastward to the vicinity of Pukauahi. Hot rock is still present at some unknown but probably shallow depth beneath this cone which frequently gives off visible steam clouds when weather conditions are favorable.

Besides the generally recognized vents at higher altitude, during the 1935 eruption a small amount of lava issued from a fissure slightly offset from the alignment of the main fissure along the edge of the flow at 11,550 feet altitude (G, fig. 2). During the eruption of 1942 the principal eruptive fissure crossed North Pit and extended along the western wall of Mokuaweoweo (figure 1), sending cascades of lava into the caldera. The fissure in North Pit was largely buried by the lava flow, but one small cone of spatter and cinder is still visible there. At several places just east of the rim of North Pit, lava issued from concentric fissures as well as from the normal radial fissures of the rift zone.

It would undoubtedly prove worthwhile to continue the mapping of the rift zone of Mauna Loa after each eruption.

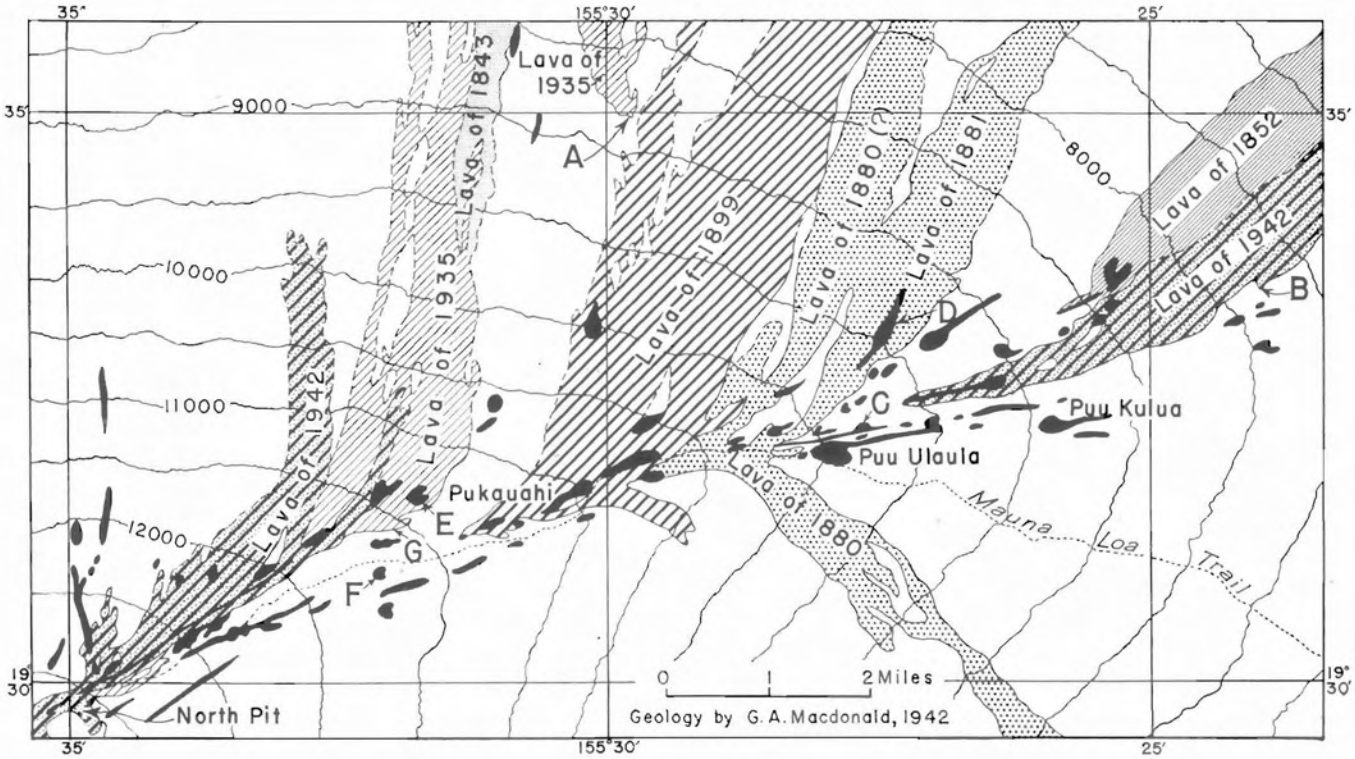

Figure 2.—Map of the upper part of the northeast rift zone of Mauna Loa, showing the location of vents and the areas covered by identifiable historic lava flows. Cinder and spatter cones are shown in solid black.

A NEW BOOK ON PACIFIC VOLCANOES

Volcanoes Declare War: logistics and strategy of Pacific volcano science. By Thomas Augustus Jaggar. 166 pp. Quarto 8 x 11 inches. Copyright 1945. 32 halftone plates, 34 text figures, 5 color plates, 2 cartoons. Paradise of the Pacific, Ltd., Honolulu, T. H. $3.75.

This handsome volume, with colored picture of Paricutin in eruption on the jacket, contains 173 separate reproductions of photographs and drawings, and a text intended for popular reading. The plates have full descriptive titles and are together in the middle of the volume. There is a glossary of technical terms and a list of references.

The table of contents covers Hawaiian volcanoes, south sea outbreaks, East Indian explosions, western Pacific rim, the Aleutian islands, Canada and the Cascade mountains, Mexico, Central America, the Caribbee eruptions, and Chile. This is followed by a review of volcano science, accenting insurance and protection, and specifically giving the author's conclusions based on studies from Pelée in 1902 to Mauna Loa in 1942.

Here are descriptions, engineering experiments, statistics, journals of expeditions, theories, adventures and surveys, insurance, and economic use of power. The author reserves his experiments with earthquakes for a later volume. He insists on the need for core drilling to rock under the oceans.

Hawaiian Volcano Observatory Report for July-September 1945

VOLCANOLOGY

July

Small fume columns were visible from the Observatory in afternoon sunlight over Mokuaweoweo on July 31. About the usual fuming was observed from the rim of Mokuaweoweo from July 23 to 29.

Tilt to the north was slightly greater than normal.

A total of 27 shakes was recorded at Kilauea and 42 at Mauna Loa.

August

Fuming in amounts greater than usual was observed over Mokuaweoweo on several afternoons. Conspicuous north tilt continued during August. This tilt indicates a pressure build-up under Kilauea. There was a conspicuous widening of some of the cracks near the southwest rim of Halemaumau.

Seismicity was low in August with 32 earthquakes recorded at Mauna Loa and only 15 at Kilauea.

September

Landslides from the southwest rim of Halemaumau became unusually conspicuous on September 17 and continued for a week with diminishing frequency. Apparently the largest slide of the series occurred at 16:59 September 17 when a section of the rim about 80 feet long and 6 or 8 feet wide went in. It caused an earthquake sufficiently large to make a conspicuous record on the Observatory seismographs.

Rapid north tilt continued during the first week in September, thereafter the northerly tilt was less than normal.

A total of 25 earthquakes was recorded at Kilauea and 30 at Mauna Loa.

R.H.F.

SEISMOLOGY

Earthquake Data, July-September 1945

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
July	1	3	2	3	0	0	4.75	2
	8	2	4	0	0	0	2.50	0
	15	3	1	0	0	1	4.25	1
	22	4	1	0	0	0	1.50	0
	29	5	3	0	0	0	2.75	0
August	5	1	1	1	0	0	1.75	0
	12	1	0	0	1	0	2.25	0
	19	3	1	0	0	0	1.25	0
	26	2	0	0	0	0	0.50	0
September	2	4	1	1	0	0	2.50	2
	9	3	2	1	0	0	2.75	0
	16	4	0	0	0	0	1.00	0
	23	5	1	2	1	0	5.75	0
	30	1	5	0	0	0	2.75	1

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours and 30 minutes slower than Greenwich. The number preceding each earthquake is the serial number of the quake for the current year.

67. July 1, 07:46, very feeble.
68. July 3, 20:06, very feeble.
69. July 4, 18:08, very feeble. Northeast rift of Mauna Loa.
70. July 6, 06:54, very feeble.
71. July 6, 13:46, very feeble.
72. July 13, 02:15, moderate. East-west dismantled. Four to six miles deep along Puna coast southwest of Kalapana. Widely felt in eastern half of island of Hawaii.
73. July 14, 02:54, very feeble.
74. July 16, 04:15, very feeble.
75. July 25, 03:46, very feeble.
76. July 25, 07:03, very feeble.
77. July 28, 10:50, very feeble.
78. July 30, 05:14, feeble. Kilauea shake. Felt locally.
79. August 2, 07:51, very feeble.
80. August 9, 10:46, slight. Generally felt in southwest part of island. East slope of Mauna Loa above Kapapala.
81. August 15, 15:26, very feeble.
82. August 27, 03:31, feeble.
83. August 30, 06:54, very feeble.
84. September 5, 09:18, feeble. Northeast rift of Mauna Loa north of Red Hill. Felt locally and in Hilo.
85. September 7, 18:51, very feeble.
86. September 8, 15:26, very feeble.
87. September 17, 16:59, feeble. Landslide at Halemaumau at this time.
88. September 19, 05:33, slight. Widely felt over entire island. Between Mauna Loa and Mauna Kea.
89. September 21, 04:47, very feeble. Kilauea origin. Not felt, but rumble heard.
90. September 23, 15:39, feeble. Northeast rift of Mauna Loa.
91. September 29, 21:45, very feeble.
92. September 29, 21:52, very feeble.
93. September 30, 02:05, very feeble.
94. September 30, 18:18, very feeble.
95. September 30, 21:49, very feeble. North end of Kilauea Crater.

TELESEISMS

July 1, 22:24, slight.
July 14, 19:14, slight. In the Marianas.
August 28, 23:52, slight. 5400 km. New Hebrides.
September 1, 13:09, slight.
September 28, 12:08, slight.

MICROSEISMS

Microseisms were moderate from July 12 to 16 inclusive and very small throughout the rest of the quarter.

TILTING OF THE GROUND

Northerly tilt was continuous throughout the quarter though less than usual during the last three weeks of September. There was a slight westerly tilt in July. The east tilt in August and September was less than normal. There was a sharp west tilt on September 19 with a recovery to the east on September 20.

CRACK MEASUREMENTS

The only measured cracks that showed any appreciable opening in July were along the southwest rim of Halemaumau. The movement of the southwest rim cracks continued in July with one crack opening 27 mm. In September there were numerous landslides from the southwest rim. One measuring station was carried away and another made inaccessible.

R.H.F.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended		Amount	Direction
July	1	0.77″	N 19° E
	8	0.99″	N 76° W
	15	0.63″	N 12° E
	22	1.08″	N 27° E
	29	0.60″	N 37° W
August	5	1.03″	N 70° E
	12	0.62″	N 12° W
	19	0.60″	N 36° E
	26	1.58″	N 23° E
September	2	0.51″	N 14° W
	9	1.56″	N 75° E
	16	0.43″	N 34° W
	23	0.43″	N 34° E
	30	0.51″	N 76° E

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UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist



ON THE DEPTH OF FOCI OF EARTHQUAKES ON THE ISLAND OF HAWAII

By R. H. FINCH

The depth of foci of island of Hawaii earthquakes ranges from near the surface—sometimes distinctly less than one mile—to 25 to 30 miles. Shakes originating near the surface under the summit of Mauna Loa may actually have foci higher than most of the seismographs on the island.

The most active rift on Mauna Loa is aligned NE–SW with a distinct bend where Mokuaweoweo is crossed. Eighteen miles of the surface length of this rift is above 10,000 feet. The most active rift system at Kilauea is roughly parallel to that of Mauna Loa. Since shallow-focus earthquakes along both Mauna Loa and Kilauea rifts may have foci above sea level, the paths of the waves of nearby shakes with such depths may lie wholly in dry rock. With greater distances or greater depths the earthquake waves would traverse layers of rock saturated with ground water. As the velocity of earthquake waves is less in saturated than in dry rock, one could easily be misled into assuming a discontinuity at the ground-water level.

Hawaiian earthquakes originate in three principal types of fault systems: (1) the fundamental rift which determines the location of the Hawaiian islands; (2) comparatively superficial faults within the volcanic structures that have been built up from the ocean floor 15,000 feet below sea level; and (3) within volcanic conduits. The minimum depth of focus that is possible in the first group is, then, about 3 miles below sea level or within the original surface of the ocean floor. Usually, of course, the depth is much greater than the 3-mile lower limit. The range in depth of Group 2 is from the surface to about 5½ miles below the summit of Mauna Loa—this is nearly 14,000 feet above sea level to about 15,000 feet below sea level. If, as would appear to be the case, the NE–SW trending rifts of Mauna Loa and Kilauea represent structural weakness within the volcanic edifices, then they must of necessity terminate at or above the ocean floor. The depth of focus of Group 3 may vary from near the surface to many miles or approximately as deep as those of Group 1. Movement in Group 3 may be produced by rising or falling of the lava column or by temperature changes induced thereby. Activity in any one group may induce activity in any other group though the effect of Group 2 shakes in this respect is probably quite small.

There are some indications that there are at least two branches of the fundamental rift under the island of Hawaii—one under Kohala and Mauna Kea and the other in the vicinity of Hualalai, Mauna Loa, and Kilauea. There is not much evidence that Mauna Kea and Kilauea are located on the same rift. It might be expected that the radius of curvature of the Hawaiian arc would become shorter as the two ends are approached but not enough to put these two volcanoes on the same rift. The distribution of the foci of deeper earthquakes strengthens the idea of the two branches of the fundamental rift.

It would not be surprising to find cases where movement along the fundamental rift was contemporaneous with movement along a superficial rift and with a volcanic eruption. In 1868 there appear to have been concomitant movements along the fundamental rift under Mauna Loa and along the southwest rift of that mountain. Wood[1] has shown that the largest shake of the

[1] WOOD, HARRY A. ON THE EARTHQUAKES OF 1868 IN HAWAII. Bul. Seis. Soc. Amer. Vol. 4, No. 4, Dec. 1914.

series should be classed as of tectonic origin. The tectonic quake or quakes with some aftershocks occurred at a time when the southwest rift was working and a maze of earthquakes resulted. The strongest shake was felt on Kauai or at a distance of about 320 miles. Subsequent studies of other quakes originating in the same general area would lead one to believe that the depth of focus of the 1868 earthquake was over 30 miles.

The present writer is of the opinion that the 1868 shake had its origin along the fundamental rift under the east slope of Mauna Loa or 15 to 20 miles northeast of the then active portion of the southwest rift of Mauna Loa. The opinion is based on later determinations of many foci with depths of 20 to 30 miles in the same general area. Jones[2] shows a grouping of such earthquakes under the east slope of Mauna Loa. Other shakes with similar depths of focus are still being located in this area.

On December 27, 1944, an earthquake strong enough to dismantle all the seismographs on the island of Hawaii occurred about 20 miles below the surface of the eastern slope of Mauna Loa. The epicenter appears to have been a little to the northeast of most of the comparatively deep focus shakes that Jones located in this area. At least 10 or 12 aftershocks accompanied the December 1944 shake. The order of magnitude of the depth of focus is attested by the fact that the shake, while doing but little damage locally, was felt on Oahu and toppled objects from shelves at places as widespread as Naalehu and Pepeekeo on Hawaii.

An earthquake of the same type, which occurred on May 19, 1945, is of special interest in that despite the fact that it dismantled only one component of the Bosch-Omori seismograph, which is some 12 miles from the epicenter, it was felt on Oahu, nearly 200 miles away. The disturbance was just strong enough to awaken light sleepers on the island of Hawaii and but little less intense on Oahu. While both components of the Mauna Loa seismograph, which is about 3 miles nearer the epicenter than the Bosch-Omori, were dismantled, horizontal motion in the epicenter area was but little more than at points 50 or more miles away. There were five or six aftershocks. The epicenter was located to the southeast of the shake of December 27 or a little lower down the east slope of Mauna Loa. General considerations indicate that the depth may have been greater than the indicated 20 miles. Owing to uncertainties in interpretation of seismograms and in travel times, our locations of earthquake foci are at best but approximations.

[2] JONES, A. E. EMPIRICAL STUDIES OF SEISMIC PHENOMENA OF HAWAII. Bul. Seis. Soc. Amer. Vol. 28, No. 4, p. 326, Oct. 1938.

Hawaiian Volcano Observatory Report for October-December 1945

VOLCANOLOGY

October

Fume columns were observed over Mokuaweoweo on several afternoons during the month. On October 21 observations were made simultaneously at the Observatory and at the rim of Mokuaweoweo. The fuming as observed from the rim was distinctly more than usual.

As in September, northerly tilt was less than usual for this season of the year. Easterly tilt was about normal.

A total of 55 seismic disturbances was recorded at Mauna Loa and 48 at Kilauea.

November

Spells of conspicuous fuming were observed over Mokuaweoweo several times during the month. On November 18 the fume was visible from the Observatory even in morning light until about 8 a.m. Very distinct fume columns were observed from the east rim of Mokuaweoweo several times during the afternoon and evening of November 29.

There was a continued lack of northerly tilt which for this season of the year is equivalent to a slight southerly tilt. Easterly tilt was about normal.

Seismicity was again low with 19 seismic disturbances recorded at Kilauea and 30 at Mauna Loa.

December

Yellow fume was observed over Mokuaweoweo during the late afternoons of December 25 and 26. Some steaming was observed on other days.

Landslides at Halemaumau were frequent during the middle of the month and on the last 3 days. The majority originated at the NW rim.

A total of 31 seismic disturbances was recorded at Kilauea and 37 at Mauna Loa.

There was an accumulation of WSW tilt during the month. Despite the falling off of N tilt in September and the unusually early change to S tilt in November there was an accumulation of 3.6" of northerly tilt during the year. This may be taken as an indication of a slight pressure build up under Kilauea. The accumulation of E tilt during the year amounted to over 6". If, as seems to be the case, there is a correlation between E–W tilt and Mauna Loa activity, then there was a pressure build up under Mauna Loa in 1945.

R.H.F.

SEISMOLOGY

Earthquake Data, October-November 1945

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Local Seismicity*	Teleseisms
October	7	2	1	0	0	1.00	0
	14	19	5	0	0	7.25	0
	21	3	3	0	0	2.25	0
	28	4	2	0	0	2.00	0
November	4	7	3	1	0	4.25	1
	11	1	1	0	0	0.75	0
	18	3	2	0	0	1.75	0
	25	2	1	0	0	1.00	0
December	2	4	3	2	0	4.50	1
	9	2	3	0	0	2.00	0
	16	3	4	0	1	4.75	0
	23	3	4	0	0	2.75	0
	30	0	3	3	1	6.50	1

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours and 30 minutes slower than Greenwich. The number preceding each earthquake is the serial number of the quake for the current year.

96. October 4, 11 : 43, very feeble.

97. October 8, 13 : 04, very feeble.

98. October 8, 19 : 38, very feeble.

99. October 9, 00 : 59, very feeble.

100. October 10, 22 : 53, very feeble.

101. October 12, 15 : 15, very feeble.

102. October 15, 05 : 45, very feeble.

103. October 16, 19 : 59, very feeble.

104. October 21, 17 : 35, very feeble. In ocean north of Mauna Kea.

105. October 25, 04 : 34, very feeble.

106. October 26, 04 : 46, very feeble.

107. October 29, 02 : 23, very feeble.

108. October 29, 21 : 18, very feeble.

109. October 29, 22 : 40, very feeble.

110. October 30, 04 : 05, feeble. Felt locally. Near Hilina Pali.

111. November 5, 18 : 59, very feeble.

112. November 17, 18 : 02, very feeble.

113. November 18, 08 : 27, very feeble. Northeast rift Mauna Loa.

114. November 24, 09 : 21, very feeble. Northeast rift Mauna Loa.

115. November 27, 18 : 25, feeble. Felt in Kau and South Kona. Southwest of Pahala.

116. November 29, 08 : 12, very feeble.

117. November 30, 09 : 25, very feeble.

118. December 1, 20 : 25, feeble. Felt at Pahala.

119. December 2, 18 : 08, very feeble.

120. December 5, 22 : 28, very feeble. Felt at Pahala.

121. December 6, 18 : 21, very feeble.

122. December 6, 20 : 27, very feeble.

123. December 11, 07 : 03, very feeble. Northeast rift Mauna Loa.

124. December 15, 00 : 03, very feeble.

125. December 15, 04 : 33, very feeble.

126. December 16, 20 : 30, slight. East-west dismantled. Felt locally and at Pahala and Hilo. East flank of Mauna Loa.

127. December 16, 23 : 12, very feeble.

128. December 19, 07 : 05, very feeble.

129. December 20, 11 : 21, very feeble.

130. December 22, 05 : 32, very feeble.

131. December 23, 03 : 07, very feeble.

132. December 24, 00 : 51, slight. East-west dismantled. Felt locally. Kilauea shake.

133. December 24, 05 : 15, feeble.

134. December 26, 01 : 02, feeble. Kilauea shake.

135. December 26, 04 : 00, very feeble.

136. December 26, 08 : 05, feeble.

137. December 29, 12 : 44, very feeble.

138. December 30, 08 : 02, very feeble.

TELESEISMS

October 29, 00 : 40, slight. Off British Columbia.

November 27, 11 : 50, moderate. Arabian Sea.

December 27, 07 : 14, moderate. Distance 4,000 miles.

MICROSEISMS

Microseisms were conspicuous from October 25 to 29, on November 12, from December 2 to 5, and on December 28. During the rest of the quarter they were very small.

CRACK MEASUREMENTS

A few of the cracks near the Halemaumau rim and along the Chain of Craters Road opened slightly, though a majority that were measured showed no movement. Landslides were frequent from the northwest rim of Halemaumau during the middle and on the last three days of December.

TILTING OF THE GROUND

There was a slight northerly tilt from October 1 to November 9 though less than normal for this season of the year. From November 9 to the end of the year there was a slight southerly tilt. The change to southerly tilt came over a month earlier than usual. The seasonal change to westerly tilt occurred on December 20 or about the usual time. There was a slight accumulation of easterly tilt during the quarter.

R.H.F.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended		Amount	Direction
October	7	0.86″	N 82° E
	14	0.81″	N 63° W
	21	0.62″	N 11° E
	28	0.44″	N 56° E
November	4	3.87″	N 86° E
	11	0.70″	N 31° E
	18	1.21″	S 23° W
	25	0.02″	N 45° E
December	2	0.76″	N 72° E
	9	0.36″	S
	16	1.15″	N 32° E
	23	1.33″	S 5° E
	30	3.27″	S 73° W

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

in cooperation with UNIVERSITY OF HAWAII

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THE VOLCANO LETTER

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PUBLISHED BY THE UNIVERSITY OF HAWAII

HAWAII NATIONAL PARK: Gunnar O. Fagerlund, Acting Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

THE TIDAL WAVE OF APRIL 1, 1946

By H. A. POWERS
Geologist, Hawaii National Park



Figure 1.—The waterfront, city of Hilo, April 1, 1946. Two thirds of the railroad bridge spanning the Wailuku River can be seen in the right background. One span was lifted from the piers and carried upstream. The railroad station occupied the barren area on the near bank of the river. The station and the tracks which circled the bay have completely disappeared. All the waterfront buildings between the railroad station and the park (marked by the trees in the center) floated into the street and collapsed. With the exception of the reinforced concrete warehouse, all of the waterfront buildings which occupied the foreground were completely demolished and scattered inland and out to sea. HONOLULU STAR-BULLETIN Photo

The Hawaiian Islands suffered their greatest natural disaster of modern times from a tidal wave which reached the islands from the north Pacific early on the morning of April 1, 1946. Over 200 persons are known to have lost their lives or to be missing. The greatest number of casualties is from the island of Hawaii, particularly from the city of Hilo. Property damage was suffered on all the islands and will total many million dollars in loss of homes and personal property. The greatest industrial losses were concentrated in the area around Hilo Bay.

The earthquake which caused the tidal waves apparently had its epicenter in the vicinity of the Aleutian Trough, a region of great ocean depth south of and paralleling roughly the Aleutian Island chain. The earthquake was recorded on all of the horizontal component instruments operated by the Volcano Observatory of the Hawaii National Park. On the Bosch-Omori instrument at the Observatory, the first impulse of the preliminary wave was recorded at approximately 02 06 20 Hawaiian Standard Time, the exact emergence being somewhat obscured by very strong microseismic motion caused by the heavy trade-wind surf which had prevailed for a number of days. The arrival of the secondary wave was recorded approximately at 02 11 10, and of a long wave at 02 14 05, indicating a probable distance from the origin of at least 2,100 miles. Reports from other seismographs indicate that 2,300 miles is more nearly correct. The earthquake was of sufficient intensity to cause continuous disturbance of the seismographs on Hawaii for two hours, though this long duration of disturbance may be due partly to a second quake which appears to be recorded in the coda of the major quake. Seven distinct aftershocks were recorded here. Most of them were registered by impulses lasting less than a minute, but a larger one at 08 44 disturbed the seismograph for about ten minutes. A disturbance of several minutes' duration starting at 06 46 probably is the record of the primary earthquake waves which traveled around the longer arc of the earth.

It is reported that the tide gage in Honolulu Harbor showed the following record of the disturbance:

06 30 Beginning of 7½-inch rise
06 36 Crest of first wave
06 42 Trough of second wave, a drop of 26¼ inches
06 48 Crest of second wave, a rise of about 33¾ inches
06 54 Trough of third wave, a drop of 40½ inches
07 00 Crest of third wave, a rise of about 4 feet

The Hilo tide gage was destroyed. Eyewitness reports indicate that the first wave occurred at Hilo a few minutes after 07 00 and electric clocks in the first damaged area were stopped at 07 06. The Observatory seismogram shows a short electric power stoppage on the suburban line at 07 18 21. Eyewitness testimony indicates that the second wave at Hilo did damage, so it is possible that this short power interruption marks the time of the crest of the second wave in Hilo Harbor at 07 18.

If these time interpretations are correct, the time-lag between arrival of the wave at the two island harbors is exactly 30 minutes. The time of the actual earthquake, taken from seismologic tables, must have been approximately 02 00 Hawaiian time. Thus the fastest wave reached Honolulu in 4 hours and 30 minutes, and Hilo in 5 hours.

The average velocity of the water wave through the open ocean approached 460 miles an hour, but slowed down in the shallow water near the islands to 300 miles an hour. The greatest speed of a wave recorded at the Volcano Observatory was that of a wave on November 10, 1938 which traveled from the Aleutian Islands at an average of 497 miles an hour.

Measurable water waves caused by submarine earthquakes in the Pacific reach Hawaiian shores perhaps as often as once a year. However, most of them cause a water rise of only a few inches and so are not noticed. Since 1800, the wave of April 1, 1946 is the seventh from a distant source to cause damage in the Hawaiian Islands. It was by far the most destructive of the seven. Though the waves of 1837 and 1877 were of greater magnitude, there was less life and property within reach of the waves in this earlier period.

The outstanding tidal waves reaching Hawaii in the nine-



Figure 2.—Wreckage of a private home and garage in the Keaukaha residential area east of Hilo.
Photo by George Duncan



Figure 3.—Wreckage of stores in the street between the railroad station and the park (trees in left background).

Photo by Gunnar O. Fagerlund

teenth century have been described by a number of writers, and were summarized by T. A. Jaggar in THE VOLCANO LETTER, No. 321, February 19, 1931.

The earliest noted was in May 1819, but no information remains as to the possible source, or the damage done.

Three severe waves were caused by earthquakes off the coast of South America. The first, November 7, 1837, affected all the islands of the Hawaiian group. An unrecorded number of lives were lost, and a number of houses were destroyed. On August 13, 1868 a wave from near Peru reached a height of 15 feet above low water at Hilo and 12 feet deep on windward Maui. The damage caused by another from Chile on May 10, 1877 included loss of five lives at Hilo and the destruction of many dwellings. Water reached into the second business block from the waterfront along Waianuenue Street, which parallels the Wailuku River.

One tidal wave was described from an earthquake off Kamchatka on May 17, 1841, but no damage is described.

The terrific Hawaiian earthquake of April 2, 1868 caused a severe local tidal wave along the south coast of the island of Hawaii, but was not so damaging in other localities. Forty-six persons lost their lives and 108 dwellings in Puna and Kau were destroyed in addition to much other damage. Water in Hilo rose 10 feet. A smaller tidal wave, apparently of local origin, did no great amount of damage on August 27, 1872.

The source of Hawaii's damaging tidal waves of this century has shifted to the north Pacific. The first, on September 7, 1918, came from Kamchatka and caused relatively small damage. One person lost his life and extensive property damage was caused at Hilo and at Kahului, Maui, on February 3, 1923 by a wave from Kamchatka. At Hilo the funneling effect of the bay forced the third and the highest wave up to nearly 20 feet above mean low sea level in the small boat harbor at the mouth of the Wailoa River. A quake off the coast of Japan started a wave on March 2, 1933 which caused some damage along the Kona coast of Hawaii.

Table 1, compiled from seismograms at the Volcano Observatory, summarizes the date, origin, and velocity of tidal waves recorded in Hawaii during the nineteenth century. Since installation of the tide gage at Hilo in 1927, it has been possible to determine travel time of waves with more accuracy.

With the present tremendous increase of American interests in the islands of the Pacific and in Alaska, it is possible that a workable system of tidal wave warning may be placed in oper-

Table 1.—Origin and Rate of Travel of Nineteenth-Century Tidal Waves Determined from Seismograms at the Hawaiian Volcano Observatory

Date	Origin	Distance	Travel Time	Average Speed
		Statute miles		*Miles per minute*
1918, Sept. 7	Kamchatka	3,200 (approx.)	7 hrs. (nearly)	7.6
1922, Nov. 11	Chile	4,900 (approx.)	11 hrs. (nearly)	7.5
*1923, Feb. 3	Kamchatka	3,000	7 hrs. (nearly)	7.2
1923, Apr. 13	Kamchatka	3,200	7¼ hrs.	7.3
1927, Nov. 4	California	2,400	5 hrs. 10 min.	7.7
1927, Dec. 28	Kamchatka	3,310	7 hrs. 35 min.	7.3
1928, June 16	Mexico	3,915	8 hrs. 30 min.	7.7
1929, Mar. 6	Aleutian Islands	2,270	4 hrs. 35 min.	8.2
1931, Oct. 2	Solomon Islands	3,680	8 hrs. 20 min.	7.45
*1933, Mar. 2	Japan	3,950	8 hrs. 25 min.	7.95
1938, Nov. 10	Alaska	2,485	5 hrs.	8.27
*1946, Apr. 1	Aleutian Islands	2,300	5 hrs.	7.7

* Except for waves indicated by an asterisk all listed were of very small size and did no material damage. However, they were originated by earthquakes of considerable magnitude which caused damaging waves near their origin. In fact, the earthquakes of 1929 and 1938 were both recorded on the seismograph as stronger than the recent one of April 1, 1946.

ation. This can be done with proper coordination of existing facilities and service organizations at very nominal expense. A workable plan must include the following important phases:

1. Immediate detection and location of submarine earthquakes in the Pacific area by a network of seismographs.
2. Computation of possible time of arrival of ensuing tidal wave at all American island or coastal installations, and immediate notification of the installations closest to the source of the wave.
3. Observation by outposts nearest to the source of the wave as to arrival time and size of the wave, and sending of immediate reports from these outposts to Central Control.
4. Report from Central Control to all vulnerable outposts and installations based on information obtained from first outpost reports.

Seismographs which would serve to greatest advantage in a system of tidal-wave warning should have two features which are not essential to the instrument in use at present: (1) the instrument must sound an alarm to notify the attendant personnel that a teleseism is being recorded, and (2) the recording method should be such that the record can be removed and prepared for study within a very few minutes.

A net of four such instruments located, perhaps, one at Honolulu and three on the North American mainland would make possible a rapid preliminary determination of the epicenter of any Pacific earthquake. Observers at these stations would make immediate studies of a quake which might be located in a critical area and would be given priority use of long distance telephone facilities to report their data to one of the four stations designated as the Central Control. This control would quickly make the best possible determination of the location of an earthquake, and *if* a tidal wave were indicated as probable, would quickly compute the possible time of arrival of a wave at vulnerable points in and around the Pacific.

Tide observation stations, to be most useful in a system of tidal-wave warning, should satisfy the following conditions: (1) be operated by an installation which can or does maintain 24-hour watch on a two-way communication system, (2) be equipped with recording tide gages which can be read easily at any time, (3) be geographically located in all possible vulnerable places in the Pacific which can satisfy the first condition.

At present, the United States Naval installations, connected by the excellent Navy Communications net, probably offer the best organization and facilities to handle the system of observation stations.

Each of the tidal observation stations would be alerted by a priority message from the previously mentioned Central Control warning of the possibility and direction of a tidal wave and the computed arrival time. The outposts first in the path of the possible wave would be notified first.

Each outpost would make negative or positive statistical reports to the Central Control immediately as it obtained negative or positive information on the appearance of the tidal wave. From these reports, relatively competent information would then be sent to areas more remotely in the path of the wave.

The functioning of such a system need not create mass hysteria, nor need it fall into the position of Aesop's boy who cried, "Wolf!" Rapid routine location of the epicenter by the seismograph net would screen out any public mention of tidal wave in connection with all earthquakes except those which actually were so located as possibly to cause a wave. The immediate collection of reports, both positive and negative, from those outposts earliest in the path of the possible wave, would make available relatively specific warnings to areas more remotely in the path of the wave.

Communities subject to tidal waves could provide an additional simple alarm system which might prevent loss of life by taking advantage of the fact that an abnormally low water precedes by a few minutes the approach of an abnormally high wave. A tide gage could be connected with a loud siren in such a manner that the alarm would be sounded when the tide gage dropped to a point somewhat below low tide mark.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

320 James Campbell Building, Honolulu 48, T. H. Telephone 3834

To the Donors and Members
Hawaiian Volcano Research Association

Your Directors this day meeting in the office of President Thurston, have to report that our Scientific Director T. A. Jaggar and his assistant R. A. Okuda are continuing laboratory work in measuring hardness of metals and minerals; the book on Pacific volcanoes was published and now is on sale on the mainland; a paper on tidal waves, a book manuscript on explosive volcanoes, and another on craters, are in press in New York; and Dr. Jaggar is now working on alleviation of tidal waves.

The disastrous beach flood of April 1 in Hawaii engages our scientists, and the Honolulu and Hilo Chambers of Commerce, and the Government. Our Association has dealt with such cataclysms and was founded to alleviate them. Some alleviation in the future is possible and with financial support our laboratories are suitable to cooperate with others in design of warning instruments.

With this program decided on, need for a larger budget is brought to your attention. We approve raising $5000 for 1946, with costs of tidal wave investigation and the usual volcanology research shared with University and National Park. We hope you will increase your generous support, and the University of Hawaii looks forward to extending this work to a Pacific Ocean Institute, a project that has been taking shape for several years past. Gifts from new donors are welcomed.

Very truly yours,

L. P. Thurston, President
L. W. de Vis-Norton, Secretary and Treasurer

April 9, 1946

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Hawaiian Volcano Observatory Report for January-March 1946

VOLCANOLOGY

January

The year opened with both Kilauea and Mauna Loa inactive.

During heavy rains on January 31 dense steam clouds arose from the Halemaumau floor. Steam was escaping from nearly all cracks in the floor with a velocity of escape sufficient to set up a swishing roar that could be heard a few feet back from the rim.

One large landslide from the northwest notch of Halemaumau was observed at 4:25 P.M. on January 3.

No perceptible earthquakes occurred during the month. A total of 25 seismic disturbances was recorded at Kilauea and 30 at Mauna Loa seismographs.

February

Two earthquakes were felt locally during the month. A good record was obtained of a shake on February 14 which originated along the lower southwest rift of Mauna Loa. It was felt in Pahoehoe, South Kona, as a vertical drop without conspicuous horizontal motion. A total of 51 shakes was recorded at Mauna Loa and 27 at Kilauea.

Normal southwest tilt obtained during the month.

March

No perceptible earthquakes were recorded in March though 44 seismic disturbances were recorded at Kilauea and 51 at Mauna Loa.

There was a slight accumulation of north tilt during the month, abnormal for this season of the year. Westerly tilt was fairly uniform and about normal for March.

A large section of the southwest rim which had been in a precarious position since last September fell in sometime during the month.

R.H.F.

SEISMOLOGY

Earthquake Data, January-March 1946

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Local Seismicity*	Teleseisms
January	6	3	5	1	0	4.25	0
	13	0	2	0	0	1.00	1
	20	1	2	0	0	1.25	0
	27	4	4	0	0	3.00	0
February	3	5	0	0	0	1.25	0
	10	2	2	0	2	5.50	0
	17	3	4	0	1	4.75	0
	24	8	0	1	0	3.00	0
March	3	9	3	0	0	3.75	0
	10	4	2	1	0	3.00	0
	17	12	2	0	0	4.00	0
	24	6	1	0	0	2.00	0
	31	7	5	0	0	4.25	0

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours and 30 minutes slower than Greenwich. The number preceding each earthquake is the serial number of the quake for the current year.

1. January 2, 22:51, very feeble.
2. January 3, 05:52, very feeble.
3. January 3, 09:18, feeble. Kilauea shake.
4. January 4, 02:26, very feeble.
5. January 4, 02:28, very feeble.
6. January 8, 10:40, very feeble. Mauna Loa shake.
7. January 10, 15:13, very feeble.
8. January 15, 09:43, very feeble.
9. January 18, 13:20, very feeble.
10. January 22, 09:21, very feeble.
11. January 26, 21:56, very feeble.
12. January 27, 02:35, very feeble.
13. January 27, 10:46, very feeble.
14. February 4, 12:12, very feeble.
15. February 6, 04:45, slight. East-west dismantled. Near coast below Pahala. Felt at Kau and South Kona.
16. February 6, 17:43, very feeble. Northeast rift of Mauna Loa.
17. February 8, 06:15, slight. Felt locally, and at Pahala and Hilo. Northeast rift of Mauna Loa.
18. February 14, 09:03, slight. Middle southwest rift, Mauna Loa.
19. February 14, 16:02, very feeble.
20. February 16, 15:26, very feeble. Mauna Loa shake.
21. February 17, 02:26, very feeble. Kilauea origin.
22. February 17, 06:27, very feeble. Northeast rift, Mauna Loa.
23. February 23, 22:44, slight. Felt at North Kona and South Kohala.
24. February 26, 09:24, very feeble.
25. March 3, 08:20, very feeble.
26. March 3, 08:38, very feeble.
27. March 5, 09:42, feeble. Near Puu Ulaula, northeast rift of Mauna Loa.
28. March 6, 00:26, very feeble.
29. March 9, 17:12, very feeble.
30. March 12, 07:04, very feeble.
31. March 12, 18:19, very feeble.
32. March 20, 15:06, very feeble.
33. March 27, 18:57, very feeble.
34. March 27, 21:44, very feeble.
35. March 28, 21:36, very feeble.
36. March 29, 01:28, very feeble.
37. March 30, 16:11, very feeble.

TELESEISMS

January 12 10:03, slight.

MICROSEISMS

Microseisms were moderate on January 17-18 and February 27-28 and moderate to strong during March. During the rest of the quarter they were slight.

CRACK MEASUREMENTS

A few of the cracks around the Halemaumau rim opened slightly during the quarter. No movement was detected at the cracks along the Chain of Craters Road.

TILTING OF THE GROUND

Westerly tilt was about normal for the quarter except for an easterly excursion from January 23 to February 5. There was but little tilting in the north-south direction until January 21 when a distinct south tilt set in and continued until March 2. There was a noticeable accumulation of north tilt during March, or opposite to the normal for this season of the year. Such a northerly tilt does not necessarily mean an increase in pressure under Kilauea because the mean temperature for March was nearly 2° F. below that for January and February.

R.H.F.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended		Amount	Direction
January	6	0.26″	S 25° W
	13	0.24″	N
	20	0.65″	N 68° W
	27	0.81″	S 27° E
February	3	2.38″	S 25° E
	10	1.64″	S 36° W
	17	0.50″	N 76° W
	24	0.81″	S 64° W
March	3	1.44″	S 48° W
	10	0.73″	N 10° W
	17	1.05″	N 66° W
	24	0.60″	N 52° E
	31	0.65″	N 68° W

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THE VOLCANO LETTER

No. 492 **Department of Interior** **National Park Service** **April-June 1946**

PUBLISHED BY THE UNIVERSITY OF HAWAII

HAWAII NATIONAL PARK: Frank R. Oberhansley, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

REANALYZING TILT RECORDS AT THE HAWAIIAN VOLCANO OBSERVATORY

By H. A. POWERS
Geologist, Hawaii National Park

Tilting of the ground under the Hawaiian Volcano Observatory continues to be one of the most critical studies maintained by the Observatory.[1] The war seriously interrupted the expansion of the investigation to include installations of clinometers at critical points on the slopes of Mauna Loa, as well as the periodic triangulation and leveling surveys in the vicinity of Kilauea. However, daily readings have been maintained from the Bosch-Omori seismograph in the old instrument cellar and from the clinometer in the new instrument cellar.

Infallible interpretation of the measurements of ground movement would increase tremendously the possibility of accurate anticipation of volcanic events. In the constant effort to improve the technique of current interpretation of tilt records, the old records are periodically re-examined and subjected to various methods of analysis. Such a re-examination is now in progress at the Observatory and results will be presented from time to time in the VOLCANO LETTER.

The chart showing the general tilt changes at the Observatory from 1913 to 1939 (published as figure 8 in VOLCANO LETTER 467, January-March 1940) is reproduced on pages 4 and 5 as figure 1. The average of daily tilt coordinates from the Bosch-Omori seismograph for each month is determined, then the tilt curve is further smoothed by plotting five-month overlapping means. This plot presents the generalized seasonal tilt pattern and the longer term accumulations of tilt. Pronounced accumulations first to the north and then to the south during the period 1913 to 1925 kept the graph sufficiently open to be fairly clearly studied. The lack of large north-south accumulations in the years since 1925 has produced a maze of overlapping traces which has lost its clarity.

[1] Bibliography on page 2.

Figure 2 (page 6) presents the same type of tilt curve for the years 1940 to 1945 inclusive. It has been drawn separately, but is on the same scale as figure 1, and the months June 1929, January 1931, January 1936, and May 1939 have been added to the curve to fix its correspondence with the curve of figure 1.

Outstanding features of figure 2 are: (1) The relatively long north-east swing from May 1940 to January 1941; (2) the equally long southerly swing from February 1941 to August 1941, but with accumulation to the east; (3) the pronounced easterly swing from September 1941 to January 1942 with the annual loop of 1941 replaced by an acute angle; (4) the accumulation of westerly tilt during the two short annual loops of 1942 and 1943; (5) the almost perfect closure of the annual loop for 1944; and (6) the accumulation of north-east tilt in 1945.

The accumulation of easterly tilt prior to, and the accumulation of westerly tilt subsequent to, the flank eruption of Mauna Loa in the spring of 1942 is quite striking. Equally striking is the absence of any surface activity in Kilauea to accompany the rather large north and south swings. The details of the tilt swings during the last six years will be discussed in a later VOLCANO LETTER; the rest of this discussion will be devoted to a further study of the long-term tilt pattern.

A legible picture of the major tilt trends during the entire period 1913 to 1945 has been regained by sacrificing the presentation of the annual loops and computing one tilt position for each year. These data are further "smoothed" by plotting three-year overlapping means which eliminates part of the detailed annual change, but yields a more legible generalized curve. The coordinates used in the plot do not carry any reference to a particular time of the year.

The graph on the left in figure 3 (page 6) shows the average

tilt position for each year, further smoothed by three-year overlapping means, for the 33 years beginning with 1913. The coincidence of tilt accumulation with major volcanic events, pointed out by the previous writers, is still very apparent in this very simplified graph.

The azimuth of Kilauea collapse, so striking in figure 1, traced by the tilt line for the spring and summer of 1924, appears again as a much longer "direction line" in figure 3. Here the annual accumulation of tilt from 1922 to 1925 makes almost a straight line on the bearing South 20 degrees West. The same azimuth shows up numerous times, both in plots of daily accumulation and in those of monthly accumulation of tilt. It occurs both as a direction of subsidence towards Kilauea, as in 1924, and as a direction of uplift preceding lava appearance in Kilauea. The accumulation of evidence now seems to indicate that the azimuth N 20 E or S 20 W is the line of response to uplift or subsidence in Kilauea for the section of Kilauea rim upon which the old instrument cellar stands. At least the evidence is strong enough to warrant the use of this direction as a starting point in analysis of the accumulated tilt pattern.

Using the direction N 20 E—S 20 W instead of true N-S as a base line, the northerly or southerly accumulations shown by the annual averages have been re-computed, and similarly the easterly or westerly accumulations have been computed at right angles to the new base line, i.e., E 20 S and W 20 N, and the two accumulations plotted in the right hand graphs of figure 3. One line thus is assumed to present average annual accumulations of uplift or subsidence of Kilauea. The other line (pseudo east-west) presents accumulations of tilt at right angles to the dominant Kilauea azimuth, and may well represent, in part at least, uplift or subsidence of Mauna Loa, though the instrument location is too far from Mauna Loa to expect a tilt magnitude comparable to that of Kilauea.

The curve of Kilauea uplift and subsidence shows four main phases: the six-year uplift of 75 seconds of arc from 1914 to 1920, most of which occurred in 1918 and 1919; the five-year subsidence of 83 seconds of arc from 1921 to 1925, most of which occurred in the collapse of 1924; 14 years of interrupted subsidence from 1925 to 1939 amounting to 21.5 seconds of arc; and interrupted uplift to the present time amounting to almost 13.5 seconds of arc at the 1945 average. The first two phases were associated with volcanic events too well known to need repetition; the latter two phases have been associated with a period of extreme volcanic quiet in Kilauea. There is little correlation to be found between the slight peaks of uplift in 1927, 1931, 1936, and 1943 and the short-lived appearances of lava in Halemaumau in 1927, 1929, 1930, 1931, and 1934. The association of no appreciable volcanic activity with no appreciable accumulation of either uplift or subsidence is in itself significant. Further, it is at least suggested by the tilt curve that the bottom of Kilauea subsidence occurred in 1939. The first interruption of the big collapse occupied two years, 1926-1927, and gained 4 seconds of arc in uplift. The second interruption of the collapse again occupied two years, 1930-1931, and gained 2 seconds of arc. The third interruption occupied three years, 1934-1936, and gained 8.7 seconds of arc and the fourth, if it be only an interruption and not the turning point, gained 10.3 seconds of arc in 4 years, 1940-1943, and has continued the uplift after a minor subsidence in only one year, 1944.

The curve presenting accumulation of tilt at right angles to the line of Kilauea uplift and subsidence (the pseudo east-west tilt) shows three main phases: a sharp easterly tilt from 1913 to 1918 of 38.5 seconds of arc; a sharp westerly tilt from 1918 to 1920 of 27 seconds of arc; and a long gradual increase of easterly tilt, with several minor interruptions, from 1920 to 1942 with a total accumulation of 22.25 seconds of arc. At first glance there appears to be excellent correlation between the main peaks of accumulated easterly tilt and major Mauna Loa activity. The easterly peak in 1918 led up to the major flank eruption of 1919 with the westerly subsidence following the lava flow. The easterly peak in 1942 coincided with the flank flow of 1942, and again westerly subsidence followed the flow, though on a much smaller scale. The flank flow of 1926 occurred on a bulge of easterly tilt, but there was no westerly subsidence of magnitude great enough to affect the average for 1927, which actually shows further accumulation of easterly tilt. The summit activity of 1933 occurred with accumulation of easterly tilt, which held static then until the flank flow of 1935. There was westerly subsidence in 1936 after the flow, but 1937 shows further easterly accumulation. The major summit flow of 1940 occurred at the bottom of three years accumulation of westerly tilt. Thus the correlation is far from being "cut and dried," but it does seem apparent that increases and decreases of pressure under Mauna Loa are reflected to a considerable extent in the tilting at the Observatory at right angles to the axis of Kilauea uplift and subsidence.

Jaggar and Finch pointed out a closer correlation between the curve of temperature and the curve of east-west tilt than between the temperature and the north-south tilt. The question of a possible cumulative effect of temperature on average annual accumulation of easterly and westerly tilt will be considered in a forthcoming VOLCANO LETTER.

Two groups of five consecutive years, 1925-1929 and 1932-1936, show very modest accumulation of either easterly or westerly tilt within the span of the group. The seasonal tilt curves of these particular years are being studied in detail in an effort to evaluate quantitatively and qualitatively a "standard" seasonal tilt pattern. If such a pattern can be reasonably established, it will facilitate greatly the week to week evaluation and interpretation of the tilt curves as they are recorded.

Bibliography

JAGGAR, T. A., JR. Seismometric Investigation of the Hawaiian Lava Column. Seismol. Soc. Amer. Bul. 10: 221-232, December 1920.

JAGGAR, T. A., JR., FINCH, R. H., AND EMERSON, O. H. The Lava Tide, Seasonal Tilt, and the Volcanic Cycle. Proc. Second Pan-Pacific Sci. Congress, Australia, 1923.

FINCH, R. H. Earthquake Prediction. Science, 61 (42) : January 9, 1925.

FINCH, R. H. Tilting of the Ground at the Hawaiian Volcano Observatory. Volcano Letter 41, October 8, 1925.

FINCH, R. H. Tilt and Changes of Elevation, Kilauea. Volcano Letter 61, February 25, 1926.

FINCH, R. H. Bulk Displacement Due to Tilting. Volcano Letter 74, May 27, 1926.

FINCH, R. H. Kilauea Report No. 757. Volcano Letter 81, July 15, 1926.

WILSON, R. M. Some Points Concerning 1927 Observations at Kilauea. Volcano Letter 130, June 23, 1927.

WILSON, R. M. Horizontal Ground Movements. Volcano Letter 143, September 22, 1927.

WILSON, R. M. Tilt. Volcano Letter 193, September 6, 1928.

JAGGAR, T. A., JR. The Swelling of Volcanoes. Volcano Letter 276, April 10, 1930.

JAGGAR, T. A., JR. Ground Movement in a Volcano. Volcano Letter 276, April 10, 1930.

POWERS, H. A. Tilt and Rainfall. Volcano Letter 303, October 16, 1930.

WINGATE, E. G. Vertical and Horizontal Ground Movement. Volcano Letter 349, September 3, 1931.

JAGGAR, T. A. Twenty Years of Volcano Study in Hawaii. Volcano Letter 381, 382, 383, 384, 1932.

WINGATE, E. G. Study of Ground Tilts at the Observatory. Volcano Letter 392, October 1932.

WINGATE, E. G. Puna Triangulation. Volcano Letter 400, June 1933.

WILSON, R. M. Ground Surface Movements at Kilauea Volcano, Hawaii. Hawaii Univ. Res. Pub. 10, 1935.

WINGATE, E. G. What May be Learned from Tilt. Volcano Letter 432, February 1936.

WAESCHE, H. H. Crack Measurements and Tilt at Hawaiian Volcano Observatory. Volcano Letter 446, April 1937.

WAESCHE, H. H. Triangulation and Level Changes at Kilauea. Volcano Letter 452, October 1937.

WAESCHE, H. H. Tilt Changes at Kilauea. Volcano Letter 467, January-March 1940.

SCHULZ, P. E. Tilt Recordings at Hawaiian Volcano Observatory and Their Conversion to Seconds of Arc. Volcano Letter 473, July-September 1941.

WAESCHE, H. H. Ground Tilt at Kilauea Volcano. Jour. Geol. 50 (6) : 643-661, 1942.

SEISMIC SEA WAVE VELOCITIES

In Transactions of the American Geophysical Union, 27 (3) : June 1946, E. C. McKay has supplied considerable statistical material dealing with the seismic sea waves induced by the Aleutian earthquake of April 1, 1946. In VOLCANO LETTER 491, January-March 1946, H. A. Powers discusses effects in Hawaii only. The velocities as given in the McKay table do not always agree with the velocities of waves induced by other disturbances that travel nearly identical paths.

In the following table are shown some of the data for the April 1, 1946, sea waves and for the August 11, 1868, Arica, Peru, shake.[1]

[1] MILNE, JOHN. EARTHQUAKES (London, 1913), p. 182.

Table 1.—Velocities for the sea waves of April 1, 1946 and August 11, 1868.

Place	Distance	Average velocity
	Statute miles	*Miles per hour*
Aleutian earthquake of April 1, 1946:		
Neah Bay, Wash.	1,687	375
Honolulu, T. H.	2,241	490
San Francisco, Calif.	2,197	398
La Jolla, Calif.	2,646	428
Valpariso, Chile	8,066	445
Arica, Peru, August 11, 1868:		
San Diego, Calif.	4,700	420
Honolulu, T. H.	6,510	529
Samoa	6,720	429
Sydney, Australia	8,680	366

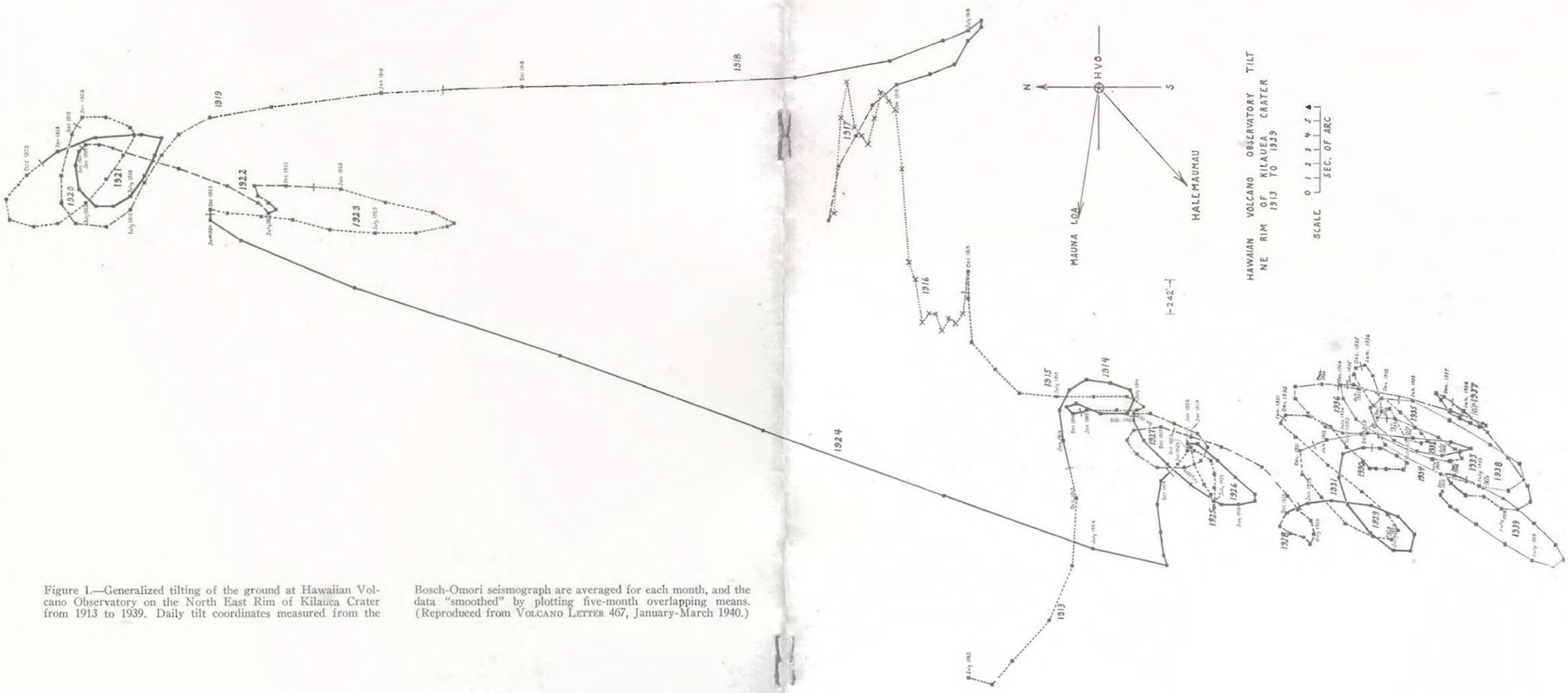


Figure 1.—Generalized tilting of the ground at Hawaiian Volcano Observatory on the North East Rim of Kilauea Crater from 1913 to 1939. Daily tilt coordinates measured from the Bosch-Omori seismograph are averaged for each month, and the data "smoothed" by plotting five-month overlapping means. (Reproduced from VOLCANO LETTER 467, January-March 1940.)

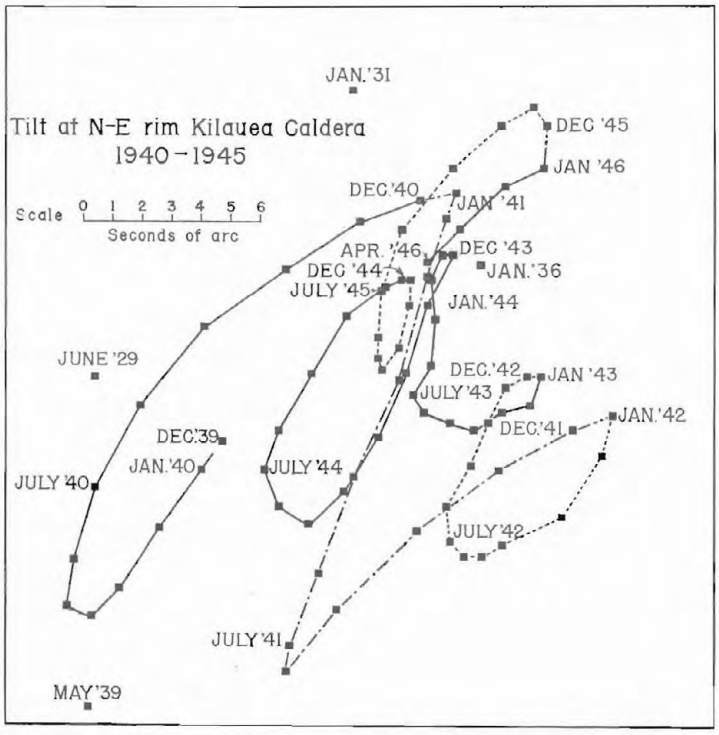
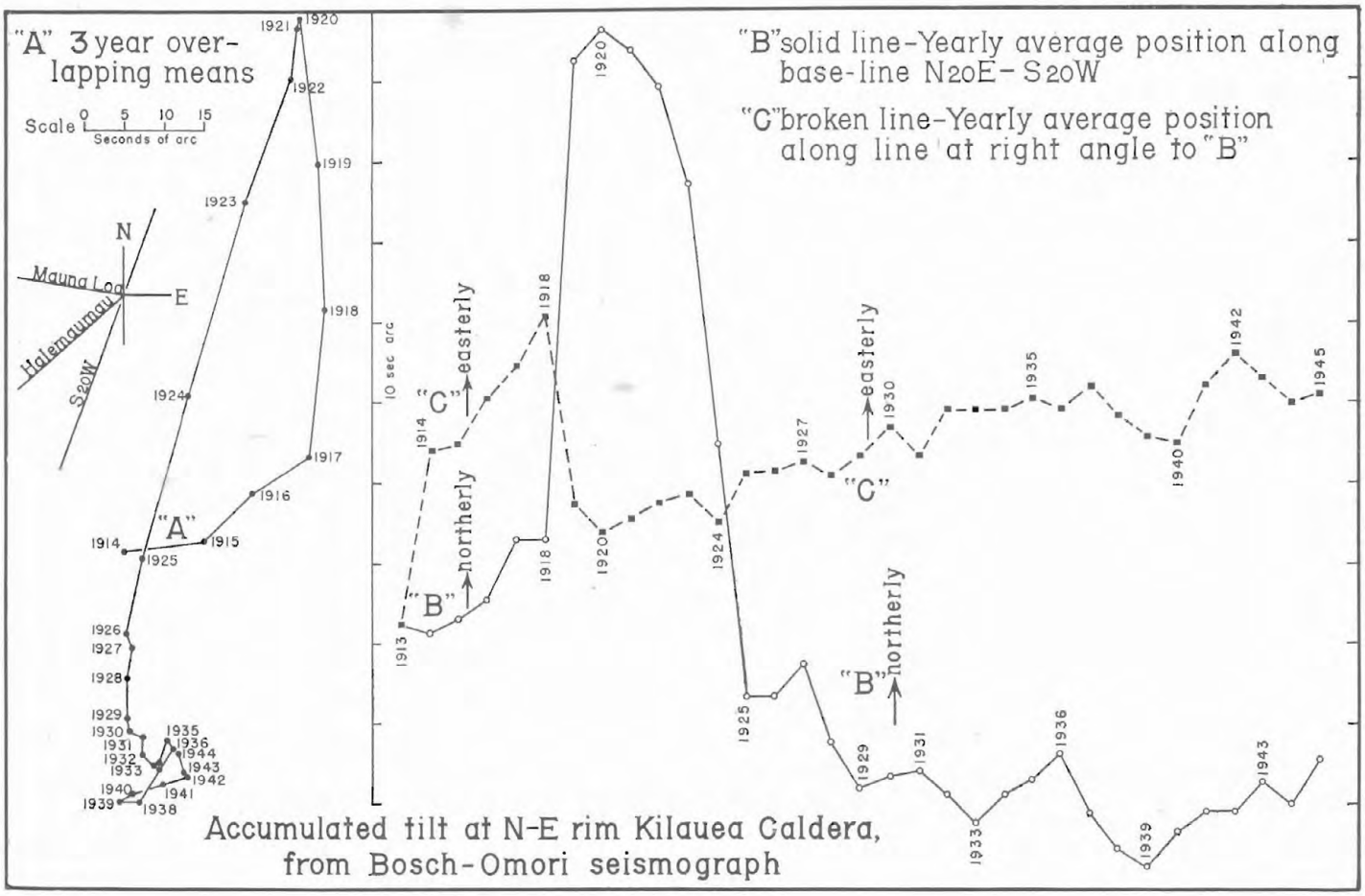


Figure 2.—A continuation of the curve of figure 1 covering the years 1940 to 1945 inclusive.

Figure 3.—"A". Data from figures 1 and 2, further smoothed by computing average coordinates for each year and plotting three-year overlapping means. "B". Accumulated annual average tilt measured on a base line N 20 E—S 20 W, the dominant direction in which the block of rim under the Observatory tilts in response to uplift and subsidence in Kilauea. "C". Accumulated annual average tilt measured at right angles to the base line used in "B," which expresses (at least in part) tilting of the Observatory rim in response to uplift and subsidence in Mauna Loa.



Hawaiian Volcano Observatory Report for April-June 1946

VOLCANOLOGY

April

A fume cloud was observed over Mokuaweoweo on April 30.

The seismographs recorded 49 local disturbances at Kilauea and 47 at Mauna Loa during April.

The tilt curve for the first four months of the year may be taken as indicating a slight build-up of internal pressure under Kilauea.

May

The number of earthquakes recorded during May was 65 at Kilauea and 68 at Mauna Loa. There has been an increase in earthquake frequency during recent months, though neither the number of shakes nor their distribution can be taken as signs of impending activity of Kilauea or Mauna Loa.

June

Mauna Loa had several spells of rather conspicuous fuming during the month. The usual amount of steaming was also observed on several days.

More earthquakes were recorded at Kilauea than at Mauna Loa—64 and 35, respectively.

Tilt records indicate that there has been a slight pressure build-up under both Kilauea and Mauna Loa during the past two years. There is, then, a possibility that either Kilauea or Mauna Loa, may erupt in the next year or two with but few additional premonitory symptoms.

R.H.F.

SEISMOLOGY

Earthquake Data, April-June 1946

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Local Seismicity*	Teleseisms
April	7	10	0	0	0	2.50	3
	14	10	0	0	2	6.50	0
	21	16	4	0	0	6.00	0
	28	5	5	0	0	3.75	0
May	5	12	1	0	0	3.50	0
	12	13	1	0	0	3.75	0
	19	5	2	0	1	4.25	0
	26	15	1	0	0	4.25	0
June	2	13	1	1	0	4.75	0
	9	12	2	1	0	5.00	0
	16	6	1	1	0	3.00	0
	23	7	2	1	0	3.75	1
	30	6	5	0	0	4.00	1

* For definition of local seismicity, see VOLCANO LETTER No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours and 30 minutes slower than Greenwich. The number preceding each earthquake is the serial number of the quake for the current year.

38. April 8, 08:58, slight. Deep under Mauna Loa. Widely felt.
39. April 9, 10:03, slight. Kilauea shake. Felt locally.
40. April 17, 12:56, very feeble.
41. April 18, 01:46, very feeble.
42. April 21, 07:10, very feeble. Deep under Kilauea.
43. April 21, 22:35, very feeble. Mauna Loa shake.
44. April 22, 10:48, very feeble. Kilauea shake.
45. April 23, 03:37, very feeble. Mauna Loa shake.
46. April 23, 22:24, very feeble. NE rift Mauna Loa.
47. April 25, 18:25, very feeble. Under E slope of Mauna Loa.
48. April 27, 19:11, very feeble.
49. April 30, 04:55, very feeble.
50. May 7, 14:38, very feeble. Mauna Loa shake.
51. May 15, 09:45, very feeble.
52. May 19, 18:36, slight. Felt locally and at Hilo.
53. May 19, 21:35, very feeble.
54. May 23, 08:40, very feeble. Under Mauna Kea.
55. May 30, 17:17, feeble. E slope of Mauna Loa.
56. May 31, 09:09, very feeble.
57. June 5, 02:39, feeble. E slope of Mauna Loa near Ainapo.
58. June 5, 10:02, slight. Felt in Kau. Along coast near Puu Kapukopu.
59. June 5, 16:17, very feeble.
60. June 8, 01:13, very feeble.
61. June 10, 02:56, very feeble.
62. June 10, 17:51, feeble. Felt in Kau.
63. June 20, 13:34, very feeble. Kilauea shake.
64. June 20, 13:38, very feeble. Kilauea shake.
65. June 20, 13:51, feeble. Kilauea shake.
66. June 26, 21:01, very feeble. E slope of Mauna Loa.
67. June 27, 04:38, very feeble. Felt in Kona.
68. June 29, 12:01, very feeble.
69. June 30, 22:02, very feeble.
70. June 30, 03:03, very feeble.

TELESEISMS

April 1, 02:06, strong. South of Unimak Island. Caused a destructive tidal wave.

June 22, 06:50, slight. 4300 km.

June 25, 21:33, slight.

MICROSEISMS

Microseisms were strong during April from the 1st to the 19th inclusive, and on the 26th and 27th. They were light to moderate on other days. During May they were strong on May 6 and light to moderate the rest of the month. Nothing but light to moderate microseisms were recorded in June.

CRACK MEASUREMENTS

There was but little movement at any of the cracks measured near the Halemaumau rim or along the Chain of Craters Road.

TILTING OF THE GROUND

There was a slight and rather uniform tilt to the south during April and May. The seasonal change in direction took place on May 31, and during June there was about the usual northerly tilt. Westerly tilt was slight and rather uniform during the quarter except for slight easterly excursions on May 20 to 29 and June 9 to 14.

R.H.F.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended	Amount	Direction
April 7	0.60″	W
14	1.14″	S 70° W
21	0.37″	N 71° W
28	0.61″	S 53° E
May 5	0.88″	S 16° W
12	1.55″	S 39° W
19	0.98″	N 60° E
26	1.08″	S 63° E
June 2	0.60″	W
9	1.15″	N 57° W
16	0.77″	S 20° E
23	0.88″	N 74° W
30	0.51″	N 69° W

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

in cooperation with UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Government, Department of the Interior, National Park Service.

The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** supplement the work of the government with research associates, instrumental plants and special investigation. Dr. T. A. Jaggar is their geophysicist resident in the National Park.

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THE VOLCANO LETTER

No. 493 **Department of Interior** **National Park Service** **July-September 1946**

PUBLISHED BY THE UNIVERSITY OF HAWAII

HAWAII NATIONAL PARK: Frank R. Oberhansley, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

THE PUNA RIFT OF KILAUEA

By R. H. FINCH

Volcanologist, Hawaii National Park

The active rift systems of Mauna Loa and Kilauea are roughly parallel and aligned northeast-southwest. The last few miles of the southwest portion of the Kilauea rift trends about S 15° W while the lower southwest portion of the Mauna Loa rift trends nearly due north and south.

A glance at the map (fig. 1) shows that it is not appropriate to speak of the northeast portion of the Kilauea rift because for the first 8 miles from Halemaumau the general direction is southeast. The direction change is not by means of a sharp angle but rather by a broad sweeping curve. Makaopuhi pit crater marks the beginning of the northeast portion. From this crater the trend is about N 60° E for about 25 miles until it passes under the ocean near Cape Kumakahi. The Puna rift, as the rift in the eastern flank of Kilauea might best be called, is interesting not only for the distinct curve in its upper reaches but also for the numerous lava flows that have originated along it and for the many pit craters.

Lava flows have issued at many places along most of the length of the Puna rift. Some of the flows issued quietly from fissures and did not build up conspicuous spatter or cinder cones, but numerous cinder cones mark the point of origin of other flows that had persistent fountains at their sources. The lava in the flows from this rift came from Kilauea by means of rift tubes—that is, lava tubes that formed in cracks at varying depths below the surface. The entrance to the SW rift tube that fed the 1920 and 1921 flows from Kilauea was only a little over 100 feet below the Halemaumau rim.[1] The entrance to the tube that fed the Puna rift flows at Makaopuhi and Napau Craters in 1922 must have been about 1,000 feet below the rim as the collapse of that year left 900 feet of the Halemaumau wall exposed and no entrance was revealed. It is interesting to note that the Reverend Titus Coan surmised that the lava in the rift tube of 1840 was about 1,000 feet below the surface.[2]

The Puna rift and its attendant tubes is continuous despite the curving upper portion. This was shown in 1840 by the lava first appearing in the curved upper portion 6 miles from the source, then near the middle portion, and finally issuing from a crack 23 miles from Kilauea caldera. The source of the lava in the flows from both the Puna and southwest rifts is in Kilauea. This has been repeatedly shown by the sinking of the lava column in Halemaumau that accompanies drainage through rift tubes. Examples are the flank flows and collapses in 1840, 1868, 1919, 1920, 1921, 1922, 1923, and probably 1924. The vents along both rifts of Kilauea are parasitic. The ascent of lava is confined to the feeding conduits under Halemaumau.

There is considerable evidence that the thickness of Kilauea lavas is comparatively slight. Stone has offered evidence that the depth of Kilauea lavas in the vicinity of Makaopuhi is about 900 feet.[3] There is, in general, a gradual decrease in the thickness of Kilauea lavas with increase in distance from the caldera. Pahala ash, which marks the base of the Kilauea series, is found at the surface with a depth of 3 to 5 feet 2.5 miles southwest of Olaa village and with lesser depths in small kipukas 0.5 and 1.3 miles southwest of Pahoa. The more southwesterly of these kipukas is very near the edge of the Puna rift zone. The Kilauea lavas of the Puna rift poured out onto a terrain that had a very flat slope on the northwest side and a steep slope with fault scarps on the southeast. These scarps are distinct in the vicinity of Hilina Pali and for 16 miles or so to the northeast. Farther on to the northeast there have been sufficient lava flows to mask

[1] Hawaiian Volcano Observatory Bul., Vol. 10, No. 5, p. 52. 1922.

[2] HITCHCOCK, C. H. HAWAII AND ITS VOLCANOES. P. 188. Honolulu, 1911.

[3] STONE, J. B. THE PRODUCTS AND STRUCTURE OF KILAUEA. Bernice P. Bishop Mus. Bul. 33, p. 38. 1926.

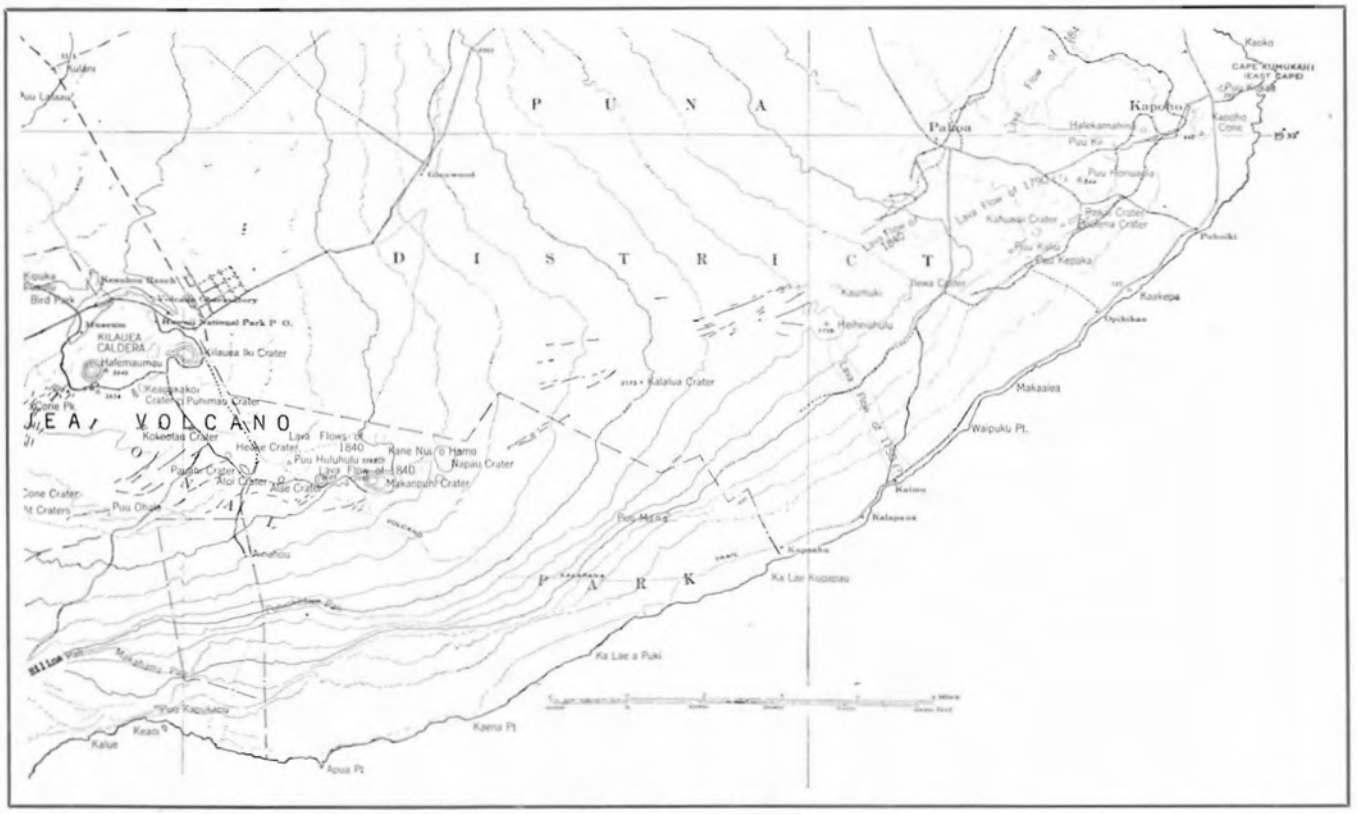

Figure 1.—Map showing the Puna rift of Kilauea and a portion of the southwest rift. Note the numerous intersections of the curved portion of the rift with NE–SW-trending fissures.

any true scarps, but the steep southeast slope indicates that the topography is still dominated by the effects of destructive forces.

Pit craters are formed by engulfment into rift tubes. Counting Keanakakoi and Lua Manu, both of which are within the general breakdown of Kilauea caldera, there are at least 18 pit craters on the Puna rift. None of the pit craters has been a source of real lava flows though lava has appeared in several of them one or more times after they were formed. Pauahi is really two pit craters of appreciable difference in age that happened to form close enough for the younger western one to break down the barrier that for a time separated it from the older eastern pit. Makaopuhi is a doublet. It is likely, though not definitely known, that its two parts formed at different ages. There are at least 14 of the pit craters in the upper portion of the Puna rift and 4 more in the vicinity of Puulena Crater, or 18 miles northeast of Napau Crater. Puulena is counted as two pits though the age difference between the two components is uncertain. Near Iilewa (Ilewa on the map) there is a distinct formation that may be a pit crater with one wall nearly buried. It was not counted to make the total of 18, however. In the southwest rift zone of Kilauea there are but two pit craters with depths of about 220 feet. The deepest one on the Puna rift is Makaopuhi with a depth of 950 feet.

The reason for the concentration of pit craters along the Puna rift is readily apparent. The upper grouping of the craters is due to the intersection of the Puna rift by a series of fissures trending NE–SW roughly parallel to the Hilina Pali breakdown series in their upper reaches and tending to an alignment with the southwest rift system in their lower. Any such intersection, even at a flat angle, would be a favorable location for the development of pit craters.

The four pit craters in the vicinity of Puulena are on the edge of the Puna rift. They are located on what appears to be a buried fault scarp of the Hilina Pali system. The slope of the country in the vicinity of these craters is 400 to 600 feet to the mile with some small ash-covered slopes that are much steeper. The ash appears to be of local origin though whether it buries Pahala ash is not certain. Large explosion blocks, definitely of local origin, are found in the vicinity of Puulena Crater.

It is conceivable that pit craters can develop at almost any place over a rift tube where appreciable stopping takes place. That they should be numerous in the upper portion of the Puna rift and non-existent or rare elsewhere, except for the four near Puulena, points to a systematic local control. A greater gas content of the lava and a resultant greater stopping near the source does not seem adequate to account for the grouping of the pit craters. The 18 pit craters are located at known or suspected places of intersection of the Puna rift by other faults.

Hawaiian Volcano Observatory Report for July-September 1946

VOLCANOLOGY

July

In July, as in June, considerable steaming was observed over Mokuaweoweo. Observations from the rim of Mokuaweoweo on July 23 showed both steam and dark fume escaping.

Forty-four seismic disturbances were recorded at Kilauea. An incomplete record indicates that there were more Mauna Loa than Kilauea shakes.

August

During the month of August, 53 earthquakes were recorded at Kilauea and 46 at Mauna Loa.

The volume of steam escaping from Mokuaweoweo has been more than normal for the last 3 years. Observations from the rim on August 28 and 29 revealed a distinct bluish cast to the fume.

There has been a gradual decrease in the amount of steam escaping at the hot area in the vicinity of Kokoolau Crater.

September

The Kilauea and Mauna Loa seismographs recorded the same number of earthquakes during September—33 each. This is the lowest monthly total recorded during the last 5 months.

A dark, conspicuous fume column was observed over Mokuaweoweo shortly after sunset on September 2. The fume column developed about 2 hours after a perceptible earthquake that originated deep under the east slope of Mauna Loa.

R.H.F.

SEISMOLOGY

Earthquake Data, July-September 1946

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Local Seismicity*	Teleseisms
July	7	19	3	0	0	6.25	0
	14	3	2	1	0	2.75	1
	21	2	2	0	0	1.50	2
	28	1	1	2	0	2.75	0
August	4	16	2	1	0	6.00	1
	11	13	1	0	1	5.75	1
	18	14	0	0	0	3.50	0
	25	6	1	0	0	2.00	0
September	1	6	1	1	0	3.00	0
	8	4	0	1	1	4.00	0
	15	3	3	0	0	2.25	0
	22	3	3	0	0	2.25	0
	29	8	6	0	0	5.00	2

* For definition of local seismicity, see VOLCANO LETTER No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours and 30 minutes slower than Greenwich. The number preceding each earthquake is the serial number of the quake for the current year.

71. July 3, 03:21, very feeble. Kilauea.
72. July 5, 12:14, very feeble. Mauna Loa, NE slope.
73. July 6, 02:06, very feeble. NE, Mauna Loa.
74. July 9, 13:33, very feeble. Deep Kilauea.
75. July 11, 04:43, very feeble. Mauna Loa, NE slope.
76. July 13, 23:34, feeble. Mauna Loa, E slope.
77. July 15, 10:45, very feeble. Mauna Loa, NE slope.
78. July 20, 11:49, very feeble. Mauna Loa, E slope.
79. July 25, 14:32, feeble. Felt at Pahala.
80. July 27, 05:51, very feeble.
81. July 28, 15:40, feeble. Kilauea.
82. July 29, 15:25, very feeble.
83. July 29, 22:51, very feeble. Mauna Loa, NE slope.
84. August 1, 12:59, feeble. Mauna Loa, NE slope.
85. August 5, 09:30, very feeble. Mauna Loa, NE slope.
86. August 8, 16:28, slight. Mauna Loa, NE slope. Felt at Kilauea.
87. August 20, 10:10, very feeble. Deep. Mauna Loa.
88. August 29, 22:45, feeble. Mauna Loa, NE slope.
89. August 30, 02:43, very feeble. Mauna Loa, SW slope.
90. September 2, 16:39, feeble. Mauna Loa, NE slope. Felt at Kilauea and Kona.
91. September 4, 13:21, slight. Mauna Loa, NE slope. Felt at Kilauea.
92. September 11, 11:59, very feeble. Mauna Loa, NE slope.
93. September 12, 10:25, very feeble. Mauna Loa, E slope.
94. September 15, 01:52, very feeble. Mauna Loa, E slope.
95. September 18, 03:33, very feeble. Shallow Mauna Loa, E slope. Felt at Kapapala.
96. September 19, 19:00, very feeble. Mauna Loa, NE slope.
97. September 20, 22:18, very feeble. Mauna Loa, NE slope.
98. September 23, 19:43, very feeble. Mauna Loa, NE slope.
99. September 24, 03:43, very feeble. Mauna Loa, NE slope.
100. September 24, 11:08, very feeble. Kilauea.
101. September 24, 20:06, very feeble. Mauna Loa, NE slope.
102. September 27, 07:00, very feeble. Mauna Loa, NE slope.
103. September 29, 23:07, very feeble. Mauna Loa, NE slope.

TELESEISMS

July 9, 02:52. Slight.
July 17, 19:50. Slight.
July 17, 21:03. Slight.
August 4, 07:33. West Indian quake.
August 8, 03:10. West Indian aftershock.
September 26, 00:28. Slight.
September 28, 16:40. About 3,750 miles distant.

MICROSEISMS

Microseisms were strong during the first 12 days of July and moderate to light during the rest of the month. August 1st to 3rd had strong microseisms with moderate and light the balance of the month. September microseisms were strong on the 1st and 2nd and again on the 29th and 30th. The rest of the month was light to moderate.

CRACK MEASUREMENTS

There was but little movement at any of the cracks measured around Halemaumau or along the Chain of Craters Road.

TILTING OF THE GROUND

The 3-month period, July-September, showed a total tilt of 4.5 seconds of arc in a direction N 26° E, which is slightly more easting than average for this season of the year.

H. A. Powers.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended		Amount	Direction
July	7	1.20″	N 49° E
	14	0.60″	N 37° W
	21	1.80″	E
	28	1.70″	N 77° W
August	4	0.50″	N 45° W
	11	0.70″	N 45° E
	18	0.50″	S 62° E
	25	0.25″	N
September	1	1.10″	N 27° W
	8	0.90″	N 45° E
	15	0.60″	S 68° W
	22	0.80″	N 64° E
	29	0.50″	E

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

in cooperation with UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Government, Department of the Interior, National Park Service.

The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** supplement the work of the government with research associates, instrumental plants and special investigation. Dr. T. A. Jaggar is their geophysicist resident in the National Park.

The **Volcano Letter**, a quarterly record of Hawaiian volcano laboratories and published by the University of Hawaii, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the above establishments.

THE VOLCANO LETTER

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HAWAII NATIONAL PARK: Frank R. Oberhansley, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

REVIEW OF "GEOLOGY AND GROUND-WATER RESOURCES OF THE ISLAND OF HAWAII," H. T. STEARNS AND G. A. MACDONALD

By H. A. POWERS

Seismologist, Hawaii National Park

Geology and Ground-Water Resources of the Island of Hawaii, Bulletin 9 of the Hawaii Division of Hydrography of the U. S. Geological Survey, and the latest of the series describing the geology and ground-water resources of the islands of the Territory of Hawaii, is the only recent publication which presents a compilation of all that is currently known of the geology of the island of Hawaii. As such, it is in a position to become the most widely read source book on Hawaii and her volcanoes. Most sections of the book merit this outstanding position in the literature, notably those parts dealing with the geomorphology of the major volcanic cones, the historic activity of both Mauna Loa and Kilauea, the geology of Mauna Kea, the petrography of Hawaii, and the ground-water resources of the island; other parts fall short of this caliber, notably the section on vocabulary of volcanic terms, the treatment of the "ash problem" of the island, and the correlation of volcanic and erosional history with Pleistocene swings of sea level and the geologic time scale.

A line-by-line study of Bulletin 9 has been made with the thought of enhancing somewhat its value as the outstanding source book on Hawaii. In the presentation of this study, to avoid prohibitive length and at the risk of appearing over-critical, less space can be devoted to favorable comment than to constructive criticism. A few remaining editorial errata, and a very few errors in statement of fact have been picked up. Attention is called to a few misquotations and a few omissions of reference to literature. Caution is indicated in certain passages in which the authors' conclusion on an unsettled question is stated in phrases which suggest that other interpretation is no longer possible.

R. H. Finch, Volcanologist, and G. O. Fagerlund, Naturalist, of Hawaii National Park, have taken an extremely active interest in this review, and significant remarks of praise or criticism are the well-considered summation of much discussion among the three of us.

A few errata and miscellaneous comments which would fit awkwardly in the subsequent paragraphs are listed here.

Plate 3, item 67. *1924* should be *1790.*

Page 7. The use of land for ranch versus forest is poorly presented by figure 3, which appears to be a map showing classification of land for tax purposes. This is partly explained on page 10.

Page 22, line 7 from bottom. The use of *dike* here does not conform to the definition given above for *dike.*

Page 26, Plate 13. The caption 13A refers to plate 13B, plates A and B being reversed.

Page 39, line 8 from bottom. *Figure 47* should be *figure 4.*

Page 48, line 3 from bottom. *Southwestern* should be *southeastern.*

Page 48, bottom line. *60 inches* should be *120 inches.*

Page 51. *Honokane Nui Valley* should be located by the text in Kohala.

Page 70. Wentworth is misquoted in regard to Halai and Puu Hono. He says that their relationship is obscure, but probably with Mauna Loa and not Mauna Kea.

Page 99, line 16. *1928* should be *1930.*

Page 108, line 9. *Aa* should be *ash.*

Page 117, line 13. *500 feet* should be *1500 feet.*

Page 119, line 17 from bottom. *Night* has no significance except to describe a period of a few hours time.

Page 120, line 16. *Water gas* might better be expressed as *water vapor.*

Page 122, last paragraph. Much periodic fuming and occasional glow in the pit characterized the quiet period at the beginning of the century, which has not been the case in the current period of quiet.

Page 127, line 8 from bottom. *Percolating* is not a good word to express the sudden rush of water necessary to create a "flash boiler" explosion.

Page 145. The phrase "It has not been recognized previously as a lava flow," is incorrect, as Sidney Powers states "The Puu Anahulu trachyte represents a flow at least 5 miles in length and over 100 feet in thickness. . . ." on page 269 of his *Notes on Hawaiian Petrology* published in 1920.

Page 198, line 13 from bottom. *Hills* should be *sills.*

Page 209, line 6 from bottom. A breeze which reverses its direction every 12 hours should not be called a *prevailing wind.*

Abstract, Geologic and Guide Maps

A visitor may get an excellent picture of the geology, volcanology, topography, and climate of the area, with a minimum of reading, by careful study of the ABSTRACT, of the geologic map (plate 1), and of the maps of points of interest (plates 2 and 3). The abstract is particularly well written, conveying a maximum of concise information. The point made in the abstract, referring to augite phenocrysts in Mauna Loa lavas, must be based on the paper by Macdonald on petrography (waiting publication as a Professional Paper of the Geological Survey), as no reference to such petrographic detail is made in Bulletin 9. A reader not familiar with the symbolic presentation of information in a geologic cross section should be cautioned not to form his conclusions as to volcanic processes from the map without careful study of the text. For example, the map symbol picturing dikes cannot convey the fact (discussed in the text) that erupting lava may move laterally as well as vertically through a crack extending from the central vent area down one or the other of the rift zones.

Definitions and Descriptions

In a work of this nature, written for the use of persons with professional backgrounds other than geology as well as for geologists, a definition of terms is probably necessary. For the non-geologist a few of the definitions are too brief to be of the greatest vlaue, *i.e.,* the definitions of rock names and *rift zone* on page 13; a few are long enough to be descriptions rather than definitions, *i.e., vent breccia* on page 19. Most of the terms used are concisely defined and well chosen, but a few are not altogether satisfactory and justify further comment.

The specific use of the word *ash,* defined on page 16, describes a fragmental volcanic product of fine size; the use of the word in a formation name, *i.e., Pahala ash* on page 71, describes a deposit essentially consisting of fine material, and the value of the word is not disturbed by the fact that some fragments of size greater than fine may be found in the deposit. In a description of a deposit in which all the ash has been produced by magmatic explosion (vitric ash), the word *ash,* by gentlemen's agreement so to speak, may be used to mean only *vitric ash.* To make the word *ash* carry this additional restriction by definition (page 18, "the terms ash and tuff, if not qualified by descriptive adjectives, refer herein to such lava fountain deposits") is impractical because it prohibits the use of the word in its originally defined sense. The authors have been forced to violate the additional restriction in so many places that a reader will find more clarity if he ignores the statement quoted above from page 18.

The use of the word *caldera* is not clear and precise throughout the text, nor is the definition given on page 14 sufficient to clarify the authors' intended usage. Parts of the discussion on pages 29 to 33 indicate that *caldera* defines the entire area of summit collapse around Mokuaweoweo and Kilauea. However, the statements of dimension indicate that *caldera* is used to denote only the areas known in the literature as the *craters* of Mokuaweoweo and Kilauea. The mere substitution of *caldera* for *crater* seems hardly justified; the introduction of *caldera* to name the entire area of active summit collapse would be very satisfactory, as it tends to emphasize the concept that Kilauea, Halemaumau, Keanakakoi, and Kilauea Iki are *craters* of more or less fugitive existence within the active *caldera* of Kilauea. Such usage would eliminate some of the discussion as to whether certain flows are flank or summit flows (page 82), since most of the troublesome ones definitely are *caldera* flows under the broad definition of *caldera.*

At times there is a tendency in science to "over define" too many terms, leaving no "free-lance" words which can be used, with appropriate adjectives, to convey a precise meaning when needed. The point is illustrated by the restricted definition of *crater* and *pit-crater* (page 16) which literally leaves one with no precise word for Halemaumau, the pit marking the most permanent vent of Kilauea.

The definitions of *aa* and *pahoehoe* are not precise and tend more to description. More precision of definition could have been gained had the authors chosen to limit the application of the terms to congealed lava forms, following Austin E. Jones.[1] Conforming to this limitation, *pahoehoe* is congealed lava with an unbroken surface of quenched glass, and *aa* is lava with a broken surface of spiny, granular, mostly crystallized rock. A flow is called *pahoehoe* or *aa* depending on which type of surface is greatly predominant. The type of surface which will form upon quenching is determined by the nearness of the liquid lava to the crystallization range of most of its constituent minerals. Nearness to crystallization is determined greatly by temperature, and secondarily by the proportion of volatile constituents in an erupted lava. Probably all Hawaiian primitive basaltic lavas are hot enough, when erupted, to quench as pahoehoe if conditions met with after eruption are favorable, *i.e.,* the turbulence of any particular body of liquid must be low enough to permit the quenched skin of glass to remain unbroken and contain the body of liquid until it congeals. If turbulence, due to fountaining or velocity of flow, postpones the formation of a containing skin of glass long enough for loss of temperature and loss of volatile constituents to bring the liquid within the critical crystallization range, quenching can no longer produce a glass skin, *pahoehoe,* but will produce granulated, spiny rubble, *aa.*

The authors' statement on page 20, "They [tumuli or pressure domes] may be formed by collapse as well as by pressure" is not at all clear. The use of *vesicular* rather than *scoriaceous* (page 20) to describe the lava immediately next to the glassy skin of pahoehoe would be more precise, as *scoriaceous* is also used in geology to express the concept of slaggy. The statement on page 20 "No true pillow lava has been found in the island—" should have been modified to anticipate references in the text to the formation of pillow lava at the submarine end of the 1859 Mauna Loa flow (plate 2, item 24, and page 85). In the definition of explosion products on page 16, avalanche material might have been mentioned as an additional source of *accessory ejecta.*

Hawaiian Volcanism in General

The section on MAJOR CONES (page 24) is an excellent, concise discussion of the broad pattern of volcanic development in the Hawaiian Islands based on intensive field study of all the volcanoes of the group. It gives authoritative corroboration to the general concept advanced by Whitman Cross in his paper on the lavas of Hawaii and their relations.[2] The chapters on Mauna Loa and Kilauea contain detailed descriptions of the forms and products of the early stages of development. The chapter on the geology of Mauna Kea is "textbook" description of one of the best type examples of a volcano which has "lived" through almost all stages of Hawaiian volcanism. The chapter on PETROGRAPHY is an excellent presentation of the processes involved and the nature of changes accomplished in the composi-

[1] THE FORMATION OF BASALTIC LAVA FLOWS. Jour. Geol. Vol. 45, No. 8, p. 873. 1937. (Not cited by the authors.)

[2] CROSS, WHITMAN. LAVAS OF HAWAII AND THEIR RELATIONS. U. S. Geol. Survey Professional Paper 88. 1915.

tion and physical characteristics of volcanic products during the development of the entire cycle.

Perhaps a word of caution should be introduced against too complete acceptance of the concept of the Eastern and Western Fundamental Fissures. Though far too incomplete as yet to constitute proof, the gradually accumulating data on the location of deep earthquakes in the islands suggest an echelon arrangement of the deep fractures, rather than separate parallel alignment.

Pleistocene Shorelines, Age of Rocks, and Geologic History

A tabulation is made on page 54 showing all Pleistocene shorelines determined to date in the Hawaiian Islands, and a summary is presented of the evidence for each found on the island of Hawaii. Study of the text shows that some of this evidence is positive, while some is largely inference. The evidence is positive that the coast of Kohala and the northeast coast of Mauna Kea were submerged in the latest 25-foot high stand of the sea. Also positive are the shoreline deposits on Kohala at 250 feet above present sea level and the evidence that the major canyons of Kohala have been drowned and re-trenched at least once since their erosion. Some soil stripping suggests that Kohala may have been submerged to 1,200 feet below present sea level, but the evidence does not compare with that found on Lanai, the type locality. Evidence of the two intermediate negative shifts of sea level is inferred, as is also the hypothesis that the major canyons of Kohala and Ninole were cut on an old surface that antedates Stearns' Lualualei 1,200-foot negative stand of the sea.

Possible stratigraphic relations and geologic age of the five volcanic series are tabulated on page 62. The relationship of the Mauna Kea glacial deposits to the Laupahoehoe volcanic series permits a logical dating of Recent or Late Pleistocene for those volcanic series which are either younger than, or interbedded with, lavas and ash deposits of the Laupahoehoe series. This category includes the surface members of the Hualalai, the Kau, and the Puna volcanic series. Those series known to be older than the base of the Pahala ash are confidently assigned a date of pre-Wisconsin. Without question this category includes the Hawi, Hamakua, Kahuku, and Hilina volcanic series, and the much older Pololu and Ninole volcanic series. There is some question in the case of the Waawaa volcanic series. The field evidence described on page 145 places it at least correlative with the Laupahoehoe series, but the lack of exposure in deep sections precludes any assurance that the Waawaa lavas lie under all of the Pahala ash section.

By definition the Hamakua, Kahuku, and Hilina series lie under the base of the Pahala ash, but another consideration perhaps justifies caution in considering them all of the same age. The surface lava flows of the Kahuku and Hilina series show much less decomposition than those of the Hamakua series. The amount of rock decomposition depends on so many factors other than age that this fact cannot be considered as compelling evidence. Only in the narrow belt of rainfall on the southeast slope of Mauna Loa are Kahuku lavas found in moisture conditions approaching those of the northeast slope of Mauna Kea. In this one area of exposure of Kahuku lavas, the lack of rock decomposition and the absence of stream erosion in their surface at least suggest that the Kahuku volcanic series may be considerably younger than the Hamakua volcanic series of Mauna Kea.

The tentative correlation and age assignment offered for the Pololu and Ninole volcanic series seem to hinge on a comparison of local erosional history with that of Oahu and West Maui. Almost all information on this subject is gained from Kohala. No field work on the Ninole series was done for this report in addition to that upon which the earlier Kau report was based. In the discussion of the great erosional unconformity between the Ninole and the overlying volcanics, the only comment (page 66) on decomposition of the rocks is that "Some of the [lava] beds are partly altered by weathering." This modest statement is hardly what one would expect to find describing the decomposition of porous lava in an area of 120 inches of rainfall which had undergone erosion sufficient to carve the topography attributed to erosion, and is certainly different from the description of decomposition of the Pololu volcanic series. One wishes that more field work had been done in the Ninole area to yield more information about the decomposition, as the possibility that block faulting may have played a great part in the formation of this "old" topography seems still not to be excluded by the present descriptions.

In the discussion of the erosional unconformity between the Pololu series and the Hawi series the authors conclude (page 178) that "a repose period intervened between the eruption of the Pololu and Hawi volcanic series." When one considers the facts—presented in the text—that the Hawi volcanic series is made up of flows numbering in the order of magnitude of only a hundred, widely separated from each other in time, each covering a very small part of the surface, one gets the impression that the general picture of erosion and surface decomposition is equally well explained by a slow dying-out of activity, not requiring a "repose period." However, there is no dearth of evidence of a great deal of decomposition of the Pololu, as well as of the older members of the Hawi, volcanic series.

To find correlation between the erosion history of Kohala and West Maui and Oahu, the rather general statement is made on page 171 that older alluvium in the Kohala valleys "was deposited during several epochs and is separated by erosional unconformities," and the inference is drawn on page 55 that different deposits of older alluvium were graded to different stands of the sea. No outcrops of older alluvium are described, nor localities cited in the text, in which an erosional unconformity was found between two deposits of the older alluvium; nor are there descriptions of any locality in which two terraces in juxtaposition show difference of surface elevation to indicate that they were aggraded to distinctly different base levels. Since this evidence is critical in the interpretation of the erosion history of Kohala, one wishes that more detailed descriptions of localities had been given in the text.

Correlation of erosion history, extending back through Pleistocene time, on island surfaces from Oahu to Kohala, presupposes no differential isostatic movement of the islands. The discussion of the correlation back to the Pliocene would be more complete had the authors introduced the question of possible isostatic movement of Kohala Mountain during the Pleistocene in response to the heavy loading associated with the building of the domes of Mauna Kea, Hualalai, and parts, at least, of Mauna Loa and Kilauea. Some data are introduced by the authors (but not discussed in this connection) which might have a bearing on this question. In discussing the structure of Kohala Mountain (page 180), it is pointed out that "an unusual number of dikes dip northward from 60 to 85 degrees in the northern side of the mountain," which is a greater departure from vertical than is to be expected. Not pointed out in the text, but apparent on plate 1 (the geologic map), is the fact that the dip of the Pololu lava surface on the southwest slope is steeper than it is on the northeast slope; and that the southwest slope, from caldera crest to shore, is shortened in comparison with the northeast slope. It would have been interesting had the possibility been discussed that these two structural facts might be related to actual structural tipping of Kohala Mountain to southward, perhaps in connection with the loading postulated above.

The section of geologic history, which cross-correlates the stratigraphic column, the geologic time scale, and the sequence of Pleistocene changes of sea level, is not as well substantiated in two instances as one would hope for from the material presented in the preceding sections of the text. The main bulk of Kohala, the Pololu volcanic series, is considered (page 56) to

be younger than the bulk of Haleakala on Maui, but is assigned a Pliocene age; whereas Haleakala has been assigned an age of Pliocene or Early Pleistocene in the bulletin on Maui.[3] One would welcome a short discussion of the basis for this change. Field evidence presented in the discussion of Mauna Kea (page 167) shows that a glacial outwash deposit, formed during melting of the summit glacier, is older than the cutting of the present Mauna Kea gulches, which have subsequently been drowned and floored with alluvium aggraded to the latest 25-foot high stand of the sea, and lastly re-trenched to present sea level. Yet, with no explanatory discussion, the time of the melting of the Mauna Kea glacier and the described sequence of erosion history are correlated with the latest eustatic lowering of sea level from plus 5 feet to the present. One would expect the melting of the glacier to be correlated with the rise of sea level leading up to the 25-foot positive stand.

Pyroclastic Deposits

The treatment of the pyroclastic deposits of the island warrants considerable comment. The authors have abandoned Wentworth's separate formation names for the different ash deposits,[4] and have combined some of the formations into a proposed new "Pahala ash." Justification for this enlarged concept of the "Pahala ash" seems to be summed up in the statement from page 72, "Despite the fact that accumulation of the Pahala ash continued over a long period, the lower part, constituting the bulk of the deposit, appears to be essentially contemporaneous all over the island. It can be traced directly across Mauna Loa to Mauna Kea, and from Mauna Kea to Kohala Mountain. The lower part . . . serves as a widespread horizon marker. . . ." In the stratigraphic tabulation on page 62, the lower part of the deposit, considered as the horizon marker, is placed on top of the Hamakua, the Hilina, and the Kahuku volcanic series, and beneath the Laupahoehoe, the Puna, and the Kau volcanic series respectively on Mauna Kea, Kilauea, and Mauna Loa. No type locality of the horizon marker is described, but one can be deduced to be on Mauna Kea at some point along the margin of the oldest flow of the Laupahoehoe volcanic series, in a cut sufficiently deep to expose a considerable section of the upper lavas of the Hamakua volcanic series. The formation name "Pahala ash" is limited to this horizon marker in the stratigraphic column (page 62), and the same limitation apparently is in the minds of the authors in many places in the text (*i.e.*, pages 68 and 103), particularly when the reference is to "Pahala time." However, in every description of the field deposits of "Pahala ash," it is pointed out that the ash sections include pyroclastics ranging in age from "Pahala" time to Recent. The reviewer believes that clarity would have been gained by retaining Wentworth's formation names for the several deposits of ash, and by introducing a new local name for the specific horizon of geologic time during which the authors believe the basal member of many of the ash sections was deposited.

The authors' concept of the origin of the Pahala ash is summarized in the section titled ORIGIN on page 71, and the discussion which governed their conclusions is largely found in the following section on distribution and character of the Pahala ash on Mauna Loa. Mauna Kea is well substantiated as the source of much of the ash, especially on its own slopes. The importance of Kilauea as a source of part of the ash is based on the presence of coarser essential lapilli and accessory lapilli, as well as thickening of the deposits to the lee of Kilauea.

The significance of the thickening of the section as proof is depreciated, perhaps, by several points brought out in the text. An unstated proportion of the extra thickness is made up of fine ash which was moved laterally by the wind (page 75) after its initial deposition from the ash showers. Since this whole area in the lee of Kilauea is dry and wind-swept, several thin blankets from a source more distant than Kilauea might easily have been concentrated into local thicker sections. Additional field work might have been directed at a more quantitative evaluation of this factor.

The described thinning of the ash from the slope of Mauna Kea to the Glenwood locality northeast of Kilauea, and the thickening again southwest of Kilauea, is critically significant only if the Glenwood section contains all of the Mauna Kea ash section. The authors cite the test borings near Mountain View and the shaft at Olaa, which penetrate no great amount of ash, as evidence in the third dimension that the Glenwood deposit does contain the whole of the ash section. The deepest borings logged (page 257) are 160 feet deep and cut through, at the most, eight flows; and the Olaa shaft cuts 220 feet through possibly 10 flows (page 248). Both are in the area inundated by flows from Mauna Loa's northeast rift, where one would expect the greatest number of flows to be interbedded in the ash section; so there is reasonable doubt that the borings and shaft are deep enough to prove the question. The small amount of decomposition of the lava flows lying immediately under the Glenwood deposits, and the elementary development of surface streams in the area (page 218), are two other factors which point toward the probability that these lava flows are correlative with some part of the Laupahoehoe volcanic series and are interbedded in the ash series, rather than correlative with the Hamakua flows older than the basal member of the ash series.

In a different part of the text (page 93), not discussed at all in connection with the problem of origin of the ash, the authors point out the possible existence of ash-producing vents, in a position to windward as favorable as Kilauea, which may have contributed to the apparent greater thickness of the sections to the lee of Kilauea. The statement is "It is probable that Mauna Kea extends 6 to 10 miles southward under the Recent lava flows of Mauna Loa directly athwart the latter's northeast rift. The hypothesis is offered that Mauna Loa Volcano terminates against the buried Mauna Kea dome approximately under the 8,000 foot level on the northeast rift. . . ."

The presence of the accessory lapilli (probably from phreatic explosions) and coarser essential lapilli are qualitatively compelling evidence as to Kilauea's contribution to the ash deposits. More detailed field work directed specifically to this phase of the problem probably would have enabled the authors to make a more quantitative appraisal of the duration and amount of Kilauea's active contribution to these ash deposits. This is particularly desirable in this instance, because the ash relationships are the most tangible evidence available in the problem of correlating the age of Kilauea.

In discussing Hualalai as a contributor to the Pahala ash, the authors obviously refer to the original Pahala ash formation on the southeast Mauna Loa and south Kilauea slopes. Hualalai probably contributed to the ash lying on the lavas mapped on Kahuku in the cliff at Kealakekua Bay which is Pahala ash under the new definition. It also contributed to the ash on the kipukas in the Kainaliu area (page 70), and to the ash interbedded with the flows of the Kau volcanic series in Kona; all correlative with the Laupahoehoe volcanic series, and thus correlative with the upper part of the new Pahala ash.

It is apparent from their discussion of the origin and distribution that the authors consider Mauna Kea the source of much of the ash in the basal "horizon marker," the ash of "Pahala time" in the stratigraphic column. This consideration would suggest that the choice of a name for the horizon should have been made, more appropriately, from some Mauna Kea feature

[3] STEARNS, H. T., and MACDONALD, G. A. GEOLOGY AND GROUND-WATER RESOURCES OF THE ISLAND OF MAUI, HAWAII. Hawaii Div. of Hydrography, Bul. 7. 1942.

[4] WENTWORTH, C. K. ASH FORMATIONS OF THE ISLAND HAWAII. Hawaiian Volcano Observatory, 3rd Spec. Rpt. 1938.

or locality. Also, the proven diversity of origin of the ash deposits in different areas constitutes an additional strong objection to the abandonment of the several local formation names for the deposits.

On page 75 the authors describe the showers of pumice and Pele's hair produced during historic eruptions from Mauna Loa and conclude "Although such deposits during any one eruption are too small to measure, the 30,000 years of Recent time, [30,000 probably used purely to indicate order of magnitude] with several eruptions each decade, must have produced an accretion of ash measurable in feet in the leeward kipukas." According to the stratigraphic column on page 62 the ash mantle from all of the eruptions of the Lower and Upper Laupahoehoe volcanic series, and from the eruptions of the exposed part of the prehistoric member of the Hualalai volcanic series must be added to the above described showers, and be interbedded with or accumulated in kipukas in the lava flows of the Kau volcanic series. Part of this deposit is described by Wentworth and called the Kona formation, and comparable deposits are exposed on the favorable parts of the eastern flank of Mauna Loa between the rift zones. In the present text, however, the only description is as follows (page 78): "The ash deposits of the prehistoric member of the Kau volcanic series are insignificant in volume. Deposits of pumice a few inches to 2 feet thick lie just leeward of the large cinder cones but they cover too small an area to be shown on plate 1." It is regrettable that the authors did not do additional field work sufficient to present a better picture of these ash deposits associated with the Kau volcanic series which have an important bearing on their study of the Pahala ash; in fact they are the upper part of the Pahala ash as newly defined.

In the section on the ash deposits of the Puna volcanic series (page 106), the authors' use of the word *ash*, not in conformity with their restricted definition on page 18, is most confusing because these Kilauea surface pyroclastic deposits (Wentworth's Keanakakoi formation) include important horizons of pure lithic material as well as horizons of pure vitric material. Careful field recognition of these two types of deposit of different physical origin, and critical separate mapping of their aerial thickness and distribution is essential before the best analysis of Kilauea's possible contribution to the older Pahala ash sections can be made. In the present publication, the authors use Stearns' former distribution map from the Kau report,[5] which has been found to be unsastifactory for a critical analysis of ash distribution by subsequent workers.[6]

Historic Volcanic Activity

Very comprehensive, yet well-summarized, discussions of historic volcanic activity are found in the three chapters on Hualalai, Mauna Loa, and Kilauea. The information presented represents a thoughtful and selective accumulation of essential material from the maze of recorded observations and data derived from lay as well as scientific sources.

Some adverse comments seem justified on the presentation of legendary evidence of activity. The statement (page 78) "Hitchcock reports an eruption in 1780 . . . and one on January 21, 1803, [from Mauna Loa] . . . but cites no authority for these statements" is incorrect. Hitchcock cites as authority for the 1780 activity, the statements of Hawaiians who correlated the time with the time of Captain Cook's ill-fated visit, an event of sufficient interest to the Hawaiians to stand clearly in their memory. He also cites as authority for the flow of January 21, 1803, a report by John Turnbull, who saw the activity from his ship as it left Kealakekua Bay. Eruptions of Mauna Loa in about 1780, 1803, and 1832 thus are all well substantiated, whereas the location of each is not exactly described in the literature. Under the circumstances it seems inadvisable to map one of several possible flows and label it *1832-?* on the geologic map.

The references to Hitchcock (page 112) on Hawaiian legends of Kilauea activity should have been checked against Hitchcock's later book,[7] Fornander's collection, and Ellis' reports, because Hitchcock himself corrects some of the material presented in his earlier short paper. The date A.D. 140 should be about A.D. 450. The idea that the activity of 1420 (not 1620) was violently explosive was Hitchcock's own surmise and not based on legend. The quotation from Ellis suggests that there was a flank flow from a cone on the Puna rift a few miles distant from Kilauea in the time of Liloa (1420 to 1450). "Within a few miles of Kilauea, we passed three or four high and extinct craters. One of them . . . sent forth, in the days of Riroa, . . . most of the lava over which we were travelling." The legendary accounts of activity in the time of Kanipahu (1180-1210) read more like descriptions of an explosive eruption.

Sufficient detailed description of different eruptions is given to bring out material needed in the excellent discussions of typical eruptions of various nature which have taken place, and the summaries of presently known facts about volcanic activity, gained from the studies of Hawaiian activity, are thorough and very clearly presented. Attention perhaps should be called to a few specific passages.

One might possibly gain the impression from the discussion of the 1790 eruption (page 116) that the "Black Ledge" was terrace left by the engulfment of 1790. This is not intended, as the "Black Ledge" marked the high point of the tremendous refilling of the crater between 1790 and the collapse prior to Ellis' visit in 1823, probably associated with the flank eruption of 1823.

The discussions of summit caldera activity compared with flank eruptions would have been a little more complete had the authors enlarged on what appears, from the descriptions, to be a difference between certain flank flows. In one type, illustrated by the Kilauea flows of 1920, 1922, and 1923, and perhaps even by the flows of 1823 and 1840, the flank flow apparently is fed by lateral passage of the lava from a lake in the caldera through shallow rift-zone channels, and no fountaining or building of vent cones is apparent at the point on the rift where the lava re-emerges. In the other type, illustrated by most of the historic Mauna Loa flank flows, and perhaps many of the pre-historic Kilauea flows, the caldera vent appears to be abandoned after a flank vent is opened and the fountaining and vent-cone building takes place on the flank at the point where the flow emerges.

The statement (page 93) that the 1935 lava flow was "bombed . . . in an effort to stop the flow . . ." is inaccurate. Quoting from the VOLCANO LETTER for December 1935, page 4, "The volcanologist recommended bombing the source at elevation 8500 feet on Mauna Loa, to break up the stability of the flow tunnels, and to divert the flowing at the source region." The wording of the text in this section, and the paucity of references, fail to convey to the reader the fact that the plans of the Volcano Observatory for such diversion of flows which threaten vital areas date back before precision bombing was possible.

The authors have made a valuable and competent tabulation of known statistical data on all historical eruptions of both Mauna Loa and Kilauea, and submit the data to searching analysis for possible periodicity of eruption and possible correlation of eruption between the two volcanoes. They conclude that the statistical record shows no periodicity, no correlation with external influences such as sun spots, and no relation between the eruptions of Mauna Loa and Kilauea, in direct opposition to the beliefs of Jaggar and other workers who have used the same statistics to demonstrate possible periodicity and cor-

[5] STEARNS, HAROLD T., and CLARK, W. O. GEOLOGY AND WATER RESOURCES OF THE KAU DISTRICT, HAWAII. U. S. Geol. Survey Water-Supply Paper 616. 1930.

[6] FINCH, R. H. THE SURFACE ASH DEPOSITS AT KILAUEA VOLCANO. Volcano Letter 478, 1942.

[7] HITCHCOCK, CHARLES H. HAWAII AND ITS VOLCANOES. Hawaiian Gazette Co., Ltd., Honolulu. 1911.

relations. There are two relevant facts which save a cautious reader from the necessity of "jumping off either deep end." First, the fact that definite volcanic activity need not culminate in a visible surface eruption, so that it is possible that many periods of sub-surface activity have occurred without being known and recorded in the hundred-odd years for which we have eye-witness testimony. Thus the historic record of activity must be considered as incomplete at best. Second, the fact that even the eye-witness record is too short to prove or disprove statistically the existence of periodicity or correlations of the sort being considered.

The authors offer a comprehensive consideration of the evidence bearing on the age of Kilauea and its structural relation to Mauna Loa and conclude that Kilauea started activity as a vent perhaps nearly coincident with the renewal of Mauna Loa activity which produced the Kahuku volcanic series. There seems to be no serious objection to considering the Hilina and the Kahuku volcanic series as the same age. At the same time, there seems to be no compelling evidence to decide for or against the Mauna Loa origin of the lavas of both series. Projections of slopes in cross section can reasonably permit either point of view and seem to favor neither. Also there is no question that Kilauea has contributed to the Pahala ash. Its type of contribution is not associated with "old age" activity, but could have started from the first eruption of the newly opened vent. Further field work may add a good deal more specific information on the questions of how much material, what kinds of material, and in what part of the section are the contributions from Kilauea in the Pahala ash deposit. Until additional information is available, the authors' conclusions are as tenable as any which have been considered, though personally the writer favors Stone's[8] thesis that the Hilina lavas are part of Mauna Loa, and that Kilauea as a vent was "born" during the time of the accumulation of the ash series lying on the Hilina lavas.

[8] STONE, JOHN B. THE PRODUCTS AND STRUCTURE OF KILAUEA. Bernice P. Bishop Mus. Bul. 33. 1926.

ERRATUM

(in VOLCANO LETTER No. 493, July-September 1946)

Page 2, last paragraph, lines 2 and 6: *for* stopping *read* stoping.

Hawaiian Volcano Observatory Report for October-December 1946

VOLCANOLOGY

October

The number of earthquakes recorded at Kilauea and Mauna Loa was 49 and 59 respectively. The shake at 18:43 on October 29 originated deep under the east slope of Mauna Loa. This shake coupled with those of September 2 and 4 may be taken as a slight indication of uneasiness of Mauna Loa. A greater than normal easterly tilt during October is probably a further indication of such uneasiness. Northerly tilt was normal.

November

Earthquakes of Mauna Loa origin predominated in November. Sixty shakes were recorded on the Mauna Loa seismograph and 54 at Kilauea. There was no tilt in the east-west direction and a slight accumulation of southerly tilt.

Fume over Mokuaweoweo was observed from the Saddle Road during the morning of November 27.

December

During December, as in the past 2 months, more earthquakes originated under Mauna Loa than under Kilauea. Seventy shakes were recorded at Mauna Loa and 54 at Kilauea. The preponderance of Mauna Loa shakes as well as the earthquake pattern are indications of continued uneasiness of Mauna Loa. Tilt records, however, do not show indications of impending activity. There was no accumulation of tilt either east or west in December. The slight southerly tilt that started in November continued in December.

R.H.F.

SEISMOLOGY

Earthquake Data, July-September 1946

Week Ended	Minutes of Tremor	Very Feeble	Feeble	Slight	Local Seismicity*	Teleseisms
October 6	4	0	0	0	1.00	0
13	10	3	0	1	4.00	0
20	8	4	0	0	4.00	0
27	7	4	0	0	3.75	0
November 3	4	2	0	0	2.00	1
10	8	2	1	1	6.00	0
17	16	3	2	0	7.50	1
24	5	2	0	0	2.25	0
December 1	9	0	0	1	4.25	0
8	9	1	1	0	3.75	0
15	9	1	3	0	5.75	0
22	13	0	2	0	5.25	2
29	9	4	0	0	4.25	0

* For definition of local seismicity, see VOLCANO LETTER No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours and 30 minutes slower than Greenwich. The number preceding each earthquake is the serial number of the quake for the current year.

104. October 8, 16:34, very feeble. Kilauea shake.
105. October 8, 23:56, slight. Felt locally and in Hilo. About 10 miles deep. NE slope of Mauna Loa, 1 mile east of seismograph.
106. October 10, 05:59, very feeble. Felt in Kona and on Maui. Deep under NW coast of Hualalai.
107. October 12, 12:59, very feeble. Kilauea shake.
108. October 14, 03:25, very feeble. Shallow focus near N end of Mokuaweoweo.
109. October 16, 10:09, very feeble.
110. October 16, 23:02, very feeble. Mauna Loa shake.
111. October 18, 01:04, very feeble.
112. October 25, 07:13, very feeble. Mauna Loa, NE rift.
113. October 25, 09:35, very feeble.
114. October 26, 05:52, very feeble.
115. October 27, 00:14, very feeble.
116. October 28, 06:53, very feeble. Mauna Loa, E slope.
117. October 29, 18:43, slight. Mauna Loa, E slope.
118. October 29, 21:00, very feeble.
119. October 29, 23:58, very feeble.
120. November 3, 19:04, very feeble.
121. November 4, 10:03, very feeble. Mauna Loa shake.
122. November 5, 08:37, feeble.
123. November 7, 00:59, very feeble. Mauna Loa shake.
124. November 11, 13:37, very feeble. Kilauea shake.
125. November 12, 13:24, feeble. Kilauea shake.
126. November 13, 05:41, very feeble. Kilauea shake.
127. November 13, 22:10, very feeble. Mauna Loa shake.
128. November 17, 01:14, very feeble. Mauna Loa, E slope.
129. November 20, 02:09, very feeble. Kilauea shake.
130. November 23, 10:15, very feeble. Mauna Loa shake.
131. November 30, 01:54, slight. Deep under E slope of Mauna Loa.
132. December 3, 12:56, feeble.
133. December 5, 11:33, very feeble. Mauna Loa, NE slope.
134. December 11, 13:53, very feeble. Kilauea shake.
135. December 12, 23:28, feeble. Kilauea shake.
136. December 13, 17:10, feeble. 5 to 10 miles under NE slope of Mauna Loa.
137. December 15, 02:36, feeble. Felt locally. Kilauea shake.
138. December 22, 07:02, feeble. Felt in eastern Hawaii. 15 miles deep, S of Hilo.
139. December 22, 11:53, feeble. Felt locally. Deep under Glenwood.
140. December 23, 00:10, very feeble.
141. December 24, 20:09, very feeble.
142. December 27, 12:05, very feeble. Kilauea shake.
143. December 28, 22:24, very feeble. Mauna Loa shake.

TELESEISMS

November 1, 00:50. slight.

November 11, 07:04. Slight.

December 20, 08:58. Moderate. Japan shake.

December 21, 00:17. Slight.

MICROSEISMS

Microseisms were moderate to strong throughout the quarter except on December 31 when they became very strong.

CRACK MEASUREMENTS

A few of the cracks around Halemaumau opened slightly in October. In November and December the cracks were stationary.

TILTING OF THE GROUND

Seasonal southerly tilt set in November 3, or a little earlier than usual. There was less than normal northerly tilt in 1946. Westerly tilt started on December 9, or about the usual time for change from easterly to westerly. There was no accumulation of tilt either east or west in 1946.

R.H.F.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended		Amount	Direction
October	6	1.14″	S 71° E
	13	2.20″	N 80° E
	20	0.84″	N 45° E
	27	0.48″	N
November	3	0.80″	N 27° E
	10	0.31″	S 45° W
	17	1.32″	S 27° E
	24	0.10″	N 45° W
December	1	0.70″	S 31° E
	8	1.48″	N 76° E
	15	1.44″	S 42° W
	22	0.24″	N
	29	1.84″	S 11° W

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

in cooperation with UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Government, Department of the Interior, National Park Service.

The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** supplement the work of the government with research associates, instrumental plants and special investigation. Dr. T. A. Jaggar is their geophysicist resident in the National Park.

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HAWAII NATIONAL PARK: Frank R. Oberhansley, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

ANNUAL TILT PATTERN AT THE HAWAIIAN VOLCANO OBSERVATORY

By H. A. POWERS

Seismologist, Hawaii National Park

The 22 years following the 1924 "collapse" of the Kilauea lava column have been relatively free of lava activity in Kilauea. Thus the tilt records from the Bosch-Omori seismograph on the northeast rim of Kilauea for this span of years offer a particularly valuable series from which to study the annual tilt pattern which is developed by forces other than visible eruptions.

As a starting point, tilt curves for a "standard" year have been computed (Figure 1, curves A and B, and columns A and B in Table 1). First an average north-south and east-west coordinate value was computed for each calendar month of the years 1925 through 1946 by adding the daily coordinates[1] of each month and dividing by the appropriate number of days. Then an arithmetic average was computed for all Januarys, Februarys, etc. The plotting of these average monthly coordinates was then compared in detail with the plotting of the actual monthly coordinates for each year in the series. Several of the actual annual "loops" departed radically from the computed average "loop" both in shape and dimension. In most of these, the departure was of a nature to be expected from volcanic events known to have occurred. A second computation of averages was made, using only the 7 years which showed the most symmetrical annual loop. This computation yielded an average loop which is remarkably comparable to the loop representing the average of all 22 years. Apparently the most radical deviations canceled themselves out in the larger average. The coordinates used to express the "standard" year were then derived by "smoothing" the 22-year averages in the direction of the values obtained in the selected 7-year average. The tilt loops for the years 1931 and 1944 most closely approach the "standard" loop. Admittedly this standard loop is not real, and perhaps never would be duplicated in nature, but it does give a quantitative picture of trends which are very real in the actual annual loops.

As the first step in the attempt to analyze the "standard" loop, the plotted curves of actual daily tilt were carefully searched for indications of dominant directions of tilt. Periods of time were chosen in which tilt continued for several consecutive days on the same azimuth. The most common direction in which tilt accumulated is N 45 E or S 45 W, associated in many instances with decided changes in air temperature. This direction also seems to have a significant structural expression, in that the Waldron Ledge segment of the rim of Kilauea Crater (the block upon which the tilt has been measured) strikes in general N 45 W, and is bounded to some extent by radial fault cracks trending N 45 E. This direction has been adopted in this study to express the direction of yielding to superficial causes of tilt. The direction N 20 E or S 20 W, which was discussed in VOLCANO LETTER No. 492, 1946, is used to express the direction of yielding to deep-seated forces affecting the Kilauea dome-structure. The most remarkable appearance of this Kilauea azimuth was in the extreme tilt to the southwest at the time of the collapse of the lava column and the explosive eruption in 1924. It has not appeared frequently in the daily tilt since 1924, but it does show up as a major direction in smoothed curves of daily and monthly tilt. These facts of occurrence are compatible with the concept that it is a direction of yielding to deeply acting forces, and that movements along it would be often interrupted by superficial movements of shorter duration. A third direction of facile movement, almost due east and west, appears occasionally. The swings of this azimuth, though rather infrequent, are of important amplitude and occur in many instances prior to a Mauna Loa eruption.

Other azimuths of tilt can be selected from the daily records, particularly from the smoothed curves. Some or all of them may have a significance which is being overlooked, but

[1] The daily coordinates refer to an arbitrary zero point, and state, in millimeters, the lateral migration of the writing pens of the instrument induced by tilting of the pendulum support. The constants are such that 10 mm. of lateral movement is induced by 1.21 seconds of tilt. Increase of ordinate and abcissa numbers indicate, respectively, north and east tilt.

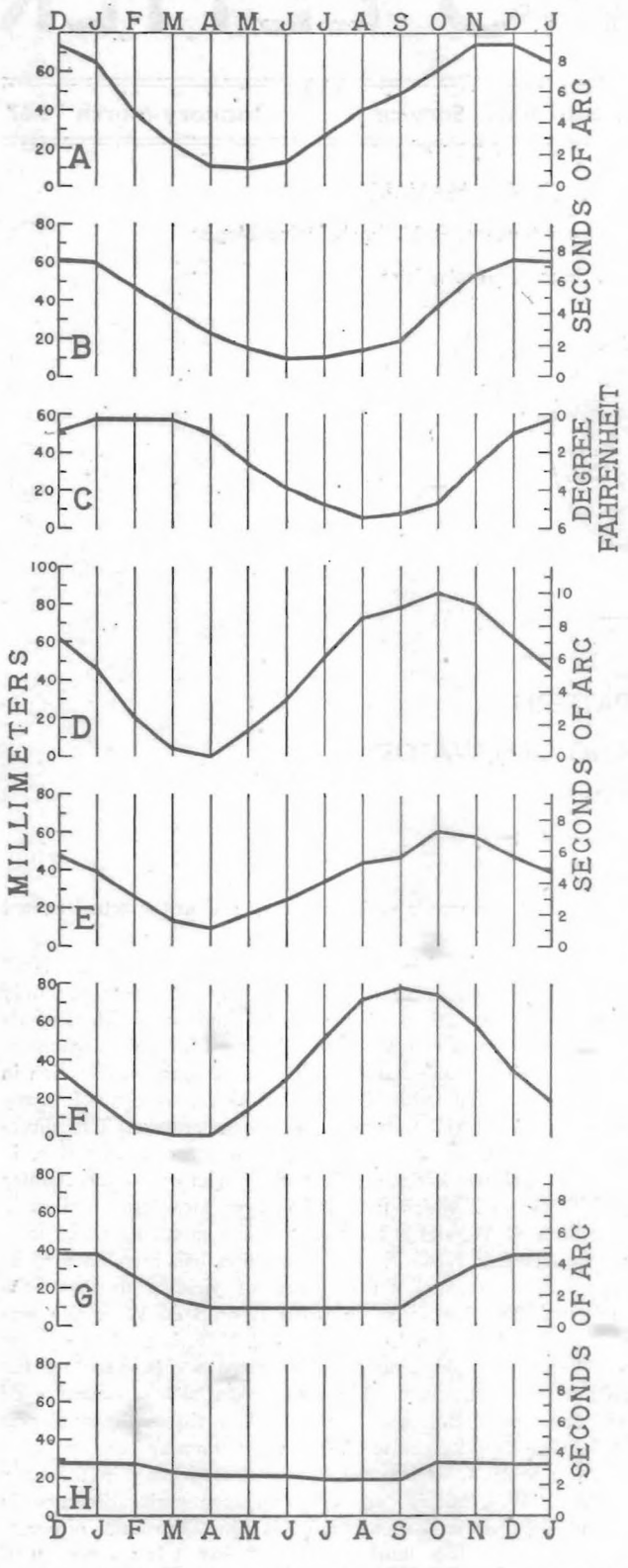

Figure 1.—*A* and *B*, respectively, N–S and E–W components of the "standard" annual tilt loop, computed from 22 years of tilt recorded by the Bosch-Omori seismograph on the northeast rim of Kilauea. North and east are up on the graph, and south and west are down. *C*, changes in mean monthly air temperature (slightly modified) on scale comparable to that of *A* and *B*. Lower temperature is up on the graph, equivalent to north or east tilt. *D* and *E*, respectively, residual N–S and E–W tilt obtained by subtracting curve *C* equally from curves *A* and *B*. *F*, postulated curve of effect of cumulative angular pull of sun. North pull is up on the graph. Scale is proportional to curve *D*. *G* and *H*, respectively, Kilauea and Mauna Loa azimuth residuals of tilt, computed from residuals remaining after subtracting *F* from *D* and *E* in proportions appropriate to tilting on direction N 20 – S 20 W. Upward pressure under the domes is up on the graphs.

this study to date seems to indicate that they are resultants of simultaneous movement on two or even three of the first-mentioned directions. Attention in this study will therefore be concentrated on the three directions postulated above: the N 45 E superficial block movement, the N 20 E Kilauea deep movement, and the east–west Mauna Loa deep movement.

Previous work[2, 3] has shown the influence of temperature change on tilt for periods of time ranging from one day, or of several consecutive days, to a year, in which increases in temperature compared with south and west tilt. A curve (not inverted) showing mean monthly range of air temperature at the Observatory was compared with the curves showing the N–S and E–W components of the "standard" tilt loop. A suggestion of similarity was observed if the temperature change was assumed to have either a three- or four-month lag in its effect on the tilt with increase in temperature correlating with north and east tilt. Study of actual annual loops versus their corresponding temperature curves showed a great lack of correspondence. It also posed the question of why the great lag in temperature effect "on the average," in the face of measured responses of daily tilt to daily temperature with at most a few hours' lag. Accordingly the mean monthly temperature curve was inverted so that decrease of temperature was associated with north and east tilt as originally advocated. Curves showing mean monthly maximum and mean monthly minimum temperature range were also introduced. It was obvious that perfect correlation of any one of the temperature curves with the tilt curves was not possible. However, studies of the daily curves show beyond a doubt that tilt is affected by temperature changes, and by presence or absence of strong insolation. Several consecutive cold cloudy days are associated with the greatest amounts of pure northeast tilt; warm cloudy days, with lesser amounts of northeast tilt; while days with extremely low minima but high insolation may show no northeast tilt at all. For the present analysis of the "standard" tilt loop, a curve intended to express a quantitative approximation of the monthly weather change which affects tilt was constructed by modifying the curve of monthly minima so as to give some weight to the factor of insolation (Figure 1, curve C). The changes of temperature are assumed to cause tilt of the superficial block in the direction N 45 E – S 45 W. The values from the temperature curve were subtracted from the values of the NS and EW components of the "standard" loop, and the residual values thus obtained give curves (Figure 1, curves D and E, and Table 1, columns D and E) which, surprisingly enough, suggest the possible tilt effect of another seasonal force, *i.e.*, the cumulated north–south component of the sun's gravitational pull.

H. O. Wood[4] outlines a theory of the possible influence of forced nutation strains on the rise and fall of lava in Kilauea. He says "These nutations (forced solar and lunar) are produced by the integration of this effect of inclined attraction upon each and every particle in the earth. If the earth were strictly rigid in the mathematical sense this action would produce only nutation and precession. But the earth is only quasi-rigid and, therefore, in addition to the tilting tendency, a tendency to the reconstitution, or readjustment, of the internal configuration of the earth particles may be expected." He evaluated the proportional influence of solar nutation and lunar nutation. and built up a time curve of strain which exhibits semi-annual maxima and minima at time of solstice and equinox, and fortnightly arches of smaller magnitude reflecting lunar influence.

[2] JAGGAR, T. A. SEISMOMETRIC INVESTIGATIONS OF THE HAWAIIAN LAVA COLUMN. Seismol. Soc. Amer. Bul. 10(4): 155-275, 1920.

[3] JAGGAR, T. A., and FINCH, R. H. TILT RECORDS FOR THIRTEEN YEARS AT THE HAWAIIAN VOLCANO OBSERVATORY. Seismol. Soc. Amer. Bul. 19(1): 38-51, 1929.

[4] WOOD, H. O. SECOND REPORT OF THE HAWAIIAN VOLCANO OBSERVATORY. Mass. Inst. Tech., 1917.

Table 1.—Tilt Values, Postulated Causal Components, and Progressive Residuals at Hawaiian Volcano Observatory

Month	A*	B*	C†		D‡	E‡	F§		G‖		H‖
	N–S	E–W	N–W	E–W	N–S	E–W	N–S	E–W	N–S	E–W	E–W
January	— 9	— 1	7	7	—16	— 8	—16	— 8	0	0	0
February	—26	—13	0	0	—26	—13	—14	— 7	—12	— 6	0
March	—16	—12	0	0	—16	—12	— 4	— 2	—12	— 6	— 4
April	—12	—12	— 8	— 8	— 4	— 4	0	0	— 4	— 2	— 2
May	— 1	— 8	—15	—15	14	7	14	7	0	0	0
June	3	— 5	—13	—13	16	8	16	8	0	0	0
July	14	1	— 8	— 8	22	9	22	11	0	0	— 2
August	13	3	— 7	— 7	20	10	20	10	0	0	0
September	8	5	2	2	6	3	6	3	0	0	0
October	13	18	5	5	8	13	— 4	— 2	12	6	9
November	13	16	19	19	— 6	— 3	—16	— 8	10	5	0
December	0	8	18	18	—18	—10	—24	—12	6	3	— 1

* Columns A and B. Coordinates of the "standard" tilt loop, stating change from preceding month, expressed in millimeters as measured on the Bosch-Omori seismograph. Negative coordinates represent south and west tilt. 10 mm. is equivalent to a tilt of 1.21 seconds of arc.

† Column C. Fractional part of tilt attributed to changes in mean monthly air temperature. 10 mm. postulated to be equivalent to a change of 1° F. Warmer temperatures postulated to cause south and west tilt. Total range of tilt on northeast–southwest direction is 8.7 seconds.

‡ Columns D and E. Residuals obtained by algebraically subtracting column C from A and B.

§ Column F. Fractional part of tilt attributed to cumulative warping of the equatorial bulge by seasonal changes in the angle of the sun's pull. Total tilt on direction N 20 E – S 20 equals 10.6 seconds.

‖ Columns G and H. Residual tilt not accounted for by columns C and F, divided onto "Kilauea" and "Mauna Loa" azimuths, respectively. This tilt may possibly represent a seasonally recurring "squeeze up" of lava pressure, followed by collapse, under the two volcanic domes, possibly associated with the kneading effect postulated in curve *F*.

Jaggar and Finch[5] suggest the possibility that the semi-annual solar tidal maxima and minima may warp the excess of mass of the earth's crust at the equator and in the Hawaiian ridge.

If Wood's strain is applied as a directional force on the equatorial bulge, and the application of the force is considered as cumulative in effect, the maximum accelerations would appear at solstice, but the points of flexure would occur at equinox. If the cumulative application of these strains actually caused a bulging to the north in summer and to the south in winter, the probable curve of bulge would be skewed somewhat in its shape from a pure sine curve. In the northern hemisphere, the north bulge might possibly show a lag because the yielding to the force would have to be a positive bulging against the elastic strength of the crust and against gravity; whereas, after the flexure from northward to southward application of the strain (at fall equinox), elastic rebound and gravity would be coupled in the same sense with the application of strain which might allow the greatest acceleration of the southing curve to appear rapidly after the point of flexure.

Curve F in Figure 1 is a crude concept of the possible cumulative north–south angular pull of the sun, skewed in accord with the discussion above. The amplitude of the curve was arbitrarily chosen to be of the same order of magnitude as that of the residual N–S tilt pictured in curve D. While the curve is not a precise mathematical computation, sufficient scientific honesty was employed in its construction to satisfy the writer that the resemblance between curves D and F is not solely due to "wishful thinking."

The residuals obtained by subtracting curve F from curves D and E are the algebraic sum of (1) the cumulative errors introduced in the analysis to this point, (2) any rhythmic tilt factors which may possibly exist but have not been considered, and (3) the average of any tilt effect caused by strictly volcanic pressure fluctuations during the period studied. These residuals have been computed to two curves, G and H, showing the residual tilt changes on the direction N 20 E to S 20 W (Kilauea) and the direction due E to W (Mauna Loa), respectively. These curves show pressure increase in the winter season and pressure decrease in the summer, which may be entirely coincidental, but also may fit with the observed fact that Hawaiian volcanic eruptions show a tendency to begin more frequently in winter than in summer.

As an approach toward a testing of the possible reality of these hypotheses, the curves of monthly tilt for the years 1930 to 1946 inclusive have been adjusted, factoring out the postulated tilt effect of the accumulated sun strain and the postulated effect of monthly changes of temperature. In the first step, monthly tilt, assumed to be caused by accumulated sun strain, was algebraically subtracted from the actual monthly tilt curves, in proper proportion from the north–south and the east–west curve to express the assumption that this tilt is effective on the Kilauea or N 20 E – S 20 W azimuth. From the residuals thus obtained, monthly tilt, assumed to be caused by the recorded changes in mean air temperature from month to month during this period, was algebraically subtracted in proper proportion to express the assumption that this tilt is superficial and affects the N 45 E – S 45 W azimuth. No attempt was here made to give a quantitative correction for changes in insolation. The residuals were then factored into tilt changes on the Kilauea azimuth (N 20 E) and the Mauna Loa azimuth (E–W).

The monthly residuals obtained from these computations are arranged in Table 2, *A* and *B*. It is apparent in the tabula-

[5] Jaggar, T. A., and Finch, R. H., *Op. cit.*

Table 2.—Monthly Residuals on Kilauea and Mauna Loa Azimuths

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
A. *Monthly residuals on Kilauea azimuth (N 20 E – S 20 W)*												
Positive residuals (NE tilt) greater than 0.6 sec.	6	4	0	5	5	4	7	4	6	11	9	11
Neutral residuals between plus 0.5 sec. and minus 0.5 sec.	5	2	6	6	7	8	6	10	7	6	6	3
Negative residuals (SW tilt) greater than 0.6 sec.	6	11	11	6	5	5	4	3	4	0	2	3
B. *Monthly residuals on Mauna Loa azimuth (E – W)*												
Positive residuals (E tilt) greater than 0.6 sec.	4	5	5	2	8	5	3	3	2	9	5	3
Neutral residuals between plus 0.5 sec. and minus 0.5 sec.	8	7	7	11	6	10	10	9	14	8	6	10
Negative residuals (W tilt) greater than 0.6 sec.	5	5	5	4	3	2	4	5	1	0	6	4

Table 3.—Adjusted Monthly Residuals on Kilauea and Mauna Loa Azimuths

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
A. *Monthly residuals on Kilauea azimuth after subtracting curve G*												
Positive residuals (NE tilt) greater than 0.6 sec.	6	5	6	7	5	4	7	4	6	3	5	6
Neutral residuals between plus 0.5 sec. and minus 0.5 sec.	5	7	5	5	7	8	6	10	7	13	7	7
Negative residuals (SW tilt) greater than 0.6 sec.	6	5	6	5	5	5	4	3	4	1	5	4
B. *Monthly residuals on Mauna Loa azimuth after subtracting curves G and H*												
Positive residuals (E tilt) greater than 0.6 sec.	3	8	9	4	8	5	3	4	1	1	2	1
Neutral residuals between plus 0.5 sec. and minus 0.5 sec.	9	7	6	11	6	10	12	9	12	8	7	9
Negative residuals (W tilt) greater than 0.6 sec.	5	2	2	2	3	2	2	4	4	8	8	7

tion for the Kilauea azimuth residuals, and less so for Mauna Loa, that there is remaining an annual curve which has not been factored out. On the Kilauea azimuth, a majority of the months show pressure increase tilt in October, November, and December, and a pressure decrease tilt in February and March. On the Mauna Loa azimuth, a majority of the months show pressure increase in October, but there are no outstanding months of pressure decrease. In view of this evidence, it is assumed that curves G and H (the residuals from the breakdown of the "standard" loop) may represent a third annually recurring tilt pattern. These curves were accordingly factored out from the actual monthly record and the residuals obtained are again grouped in Table 3, *A* and *B*. Approximately half of the residuals now show a neutral change of tilt, slightly more than one fourth show pressure increase, and one fourth show pressure decrease. This distribution might be expected from a random group of numbers. However, the plot of the 204 residuals in their respective order in the 17-year record shows pressure trend groupings. Of the 117 months on the Kilauea azimuth which show an appreciable tilt residual, only 31 occur as zigzag months, *i.e.*, isolated months flanked by residuals of opposite sign, and the rest occur in groups of 2 to 7 consecutive months with the same pressure sign. On the Mauna Loa azimuth, of 98 months, only 25 occur as zigzag months. This grouping in patterns suggests that the residuals may represent real tilt fluctuations caused by changes of volcanic pressure, and not merely accidental random values produced by the manipulation of a set of numbers.

SUMMARY

A "standard" annual tilt loop is derived from study of the tilt of a block of the northeast rim of Kilauea Crater recorded on the Bosch-Omori seismograph during the years 1924 to 1946, inclusive. From patterns of tilt developed during short periods of several days' duration, the hypothesis is advanced that the recorded tilting of this block is the resultant of tilting from three principal causes: (1) a superficial tilting in a northeast–southwest direction stimulated by surface forces, chiefly changes in air temperature and insolation; (2) a deep-seated tilting in the direction N 20 E – S 20 W, stimulated by changes of pressure under the dome of Kilauea; and (3) a deep-seated tilting in the direction approximately east–west, stimulated by changes of pressure under the dome of Mauna Loa.

The quantitative effect of seasonal changes of temperature is estimated to be a 12 second of arc tilt to the northeast for each drop of 1° F. in the mean monthly air temperature, and vice versa. The average annual effect is postulated to be a tilt to the southwest of about 8 seconds from April to September, and a northeast recovery of equivalent amount from October to February.

The hypothesis is advanced that two cyclical forces of annual period also affect the tilt. The first is postulated to be an annual swelling and deflation due to the cumulative effect of the angular pull of the sun on the equatorial bulge and the Hawaiian ridge. The effect of this cause is postulated to be a tilt in the direction N 20 E (at the site of the Bosch-Omori seismograph) of approximately 10.5 seconds of arc from April to September, and a recovery of equal amount and opposite direction from October to March. The second is postulated to be an annual swelling of about 5 seconds of arc in the direction N 20 E during October, November, and December, offset by an equivalent subsidence to the S 20 W in February, March, and April. A similar swelling to the east of less than 1 second of arc occurs in October, with the recovery spread over several spring and summer months. The thought is tentatively advanced that this short tilt loop expresses an actual annual "squeeze up" of lava pressure within the two volcanic domes which is an aftermath of the kneading of the equatorial bulge by the annual change in angular pull of the sun. Some slight support to this thought is offered by the fact that more eruptions of both Mauna Loa and Kilauea in historic time have started during the winter months than during the rest of the year.

The 204-month tilt record from the Bosch-Omori seismograph for the years 1930 to 1946 inclusive, has been adjusted by algebraically subtracting the postulated temperature effect and the three postulated deep-seated tilt effects. The residual tilt curves express the algebraic sum of (1) errors in the hypotheses and (2) true tilt due to increase and decrease of volcanic pressure. The fact that the residual curves show patterns of increase and decrease of pressure of several months' duration encourages the thought that the latter outweighs the former. A critical analysis of these residual monthly curves will be reported in a future VOLCANO LETTER.

Hawaiian Volcano Observatory Report for January–March 1947

VOLCANOLOGY

January

The year opened with both Kilauea and Mauna Loa inactive. Unusually heavy steaming from Mokuaweoweo was observed from January 19–22 inclusive. On January 21 the steam ascended as distinct columns a few hundred feet above the rim of Mokuaweoweo.

Tilt to the southwest was in about the usual amount for January. Tilt records indicate a slight decrease in pressure under Kilauea during 1946.

Sixty-three earthquakes were recorded on the Mauna Loa seismograph and 55 at Kilauea.

February

The number of earthquakes recorded during February, 35 at Kilauea and 42 at Mauna Loa, was the lowest since last September. Earthquakes originating from the southwestern part of Mauna Loa were more numerous than in the preceding several months.

There was a distinct accumulation of southerly tilt and a slight easterly tilt during the month. Such a southerly tilt is normal for February. The slight easterly tilt, instead of the normal westerly, may indicate an increase of pressure under Mauna Loa.

March

There was an increase in seismicity for the month because of an increase both in the total number of earthquakes and in the number of perceptible shakes. Fifty-three earthquakes were recorded at Kilauea and 62 at Mauna Loa.

The southwest tilt usual for this season of the year ceased about the last of February and was not resumed in March. The lack of southwest tilt may be explained partially by the fact that the mean temperature for March was lower than that for February.

R.H.F.

SEISMOLOGY

Earthquake Data, January–March 1947

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
January	5	3	1	0	0	0	1.25	0
	12	8	2	0	0	0	3.00	0
	19	6	3	0	1	0	5.00	0
	26	20	2	1	0	0	7.00	2
February	2	12	2	0	0	0	4.00	0
	9	6	0	0	1	0	3.50	0
	16	5	3	0	0	0	2.75	0
	23	10	3	0	0	0	4.00	0
March	2	5	0	1	0	0	2.25	1
	9	12	3	0	0	0	4.50	0
	16	8	0	2	0	0	4.00	0
	23	5	2	1	0	1	6.25	0
	30	9	2	1	2	0	8.25	0

* For definition of local seismicity, see VOLCANO LETTER No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours and 30 minutes slower than Greenwich. The number preceding each earthquake is the serial number of the quake for the current year.

1. January 2, 04:16, very feeble. Kilauea shake.
2. January 9, 07:16, very feeble. Mauna Loa shake.
3. January 11, 02:52, very feeble. Mauna Loa.
4. January 13, 01:43, very feeble. Mauna Loa.
5. January 15, 09:47, slight. NE rift Mauna Loa.
6. January 16, 14:03, very feeble. Mauna Loa.
7. January 19, 07:42, very feeble.
8. January 22, 22:46, feeble. Kilauea.
9. January 25, 18:16, very feeble.
10. January 26, 17:34, very feeble. Kilauea.
11. January 28, 16:22, very feeble. Near Mokuaweoweo.
12. January 29, 20:46, very feeble. Mauna Loa.
13. February 5, 22:53, slight. Kilauea.
14. February 11, 05:15, very feeble. W slope Mauna Loa.
15. February 13, 02:37, very feeble. Kilauea.
16. February 13, 09:44, very feeble. Mauna Loa.
17. February 17, 02:39, very feeble. Kilauea.
18. February 19, 15:19, very feeble. Felt in Kona.
19. February 21, 18:06, very feeble. Mauna Loa.
20. February 26, 18:54, feeble. NE rift Mauna Loa. Felt generally in eastern Hawaii.
21. March 5, 23:08, very feeble. Kilauea.
22. March 8, 21:40, very feeble.
23. March 8, 23:03, very feeble.
24. March 13, 03:52, feeble. Felt locally.
25. March 15, 16:14, feeble. Kilauea. Felt locally.
26. March 19, 23:06, moderate. Widely felt on island of Hawaii. Deep under Mauna Loa. Mauna Loa instruments dismantled.
27. March 20, 11:41, very feeble.
28. March 21, 17:37, feeble. Keahole Point, Kona.
29. March 22, 14:29, very feeble.
30. March 28, 09:57, feeble.
31. March 28, 09:59, very feeble.
32. March 28, 11:56, slight. Mauna Loa.
33. March 29, 20:11, slight. NE slope Mauna Loa. Felt locally and at Hilo.
34. March 30, 15:50, very feeble.
35. March 31, 00:37, very feeble. NE slope Mauna Loa.

TELESEISMS

January 24, 06:17, slight.
January 25, 23:50, slight.
February 25, 21:25, slight.

MICROSEISMS

Microseisms were moderate to strong throughout the quarter except for light spells on January 16; February 16, 21–23; and March 2–5, 27–31.

CRACK MEASUREMENTS

Cracks that were measured around Halemaumau and along the Chain of Craters Road showed practically no movement.

TILTING OF THE GROUND

Normal southwesterly tilt obtained until February 25. From this date until the end of the quarter there was no tilt accumulation.

R.H.F.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended		Amount	Direction
January	5	1.50″	S 29° W
	12	0.60″	S 35° W
	19	1.70″	S 21° W
	26	2.04″	S 69° W
February	2	0.17″	S
	9	2.04″	S 45° W
	16	0.26″	S 64° E
	23	0.50″	S 45° W
March	2	0.17″	N 45° E
	9	0.36″	N 72° E
	16	1.37″	S 45° W
	23	0.95″	N 40° E
	30	0.38″	S 19° E

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
in cooperation with UNIVERSITY OF HAWAII

The Hawaiian Volcano Research Association was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Government, Department of the Interior, National Park Service.

The University of Hawaii cooperates in maintaining a research laboratory at Hawaii National Park. The Association and the University supplement the work of the government with research associates, instrumental plants and special investigation. Dr. T. A. Jaggar is their geophysicist resident in the National Park.

The Volcano Letter, a quarterly record of Hawaiian volcano laboratories and published by the University of Hawaii, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the above establishments.

THE VOLCANO LETTER

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UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist



KILAUEA IN 1790 AND 1823

By R. H. FINCH

Volcanologist, Hawaii National Park

The object of this paper is to review the accounts dealing with the activity of Kilauea in 1790 and the lava flow of 1823 and to discuss probable events between these years.

There are several versions of the 1790 explosive eruptions of Kilauea based largely on accounts given by Ellis[1] and Dibble.[2] Accounts and interpretations by various authors were reveiwed by T. A. Jaggar[3] in 1921. Facts of the 1924 explosive eruption make it possible to give a different interpretation to some of the details.

The explosive eruption of 1790 was an important event in Hawaiian history as it occasioned the destruction of a portion of the army of Keoua, a chief of Hawaii, that was engaged in a civil war. The army had come to the volcano by the trail through Olaa from Hilo and had camped at the northern end of the crater. Hitchcock[4] assumed that the army passed to the south of Kilauea crater on the upper Puna-Kau trail across the Kau Desert. In view of the fact that the army camped for 3 nights and 2 days at Kilauea, the trail by the northern rim of the crater where water was available seems a more logical route. Bloxam[5] in 1825 was shown the place to the north of Kilauea Iki where some of Keoua's troops had encamped. The distribution of the 1790 ash also indicates that the northern route was the one used. An explosion took place shortly after the arrival of the army at Kilauea, and other explosions occurred during the next 2 days. On the third day the army continued on its way in three different companies. Shortly after getting under way a more violent explosion occurred and totally destroyed the middle company of about 80 people. The probable position of the middle company was at an elevation of about 3,800 feet on the Kapapala-Uwekahuna trail near the outer rim of Kilauea. The greatest thickness of the 1790 ash is found on the west-southwest inner rim of Kilauea crater and as the thickness diminishes rapidly both to the northwest and to the southeast, it appears that the greater thickness here is due to one or more directed blasts. The middle section of the army may have been passing at the time of a directed blast.

All native accounts agree that incandescent material was present in the explosion clouds. Some have interpreted the native accounts as indicating that spouting columns of molten lava were present. The absence of pumice and the relatively few bombs in the explosion debris make this idea improbable. The incandescence of an appreciable amount of material thrown out and numerous lightning flashes could account for all the glow reported. Many of the night explosions in 1924 produced a brilliant glow, and the sand and dust of some explosions was hot enough to scorch vegetation 1,800 feet from the Halemaumau rim. The deaths in the middle section of Keoua's army can easily be accounted for by hot sand and dust. The amount and distribution of the 1790 ash indicate that the explosions of that

[1] ELLIS, WILLIAM. NARRATIVE OF A TOUR THROUGH HAWAII . . . (Honolulu, 1917), p. 187.

[2] DIBBLE, SHELDON. HISTORY OF THE SANDWICH ISLANDS (Lahainaluna, 1843), p. 65.

[3] [JAGGAR, T. A.] *in* Hawaii. Volcano Observ. Monthly Bul., 9 (7): 114-118, July, 1921.

[4] HITCHCOCK, CHARLES H. HAWAII AND ITS VOLCANOES (2nd ed.; Honolulu, 1911), p. 165.

[5] BLOXAM, ANDREW. DIARY OF ANDREW BLOXAM, NATURALIST OF THE "BLONDE," . . . Bernice P. Bishop Mus. Spec. Pub. 10 (Honolulu, 1925), p. 10.

year were larger than in 1924. It may be assumed then, that in some of the larger explosions in 1790 the ash was still hot at a distance of 1½ miles from the explosion vent. The 1½ miles is a possible distance of the middle company. A temperature below the charring point of dry grass, about 400° F., could easily cause death and yet show no signs of severe burns.

The 1790 explosions were essentially phreatic in that they were produced by ground water gaining access to the conduit from which molten lava had recently withdrawn. The molten lava that was present as evidenced by cored bombs was not essential to the mechanics of the explosions. The bombs found in the ash may have been produced from a trapped pocket of lava that was left behind in the retreat of the lava column.

The 1790 ash represents the topmost layer, except for a small amount of 1924 ash, of the rather coarse material of the ash deposits around Kilauea. The greatest depth on the rim is 45 inches at the west-southwest. On the southwest rim it is about 12 inches thick. To the east of Cone Peaks, 9 inches of the 1790 ash are still in place. The time required to produce the widespread erosional unconformity that is found between the upper layer of coarse material and the next layer under it definitely indicates that the two topmost layers are not the product of one explosive period.

There had been one, perhaps two, lava flows in eastern Puna previous to the 1790 explosions. It is reasonable to suppose that the 1790 eruptions followed a collapse in the crater accompanying an eastern Puna lava flow. Ellis (p. 214) tells of a lava flow in the Malama district of eastern Puna about 30 years prior to his visit, or about 1790. On page 218 he tells of a lava flow in about the same area, which occurred in the time of Taraiopu. Fornander[6] shows that Taraiopu is another name for Kalaniopuu, who died about 1782. It is doubtful if these two accounts refer to the same flow. The description of the Kalaniopuu flow fits well the southern portion of what Macdonald[7] has called the lava flow of 1793 [1790]. The Macdonald map shows two flows essentially parallel and two separate fissure sources. The separate fissures are merely a further indication and not a proof that there were two flows. Thrum in the Fornander collection[8] lists a great eruption of Kilauea in 1783. As Hawaiian dates at this time were not exact, one wonders if the older of these eastern Puna flows was the great eruption of 1783.

The condition of Kilauea following 1790 is not known. On January 11, 1794, (Hitchcock, p. 161) Vancouver passed to the south of Kilauea and reported columns of smoke arising. This may have been due to short-lived activity such as has occurred several times since 1924 or it may have been due to a dust cloud in the Kau Desert. Menzies, on February 12, 1794, (Hitchcock, p. 72) reported an eruption from Kilauea in terms suggesting that he had merely encountered a dust cloud from the Kau Desert.

Sometime in the period between 1790 and 1823—the year of a great collapse in Kilauea and a lava flow from the southwest rift—a considerable quantity of pumice was deposited over the upper Kau Desert. The pumice is 44 inches thick near the southwest rim of Kilauea and can be found in place 1½ miles from the rim. It probably came from a vent near the southern end of Kilauea while trade winds were blowing. It may well be that Kilauea showed but little or no activity for several years following 1790 and that the pumice eruption occurred about the time that continuous activity commenced.

The sinking of the lava column in 1823 left a relatively flat floor about 1,000 feet below Uwekahuna.[9] The flat floor indicated the drainage of a lava lake involving nearly all of Kilauea crater. The drainage must have been through a crack leading to the southwest rift system that was about 700 to 800 feet below the Kilauea rim on that side. Widespread activity prior to the 1823 lava flow and collapse is evidenced by the presence of several spatter cones on the black ledge as shown by a sketch in Ellis, page 176. The black ledge which represented the level reached by molten lava prior to the 1823 flow resulted from contact cooling with the crater walls. The flatness of the floor after the collapse of 1823 is a good indication that the crates had been filled with molten lava and that the fill must have been made in a short time.

The infilling of the crater prior to the collapse in 1832 affords a clue as to the possible time involved in the infilling prior to 1823. The volume of the infilling prior to the 1823 collapse is not known, but it must have exceeded the amount engulfed in 1823 plus the volume of the black ledge. The 1790 explosive episode must have left a pit or some portion of the crater with a depth much greater than the 1,000 feet below Uwekahuna found by Ellis. Such a pit may have been partially filled by short-lived activities prior to the commencement of continuous activity. As there is no way of estimating the volume of such a pit it will be ignored in what follows. A crude approximation of the volume of the pre-1823 infilling may be had by taking the amount engulfed in 1823, 19,052,000,000 cu. ft. (Volcano Letter 470 and 471), and adding an estimate for the volume of the black ledge, 120,000,000 cu. ft., thus obtaining a total of 19,172,000,000 cu. ft. The fill in Kilauea crater between 1825 and 1832 was estimated to have been 23,850,000,000 cu. ft. (Volcano Letter 471) or at a rate of 3,400,000,000 cu. ft. a year. Applying this rate to the 19,172,000,000 cu. ft., we obtain 5.6 years as the time required to make the pre-1823 fill. Now the fill may have been considerably greater than the amount given above but the rate of fill may have been greater than that between 1825 and 1832, so that an estimate of 6 or 7 years as the time required to complete the fill prior to the 1823 collapse seems reasonable. This would seem to indicate the possibility that Kilauea was rather quiet or inactive for about 25 years after the 1790 explosions.

[6] FORNANDER, ABRAHAM. AN ACCOUNT OF THE POLYNESIAN RACE (London, 1880), Vol. 2, p. 204.

[7] MACDONALD, GORDON A. LAVA FLOWS IN EASTERN PUNA. Volcano Letter 474, 1941, p. 1.

[8] FORNANDER, ABRAHAM. FORNANDER COLLECTION OF HAWAIIAN ANTIQUITIES AND FOLK-LORE. Bernice P. Bishop Mus. Mem. (Honolulu, 1919), Vol. 6, Part 2, p. 317.

[9] FINCH, R. H. ENGULFMENT AT KILAUEA. Volcano Letter 470, 1940, p. 1.

Hawaiian Volcano Observatory Report for April–June 1947

VOLCANOLOGY

April

The numbers of earthquakes recorded at Kilauea and Mauna Loa during April, 41 and 49 respectively, were less than in March. Six earthquakes, two of which were felt at Kapapala, were recorded in an interval of 1 hour and 40 minutes on the morning of April 12. The shakes originated at three different places and thus have but little volcanic significance. The majority of the earthquakes recorded in April appear to have originated under the eastern half of Manua Loa.

May

The total number of shakes recorded in May, as in the past 8 months, was greater at Mauna Loa than at Kilauea, or 54 and 43 respectively. During the latter part of the month there was a slight increase in the number of shakes originating under Kilauea.

Seasonal westerly tilt continued throughout the month. There was no tilt in the north-south direction.

June

The numbers of earthquakes recorded during the month were: Mauna Loa, 48, and Kilauea, 45. Earthquake No. 79, which occurred at 05:04 on June 19, had unusually long periods for all phases. This long period was also shown on the Mauna Loa and Hilo seismographs. The quake had a shallow focus under Kilauea.

A conspicuous fume cloud was observed over Mauna Loa about sundown on June 11.

R.H.F.

SEISMOLOGY

Earthquake Data, April–June, 1947

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
April	6	7	2	0	0	0	2.75	0
	13	2	4	2	3	0	10.50	2
	20	2	2	3	0	0	4.50	0
	27	6	3	1	0	0	4.00	0
May	4	10	5	1	0	0	6.00	0
	11	9	3	0	1	0	5.75	0
	18	5	2	0	0	0	2.25	0
	25	5	0	1	0	0	2.25	0
June	1	6	6	0	0	0	4.50	0
	8	16	0	0	0	0	4.00	0
	15	6	1	0	0	1	5.00	0
	22	10	2	0	0	1	6.50	0
	29	5	0	0	1	0	3.25	0

* For definition of local seismicity, see VOLCANO LETTER No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours and 30 minutes slower than Greenwich until June 8 then 10 hours slower. The number preceding each earthquake is the serial number of the quake for the current year.

36. April 2, 23:57, very feeble.
37. April 8, 05:10, very feeble.
38. April 10, 05:57, very feeble. Mauna Loa shake.
39. April 12, 01:07, feeble. Probably Mauna Loa.
40. April 12, 01:10, feeble.
41. April 12, 01:46, slight. Felt at Kapapala.
42. April 12, 02:28, slight.
43. April 12, 02:29, slight. Felt at Kapapala.
44. April 12, 02:49, very feeble.
45. April 12, 18:27, feeble. Kilauea shake.
46. April 13, 06:05, very feeble.
47. April 13, 06:21, very feeble.
48. April 15, 16:15, feeble.
49. April 17, 01:27, very feeble.
50. April 20, 03:27, very feeble.
51. April 20, 12:17, feeble.
52. April 20, 23:27, feeble.
53. April 21, 23:58, very feeble.
54. April 22, 14:40, feeble. NE slope Mauna Loa.
55. April 23, 20:07, very feeble.
56. April 24, 03:14, very feeble.
57. April 28, 07:34, feeble.
58. April 28, 22:30, very feeble.
59. April 29, 06:17, feeble. Mauna Loa.
60. April 29, 23:18, very feeble.
61. April 30, 04:24, very feeble.
62. May 2, 10:44, very feeble. Mauna Loa.
63. May 3, 03:58, very feeble.
64. May 5, 19:58, slight.
65. May 9, 06:07, very feeble.
66. May 9, 17:10, very feeble.
67. May 11, 05:09, very feeble.
68. May 15, 21:18, very feeble.
69. May 17, 09:38, very feeble. Kilauea.
70. May 21, 09:44, feeble. SW rift Kilauea.
71. May 27, 03:31, very feeble. Kilauea.
72. May 27, 17:09, very feeble.
73. May 29, 17:12, very feeble. Kilauea.
74. May 31, 03:05, very feeble. Kilauea.
75. May 31, 17:37, very feeble.
76. June 1, 05:48, very feeble. Mauna Loa.
77. June 9, 14:53, very feeble.
78. June 14, 23:00, moderate. Felt locally and as far as Papaikou. Moderate depth under Kilauea. Mauna Loa instrument dismantled.
79. June 19, 05:24, moderate. EW dismantled. Felt locally. Shallow under Kilauea.
80. June 19, 05:36, very feeble.
81. June 21, 11:01, very feeble. Mauna Loa.
82. June 26, 14:23, slight. Felt locally, Naalehu, and Hilo. 15 miles under E slope Mauna Loa.

TELESEISMS

April 10, 05:43, slight. Southern California.

April 13, 21:14, slight. Japan.

MICROSEISMS

Microseisms were strong from April 6th to the 9th and light to moderate during the rest of the month. They were moderate during the entire month of May. In June they were light to moderate from the 1st to the 11th and then moderate for the rest of the month.

CRACK MEASUREMENTS

A few of the cracks around Halemaumau opened slightly in April. No appreciable movement of any of the cracks measured was detected in May and June.

TILTING OF THE GROUND

Seasonal southerly tilt ceased during the latter part of March and there was a very slight accumulation of northerly tilt during the quarter. Westerly tilt continued throughout the quarter.

R.H.F.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Weed Ended	Amount	Direction
April 6	1.09″	N 84° W
13	0.43″	N 34° E
20	1.68″	S 86° W
27	0.38″	S 20° W
May 4	0.54″	N 63° W
11	0.26″	N 28° E
18	0.76″	N 71° E
25	0.96″	N 83° W
June 1	0.80″	S 64° W
8	0.86″	N 56° W
15	0.12″	N
22	0.43″	N 34° E
29	0.73″	S 80° W

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THE VOLCANO LETTER

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HAWAII NATIONAL PARK: Frank R. Oberhansley, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist



THE INACTIVE PERIODS OF KILAUEA

By R. H. FINCH

Volcanologist, Hawaii National Park

Continuous activity of Kilauea ceased with the withdrawal of the lava column preceding the explosive eruption in May, 1924. Since then there have been seven periods of short-lived activity. The last activity was on October 9, 1934. The present period of inactivity—practically 13 years—is the longest on record. The 13-year period from 1894 to 1907 has sometimes been compared with the present. The 1894–1907 period, however, is not comparable as in those years there was much fuming and occasional glow in Halemaumau. Meager data indicate that there may have been a similar period of inactivity following the 1790 explosions.

Discrepancies in the estimates of the percentage of the time that Kilauea has been inactive since the written record began in 1823, are to be expected. Some of the discrepancies may be accounted for by differences in the definition of activity and others may be due to differences in the interpretation of the records. For the 47 years prior to the establishment of the Hawaiian Volcano Observatory in 1912, the history of Kilauea is quite faithfully given in the record books of the Volcano House, the hotel on the northeast rim of the crater. Some of the indications of lack of activity even after the hotel was established in 1865 may be due more to a lack of observations than to actual inactivity. A study of the hotel record books shows that some periods of slight activity between spells of spectacular activity have erroneously been classed as inactive.

Any period in which magmatic effervescence is indicated as at or near the surface is classed as active in this discussion. To be conservative, for periods with considerable fuming and incomplete observations (as in 1849–1851 and 1894–1907), the duration of inactivity as given in Table 1 is greater than if the above definition were strictly followed. An open vent which is fuming in appreciable volume with lava occasionally visible had best be classed as active. Periods in which high-level internal activity without fuming is indicated, as in November–December, 1944,[1] are thus not classed as active.

A list of the known inactive periods of Kilauea from 1823 to May, 1924, inclusive, is shown in Table 1.

[1] FINCH, R. H. THE NOVEMBER–DECEMBER 1944 CRISIS AT KILAUEA. Volcano Letter 486, 1944.

Table 1.—Dates and Duration of Inactive Periods at Kilauea

Year	Duration	Remarks	Year	Duration	Remarks
	Months			*Months*	
1848	1	See note *A* below	1897	7	
1849	6	See note *B*. May be less	1898	11	
1850	6	May be less	1899	10	
1851	6	May be less	1900	9	
1852	1		1901	8	
1868	1		1902	5	See note *C*
1871	2		1903	7	
1879	1		1904	9	
1886	1		1905	2	
1891	1		1906	5	
1894	1	Fuming nearly continuous 1894–1907	1907	3	
1895	8		1913	1	
1896	6		1922	1	

Note *A*. Stearns and Macdonald[1] show questioned inactive periods in 1823, 1832, and 1840. The writer's interpretation of the records makes activity continuous in these years.

Note *B*. A plug dome formed at the Halemaumau vent in 1848. Mr. Coan correctly explained its formation as being due to the "compound action of upheaving forces from beneath and of eruptions from the openings forming successive layers upon its external surface."[2] Unusually viscous lava that issued from cracks in the plug was of comparatively small volume though sufficient to give a more or less smooth outline. The dome was over 300 feet high and about 2,000 feet in diameter. The continuance of the dome through 1849, 1850, and 1851 indicates that the lava column was high during these years; otherwise the dome would have collapsed. In the spring of 1852 there was a pit in the top of the dome. This was about 100 feet in diameter with a boiling pool of lava about 100 feet below the rim. The dome gradually disappeared by engulfment. A similar elevation of the epimagma took place prior to 1846. In the earlier 1840's elevation, the area involved was much greater than in 1848. Also there was a greater volume of less viscous molten lava.

Note *C*. On February 14, 1902, it was found that there was a recent lava fill in the bottom of Halemaumau, but the activity was not observed despite a rather close watch from the hotel.

[1] STEARNS, HAROLD T. and MACDONALD, GORDON A. GEOLOGY AND GROUND-WATER RESOURCES OF THE ISLAND OF HAWAII. Hawaii Div. of Hydrography, Bul. 9. 1946.

[2] DANA, JAMES D. CHARACTERISTICS OF VOLCANOES. (New York 1891), p. 80.

Since the explosive eruption in 1924, there have been seven periods of activity at Kilauea. Prior to the commencement of the present 13-year period of inactivity in 1934, the longest period of inactivity since 1924 was the three years from July, 1924, to July, 1927. The dates and duration by days of the active periods since May, 1924, are shown in Table 2. If the duration of inactivity by months were used, as in Table 1, for the 23 plus years of this period most of the entries would be 12, or 11 and a fraction.

Table 2.—Eruptions at Kilauea Since May, 1924

Date	Duration
	Days
July 1924	12
July 1927	14
February 1929	2
July 1929	4
November–December 1930	18
December 1931–January 1932	13
September–October 1934	33

The total in the above table is 96 days. This means that Kilauea has been active but a little over 1.1 per cent of the time since May, 1924.

During the 124 years and 9 months ended September 30, 1947, Kilauea has been active about 73 per cent of the time. For the 123 years ended 1945—the period used by Stearns and Macdonald, p. 112—the writer finds that Kilauea was active about 75 per cent of the time. The Stearns and Macdonald computation makes the figure about 67 per cent. This means that they classed as inactive about 110 months which the writer called active. The statement that Kilauea was active almost continuously from 1823 to May, 1924, is correct. Computations show that Kilauea was active about 90 per cent of the time during this period.

The behavior of Kilauea before and after the 1924 explosions indicates that an explosive eruption marks a turning point in the behavior of Kilauea. During the 16 years preceding the 1924 explosions, Kilauea was active over 98 per cent of the time. During the first 16 years following the explosions, activity totaled 1.7 per cent.

In VOLCANO LETTER 496, p. 2, the writer has given some calculations to indicate that Kilauea may have become continuously active about 1816 to 1818 or 26 to 28 years after the 1790 explosions. An estimate of 25 to 30 years would probably be better than 26 to 28 as 1790 might well be given 1790± and 1816 to 1818 is derived by calculations based on assumptions. If the behavior of Kilauea after 1924 is to be similar to the behavior following 1790—analogy and suggested periodicity in the occurrence of steam blasts make this seem a possibility—then some year from 1947 onward should be the equivalent of 1816±. It should be borne in mind that there is always the possibility of another period of short-lived activity before a resumption of continuous activity.

Hawaiian Volcano Observatory Report for July–September 1947

VOLCANOLOGY

July

July, 1947, was the quietest month seismically since September, 1946. The number of earthquakes recorded at Mauna Loa and Kilauea, respectively, were 29 and 14. Many of the shakes appear to have originated along the northeast rift of Mauna Loa with shallow foci. For the year ended June 30 there was a slight accumulation of southwest tilt which may be taken as indicating a slight pressure decrease under Kilauea.

August

In August, for the first time in several months, more earthquakes were recorded at Kilauea than at Mauna Loa, or 40 and 39, respectively. A conspicuous fume cloud was observed over Mokuaweoweo on August 5. From the rim it appeared dense and bluish. Ordinary steam clouds from Mokuaweoweo were observed several times during the month.

September

During September more earthquakes of Mauna Loa than of Kilauea origin were recorded, or 33 and 20, respectively. Two earthquakes that indicate deep-seated uneasiness along the fundamental rift under Hawaii occurred during the month. The first was at 05:50 on September 21 with a depth of from 20–25 miles and the second at 04:05, September 30 with a depth of 8–10 miles.

R. H. F.

SEISMOLOGY

Earthquake Data, July-September 1947

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
July	6	1	0	0	0	0	0.25	0
	13	1	1	0	0	0	0.75	0
	20	0	2	1	0	0	2.00	0
	27	2	0	3	0	0	3.50	1
August	3	1	2	0	0	0	1.25	0
	10	0	2	0	1	0	4.00	0
	17	1	3	0	0	0	1.75	1
	24	0	2	1	1	1	7.00	0
	31	4	3	0	0	0	2.50	0
September	7	3	4	1	0	0	3.75	0
	14	2	0	1	0	0	1.00	0
	21	2	0	0	1	0	2.50	0
	28	2	1	0	0	0	1.00	1

* For definition of local seismicity, see VOLCANO LETTER No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number of the quake for the current year.

83. July 7, 05:59, very feeble.
84. July 14, 11:52, feeble. Kilauea shake.
85. July 15, 12:25, very feeble. Mauna Loa.
86. July 17, 15:17, very feeble.
87. July 21, 06:18, feeble. Mauna Loa.
88. July 23, 01:52, feeble. Kilauea.
89. July 23, 10:25, feeble. SW rift Mauna Loa.
90. July 26, 16:57, very feeble. NE rift Mauna Loa.
91. July 28, 15:40, very feeble.
92. July 30, 17:15, very feeble. Kilauea.
93. August 7, 05:04, very feeble. NE rift Mauna Loa.
94. August 7, 20:36 slight. Felt locally, and at Naalehu and Hilo. E slope Mauna Loa.
95. August 10, 02:16, very feeble. NE rift Mauna Loa.
96. August 11, 12:52, very feeble.
97. August 12, 07:42, very feeble. Mauna Loa.
98. August 15, 18:46, very feeble. Mauna Loa.
99. August 18, 09:52, moderate. E–W seismograph dismantled. Felt locally and at Naalehu. Deep under Kilauea.
100. August 18, 10:01, feeble. Kilauea.
101. August 18, 14:11, feeble. Mauna Loa.
102. August 19, 01:22, very feeble.
103. August 19, 06:44, slight. Felt locally and at Naalehu. Mauna Loa.
104. August 24, 02:35, very feeble. Kilauea.
105. August 28, 15:15, very feeble. Mauna Loa.
106. August 29, 21:49, very feeble. Mauna Loa.
107. August 30, 15:21, very feeble.
108. September 1, 01:33, very feeble.
109. September 2, 05:17, very feeble. Kilauea.
110. September 4, 17:49, very feeble.
111. September 6, 17:28, feeble. Kilauea.
112. September 6, 17:45, very feeble. Kilauea.
113. September 12, 04:29, feeble. Kilauea.
114. September 21, 05:50, slight. Widely felt on this island and by a few on Maui. About 20–25 miles deep below Humuula.
115. September 22, 07:41, very feeble.
116. September 30, 04:04, moderate. Generally felt from South Kona to Hilo. Instruments dismantled. 6–8 miles deep east of Kilauea.
117. September 30, 04:09, slight.

TELESEISMS

July 24, 02:24, slight. New Hebrides.
August 17, 20:23, slight.
September 23, 04:10, slight. Off North California coast.
September 26, 06:14, slight.

MICROSEISMS

Microseisms were moderate on July 8, 9, and 10 and on the last three days of September. During the rest of the quarter they were light.

CRACK MEASUREMENTS

Some of the cracks around Halemaumau opened slightly, though the majority showed but little or no movement.

TILTING OF THE GROUND

Northerly tilt was quite uniform throughout the quarter except for a strong spurt during the last week in August and a sharp southerly tilt September 8–13. Tilting in the east–west direction was about stationary until July 25 when a rather uniform east tilt set in to continue through September.

R. H. F.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended		Amount	Direction
July	6	0.72″	E
	13	0.48″	N
	20	0.86″	N 56° W
	27	1.30″	N 22° E
August	3	0.97″	N 82° E
	10	0.26″	S 26° W
	17	0.50″	N 45° E
	24	1.05″	N 40° E
	31	1.87″	N 15° E
September	7	0.96″	S 83° E
	14	1.08″	S 7° W
	21	0.77″	N 52° E
	28	0.53″	N 63° E

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HAWAII NATIONAL PARK: Benjamin F. Moomaw, Acting Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

REVIEW OF "ORIGIN AND DEVELOPMENT OF CRATERS" BY T. A. JAGGAR

By R. H. FINCH
Volcanologist, Hawaii National Park

In the *Origin and Development of Craters,* Dr. T. A. Jaggar sets forth many of his ideas gained from a lifetime study of volcanoes. The book is memoir No. 21 of the Geological Society of America and contains 508 pages, 14 text figures, and 87 plates. The price at New York is $6.00.

Dana, in his *Characteristics of Volcanoes,*[1] generalized from Hawaiian volcanoes. Jaggar's memoir is modeled on Dana's book. It would be well for all readers of *Origin and Development of Craters* to peruse carefully the abstract and introduction. This will help in an understanding of the author's aims and prepare the reader for Part 1, which is largely the hitherto unpublished material in the record books of the Hawaiian Volcano Observatory from the second week of April, 1912, to the last of June, 1913. This section gives an excellent picture of the features and behavior of a lava lake as well as the initiation and development of observational methods. The strictly diary part probably is too detailed for most readers and might well have been included as an appendix. This comment might also apply to the diary of Part 3, Kilauea Steam Blast Eruption, 1924. The manner of treatment makes reading of the book rather difficult for all but those especially interested. It is not, however, intended as a popular book on Kilauea and Mauna Loa.

On page 267 occurs the statement: [The author] "makes no apology for introducing anywhere, if it is relevant, a geological discussion." Interpretation and definition are thus mingled with description. If there is any defect in this treatment it is largely overcome by a good index and an excellent table of contents. The table of contents merits attention as it permits those who lack time to read the book page by page to read by topics. The table of contents will also be especially helpful in using the memoir as a reference.

Part 2 gives a more or less chronological account of the activity of Kilauea and Mauna Loa from 1909 to 1935 and a condensation of 26 years of Hawaiian volcano observations and experiments. The author states that "The year 1909 is a good year to begin with because until 1913 the lava was intensely active but receding." The purely historical account of Hawaiian volcanoes given by Hitchcock[2] and Brigham[3] stops with 1908 and June, 1909, respectively. The year 1909 is thus an especially appropriate year with which to begin this part.

In the subtitle for Part 2—"The Cross of Hawaii"—the belief that Kilauea may be older than Mauna Loa is kept alive, though on page 90 there is the statement that geological mapping may demonstrate that Mauna Loa is older than Kilauea.

Mingled with the history in Part 2 are many geological discussions and the results of experiments. In 1912 a temperature of 1000° C. was found 2 feet below

[1] DANA, J. D. CHARACTERISTICS OF VOLCANOES. Dodd Mead, New York. 1891.

[2] HITCHCOCK, C. H. HAWAII AND ITS VOLCANOES. Hawaiian Gazette Co., Ltd., Honolulu. 1911.

[3] BRIGHAM, W. T. THE VOLCANOES OF KILAUEA AND MAUNA LOA. Bernice P. Bishop Mus. Mem. Vol. 2, No. 4, Honolulu, 1909.

the surface. The so-called "floating islands" were found to be but some of the epimagma, or the somewhat stiff upper portion of the lava column that normally forms the basin in which the lava lakes are located. The depth of the lava lake—40 to 50 feet—was determined both by experiment and direct observation.

On page 125 there is a discussion under the title, "Sympathy of Kilauea with Mauna Loa," wherein it is stated that there was an increase in output of a Kilauea flow attending the 1919 eruption of Mauna Loa. Collapses in Halemaumau following eruptions of Mauna Loa in 1914 and in 1916 offered definite suggestions of sympathy between the two volcanoes. There are indications of a similar collapse at Halemaumau in 1855 following an eruption of Mauna Loa in that year. These suggestions of sympathy led to the successful forecast of a collapse in Halemaumau in 1919 (p. 34).

The case for comparing the amphitheater breaches in the slag heap, Mauna Iki (p. 143), and large amphitheaters is not too good. The Mauna Iki slag heap was built up in days and the interior was composed of hot pasty material while the large amphitheater embayments occur in structures that were centuries in forming. Mohokea is cited as one such breach. Stearns and Macdonald[4] maintain that Mohokea was produced by erosion. Powers,[5] however, points out that block faulting may have played an important part in the formation of the Mohokea embayment.

The behavior of the upper end of the Kilauea lava column is quite fully treated in Part 4, Sketch Maps and Profiles of Halemaumau, 1917–1934. This method of treatment of necessity duplicates some of the history given in Part 2. Before detailed discussions of the maps and profiles are taken up there are seven pages of general statements. In reading this Part one wishes that the pertinent plates had been included as text figures instead of in an envelope containing 14 loose plates on the inside back cover. As printed, most are already of a size suitable for use as text figures.

Part 5 is a short summary of the histories of Kilauea and Mauna Loa. An excellent feature of this Part is a list of discussions bearing on crater history that appeared in the *Bulletin of the Hawaiian Volcano Observatory*. This is a helpful contribution as the *Bulletin* was never indexed. The table (p. 327) outlining Hawaiian activities is not intended as a complete listing of active years but rather to show lava culminations and lowerings. The propriety of giving probable times and amounts of lowering in such a table for the years 1800 and 1810, for which there are no records, is questioned. The dates and amounts of lowering are taken from the hypothetical portion of Plate 86.

On page 329 the author, as do Stearns and Macdonald,[6] favors a position south of the summit crater of Mauna Loa as the locus of the 1832 flow. The reviewer feels that the 1832 eruption was at the summit with a possible short flow from the northeast rim.

The idea that the north and south flanks of Mauna Loa at Humuula and Kahuku lands may be thought of as breaking down, undermined by lava flows, is given on page 333. Aside from the ancient breakdown to form the Kahuku Pali near the south point of Hawaii, there are no surface indications of such a process. If, as seems to be the case, the rise of lava at Mauna Loa is confined to the feeding conduits under Mokuaweoweo we would not expect much undermining by outflow at the places in question.

Part 6, Principles of Crater Evolution, commences with 10 pages of general statements of some of the broader aspects of volcanism. The subtitle for this part, "Earth, the Offspring of the Sun," emphasizes solar derivation. The next 40 pages treat of the work of 17 authors dealing with classification and ideas of volcanic processes. Direct quotations from many authors and comments on the work of all are given. There is evidence of a gradual increase in knowledge of volcanic processes. "Crater Physics and Chemistry" are treated in the last 20 pages of this Part. The importance of combustible gases in volcanic processes is emphasized. The three types of magma: hypomagma (profound and gas charged, rising from the earth's interior—the lava column in the depths), pyromagma, (the frothy fluid in lakes and flows), and epimagma (the stiff or pasty upper portion of the lava column) are discussed more fully here than elsewhere in the book.

Part 7, Summary and Conclusions, is a stimulating résumé with thought-provoking speculations on several subjects. The author's idea of ignisepta, "igneous partitions in earth mantle profound to the core" or "giant rift belts full of magma, leading down to the centrosphere," merits careful consideration.

The 73 plates of photographs deal mainly with Kilauea and Mauna Loa though a few are included dealing with the history of the Hawaiian Volcano Observatory. It is an excellent collection of photographs and, with the more extensive legends than usual, gives a quite comprehensive view of volcanic processes and products as exemplified by Kilauea and Mauna Loa.

The memoir is an outstanding contribution to the literature on volcanoes and will maintain this position for years to come.

[4] STEARNS, HAROLD T. and MACDONALD, GORDON A. GEOLOGY AND GROUND-WATER RESOURCES OF THE ISLAND OF HAWAII. Hawaii Div. of Hydrography, Bul. 9. 1946. P. 66.

[5] POWERS, H. A. REVIEW OF "GEOLOGY AND GROUND-WATER RESOURCES OF THE ISLAND OF HAWAII." Volcano Letter No. 494. 1946. P. 3.

[6] *Op. cit.*

Hawaiian Volcano Observatory Report for October–December 1947

VOLCANOLOGY

October

October was quiet seismically at Kilauea with but 11 earthquakes recorded. This is the smallest number recorded at Kilauea for many months. The Mauna Loa seismograph recorded a more usual number, or 30. The majority of the Mauna Loa shakes were very small with origins along the northeast rift. The strongest earthquake of the month occurred at 02:13, October 31. It dismantled the Mauna Loa and Kona seismographs. The indicated origin of the quake was at a depth of 12–15 miles below the southern end of Mokuaweoweo. There was about the usual northerly tilt during the month. The slight westerly tilt was opposite in direction to the normal for October. Tilting of the ground gave no indication of impending activity.

November

November, like October, was quiet seismically with but 18 earthquakes recorded on the Kilauea and Mauna Loa seismographs. This is the smallest number recorded at Mauna Loa for several years. The distinct earthquake of October 31 may have occasioned movement along the rift that extends from Mokuaweoweo to Kealakekua Bay. The Kona seismograph recorded two shakes from this rift on November 18 and 19. The rift was active in 1877 producing a small lava flow in Kealakekua Bay. On November 25 there were two periods of continuous tremor each lasting over 3 minutes. The tremor was more like that which accompanies an outbreak of Mauna Loa than individual earthquakes. The origin of the tremor was at Kilauea.

On November 15, following a 4-inch rainfall, heavy steam clouds developed in Halemaumau.

December

December was the third consecutive month with but few earthquakes of Kilauea origin. The Kilauea seismographs recorded but 16 shakes while the Mauna Loa instrument recorded 43. Five of the shakes were perceptible. One of these originated deep under Kilauea and four had shallow origins under various portions of Mauna Loa. The preponderance of Mauna Loa shakes, together with a distinct easterly tilt during the month, may be taken as signs of slight uneasiness under Mauna Loa. History and the scattered earthquakes give some indications that the next eruption of Mauna Loa will be at the summit. There was a slight accumulation of southeast tilt during 1947.

R. H. F.

SEISMOLOGY

Earthquake Data, October–December 1947

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
October	5	3	1	0	1	1	6.25	0
	12	1	0	0	0	0	0.25	0
	19	0	0	0	1	0	2.00	1
	26	0	2	0	0	0	1.00	0
November	2	2	2	0	0	1	4.00	1
	9	1	1	1	0	0	1.75	1
	16	1	3	0	0	0	1.75	0
	23	1	1	0	0	0	0.75	2
	30	6	2	0	0	0	2.50	0
December	7	2	0	0	0	0	0.50	0
	14	1	1	1	0	1	4.75	0
	21	2	2	1	1	0	4.50	0
	28	0	0	1	1	0	3.00	0

* For definition of local seismicity, see VOLCANO LETTER No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

118. October 3, 09:21, very feeble.
119. October 17, 00:27, slight. Generally felt on eastern part of island. Near Kapapala.
120. October 23, 09:42, very feeble.
121. October 24, 18:02, very feeble. Felt at Naalehu.
122. October 28, 22:00, very feeble.
123. October 30, 15:07, very feeble.
124. October 31, 02:13, moderate. E–W dismantled. Widely felt eastern half of island. Clocks stopped in South Kona. Origin under summit of Mauna Loa.
125. November 8, 15:53, feeble. Mauna Loa shake.
126. November 8, 16:15, very feeble. Mauna Loa.
127. November 13, 21:01, very feeble. Mauna Loa.
128. November 15, 01:43, very feeble.
129. November 16, 03:55, very feeble. Kilauea shake.
130. November 23, 01:17, very feeble. Mauna Loa.
131. November 25, 08:43, very feeble.
132. November 25, 11:31, very feeble. Kilauea.
133. December 9, 21:14, feeble.
134. December 12, 12:50, very feeble.
135. December 14, 10:10, moderate. Felt locally and at Hilo. E–W dismantled. 20 miles under Kilauea.
136. December 17, 00:01, very feeble. Felt at Kapapala. East slope of Mauna Loa.
137. December 18, 09:01, very feeble. Mauna Loa.
138. December 19, 23:07, feeble. East slope of Mauna Loa.
139. December 20, 05:18, slight. Felt eastern half of island. Near summit of Mauna Loa.
140. December 22. 02:55, feeble. East slope of Mauna Loa.
141. December 24, 06:38, slight. Felt locally, and at Hilo and Naalehu. East slope of Mauna Loa near Ainapo.
142. December 29, 16:28, very feeble.

TELESEISMS

October 15, 16:18, slight. Near Fairbanks, Alaska.

November 1, 05:12, slight. Peru.

November 3, 14:20, slight.

November 20, 18:14, slight. Mexico.

November 21, 22:26, slight.

MICROSEISMS

Microseisms were moderate to strong October 25–31 and December 11–21 and light on other days.

CRACK MEASUREMENTS

Some of the cracks near the southwest rim of Halemaumau opened slightly; other measured cracks were essentially stationary.

TILTING OF THE GROUND

The seasonal northerly tilt that continued until November was less than usual. There was a slight southerly tilt from November 7 until December 20, then a slight northerly tilt until the end of the year. There was a slight westerly tilt during the first week in October. On October 7 a distinct easterly tilt commenced that continued until December 16. During the last half of December there was a slight accumulation of westerly tilt.

R. H. F.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended		Amount	Direction
October	5	0.94″	N 50° E
	12	0.77″	N 19° E
	19	0.60″	N 37° W
	26	0.97″	N 83° W
November	2	0.86″	N 74° E
	9	1.08″	E
	16	1.46″	N 80° E
	23	0.70″	N 59° E
	30	0.12″	W
December	7	2.04″	N 62° E
	14	2.70″	S 33° E
	21	0.62″	S 22° W
	28	1.34″	N 22° W

TRANSFER OF THE HAWAIIAN VOLCANO OBSERVATORY

On December 28, 1947, by order of the Secretary of the Interior, the Hawaiian Volcano Observatory was transferred to the United States Geological Survey. The Observatory will continue measurement and observation of volcanic behavior, and, in addition, will serve as a training station in the Geological Survey's program of volcanic studies in the Pacific and elsewhere.

It is anticipated that with the expanded program and with growing fundamental interest in study of volcanoes, a period of renewed growth and accomplishment is indicated for the 40-year-old Hawaiian Volcano Observatory.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
In cooperation with UNIVERSITY OF HAWAII

The Hawaiian Volcano Research Association was founded in 1911 for record of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Government, Department of the Interior, National Park Service.

The University of Hawaii cooperates in maintaining a research laboratory at Hawaii National Park. **The Association** and the **University** supplement the work of the government with research associates, instrumental plants and special investigation. Dr. T. A. Jaggar is their geophysicist resident in the National Park.

The Volcano Letter, a quarterly record of Hawaiian volcano laboratories and published by the University of Hawaii, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the above establishments.

THE VOLCANO LETTER

No. 499 **U. S. Geological Survey** **January—March, 1948**

PUBLISHED BY THE UNIVERSITY OF HAWAII

U. S. GEOLOGICAL SURVEY: R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist



THE ACTIVE PERIODS OF MAUNA LOA

By R. H. FINCH

Volcanologist, U. S. Geological Survey

This note is intended as a companion one to the discussion of the inactive periods of Kilauea in VOLCANO LETTER No. 497. A similar study of the activity of Mauna Loa, owing to the small percentage of the time it has been active in its recorded history, is simplified if the active periods are used.

Dr. T. A. Jaggar[1,2] and Stearns and Macdonald[3] have made rather comprehensive statistical studies of Mauna Loa outbreaks. There can be but minor differences in the estimates of the small percentage of the time that Mauna Loa has been active. Differences have arisen as to whether some eruptions are to be classed as summit or flank. For example, Jaggar and the writer class the 1832 outbreak as a summit eruption while Stearns and Macdonald class it as a flank eruption. The 1851 outbreak is classed as a flank eruption by Jaggar, though by most definitions it is best classed as summit activity.

A summit eruption is one that takes place in or near the caldera and does not produce a lava flow originating in a rift outside the caldera area. A flank eruption is one that occurs on a rift outside the caldera. The records indicate that all flank eruptions start with short-lived activity at or near the summit. The duration of this preliminary activity varies from a few hours to 2 or 3 days. Such activity at the summit indicates that the ascent of lava from the depths is confined to the feeding conduits under Mokuaweoweo, the caldera of Mauna Loa. The longest dimension of the general breakdown that constitutes the caldera is more than 5 miles northeast-southwest and is roughly parallel to the southwest portion of the main rift of Mauna Loa. The southwestern limits of the caldera are not well defined, as the area has been covered by numerous lava flows some of which continued down the mountain for several miles. It is not surprising, then, that an outbreak may be placed in the caldera by one observer and on the southwest rift by another.

A list of the known eruptions of Mauna Loa and the probable duration of each is shown in Table 1.

The first eruption of Mauna Loa for which there is a definite date started on June 20, 1832. The table shows that during the 115 years and 9 months from this date to the present (March 31, 1948), Mauna Loa has been active 2,718 days, or 6.4 per cent of the time. It is interesting to note that the average duration of the 33 eruptions, starting with that of 1832, is 82 days. This large number is due mainly to four long-continuing eruptions, viz.: 1855-56, 480 days; 1859, 300 days; 1873-74, 560 days; and 1880-81, 275 days.

The first reported eruption of Mauna Loa, which is based on tradition, occurred about 1780. The exact date is not known but reports from different sources place the date definitely about 1780. The Turnbull report of activity in 1803 is quite definite and was probably a summit eruption[4]. The next reported eruption was in 1832. There may have been two or more eruptions between 1780 and 1832 instead of the one that was reported. A review of the records of the 1832 eruption rather definitely makes it a summit one, though there may have been one or more short lava flows from the caldera area. Stearns thought that a recent but un-

[1] JAGGAR, T. A. HISTORY OF MAUNA LOA. Paradise of the Pacific, Vol. 46, No. 2, Honolulu, 1934.

[2] JAGGAR, T. A. THE COMING LAVA FLOW. Volcano Letter No. 440. Oct., 1936.

[3] STEARNS, H. T., and MACDONALD, G. A. GEOLOGY AND GROUND-WATER RESOURCES OF THE ISLAND OF HAWAII. Hawaii Div. of Hydrography Bul. 9. 1946. Pp. 86-92.

[4] HITCHCOCK, CHARLES H. HAWAII AND ITS VOLCANOES. Hawaiian Gazette Co., Ltd., Honolulu, 1911. P. 80.

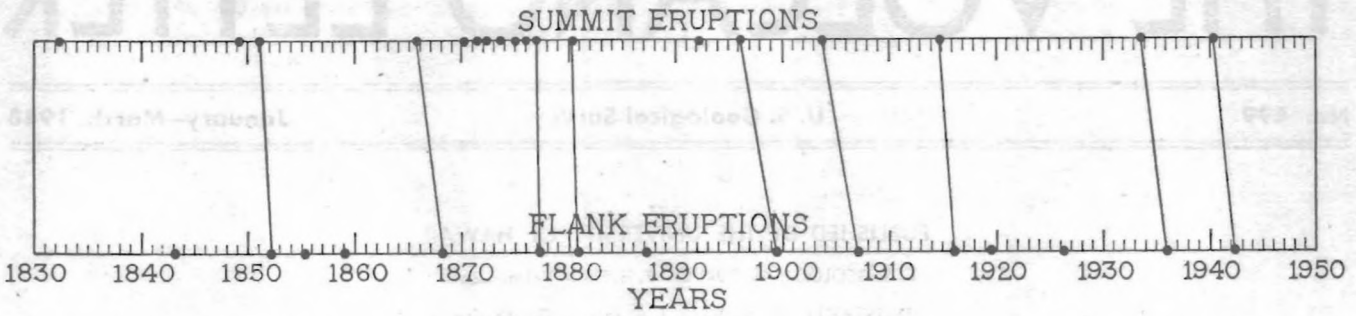

Figure 1.—Summit and flank eruptions of Mauna Loa plotted according to dates. The diagonal lines connect summit eruptions that were followed by flank eruptions without any intervening eruption.

dated lava flow from an elevation of about 8,000 feet on the southwest rift above Waiohinu occurred in 1832[5]. Aside from the freshness of the flow there is little to justify such a belief. An old map of the Hawaiian government survey shows a short flow from the east rim of Mokuaweoweo dated 1832. There is no such recent flow at the place indicated on the map. A mile or so to the north and to the southwest there are flows fresh enough to have occurred in 1832. The Goodrich[6] account of the 1832 outbreak states that it lasted from 2 or 3 weeks and that lava flowed from several vents about the summit. The records of later eruptions show that when a flank eruption starts, activity at the summit ceases. The belief that activity in 1832 was confined to the summit seems justified.

[5] STEARNS, H. T., and W. O. CLARK. GEOLOGY AND WATER RESOURCES OF THE KAU DISTRICT, HAWAII. U. S. Geological Survey, Water-Supply Paper 616, 1930. P. 71.

[6] GOODRICH, JOSEPH. VOLCANOES AND VOLCANIC PHENOMENA OF HAWAII. Amer. Jour. Sci. 1st Ser., Vol. 25, 1833. P. 199.

TABLE 1. YEAR, LOCATION, AND DURATION OF THE ACTIVE PERIODS OF MAUNA LOA.

PLACE AND YEAR OF ERUPTION		DURATION DAYS
SUMMIT	FLANK	
1780		?
1803		?
1832		21
	1843	120
1849		21
1851		12
	1852	20
	1855–56	480
	1859	300
1865		120
	1868	16
1870		14
1871		30
1872		145
1873–74		560
1875		60
1876		7
	1877	11
1880		6
	1880–81	275
	1887	15
1887–88		40
1892		3
1896		15
	1899	26
1903		61
	1907	15
1914–15		45
	1916	14
	1919	42
	1926	19
1933		17
	1935	42
1940		132
	1942	14

In studying the record books of the Volcano House, the hotel on the northeast rim of Kilauea, two different accounts of a summit eruption in 1871 were found. This eruption is not given in the list compiled by Hitchcock and subsequent writers. The first entry in the record book under the date of August 9, 1871, reads, "A great fire to be seen in the Mono Loa Crater." On August 28, the second entry reads, "Faint light at night from the outbreak on Mauna Loa." A search was then made to see if Macdonald[7] had found any reference to this outbreak. The Macdonald bibliography shows that Titus Coan had reported the outbreak in the *American Journal of Science* in 1871. Coan reported that Mauna Loa had been active for weeks prior to August 22, 1871. The record book of the Volcano House indicates that the eruption lasted about a month as there was no activity in Mokuaweoweo early in September, 1871. It seems safe to give a value of 30 days for the duration of activity in 1871.

In accordance with the definition of activity given in the discussion of the inactive periods of Kilauea in VOLCANO LETTER No. 497, the summit eruption of 1887-88 has been included in the table though no molten lava was observed. The intermittent fuming and steaming spell of November, 1943 (VOLCANO LETTER No. 482) has not been included in the list because of the very short duration, the small volume of fume involved, and the fact that it was intermittent.

There is the possibility that occasionally a short-lived summit eruption has escaped notice owing to the remoteness of the summit of Mauna Loa and the fact that it is often obscured by clouds. In 1873, Green[8] noted no glow over the summit of Mauna Loa during three clear nights prior to his ascent of the mountain on June 6, but when the crater rim was reached, a light smoke could be seen drifting away and great fountains were playing. There was insufficient fume to reveal the activity at a distance either by day or night. A characteristic tremor that is recorded on the seismographs

[7] MACDONALD, G. A. BIBLIOGRAPHY OF THE GEOLOGY AND WATER RESOURCES OF THE ISLAND OF HAWAII. Hawaii Div. of Hydrography, Bul. 10. Honolulu, 1947.

[8] GREEN, W. L. VESTIGES OF THE MOLTEN GLOBE. Honolulu, 1887. P. 167.

during Mauna Loa eruptions indicates that an outbreak can now be detected whether the mountain is visible or not.

It has often been stated that a summit eruption is usually followed by a flank eruption in about two years. Computations made from the preceding graph (Fig. 1) indicate that this relationship holds for only about 56 per cent of the time. The 1832-43 relationship has not been used in these computations as the interval between the two outbreaks was 10½ years. Activity may have been more continuous in 1870-77 than indicated in Figure 1, where seven different summit eruptions are plotted. The 56 per cent was derived by calling this group four instead of seven. The last eight summit eruptions have been followed by flank eruptions 75 per cent of the time with an average interval of 18 months. A summit eruption is thus a factor that may be considered in forecasting flank eruptions.

Hawaiian Volcano Observatory Report for January—March, 1948

VOLCANOLOGY

January

The Mauna Loa seismograph recorded 29 earthquakes during January and 26 were recorded at the Kilauea seismograph. Of the five perceptible shakes felt during the month four originated under Mauna Loa and one under Kilauea.

Landslides from the walls of Halemaumau were especially frequent from January 15 to 18, inclusive.

February

Eight more earthquakes were recorded at Mauna Loa than at Kilauea, or 28 and 20, respectively. Three perceptible shakes originated under the southwest slope of Mauna Loa and one under Kilauea Crater.

The seasonal change in direction of tilt from northeast to southwest occurred about the middle of December. There was a normal accumulation of southerly tilt during February while westerly tilt was distinctly less than normal.

March

Forty earthquakes were recorded during the month. Thirteen more shakes were recorded at Mauna Loa than at Kilauea. The strongest earthquake of the month occurred at 16:18 March 19. It originated deep under Kilauea and was generally felt over the eastern part of the island of Hawaii.

There was a slight accumulation of easterly tilt since the middle of February. As westerly tilt is usual for this season of the year, the easterly tilt gives some indication of a pressure increase under Mauna Loa. The rapid southerly tilt that started at the beginning of the year continued throughout the month.

R. H. F.

SEISMOLOGY

Earthquake Data, January—March, 1948

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
January	4	2	1	1	0	0	1.00	0
	11	7	1	0	1	0	4.25	0
	18	6	0	1	1	0	4.50	1
	25	1	1	0	0	0	0.75	1
February	1	1	2	1	1	0	4.25	1
	8	1	8	0	1	0	6.25	0
	15	1	1	1	0	0	2.25	0
	22	2	0	1	1	0	3.50	0
	29	1	2	0	0	0	1.25	1
March	7	1	3	0	0	0	1.75	0
	14	3	0	1	1	0	3.75	0
	21	3	2	0	0	1	4.75	0
	28	0	2	1	0	0	2.00	0

* For definition of local seismicity, see VOLCANO LETTER No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

1. January 3, 06:04, feeble. Felt locally. Under Mokuaweoweo.
2. January 8, 16:15, slight. Felt locally. East slope Mauna Loa.
3. January 10, 17:11, slight. Felt locally. East slope Mauna Loa.
4. January 11, 1:50, very feeble.
5. January 15, 6:16, slight. Felt locally and at Hilo. NE slope Mauna Loa.
6. January 17, 9:50, feeble. Near Hilina Pali.
7. January 18, 12:10, very feeble.
8. January 23, 15:04, very feeble.
9. January 26, 23:02, slight. Felt from Naalehu to Hilo. NE rift Mauna Loa.
10. January 29, 8:55, very feeble.
11. January 31, 10:32, very feeble.
12. February 1, 11:58, feeble. Felt at Naalehu. SW slope Mauna Loa.
13. February 2, 1:12, very feeble.
14. February 2, 22:31, very feeble.
15. February 6, 13:44, very feeble.
16. February 6, 16:17, very feeble.
17. February 7, 8:59, very feeble.
18. February 7, 18:04, very feeble. SW slope Mauna Loa.
19. February 8, 3:56, slight. Kilauea.
20. February 8, 4:18, very feeble. Kilauea.
21. February 8, 7:07, very feeble. Kilauea.
22. February 10, 10:40, very feeble. Mauna Loa.
23. February 12, 4:14, slight. SW slope Mauna Loa.
24. February 20, 9:30, slight. Felt locally. Kilauea.
25. February 20, 9:37, feeble. Kilauea.
26. February 26, 0:52, very feeble. Mauna Loa.
27. February 27, 21:20, very feeble.
28. March 2, 10:05, very feeble. Mauna Loa.
29. March 2, 17:07, very feeble.
30. March 5, 2:43, very feeble. Mauna Loa.
31. March 9, 8:30, very feeble. Mauna Loa.
32. March 9, 15:46, slight. Felt from Hilo to Kona. Off coast north of Hualalai.
33. March 16, 3:43, very feeble.
34. March 19, 16:18, moderate. E–W dismantled. Felt from Hilo to Naalehu. Deep under Kilauea.
35. March 19, 23:09, very feeble. Felt at Naalehu.
36. March 26, 6:08, feeble. Mauna Loa.
37. March 27, 1:03, very feeble.
38. March 27, 11:44, very feeble.
39. March 30, 0:53, very feeble.
40. March 31, 8:41, very feeble. Mauna Loa.
41. March 31, 16:44, very feeble.

TELESEISMS

January 13, 16:55, slight. 1200 km. north of Easter Island.
January 24, 8:20, slight. Philippines.
January 27, 2:06, slight.
February 29, 15:30, slight. New Guinea.

MICROSEISMS

Microseisms were moderate to strong January 23–31 and February 8–10 and moderate March 26–31. They were present though slight on other days.

CRACK MEASUREMENTS

Despite many slides from the walls of Halemaumau during the middle of January all cracks that were measured showed but little or no movement during the quarter.

TILTING OF THE GROUND

The southerly tilt that was continuous throughout the quarter was slightly greater than usual. There was about the usual accumulation of westerly tilt until February 20. From this date until March 31 there was an accumulation of one second of arc of easterly tilt. As there is normally a westerly tilt during this season of the year one second of easterly tilt may actually be greater than the figure indicates. Past records suggest that an easterly tilt is an indication of increase of pressure under Mauna Loa.

R. H. F.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended		Amount	Direction
January	4	1.4″	S 49° W
	11	1.2″	S 36° W
	18	1.0″	S 35° W
	25	0.9″	S 56° E
February	1	1.5″	S 75° W
	8	0.4″	S 18° W
	15	1.5″	S 29° W
	22	1.2″	S 35° E
	29	1.5″	S 18° E
March	7	0.9″	S 50° W
	14	0.1″	E
	21	2.1″	S 30° E
	28	1.0″	S 60° W

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter,** a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

THE VOLCANO LETTER

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U. S. GEOLOGICAL SURVEY: R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

THE TELESEISM ANNUNCIATOR AT THE HAWAIIAN VOLCANO OBSERVATORY

By BURTON J. LOUCKS

Instrument Maker, U. S. Geological Survey

The Hawaiian Volcano Observatory has issued warnings of the possibility of a tsunami or tidal wave on several occasions. The warnings were based on the seismograms of distant earthquakes and were made only when the fact that a strong shake had occurred was discovered during routine attention to the seismographs. The disastrous tidal wave of April 1, 1946,[1, 2] brought forcibly to mind the need for immediate discovery of the recording of potential tsunami-producing earthquakes regardless of the time of occurrence.

The April 1, 1946, earthquake started recording on the Observatory seismographs at 2:06 A.M. but it was not noted until the record was changed at 7:30 A.M., over half an hour after the waves reached Hilo. If the record had been seen earlier, a warning of the possibility of a tidal wave would have been issued. Experience had taught that the amplitude and distance to origin were such as to indicate the possibility of a tidal wave.[3]

In cooperation with the Hilo Chamber of Commerce, an earthquake annunciator was set up in the seismograph vault of the Hawaiian Volcano Observatory on December 16, 1946. The installation is intended to be only a stopgap to function until the U. S. Coast and Geodetic Survey station at Barbers Point, Oahu, is in operation.

[1] POWERS, H. A. THE TIDAL WAVE OF APRIL 1, 1946. Volcano Letter 491, 1946.

[2] MACDONALD, G. A., SHEPHERD, F. P., and COX, D. C. THE TSUNAMI OF APRIL 1, 1946, IN THE HAWAIIAN ISLANDS. Pacific Science, 1 (1) : 21–37, 1947.

[3] FINCH, R. H. ON THE PREDICTION OF TIDAL WAVES. Proc. 2nd Pacific Science Congress, Australia, 1923. P. 1368.

The instrument consists of a horizontal seismograph pendulum with a boom and magnifying lever (Fig. 1). Whenever a quake of appreciable amplitude occurs, the long arm of the lever makes alternate contact with two pools of mercury (Fig. 2) and closes an electrical circuit. In this circuit (Fig. 3) is a buzzer that is audible in the Observatory building and a relay that closes another circuit with buzzers located in the residences of two members of the Observatory staff. One component of the Hawaiian-type seismograph is used. The heavy mass is a 3-foot section of 8-inch steel pipe filled with sand. The pipe is bolted into a framework of steel 2 by ½ inches with about 3 inches projecting out at the back, both top and bottom. These projections are slotted and 1½-inch pieces of No. 20 music wire with retainers on the ends are inserted in the slots and corresponding ones in the adjustable back plate to suspend the heavy mass as a horizontal pendulum. An aluminum boom is secured to the pipe framework and projects forward about 4 feet from the hinge line. The forward end of the boom is coupled to the magnifying lever by a thin piece of brass with cups that fit over phonograph needles in the end of the boom and of the short arm of the lever. A piece of steel wire which projects downward about ½ inch from the end of the long arm of the magnifying lever makes contact with the mercury when the pendulum oscillates or becomes displaced by tilt. Two brass rods project up from the lever support on either side of the end of the boom to act as buffers in case of strong local shakes. The buffers are wired into the electrical circuit. If a strong local earthquake dis-

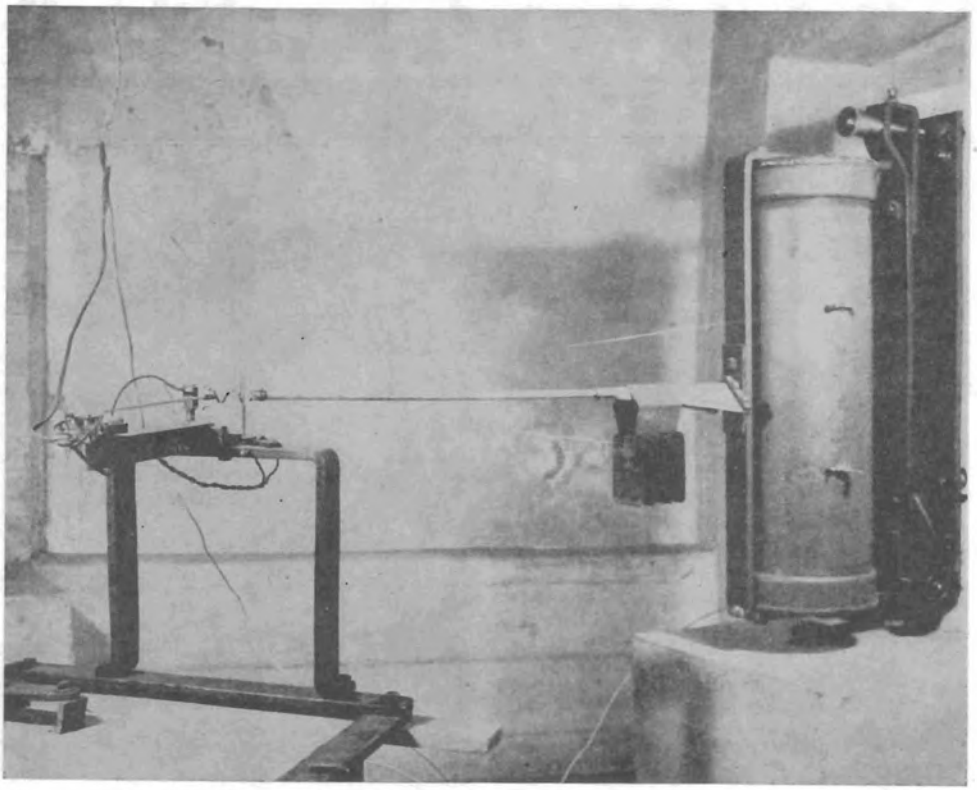

Figure 1. General view of the teleseism annunciator. The damping vanes on the boom near the heavy mass are not in use.

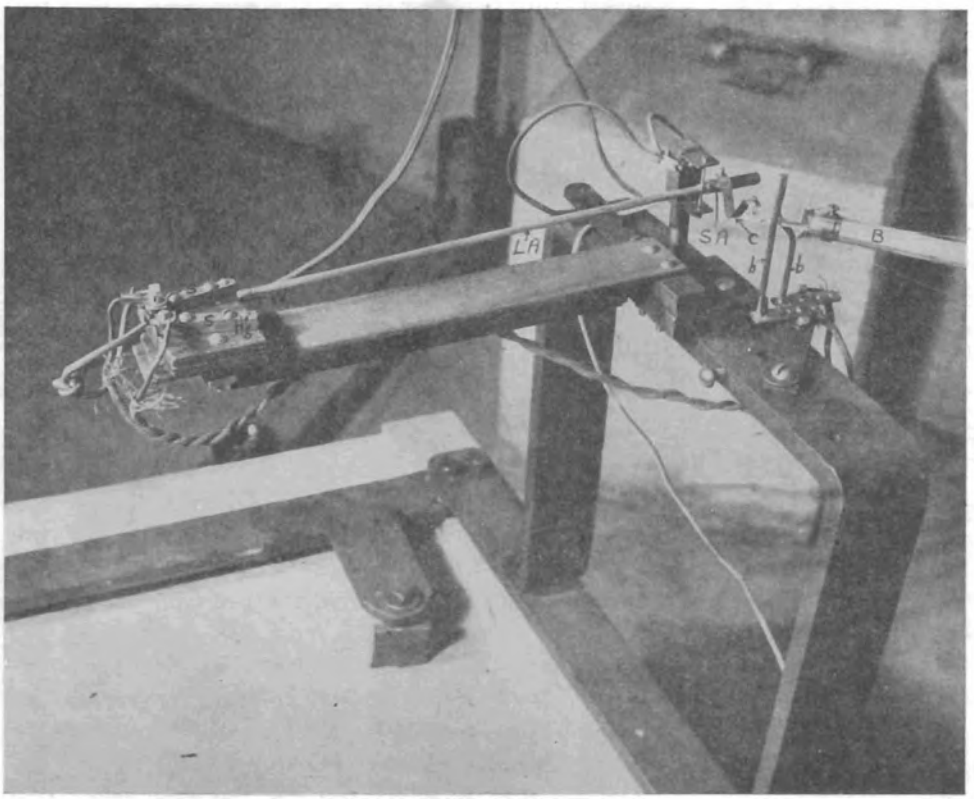

Figure 2. Details of magnifying lever and wiring. **B**, boom; **b**, **b**, buffers; **c** is the link that couples boom to magnifying lever; **SA** is short arm and **LA** long arm of magnifying lever; **W** is wire that contacts mercury pools; **Hg** is the mercury pool; and **s** is the steel bar that holds the mercury.

NATIONAL PARK SERVICE PHOTOGRAPHS BY DOUGLASS H. HUBBARD

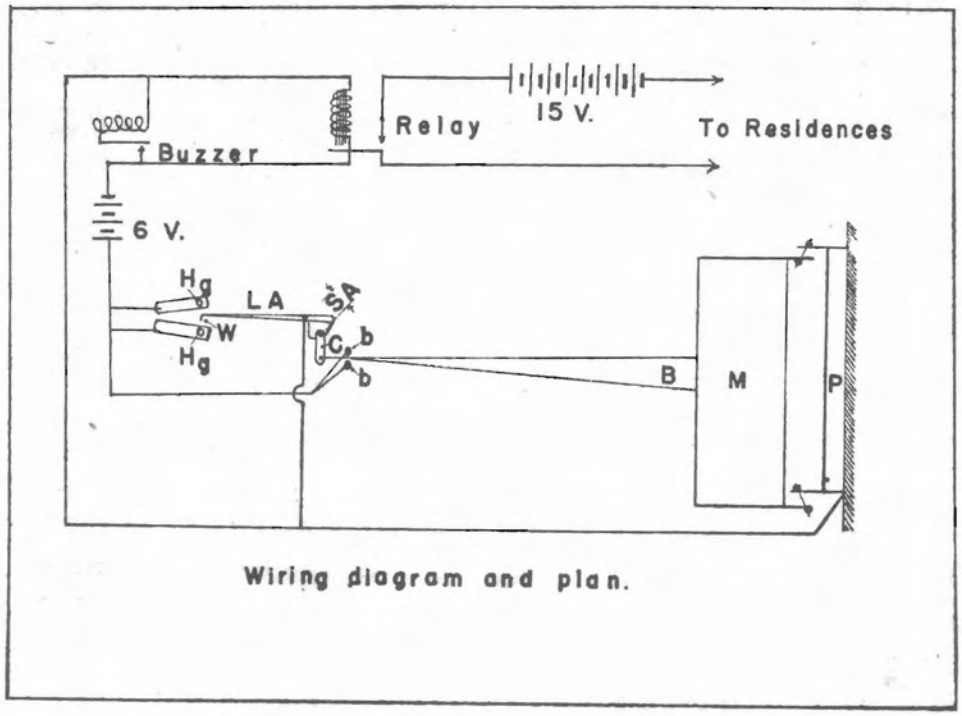

Figure 3. Wiring diagram and plan of the teleseism annunciator. Letters correspond to those in Figure 2.

mantles the instrument by throwing off the coupling mentioned above, it will still continue to function as an annunciator by means of the buffer contacts, though with diminished sensitivity.

The pools of mercury are in steel bars mounted on a piece of insulating material and are 1⅝ inches apart. When first set up they were only ¾ of an inch apart. Tilt due to daily temperature changes was so great that it was found necessary to increase the distance.

When the instrument was first installed, it was operated with a period of 12 seconds. To reduce the trouble due to tilt, the period was reduced to 7 seconds. The pendulum is undamped.

The instrument has been quite satisfactory and has announced several local earthquakes as well as a few teleseisms. It gave a good warning signal for the teleseism of May 14, 1948, which caused the tidal wave warning system in the Territory to be put into operation. This earthquake was the only one announced which was deemed to have sufficient amplitude and proper distance to justify a warning of the possibility of a tidal wave.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR APRIL-JUNE, 1948

VOLCANOLOGY

April

Forty-two earthquakes were recorded in April. Thirty-eight of the quakes were recorded on the Mauna Loa seismograph and 14 at Kilauea. The felt earthquakes which occurred at 00:25 April 26 originated near the north end of the Kilauea caldera. The facts that the shake was slight to moderate at the Observatory and was recorded as a tremor only on the Mauna Loa seismograph 10 miles away, indicate a very shallow focus.

The strong southerly tilt that set in about the first of the year continued until the last of April.

May

The earthquakes which occurred in May had widely scattered origins, as in the past several months. Twenty-eight quakes were recorded during the month, the majority of which originated under various portions of Mauna Loa. Twenty-five of the shakes were recorded on the Mauna Loa seismograph and 11 at Kilauea.

The accumulation of seasonal westerly tilt during the first 5 months of the year was the smallest for several years, and the records indicate that this may be taken as a suggestion of a slight pressure build up under Mauna Loa. The unusually sharp southerly tilt which began the first of the year ceased early in May.

A conspicuous steam cloud was observed over Mokuaweoweo at sunset on May 16 and on several other days during the month. Such observations are rather common at this season of the year.

June

Thirty local earthquakes were recorded in June. Of this number 28 were recorded on the Mauna Loa seismograph and 18 at Kilauea.

There was no accumulation of tilt during the month. The lack of westerly tilt rather than a positive easterly tilt is the only indication of a pressure build up under Mauna Loa.

R.H.F.

SEISMOLOGY

Earthquake Data, April-June 1948

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
April	4	0	4	0	0	0	2.00	0
	11	0	3	0	1	0	3.50	0
	18	0	2	0	0	0	1.00	0
	25	2	1	0	1	0	1.00	0
May	2	1	2	0	0	0	1.25	0
	9	0	0	0	0	0	0	0
	16	2	0	0	0	0	0.50	1
	23	2	1	0	1	0	3.00	1
	30	1	2	1	1	0	3.75	0
June	6	1	3	2	0	0	3.75	0
	13	2	0	0	0	0	0.50	0
	20	2	1	0	1	0	3.00	1
	27	0	3	0	0	0	1.50	0

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

42. April 5, 11:23, very feeble.
43. April 6, 0:25, slight. Felt locally. Shallow under northern end of Kilauea caldera.
44. April 6, 19:53, very feeble.
45. April 6, 22:12, very feeble.
46. April 14, 9:01, very feeble.
47. April 15, 3:37, very feeble. Kilauea.
48. April 24, 10:05, slight. Felt locally and at Hilo. East slope of Mauna Loa.
49. April 24, 23:59, feeble. Felt locally. Mauna Loa.
50. April 28, 20:53, very feeble.
51. April 30, 0:51, very feeble. Mauna Loa.
52. May 20, 20:04, very feeble. Under Mokuaweoweo.
53. May 22, 11:34, slight. Deep under Hualalai.
54. May 24, 23:16, slight. Felt locally. N.E. rift of Mauna Loa.
55. May 26, 0:39, feeble.
56. May 29, 16:29, very feeble. Under Mokuaweoweo.
57. May 29, 18:45, very feeble.
58. June 1, 7:34, feeble. Felt at Ainahou.
59. June 2, 21:13, very feeble.
60. June 3, 8:58, very feeble.
61. June 5, 12:08, very feeble.
62. June 6, 10:17, feeble. Kilauea.
63. June 18, 6:05, very feeble.
64. June 19, 17:06, slight, Felt locally, East slope of Mauna Loa.
65. June 24, 17:49, feeble.
66. June 25, 10:18, feeble. Kilauea.
67. June 25, 13:05, feeble. Felt locally. Mauna Loa.
68. June 26, 1:42, slight. Under Oahu; felt at Hilo.
69. June 28, 10:51, very feeble.

TELESEISMS

May 14, 12:40, moderate. Aleutians.
May 17, 7:57, slight. South of Alaska peninsula.
June 17, 3:04, slight.
June 29, 0:36, slight.

MICROSEISMS

Microseisms were moderate on April 9, 10, 24, and 25 and slight on other days.

CRACK MEASUREMENTS

A few of the cracks that were measured in the vicinity of Halemaumau rim showed slight openings.

TILTING OF THE GROUND

Seasonal southerly tilt, which was stronger than usual during the first 4 months of the year, continued until May 4, when a slight northerly tilt began. The seasonal change from westerly to easterly tilt occurred on June 9.

R.H.F.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended		Amount	Direction
April	4	1.2″	S 11° E
	11	2.4″	S
	18	1.0″	N 82° W
	25	1.2″	S
May	2	0.4″	S 19° W
	9	0.8″	N 61° W
	16	0.2″	N 45° E
	23	0.8″	S 56° E
	30	1.2″	N 11° W
June	6	0.2″	S 45° E
	13	1.0″	S 55° W
	20	0.4″	N 72° E
	27	0.9″	N 9° W

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The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter**, a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

THE VOLCANO LETTER

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U. S. GEOLOGICAL SURVEY: R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

THE NEW LOCATION OF THE HAWAIIAN VOLCANO OBSERVATORY

By RUY H. FINCH

Volcanologist, U. S. Geological Survey

One of the results of the transfer of the Hawaiian Volcano Observatory from the National Park Service to the U. S. Geological Survey is the establishing of the Observatory in a new location. It is being moved to the old National Park Museum and Lecture Hall buildings at Uwekahuna Bluff on the western rim of Kilauea Caldera (see figure). The buildings have been remodeled to include offices, shops, and laboratories.

The Observatory was located on the northeast rim of the Caldera from the time it was established in 1912 until 1941, when it was moved 600 feet back from the rim into the newly constructed Observatory and Naturalist Building. The vertical seismograph and a tilt meter were placed in a cellar under this building. The Bosch-Omori seismograph, the principal instrument of the Whitney Laboratory of Seismology, was left in its old location[1] under a concrete slab and 18 inches of soil.

Both the first and second locations of the Observatory were on badly fissured basalt with numerous steam cracks. Because the concrete floor was built over steam cracks, the temperature of the cellar at the original location is about 95° F. the year around. For similar reasons the cellar of the second location has a constant temperature of about 85° F. The mean annual air temperature of the area is about 61° F. A commercial highway passes about 200 feet from each cellar, and the records are marred by the frequent passing of heavy trucks.

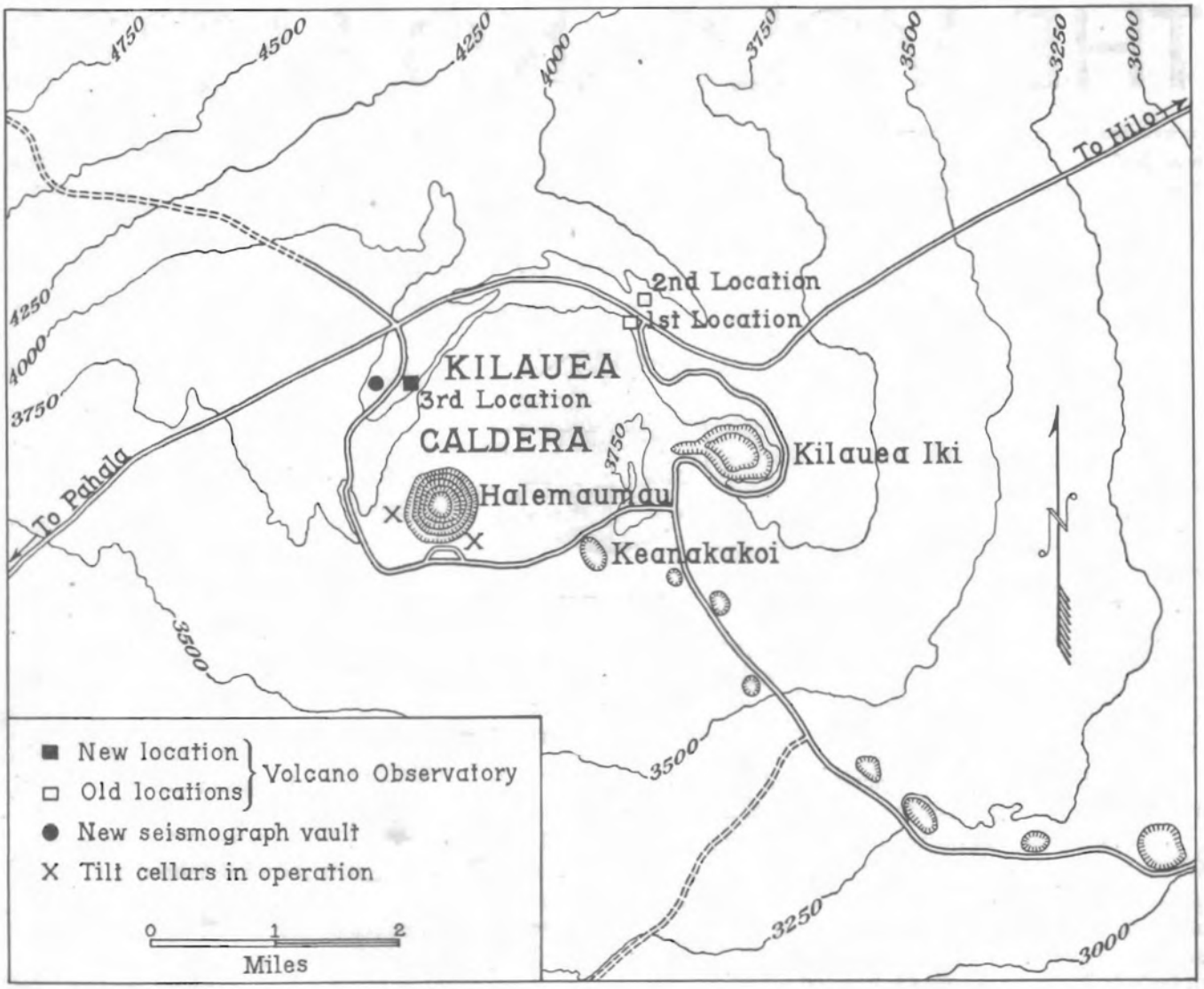
[1] Volcano Letter 475, 1942.

Tilt records have been taken from the Bosch-Omori seismograph since 1913. The instrument has been operated since 1919 with a period of about 7.7 and a magnification of about 115. It is proposed to operate this seismograph in its present location for another year before removal to the new cellar near Uwekahuna (see figure). This will afford an opportunity to correlate tilt records of the two locations, one on the northeast rim and the other on the northwest.

The Bosch-Omori seismograph tilt records do not correlate well with those obtained from a special tilt pendulum under the Observatory–Naturalist Building. When the numerous fissures of the area are considered, this is not surprising. Despite the nearly constant temperature of the second cellar, the tilt records obtained here were marred by the large tilt produced by diurnal temperature changes in the superstructure. The tilt data measured at the original location of the Observatory are real as they have been checked by leveling.[2]

The new location of the Observatory is at an elevation of 4,075 feet a short distance southerly from the highest point on Kilauea Mountain. It is 1 mile northwest from the center of Halemaumau just off the Crater Rim Road. The site affords a good view of Kilauea Caldera, the southwest rift, and part of the Puna rift as well as

[2] JAGGAR, T. A., and FINCH, R. H. TILT RECORDS FOR THIRTEEN YEARS AT THE HAWAIIAN VOLCANO OBSERVATORY. Bull. Seis. Soc. Amer. Vol. 19, No. 1, 1929. See also leveling data in T. A. Jaggar, Memoir 21, Geol. Soc. Amer., pp. 208–214, 1947.



Map showing the positions of the successive locations of the Hawaiian Volcano Observatory, the new seismograph vault, and the tilt cellars now in operation.

Mauna Loa. This was the first site selected by Dr. T. A. Jaggar for the Observatory in 1912 but was given up on account of the scarcity of water and its relative inaccessibility at that time.

A new seismograph cellar has been constructed 1,250 feet nearly due west of the Uwekahuna Bench Mark. The new cellar is 1⅛ miles from the center of Halemaumau, about 1 mile closer than the old cellar. It is 450 feet from the Crater Rim Road and about 2,000 feet from the around-the-island highway. The cellar is 12 x 20 feet with an entrance way 5 x 8 feet to serve as an air lock and processing room. The roof is a reinforced concrete slab covered with about 18 inches of volcanic ash. The foundation of the cellar is within massive basalt which lies under 20 inches of ash. There is only one visible fissure between the cellar and the Caldera rim. During the week ended September 16 a thermograph trace made in the cellar showed a drop of less than 1½° F. This record, which was obtained during a dry spell, showed a diurnal variation of about ½° F. The maximum was reached about 6:00 p.m.

The first instrument installed was a portable tilt meter oriented to measure east–west tilt. For the first 2 weeks values obtained seemed to be due largely to cellar floor and instrumental adjustments.

Two tilt meters and the vertical seismograph will shortly be installed in the new cellar. In about a year the Bosch-Omori seismograph will be moved over, and later on it is planned to install a higher-magnification instrument.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JULY–SEPTEMBER, 1948

VOLCANOLOGY

July

Forty-one earthquakes were recorded during July. Thirty-seven of the shakes were recorded at Mauna Loa and 19 at Kilauea. Six of the seven earthquakes recorded on July 30 were perceptible. They originated at a depth of about 6 miles to the east of Kilauea Caldera. These quakes furnish the most conspicuous signs of uneasiness under Kilauea that have been noted during the last 3 years.

Seasonal northerly tilt during July was slightly greater than usual.

August

Only 27 earthquakes were recorded during August. Eleven of the shakes were recorded at Kilauea and 23 at Mauna Loa. The uneasiness at Kilauea which was quite distinct on July 30 did not continue. The only perceptible quake recorded during August (at 03:04, August 3) had a shallow origin under the northeast rift of Mauna Loa.

There was no accumulation of tilt in the east–west direction during the month. The north–south tilt curve shows an accumulation of northerly tilt greater than in 1946 or 1947. This may be taken as an indication of a slight pressure build up under Kilauea.

September

The majority of the 30 earthquakes recorded during September originated under Mauna Loa. Twenty-one of the shakes were recorded at Kilauea and 26 at Mauna Loa. The strongest of these shakes occurred at 8:20 a.m., September 13. It originated at a depth of 20–25 miles below the surface between Hilo and Mauna Kea.

The north–northeast tilt during the month of September was about normal for this season of the year.

SEISMOLOGY

Earthquake Data, July–September 1948

Week Ended	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
July 4	4	2	0	1	0	4.00	0
11	0	0	0	0	0	0	0
18	2	2	0	0	0	1.00	3
25	0	1	1	0	0	1.50	2
August							
1	3	1	1	3	2	13.25	0
8	1	3	0	0	1	4.75	0
15	1	0	0	0	0	0.25	0
22	0	0	0	0	0	0	0
29	2	2	0	0	0	1.50	0
September							
5	1	3	1	0	0	2.75	0
12	3	0	1	0	0	1.75	2
19	0	2	0	1	1	6.00	0
26	4	0	1	0	0	2.00	0

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

70. July 3, 18:14, very feeble, Mauna Loa.
71. July 12, 0:29, very feeble. Felt at Naalehu.
72. July 17, 6:11, very feeble. Felt at Naalehu.
73. July 19, 10:08, very feeble. Kilauea.
74. July 24, 13:19, feeble. Felt locally and at Hilo. Mauna Loa.
75. July 30, 2:28, moderate. Awakened some people. East of Kilauea Caldera.
76. July 30, 2:31, moderate. Same location as No. 75.
77. July 30, 2:44, slight. Same location as No. 75.
78. July 30, 12:28, feeble. Same location as No. 75.
79. July 30, 16:46, slight. Same location as No. 75.
80. July 30, 16:56, slight. Same location as No. 75.
81. August 1, 8:59, very feeble.
82. August 3, 3:04, moderate. Felt locally and at Hilo. NE rift of Mauna Loa.
83. August 4, 15:59, very feeble. Kilauea.
84. August 6, 14:23, very feeble. NE rift of Mauna Loa.
85. August 8, 5:14, very feeble. Felt locally. Mauna Loa.
86. August 10, 6:38, very feeble. Mauna Loa.
87. August 29, 17:48, very feeble. Mauna Loa.
88. August 29, 17:49, very feeble.
89. September 3, 20:31, very feeble.
90. September 4, 7:36, very feeble. Near Mokuaweoweo.
91. September 5, 8:01, feeble. Felt locally and at Hilo. NE rift of Mauna Loa.
92. September 5, 8:52, very feeble. Mauna Loa.
93. September 7, 11:05, feeble. Felt locally. Mauna Loa.
94. September 13, 8:20, moderate. Generally felt on east half of island. 20–25 miles deep, SE of Mauna Kea.
95. September 15, 9:45, slight. Near Mokuaweoweo.
96. September 18, 22:23, very feeble. Mauna Loa.
97. September 19, 14:51, very feeble. Mauna Loa.
98. September 21, 18:44, feeble. Mauna Loa.
99. September 28, 3:53, very feeble. Mauna Loa.

TELESEISMS

July 14, 12:48, slight. Near New Guinea.
July 15, 1:12, slight. Off coast of Mexico.
July 15, 20:30, slight.
July 22, 10:22, slight. Off west coast of Vancouver Island.
July 22, 11:10, slight.
September 8, 5:17, slight. Near Tonga.

MICROSEISMS

Microseisms were moderate during the latter half of September and slight on other days.

CRACK MEASUREMENTS

The cracks measured in the vicinity of Halemaumau rim were either stationary or opened only slightly.

TILTING OF THE GROUND

Easterly tilt was unusually slight but nearly continuous throughout the quarter. Northerly tilt was continuous and a little greater than in the past two years.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended		Amount	Direction
July	4	0.2″	S 45° E
	11	1.2″	N 30° E
	18	0.4″	W
	25	1.0″	N 7° W
August	1	1.2″	N 53° E
	8	0.3″	N 26° E
	15	1.0″	N 30° W
	22	0.6″	N 12° E
	29	0.7″	N 45° E
September	5	1.3″	N 57° W
	12	0.6″	N 37° E
	19	0.5″	N 14° E
	26	1.4″	N 48° E

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THE VOLCANO LETTER

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UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist



FLOW-PUMICE ON HAWAIIAN BASALTS

By R. H. FINCH, HOWARD A. POWERS, and GORDON A. MACDONALD

U. S. Geological Survey

Mauna Loa is a large, elongate shield volcano, built of lava flows of primitive olivine basalt to an altitude exceeding 13,600 feet above sea level and 30,000 feet above the ocean floor. Most eruptions take place from fissures in two rift zones which meet in a summit caldera. All known eruptions have started in the summit region. In some, activity is confined to the summit; in others, after brief summit action, the main eruption breaks through fissures in the flank of the mountain. In historic time, Mauna Loa has not established and maintained a lake of fluid lava comparable to the lake which has been typical of much of the historic activity of Kilauea.

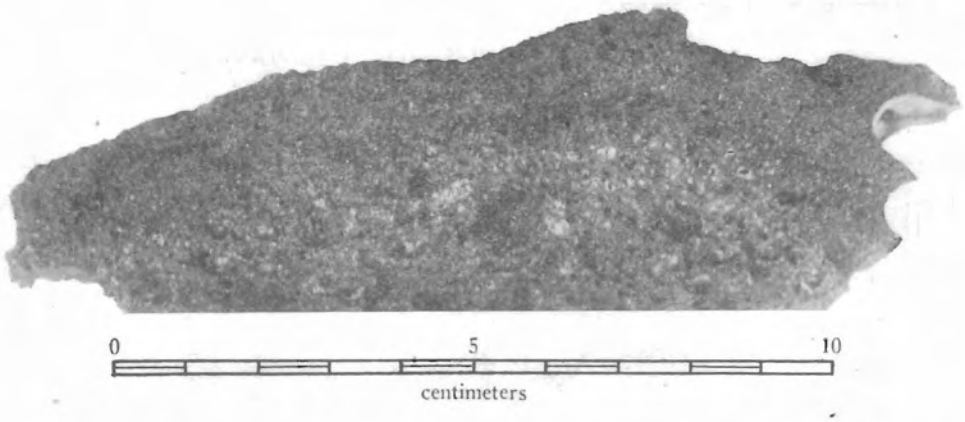
Cones of pyroclastic material have been built around Mauna Loa vents where lava fountaining has persisted for more than a few hours. Most cones contain much pumice. In addition, a skin of pumice is found on thin, short flows adjacent to eruptive fissures both in the summit area and along the rift zones. The material has previously been observed[1] and studied[2] but without regard to the process of formation.

The flow pumice, as much as an inch in thickness, is composed of basaltic glass, drawn out into thin vesicle walls, which are brown in color. Most of the vesicles are small, and only slightly elongated in the direction of flow of the lava. A few much larger elongated cavities are scattered through the pumice skin. A cube of the flow-pumice chosen to contain the least possible number of larger gas cavities has a gross density of about 0.6; the density of the glass is about 2.7. Thus, the porosity of the pumice due to gas inflation is about 75 percent. The pumice grades abruptly into a layer of vesicular black glass in which the vesicle walls are thicker and the vesicles are larger and less numerous. The layer of black glass grades into the grossly vesicular, partly crystallized rock which forms the bulk of each flow layer of lava. In this inner part, the gas cavities are so large that gross density determination is impractical; but by inspection, the gross porosity of the interior is of the same order of magnitude as that of the surface pumice.

Several details of the field occurrence of the pumice aid in interpreting the process of its formation. At the margin of many of the pumice-covered flows, the last ooze of liquid which formed the toe of the flow was quenched at its exposed surface into vesicular black glass rather than into true brown pumice. Elsewhere, the pumice-covered crust had cracked in places, allowing interior fluid to ooze upward through the cracks. Surface quenching of this residual liquid also produced the vesicular black glass rather than brown pumice. It is apparent in the field that the emplacement of these pumice-covered flows was completed in but a few minutes. During this short time, the liquid of the interior

[1] GREEN, W. L. VESTIGES OF THE MOLTEN GLOBE. Part 2, 281–282. Honolulu, 1887.

[2] MACDONALD, G. A. PETROGRAPHY OF THE ISLAND OF HAWAII. U. S. Geol. Sur. Professional Paper 214-D. In press.



Specimen of pumice-surfaced lava collected from the 1942 summit flow of Mauna Loa. The pumice is brown, nearly ½ inch in thickness, and grades abruptly into black vesicular glass. Photo by V. R. Bender, National Park Service.

part of the flow, insulated by the skin of pumice, lost enough of its dissolved volatile component but retained enough heat so that oozes of it which reached the air were quenched as black glass. In many other places, only small patches of the pumice-surfaced flows remain exposed because they have been buried by gushes of less gas-rich lava extruded later in the same eruption. These later gushes have congealed with the more common skin of black glass.

Pumice-covered pahoehoe from the 1942 summit activity is exposed throughout an area of about a quarter of a square mile; in an equally large area it is now buried. Lava flows extruded from nearly 4 miles of open fissure during less than 10 hours of eruption cover a total area of 3⅓ square miles. Flows distant from the fissure have an aa surface; the flows near the fissure have a pahoehoe surface. The pumice-surfaced pahoehoe is restricted to gushes of lava which traveled less than a quarter of a mile from their vents. The main flow of 1942 issued from a fissure in the northeast rift zone at an altitude below 9,400 feet, and began about 24 hours after the summit activity had ceased. There is very little pumice-surfaced pahoehoe at this lower fissure, though pumice is plentiful in the pyroclastic cone which was built around the persistent lava fountains. Abundant pumice-surfaced lava is associated with some of the older flank fissure vents, but the pumice was clearly formed only on the earliest gushes of lava.

These occurrences of pumice contribute some data on the time and manner of escape of volatiles from basaltic magma in the Hawaiian volcanoes. Separation of some volatiles from the liquid must have taken place during its rise in the feeding dikes, because fountaining at the vents indicates bursting of gas bubbles, and many larger gas bubbles have left cavities in the pumice formed both at the fountains and on the pahoehoe flows. However, the formation of pumice among the pyroclastic products and as a skin on lava flows indicates that the liquid reached the surface with sufficient volatiles in solution to inflate it to four times in subsurface volume. The fact that pumice does not form on lava surfaces more than a few hundred yards in distance and a few minutes in time away from the point of emission suggests that the release of volatiles involved is nearly explosive in its rapidity and occurs as soon as the magma appears at the surface. Inherently, the great bulk of the congealed products of eruption can give evidence only of the fact that volatile constituents were present and did escape; evidence of the time and manner of this escape is found only in the small amount of material which was quenched as fountain product and as the surface phase of short flows very near the vents.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR OCTOBER–DECEMBER, 1948

VOLCANOLOGY

October

Forty-nine seismic disturbances were recorded at Mauna Loa and 44 at Kilauea. Nearly all of the 76 individual earthquakes were very weak. The majority originated either under Kilauea Caldera or along the northeast rift of Mauna Loa.

North–northeast tilting of the ground on the northeast rim of Kilauea continued at a rate normal for this season of the year.

Moderate amounts of sulphurous fume were observed in the summit crater of Mauna Loa on October 5 and 6.

November

Fifty-two seismic disturbances were recorded during the month. Though the numbers recorded at Kilauea and Mauna Loa were 44 and 38 respectively, the majority of the more distinct shakes originated under Mauna Loa.

The rapid easterly tilt that marked the first half of the month ceased on November 14, and there was no accumulation of tilt in the east–west direction during the last half. There was no accumulation of north–south tilt in November.

December

There was no visible activity at any Hawaiian volcano during 1948. Tilt and earthquake data indicate that there was also a lack of any appreciable subterranean activity.

Seventy-five local earthquakes were recorded during December. Seventy-two of these were recorded at Mauna Loa and 61 at Kilauea. A majority of the earthquakes were weak and originated on the northeast rift of Mauna Loa.

The seasonal change from easterly to westerly tilt occurred on December 2, and there was a slight accumulation of westerly tilt during the month. Seasonal northerly tilt continued until December 27, when normal southerly tilt set in. There was a slight accumulation of easterly tilt during 1948.

R.H.F.

SEISMOLOGY

Earthquake Data, October–December 1948

Week Ended		Tremor	Very Feeble	Feeble	Slight	Local Seismicity*	Teleseisms
October	3	3	1	0	0	1.25	0
	10	4	4	0	0	3.00	1
	17	14	0	0	0	3.50	0
	24	10	2	0	0	3.50	0
	31	8	1	0	0	2.50	0
November	7	5	0	0	0	1.25	0
	14	10	0	1	0	3.50	0
	21	11	1	0	0	3.25	0
	28	10	4	0	0	4.50	0
December	5	10	0	0	0	2.50	2
	12	14	2	1	0	5.50	0
	19	13	1	0	1	5.75	0
	26	10	3	0	0	4.00	0

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

100. October 7, 18:12, very feeble. Hualalai.
101. October 9, 00:53, very feeble. Mauna Loa.
102. October 9, 18:06, very feeble.
103. October 10, 12:06, very feeble. Mauna Loa.
104. October 18, 10:51, very feeble. NE rift Mauna Loa.
105. October 18, 17:30, very feeble. NE rift Mauna Loa.
106. October 27, 16:13, very feeble. Kilauea.
107. November 14, 03:28, feeble. NE rift Mauna Loa.
108. November 21, 09:33, very feeble.
109. November 23, 13:22, very feeble. Mauna Loa.
110. November 25, 09:55, very feeble.
111. November 28, 09:45, very feeble. Mauna Loa.
112. December 7, 20:22, very feeble. NE slope Mauna Loa.
113. December 9, 06:44, very feeble. Mauna Loa.
114. December 9, 15:05, feeble. Felt locally.
115. December 13, 07:35, slight. Mauna Loa. Record being changed.
116. December 18, 14:57, very feeble. NE rift Mauna Loa.
117. December 20, 09:01, very feeble. Mauna Loa.
118. December 23, 21:02, very feeble. Mauna Loa.
119. December 26, 03:30, very feeble.
120. December 28, 11:08, very feeble. East slope Mauna Loa.
121. December 28, 14:08, very feeble.
122. December 29, 19:58, very feeble.

TELESEISMS

October 5, 11:15, slight. Near northern Iran.
December 3, 14:32, slight. Off west coast of Mexico.
December 4, 14:01, slight. Southern California.
December 30, 14:00, slight.

MICROSEISMS

Microseisms were strong October 18–25 and November 1–12 and moderate during the rest of the quarter.

CRACK MEASUREMENTS

A few of the cracks near the Halemaumau rim showed a slight opening, though a majority of the cracks that were measured showed no appreciable movement.

TILTING OF THE GROUND

There was a rapid accumulation of easterly tilt from October 27 to November 14. The seasonal change to westerly tilt occurred on December 2. During the year of 1948 there was an accumulation of easterly tilt. Normal northerly tilt continued to December 27, when seasonal southerly tilt set in. Northerly and southerly tilt were about equal in 1948.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended		Amount	Direction
October	3	0.3″	S 27° W
	10	0.4″	N 20° E
	17	0.8″	N 19° E
	24	0.9″	N 34° W
	31	1.2″	N 50° E
November	7	0.6″	N 78° E
	14	4.5″	S 11° E
	21	0.4″	N 27° W
	28	0.7″	N 9° E
December	5	0.7″	N 59° E
	12	0.5″	N 63° W
	19	0.5″	S 78° W
	26	0.6″	N

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter**, a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

THE VOLCANO LETTER

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U. S. GEOLOGICAL SURVEY: R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

THE MAUNA LOA ERUPTION OF JANUARY, 1949

By GORDON A. MACDONALD and RUY H. FINCH

U. S. Geological Survey

HISTORY OF THE ERUPTION

Mauna Loa resumed eruptive activity on January 6, 1949, after a period of quiescence of 6 years and 8 months. The eruption, which was confined to the summit caldera, Mokuaweoweo, and to the uppermost part of the southwest rift zone, is to be classed as a summit eruption. Following the flank eruption of 1942 on the northeast rift, it thus continues the alternation of summit and flank eruptions which has existed since 1926.

At 4:15 p.m. on January 6 a dull rumbling was heard at the Hawaiian Volcano Observatory, apparently originating at the summit of Mauna Loa, 20 miles away. From the Observatory, the summit was hidden by a heavy cloud layer along the southeastern slope of the mountain; but from Hilo to Mountain View, on the eastern slope, the view of the summit was unobstructed. At about 4:00 p.m. B. F. Moomaw of the National Park Service saw, from the highway a short distance southeast of Olaa, a puff of fume rising from the summit. At about 3:45 or 3:50 p.m. Mrs. Walter Eklund observed fume at the summit of the mountain, from the highway in southern Kau. The registration of continuous tremor on the Bosch-Omori seismograph at Kilauea began at 3:47 p.m., indicating the movement of magma in the conduit at that time.

The precise time of beginning of the eruption thus is uncertain. It seems probable that some harmonic tremor may have preceded arrival of the magma at the surface, and therefore the probable time of beginning of surface lava activity may be placed between 3:50 and 4:15 p.m. The arrival of lava at the surface may have been preceded by an increase in the amount of fume being liberated at the summit of the mountain.

The heavy rumbling sounds, audible 20 miles away, indicate that some of the early bursts of gas liberation were of explosive violence. There is no known previous instance of such sounds, originating in summit activity of Mauna Loa, being audible at Kilauea. The audibility may have been partly the result of reflection from a high cloud layer which extended above the summit of Mauna Loa at the time. The strength of the early bursts is further indicated by the finding of pumice at 11,000 feet altitude on the northeastern flank of the mountain, 7 miles from the nearest lava fountains, and of Pele's hair at Kulani Camp, 20 miles east of the fountains.

The lava broke out along a fissure which extended south-southwesterly across the floor of Mokuaweoweo caldera from a point north of its center, up over the boundary cliff of the caldera, and about 1.7 miles down the southwestern flank of the mountain. The distribution of glow, as seen from the Volcano Observatory, indicated that lava fountaining was nearly, if not completely, continuous along this crack, a distance of about 3 miles. On the morning of January 7, D. H. Hubbard of the National Park Service observed the activity from the air and reported that two fountain areas were still active on the southwest rift. However, by the morning of January 9 aviators reported only fume along the fissures outside the caldera, except for very weak intermittent fountaining and short flows at one point. As is usual with summit eruptions of Mauna Loa, activity outside the caldera lasted only a relatively few hours. Within 24 hours it was largely over, and within 72 hours activity was entirely confined within the caldera.

The short-lived fountains, on the upper part of the southwest rift outside the crater, gave vent to a copious outpouring of lava during the first few hours of the eruption. This lava formed several short flows in addition to one long flow which moved rapidly westward just north of, and partly overlying, the lava flow of 1851. (See figure 1.) In its first 24 hours, this flow advanced about 6 miles. It was short-lived, however; with the dying of fountain activity outside the caldera the supply of lava was cut off, and by January 8 the flow appeared to be essentially dead. The lower end of the flow reached an altitude of about 8,500 feet, 6.5 miles from its source.

On the afternoon of January 7, lava fountain activity within the caldera itself had become restricted to two short lengths of the fissure. North of the 1940 cinder cone, near the middle of Mokuaweoweo, a nearly continuous line of fountains half a mile long played to an average height of about 50 feet with occasional bursts up to about 150 feet. As nearly as could be ascertained, these fountains were situated on or close to a zone of fuming fissures which had been observed by Macdonald and Powers in October 1948 (VOLCANO LETTER 502). From these fountains a small lava stream moved westward, forming a pond of lava between them and the western caldera wall; another larger flow was moving eastward.

The other active portion of the fissure was situated at and close to the base of the southwestern wall of the caldera. There a small fountain played intermittently from the fissure directly at the base of the wall, with occasional spurts from the fissure part way up the wall; a much larger and steadier fountain played a short distance out from the wall on the caldera floor. The larger fountain shot constantly to heights of 150 to 200 feet, with occasional bursts as high as 300 feet. The fountains at the southwestern edge of the caldera sent a flow northward into the caldera west of the 1940 cone joining the flow from the more northerly group of fountains, and another flow eastward. The flow to the east divided, sending one branch in the direction of South Pit and another northeastward along the base of the caldera wall. The latter branch joined the flow from the northern fountain-chain, leaving the 1940 cinder cone and part of its surrounding lava shield protruding as an island in the

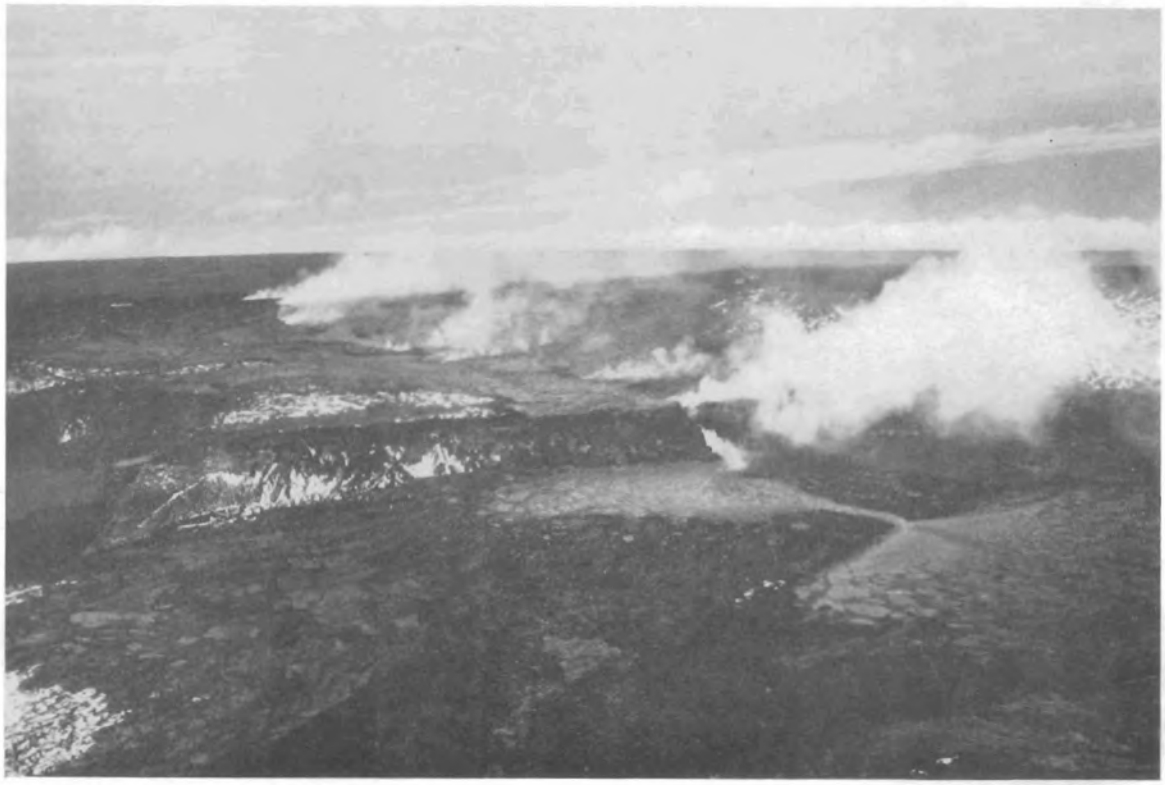

PLATE 1. Eruptive fissure extending up over the southwestern wall of Mokuaweoweo caldera and on down the southwest rift zone of Mauna Loa, on the morning of January 7, 1949. Large lava fountains are playing from the fissure at the base of the caldera wall, and smaller ones can be seen in the background along the southwest rift. In the foreground, new lava is pouring onto the caldera floor, and to the left into South Pit. OFFICIAL PHOTOGRAPH, U. S. NAVY.

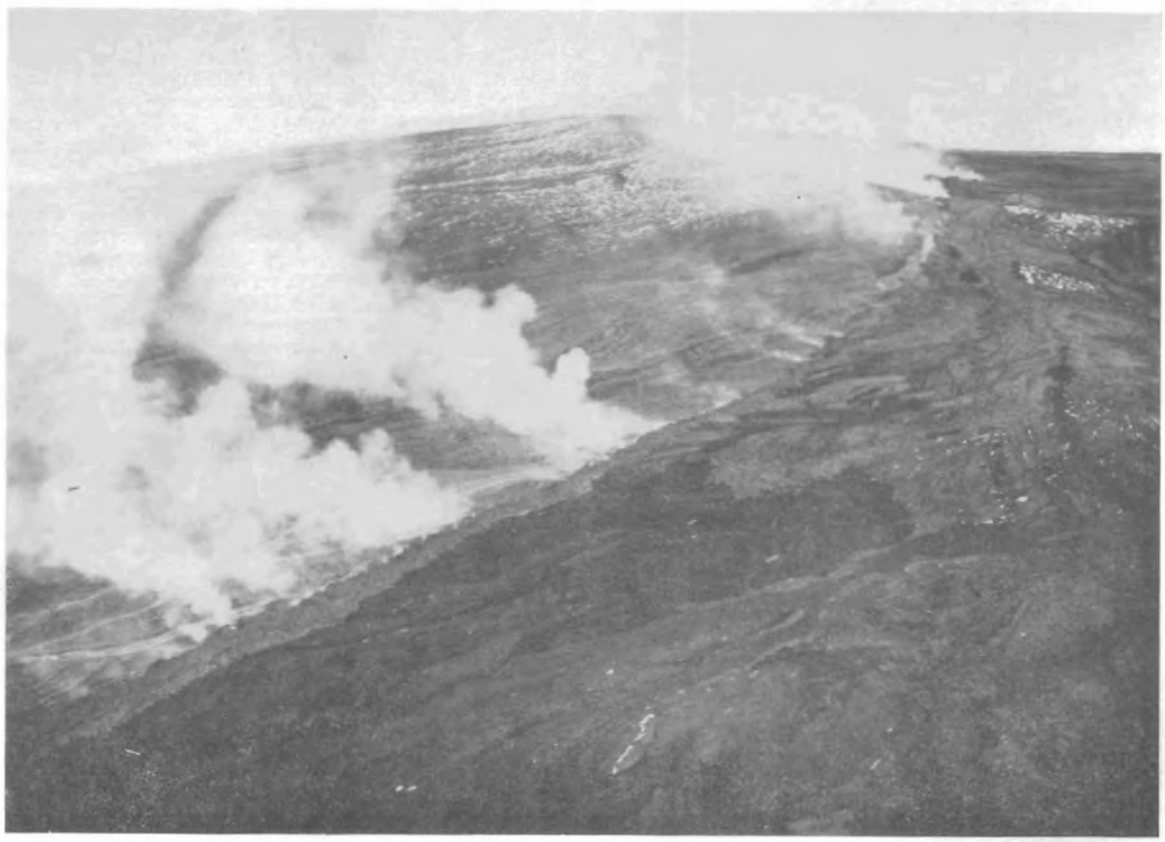

PLATE 2. Spatter rampart and small lava fountains along the fuming fissure on the upper part of the southwest rift zone on the morning of January 7, 1949. The upper part of the western lava flow is visible just left of the fissure. Mokuaweoweo caldera and the summit of Mauna Loa are in the background. OFFICIAL PHOTOGRAPH, U. S. NAVY.

new lava. The eruptive fissure split the 1940 cone and the cone was fuming strongly. During the earliest hours of the eruption a small amount of lava spilled from the fissure at the base of the cone, but by the morning of January 7 these flows were dead and had been partly buried by lava from the northern and southwestern fountains. By the afternoon of January 7 more than two-thirds of the caldera floor had been flooded with new lava, largely pahoehoe.

The fountain-chain near the center of Mokuaweoweo was as short-lived as the fountaining outside the caldera. At 2:00 p.m. on January 9 a Navy pilot reported that the fountains in the middle of the caldera had entirely stopped although the spatter rampart built by them was still fuming strongly. At that time, and for the next several days, reports from planes flying over the mountain indicated that the fountains at the base of the southwest wall were continuous but were varying greatly in the strength of their activity. Lava from them continued to pour both into the caldera and into South Pit. Fountain activity was building a cinder cone against the caldera wall.

For a week or more the southwestern fountains appear to have remained of small, although variable, size. After that, however, they greatly increased in height, ultimately becoming what may have been the highest fountains yet observed on Mauna Loa. On January 19, a United Airlines pilot reported two large fountains, 400 to 500 feet high. On January 21, Frank Hjort and James Orr of the National Park Service reported two fountains, one shooting from the fissure in the lower part of the caldera wall, and the other on the caldera floor about 100 feet from the wall. The fountains were building a compound cinder and pumice cone. The wall-fountain was the smaller of the two. The larger fountain they estimated to be 300 to 500 feet high. On January 23, Orr and D. H. Hubbard estimated the height of the large fountain to be well over 500 feet with some of the higher bursts possibly reaching more than 800 feet. These very high fountains, together with strong shifting winds, resulted in wide distribution of Pele's hair over the southern part of the island, from Napoopoo on the western coast, 21 miles from the summit of Mauna Loa, to the Kau Desert and Kilauea caldera, an equal distance southeast of the summit. The high fountains produced an exceptionally large amount of pumice. The accumulation of this pyroclastic pumice around the vent built up a pumice cone which was banked against the caldera wall and eventually overtopped it, projecting approximately 100 feet above the old rim of the caldera at that point, and resting partly on the outer slope of the mountain. (See figure 2.) West of the cone a blanket of pumice covers an area about a mile long and half a mile wide and attains a depth of as much as 20 feet near the base of the cone.

Hjort and Orr report that on the night of January 21 the two fountains were inclined somewhat toward the east and that most of the ejecta fell into a pool of lava at the eastern, breached side of the cone. Thence the lava moved eastward in a pahoehoe river about 75 feet wide, spreading into aa flows about half a mile from the vent. During the afternoon and evening there was no evidence of lava moving into South Pit. At 3:00 a.m. on January 22 there occurred a moderate earthquake, which apparently broke the rim of the pool at the east base of the cone and allowed two new flows of aa to pour into South Pit. At that time most of the early floods of pahoehoe on the caldera floor had been buried by later flows of aa. The South Lunate Platform, which in 1914 formed a conspicuous crescentic bench at the southern end of the caldera, had been almost wholly buried by new flows. Its north-facing escarpment, now totally obliterated, had been progressively lessened in height by infilling of the inner pit of the caldera in 1933 and 1940.

On January 23, Orr reports, the fountains were pulsating, the wall-fountain with a period of about 3 seconds and the larger fountain with a period of about 1 second. The temperature of the wall-fountain appeared to be a little higher than that of the larger fountain.

The lava fountaining was accompanied by the liberation of huge volumes of fume, smelling strongly of sulfur dioxide. On January 26 the pale brown fume cloud could be seen extending at least 30 miles southwest of the summit of the mountain. On February 1 and 2 sulfurous fume was noticed by residents from North Kona to Waimea, 40 miles north of the summit of the mountain.

The lava pouring into South Pit gradually filled it to the point of overflow. On January 25 Ercell Hart of the Hawaiian School of Aeronautics reported that the lava fill had reached the level of the low southeastern rim of the pit; late on the same day the pit overflowed. The lava stream moved southeasterly, and by the evening of the 26th it had attained a length of about 2 miles from South Pit, or 3 miles from its source at the fountains. On the morning of January 27 the flow was moving in three branches, and by the evening of that day the longest of these had reached a point about 3.2 miles from South Pit. Thereafter the speed of advance of the flow greatly decreased, and on the evening of January 28 transit angles from the Volcano Observatory indicated that it had advanced only about 0.2 mile in the preceding 24 hours. By the evening of January 31 the flow-front had reached a distance of about 4 miles from South Pit, but after that day it advanced very little.

On January 29 or 30 a new branch of the flow broke out near South Pit, and this new branch appears to have robbed the older one of its supply of lava. The new stream advanced downslope just east of the older one and partly overlapping it. It moved more slowly than the earlier flow and eventually attained a length of only 2 miles from South Pit. On the morning of February 7 it was still advancing very slowly. Its advance probably ended on February 8, two days after the cessation of lava fountaining at the vent. On February 7 a small amount of movement was still visible in the older flow also. This continuation of movement of the flows after the end of lava extrusion at the vent probably resulted from draining of the still-fluid lava from the feeding tubes in the flows on the upper slopes of the mountain.

During the night of February 4 the fountain activity at the southwestern edge of the caldera was still moderately strong, producing a pronounced glow on the rising fume column. By mid-morning on February 5, however, fountain activity had become very weak and irregular, only occasional small bursts of liquid lava spray being visible in the cone. Lava was moving underground through a tube almost to the wall of South Pit. There it issued in a small amphitheatral depression in slightly older 1949 aa, flowed as a pahoehoe stream to the edge of South Pit, cascaded down the wall, and spread slowly over the floor of the pit as a sluggish aa flow. The speed of movement of the liquid lava in the cascade was estimated to be generally about 10 miles an hour, reaching about 15 to 20 miles an hour in a short steep portion of the descent. On the floor of South Pit the aa flow was spreading at a rate of only a few feet an hour. About 2:00 p.m. a sudden increase in lava liberation greatly augmented the volume of the cascade and caused a brief rapid spreading of aa tongues in South Pit. Within half an hour the voluminous burst of lava was over, and by 5:00 p.m. there was no further evidence of movement of lava down the cascade into South Pit. The flows on the caldera floor also appeared to be lifeless except for many small secondary fumaroles. On the morning of February 6 the cinder cone at the southwestern edge of the caldera was visited; no further signs of activity could be detected, other than slight glow in the fountain pits and voluminous liberation of SO_2-rich fume. Even on its outer slopes, the cone was still red-hot only a few inches beneath the surface. The lava-pool and flow-channel east of the cone had been completely drained, and collapse had exposed the end of the empty lava-tube leading toward South Pit. Thus this phase of the eruption came to an end on the afternoon of February 5, having lasted just 30 days.

From February 6 to the date of writing (March 22) fume frequently has been visible at the mountain top. On several nights observers at scattered points on the southern part of the island have also reported a distinct glow at the summit. This glow may have resulted from brief weak resumptions of lava fountaining or quiet outwelling of lava, or possibly from slumping of portions of the hot cinder cone or of the cascade into South Pit, exposing glowing material. However, at no time when observers were actually present at the summit or flying over it in planes could any glow or lava movement be seen.

THE CONE

During the early hours of the eruption the "curtain of fire" which issued along the upper part of the southwest rift zone outside of the caldera built a long row of spatter ramparts and small spatter cones. These ranged up to about 20 feet in height, but were mostly less than 5 feet. A similar spatter rampart was built by the fountain-chain in the central part of the caldera.

The true cone building was restricted to the big, long-lived fountains at the southwestern edge of the caldera. The cone built there is one of the largest on Mauna Loa, rivaling in size that of the 1940 eruption. The big cone is built on a broad lava shield which overlies the former South Lunate Platform. The cone itself is compound. An outer cone, breached on the eastern side, consists largely of fine cinder and pumice and rests partly on the outer slope of the mountain and partly on the caldera floor and against the boundary cliff. (See figure 2.) The top of the outer cone is about 100 feet above the former rim

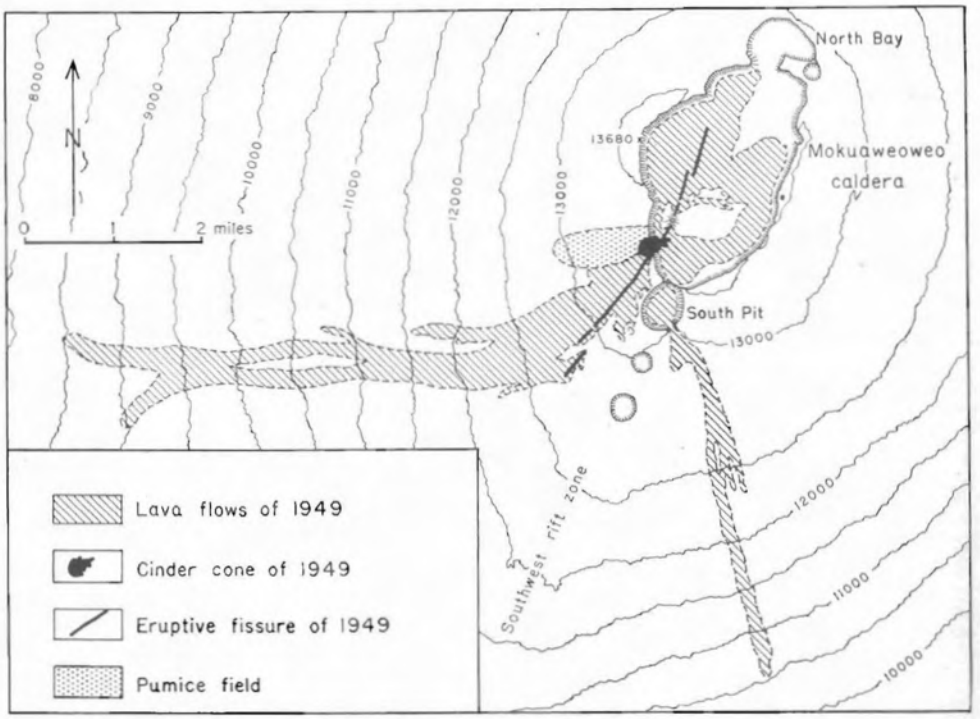

FIGURE 1. Map showing the approximate location of the 1949 lava flows and vents on Mauna Loa.

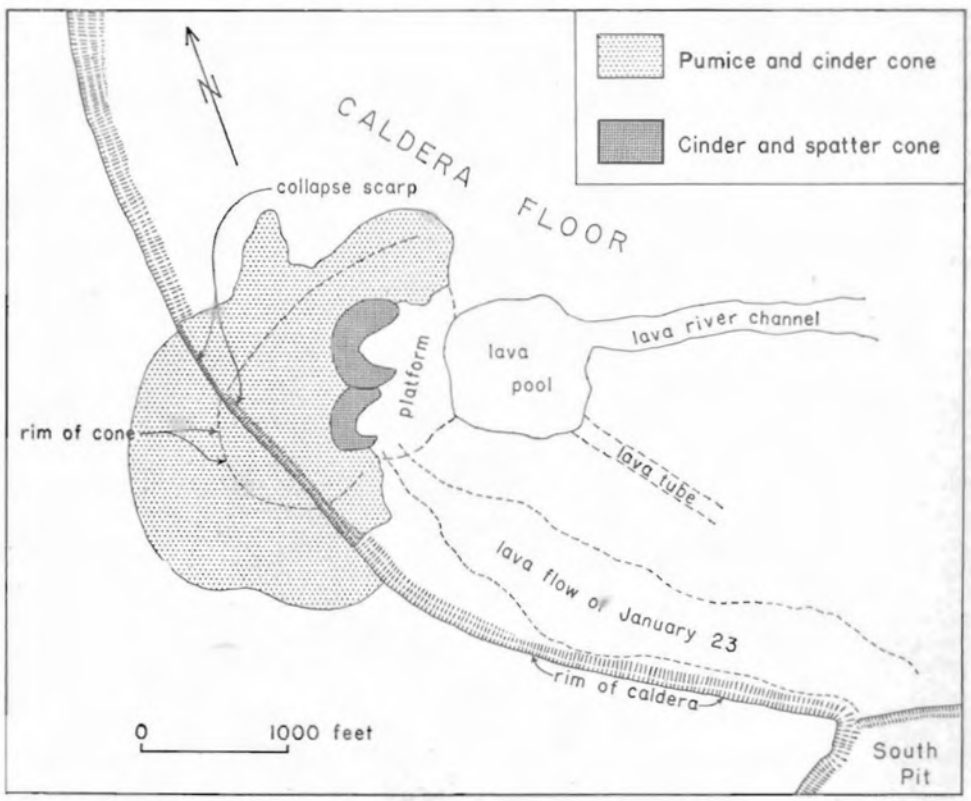

FIGURE 2. Sketch map of the cone area of the 1949 eruption.

of the caldera wall and 250 feet above the lava shield at its base. Its maximum diameter is about 1,500 feet. At the eastern edge of the large cone, and partly enclosed within it, is a small double cone of coarse cinder and spatter, built around the final sites of the two lava fountains. Each crater of the small cone also is breached on the eastern side. The inner cone probably was built during the stage of reduced gas pressure and lower fountains which directly preceded the end of the eruption. This decrease in gas content of the lava in the declining stage also resulted in the deposition of a few rather dense black "pancake" and ribbon bombs on the surface of the pale brown pumice on the southern slope of the outer cone.

The thick accumulation of ejecta against the boundary cliff of the caldera appears to have caused the northeastward migration of the smaller of the two cone-building lava fountains. On January 23, when the cone was visited by Orr and Hubbard, the fountain was situated directly against the caldera wall. By the end of the eruption, however, it had moved outward to the southernmost of the two small cinder and spatter cones, about 150 feet northeast of the base of the wall.

Lava escaping from the cone formed a pool on the lava shield just east of the cone, then drained eastward through an open lava river channel, and southeastward through tubes toward South Pit. At the end of the eruption the lava pool was drained

and its walls collapsed, exposing the mouth of a large lava tube, about 35 feet high, leading toward South Pit. (See figure 2.) The large cinder and pumice cone also partly collapsed, producing a northeast-facing scarp 10 to 15 feet high across the top of the cone. The position of the scarp was governed by the underlying caldera wall. Slumping also produced minor scarps on the outer slope of the cone.

THE LAVAS

The early lava flows in Mokuaweoweo caldera were almost entirely pahoehoe, but as the eruption progressed these were largely covered by later flows of aa. The depth of the fill in Mokuaweoweo is difficult to estimate, but probably averages about 20 feet.

The lavas erupted along the upper part of the southwest rift are pahoehoe near the vents, but as the flows moved downslope they gradually changed to aa. The average thickness of the aa in the lower part of the flow is probably about 10 to 12 feet. Near the vents the pahoehoe flows are very thin, averaging from 2 to 3 feet thick. The flows near the vents were very rich in gas and produced typical shelly pahoehoe with many open tubes and blisters covered by a crust only a few inches thick. The surface of much of this pahoehoe is a thin shell of brown pumice, similar to that formed on many pahoehoe flows in the summit region of Mauna Loa. (See VOLCANO LETTER 502.) Downslope the pahoehoe becomes denser and less shelly.

The lava spilling into South Pit was partly pahoehoe and partly aa. In cascading over the cliff which separated South Pit from Mokuaweoweo some of the pahoehoe changed into aa, probably because of the intense stirring of the liquid and loss of gas. Many exotic blocks which tumbled down from the older lava flows exposed in the walls of the pit are recognizable in the aa. The depth of the fill in South Pit is about 50 feet. At the low gap in the rim of the pit, at its southeastern side, pahoehoe issued from beneath the aa. An arcuate ridge of aa, 10 to 15 feet high, marks the underlying buried wall of the pit. This ridge appears to have been pushed up by the pahoehoe which issued from beneath it.

Just southeast of South Pit the lava is pahoehoe, much denser and more massive than that of the earlier flow from the upper end of the southwest rift. The surface of the flow near South Pit is largely a very rough "shark-skin" type; over the major tubes it shows an accumulation of sublimated sulfur and some white sulfo-salts. On the surface of the pahoehoe near the zone where it issued from beneath the aa there was formed a series of minute, tensional fault scarps, up to 8 inches high, facing down-flow. On the faces of some of these scarps there is found a moderately good development of dendritic lava. Downslope the pahoehoe gives place to aa, and most of the southern flow is aa, averaging 10 to 15 feet thick.

The approximate area and volume of the 1949 lava and of each of its principal divisions are shown in table 1. The figures are not of great accuracy, and indicate only an order of magnitude. The total volume of the lava, 71 million cubic yards, is somewhat less than the volume of the lava of the 1940 and 1942 eruptions, each of which approximated 100 million cubic yards.

TABLE 1. AREA AND VOLUME OF 1949 LAVA

DIVISION OF THE FLOW	AREA (SQ. MILES)	VOLUME (CU. YARDS)
Mokuaweoweo	1.9	40,000,000
South Pit	0.2	8,000,000
Western flow	3.1	16,000,000
Southern flow	0.6	7,000,000
Total	5.8	71,000,000

Temperature measurements with an optical pyrometer were made on the glowing interior portion of a thick aa flow in South Pit on the afternoon of February 5. The glowing portion of the flow was well exposed in a large crack. Three observations were made, all yielding readings close to 760° C. This temperature is believed accurate within 50°. The flow was essentially motionless, but was still creeping a little.

Geiger counter observations were made by D. C. Cox on the hot lava in and close to South Pit on the afternoon of February 5. The number of clicks in the earphones ranged from 38 to 45 per minute. This is of the same order of magnitude as results obtained on the nearby lavas of prehistoric age and only slightly higher than those obtained by Mrs. B. J. Loucks on lavas of Kilauea volcano ranging in date from 1921 to prehistoric. The results are of the order of magnitude to be expected from cosmic radiation, and may have been caused by that alone. Dental X-ray films were mounted on a rock monument at the summit rest-house, 1.5 miles from the lava fountains, and exposed to

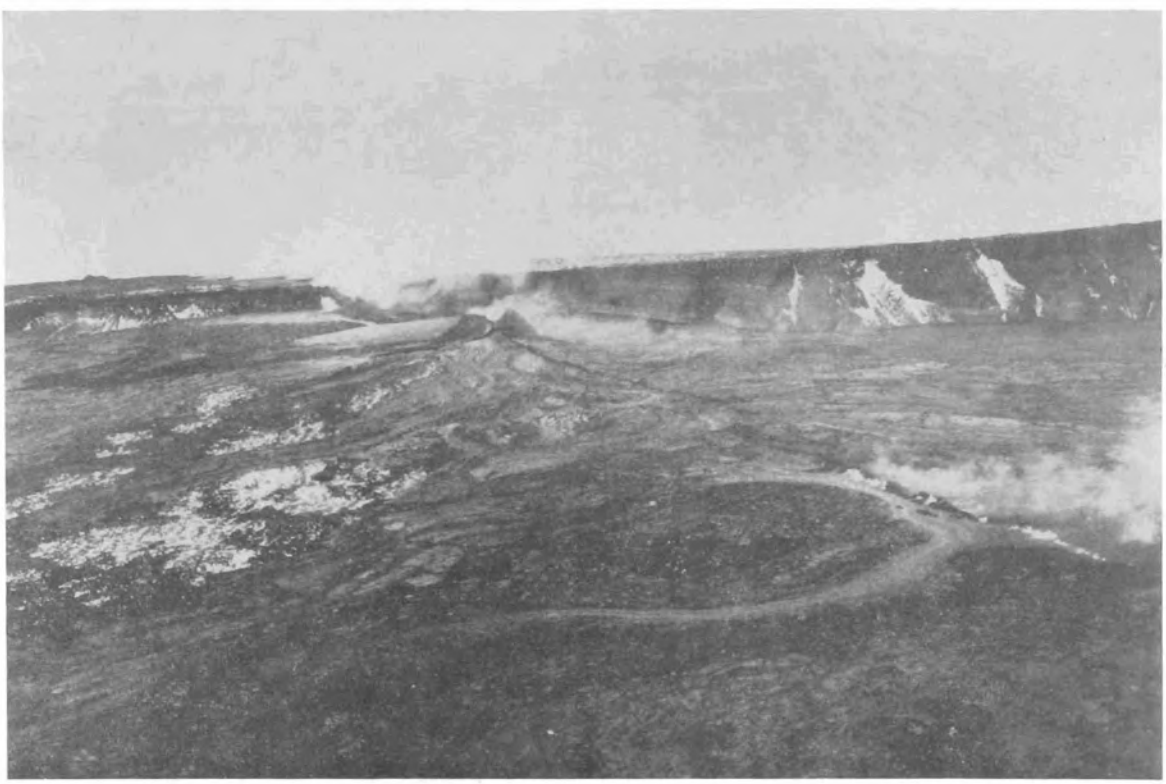

PLATE 3. Mokuaweoweo caldera, looking southwestward on the morning of January 7, 1949. In the right foreground is the northern fountain-chain and the lava flow leading eastward from it. In the middle distance the fissure can be seen cutting through the 1940 cinder cone, which is fuming strongly. OFFICIAL PHOTOGRAPH, U. S. NAVY.

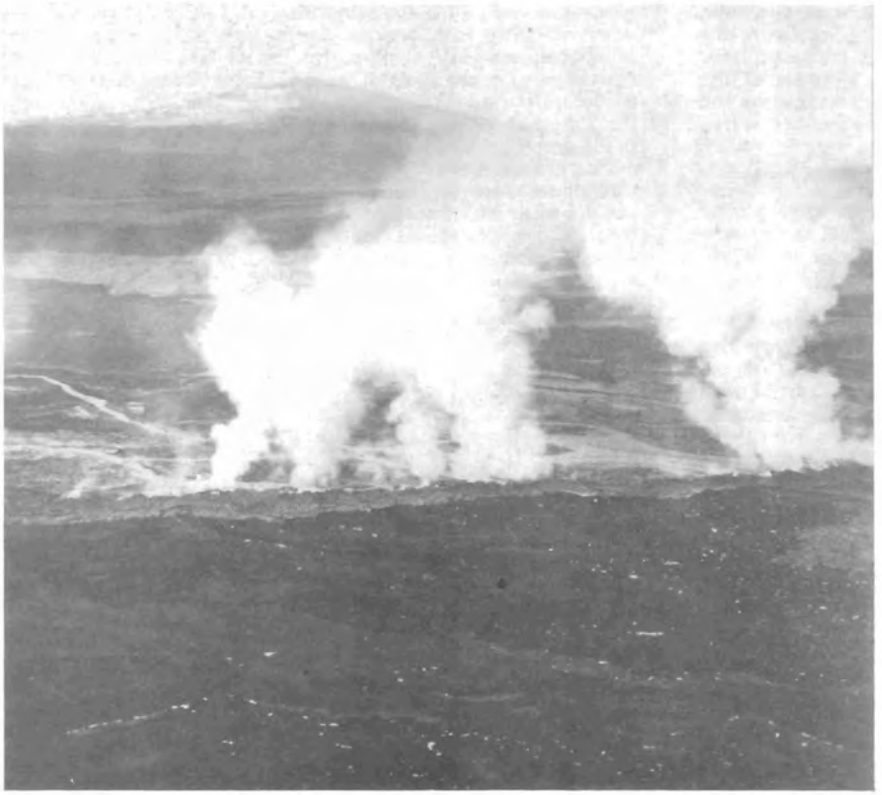

PLATE 4. Lava fountains and upper end of the western flow along the upper part of the southwest rift zone on the morning of January 7, 1949. The spatter rampart and the main lava rivers of the flow are clearly visible. Hualalai volcano is in the background. OFFICIAL PHOTOGRAPH, U. S. NAVY.

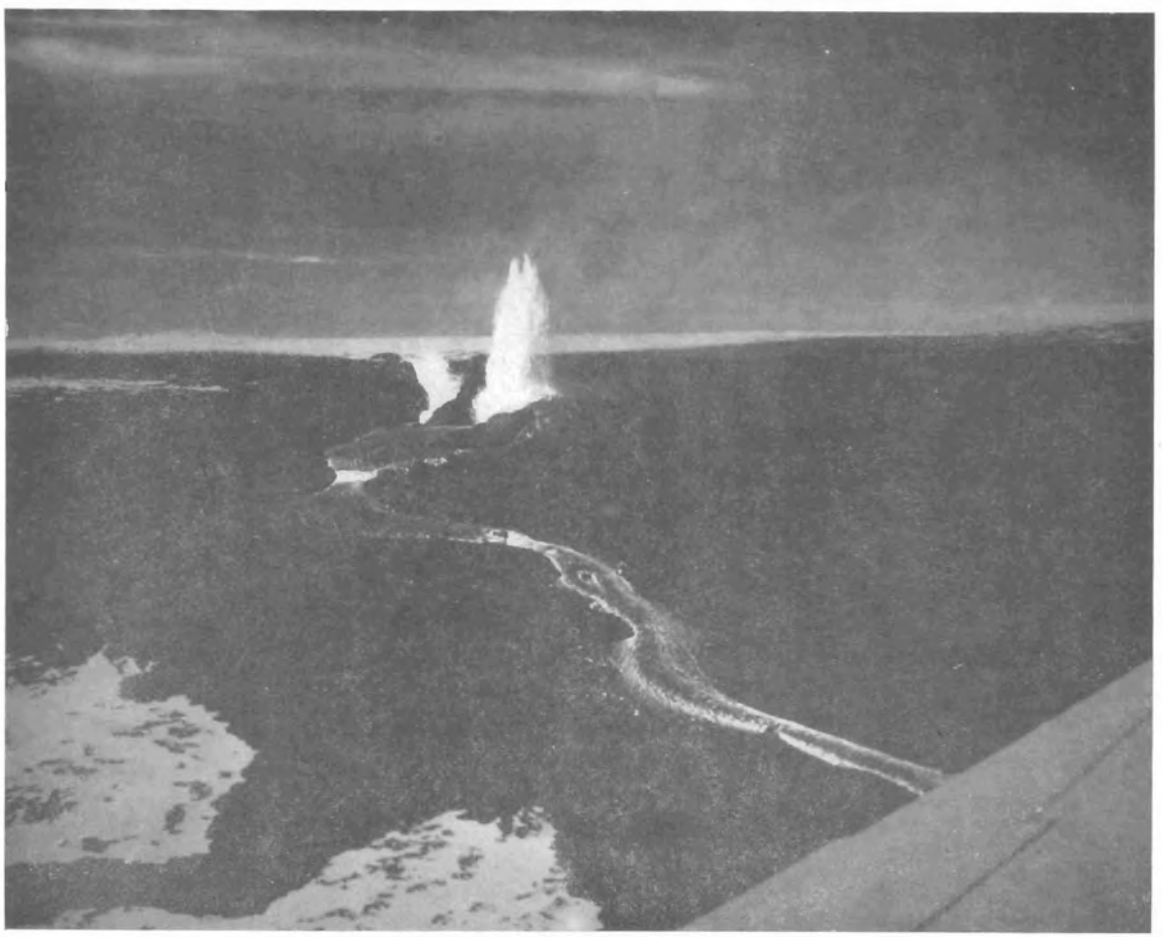

PLATE 5. Lava fountains and flow at the southwestern edge of Mokuaweoweo caldera on the evening of January 19, 1949. The smaller fountain on the left is the wall fountain. The larger fountain is about 500 feet high. PHOTOGRAPH BY K. OTAKI, ACE PORTRAIT STUDIO.

radiation from the fountains for a period of 12 days, from January 24 to February 5. These films showed practically no fogging. Samples of the early lava from Mokuaweoweo and pumice from the fountains were tested for radioactivity by Dr. Harvey White of the University of California, but no radioactivity was found.

PETROGRAPHY

The 1949 lava is a basalt containing approximately 3 per cent olivine. The rock of the more massive central portions of the southern flow, both aa and pahoehoe, is essentially crystalline, containing only a small amount of glass. It consists largely of labradorite and pigeonite (optic angle very small), with less abundant iron ore, olivine, and dark brown, interstitial glass. A roughly stellate arrangement of the feldspar microlites is present in some thin sections. A few of the olivine grains have the dimensions of phenocrysts, with lengths up to 2 mm., but the texture is seriate rather than truly porphyritic.

The rock of the upper portions of the western flow contains a larger proportion of glass, but is otherwise similar to that of the southern flow. The glass of the pumice from the fountains has a refractive index of 1.597 (± .003).

EARTHQUAKES AND GROUND TILT ASSOCIATED WITH THE ERUPTION

No distinct earthquake pattern preceded the 1949 outbreak of Mauna Loa. However, the number of earthquakes recorded in December on the Mauna Loa seismograph, at an altitude of 6,600 feet about 13 miles from the northern end of Mokuaweoweo, greatly exceeded those recorded in any of the preceding 5 months. (See table 2.)

TABLE 2. EARTHQUAKES RECORDED ON MAUNA LOA SEISMOGRAPH DURING 1948

MONTH	NUMBER OF EARTHQUAKES
December	72
November	38
October	47
September	26
August	23
July	37

Most of the quakes during December were tremors with shallow foci. Although a few of them originated under Mokuaweoweo, most of those whose origins were determined originated under the east slope of Mauna Loa or on the northeast rift. The strongest earthquake immediately preceding the eruption occurred on December 13. Its origin was at a shallow focus under the northeast rift about 2 miles from Mokuaweoweo.

Of the approximately 60 earthquakes recorded on the Mauna Loa seismograph in January 1949, 16 occurred on January 6, the day the eruption started. The number of shakes accompanying the outbreak of this summit eruption was less than during flank eruptions. This is to be expected because of the shorter distance of fissuring. During flank eruptions fissuring extends across the summit and also occurs far down the flank, whereas in summit eruptions it is restricted to the summit region. One of the strongest shakes during the eruption occurred at 3:59 p.m. on January 6 at about the time of commencement of surface activity. Its origin appears to have been at a depth of about 5 miles, approximately 2 miles northeast of Mokuaweoweo. If, as seems probable, this quake occurred at the time the fissure across Mokuaweoweo and a little way down the southwest rift was opened, the initial movement must have been at the northeastern end of the fissure.

Continuous harmonic tremor commenced on the Bosch-Omori seismograph at the northern rim of Kilauea caldera, 21 miles from the scene of eruption, at 3:47 p.m. on January 6 and ceased to be apparent at 3:00 a.m. on January 7.

During the year 1948 there was an accumulation of easterly ground-tilt at the northern rim of Kilauea caldera. The eastward tilting was especially strong during the first half of November. Records of several eruptions of Mauna Loa seem to indicate that easterly tilt is an evidence of increase of pressure under that mountain. Despite the easterly tilt and the fact that the average interval between Mauna Loa eruptions (about 4 years) had already been exceeded by more than 2 years, the earthquake pattern did not seem positive enough to justify a prediction of impending activity.

ACKNOWLEDGMENTS

We wish to express our thanks to all those many persons who have contributed information or otherwise aided in the study of the eruption. Deserving of special mention are: Superintendent Frank R. Oberhansley and Chief Ranger Frank A. Hjort of Hawaii National Park, who greatly aided us by the loan of riding horses and packing equipment up the mountain; Ranger James B. Orr, who kindly permitted the use of his field notes on the eruption; Naturalist Douglass H. Hubbard and Ranger V. R. Bender, who contributed ground and air observations; Pilot Ercell Hart, of the Hawaiian School of Aeronautics, who made repeated reports on the progress of the eruption; Harry M. Blickhahn, editor of the Hilo Tribune-Herald, who promptly passed on to the Volcano Observatory the information which came to him; Doak C. Cox, geologist for the Hawaiian Sugar Planters' Association Experiment Station, who operated the Geiger counter at the summit of the mountain; and Dr. Harvey E. White of the University of California Physics Department, who made radioactive determinations on several lava specimens.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JANUARY–MARCH, 1949

VOLCANOLOGY

January

An eruption of Mauna Loa started on January 6 and continued through the rest of the month. History and a lack of a definite earthquake pattern had led members of the Observatory staff to believe that the next eruption would be at the summit. There was but little positive data upon which to forecast an impending eruption, however. A strong easterly tilt of seven seconds of arc near the northern end of Kilauea Caldera in November 1948 was but little greater than similar tilts in 1946 and 1947. Such a tilt could be taken only as a suggestion and not as a good indication of a pressure increase under Mauna Loa that might lead to surface activity. The November tilt and the distinct blue fumes observed in Mokuaweoweo during October 1948 do give some indications that lava was rising in Mauna Loa 3 months prior to its appearance at the surface.

Sixty-seven earthquakes were recorded during the month. Fifty-eight shakes were recorded at Kilauea and 51 at Mauna Loa. The Mauna Loa total is incomplete because the seismograph was dismantled by earthquakes on two occasions. The records of at least eight shakes were lost.

Strong southerly tilt continued throughout the month. Easterly tilt continued until January 16 and then westerly tilt a little stronger than normal set in.

February

The Mouna Loa eruption, except for fuming, came to an end on February 5.

Sixty-four earthquakes were recorded during the month. Of these 47 were recorded at Kilauea and 52 at Mauna Loa.

Strong southerly tilt was continuous in February except for distinct northerly tilt accompanying the strong earthquake on February 26. Normal easterly tilt continued throughout the month.

March

Fuming from Mokuaweoweo was continuous throughout the month.

Thirty-one earthquakes were recorded in March. Thirty of the shakes were recorded on the Mauna Loa seismograph and 16 at Kilauea.

Northerly tilt set in March 6 and continued through the end of the month. Westerly tilt was about normal for March.

CRACK MEASUREMENTS

A few of the cracks near the east rim of Halemaumau opened slightly. The other cracks that were measured showed no appreciable movement.

SEISMOLOGY

Earthquake Data, January–March 1949

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
January	2	6	3	0	0	0	0	2.50	0
	9	17	2	0	1	0	0	7.25	0
	16	5	0	0	2	0	0	5.25	0
	23	5	1	1	0	0	0	2.75	0
	30	13	3	1	0	3	0	14.75	0
February	6	5	1	0	0	0	0	1.75	0
	13	1	1	0	0	0	0	0.75	0
	20	6	8	2	0	0	0	5.50	1
	27	12	3	2	0	0	1	10.50	0
March	6	0	3	2	1	0	0	5.50	0
	13	4	1	0	0	0	0	1.50	0
	20	1	0	0	0	0	0	0.25	0
	27	3	1	0	0	0	0	1.25	1

* For definition of local seismicity, see Volcano Letter 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

1. January 4, 20:20, very feeble.
2. January 6, 15:59, moderate. Near Mokuaweoweo.
3. January 7, 03:10, very feeble.
4. January 8, 00:49, moderate. 10–15 miles deep under Alae Crater area.
5. January 15, 00:40, moderate. 20–25 miles deep above Wood Valley.
6. January 15, 11:16, slight. Under ocean west of Kohala.
7. January 16, 14:30, slight. 9 miles deep. Kau Desert near Kilauea.
8. January 20, 14:27, very feeble. Deep. 10 miles southwest of Waimea.
9. January 20, 18:09, feeble. Northeast rift Mauna Loa.
10. January 26, 13:06, feeble. Deep. 10 miles southwest of Waimea.
11. January 26, 11:45, very feeble. Deep under east slope of Mauna Loa.
12. January 26, 23:57, moderate. 5 miles deep near Ohaikea.
13. January 27, 00:04, slight. 6 miles deep, east slope of Mauna Loa.
14. January 27, 00:16, very feeble.
15. January 28, 15:50, moderate, E-W dismantled. 5 miles deep, east slope of Mauna Loa.
16. January 28, 19:45, moderate, E-W dismantled. 8 miles deep, east slope of Mauna Loa.
17. January 29, 03:29, very feeble. East slope, Mauna Loa.
18. February 4, 22:16, very feeble.
19. February 7, 18:08, very feeble. Mauna Loa.
20. February 17, 07:33, very feeble.
21. February 19, 01:13, feeble.
22. February 19, 04:34, very feeble.
23. February 19, 12:04, very feeble.
24. February 19, 14:47, very feeble.
25. February 19, 17:06, very feeble. Kilauea.
26. February 20, 08:45, very feeble. Mauna Loa.
27. February 20, 09:32, very feeble. Mauna Loa.
28. February 20, 09:46, very feeble.
29. February 20, 21:16, feeble. Kilauea.
30. February 21, 16:22, very feeble.
31. February 22, 04:48, feeble. Kilauea.
32. February 23, 23:55, very feeble.
33. February 24, 01:02, very feeble.
34. February 26, 13:20, very feeble. Felt at Kapapala.
35. February 26, 13:54, strong. Instruments dismantled. Strongly felt from Hilo to Naalehu. Shallow focus, northeast rift Mauna Loa at 7,000 feet.
36. February 27, 05:13, very feeble.
37. February 27, 10:28, slight. South slope, Kilauea.
38. February 27, 13:45, feeble. Felt at Pahala.
39. February 27, 17:18, feeble. East slope, Mauna Loa.
40. February 28, 16:58, very feeble. Northeast rift Mauna Loa.
41. March 2, 14:20, very feeble.
42. March 11, 09:31, very feeble.
43. March 23, 11:35, very feeble. Kilauea.
44. March 29, 10:58, very feeble.

TELESEISMS

February 14, 08:30, slight.
March 24, 11:11, moderate. Off north California coast.

MICROSEISMS

Microseisms were strong from January 5–7 and from February 28 to March 1. On other days they were weak to moderate.

TILTING OF THE GROUND

There was a rapid easterly tilt from January 1 to 10 when seasonal westerly tilt set in and continued until March 24. There was a slight easterly swing from March 25 to 28, then a recovery to the west. With the exception of a sharp northerly tilt accompanying the strong earthquake of February 26, southerly tilt was continuous from January 1 to March 6. From March 7 to 31 there was a slight accumulation of northerly tilt.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended		Amount	Direction
January	2	1.3″	S 25° W
	9	3.1″	S 36° E
	16	2.9″	S
	23	2.4″	S 49° W
	30	4.1″	S 68° W
February	6	1.8″	S 19° E
	13	1.2″	S 62° W
	20	0.9″	S 23° E
	27	2.4″	N
March	6	1.6″	S 39° W
	13	0.6″	N 45° W
	20	1.0″	N 45° W
	27	1.4″	N 59° E

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter,** a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

THE VOLCANO LETTER

No. 504 **U. S. Geological Survey** **April–June, 1949**

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UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist



ACTIVITY OF MAUNA LOA DURING APRIL, MAY, AND JUNE, 1949

By GORDON A. MACDONALD and RUY H. FINCH

The 1949 eruption of Mauna Loa commenced on January 6, and the major activity continued until February 5. This activity consisted of outpouring of lava flows on the caldera floor and down the western and southern flanks of the volcano from vents near the summit, and building of a large cinder and pumice cone at the southwestern margin of the caldera. The activity and cone have been described in VOLCANO LETTER 503.

Following the end of lava fountaining on February 5, fume rising from Mokuaweoweo was visible almost constantly during the remainder of February and March. It was obvious that the magma column must be standing at a very high level in the conduit. On several different nights a distinct glow was reported at the summit of the mountain. Thus, at 2 a.m. on February 19, Charles Hoeppel of the U. S. Coast and Geodetic Survey observed a strong reddish reflection on the fume column. However, at no time when observers were able to see into the caldera was there any sign of lava fountaining or flow. At the time, there was some doubt whether the observed glow was the result of weak resumptions of lava extrusion, or of slumping of surficial parts of the cinder cone or lava cascades, revealing hot glowing material beneath. In view of later developments, there is now little question that the glow resulted from brief quiet outwellings of lava.

The following table lists the dates on which fume or glow was reported and the place from which the observation was made. During many days the summit of the mountain was cloud-covered and invisible to persons at low altitudes. On some days when it was visible, winds at the summit may have been strong enough to dissipate small amounts of fume and make it undetectable from a distance.

OBSERVATIONS ON ACTIVITY OF MAUNA LOA FROM FEBRUARY 7 TO APRIL 7, 1949.

DATE	LOCATION OF OBSERVER	TYPE OF ACTIVITY
Feb. 15	Summit	Weak fume but no glow
17	Kilauea	Weak fume
18	Pahala and Naalehu	Weak glow and fume
19	Near Pahala	Two conspicuous puffs of fume in early morning
19	Planes over summit	Fume but no glow
21	Kilauea	Thin fume during morning
21	Kulani Camp	Glow in evening
22–27	Kilauea	No fume visible
28	Kilauea	Light fume
Mar. 1	Kilauea	Light fume during day
1	Naalehu	Distinct glow in evening
16	Kilauea	Strong fume column in evening
18	Kilauea	Strong fume column in evening
19	Kilauea	Weak fume
20–21	Kilauea	Strong fume in evening
22–23	Kilauea	Weak fume
28	Humuula	Pulsating fume cloud in morning
28	Kilauea	Glow in evening
April 1–6	Kilauea	Conspicuous fume

During late March or early April the quiet outflow of lava became essentially continuous, and was observed at close range by staff members of Hawaii National Park. The account of the activity on April 7 to 9 and May 5 to 7 is based largely on the excellent reports of Ranger James B. Orr, and the writers wish to thank Mr. Orr for making the reports available. The results of the activity were examined on the ground by Macdonald, in company with Orr, on the second and third of June, after lava extrusion again had ceased.

The precise date when lava extrusion again became fairly continuous is uncertain. On March 28 the fume column rising from Mokuaweoweo was unusually conspicuous, and on the evening of that day the glow was intense. On April 1, harmonic tremor was recorded for

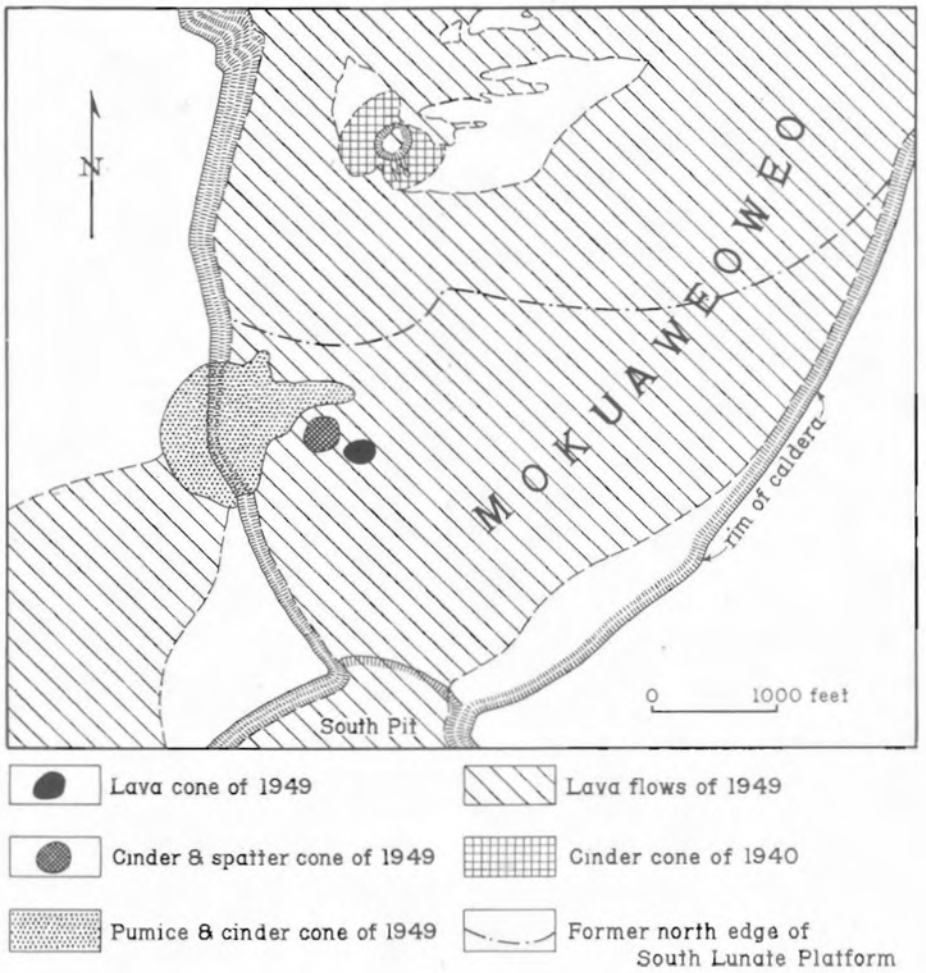

FIGURE 1. Sketch map of the southern portion of Mokuaweoweo caldera on June 3, 1949, after the end of lava extrusion.

a few minutes on both the Mauna Loa seismograph and the Bosch-Omori seismograph at Kilauea. Orr's observations at the summit on April 7 indicate that at that time lava extrusion must already have been in progress for several days. It appears probable, therefore, that fairly continuous lava extrusion was resumed sometime between March 28 and April 1.

The activity of April and May was confined entirely to the vent area on the floor of Mokuaweoweo caldera close to its southwestern wall. The large-scale lava fountaining of late January had built up a big cone of fine cinder and pumice resting against the caldera wall and on the outer slope of the mountain. (See figure 2, VOLCANO LETTER 503.) Within the breached crater of this large cone, diminished fountain activity in early February had built a smaller double cone of coarse cinder and spatter.

On April 8 the small cinder and spatter cone was rhythmically emitting voluminous puffs of fume, but no lava. About 250 feet east of the fuming cinder cone a small lava cone had been built, about 80 feet high and 150 feet across at the base, with a crater 40 feet in diameter containing a small, surging pond of molten lava. The lava composing the cone was notably denser than the highly vesicular lavas which had characterized the earlier phases of the eruption. The lava pond in the crater heaved slowly up and down, the depth from the rim to the pond surface ranging from a few inches to 15 feet during the few hours it was under observation. However, no overflow of lava occurred while Orr was there, from April 7 to 9, although the cone obviously had been built up by repeated overflows previous to April 7 and continued to grow by additional overflows later. From the vent area liquid lava moved through tubes beneath the surface, emerging about a mile east–northeast of the cones to feed two sluggishly advancing flows of aa. Another small sluggish aa flow was moving southeastward into South Pit.

On May 5 the height of the lava cone had increased to about 95 feet, as measured from its southeastern base. The lavas composing it were still relatively dense, and the pond of molten lava was still present in its crater. The cinder and spatter cone was the principal source of fume and had liberated some short flows of lava which partly veneered its flanks. Some of this lava was dense, but some was highly vesicular and shelly. A small pahoehoe flow was spreading near the base of the lava cone; another larger flow moved through tubes, issuing about a mile northeast of the cone to form a moderately active pahoehoe flow.

The activity at the cones on May 7 showed a distinctly cyclic pattern, the cycles being repeated at approximately 3½-hour intervals. Successive cycles were essentially identical, except for minor variations in the duration of the parts of the cycle. The cycle commenced with a loud hissing and roaring within the cinder and spatter cone, accompanied by copious liberation of pale brown to white fume. This lasted for 5 minutes, and was followed by rapid outpouring of gas-rich pahoehoe accompanied by a little fume. The lava effusion lasted about 45 minutes, the rapidity of extrusion gradually decreasing until all flows ceased. Within about 5 minutes after the lava ceased to flow, the hissing and roaring within the cone started again. At the summit of the cone the escaping gas tilted large slabs of partly cooled pahoehoe, lifting some of them a foot or two, then dropping them back into place. This relatively violent escape of gas continued for about 10 minutes. Immediately afterward the lava cone, which had been quiescent with its crater empty, started to fume copiously, and shortly thereafter fluid lava entered the bottom of the crater from an opening on its west–southwest side. Within 10 minutes the crater was completely filled. With the entrance of lava into the crater fuming was greatly diminished, and by the time the crater was filled fuming had practically ceased. The fluid lava bulged up above the crater rim as a broad flat dome a foot or two high, then the confining crust ruptured and the lava poured down the flanks of the cone. The crust of the bulge of lava at the summit of the cone was continually broken up, forming large irregular plates of still flexible pahoehoe which coasted down the flows on the flank of the cone, crumpling and twisting as they encountered obstacles. This phase of overflow from the lava cone continued with varying intensity for about an hour. Then the lava in the crater drained away, accompanied by liberation of large volumes of fume at the lava cone and by the renewal of the hissing and roaring in the cinder and spatter cone. This was followed by a period of quiet lasting about an hour, after which the entire cycle was repeated.

The date of final cessation of the lava extrusion is uncertain. Flows still were moving actively on the caldera floor east of the vent on May 19, when the summit was visited by H. Whitten. When Orr and Macdonald reached the summit on June 2 there was no sign of movement in any of the flows, although a weak glow still was visible on the cinder cone. The cone still was fuming copiously on June 2, but by the afternoon of June 3 the fume was very light and consisted almost entirely of steam. During the remainder of June no glow, and only weak fuming, were reported. Lava extrusion ended sometime between May 20 and June 2, probably about the end of May. The eruption appears to be over, although it is still possible that another resumption of activity may occur.

On June 3 both the cinder cone and the lava cone were climbed and examined in detail. The cinder cone was an irregular dome, about 80 feet high, with no sign of a crater. It was largely veneered with very late flows of frothy pahoehoe. (See plate 1.) The lava cone was about 110 feet high, with a crater some 30 feet across and 50 feet deep. (See plate 2.) The late lavas, erupted at the lava cone after Orr's visit on May 5, were shelly gas-rich pahoehoe, in contrast to the denser, partly degassed lavas which built most of the cone.

It is estimated that the volume of lava extruded in the late phase of the eruption after February 5 was about 4 million cubic yards, bringing the total volume for the eruption to about 75 million cubic yards. The late lavas were restricted to the southern end of Mokuaweoweo caldera, and completed the burial of the northward-facing scarp of the South Lunate Platform, which had already been partly buried by the lavas of 1933 and 1940. Only at its western end is there still visible a topographic expression of the scarp, mantled by cascades of the 1949 lavas. (See figure 1.)

It has already been pointed out that the pahoehoe lava which formed most of the lava cone was strikingly dense, as compared to the highly vesicular and shelly pahoehoe which characterized the earlier lavas of the eruption in the area close to the vents. It resembled much more closely the pahoehoe which forms in long flows which have traveled through tubes many miles from the vents. In the case of the 1949 lava, the denseness resulted from loss of gas before the lava reached the surface. The change from gas-rich to gas-poor lava as the eruption progressed might have been explained by assuming a gas-enriched "head" on the magma column which was released during the early stages of the eruption and gradually exhausted as activity continued. This explanation might be acceptable if the change in gas content had been entirely unidirectional. But it was not. The latest lavas of the eruption, instead of being as dense as or even denser than those which built the bulk of the lava cone, were again frothy and gas-rich like the earliest lavas. The change was from gas-rich to gas-poor, and then back again to gas-rich lavas.

A possible explanation of the changes in density of the erupted lavas is suggested by the time relationships of the density types to the character of the rest of the activity. The dense lavas which built most of the lava cone, and also were erupted in early May or late April at the cinder and spatter cone, were erupted following a period of nearly 2 months duration during which there was very little surface outflow of lava, but nearly continuous liberation of large volumes of fume. Possibly during this period the upper part of the magma column stood undisturbed at levels high enough to permit vesiculation, and for a period long enough for a large proportion of the gas bubbles to escape, supplying the gas for the fume cloud. However, at levels

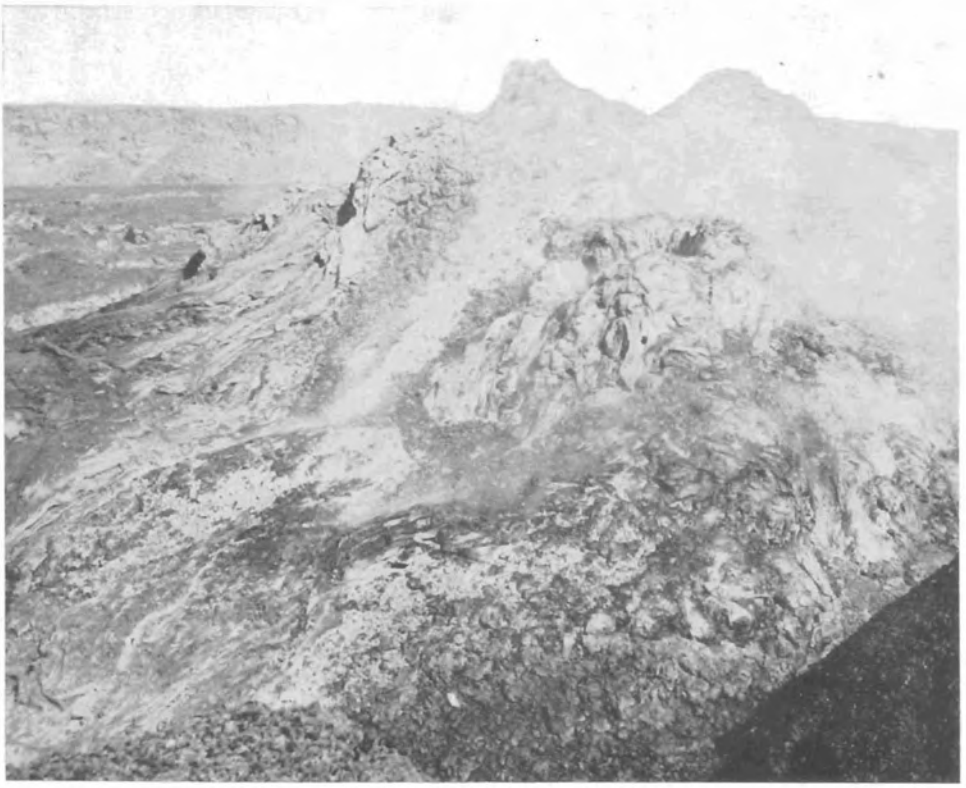

PLATE 1. The small cinder and spatter cone, largely veneered with thin lava flows, seen from the northern rim of the pumice cone, June 3, 1949. PHOTOGRAPH BY G. A. MACDONALD.



PLATE 2. Lava cone, seen from near the summit of the cinder and spatter cone, June 3, 1949. PHOTOGRAPH BY J. B. ORR, NATIONAL PARK SERVICE.

below the depth at which appreciable vesiculation could occur the magma lost only the small proportion of gas which was dissipated upward by diffusion. Convection probably would not be very effective in the narrow feeding fissure which led the lava to the surface. When lava extrusion was resumed after the 2-month period of quiet, the first erupted, upper part of the magma body was gas-poor and produced dense lavas. But as time went on the upper, partly degassed portion of the magma was exhausted, and lavas reaching the surface were again as rich in gas, or nearly so, as had been the earliest lavas of the eruption.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR APRIL–JUNE, 1949

VOLCANOLOGY

April

About the end of March, quiet lava extrusion became fairly continuous in Mokuaweoweo, and continued through April. The activity is described in the foregoing article. Fume rising from Mokuaweoweo was visible from the Volcano Observatory on many occasions during April.

Thirty-two earthquakes were recorded in April. Sixteen of these were recorded at Kilauea and 23 at Mauna Loa.

There was a small accumulation of northwesterly tilt during April, possibly indicating a slight increase of pressure under Kilauea and a decrease under Mauna Loa.

May

Quiet lava effusion in Mokuaweoweo continued through most of May. It came to an end sometime between May 20 and June 2, probably about May 30.

Forty-three earthquakes were recorded during May. Of these 31 were recorded at Kilauea and 38 on Mauna Loa. In addition, about 225 tremors of Mauna Loa origin were recorded on the Mauna Loa seismograph on May 20 and 21. These resembled the records produced by small explosions, rather than by ordinary small earthquakes. Many of them were recorded also at Kilauea, and some on the Hilo and Kona seismographs.

Three earthquakes were felt locally during May. The strongest occurred at 5:02 a.m. on May 2. It originated in Kona, where some objects were shaken from shelves, and the seismograph at Kealakekua was broken. As in October and November, 1947, several of the larger shakes originated under the west slope of Mauna Loa, inland from Kealakekua Bay.

There was an accumulation of south tilt, and a little east tilt during May. The latter is normal for this time of year.

June

Both Mauna Loa and Kilauea remained quiet throughout June. A total of 32 earthquakes were recorded, 28 of them at Kilauea, and 27 of them on Mauna Loa. Of these, a moderate earthquake originated at a shallow depth on the northeast rift zone of Mauna Loa on June 8, and two feeble earthquakes at a depth of about 10 miles under the southern slope of Mauna Loa, near Punaluu Kahawai, on June 25.

A small accumulation of southerly tilt occurred during June, probably indicating either a slight decrease of pressure under Kilauea or a slight increase under the northeast rift of Mauna Loa. Almost no net change in tilt in an east–west direction was recorded during the month.

The average interval between summit eruptions of Mauna Loa and following flank eruptions during the past century has been 20 months. On this basis, assuming the 1949 summit eruption to have ended about the end of May, a flank eruption of Mauna Loa might be expected about the end of January, 1951. However, it is important to realize that the average interval means little. Sometimes a summit eruption of Mauna Loa is followed by another summit eruption, not by a flank outbreak. Even when a summit eruption has been followed by a flank eruption, the interval between them has ranged from 6 to 38 months. Prediction of Mauna Loa eruption entirely on the basis of historic precedent is highly uncertain, and thus far there is little else on which to base a forecast of the next eruption.

SEISMOLOGY

Earthquake Data, April–June, 1949

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
April	3	15	3	0	0	0	0	5.25	0
	10	7	3	0	0	0	0	3.25	0
	17	9	0	0	0	1	0	5.25	1
	24	3	0	0	0	0	0	0.75	0
May	1	8	0	0	0	0	0	2.00	1
	8	3	0	0	0	2	0	6.75	1
	15	3	2	1	0	0	0	2.75	0
	22	266	0	4	0	0	0	70.50	0
	29	13	1	3	0	1	0	9.75	0
June	5	7	2	0	0	0	0	2.75	0
	12	3	3	0	0	1	0	5.25	0
	19	3	3	0	0	0	0	2.25	0
	26	5	1	2	1	0	0	5.75	0

* For definition of local seismicity, see Volcano Letter 371.

The data for the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

45. April 4, 02:59, very feeble.
46. April 7, 09:55, very feeble. Mauna Loa.
47. April 8, 16:30, very feeble. Mauna Loa.
48. April 11, 18:40, moderate, both components dismantled at Mauna Loa. Kaoiki fault. Felt at Naalehu.
49. May 2, 05:02, strong, Kona seismograph broken. West slope of Mauna Loa. Intensity about 4 on Rossi-Forrel and modified Mercalli scales. Felt in Hilo, strongly at Puu Ulaula, and generally from Holualoa to Naalehu. Many sleepers wakened, some rushed out doors. Some objects thrown from shelves in the area from Honaunau to Kealakekua.
50. May 2, 12:55, feeble. Mauna Loa. Felt at Kapapala.
51. May 7, 23:26, strong, both components dismantled at Mauna Loa. Focus at about 12 miles depth beneath Mokuaweoweo. Felt at Holualoa, Kealakekua, Naalehu.
52. May 9, 03:26, very feeble.
53. May 9, 17:02, very feeble.
54. May 14, 10:54, very feeble.
55. May 21, 01:06, feeble. West slope of Mauna Loa. Felt at Holualoa.
56. May 21, 02:25, feeble. West slope Mauna Loa.
57. May 21, 08:38, feeble.
58. May 21, 10:01, feeble.
59. May 23, 10:24, moderate, both components dismantled at Mauna Loa. South slope Mauna Loa near Kapapala. Felt at Kilauea and Hookena, strongly at Pahala.
60. May 25, 15:10, very feeble.
61. May 26, 14:44, very feeble.
62. May 28, 17:30, feeble. West slope Mauna Loa. Felt at Holualoa.
63. May 29, 01:04, feeble. Kaoiki fault near Ainapo.
64. May 30, 04:18, feeble.
65. June 3, 04:05, very feeble.
66. June 8, 14:12, moderate, both components dismantled at Mauna Loa. Northeast rift of Mauna Loa, shallow.
67. June 9, 18:07, very feeble.
68. June 11, 05:41, very feeble. Northeast rift of Mauna Loa.
69. June 11, 08:05, very feeble.
70. June 17, 05:49, very feeble.
71. June 19, 05:05, very feeble. Mauna Loa.
72. June 19, 12:53, very feeble. Mauna Loa, northeast rift.
73. June 23, 15:34, feeble.
74. June 25, 15:45, feeble. Focus at about 10 miles depth under south slope of Mauna Loa near Punaluu Kahawai.
75. June 25, 19:27, slight. Location same as number 74.
76. June 26, 08:43, very feeble.
77. June 27, 01:57, feeble. Mauna Loa.
78. June 28, 04:53, very feeble. Mauna Loa.
79. June 30, 07:03, very feeble. Kilauea northeast rift, shallow.

TELESEISMS

April 13, 10:03, slight. Between Olympia and Tacoma, Washington.

April 29, 15:36, slight. South coast of Mindanao, Philippine Islands.

May 2, 20:05, slight. Kurile Islands.

MICROSEISMS

Microseisms were slight from April 1 to 9, moderate on April 10 and 11, slight from April 12 to 19, moderate from April 20 to 28, and slight from April 29 to June 30.

CRACK MEASUREMENTS

Most of the cracks measured showed no appreciable movement. However, the crack at the observation area at the east rim of Halemaumau opened 2 millimeters at its northern end during the interval from March 31 to June 30. During the interval since August 31, 1948, it has opened 12 millimeters. The amount of opening decreased southward, reaching essentially zero at the southern end of the crack.

TILTING OF THE GROUND

From April 1 to 22 there was very little tilting of the ground surface in a north–south azimuth. From April 22 to May 4 there was a slight northerly tilting, from May 4 to 29 a distinct southerly tilting, from May 29 to 31 a small northerly tilting, and from May 31 to June 30 a small accumulation of southerly tilting. In the east–west azimuth, there was a small accumulation of westerly tilt between April 1 and 29, a nearly equal accumulation of easterly tilt between April 29 and May 27, and a slight accumulation of westerly tilt from May 27 to June 30. The net westerly tilting is normal for this quarter of the year, although the tilting during June is normally slightly to the east instead of slightly westward. The accumulation of southerly tilt during May and June is abnormal, tilting during these two months generally being distinctly northward.

Table of Tilt at Observatory on Northeast Rim of Kilauea

Week Ended		Amount	Direction
April	3	0.9″	N 45° W
	10	0.7″	S 83° W
	17	0.0	——
	24	0.7″	N 39° W
May	1	0.6″	N 80° W
	8	0.7″	S 56° E
	15	0.6″	S 19° W
	22	0.5″	S 45° E
	29	0.4″	S 34° E
June	5	1.0″	N 19° W
	12	0.5″	S 45° W
	19	0.6″	N 22° W
	26	1.1″	S 56° E

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
In cooperation with the UNIVERSITY OF HAWAII

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THE VOLCANO LETTER

No. 505 **U. S. Geological Survey** **July–September, 1949**

PUBLISHED BY THE UNIVERSITY OF HAWAII

REPORT ON PRELIMINARY WORK FOR RADIATION SURVEY

By RUTH C. LOUCKS

INTRODUCTION

In August, 1948, a series of experiments was initiated to determine to what extent available materials could be used to make a survey of radiation from volcanic sources. At that time available materials consisted of X-ray film and a small spectrograph. Later a Geiger type survey meter was made available to the Hawaiian Volcano Observatory.

X-RAY FILM

Since X-ray film registers radiation both longer and shorter than the X-ray range, it appeared to be a possible medium for recording any short-wave radiation that might be present. No X-rays are expected because of their nature, but ultraviolet radiation and gamma radiation may be recorded on X-ray film. Dental pack film was selected for this work because of the ease of handling.

The first series of films, exposed for 10 weeks at Red Hill (10,000 feet) and the rim of Mokuaweoweo, showed heavy fogging of unshielded films and no fogging of slightly shielded films. By accident two films were exposed back to back. The front one was fogged, while the one which was shielded by the two lead foil backing sheets was unfogged. The fact that even masking tape, with which the films were taped to rocks, produced a shadow on the films indicated that the radiation recorded was of relatively long wavelength. Temperature changes from below freezing to above 70° F. apparently did no damage. One film was left for a year deep in a crevice in the roofed cave near the rim of North Bay known as Hotel de Jaggar. It showed slight darkening, possibly due to the small amount of radioactivity in Hawaiian lavas. Film exposed to Hawaiian lava for 12 weeks showed no darkening, but the longer exposure of a year may have recorded the slight amount of radioactivity present (Piggot: Amer. Jour. Sci., 5th Ser., 22(127) : 1931).

The second series was tested at the Kilauea region to determine whether the film pack was actually light tight (for visible light) and whether any of the darkening could be attributed to cosmic rays. The film tested for light tightness was unfogged. Cosmic rays produced no measurable darkening on any of the films tested. The only darkening was due to radioactive lead in the masses of the tiltmeter in the Uwekahuna vault. The radioactivity of the lead was later checked with the Geiger counter. The exposure of 5 weeks produced slight darkening on the film at a distance of 12 to 15 feet from the radioactive lead. This darkening served as a check of the sensitivity of the film to gamma radiation.

The third series of tests was made at Red Hill using unshielded film and film shielded by aluminum foil and various thicknesses of lead. Film was placed in four slots of a lead-covered box. One film was uncovered, one covered by 0.11 mm. of aluminum foil, one by 3.5 mm. of lead, and one by laminations so arranged that one third was uncovered, one third covered by 1.75 mm. of lead, and one third by 3.5 mm. of lead. These were exposed nearly 6 months. The unshielded film was darkened, while the film shielded by aluminum foil and the lead was undarkened. Thus it appears that the darkening encountered was due to ultraviolet radiation and may be eliminated by encasing the film in aluminum foil. The writer wishes to acknowledge the assistance given by the dispensary of Kilauea Military Camp in developing all X-ray films.

SPECTROGRAPH

The spectrograph (Gaertner, Model L 250-W) was checked and calibrated in the laboratory by Harvey E. White of the University of California Physics Department, during a visit to the Volcano Observatory. This is a low-dispersion instrument mounted so as to be used with a tripod in the field. It appeared that an easy way to record the exact object, toward which the spectrograph slit was pointed, would be by the use of a small camera mounted on the tripod with the spectrograph. D. C. Cox donated a camera for this purpose.

GEIGER COUNTER

A Geiger-Mueller counter (El-Tronics, Inc., Survey Meter SGM-18A) was received by the Observatory early in 1949. A few tests were made to determine what might be expected in the way of background radiation (cosmic rays).

1949 ERUPTION

Two series of X-ray films were exposed at the summit of Mauna Loa during the 1949 eruption. Both were exposed near the rest house, about 1 mile or more from the nearest activity. Twice during January, 1949, film was taped to the stone monument in front of the rest house and exposed for periods ranging from 17 hours to 17 days. Since the films were unshielded, there was no noticeable darkening other than that which might be expected from ultraviolet light. At that distance one could not expect to record gamma radiation.

G. A. Macdonald and D. C. Cox took the Geiger counter to the summit of Mauna Loa and made some observations. Their readings were no higher on new lava than on the old lava. However, when they attempted to make readings in a hot crack, they got no reading because the counter does not register correctly above 125° F.

The field conditions were such that it seemed best not to take the spectrograph to the summit.

CONCLUSIONS

It appears that none of the work done during the 1949 eruption constitutes a conclusive test of radiation associated with volcanic activity, particularly the possible presence of short-lived radioactive substances in the gases liberated in the big lava fountains. The films exposed were too far from activity to be significant, and the Geiger counter readings were not complete enough to be conclusive. However, the work done so far serves to point out what should be done to make such tests valid. The year's work shows that among the three recording devices the radiation spectrum from cosmic rays down through the visible range is covered.

THE HOLLOW CINDER CONE OF THE 1949 ERUPTION OF MAUNA LOA

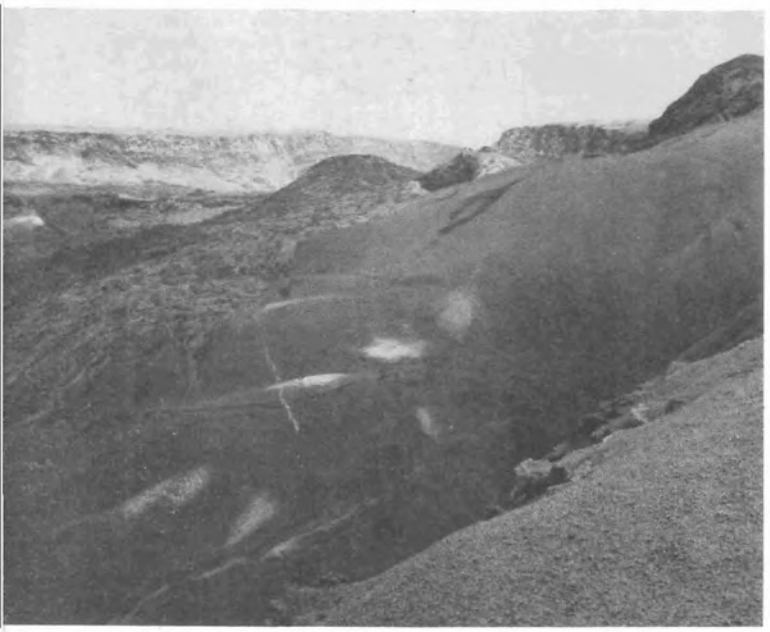
By GORDON A. MACDONALD

The small cinder and spatter cone, which developed within the breached crater of the larger cinder and pumice cone during the late stages of the 1949 eruption of Mauna Loa, has been described in previous issues of the VOLCANO LETTER. Previous to mid-April the cone had consisted entirely of coarse cinder and spatter. Between April 9 and May 6 the cone started to erupt short thin lava flows, which by early June had almost entirely covered its slopes, hiding the cinder core.

Mokuaweoweo caldera was again visited by the writer on July 26, in company with Ranger J. B. Orr of Hawaii National Park, and Tad Nichols, photographer. It was then found that the cinder and spatter cone had partly caved in, revealing a large cavity in its center. The hole formed by the collapse was on the northeastern side of the cone, and its walls clearly displayed a cross section of the cone. At the surface was the veneer of lava, averaging 6 to 8 feet thick, and consisting of a complex of many thin pahoehoe flows lying parallel to the surface of the buried cinder cone. Many of the flows showed cross sections of filled or partly filled pahoehoe tubes. Beneath the lava veneer the cone consisted of coarse cinder and spatter, largely welded together, and crudely bedded. The fragments ranged up to about 2 feet in length, although most were less than 1 foot. Most were irregular, although some were fairly regular Hawaiian type ("cow-dung") bombs.

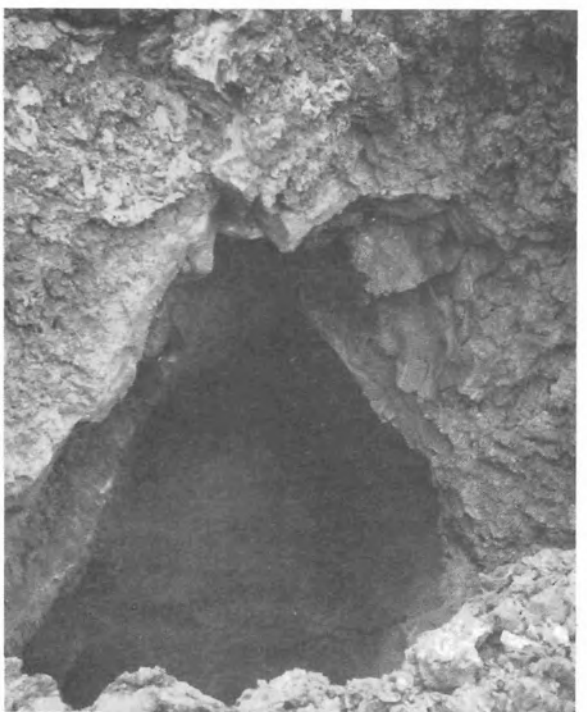
By far the most interesting feature of the cone was the open chamber at its center. The chamber was roughly the shape of an artillery projectile, about 25 feet across, with nearly vertical walls which arched inward to a point at the top. The opening was about 40 feet high, but had been higher, as the visible floor was formed of loose rubble which resulted from the collapse of the cone. The walls of the chamber were lined with a layer of pahoehoe 2 to 4 feet thick, in which the flow-lines and flow-planes were disposed parallel to the walls of the chamber and nearly vertical. At the apex of the chamber the pahoehoe lining was continued upward as a 3-foot dike which led to the two small spatter conelets at the summit of the cone.

Apparently the lava rose into the cone, making room for itself by removing the material which in earlier stages formed the core of the cone. There is no evidence whether the removal was by stoping or by redissolving the hot cinder, or both. At the end of the eruption the magma column withdrew, leaving the center of the cone empty, but the walls of the cavity veneered with a thin layer of lava.



LEFT

PLATE 1. View of the cone area of the 1949 eruption, from the top of the caldera wall to the north. In the foreground and on the right can be seen the big pumice cone built on and against the caldera rim during early stages of the eruption. The fissures are the result of partial collapse of the cone, and the white areas are the result of alteration and deposition by escaping gases. In the middle distance can be seen the hollow cinder and spatter cone, and to its left the lava cone. PHOTO BY G. A. MACDONALD.



RIGHT

PLATE 2. The open chamber in the center of the small cinder and spatter cone. The chamber is lined with a thin layer of pahoehoe lava, and on the right the nearly vertical flow-banding in the pahoehoe lining is clearly visible. At the top a flow-banded dike leads upward through the cinder. The chamber is approximately 20 feet across. PHOTO BY G. A. MACDONALD.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JULY–SEPTEMBER, 1949

VOLCANOLOGY

July

Since the end of lava extrusion about the end of May, Mauna Loa has remained quiet. Mokuaweoweo was visited on July 26. No signs of lava activity could be detected although the new cone built during the early months of 1949 was still hot and fuming weakly and a faint pall of bluish fume hung over the crater of the 1940 cone. The small cinder and spatter cone within the crater of the larger cinder and pumice cone of the 1949 eruption had partly collapsed, and the center of the cone was seen to be occupied by an open chamber lined with a thin layer of pahoehoe.

Forty-six local earthquakes were recorded on the seismographs of the Volcano Observatory during the month of July. Of these, 31 were recorded at Kilauea and 34 at the seismograph on the eastern slope of Mauna Loa. (The total is not the same as the sum of those recorded at each of the stations, because many earthquakes were recorded at both stations.) On July 5 a moderately strong earthquake occurred at a depth of 10 to 15 miles on the east rift zone of Kilauea volcano, in the vicinity of Kapoho. At 8:52 p.m. on July 29 a strong shallow earthquake occurred on the northeast rift of Mauna Loa near the summit of the mountain. This earthquake, which dismantled both components of the Mauna Loa seismograph, was felt strongly at Kapapala and much less strongly by many persons in the area from Kilauea crater to Hilo.

On July 23, at 12:35 a.m., the Bosch-Omori seismograph recorded the long waves of a heavy earthquake with its origin near the New Hebrides Islands.

During the month of July the tiltmeter at the northeastern edge of Kilauea caldera accumulated a small amount of northerly tilt of the ground surface, but there was little change in tilt in the east–west direction. There is generally weak but pronounced easterly tilting and moderately strong northerly tilting at this season of the year. Hence the absence of appreciable easterly tilting and less than normal northerly tilting probably result from a slight decrease in pressure beneath Mauna Loa and Kilauea.

August

Mauna Loa and Kilauea remained quiet during August, although light fume was observed at the summit of Mauna Loa late on the afternoon of August 30.

Forty-seven local earthquakes were recorded on the seismographs during the month of August. Of these, 33 were recorded at Kilauea and 44 at the station on the eastern slope of Mauna Loa. A moderately strong earthquake which was felt in the area east of Kilauea crater at 2:26 p.m. on August 30 had its origin at a depth of 20 to 25 miles, about 8 miles south-southeast of Apua Point. An earthquake, which originated at a depth of about 30 miles under the southwest rift of Mauna Loa at 7:22 p.m. on August 31, was felt weakly in Kona.

On August 5 the seismographs recorded the great earthquake which caused tremendous damage and several thousand deaths in the region around Ambato, in Ecuador. On August 21 they recorded the great earthquake in British Columbia. This earthquake was of considerably greater magnitude than that of August 5 in Ecuador, and the smaller amount of damage must be attributed to its occurrence in an unpopulated area. It was so violent that it dismantled the seismographs, of comparatively low sensitivity, at the Volcano Observatory, 3,000 miles from its origin. It probably is the strongest distant earthquake thus far recorded at the Volcano Observatory. Aftershocks of the British Columbia earthquake were recorded until August 23.

During August the tiltmeter at the northeastern edge of Kilauea caldera recorded moderately strong northerly tilting of the ground, which is normal for this season of the year. There was almost no tilting in the east–west direction. Because there is normally an easterly tilting during this season, the lack of tilt in the east–west direction probably indicates a decrease of volcanic pressure under Mauna Loa.

September

The Hawaiian volcanoes remained quiet during September. The morning of September 6 marked the anniversary of the beginning of the last eruption of Kilauea. The 15 years since that eruption constitute the longest quiet period in historic record. The 13 years from 1894 to 1907 saw little lava activity, but fuming was almost continuous, and glow in Halemaumau was frequent, and one brief period of lava extrusion in Halemaumau appears to have occurred in 1902 (see VOLCANO LETTER 497, 1947). There is no indication that the end of the quiet period is near. Neither ground tilting nor earthquakes appear to indicate activity of Kilauea or Mauna Loa in the close future.

Forty-seven local earthquakes were recorded on the seismographs of the Hawaiian Volcano Observatory during September. Of these, 40 were recorded at Kilauea and 41 at the Mauna Loa station. On September 1 a sharp earthquake was felt strongly from Kapapala to Naalehu, and weakly in Kona and from Hawaii National Park to Hilo. It originated 3 to 4 miles northeast of the Kapapala Ranch headquarters, on the Kaoiki fault zone. A smaller earthquake, less generally felt, originated a little farther northeast on the same zone of faulting on September 14. An earthquake felt by a few persons in South Kona on September 16 had its origin near the coast about 5 miles south of Hookena, possibly on the Kiholo Pali fault.

On September 27, the seismographs recorded a distant earthquake which occurred in or near southern Alaska.

During the month of September the tiltmeter at the northeastern edge of Kilauea caldera recorded a slight easterly and a moderate northerly tilting of the ground surface which is normal for this season of the year.

G. A. MACDONALD

SEISMOLOGY

Earthquake Data, July–September, 1949

(Based on Bosch-Omori seismograph on rim of Kilauea caldera.)

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
July	2	6	1	0	0	0	0	2.0	0
	9	13	2	0	0	1	0	7.25	0
	16	3	0	0	0	0	0	0.75	0
	23	5	1	0	0	0	0	1.75	1
	30	3	1	0	0	1	0	4.25	0
August	6	6	1	0	0	0	0	2.0	1
	13	7	2	0	0	0	0	2.75	0
	20	2	4	0	0	0	0	2.5	0
	27	9	2	1	0	0	0	3.25	2
September	3	1	2	0	1	0	1	7.25	0
	10	11	0	0	0	0	0	2.75	0
	17	4	2	1	0	0	0	3.0	0
	24	9	3	0	0	0	0	2.75	0
October	1	6	2	0	0	0	0	2.5	1

* For definition of local seismicity, see Volcano Letter 371.

The data for the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

80. July 5, 00:44, moderate. East rift of Kilauea near Kapoho, about 12 miles deep. Not reported as felt.
81. July 5, 17:13, very feeble.
82. July 8, 12:42, very feeble.
83. July 19, 09:55, very feeble.
84. July 28, 17:36, very feeble.
85. July 29, 20:52, moderate. Both components of Mauna Loa instrument dismantled. Felt strongly at Kapapala, weakly from Hawaii National Park to Hilo. Focus about 6 miles deep about 3 miles ENE of Mokuaweoweo.
86. August 5, 14:49, very feeble.
87. August 8, 18:35, very feeble. On west flank of Mauna Loa near Kaunene, 12 to 15 miles deep.
88. August 12, 19:05, very feeble. Southeast slope of Mauna Loa between Ainapo and Ohaikea, shallow.
89. August 16, 02:20, very feeble. Southeast slope of Mauna Loa about 7 miles northwest of Pahala.
90. August 16, 16:23, very feeble. About 2 miles south of Poliokeawe Pali, south of Kilauea caldera.
91. August 19, 07:15, very feeble. About 10 miles deep, near the shore northwest of Huehue Ranch.
92. August 19, 19:24, very feeble. Northeast rift of Mauna Loa at about 7,500 feet.
93. August 21, 18:49, feeble. Felt by a few persons in Volcano district. Offshore, southeast of Kilauea caldera.

94. August 24, 06:03, very feeble.
95. August 24, 14:18, very feeble.
96. August 30, 14:27, slight. Beneath ocean, about 8 miles SSE of Apua Point, 20 to 25 miles deep. Felt in Volcano district.
97. August 31, 19:23, very feeble. Felt at Holualoa. Under southwest rift of Mauna Loa, about 30 miles deep.
98. Sept. 1, 12:53, moderate. Both components of Mauna Loa instrument dismantled. Felt strongly from Kapapala to Naalehu, weakly from Volcano district to Hilo and in Kona from Pahoehoe to Holualoa. Origin on Kaoiki fault, about 3 to 4 miles northeast of Kapapala Ranch headquarters.
99. Sept. 2, 02:31, very feeble.
100. Sept. 12, 03:46, very feeble.
101. Sept. 14, 16:47, feeble. About 6 miles deep, on Kaoiki fault about 3 miles west of Uwekahuna. Felt in Hilo.
102. Sept. 16, 14:08, very feeble. Felt in South Kona. Origin near coast, about 5 miles south of Hookena.
103. Sept. 18, 20:38, very feeble.
104. Sept. 22, 01:31, very feeble. Under southwest edge of Kilauea caldera, about 8 miles deep.
105. Sept. 23, 21:08, very feeble.
106. Sept. 26, 08:27, very feeble.
107. Sept. 28, 12:13, very feeble.

TELESEISMS

July 23, 00:35, slight. New Hebrides Islands; provisional epicenter.

August 5, 14:43, moderate. Central Ecuador, centering around Ambato.

August 21, 18:09, very large. Both components of Bosch–Omori seismograph at Kilauea, and the north–south component of the Mauna Loa seismograph were dismantled. Queen Charlotte Islands, off coast of British Columbia. Caused 2-foot tidal wave at Ketchikan, Alaska.

August 23, 10:38, slight. Probably an aftershock of the British Columbia earthquake.

Sept. 27, 05:38, slight. Origin probably near Juneau, in southern Alaska.

MICROSEISMS

Microseisms were slight from July 1 to 10, moderate from July 11 to 22, slight from July 23 to 29, moderate from July 30 to August 6, slight from August 7 to 20, moderate from August 21 to 27, slight from August 28 to September 1, moderate from September 2 to 10, strong from the afternoon of September 10 through September 14, and moderate for the remainder of the month of September.

CRACK MEASUREMENTS

Most of the cracks measured showed no appreciable movement. However, the crack at the observation area on the east rim of Halemaumau continued to open slightly. During the interval from June 30 to September 30, stations near the northern end of this crack showed opening of 2 to 3.5 millimeters, and stations near the southern end showed opening of about 0.5 millimeter.

TILTING OF THE GROUND

There was a net northerly tilting of the ground surface of 3.5 seconds of arc at the northeastern rim of Kilauea caldera between July 1 and August 21. Minor reversals to southerly tilt occurred during the periods July 9 to 12, 25 to 30, and August 9 to 10. There was slight southerly tilting from August 21 to 23, slight northerly tilting from August 23 to September 17, and slight southerly tilting from September 17 to October 1. The net change from July 1 to October 1 was a northerly tilt of 3.4 seconds of arc. In the east–west azimuth, there was an accumulation of 0.5 second of easterly tilt from July 1 to July 5. From July 5 to September 1 there were minor oscillations from easterly to westerly tilt, but no net accumulation of either. From September 1 to 4 there was a sharp westerly tilting, followed by a moderate easterly tilting during the remainder of the month. The net accumulation of easterly tilt from July 1 to October 1 was 0.9 second of arc.

Table of Tilt at Seismograph Vault on Northeast Rim of Kilauea Caldera

Week Ended		Amount	Direction
July	2	1.4″	N 40° W
	9	0.6″	N 12° W
	16	0.4″	S 64° E
	23	0.9″	N 32° E
	30	0.7″	S 16° W
Aug.	6	1.1″	N 16° W
	13	0.1″	N 45° W
	20	1.1″	N
	27	0.3″	S 70° E
Sept.	3	0.2″	N
	10	0.1″	E
	17	0.4″	N 32° E
	24	0.6″	S 18° W
Oct.	1	0.8″	N 76° E

TEMPERATURE MEASUREMENTS

Weekly measurements of the temperature at the steam well at Sulfur Bank were resumed on September 10. The following uniform procedure has been adopted. The ½-inch plug at the top of the casing of the more easterly of the two drill-holes is removed, and the well is allowed to blow freely for 10 minutes. A maximum thermometer is then completely inserted into the aperture and allowed to remain 5 minutes. To date, the measured temperature has been uniformly 206° F.

Measurements at steaming cracks at Sulfur Bank have ranged from 203° to 208°, probably because of non-uniform exposure. Changes in the amount and direction of the wind appear particularly effective in altering the measured temperature.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:
R. H. Finch, Volcanologist, Director
G. A. Macdonald, Geologist
C. K. Wentworth, Geologist, part-time
B. J. Loucks, Instrument maker
Ruth B. Loucks, Assistant

University of Hawaii:
T. A. Jaggar, Geophysicist

Seismograph Station Operators:
Hilo Station:
Brother B. T. Pleimann, Saint Joseph's School
Kealakekua Station:
H. M. Tatsuno, Konawaena School

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In cooperation with the UNIVERSITY OF HAWAII

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THE VOLCANO LETTER

No. 506 **U. S. Geological Survey** **October–December, 1949**

PUBLISHED BY THE UNIVERSITY OF HAWAII

BOMBING TO DIVERT LAVA FLOWS

By RUY H. FINCH and GORDON A. MACDONALD

Probably the first attempt to alter the course of a lava flow by artificial means occurred during the 1669 eruption of Etna volcano. The flow was advancing toward the city of Catania and seemed likely to destroy it. In an attempt to save the city, several dozen men covered themselves with wet cowhides for protection against the heat and dug a channel through the wall of hot lava at one edge of the flow. The operation was initially successful. A stream of lava escaped through the gap thus created and moved away at a high angle to the direction of the original flow, partly relieving the pressure on the stream moving toward Catania. Unfortunately, however, the new flow moved toward the town of Paterno, and some 500 irate citizens of that town descended upon the men of Catania and drove them away from the newly dug lava channel. Left unattended, the gap in the flow wall soon clogged up with cooled lava, and the main branch of the flow continued toward Catania, partly destroying it (Rittmann, 1929, pp. 95–96). This early attempt, although it ended in failure, demonstrated the possibility of diverting part or all of a lava flow to a new course by artificially breaking down the confining wall of the flow.

Digging away of the edge of the flow, by hand or by machine, is a difficult and possibly dangerous procedure. It is easier and quicker to blast away the lava by means of explosives. The late Lorrin A. Thurston suggested orally in the early 1920's that in the case of pahoehoe lava flows descending gentle slopes, high explosives might be thrust out over the flow on long poles and dropped through windows in the feeding tube near the flow source, shattering the tube, forcing the lava to spread out again near the source, and removing the supply of lava from the advancing lower end of the flow (Thurston, 1929). Similar methods had been under discussion for several years by members of the staff of the Hawaiian Volcano Observatory. Thurston's suggestion was accepted and advocated by Jaggar (1931), and during the Mauna Loa eruption of 1935 Jaggar introduced the method of emplacing the explosive by dropping military bombs from airplanes (Jaggar, 1936). This is generally the most practical way of transporting and emplacing the explosive. In some instances shells from nearby big guns might be more effective because of the greater accuracy with which they can be directed; but for the most part potential diversion sites are too inaccessible to be conveniently or quickly reached by artillery.

There are three principal ways in which bombing can bring about diversion of the fluid lava, thereby robbing the older flow below the point of diversion of its supply of lava and causing stagnation of the lower end of the flow. These are: (1) bombing of the natural levees along the open lava river of an aa flow or a young pahoehoe flow in which tubes have not yet formed; (2) bombing of the main feeding channel of a mature pahoehoe flow in which tubes have become well developed; and (3) bombing of the walls of the cinder cone at the source of the flow.

In well-established lava flows on little-dissected terrane the liquid lava of the main feeding channels commonly is confined within tubes or between natural levees and is at a level several feet higher than that of the land surface adjacent to the flow. Where the lava river is still open and confined between levees, breaking down of the levee therefore will allow the liquid lava to escape to one side and form a new flow, robbing the old flow of part or all of its supply of liquid lava. If topographic conditions are favorable, the new flow may move off at a high angle to the direction of the older flow, and reach some entirely different destination. More commonly, however, because the older flow was guided by

the direction of steepest slope or pre-existing topographic depressions, the new flow follows the same direction and moves downslope along the edge of the older one. If it does so, it may eventually reach the same place at which the older flow terminated. However, the advance of the lava as a whole is greatly delayed, because the diverted flow may take days, or even weeks, to reach the point attained previously by the older flow. When the second flow has reached the danger point, it also can be bombed, thus still further delaying the advance of the lava front.

A long stretch of the flow, or several separate points on the flow, may be suitable for bombing. If so, in general it appears advisable to select the lowest suitable site for bombing first. If it then becomes necessary to bomb the flow again at a later date the higher sites are still available. On the other hand, if the higher sites are bombed first the new lava streams advancing along the edges of the older one may so alter conditions that the lower sites are no longer suitable. In general, it appears desirable to wait as long as is safely possible before bombing the flow. Every day which bombing is delayed brings the eruption that much closer to an end, and, in general, sees the rate of extravasation diminished. Premature bombing may result in the process having to be repeated, whereas a single bombing might have sufficed had it been delayed a little longer. Care must be taken, however, to allow a sufficient margin of time to cover the possibility of periods of bad weather with low visibility (when bombing is impossible) and rapid forward spurts of the flow.

The practicability of breaking down the levee of an open lava stream by aerial bombing was demonstrated during the 1942 eruption of Mauna Loa (Finch, 1942, p. 4). Disruption of the levee by bombs resulted in at least one new lava stream which poured out through the break in the wall. Topography was not favorable to direct the new flow away from the course of the older one, and consequently it flowed along the edge of the older one for a short distance and then rejoined it. Even such a brief diversion may have some effect in retarding the advance of the front of the major flow, owing to the rapid cooling of the channel of the main flow below the point of diversion, and consequent chilling of the next lava to enter it, with the accompanying tendency to clog the channel.

The method of bombing the main tubes of a pahoehoe flow was tried during the 1935 eruption of Mauna Loa (Jaggar, 1936). Bombs dropped on the roof of the tube may break in the roof and cause the tube to become clogged with solid fragments. Or bombs dropped into the liquid lava within the tubes through the roof or through windows in the roof may cause sufficiently violent stirring of the liquid to transform it from pahoehoe to aa, with increase in viscosity or even local congelation. If it is not swept away with the current, this mass may cause a plugging of the tube. If in either way the tube becomes clogged, the result is an overflow of liquid lava from the tube at the point of clogging and a partial or total removal of the supply of liquid from the tube farther downslope. The lava which overflows at the break forms new tongues which advance downslope on top of, or alongside of, the older flow. If the eruption continues long enough these tongues may develop new major tubes, and may in time reach or pass the terminus of the older flow, but the advance of the lava as a whole will have been delayed and the end of the eruption will be that much closer. It may be possible to repeat the bombing if necessary.

The cinder and spatter cones formed at the source of lava flows commonly contain pools of lava which are held at levels several feet above the surrounding land surface. Likewise, the liquid surface of a mature lava flow issuing from the cone is generally several feet above the adjacent terrane. Breaking down of the cone walls, either naturally or induced by bombing, therefore will allow the liquid in the cone to escape over the surrounding ground, robbing the established lava flow of part or all of its supply of new lava. Many of the cones on the rifts of Mauna Loa have a form especially favorable for bombing. They are built by rows of lava fountains spurting from fissures, and are long and narrow, with relatively thin walls which probably would be quite easy to break down by bombing. Bombing of the walls of the source cone has been suggested (Finch, 1942, p. 6; Macdonald, 1943, p. 255), but has not yet been tried. However, during the 1942 eruption of Mauna Loa there occurred a natural breakdown of the cone walls liberating floods of pahoehoe. A new flow advanced seaward parallel to the older channel. A day later, forward movement at the front of the older flow had practically ceased.

Successful diversion of lava flows by bombing depends upon a combination of several favorable circumstances, including: a lava river flowing in a channel or lava held in the source cone at a level higher than the adjacent land surface; narrow levees, thin cone walls, or thinly roofed tubes which can be broken open by bombs; and favorable topography. The first two conditions are commonly present during eruptions of basaltic lava, but favorable topography is not so general. On the slopes of volcanoes which have been appreciably dissected by erosion, flows may be confined within valleys and diversion may be difficult or impossible. Even under those conditions, however, it may be possible to delay greatly the advance of the flow front by repeated bombing and spreading of the lava in the upper reaches of the valley. On the undissected or little-dissected slopes of young volcanoes, where erosion has not yet cut valleys, bombing to divert the flow is both possible and practical.

It must be pointed out that successful diversion is only possible where the flow has continued long enough to establish well-defined channels, or build at least moderate-sized cones. Probably little can be done with the voluminous bursts which occur during the early hours of Mauna Loa eruptions when the flows are spreading rapidly in several directions and moving through many shifting and anastomosing channels. Fortunately, these early floods are generally high on the mountain where they constitute no danger. Likewise, it must be realized that time is required to prepare the planes and load the bombs, as well as to select the targets and put the plan into operation. Therefore, diversion by bombing may not be possible in time to avert catastrophe where the flow is advancing rapidly down steep slopes, or where the point of outbreak of the flow is too close to the area it is desired to save. It is difficult to place any definite limit on the distance of the vent from the endangered area within which time is insufficient to permit bombing to divert the flow. This depends on the fluidity of the particular lava stream, on the slope, and on the general character of the terrane. For average Hawaiian eruptions, with average slope conditions, it may be about 7 miles. Where the distance is less than that, or where slopes are steep and flow of the lava rapid, only lava barriers such as those suggested by Jaggar (1945) can furnish protection.

REFERENCES

FINCH, R. H., 1942. THE 1942 ERUPTION OF MAUNA LOA. Volcano Letter 476:1–6.

JAGGAR, T. A., 1931. PREPAREDNESS AGAINST DISASTER. Volcano Letter 338:1–4.

——— 1936. THE BOMBING OPERATION AT MAUNA LOA. Volcano Letter 431:4–6.

——— 1945. PROTECTION OF HARBORS FROM LAVA FLOW. Amer. Jour. Sci. 243-A:333–351.

MACDONALD, G. A., 1943. THE 1942 ERUPTION OF MAUNA LOA, HAWAII. Amer. Jour. Sci. 241:241–256.

RITTMANN, A., 1929. DER ATNA UND SEINE LAVEN. Naturwissenschaften 17:94–100.

THURSTON, L. A., 1929. Honolulu Advertiser, Sept. 27 [newspaper].

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR OCTOBER–DECEMBER, 1949

VOLCANOLOGY

October

A total of 39 earthquakes was recorded in October. Of this total 31 were recorded at Kilauea and 37 at the Mauna Loa station. Two of these earthquakes, whose origins were determined, originated under Mokuaweoweo. The stronger of these two shakes was felt at Pahala at 07:55, October 22. Four shakes occurred in less than 15 minutes during the evening of October 26. Three of the shakes were plainly felt at the Kapapala ranch house. They originated along the Kaoiki fault near Kapapala.

The accumulation of northeasterly tilt at the northern end of Kilauea caldera during October was in about the usual amount for this season of the year.

November

An unusual feature of this month was a swarm of earthquakes under Mauna Kea. Sixteen shakes occurred between 09:46 and 20:31 on November 4. A few of the stronger shakes were felt by hunters who were at an elevation of 10,000 feet on Mauna Kea, and they were perceptible at scattered points on the island. An earthquake which occurred at 07:58, November 28, was felt over most of the island. It originated under the east slope of Mauna Loa near Mokuaweoweo at a depth of 20 miles and was strong enough to dismantle seismographs at Hilo, Kilauea caldera rim, and on the east slope of Mauna Loa.

There was about the usual accumulation of northeasterly tilt during the month.

A land slide from the walls of Halemaumau at 14:21, November 24, produced a large brown dust cloud.

December

A distinct feature of the month was the recording of 262 earthquakes on the Mauna Loa seismograph on December 28. Four of the shakes were registered as very feeble and the rest were small tremors. About 80 of the shakes were recorded on the Bosch-Omori seismograph under the Volcano House and 47 on the Kona instrument at Kealakekua. In at least two instances 3 distinct tremors were recorded in 30 seconds. Shortly before the shaking ceased, or at 23:02, continuous tremor started and lasted for 18 minutes.

The frequency of the tremor and the rather uniform small amplitude suggest an intrusion at moderate depth under the northeast rift of Mauna Loa at about 12,000 feet or above.

In addition to the swarm of earthquakes on December 28, 42 shakes were recorded during the month. Of this total 39 were recorded on the Mauna Loa instrument and 25 at Kilauea. Two of the earthquakes were strong enough to be perceptible and both originated under Kilauea. The first occurred at 03:06, December 11. It originated deep under Kilauea and was recorded on seismographs on Oahu. The second occurred at 15:09 also on December 11. It originated at a shallow depth under the northern end of Kilauea caldera and was accompanied by a distinct roar.

R. H. FINCH.

SEISMOLOGY

Earthquake Data, October–December, 1949

(Based on Bosch-Omori seismograph on rim of Kilauea caldera.)

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
October	8	7	2	1	0	0	3.75	0
	15	5	0	0	0	0	1.25	0
	22	7	2	0	0	0	2.75	1
	29	2	3	1	0	0	2.00	0
November	5	14	6	3	0	0	9.50	0
	12	2	0	0	0	0	0.50	1
	19	0	0	0	0	0	0.00	1
	26	3	1	0	0	1	4.25	2
December	3	2	0	0	0	0	0.50	0
	10	5	0	0	0	0	1.25	0
	17	5	1	2	1	0	5.75	3
	24	3	0	0	0	0	0.75	0
	31	88	0	0	0	0	22.00	1

* For definition of local seismicity, see Volcano Letter 371.

The data for the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

108. Oct. 2, 01:28, very feeble. South edge Kilauea caldera.
109. Oct. 3, 08:44, very feeble. 4-5 miles deep on Hilina-Paliokeawe fault 8 miles southeast of Volcano House.
110. Oct. 3, 16:57, very feeble.
111. Oct. 22, 03:51, very feeble. East slope Mauna Loa.
112. Oct. 22, 07:55, very feeble. Felt Pahala. South end Mokuaweoweo.
113. Oct. 23, 10:14, very feeble. East slope Mauna Loa.
114. Oct. 26, 17:58, feeble. Felt at Kapapala.
115. Oct. 26, 18:12, very feeble. Felt at Kapapala.
116. Oct. 27, 03:56, very feeble.
117. Oct. 30, 10:56, very feeble.
118. Nov. 4, 10:37, very feeble.
119. Nov. 4, 10:52, very feeble.

120. Nov. 4, 11:44, very feeble.
121. Nov. 4, 12:00, very feeble. 118 to 121 probably same location as 122.
122. Nov. 4, 12:12, feeble. Felt by hunters at 10,000 feet on Mauna Kea. At a depth of 20 miles under summit of Mauna Kea.
123. Nov. 4, 13:02, feeble. Same as 122.
124. Nov. 4, 14:10, feeble. Same location as 122.
125. Nov. 5, 18:45, very feeble. Under east slope of Mauna Kea.
126. Nov. 23, 02:49, very feeble. Mauna Loa.
127. Nov. 25, 07:58, moderate. Instruments dismantled. Felt locally and from North Kona to Hilo. 20 miles under east slope of Mauna Loa near Mokuaweoweo.
128. Dec. 11, 03:06, feeble. Felt locally. Deep under Kilauea.
129. Dec. 11, 15:08, slight. Felt locally and accompanied by roar. Under north end of Kilauea caldera.
130. Dec. 12, 18:56, feeble. Kilauea.
131. Dec. 16, 07:35, very feeble.

TELESEISMS

Oct. 19, 11:11, slight. Solomon Islands.
Nov. 9, 13:32, slight. North of Easter Island.
Nov. 19, 22:29, slight. Gulf of California.
Nov. 21, 15:02, slight. Kermadec Islands.
Nov. 26, 22:52, slight. Tonga.
Dec. 16, 21:46, slight.
Dec. 16, 22:16, slight.
Dec. 17, 05:58, slight. Near southern tip of South America.
Dec. 25, 20:45, slight.

MICROSEISMS

Microseisms were slight October 26-28 and November 17-21 inclusive, strong from November 12-14, and moderate on other days.

CRACK MEASUREMENTS

The northern end of the crack at the observation area on the east rim of Halemaumau opened 2 millimeters during the 3 months ending December 31. All other cracks that were measured showed little or no movement.

TILTING OF THE GROUND

There was an accumulation of north tilt amounting to 3.3 seconds of arc between October 1 and November 21. The seasonal change to southerly tilt occurred earlier than common, and from November 22 to December 31 there was an accumulation of 2.2 seconds of south tilt. The 4.8 seconds of east tilt between October 1 and December 31 was about the usual for this season of the year.

Table of Tilt at Seismograph Vault on Northeast Rim of Kilauea Caldera

Week Ended		Amount	Direction
Oct.	8	0.7″	N 9° E
	15	2.1″	N 47° E
	22	0.3″	N 26° E
	29	0.7″	N
Nov.	5	0.4″	S 34° W
	12	1.1″	N 26° E
	19	1.5″	N 76° E
	26	0.6″	S 54° W
Dec.	3	1.0″	N 70° E
	10	1.1″	S 12° E
	17	1.3″	S 73° E
	24	1.5″	S 39° W
	31	0.6″	N 53° E

TEMPERATURE MEASUREMENTS

There was a positive decrease in the temperature of the steam well at Sulfur Bank. The decrease amounted to 2° F.—from 206° F. on October 1 to 204° on November 30. The temperature in December appeared to be nearly constant at 204° F. A vent in the Sulfur Bank showed a similar drop from 205° F. on October 1 to 203° F. on December 28. The decrease does not show a good correlation with heavy rainfall and perhaps is a regular seasonal change.

The highest temperature found in the Kokoolau steaming area on November 4, 1949, was 190° F., or a little less than was common for several years after it was noted that trees were being killed there in 1938.

At the Aloi crater steaming area the highest temperature found on November 4 was 194° F.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:
R. H. Finch, Volcanologist, Director
G. A. Macdonald, Geologist
C. K. Wentworth, Geologist, part-time
B. J. Loucks, Instrument maker
Ruth B. Loucks, Assistant

University of Hawaii:
T. A. Jaggar, Geophysicist

Seismograph Station Operators:
Hilo Station:
Brother B. T. Pleimann, Saint Joseph's School
Kealakekua Station:
H. M. Tatsuno, Konawaena School

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter**, a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

THE VOLCANO LETTER

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THERMAL WATER ON KILAUEA VOLCANO

By RUY H. FINCH and GORDON A. MACDONALD

The numerous steam vents within Kilauea caldera are well known. For the most part the steam contains no other gases and appears to represent merely ground water of meteoric origin which has been heated to, or slightly above, the boiling point by contact with bodies of hot rock. At Sulphur Bank and at the nearly buried solfataric area east-southeast of Halemaumau the steam is mixed with a small proportion of sulfur gases and carbon dioxide of magmatic origin, but even there the majority of the steam probably is derived by heating of ground water.

In addition to the steam vents at Kilauea caldera, there are four known occurrences of warm water on Kilauea volcano. It has been reported in a crack near Waiwelawela Point, 12 miles east of Pahala (Stearns and Clark, 1930, p. 190), but no record of the temperature of the water at that locality is known. The warm water undoubtedly results from heating of basal ground water by contact with hot intrusive rock along the southwest rift zone of Kilauea.

The other three occurrences of warm water are all in eastern Puna, on or near the east rift zone of Kilauea. One of these is the well-known "Warm Spring" near the northern base of Puu Kukae, about 0.8 mile east-northeast of Kapoho. The water is basal ground water. It forms a pool in a crack at the foot of the small fault scarp which marks the southern edge of a small graben, or block of rock which has sunk down between two faults. Brigham (1868, p. 374) reported that in 1864 this pool (called by him the "Blue Grotto") had a temperature of 90° F. At present the temperature is only a little above the average air temperature. Measurements on January 11, 1950, gave a water temperature of 84° F. and an air temperature of 79°.

Another pool of warm water is situated half a mile northwest of that just described and within the same graben. The water is in a crack at the back of a shallow cave, the entrance of which is at the base of a low northward-facing fault scarp about 750 feet south of the higher fault scarp that marks the northern edge of the graben. The locality is about 0.6 mile north of the highway junction at Kapoho and 0.2 mile east of the Kapoho-Koae road. At one time the water was bottled for sale under the trade-mark "Volcano Water." The temperature of the water is only a little above that of the air outside the cave. On January 11, 1950, the water temperature was 83° F., and the temperature of the air in the cave was 77°.

The third occurrence of warm water is at Pohoiki, about 3 miles south of Kapoho. There basal springs issue just above sea level from a cobble beach at the head of a small bay. The springs are within the zone of splash from the ocean waves and are distinctly brackish. On January 11 the water temperature was 91° F., and the air temperature 77°.

No other warm waters are known on the island of Hawaii, although steam issues from vents in the caldera of Mauna Loa and on both rift zones. The amount of warm water, at first glance, seems surprisingly small in view of the large amount of volcanic heat undoubtedly still present beneath the surface. However, because of the high permeability of the rocks, as Stearns and Clark (1930, p. 190) have pointed out, most juvenile and meteoric hot waters probably become diluted and cooled at the basal water table and do not reach the surface.

REFERENCES

BRIGHAM, W. T. NOTES ON THE VOLCANIC PHENOMENA OF THE HAWAIIAN ISLANDS . . . . Boston Soc. Nat. Hist. Mem., vol. 1, pp. 341–472, 1868.

STEARNS, H. T., and CLARK, W. O. GEOLOGY AND WATER RESOURCES OF THE KAU DISTRICT, HAWAII. U. S. Geol. Survey, Water-Supply Paper 616, 194 pp., 1930.

ORIGIN OF PUEHU CINDER CONE, KAU

By GORDON A. MACDONALD and RUY H. FINCH

Puehu cinder cone is a small but prominent cone situated just south of the main highway from Kilauea caldera to Honuapo, about 0.4 mile southwest of the junction with the road to Punaluu. It lies on the southern slope of Mauna Loa about 1.2 miles west of the boundary between the surface lavas of Mauna Loa and Kilauea and is surrounded and partly buried by aa lavas of Mauna Loa. The cone is being excavated to supply cinders for use on roads. Before the mining of cinders began, the cone was about 50 feet high above the lavas on its downhill side, and its exposed base was about 200 feet above sea level. At present a large pit on the southeastern side of the cone exposes cinder for a depth of about 100 feet and has not yet reached the base of the cone.

Stearns and Macdonald (1946, pl. 1) classified the cone as a littoral cone of the Kau volcanic series, formed by steam explosions where lavas of Mauna Loa entered the sea. The better exposures which have resulted from recent excavation indicate that interpretation to be erroneous.

Puehu cone clearly is a cone formed at a primary lava vent. The ejecta exposed in the new cuts are typical of primary cinder cones built at vents. They are moderately to highly vesicular, or even pumiceous, cinder and spatter. Moreover, several thin layers of lava are interbedded with the cinder, some of them obviously rootless flows formed by the aggregation of heavy showers of fluid spatter on the flanks of the cone. Some of these flows still show welded spatter on their surfaces. Lava extends all the way to the summit of the cone, 25 feet higher than the surface of the adjacent aa flow on the uphill side of the cone. On the northeastern side of the cone there is exposed a 15-foot thick section of thin-bedded pahoehoe, the beds ranging from 1 to 6 inches thick and averaging 2 to 3 inches. The rock is olivine basalt with sparingly to moderately abundant phenocrysts of olivine up to about 4 mm. long; much of it is highly vesicular. Such very thin-bedded, highly vesicular pahoehoe typically is found in close proximity to primary vents. Neither it nor the rootless flows would be expected to form on a littoral cone where relatively viscous aa lava enters the sea, nor have they been observed on known littoral cones.

Besides the presence of the aforementioned features typical of cones formed at primary vents, there is a complete absence of the features typical of littoral cones. The angular grains of relatively dense glass, which are characteristic of littoral cone deposits (Macdonald, 1949, p. 72), could not be found. Neither are there present any of the angular blocks of relatively dense lava which are common on the slopes of Puu Hou, the littoral cone formed by the Mauna Loa flow of 1868, and the older littoral cones farther west.

The lower slopes of Puehu cone in the new excavations are covered by as much as 15 feet of yellow Pahala ash, with one intercalated lava flow. The cinder layers in the cone were partly truncated by erosion before deposition of the ash. The Pahala ash is absent from most of the top of the cone, but 2 to 3 feet of ash are preserved in local pockets. Most of the ash appears to have been eroded off the upper slopes of the cone. The ash overlying the lower slopes appears to be the result of primary deposition, and there is no evidence that the thickness of the ash layer resting on the lower slopes of the cone was appreciably increased by secondary deposition of ash eroded from the top of the cone.

The presence of 15 feet of Pahala ash overlying the lower slopes of the cone indicates that the cone is somewhat older than previously was believed. Obviously, it must already have been in existence during the period of deposition of the Pahala ash, and therefore it is older than the rocks of the Kau volcanic series, which are younger than the Pahala ash. However, the Pahala ash has a thickness of 55 feet on Puu Enuhe, only 2.5 miles northwest of Puehu cone (Stearns and Clark, 1930, p. 66). Consequently, it is probable that only part of the total thickness of the Pahala ash overlies the Puehu cone and that the cone is of late Pahala age.

Puehu cone is situated about 12 miles east of the southwest rift zone of Mauna Loa and even farther from any other known vents of Mauna Loa. It lines up with no known Mauna Loa rifts. In contrast, it is only about 3.5 miles from the closest visible vent on the southwest rift zone of Kilauea volcano and lies directly in line with that rift. The cone itself is somewhat elongated in a direction parallel to the Kilauea rift, possibly because the vent fissure had that trend. Although it cannot be definitely proved, it appears highly probable that the cone was formed by eruption from the southwest rift of Kilauea and that it belongs to Kilauea rather than to Mauna Loa.

It is concluded that Puehu cone is a primary cinder cone formed by eruption at a lava vent during late Pahala time, and that it probably belongs in the Hilina volcanic series of Kilauea volcano and is correlative with the upper part of that series exposed in Hilina Pali. If this interpretation is correct, the southwest rift zone of Kilauea must have been in existence at least by late Hilina time, thus strengthening the conclusion of Stearns

and Macdonald (1946, pp. 135–136) that the Hilina volcanic series was derived from Kilauea, as opposed to the belief of Stone (1926, pp. 38, 49–50) and Powers (1946, p. 6) that the Hilina lavas are part of Mauna Loa.

REFERENCES

MACDONALD, G. A. PETROGRAPHY OF THE ISLAND OF HAWAII. U. S. Geol. Survey, Prof. Paper 214-D, pp. 51-96, 1949.

POWERS, H. A. REVIEW OF "GEOLOGY AND GROUND-WATER RESOURCES OF THE ISLAND OF HAWAII," BY H. T. STEARNS AND G. A. MACDONALD. Volcano Letter, 494, pp. 1-6, 1946.

STEARNS, H. T., and CLARK, W. O. GEOLOGY AND WATER RESOURCES OF THE KAU DISTRICT, HAWAII. U. S. Geol. Survey, Water-Supply Paper 616, 194 pp., 1930.

——— and MACDONALD, G. A. GEOLOGY AND GROUND-WATER RESOURCES OF THE ISLAND OF HAWAII. Hawaii Div. Hydrography, Bull. 9, 363 pp., 1946.

STONE, J. B. THE PRODUCTS AND STRUCTURE OF KILAUEA. B. P. Bishop Mus. Bull. 33, 59 pp., 1926.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JANUARY–MARCH, 1950

VOLCANOLOGY

January

The year opened with both Kilauea and Mauna Loa inactive save for the usual steam vents and solfataras.

Only 24 earthquakes were recorded during the month. This is the smallest monthly total since October, 1948. Twenty-two of the shakes were recorded on the Mauna Loa seismograph and 17 at Kilauea.

There was an accumulation of 7.8 seconds of arc tilt to the south-southwest during January. This is a little more than usual for this season of the year.

The fact that the lava fill in Halemaumau is still hot was shown by pronounced steaming following heavy rains on January 10.

February

A total of 29 earthquakes was recorded during February. Of this number, 26 were recorded on the Mauna Loa seismograph and 21 at Kilauea.

Dust clouds were especially conspicuous in the Kau Desert on February 12.

A landslide of appreciable magnitude from the walls of Halemaumau was observed at 09: 50 on February 13.

March

Northerly tilt during March indicates that there was a distinct pressure build-up at Kilauea. This increase of pressure was strong enough to overcome the southerly tilt usual for March and to show a positive northerly tilt of 6 seconds of arc. This is the strongest northerly tilt recorded here for several years.

The distribution of the earthquakes recorded during March also indicates a slight uneasiness under Kilauea volcano. Of the 37 shakes recorded during the month, 35 were registered on the Kilauea seismograph and 16 on the Mauna Loa instrument. Most of the earthquakes of Kilauea origin had shallow foci.

Mokuaweoweo was visited by G. A. Macdonald and J. B. Orr on March 28 to 30. No activity was observed other than the mild solfataras, and no changes were noted since the last visit in October, 1949, other than minor collapses in the small cones built during the 1949 eruption. Solfataras are located in the crater of the 1940 cone, on its northern slope, and on the caldera floor north of it. The gas liberated is largely steam, but contains a little sulfur dioxide and in places a small amount of sulfur is being deposited. The 1949 cones are still hot at many places, a little steam is being given off, but no sulfurous gas was detected. Pale yellow stalactites, probably of sulfates, are forming in the hollow 1949 cone. Collapse of the walls of the crater of the 1949 lava cone has reduced the depth of the crater to about 15 feet.

R. H. FINCH

CRACK MEASUREMENTS

None of the cracks that are regularly measured showed an appreciable movement during the 3 months ended March 31.

TILTING OF THE GROUND

Strong southerly tilt set in shortly after the beginning of the year and continued until February 9. The accumulation for the period amounted to 11 seconds of arc. From February 9 to March 5 there was no accumulation of tilt in the N-S direction. Strong northerly tilt commenced on March 6, or about 1 month earlier than usual. The northerly tilt from March 6 to 31 amounted to 6 seconds of arc.

Table of Tilt at Seismograph Vault on Northeast Rim of Kilauea Caldera

Week Beginning		Amount	Direction
January	1	1.4″	S 41° E
	8	2.0″	S 10° E
	15	2.2″	S 52° W
	22	2.0″	S 10° W
	29	1.4″	S 41° W
February	5	2.2″	S 45° E
	12	0.5″	S 64° W
	19	0.3″	N 61° W
	26	1.2″	S 65° W
March	5	1.2″	N 36° W
	12	0.2″	N
	19	2.2″	N 4° E
	26	2.3″	N 3° E

SEISMOLOGY

Earthquake Data, January–March, 1950

(Based on Bosch-Omori seismograph on rim of Kilauea caldera.)

Week Beginning		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
January	1	4	0	0	0	0	0	1.00	0
	8	4	0	0	0	0	0	1.00	1
	15	3	2	0	0	0	0	1.75	0
	22	2	0	1	0	0	0	1.50	0
	29	3	0	0	0	0	0	0.75	0
February	5	4	0	0	0	0	0	1.00	0
	12	0	1	0	2	0	0	4.50	0
	19	6	1	0	0	0	0	2.00	0
	26	3	2	1	0	0	0	2.75	1
March	5	7	2	0	0	0	0	2.75	0
	12	7	2	0	1	0	0	4.75	0
	19	7	0	0	1	0	1	8.75	0
	26	11	2	0	0	0	0	3.75	0

* For definition of local seismicity, see Volcano Letter 373.

The data for the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

1. Jan. 13, 11: 54, very feeble. Inland from Kealakekua Bay.
2. Jan. 20, 19: 31, very feeble. Mauna Loa.
3. Jan. 21, 04: 40, very feeble. Near summit of Mauna Loa.
4. Jan. 25, 16: 26, feeble. Felt at 29 Miles and Hilo.
5. Feb. 12, 06: 09, slight. Felt locally and at Naalehu. Near Makaopuhi.
6. Feb. 13, 11: 59, slight. Felt locally and at Hilo. Eight miles deep under east slope of Mauna Loa.
7. Feb. 15, 16: 52, very feeble. Mauna Loa.
8. Feb. 19, 08: 00, very feeble.
9. Feb. 26, 14: 01, very feeble. Kilauea.
10. Feb. 28, 04: 26, very feeble. Mauna Loa.
11. Mar. 1. 08: 00, feeble. Southwest of Hilo.
12. Mar. 7, 21: 47, very feeble. Mauna Loa.
13. Mar. 11, 19: 59, very feeble. Kilauea.
14. Mar. 17, 02: 35, slight. Shallow; under Kilauea.

15. Mar. 17, 04 : 05, very feeble.
16. Mar. 24, 14 : 14, slight. Shallow ; under Kilauea.
17. Mar. 25, 05 : 43, strong. Widely felt on island of Hawaii. Seismographs dismantled. 15-20 miles deep under 5,000-foot contour, east slope of Mauna Loa.
18. Mar. 28, 10 : 57, very feeble. Mauna Loa.
19. Mar. 31, 03 : 43, very feeble. Kilauea.

TELESEISMS

Jan. 9, 17 : 30, slight. Off south coast of Mexico.
Feb. 28, 00 : 30. North coast of Hokkaido.

MICROSEISMS

Microseisms were moderate during the first 2 weeks of January and the last few days of March and slight on other days.

TEMPERATURE MEASUREMENTS

The temperature of the steam well at the Sulfur Bank was 206° F. in October, 1949, then dropped to 204° F. in November. The 204° F. temperature continued until the latter part of March, when a temperature of 202° F. was measured.

MAGNETIC OBSERVATIONS

H. R. Joesting and J. H. Swartz of the Geophysics Branch of the Geological Survey, and R. E. Wilcox of the Volcano Investigations Unit, spent the first 3 weeks of February at the Observatory setting up procedures to be followed in a program of magnetic observations and calibrating instruments and instructing Observatory personnel in their use. The instruments to be used are two Askania-type magnetometers built by Wolfson of Toronto. A series of permanent observation stations is being established on Kilauea and the lower slopes of Mauna Loa, and periodic readings will be taken to determine the variation in the vertical component of the earth's magnetic field, particularly the changes in differences between the various stations.

The magnetic permeability of rocks is decreased by an increase of temperature, and above a certain temperature (known as the Curie point) they become entirely non-magnetic. Thus a body of hot magma rising beneath the surface of the volcano should be non-magnetic, and the rocks around and above it should become less and less magnetic as they are heated up. It is hoped that this reduction in strength of magnetism may be detectable at the surface, and that the effect may appear long enough before the magma reaches the surface to be useful in predicting eruptions.

During February and early March, 29 stations were established around and in Kilauea caldera, along the Chain of Craters road and the upper part of the Hilina Pali road, and along the road to the Mauna Loa seismograph. At each station concrete blocks were built on which to set up the tripod of the magnetometer. It is planned to occupy each of the stations at least once a month, and oftener if possible.

On March 27 to 30 a series of dip-needle measurements was made on Mauna Loa by G. A. Macdonald of the Observatory staff and J. B. Orr of Hawaii National Park as part of the general study by the Observatory of earth magnetism in the vicinity of the volcanoes. The measurements were made along the trail from Kilauea to the summit of Mauna Loa, part way around the summit caldera, and across the floor. Preliminary analysis of the results shows that in general the strength of the magnetic attraction was less along the rift zones than elsewhere on the mountain. It is to be expected that these zones would be hotter than the rest of the mountain and have a smaller magnetic attraction.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:
R. H. Finch, Volcanologist, Director
G. A. Macdonald, Geologist
C. K. Wentworth, Geologist, part-time
B. J. Loucks, Instrument maker
Ruth B. Loucks, Assistant

University of Hawaii:
T. A. Jaggar, Geophysicist

Seismograph Station Operators:
Hilo Station:
Brother B. T. Pleimann, Saint Joseph's School
Kealakekua Station:
H. M. Tatsuno, Konawaena School

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter**, a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

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THE JUNE 1950 ERUPTION OF MAUNA LOA

By R. H. FINCH and GORDON A. MACDONALD*

Part I

NARRATIVE OF THE ERUPTION

INTRODUCTION

Following the end of the 1949 summit eruption of Mauna Loa, magma pressure remained high, and the molten lava continued to stand high in the conduit. A moderate release of fume continued in the summit caldera throughout the rest of 1949 and the spring of 1950. A normal accumulation of eastward ground tilting was recorded at the Volcano Observatory during the fall of 1949, but during the spring of 1950 westward tilting was markedly less than usual, apparently indicating a tumescence of the mountain. On the basis of past history, it was expected that the summit eruption would be followed by a flank eruption, probably within 2 years; the apparent high position of the magma column suggested that the interval might well be shorter. During May many earthquakes originated at Mauna Loa and pointed to a distinct uneasiness of the volcano. These culminated on May 29 with a strong earthquake originating on the southwest rift near the summit. In a bulletin released by the Observatory, published in newspapers on May 30, Finch called attention to the unrest of the southwest rift of Mauna Loa and stated that if the eruption came soon it would take place there. The expected eruption came on the evening of June 1, 1950.

ACKNOWLEDGMENTS

Many people gave valuable aid during the eruption by contributing information on the activity. It is impossible to list all by name, but to all of them we extend our sincere thanks. Some persons should receive special mention. Colonel L. W. Bryan, island commander of the Hawaii National Guard and island forester of the Territorial Board of Agriculture and Forestry, was exceedingly active in making observations from the air and deserves much credit for his work in keeping track of the flows and warning of danger from them during the first days of the eruption. His unsurpassed knowledge of the terrain was of very great aid. William Stearns and Donald Campbell of Murray Aircraft Agricultural Service contributed many excellent observations from the air. Sergeant Wilmot Vredenburg of the Hawaii Police Department passed on much information on the activity of the Ohia Lodge flow near the highway. Ernest Martin, manager of Kahuku Ranch, contributed information on the lava flows in the Kau District from personal observations and from those of his cowboys. Mrs. Myrtle Hansen of Naalehu was exceedingly helpful in relaying information from various sources in the Naalehu and Waiohinu area as well as in contributing her own observations on the lava flows and earthquakes.

Harry Blickhahn, editor of the *Hilo Tribune-Herald,* and Vern Hinkley, managing editor of the *Honolulu Star-Bulletin,* also were very helpful in passing on information and photographs as they received them.

Pilots of Army and Navy planes made observations from the air, and several of these, as well as observations by commercial pilots, were relayed by the staff of the Civil Aeronautics Authority at Hilo.

Members of the staff of Hawaii National Park contributed many valuable observations on the flows and vent activity. F. A. Hjort, chief ranger, and V. R. Bender, ranger, made aerial observations on the morning of June 2 and observations on the ground at the lower line of vents on June 3 and 4. F. R. Oberhansley, superintendent, I. J. Castro, assistant superintendent, and Herbert Quick, superintendent of construction and maintenance, observed the vent activity from the air on June 3.

* Director and Geologist, respectively, Hawaiian Volcano Observatory, U. S. Geological Survey, Hawaii National Park.



FIGURE 1. Map of the island of Hawaii, showing the approximate positions of the lava flows of June, 1950 (solid black). Numbers in circles indicate the flows referred to in the text: 1. Flow from the initial outbreak above 11,000 feet altitude; 2. Punaluu flow; 3. Hookena flow; 4. Magoon Ranch flow; 5. Ohia Lodge flow; 6. Kahuku flow. Older historic flows are stippled. Most of the flows originate along the two major rift zones.

D. H. Hubbard, naturalist, made observations from the sea and from the ground at the northern side of the Hookena flow on June 2 and 3.

D. C. Cox, geologist for the Hawaiian Sugar Planters' Association, cooperated with the Volcano Observatory staff in making observations on the lava flows and the vent activity and furnished the Observatory with a complete set of his field notes.

Several members of the U. S. Geological Survey not attached to the Observatory staff also cooperated in the investigation and were of great aid in the collection of data in the field. They include C. K. Wentworth, geologist for the Honolulu Board of Water Supply and part-time geologist for the Observatory; D. A. Davis, district geologist; M. H. Carson, district engineer; G. D. Robinson, assistant chief of the General Geology Branch; and Arnold Mason, geologist with the Pacific Geological Surveys Section. H. R. Joesting and J. R. Swartz of the Geophysics Branch carried on magnetometer observations during the eruption.

NARRATIVE

On the evening of June 1, 1950, Mauna Loa volcano erupted from its southwest rift. Glow was first seen from the Volcano House at Kilauea at about 9:25 P.M., but harmonic tremor started registering on the seismograph at 9:04 and it is probable that the eruption actually started then or very shortly afterward. About 9:10 Mr. and Mrs. Alfred Hansen, in Naalehu, heard a deep rumbling from the direction of the top of the mountain.

The first outbreak was high on the rift. At first two narrow illuminated columns of fume were visible, but these rapidly expanded down the mountain slope. A fissure 2.5 miles long opened from about 12,600 to 11,250 feet altitude, the upper end being close to the small pit crater Lua Hou and the lower end near Sulphur Cone. From this fissure poured great volumes of fume rising in a relatively narrow column about 2 miles into the air then spreading laterally to form a mushroom-shaped cloud brightly illuminated by the glare of the incandescent lava beneath. A flood of fluid gas-rich

lava poured from the fissure and down the mountainside, most of it going westward toward the Kona District. Many short flows were formed, and one long flow (flow 1, Fig. 1) extended downslope about 5 miles to an altitude of about 9,000 feet. Robert Duncan of Pahala reported hearing the roar of the lava fountains about 15.5 miles away, at the junction of the Kapapala Ranch road with the highway.

The outbreak at the upper source lasted only a few hours. By 12:30 A.M. on June 2, the glow at the upper source was distinctly less, and by 1:30 A.M. it was feeble. At that time the activity at the upper source had diminished greatly and may already have been finished.

At 10:15 P.M. on June 1, observers at the Volcano Observatory and along the Kau-Volcano highway noticed a small puff of fume rising from a point on the rift at about 8,250 feet altitude approximately 8 miles southwest of the lower end of the glowing fume column at the upper source. At 10:23 bright glow appeared on the fume cloud, indicating that fluid lava had reached the surface. The illuminated fume column rapidly spread as the length of the erupting fissure increased. Margaret Finch, watching from the Volcano Observatory, observed the glow expanding up the mountain, indicating that the fissure opened upslope. The glow from this lower source continued to increase rapidly until 10:45, when it was obscured by clouds. Lava fountain activity was very strong. At 11:40 Finch and Macdonald could hear the roar of the lower fountains distinctly at the point where the highway crosses the western branch of the 1907 lava flow, nearly 15 miles from the site of the eruption.

Early on the morning of June 2 the activity was observed from the air by Frank Hjort. He reported lava fountaining from a line of fissures about 7 miles long extending from about 10,500 down to 8,000 feet altitude. Between the main line of fissuring and the shorter westerly line a broad pond of molten lava had accumulated. Floods of very fluid lava were pouring westward toward Kona, in a series of anastomosing streams. Lava from the principal fissure was pouring over the shorter westerly fissure, partly drowning it. Sulfur dioxide fumes were very strong. About noon Ross Bender flew over the source area. He reported two principal lines of lava fountains playing along fissures at approximately 10,000 and 8,500 feet altitude. The source at 10,000 feet was largely obscured by fume, but no lava movement was observed there or in the flows originating there. From the source at 8,500 feet great floods of lava were pouring westward. At the time of his first observations lava fountains were playing from several isolated stretches of the fissure below 9,000 feet, but while he watched the activity increased and fountains developed along the intervening portions of the fissure, making the curtain of fountains essentially continuous. Some of the fountains he estimated to be about 300 feet high.

A similar condition was reported on the afternoon of June 3, when Frank Oberhansley, I. J. Castro, and Herbert Quick flew over the scene of activity. The lava fountains formed an almost continuous "curtain of fire," averaging 150 to 200 feet high, with some of the bursts reaching 300 feet or even more.

The line of fissures forming the lower source was not continuous. Over a stretch of about 2.5 miles, between 8,950 feet and 9,750 feet altitude, there appears to have been no lava liberation. Between 9,750 and 10,500 feet altitude there was a line of active fountains 1.6 miles long. Below 8,950 feet altitude there was a series of nearly aligned fissures, en echelon and commonly slightly overlapping.

During the first few hours of the eruption two very rapid flows were poured out from the vent area centering at 10,000 feet altitude. One of these (flow 2, Fig. 1) advanced south-southeastward in the general direction of Punaluu. By daybreak on June 2 it had passed the ranch road a short distance west of Punaluu Kahawai. On the morning of June 2 it was examined from the air by L. W. Bryan. At that time it had reached an altitude of about 5,500 feet, approximately 10 miles from its source, but its advance appeared to be essentially over.

The other flow (flow 3, Fig. 1) from the 10,000-foot source moved rapidly westward into the Kona District. At 12:20 it was less than a mile above the highway, and Ruth Macdonald reported that the roar and explosions caused by the lava advancing through the forest were clearly audible and the glare from hot lava and burning vegetation was strong. The flow crossed the highway at about 12:30, destroying Hookena Post Office, several houses, and a filling station. There was a light but steady fall of fine black ash and some Pele's hair mixed with rain. The flow reached the sea, 0.8 mile below the highway, at about 1:05 A.M. on June 2, having covered its 15-mile course down the mountainside at an average rate of 5.8 miles an hour. Where the hot lava entered the sea, a great billowing column of steam arose. However, observers reported no apparent increase in the amount of ash in the air. This first flow to reach the ocean is termed hereafter the Hookena flow.

By daylight lava movement in the Hookena flow had greatly diminished. By 11:00 A.M. it had practically ceased, and very little steam was rising where the flow entered the ocean.

Early on the morning of June 2 another flow branched off from the Hookena flow. The new flow (flow 4, Fig. 1) diverged southward from the older one, and at about 5:00 A.M. it crossed the highway at the Magoon Ranch house, 1.2 miles south of the earlier flow. The ranch house was destroyed, as also were two or three other

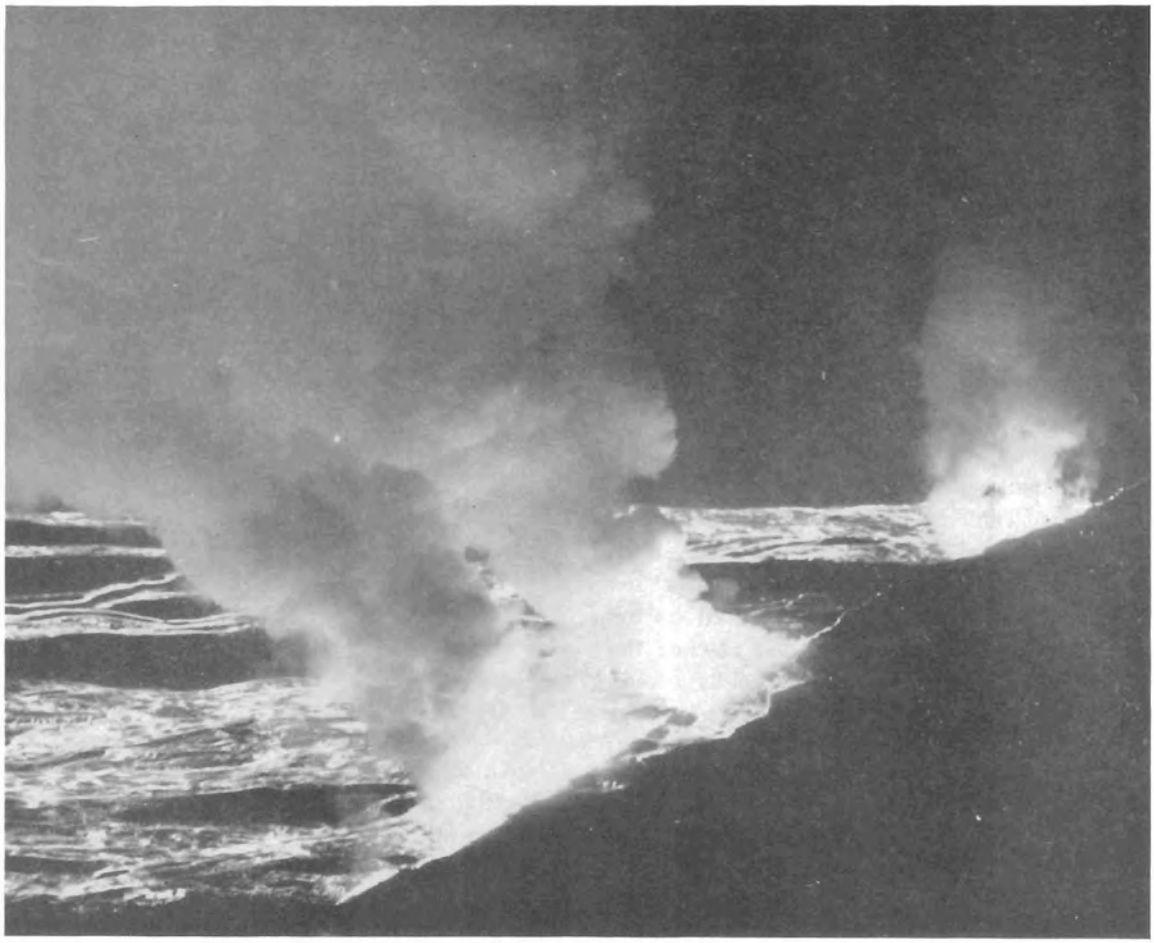

PLATE 1. Floods of lava and clouds of fume issuing from the eruptive fissure at 3:00 A.M. on June 2, 1950. The lava is flowing westward toward Kona. PHOTO BY HONOLULU STAR-BULLETIN.

houses. The flow was aa in character. Along the highway just south of the main ranch house, the advance of the lava was checked by a loose stone wall, about 3 feet high. The lava eventually piled up enough to spill over the wall, but it does not appear to have seriously damaged the wall, and for a distance of about 250 feet it spread only 15 to 20 feet beyond the wall. Farther north the flow continued unchecked on down the mountainside. It entered the sea at 12:04 P.M., destroying another house and part of a coconut grove.

For about an hour and a half before it reached the ocean, the advance of the flow was observed by Macdonald and B. J. Loucks. By that time the lava had lost its initial great fluidity and was creeping ahead at a rate of only about 750 feet an hour. The flow was descending a steep slope half a mile inland and spreading out as a broad fan over the flat sparsely vegetated terrane near the coast. As the edge of the flow engulfed the few large trees there were minor explosions, with flashes of flame. Occasionally similar roars and flashes came from the central part of the flow, probably from tree trunks buried in the flow. Many tree trunks were carried down with the flow from farther upslope. Some of these rode along on the flow surface or projected upward from it, flaming like torches.

At 11:30 A.M. the volume of lava in the flow suddenly increased, and a new flood of lava moved out over the older still-moving flow on the steep slope below the highway. At the base of the slope the new aa front spread out fanwise over the older lava, flowing at about twice the speed of the earlier front, which itself was still advancing. At 12:04 the first front entered the ocean, and a huge column of steam arose in great billows with a cork-screw motion rotating counterclockwise. No sign of ash being thrown up where the flow entered the sea could be seen. At 12:10 the second gush of lava reached the sea. The steam column increased, but there was no evidence of any strong explosive action or any appreciable amount of ash being thrown up. In the meantime the constant light fall of fine black ash, with some Pele's hair, continued as it had all morning.

By the afternoon of June 3 movement in the Magoon Ranch flow appeared to have largely or wholly ceased although the column of steam rising where the flow entered the ocean appeared strong.

Another flow appears to have started late on the night



PLATE 2. Lava fountains as much as 250 feet high playing along part of the fissure on the morning of June 2, 1950. OFFICIAL PHOTOGRAPH, FLEET AIR PHOTOGRAPHIC LABORATORY UTILITY SQUADRON 7, U. S. NAVY.



PLATE 3. Braided lava streams flowing westward near the active rift on the morning of June 2, 1950. OFFICIAL PHOTOGRAPH, FLEET AIR PHOTOGRAPHIC LABORATORY UTILITY SQUADRON 7, U. S. NAVY.

of June 1, advancing westward south of the Magoon Ranch flow. Because it later destroyed the Ohia Lodge, this flow (flow 5, Fig. 1) may be called the Ohia Lodge flow. The earlier flows started at the erupting fissure at about 10,000 feet altitude, but the Ohia Lodge flow originated at the lower line of fissures between 8,000 and 9,000 feet altitude. At 12:20 P.M. on June 2, Macdonald and Loucks were with a police detail and a small group of refugees at Ohia Lodge waiting developments from this new flow which was known to be advancing through the forest a short distance above the road. Because of the large amount of smoke and fume, combined with a low cloud cover, visibility was very poor and the exact location of the flow front was unknown. About 12:30 a patroling National Guard plane flew over at very low altitude and dropped two Mae West life jackets to which were attached warnings to leave immediately for the southward. These instructions were carried out.

At approximately 2:00 P.M. the Ohia Lodge flow reached the highway about a quarter of a mile south of Ohia Lodge and 4 miles south of the Magoon Ranch flow. At about 3:30 P.M. it entered the ocean just north of Heku Point, having taken an hour and a half to cover the 1.3 miles from the road to the sea. Again a great billowing cloud of steam arose with a counterclockwise rotational movement, but again there was no sign of violent explosion or of the formation of any appreciable amount of ash where the lava entered the sea.

By 5:00 P.M. a line of steaming water, marking the sub-sea course of the flow, extended out to sea for about half a mile from the point where the Ohia Lodge flow entered the ocean. Close to the shore and directly over the submerged flow, the water was boiling, and a semicircular area of hot turbulent water extended for a mile offshore. Many fish were killed and were seen drifting or were washed up on the shore during succeeding days. The prevailing currents drifted the area of hot water southward. Off Milolii, 5 miles south of the flow, many charred logs were seen floating in the water. These were the remains of tree trunks carried down on the top of the flows and dumped into the sea.

At 4:00 P.M. the Ohia Lodge flow was about 750 feet wide and 10 feet thick at the highway. Its outer edges were slowly moving fields of aa, creeping along at a rate of only a few feet an hour. Near its center there appeared to be a narrow, more rapidly moving, lava river, but visibility was very poor and the edge of the flow was still too hot to climb. The flow was still spreading a little laterally. Occasionally trees were pushed over at the edge of the flow. Others burst into flame while they were still standing as the heat from the lava dried out the foliage and raised it to kindling point. Minor explosions were heard from time to time as trees were engulfed in hot lava and the water in their tissues suddenly transformed into steam.

The odor of hydrocarbon gas, probably largely methane, was strong, and the flow smelled much like a leaking gas stove. Yellow flames were common along the edges and top of the flow, issuing from the lava, and there were also many blue flames resembling the flame of a well-adjusted gas burner. These gases undoubtedly were derived from the destructive distillation of the vegetation buried and engulfed by the lava. Many flames burned at cracks in the old lava—commonly 10 to 15 feet and rarely as much as 50 feet or even more from the edge of the new flow. Some of these flames were quite steady, but many went out periodically at the surface only to re-ignite within the crack and burst out again at the surface with a loud "whoomp"! Some of these gas ignitions were explosively violent, throwing rock fragments several feet.

Along the edge of the flow the vegetation was partly broken, leaves were partly blown off trees, and leaves of ti plants were shredded and broken off. Most of the breaking appeared to have been by blasts from the direction of the flow. These were probably in part marginal explosions caused by ignition of hydrocarbon gases, but some of the damage was observed to be caused by the small but strong whirlwinds which formed over the flow and moved across it.

At 6:00 P.M. it was possible to climb the edge of the flow and go out onto it about 150 feet. Beyond that point the gas and heat were unbearable. From the vantage point on the top of the flow, the central lava river could be seen clearly. It was about 25 feet wide. At highway level it was flowing at an estimated rate of 15 miles per hour, but about half a mile upslope from the highway there was a broad double lava cascade on a steeper slope where the speed was estimated to be 25 miles an hour. Temperature measurements on the river ranged from 880° to 900° C. A spectacular feature of the lava river was the many large blocks which it carried along. The blocks were as much as 20 feet high and 30 feet long, although most of them were much smaller. Most were largely incandescent, though a few were largely dark. Occasionally large blocks became wedged sideways in the channel, causing local overflows. The blocks appeared to have been dragged along by a lower, less rapidly moving and probably more viscous stratum in the river. Some could be seen to be moving distinctly less rapidly than the surficial part of the river around them.

Condensation of water in the steam cloud which rose where the lava entered the sea caused a continuous rain beneath the cloud. That the rain was caused largely by the cloud is shown by the fact that just south of the edge of the cloud there was no rain and the night was

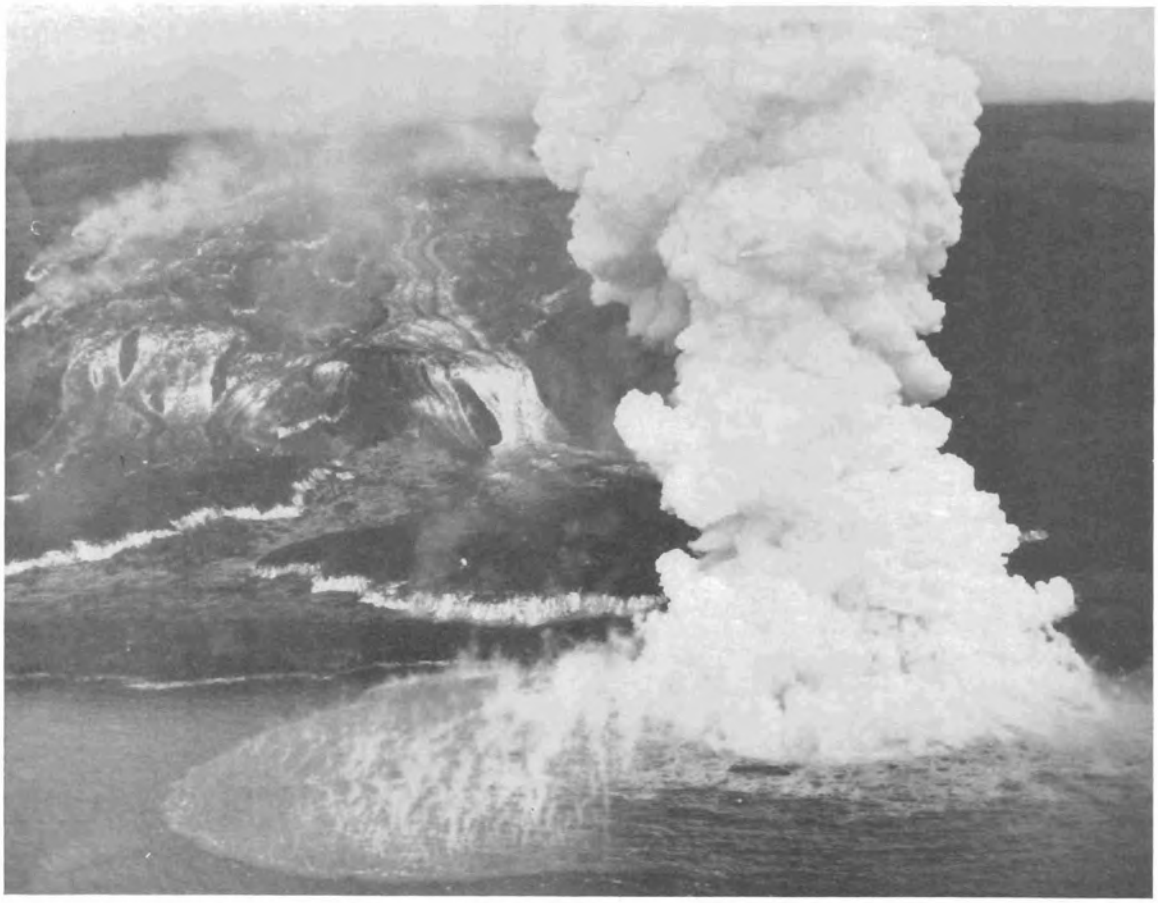

PLATE 4. Ohia Lodge flow pouring into the ocean at about 4:00 P.M., June 2, 1950. In the foreground a high column of steam is rising where the southernmost tongue reaches the ocean. Boiling and steaming water is visible off shore. In the background the flow is descending the mountainside, with smoke rising from the burning forest. Two large, brightly glowing fronts of aa are visible near the left side of the picture. OFFICIAL PHOTOGRAPH, AIR NATIONAL GUARD, 199 FIGHTER SQUADRON.

fairly clear. There was enough salt in the rain beneath the steam cloud to cause the drops to sting the face and eyes and to form a peculiar thin glaze on cars. This glaze was very difficult to remove, even by washing.

At 12:20 A.M. on June 3, Macdonald and Loucks started down the southern side of the flow from the highway. About half a mile from the ocean the flow reached the top of a steep slope formed by a buried fault scarp. There it divided into three branches. At a point just above the steepening of slope the speed of the lava in the river was estimated to be about 15 miles an hour, but as it cascaded down the buried scarp the lava reached a speed estimated at 25 to 30 miles an hour. Temperatures on the cascade were as high as 930° C. On the flatter ground below the scarp the flow slowed and spread out to form a broad fan about three quarters of a mile wide. The central lava river was the most active, and the steam column caused by it was the largest. The river appeared as a bright orange-red streak with long dark streaks paralleling the edge of the river. The southern river was moving less rapidly, and its surface was largely covered with dark blocks between which could be seen red glow.

There was a light but continuous fall of black ash of sand and silt sizes. Some of this ash may have been formed by steam explosions where the lava entered the sea, but much of it appeared to be fine debris picked up from the flow by the numerous small whirlwinds which swept over its surface.

Just above the big cascade blue or greenish-blue flames were common in the slow-moving margin of the flow, and yellow flames even more common. Dancing pale blue flames, resembling will-o-the-wisps, occasionally were seen for a few moments over the main lava river, as much as 35 to 50 feet above the river, and isolated from it by clear air. Some of these appeared to be nearly formless, but others looked like fire-balls.

The Ohia Lodge flow below the highway was examined on the morning of June 3 by D. C. Cox, D. A. Davis, and C. K. Wentworth. At 10:30 A.M. the condition was much like that of the previous night. At 10:35 a sudden increase in the volume of lava in the flow was observed. The speed of the lava in the big cascade between the highway and the shore increased notably, and a sheet of more rapidly moving lava appeared to override the older, less-rapidly flowing sheet.

By 11:15 the surge had decreased and the speed of flow lessened again. Davis estimated the speed in the cascade to be about 20 miles an hour during the peak of the surge and 5 to 6 miles an hour as the surge abated. During the surge the lava fan at the foot of the cascade had built up appreciably. At 11:30, after the surge had ceased, the surface of the central part of the fan was seen to be subsiding as the fluid lava underneath drained away, leaving higher ridges around its edges. The observers on the landward side of the fan could see no lava spilling from the outer edge of the fan into the sea, hence the drainage must have been through hidden subterranean passages. The drainage into the sea was accompanied by an increase in the size of the steam column, some minor explosions along the shore, and pushing up of small lava ridges from the water just offshore.

From 1:00 P.M. June 3 until 7:00 A.M. June 4, the Ohia Lodge flow about 2,000 feet inland from the road was observed by Wentworth, Davis, and Cox. Two streams of lava descended a steep slope in a cascade about half a mile long and reunited to form a single stream before reaching the road. At the foot of the cascade the flow was about 1,000 feet wide. Just north of this main flow another tongue of lava was advancing slowly seaward, burning trees and knocking them over. Optical pyrometer measurements made by Davis and Cox on the surface of the lava river indicated temperatures ranging from 850° to 980° C. About 2:00 P.M. the volume and velocity of the main flow commenced to increase. This surge reached its maximum about 2:30, after which the volume again decreased. Wentworth estimated the volume of actively moving lava in the flow during the surge to be five to ten times as great as that before and after the surge. Similar surges were observed in both channels of the flow at intervals of 65 to 85 minutes during the rest of the afternoon and night. Davis estimated the speed of flow in the main rivers to range from 5 to 20 miles an hour, and angular measurements by Wentworth and Cox during a surge at 11:25 P.M. demonstrated speeds of 7.8 to 8 miles an hour. The front of each surge advanced down the lava river channel, as an aa front 10 to 25 feet high, with loud clinking and crunching sounds. During the larger surges new lava spread from the river over much of the surface of the flow and, directly preceding and during some of the surges, there appeared to be a definite, though small, heating up and inflation of the stationary aa fields at the edge of the flow.

During the afternoon of June 4 the Ohia Lodge flow was watched by Arnold Mason of the U. S. Geological Survey. Conditions remained much as on the preceding day. Several surges of lava were observed, the last three at approximately 5:30, 6:00, and 6:30 P.M. When Finch and Cox arrived at 6:30 P.M. they found that at the road level the flow had been considerably widened by a new tongue which had come down parallel to the older one on its northern side, destroying Ohia Lodge. A sluggish lava river in the new tongue was feeding a slow-moving aa front just below the road. The entire flow at road level was about a quarter of a mile wide. Another tongue still farther north was advancing slowly through the forest about half a mile above the road. Its presence was revealed by occasional glimpses of glowing lava and by a bright glow from burning vegetation.

Davis returned to the Ohia Lodge flow above the road about noon on June 5. The width of the flow had increased to approximately 1,500 feet, and the active channels were entirely in the northern part of the flow. The lava was moving much more slowly than on the two preceding days, and the surges were smaller and of shorter duration. The maximum speeds in the lava rivers were estimated at 4 to 5 miles an hour. The new tongue north of the main flow was still advancing. Cox and Macdonald returned to the flow at 2:00 P.M. and went out onto the flow about 250 feet. The southern edge of the flow was still hot, but essentially motionless. The northern edge, beyond the river, was moving slowly. The flow as a whole had increased in thickness to an average of 20 to 25 feet. On the flat near the coast the flow had spread about 750 feet farther south than on June 3. The coastline had been transformed from a shallow embayment to a slight promontory.

Late in the evening of June 2, or early on June 3, another flow (flow 6, Fig. 1) started from the vent area at 8,300 feet altitude and moved southward down the mountain slope toward the main buildings of the Kahuku Ranch. This has been named the Kahuku flow. The upper portion of the flow was narrow, from 0.1 to 0.15 mile wide. On June 3 the flow was very active, with a narrow bright red lava river in the middle of a dark streak of aa. On June 4 the flow was still very active but was spreading out to form a front nearly half a mile broad at about 7,200 feet altitude, 3½ miles from its source. The lava river was reported to be on the order of 100 feet wide. On June 5 Don Campbell, from aerial observations, reported that the Kahuku flow was still advancing but appeared to have slowed. On the morning of June 6, James Beatty reported that the front had reached an altitude of about 6,500 feet. Movement continued through June 6 and the early hours of June 7, bringing the lower end of the flow to approximately 6,300 feet altitude, 5.8 miles from its source. On the afternoon of June 7 the lower portion of the flow appeared dead, but there was still some movement in the flow near the vents. By the morning of June 8 the flow was completely dead.

Frank Hjort and Ross Bender reached the vent area

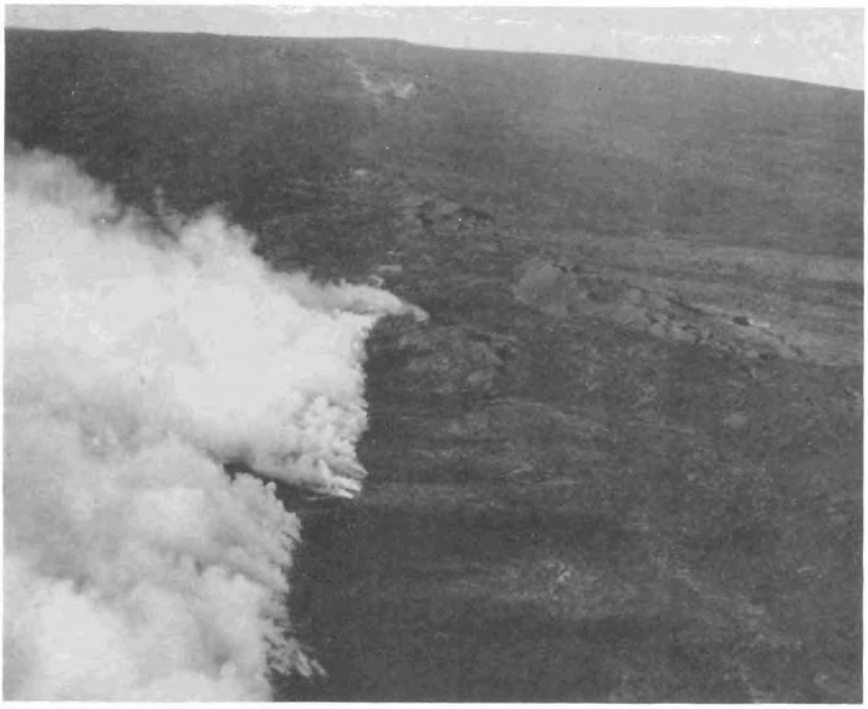

PLATE 5. Heavy fume clouds rising from the rift between 9,000 and 10,000 feet altitude, June 9, 1950. The heads of the Punaluu and Hookena flows are visible in the middle distance, and behind them fainter fume rises in the vicinity of Sulphur Cone. PHOTO BY WERNER STOY, CAMERA HAWAII.

on the afternoon of June 3 and camped at 8,700 feet altitude near the upper end of the lower line of vents. The fissure near 10,000 feet altitude was fountaining sporadically, but most of the activity was concentrated along the lower fissures below 8,900 feet altitude. From 4:30 to 8:00 P.M. activity on the lower fissures was continuous but varied rhythmically in intensity and character. Approximately once an hour an upsurge of activity commenced near the upper end of the fissure and migrated down along the fissure. Each revival of activity commenced at a large spatter cone at about 8,800 feet altitude with a loud roaring noise much like the exhaust from a steam boiler. This rush of gas was followed by a spray of lava droplets and red-hot cinder. The roaring release of gas migrated downhill along the rift, at some places giving rise to noises like thunder or heavy artillery. As the gas release ceased, the fountain activity and amount of lava liberation increased progressively along the rift until it was essentially continuous along the 2 miles of fissure which was in view. The fountains were lower than earlier in the eruption, playing to heights of about 50 feet. This activity gradually abated, and there was a lull of 20 minutes to a half-hour duration before the violent gas release started again at the upper end of the fissure and the cycle was repeated.

Most of the liberated lava was pouring westward toward Kona and feeding the Ohia Lodge flow. A front of hot lava 0.7 mile long had accumulated on the east side of the rift and was spilling southeastward to feed the Kahuku flow. At the head of the Kahuku flow the lava plunged over the steep slope of a buried cinder cone making a spectacular double cascade some 500 feet long and 200 feet wide. The rate of flow in the cascade was probably of the order of 35 miles an hour. Near the base of the cascade the highly fluid lava struck a bump on the channel floor, and the liquid was directed upward and outward into the air. At first view, from a distance, it appeared to Bender to be a fountain in the river, but on closer inspection its true nature was obvious.

A party composed of Geological Survey and National Park personnel reached the vent area on the afternoon of June 6. The cascade at the head of the Kahuku flow was still active, but the speed of flow had greatly decreased, not exceeding 10 miles an hour on the steepest slope. Fluctuations in the volume of flowing lava were obvious and occurred at approximately half-hour intervals. During the night of June 6 the lava fountains along the rift were low and sporadic. Increases in activity continued to occur about every half hour and progressed downslope along the rift. Only once was the increase in lava output preceded by a loud blowing noise and shower of incandescent cinder from the large spatter cone at 8,800 feet altitude.

On the morning of June 7 activity along the rift was still weak. Above 8,600 feet altitude the vents were fuming strongly, but no lava was being poured out. Below that altitude fountaining continued, but none of the fountains was more than 25 feet high, and most were only a few feet.

About 3:00 P.M. Davis, Cox, and Macdonald crossed the still hot pond of shelly pahoehoe which had fed the Kahuku flow and approached within 15 feet of the lava river. At 8,440 feet altitude two branches of the river plunged over a 25-foot cascade and joined at its foot.

Most of the river was moving only 3 or 4 miles an hour and was largely crusted over with a skin of wrinkled and ropy pahoehoe. In the cascade, however, the speed of flow was estimated at 30 miles an hour, and the crust was broken up to reveal the incandescent liquid beneath. Measurements with an optical pyrometer on the hot lava in the cascade yielded temperatures from 1030° to 1040° C.

Below the cascade the lava river flowed directly along the eruptive fissure, burying several lava fountains which occasionally shot through the river. Near the foot of the cascade there was a dome-shaped fountain which averaged about 10 feet across at its base and 5 feet high. This fountain resembled the dome of water which forms over the mouth of some artesian wells. Its bright orange hemisphere looked like half an orange set on the lava river. Just downstream from the dome fountain the rush of the liquid lava leaving the cascade gave rise to a hydraulic jump, with a standing wave 4 to 8 feet high.

About 500 feet down the rift from the cascade a small lava fountain was shooting 10 to 25 feet high. It was not a continuous jet, but consisted of repeated spurts of lava which separated in the air into large blobs. This fountain was typical of many which could be seen on down the rift. At the base of the fountain lava was flowing out pulsatingly, the pulses coming every 1 to 2 seconds, giving rise to a heaving motion much like that commonly observed in a pot of boiling thick porridge. A small lava shield was building up around the vent, but most of the lava was flowing down the slope of the shield to join the main river. The latter closely paralleled the erupting fissure for about a quarter of a mile then joined a large stream of lava flowing toward Kona.

Fluctuations in the amount of lava output came at roughly half-hour intervals. Following surges, the level of the lava in the river dropped, exposing along the banks rows of hot flexible lava stalactites which swayed back and forth in the blasts of gas or as their ends touched the flowing liquid much like willow roots along a creek. Many of them eventually were broken off, probably as they became more brittle with cooling, and floated away in the stream.

About 4:30 P.M. on June 7 there commenced a revival of activity along the entire rift. By 7:00 P.M. sporadic lava fountaining could be seen at a distance along the fissure near 10,000 feet altitude, and a little red lava could be seen moving in the head of the Hookena-Magoon Ranch flow. Along the fissure below 8,900 feet altitude the amount of fountaining and lava outpouring had increased. The surges in the lava river grew in size until, during peaks, the river channel was filled to the brim and locally overflowed sending tongues of pahoehoe rolling toward the observers. The height of the standing wave of the hydraulic jump below the cascade increased to about 12 feet and that of the dome fountain to about 8 feet. The temperature of the lava appeared to increase with the activity, and at 7:20 P.M. pyrometer measurements on both the cascade and the dome fountain gave temperatures of 1070° C. Some of the lava spilled eastward and formed a stream across the lower end of the former lava pond to the head of the Kahuku flow. Most of it, however, continued to westward.

As darkness came, many flames were visible over the vents along the rift. Most of them were at vents from which lava was no longer issuing, but some were at spattering vents. No flames were observed at vents from which lava was flowing in abundance. Most of the flames were greenish-yellow, but some were pale greenish-blue. The average length of the flames above the mouths of the conelets was about 5 feet, but some were as much as 20 feet long.

The revival of activity continued until about 2:00 A.M. on June 8. After that the strength of activity gradually decreased. At 6:00 A.M. the rift was still moderately active, but much less so than on the previous evening. A roaring gas vent was heard occasionally at about 8,400 feet altitude. The cascade at the head of the Kahuku flow was no longer active, and crossings of the flow itself at two places revealed it to be completely dead.

G. D. Robinson and B. J. Loucks reached the Ohia Lodge flow on the afternoon of June 6 and spent most of the night observing it in the area between the highway and the sea. About half a mile below the highway the channel divided into two branches, the southernmost of which was the more active. A short distance farther downslope the southerly channel again divided, so that there were three channels. Surges in activity were observed at approximately half-hour intervals. During lulls in the activity the lava movement was largely restricted to the central channel, but during the larger surges all three channels became very active. Will-o-the-wisps were again observed over the flow. On June 7 the Ohia Lodge flow was still very active, the principal movement at the highway being in a lava river which was flowing in a channel about 15 feet deep near the northern edge of the flow. William Stearns reported that a new spur on the southern side of the flow, about 5 or 6 miles long, was advancing slowly.

On June 8 a small overflow occurred on the southern side of the Ohia Lodge flow about a quarter of a mile above the highway. The tongue advanced only a few hundred yards before rejoining the main flow. On June 9 the flow appeared to have become distinctly more sluggish. The flow was again visited on June 10 by Robinson and Wentworth, in company with H. R. Joesting and J. H. Swartz of the Geological Survey and Juliette Wentworth. Conditions were much the same as they

had been when last seen by Robinson on the morning of June 8. However, in the interim, lava had been newly added, by repeated overflows of the channel, to the surface of much of the flow in the vicinity of the road. Several surges of activity were observed during the evening, the intervals between surges ranging from 13 to 45 minutes. Pyrometer measurements by Robinson on large glowing blocks in the river and on the surface of the river itself yielded temperatures ranging from 840° to 940° C. Cherry-red lava exposed in a cave in the older stationary aa margin of the flow gave a temperature of 675° C.

On June 11 Macdonald and D. H. Hubbard examined the flow where it entered the sea. No movement could be detected in the major part of the flow on the coastal flat, and the volume of steam being formed at the ocean was small. Lava was still pouring over the escarpment a quarter of a mile inland, but it was rather dull red in color and appeared much more viscous than during earlier observations. The speed of the lava on the steep cascade was only about half a mile an hour. Two strong surges of lava at the cascade were observed, one at 2:30 and the other at 4:30 P.M. At the foot of the cascade the lava turned southward and spread out to form a big aa flow which was advancing seaward along the southern edge of the older flow at a rate of approximately 1,000 feet an hour. The front of this flow was the largest the writers have observed in Hawaii. It was about 1,000 feet wide, at least 50 feet high, and very active. One after another, blocks up to 10 feet in diameter became detached from the front of the flow and rolled to the base. The blocks were accompanied and followed by trains of finer incandescent debris, and patches of incandescent lava were revealed as the blocks broke away from the front. Clouds of pale brown dust arose from the pulverization of the fragments rolling down the flow front. A hundred yards from the active front the radiant heat was so great that the observers' faces were scorched, and cameras became so hot they were difficult to hold.

At 3:00 to 4:00 A.M. on the morning of June 12 there was widespread overflowing of the channel of the Ohia Lodge flow at the level of the highway. Later in the morning and during the afternoon the glow in the flow was dull and lava movement was small. Shortly after 9:00 P.M. a bright glow was seen inland from the road, and by 10:15 a new surge of lava was producing flooding on the northern side of the flow. This appears to have been the last big surge. Movement in the flow at the highway stopped on June 13, although on June 14 cowboys of the C. Q. Yee Hop Ranch reported lava still moving in the flow 6 miles above the highway. At about noon on June 15 the pilot of a Navy plane reported lava bubbling from the lower 200 yards of the source fissure and fume being liberated along about 3 miles of fissure. From that time on, glow at the source area was observed nearly every night until June 22. On the afternoon of June 22, John Peoples of the U. S. Coast Guard flew over the source area and reported hot bubbling lava and a large amount of fume along the rift.

The last well-authenticated observation of glow at the source was by Finch, at 1:00 A.M. on June 23, and the eruption is believed to have come to an end on that date. Aerial observations on later days revealed much fume along the fissures but no signs of moving lava. Fume liberation continued abundant through the remainder of June.

A further discussion of special features of the eruption will appear in the next VOLCANO LETTER.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR APRIL–JUNE, 1950

VOLCANOLOGY

April

The northward tilt that started early in March continued through April. The northward tilt of 3.2 seconds of arc in April, when coupled with the 6 seconds in the same direction in March, indicates a distinct pressure increase under Kilauea Volcano.

Seasonal westward tilt ceased on March 14 and an eastward tilt set in to continue until the last of April. If an eastward tilt indicates a pressure increase under Mauna Loa then there has been a simultaneous increase of pressure under Kilauea and Mauna Loa.

Of the 77 earthquakes recorded during April, 61 were recorded at Kilauea and 56 on the Mauna Loa seismograph. The Kilauea total is larger than usual and points to uneasiness at Kilauea. However, the foci of most of the shakes were shallow and many were under the northern end of the caldera. The shallowness and location of foci far from the volcanic axis at Halemaumau appear to decrease their significance as an indication of impending activity.

Some of the cracks in the vicinity of the Halemaumau rim opened slightly. A more-or-less expected accompaniment of the continued pressure build-up was the spreading of some of the cracks on the caldera floor that are connected with the rift system of Kilauea.

May

The monthly total of earthquakes for May was 102. During the first half of the month more of the earthquakes originated under Kilauea than Mauna Loa, but during the latter half Mauna Loa quakes predominated. As far as earthquakes were concerned it appeared as though uneasiness had shifted from Kilauea to Mauna Loa. Many of the shakes originated under the upper end of the southwest rift of Mauna Loa.

During the first 2 weeks of May there was a slight east-southeast tilt. Then a distinct north-northeast tilt set in to continue until May 29. Following the strong earthquakes of May 29 there was a tilt of 2.4 seconds of arc to the southwest, or opposite the usual direction for the latter part of May.

June

A total of 279 earthquakes was recorded on the Kilauea seismograph during June. Owing to the frequent dismantling of the Mauna Loa seismograph during the progress of the flank eruption the total for that instrument is unknown but probably about the same as for Kilauea. Most of the earthquakes originated along the southwest rift of Mauna Loa.

There was an accumulation of 6.4 seconds of arc tilt to the northeast during the first 14 days of June, then a slight northwest tilt for the rest of the month. It is interesting to note that a marked decrease in the rate of output of lava from the southwest rift of Mauna Loa coincided roughly with the cessation of rapid northeast tilt.

SEISMOLOGY

Earthquake Data, April–June, 1950

(Based on Bosch-Omori seismograph on rim of Kilauea caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
April 2	10	0	2	0	0	0	4.50	0
9	7	0	0	0	0	0	1.75	0
16	12	0	0	0	0	0	3.00	1
23	17	4	1	0	0	0	7.25	0
30	20	8	1	1	0	0	10.00	1
May 7	16	5	1	0	0	0	7.50	0
14	13	4	1	0	0	0	6.25	0
21	7	2	0	0	0	0	2.75	1
28	29	17	2	2	0	1	25.75	0
June 4	86	44	12	8	8	0	95.50	0
11	34	15	4	2	3	1	37.00	0
18	7	3	0	0	1	0	7.25	1
25	5	1	1	0	0	0	2.75	0

* For definition of local seismicity, see Volcano Letter 371.

The data for the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

20. April 5, 04 : 50, feeble. Felt locally. Kilauea quake.
21. April 8, 00 : 35, feeble. Mauna Loa shake.
22. April 23, 01 : 15, very feeble. Kilauea.
23. April 25, 10 : 09, very feeble. Mauna Loa.
24. April 27, 23 : 53, very feeble. Kilauea.
25. April 28, 02 : 26, feeble. Kilauea.
26. April 29, 21 : 11, very feeble. Mauna Loa.
27. May 3, 03 : 48, very feeble.
28. May 3, 12 : 08, very feeble. Mauna Loa.
29. May 3, 22 : 19, very feeble. Kilauea.
30. May 4, 01 : 01, very feeble.
31. May 4, 04 : 35, feeble.
32. May 4, 05 : 51, slight. Felt at Kapapala.
33. May 4, 05 : 54, very feeble. Felt at Kapapala.
34. May 4, 06 : 02, very feeble. Felt at Kapapala.
35. May 4, 07 : 31, very feeble.
36. May 6, 03 : 47, very feeble.
37. May 7, 03 : 10, very feeble. Mauna Loa.
38. May 8, 12 : 01, very feeble.
39. May 8, 12 : 41, very feeble. Mauna Loa.
40. May 11, 13 : 06, very feeble.
41. May 11, 19 : 38, feeble. Mauna Loa.
42. May 13, 09 : 27, very feeble. Mauna Loa.
43. May 14, 18 : 39, feeble. Mauna Loa.
44. May 18, 10 : 47, very feeble. Mauna Loa.
45. May 18, 14 : 44, very feeble. Mauna Loa.
46. May 19, 00 : 02, very feeble. Mauna Loa.
47. May 20, 01 : 57, very feeble. Mauna Loa.
48. May 26, 01 : 45, very feeble. Mauna Loa.
49. May 27, 11 : 33, very feeble. Kilauea.
50. May 28, 08 : 27, very feeble. Mauna Loa.
51. May 29, 15 : 17, strong. Upper southwest rift of Mauna Loa. Widely felt. All instruments dismantled. Damage to water tanks, stone walls, etc., in Kona.
52. May 30, 14 : 37, very feeble. Mauna Loa.
53. May 30, 17 : 28, slight. Mauna Loa.
54. June 1, 13 : 59, very feeble. Mauna Loa.
June 1, 21 : 04, harmonic tremor of Mauna Loa eruption starts. Recorded continuously through June 3, then with lesser amplitude and intermittently until afternoon June 13.

Earthquakes accompanying the first 13 days of the Mauna Loa eruption.

Most of the quakes originated on the southwest rift of Mauna Loa.

Serial Numbers	Date	Number of Shakes
55– 58, inclusive	June 2	4
59– 73, inclusive	3	39
74– 91, inclusive	4	39
92–107, inclusive	5	28
108–115, inclusive	6	23
116–126, inclusive	7	15
127–133, inclusive	8	7
134–143, inclusive	9	10
144–146, inclusive	10	3
147–158, inclusive	11	23
159	12	6
160–164, inclusive	13	7
165–168, inclusive	14	13

169. June 15, 10 : 14, slight.
170. June 16, 16 : 03, very feeble.
171. June 16, 23 : 13, very feeble.
172. June 17, 06 : 31, very feeble.
173. June 19, 09 : 22, very feeble. Felt locally. 7 miles deep, east slope of Mauna Loa near Ohaikea.
174. June 21, 07 : 06, moderate. Felt locally. Kilauea.
175. June 21, 08 : 03, very feeble.
176. June 21, 08 : 29, very feeble.
177. June 26, 19 : 56, feeble. Felt at Naalehu.

TELESEISMS

April 18, 05 : 00, slight. Southwest of Galapagos.
April 30, 01 : 00, slight. North of Easter Island.
May 25, 15 : 27, slight. New Hebrides.
June 24, 12 : 34, slight. New Hebrides.

MICROSEISMS

Microseisms were moderate on April 4–5, 29–30, and May 10–11. They were present though slight on other days throughout the quarter.

CRACK MEASUREMENTS

Accompanying the rapid northward tilt during March, April, and May there was a distinct opening of some of the cracks on the caldera floor that are roughly aligned with the southwest rift of Kilauea. At one station there was an opening of 4 millimeters and at another the opening amounted to 9 millimeters. Such an opening is an expected accompaniment of the doming indicated by tilt. A portion of the crack at the tourist station on the east rim of Halemaumau opened 8 millimeters between March 31 and June 30.

TILTING OF THE GROUND

The strong northward tilt which started in March continued until May 29 and amounted to 11.4 seconds of arc. A distinct southerly tilt followed the large earthquake of May 29. Northward tilt was resumed on June 5. Between June 5 and June 17 there was a rapid northward tilt amounting to 3.8 seconds. From June 17 to the end of the month, northward tilt was about normal for this season of the year.

The lack of normal westerly tilt that was noted in March continued until April 10 when a positive eastward tilt commenced that continued until June 14 except for some rapid fluctuations from May 29 until June 8. There was an unusually rapid eastward tilt of 5.9 seconds between June 7 and June 14. From June 14 to June 30 there was a slight westward tilt, which is opposite to the normal direction for this season of the year.

Table of Tilt at Seismograph Vault on Northeast Rim of Kilauea Caldera

Week Beginning	Amount	Direction
April 2	0.2″	N 45° E
9	0.3″	N 45° E
16	1.0″	N
23	1.4″	N 60° E
30	1.8″	N 16° E
May 7	0.5″	W
14	1.2″	N 37° E
21	1.0″	N 7° E
28	1.7″	S 40° W
June 4	3.5″	N 70° E
11	3.0″	N 51° E
18	0.3″	N 27° E
25	0.1″	E

TEMPERATURE MEASUREMENTS

The temperature of the steam well at the Sulfur Bank was constant at 204° F. in April, May, and June.

MAGNETIC OBSERVATIONS

Routine magnetometer measurements were continued at intervals of approximately 1 month. H. R. Joesting and J. H. Swartz of the Geological Survey's Geophysics Branch spent a week at the Observatory during the eruption of Mauna Loa in June, making additional measurements and calibrating instruments.

Until May 9 most of the stations on the line along the Mauna Loa truck trail showed a decrease in vertical magnetic intensity with respect to the base station near the rim of Kilauea caldera at Uwekahuna. The next measurements, on June 9 and 12, showed a marked increase in the strength of attraction at most of the stations. Several of the stations showed a very rapid rise between June 9 and 12. It is possible that the beginning of this rise may have coincided roughly with the beginning of the Mauna Loa eruption.

THE VOLCANO LETTER

No. 509 **U. S. Geological Survey** **July–September, 1950**

PUBLISHED BY THE UNIVERSITY OF HAWAII

THE JUNE 1950 ERUPTION OF MAUNA LOA

By GORDON A. MACDONALD and R. H. FINCH

Part II

SPECIAL FEATURES

LAVA FLOWS

The lava of the 1950 eruption of Mauna Loa ranges from basalt to olivine basalt. The first lava erupted along the upper part of the rift contains very few olivine phenocrysts, and no dunite inclusions were observed. In contrast, the lavas erupted later from the portion of the rift below 11,000 feet altitude contain many phenocrysts of olivine up to about 5 millimeters long. Angular inclusions of dunite, up to about 3 centimeters across, are fairly common in the lavas from the lower vents. It appears probable that the marked difference in abundance of olivine phenocrysts in the early and late lavas is the result of sinking of olivine crystals in the magma column before the eruption. The first lavas liberated at the upper vents were derived from the upper part of the magma column, which had been impoverished in olivine. Later the lava was derived from a lower level in the magma column, in which the abundance of olivine phenocrysts had been increased by sinking of crystals from higher levels. A similar, but even more marked, difference has been found between the early and later lavas of the 1840 eruption of Kilauea (Macdonald, 1944).

Figure 1 is a map showing the distribution of the lava flows. All of the flows except the upper flow (no. 2) and the Kahuku flow (no. 7) have been plotted from vertical air photos taken at the request of the Volcano Observatory by Richard O. Mahan for the R. M. Towill engineering firm in Honolulu.

The accompanying table shows the approximate area and volume above sea level of each of the major lava flows of the 1950 eruption and the estimated average thickness of each flow. The areas were scaled from the map of the flows. The average thickness of several separate segments of each flow was estimated from ground observations at several points along the flows and from the appearance in the aerial photographs, then the average thickness of the whole flow was calculated from these values. The volumes were calculated by using the scaled areas and the estimates for average thickness of successive portions of the flows. It is believed that any error in thickness and volume is on the conservative side. The total area of the flows above sea level is 35.6 square miles, and the volume is on the order of 514 million cubic yards. It is estimated that more than 100 million cubic yards of lava flowed out under the ocean and is now lost to view. The total volume of lava erupted, therefore, was very probably more than 600 million cubic yards, or somewhat more than the estimated volume (600 million cubic yards) of the largest previous historic eruption, the 1859 lava flow of Mauna Loa (Stearns and Macdonald, 1946, p. 79). It is estimated that between one-half and two-thirds of the total volume of lava was poured out during the first 36 hours of the 1950 eruption.

AREA, THICKNESS, AND VOLUME OF 1950 LAVA FLOWS ABOVE SEA LEVEL

NAME OF FLOW	NUMBER ON MAP (FIG. 1)	AREA	AVERAGE THICKNESS	VOLUME
		Sq. miles	*Feet*	*Cu. yds.*
Upper rift . . .	1	3.74	4.5	17,000,000
Upper west flank	2	1.25	7.6	11,000,000
Hookena	3	6.73	8.3	59,000,000
Magoon Ranch	4	5.74	9.3	55,000,000
Punaluu	5	7.25	13.5	101,000,000
Ohia Lodge . .	6	8.47	27.6	241,000,000
Kahuku	7	1.44	12.0	18,000,000
Keokeo	8	1.00	12.0	12,000,000

TEMPERATURE MEASUREMENTS

Approximately 75 readings were made with an optical pyrometer during the eruption. Of these, about one-third were made during daylight hours and are of little value. Comparison of readings made during daylight with those made at night indicates that the extraneous illumination during daytime results in readings which are consistently too high. Most daylight readings appear to be between 50° and 100° C. higher than read-

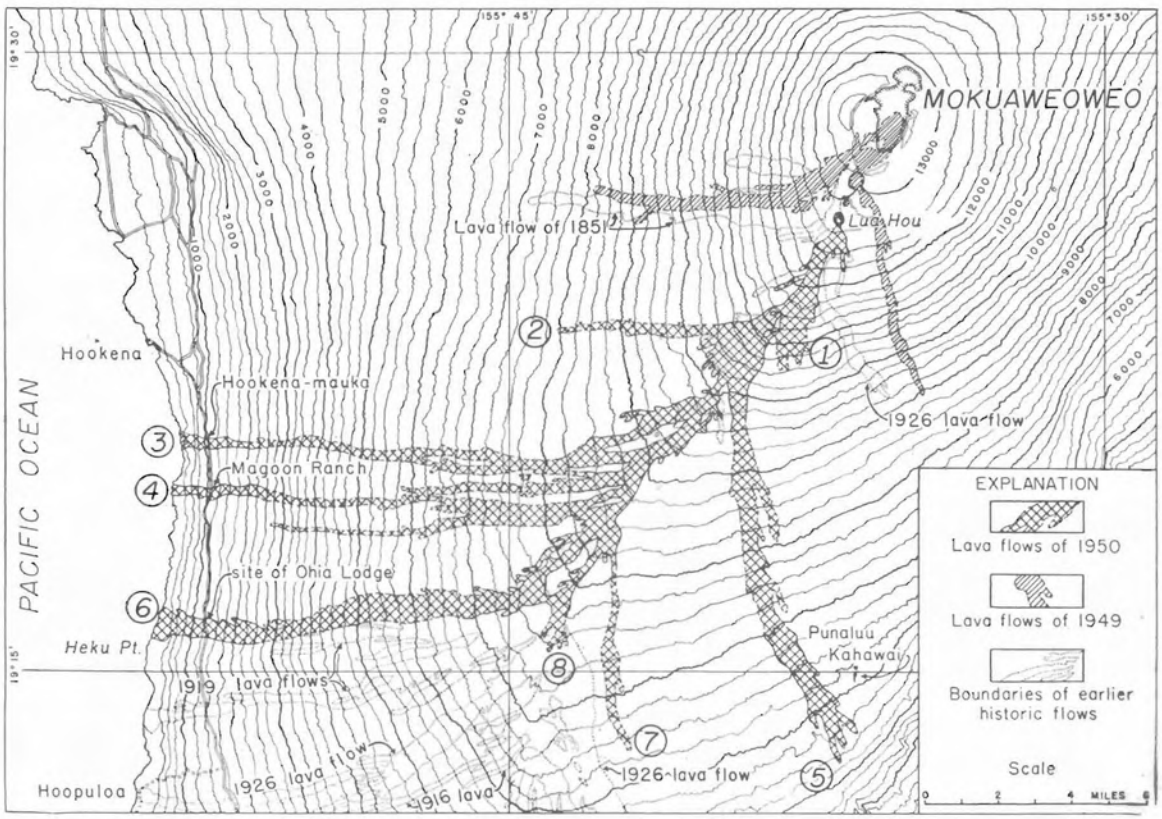

FIGURE 1. Map of a portion of the southwest rift of Mauna Loa showing the 1950 and some earlier historic lava flows.

ings on the same object at night. The values cannot, however, be successfully corrected, because the amount of extraneous light was variable and undetermined. Only the night readings have been used. The values obtained at night were quite consistent. Repeated readings on the same near-by object at intervals of a few seconds showed variations of only a few degrees. On the other hand, readings on the surface of the lava river showed a range of approximately 100°, owing at least in part to variations in the amount and thickness of crust on it.

Only a few of the pyrometer readings were made under close approximations to "black body" conditions. Therefore a small correction for the coefficient of light absorption of gray bodies should be applied. The amount of the correction has not been determined, but, for leucite basanite of Nyamuragira, Verhoogen (1948, p. 131) found it to be about 20° at 1,000° C. It is probable, therefore, that the observed temperatures given in the accompanying table should be increased by about 20°.

It is noteworthy that the temperatures of the dome fountain and of the river at the vents are of the same order of magnitude as those obtained by Verhoogen (1948, pp. 133–136) at Nyamuragira. In comparison, the temperature at the surface of the Kilauea lava lake in 1916 was about 1,000°, that at a depth of 1 meter was about 860°, and that at a depth of 13 meters was about 1,170°. The latter temperature was believed to be higher than that of the magma rising through the conduits (Jaggar, 1917). The high temperature of 1,100° measured in the throat of the inactive spatter cone on June 7, 1950, probably was partly the result of gas heating.

There probably was very little lowering of apparent temperature by crust on the very turbulent lava in the river at the vents, and the actual temperature of emission of the lava may be taken as close to 1,070°. On the other hand most of the readings on the lava river at the highway probably were to some degree affected by the presence of crust on the river. The actual internal temperature of the river at the highway was probably near the upper end of the range of observed temperatures—in the vicinity of 950°. Thus the lava of the Ohia Lodge flow cooled about 100° in traversing the 10 miles from the vents to the highway. At 950° it was still fluid and free-flowing. At 675° it had become immobile. The temperatures of 850° to 870° measured in cracks in the stagnant aa on June 2 may have been appreciably higher than the internal temperatures because of surficial heating by burning gases. During the 1949 eruption of Mauna Loa, lava with a temperature of about 760° was found to be still capable of a little movement (Macdonald and Finch, 1949, p. 5).

TEMPERATURE MEASUREMENTS

OBJECT MEASURED	NUMBER OF READINGS	TEMPERATURE °C. RANGE	TEMPERATURE °C. AVERAGE	DATE
Cascade in lava river at vents . . .	5	1030–1070	1050	June 7
Dome fountain in river at vents . .	3	1060–1080	1070	June 7
Lava river of Ohia Lodge flow near highway	16	850–980	916	June 2–4
Lava river of Ohia Lodge flow about ½ mi. from ocean	3	910–930	920	June 3
Lava river of Ohia Lodge flow near highway	15	840–940	898	June 10
Glowing lava in flaming crack in aa at nearly motionless edge of flow at highway (flow had crossed highway about 6 hours earlier) .	3	850–870	860	June 2
Glowing lava in crack in aa at stationary margin of flow at highway (flame absent) .	Several	.....	675	June 10
Glowing throat of spatter cone at vents (not active when readings were taken, but active a few hours earlier, and still emitting gas) . .	3	1090–1110	1100	June 7

RADIATION STUDIES

Two series of counts with a Geiger-Muller counter were made on June 2 and 5 at 11 stations along the highway at and near the Ohia Lodge flow. The number of clicks per minute varied considerably, but the averages close to the flow and on the flow are a little less than those at a distance from the flow. The averages are as follows:

500 to 1,000 feet from flow . . . . . 21 clicks per minute
10 to 300 feet from flow . . . . . 20 clicks per minute
On flow 75 to 250 feet from edge . 17 clicks per minute

It is possible that the higher temperature on and near the flow affected the sensitivity of the instrument, reducing the count. However, at no time was the temperature of the wand holding the tube high enough to be unbearable, or even particularly uncomfortable, to the unprotected hand of the operator. The evidence appears to indicate that there was no marked increase in radiation as the flow was approached, and, therefore, that the lava was not appreciably radioactive at the level of the highway. No counter readings were made at the vents.

Samples of lava collected where the flow crossed the road showed no radioactivity when tested by Dr. Harvey E. White of the University of California.

TILTING OF THE GROUND

Indications of a pressure build-up under both Kilauea and Mauna Loa volcanoes in February, March, April, and May were given by the tilt curves obtained at the Whitney Laboratory of Seismology on the northeast rim of Kilauea Caldera. Normally there is a seasonal southwest tilt during the first 5 months of the year (Powers, 1947, p. 2). In 1950, however, seasonal tilt was exceeded by oppositely directed volcanic tilt so that south tilt ceased on February 9 and west tilt on March 19.

A rapid northward tilt started on March 6 and continued until the end of June, except for a southward tilt of 2.2 seconds of arc from May 29 to June 5. Over half of this southward tilt, or 1.2 seconds, accompanied a strong earthquake on May 29. The northward tilt from March 6 until May 29 amounted to 11.5 seconds of arc. The 77 earthquakes recorded in April, a majority of which originated at Kilauea, together with the strong north tilt, indicated a distinct uneasiness of Kilauea Volcano.

A positive easterly tilt which followed the cessation of seasonal west tilt on March 19 continued through May 28. The 102 earthquakes recorded during May, a majority of which originated under Mauna Loa, together with the easterly tilt, indicated that Mauna Loa had become more uneasy than Kilauea. There was a sharp westerly tilt on May 29 and 30 following the strong quake on May 29. Despite some fluctuations there was an accumulation of 6.0 seconds of arc of east tilt from May 31 to June 14. It is interesting to note that strong east tilt accompanied the outbreak of Mauna Loa and continued until there was a noticeable decrease in lava output. Evidence is accumulating that there is a correlation between east tilt and Mauna Loa eruptions. In 1950 east tilt set in 2 months and 12 days prior to the outbreak of Mauna Loa. Distinct east tilt preceded the 1949 eruption by 2 months and 8 days.

HARMONIC TREMOR

Very conspicuous harmonic tremor (Finch, 1944) was recorded on the seismographs at Kilauea, on the east slope of Mauna Loa, and at Kealakekua in Kona for over an hour after the eruption began. In the following discussion the records from the Kilauea seismograph on the northeast rim of Kilauea Caldera only are used. During the summit eruptions in 1940 and 1949 the Kilauea instrument, 22 miles from the site of the eruption, recorded harmonic tremor for 5 and 12 hours, respectively. The tremor was recorded for a similar number of hours during earlier eruptions. Though the upper eruption source of the 1950 outbreak was at a distance of 24 miles, or a little greater than in 1940 and 1949, the maximum double amplitude recorded in 1950—5 millimeters—was several times that of earlier years. The period of this large-amplitude early tremor was 0.5 seconds.

Instead of the tremor slowly dying out after a few hours, as it usually does, in 1950 it continued to be recorded intermittently until June 13, although about 4 hours after the initial outbreak at 12,600 to 11,250 feet altitude most of the lava was issuing from vents between 10,500 and 8,000 feet, about 30 miles from the Kilauea seismograph.

After the first few hours the amplitude of the tremor decreased greatly, but the double amplitude still ranged

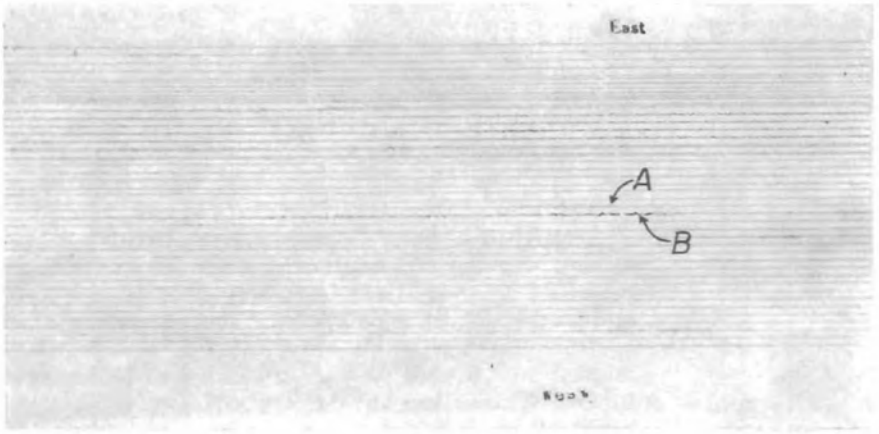

FIGURE 2. Harmonic tremor as recorded 30 miles from eruption source on June 2, 1950. A is the record of an earthquake, and B is due to an artificial disturbance.

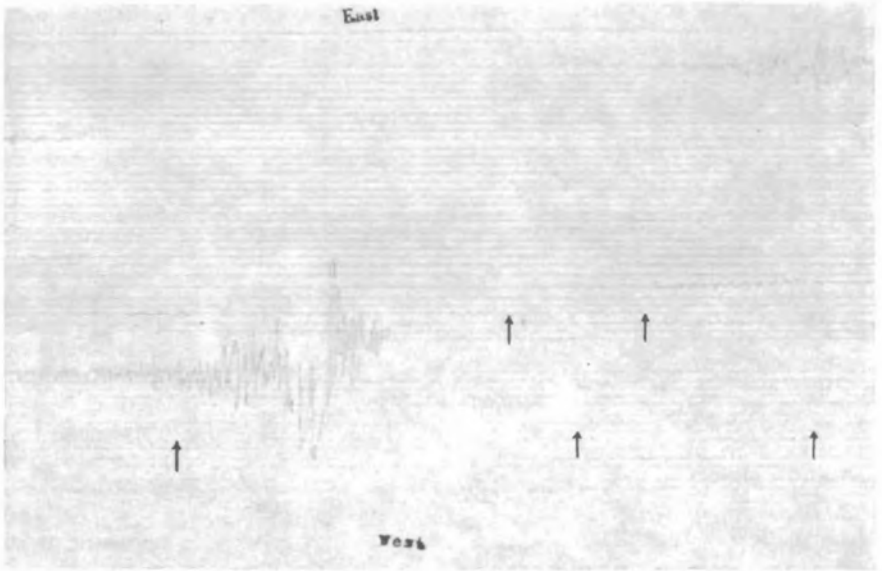

FIGURE 3. From the record of June 3, showing five spells of unusual harmonic tremor with a period of about 2 seconds. Arrows point to the beginning of each spell.

up to 0.7 millimeter (Fig. 2), which is equal to or larger than recordings in 1940 and 1949. The period of the tremor ranged up to 1.5 seconds.

The large amplitudes of the harmonic tremor at the onset of the eruption, and the fact that tremors continued after the distance to the source increased from 24 to 30 miles, indicated that the rate of output of lava was greater than usual.

On June 3 it was noticed that the harmonic tremor was not continuous, indicating fluctuations in the volume of lava being emitted. Direct observations both at the source and where the lava crossed the road showed fluctuations in volume.

Whether the harmonic tremor is produced by movements of lava in the primary conduits under Mokuaweoweo, the summit crater of Mauna Loa, or in the eruption fissures is not known, though evidence favors the latter. As noted above, in most eruptions harmonic tremor is recorded for a few hours only. In the 1942 flank eruption, harmonic tremor was recorded for a few hours during the preliminary activity at the summit (distance 22 miles) and then for 7 days after the lava broke out along the northeast rift at a distance of only 14 miles from the recording instrument. The facts that the tremor ceased being recorded a little before activity at the summit stopped and resumed, to continue for 7 days, after the lava broke out at a distance of 14 miles, indicate that the tremor originates in the eruption fissures.

On June 2 another type of harmonic tremor, apparently not previously recorded at the Hawaiian Volcano Observatory, was noticed (Fig. 3). The most frequent period of this type of tremor is roughly 2 seconds. Fourteen spells of this type of tremor were recorded on June 3, and 13 on June 4. Smaller numbers were recorded on other days, with the last on June 12.

EARTHQUAKES

Earthquakes and tilting of the ground surface during March and April caused speculation as to the possibility of an eruption at Kilauea. In May, however, quakes of Kilauea origin became less numerous and the number with Mauna Loa origin predominated. Many of the Mauna Loa quakes originated under the upper end of the southwest rift.

The following table shows the number of earthquakes per week recorded at the northeastern rim of Kilauea Caldera during May and June:

Week Beginning	No. of Quakes
April 30	30
May 7	21
14	18
21	9
28	58
June 4	158
11	60
18	11
25	7

A larger number of earthquakes during the early part of a flank eruption than during a summit eruption is to be expected because of the greater length of fissuring. In 1950 there was a progressive fissuring of the southwest rift for a distance of 13 miles. Normally, when both Mauna Loa and Kilauea are quiet, only five or six earthquakes per week are recorded.

LACK OF LITTORAL EXPLOSION

The absence of large littoral explosions or the formation of much ash where the lava entered the ocean was a striking feature of the 1950 eruption. Many aa flows entering the sea cause violent steam explosions which throw into the air large amounts of ash and which build littoral cones of ash and cinder (Macdonald, 1944). This happened in 1840, 1868, 1919, and 1926 (Jaggar, 1919, 1926). Many pahoehoe flows enter the water quietly, with only moderate evolution of steam, because the quickly formed pahoehoe skin provides an insulation which separates the very hot lava inside from the water. Aa flows, on the other hand, typically have a much broken and discontinuous surficial layer which permits the water easy access to the hot interior, with resultant strong explosions. A minor amount of such activity apparently did occur during the 1950 eruption. On June 3, D. C. Cox, going down the southern edge of the Ohia Lodge flow with D. A. Davis and C. K. Wentworth, noticed an increase in the amount of falling ash as they approached the coast and came under the steam cloud. Also, some of the moving pictures taken from the sea show small puffs of dark cloud, almost certainly ash, mixed with the white steam. However, littoral explosion and ash-making were very minor, certainly not nearly comparable with those in 1919 and 1926. Probably this was because the main lava rivers entering the sea were hotter and had a more unbroken surface than those of the 1919 and 1926 flows, thus preventing such rapid and easy entrance of the water to the hot interior. Once the flow into the ocean was well established a continuous crust may have formed over the lava river, acting as an insulator in

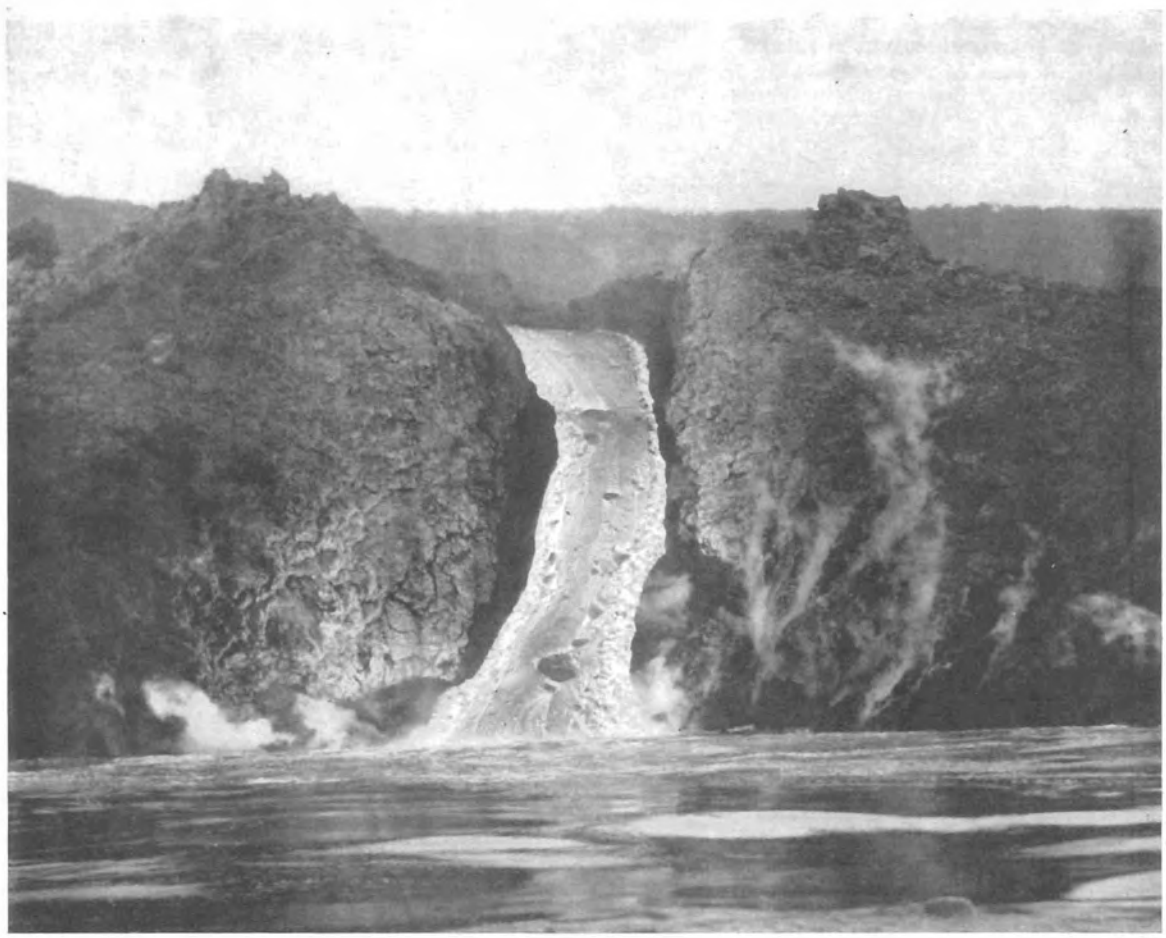

Figure 4. A lava river of the Ohia Lodge flow entering the sea. When such a river with practically unbroken surface entered the ocean, it produced but little steam. Bursts of steam were produced whenever blocks projecting above the surface of the river struck the water.—Photo by T. Matsumoto; courtesy Trans-Pacific Airlines.

much the same way as does the pahoehoe skin. Figure 4 shows such a lava river entering the sea and producing but very little steam. Whenever a block of appreciable size (some appear as dark objects in Figure 4) that was carried along by the lava river entered the water, it did produce a large burst of steam.

REFERENCES

FINCH, R. H. HARMONIC TREMOR. Volcano Letter 483, pp. 1–2, 1944.

JAGGAR, T. A. ACTIVITY OF MAUNA LOA. Hawaiian Vol. Obs. Bull. 7(10): 151, 1919.

——— JOURNAL OF MAUNA LOA ERUPTION. Hawaiian Vol. Obs. Bull. 14: 41–42, 1926.

MACDONALD, G. A. THE 1840 ERUPTION AND CRYSTAL DIFFERENTIATION IN THE KILAUEAN MAGMA COLUMN. Amer. Jour. Sci. 242: 177–189, 1944.

POWERS, H. A. ANNUAL TILT PATTERN AT THE HAWAIIAN VOLCANO OBSERVATORY. Volcano Letter 495, pp. 1–5, 1947.

STEARNS, H. T., and MACDONALD, G. A. THE GEOLOGY AND GROUND-WATER RESOURCES OF THE ISLAND OF HAWAII. Hawaii Div. Hydrography, Bull. 9, 363 pp., 1946.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JULY–SEPTEMBER, 1950

VOLCANOLOGY

July

The southwest rift vents of Mauna Loa emitted conspicuous amounts of fume during July.

A total of 69 earthquakes was recorded in July. Of these 59 were recorded at Kilauea and 25 at Mauna Loa. A majority of the earthquakes were of Kilauea origin, and they originated at shallow depths near the northern edge of Kilauea Caldera.

A slight westward tilting, or opposite in direction normal for this season of the year, indicates a pressure decrease under Mauna Loa. Northward tilt during July was greater than normal and indicates an increase of pressure at Kilauea.

The southwest rift vents of Mauna Loa were inspected on July 11. Large quantities of fume were being liberated.

August

In August, as in July, Kilauea was more active seismically than Mauna Loa. A total of 320 earthquakes was recorded in August. Of these, 312 were on the seismograph at Kilauea and 30 on the seismograph on the east slope of Mauna Loa. Most of the quakes originated at shallow foci under the northern end of Kilauea Caldera. Shaking was nearly continuous on August 2, when 241 quakes were recorded. Only three of these 241 quakes were felt. An earthquake accompanied by a roar was felt at Naalehu at 10:58 A.M., August 11. Another perceptible quake with epicenter low down under the northeast slope of Mauna Loa was felt in Hilo and at Kilauea at 12:18 P.M., August 27.

Tilt in the east–west direction during August was of the usual seasonal value. Rapid north tilt which started on July 15 continued until August 16. From August 17 to the end of the month there was a slight accumulation of south tilt. The accumulation of northward tilting since the first of the year, 9 seconds of arc, indicates a pressure increase preceding, during, and after the June eruption of Mauna Loa.

Fume was observed over the southwest rift of Mauna Loa on several days during the month.

Landslides from the Halemaumau rim were observed on August 29.

September

A total of 25 earthquakes was recorded in September. Of this number, 21 were recorded at Kilauea and 13 on the Mauna Loa seismograph.

East tilt was less than usual for September and may be taken as an indication of a slight pressure decrease under Mauna Loa. North tilt was normal for this season of the year.

Fume was observed over the southwest rift of Mauna Loa several times during the month. Following heavy rains on Mauna Loa on September 29 and 30 large fume clouds developed over the June, 1950, eruption source. The mixed steam and fume clouds started reports that Mauna Loa was erupting.

SEISMOLOGY

Earthquake Data, July–September, 1950

(Based on Bosch-Omori seismograph on rim of Kilauea Caldera)

Week Beginning		Minutes of Tremor	Very Feeble	Feeble	Slight	Local Seismicity*	Teleseisms
July	2	5	0	0	0	1.25	1
	9	2	2	0	0	1.50	1
	16	6	3	0	0	3.00	0
	23	23	3	2	0	7.25	2
	30	223	43	2	1	81.25	0
Aug.	6	24	4	1	0	8.00	1
	13	14	2	0	0	4.50	1
	20	3	0	0	0	0.75	0
	27	4	1	1	0	2.50	0
Sept.	3	7	0	0	0	3.25	0
	10	2	1	1	0	2.00	1
	17	7	0	0	0	1.75	0
	24	3	1	0	0	1.25	1

* For definition of local seismicity, see Volcano Letter 371.

The data for the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

178. July 1, 12:55, very feeble. Mauna Loa.
179. July 12, 03:12, very feeble. Kilauea.
180. July 12, 20:46, very feeble. East slope Mauna Loa.
181. July 19, 20:48, very feeble. Southwest slope Mauna Loa.
182. July 20, 03:45, very feeble. West slope Mauna Loa.
183. July 21, 15:29, very feeble. Kilauea.
184. July 23, 13:11, very feeble. Kilauea.
185. July 24, 15:42, feeble. Felt locally. North end Kilauea Caldera.
186. July 25, 19:30, very feeble. Kilauea.
187. July 26, 12:14, feeble. Mauna Loa.
188. July 29, 18:56, very feeble. Kilauea.
189. July 31, 04:29, slight. Felt locally. North end Kilauea Caldera.
190. July 31, 15:18, very feeble. Kilauea.
191. Aug. 1, 02:57, very feeble. Kilauea.
192. Aug. 1, 20:43, very feeble. Kilauea.
193–231 inclusive, Aug. 2, 39 quakes originating under north end of Kilauea Caldera.
232. Aug. 3, 02:15, very feeble.
233. Aug. 3, 04:43, very feeble.
234. Aug. 8, 06:04, very feeble. Kilauea.
235. Aug. 8, 10:21, very feeble. Kilauea.
236. Aug. 9, 14:27, very feeble. Kilauea.
237. Aug. 10, 07:35, very feeble.
238. Aug. 11, 10:58, feeble. Felt at Naalehu.
239. Aug. 13, 05:15, very feeble. Kilauea.

240. Aug. 19, 05:12, very feeble. Felt locally. Kilauea.
241. Aug. 27, 12:18, feeble. Felt locally and at Hilo. North slope Mauna Loa.
242. Aug. 28, 10:25, very feeble. Upper northeast rift Mauna Loa.
243. Sept. 15, 07:42, very feeble. Kilauea.
244. Sept. 16, 21:51, feeble. Felt locally and at Hilo. Northeast rift Mauna Loa.
245. Sept. 30, 17:06, very feeble. Mauna Loa.

TELESEISMS

July 8, 16:09, slight. Near Easter Island.
July 12, 01:27, slight. Aleutians.
July 29, 06:58, slight. Molucca Passage.
July 29, 13:58, slight. Solomon Islands.
Aug. 6, 16:57, slight. Mindanao, P. I.
Aug. 15, 04:24, strong. Burma border.
Sept. 10, 05:25, slight. New Hebrides.
Sept. 28, 20:36, moderate.

MICROSEISMS

Microseisms were strong on August 13, 14, and 15, and moderate on August 16 and from September 11 to 19. On other days they were slight.

CRACK MEASUREMENTS

One end of the crack near the tourist station on the east rim of Halemaumau opened 1 centimeter from June 30 to September 30. At a greater distance from the end of the crack the opening was 2 millimeters. Other cracks measured showed but very little movement.

TILTING OF THE GROUND

A slight westerly tilt in July may be taken as an indication of a pressure decrease under Mauna Loa. Normally there is an east tilt in July. During August and September usual seasonal tilt obtained.

Except for a south tilt August 17 to 21, north tilt was continuous and in a little greater amount than normal for this season of the year.

Table of Tilt at Seismograph Vault on Northeast Rim of Kilauea Caldera

Week Beginning		Amount	Direction
July	2	0.9″	N 15° W
	9	0.5″	S 64° W
	16	1.0″	N 6° E
	23	1.0″	N 20° W
	30	2.4″	N 17° E
August	6	1.4″	N
	13	2.6″	S 82° E
	20	0.8″	W
	27	0.5″	N 14° E
September	3	0.8″	N 18° W
	10	0.9″	N 57° E
	17	0.5″	N 45° E
	24	0.6″	S 53° W

TEMPERATURE MEASUREMENTS

The temperature of the steam well at the Sulfur Bank was constant at 204° F. in July, August, and September.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

R. H. Finch, Volcanologist, Director
G. A. Macdonald, Geologist
C. K. Wentworth, Geologist, part-time
B. J. Loucks, Instrument maker
Catherine R. Hjort, Secretary

University of Hawaii:

T. A. Jaggar, Geophysicist

Seismograph Station Operators:

Hilo Station:

Brother B. T. Pleimann, Saint Joseph's School

Kealakekua Station:

H. M. Tatsuno, Konawaena School

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter**, a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

THE VOLCANO LETTER

No. 510 **U. S. Geological Survey** **October–December, 1950**

PUBLISHED BY THE UNIVERSITY OF HAWAII

THE DECEMBER 1950 SUBSIDENCE AT KILAUEA

By R. H. FINCH

At noon on December 8, 1950, after several weeks of generally normal seismic conditions, the frequency of occurrence of earthquakes recorded by the seismographs suddenly increased. Simultaneously a rapid southwesterly tilt started at the Whitney Station on the northeast rim of Kilauea.

The origins of the early earthquakes were in the vicinity of Kokoolau Crater (Fig. 1), 4 miles from the Whitney Station, under the upper end of the system of fissures between the east and southwest rifts of Kilauea. During the night of December 8–9, earthquakes continued to originate in the region of the early shakes; others showed greater distances as though there was a progressive cracking to the southwest. By early morning on December 9 many of the quakes were being plainly felt at Kapapala (Fig. 1). The indicated origin of some of the stronger shakes on this date was a little to the east of Kamakaia Hills. The strongest quake of the series occurred at 21:25, December 10, with an indicated origin also a little to the east of Kamakaia Hills, and was generally felt over the eastern half of Hawaii.

The epicenters of the quakes were distributed over a linear extent of 15 miles, from the Chain of Craters Road to the upper end of the 1823 lava flow. The indicated depth of focus of many of the earthquakes was 4–5 miles.

The total number of earthquakes recorded during the period of rapid subsidence, December 8–14, was at least 656. The maximum number of quakes in any one day was more than 200 on December 10. For several hours each day on December 8, 9, and 10 quaking was so nearly continuance that it was impossible to separate the records of numerous small quakes. The following table shows the number of earthquakes by day:

DATE	NUMBER OF QUAKES
Dec. 8	133+
9	149+
10	200+
11	112
12	33
13	17
14	12

On December 11 a small crack trending NNE–SSW with a few millimeters downthrow on the Kilauea Caldera side was noted on the road near Kokoolau Crater. Two small cracks trending NE–SW were later observed about 2 miles to the southwest of Kokoolau Crater.

The fact that the earthquakes accompanied a rapid subsidence of the entire top of Kilauea was shown by tilt records. A seasonal northeasterly tilt usually continues until the latter part of December, when a seasonal change to the southwest usually occurs. A rapid southwesterly tilt at the Whitney Station started on December 8 and continued for 4 days with a cumulative total of 14.5 seconds of arc. During the same 4 days the cumulative total at the Uwekahuna Station (Fig. 1) was 22.1 seconds of arc to the east-southeast. In both cases tilting was much more rapid than normal seasonal tilting. These values place the maximum subsidence a little to the northeast of Halemaumau, about the same position as that of the maximum subsidence of 1920–24 determined by Wilson[1] on the basis of leveling. Calculations indicate that the maximum subsidence in 1950 was in excess of 1 foot. Figure 2 shows the tilt curves obtained at the Whitney Station. The

[1] WILSON, R. M. GROUND SURFACE MOVEMENTS AT KILAUEA VOLCANO HAWAII. Hawaii Univ. Res. Pub. No. 10. 1935.

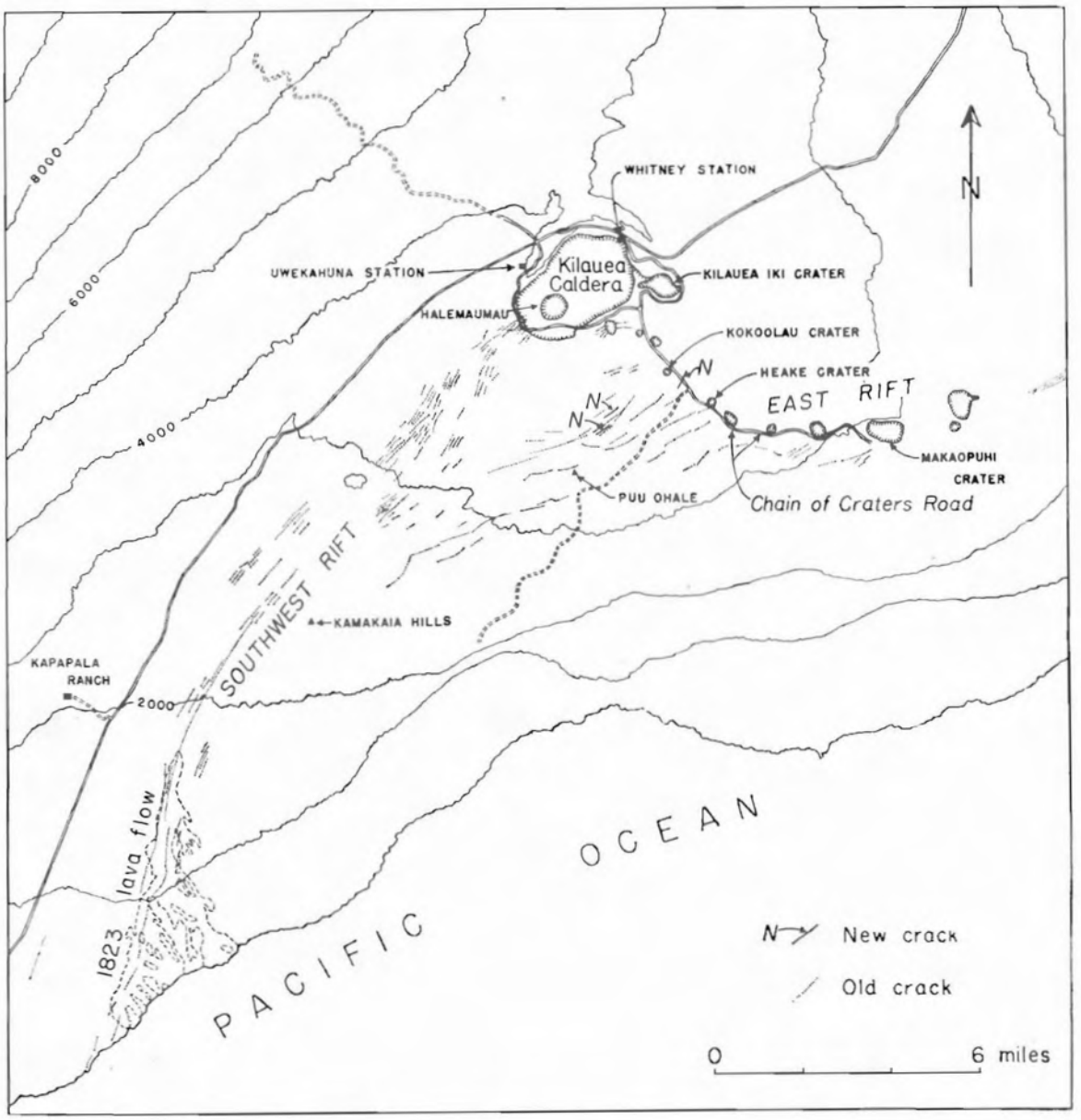

FIGURE 1. Map of Kilauea Caldera and vicinity. The 656 earthquakes recorded during the December, 1950, subsidence originated along the rift zone extending from Kokoolau Crater to beyond the Kamakaia Hills. New cracks were observed at places marked N.

sinking implied by the 14.5 seconds of arc south–southwest tilt is less than the implied tumescence during the 5 months from March to July, 1950, when there was a tilt of 21 seconds to the north–northeast.

Tilting, earthquakes, and cracks at the surface indicate that a considerable area, probably several miles in diameter around Kilauea Caldera, subsided. The location of the earthquakes and the new cracks indicate that a triangular block bounded by the east and southwest rifts and a line from Kokoolau Crater to the upper end of the 1823 lava flow underwent a greater movement than adjacent areas.

Several short spells of harmonic tremor recorded on December 10 and 11 indicate that there was some movement of magma at a depth of 4 or more miles (the depth of focus of many of the earthquakes). Tilt records indicate that pressure continued to build up under Kilauea for nearly 2 months after Mauna Loa ceased to erupt in June, 1950. Whether the rapid pressure decrease in December was accompanied by a retreat of the lava into the depths or by a more or less horizontal drainage into the southwest rift or elsewhere is not known. The writer favors the possibility of retreat of the lava column to depth.

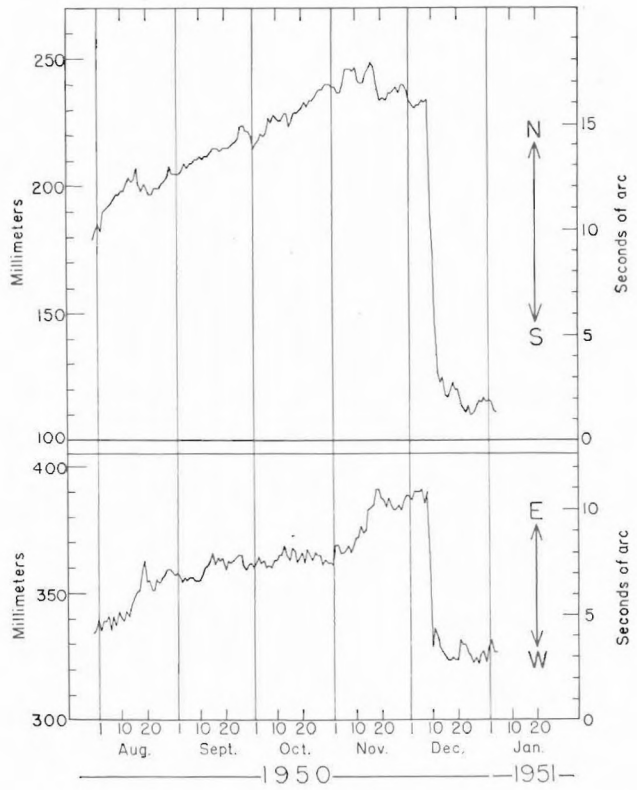

FIGURE 2. Graph of ground tilting at the Whitney Laboratory of Seismology at the northeast rim of Kilauea Caldera from August to December, 1950, showing the rapid south and west tilt on December 8 to 12. The resultant tilt for these 4 days was 14.5 seconds of arc to the south–southwest. Tilting at normal rates preceded and followed the rapid tilting.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR OCTOBER–DECEMBER, 1950

VOLCANOLOGY

October

Only 25 earthquakes were recorded in October. Of these, 24 were recorded at Kilauea and 19 on the Mauna Loa seismograph. A slight earthquake that was felt all over the island of Hawaii on October 11 originated at a depth of about 25 miles under the east slope of Mauna Loa.

Northward tilting of the ground was about normal for this season of the year and eastward tilting was less than usual.

The vents of the 1950 lava flows on the southwest rift of Mauna Loa continue to liberate fume. The fume was especially conspicuous on October 19.

November

Both Mauna Loa and Kilauea continued quiet during November. Kilauea has had no surface manifestation of activity in more than 16 years. There have been two spells of subterranean activity during these 16 years with sufficient magnitude to be easily detected by seismographs and tiltmeters. One was in November–December, 1944, and the other in April, 1950.

Forty earthquakes were recorded in November. Of these, 38 were recorded at Kilauea and 20 on the Mauna Loa instrument. Many of the quakes originated at shallow depths under the northern end of Kilauea Caldera. A continuous tremor was recorded on all seismographs on the island from 13:17 to 13:37 on November 17.

Northeastward tilting of the ground was about normal until November 16. Following heavy rains on November 15, 16, and 17 there was a slight southwest tilt. For the month as a whole there was a slight eastward tilt.

Landslides from the Halemaumau rim were common in November. The heavy rains of November 15, 16, and 17 produced conspicuous steam clouds in Halemaumau.

A conspicuous cloud was observed over the 1950 flow vents from Mauna Loa on November 15.

December

The total number of earthquakes recorded in December was 701. Of this total, 656 were recorded during 7 days—December 8–14. Owing to the frequent dismantling of the Mauna Loa seismograph no total can be given for that station.

A total of 1,702 earthquakes was recorded during 1950.

The rapid subsidence of Kilauea that began on December 8 may be taken as an indication of a sinking of the lava column under Kilauea. There had been a definite increase of magmatic pressure under Kilauea for 2½ months prior to the outbreak of Mauna Loa on June 1. The pressure build-up, as indicated by north tilt, continued definitely until the middle of August and probably until November 19. The rapid subsidence began, then, about 3 weeks after the cessation of the pressure build-up.

Tilting of the ground was slight in December except for the 14.5 seconds of arc south–southwest tilt accompanying the December 8–14 subsidence.

Conspicuous clouds were observed over the southwest rift of Mauna Loa on December 12 and less conspicuous ones on several other days.

Several landslides from the Halemaumau rim were observed.

During strong winds on December 26 most of the Kau Desert was obscured by dust clouds.

SEISMOLOGY

Earthquake Data, October–December, 1950

(Based on Bosch-Omori seismograph on rim of Kilauea Caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
Oct. 1	6	0	0	0	0	0	1.50	2
8	6	2	0	1	0	0	4.50	0
15	5	0	0	0	0	0	1.25	1
22	3	0	0	0	0	0	0.75	1
29	4	3	0	0	0	0	2.50	1
Nov. 5	9	1	0	0	0	0	2.75	3
12	8	1	0	0	0	0	2.50	0
19	7	1	0	0	0	0	2.25	0
26	3	4	0	0	0	0	2.75	1
Dec. 3	220	46	7	13	3	0	120.00	2
10	250	62	39	24	6	1	202.50	1
17	11	3	2	1	0	0	8.25	0
24	6	1	0	0	1	0	5.00	0

* For definition of local seismicity, see Volcano Letter 371.

The data for the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

246. Oct. 8, 05:49, very feeble.
247. Oct. 11, 20:06, slight. Felt over most of Hawaii. 20–25 miles deep under east slope of Mauna Loa.
248. Oct. 12, 07:33, very feeble.
249. Oct. 31, 02:53, very feeble.
250. Nov. 1, 15:28, very feeble. Kilauea.
251. Nov. 4, 03:02, very feeble. Kilauea.
252. Nov. 11, 23:34, very feeble. Kilauea.
253. Nov. 13, 18:22, very feeble. Kilauea.
254. Nov. 19, 23:23, very feeble. Kilauea.
255. Nov. 26, 19:53, very feeble. West slope, Mauna Loa.
256. Nov. 30, 14:18, very feeble. Mauna Loa.
257. Dec. 1, 01:37, very feeble. Kilauea.
258. Dec. 2, 20:54, very feeble. Southwest slope, Mauna Loa.
259. Dec. 7, 00:27, very feeble.
260. Dec. 7, 05:40, very feeble. Southwest slope, Mauna Loa.

Earthquakes accompanying the subsidence at Kilauea. Moderate or stronger quakes only are listed separately.

SERIAL NUMBER	DATE
261–278	Dec. 8
279–327	Dec. 9
328–398	Dec. 10
399–430	Dec. 11
431–437	Dec. 12
438–442	Dec. 13
443–447	Dec. 14

290. Dec. 9, 05:43, moderate. Widely felt. East of Mauna Iki. 4–5 miles deep.
323. Dec. 9, 20:45, widely felt. Instruments dismantled. Near Kamakaia Hills.
325. Dec. 10, 05:57, moderate. 4–5 miles deep, near Kamakaia Hills.
326. Dec. 10, 08:23, moderate. Below Kamakaia Hills.
369. Dec. 10, 17:29, moderate. Kamakaia Hills.
370. Dec. 10, 17:57, moderate. Near Puu Ohale.
379. Dec. 10, 21:25, strong. Widely felt. Instruments dismantled. Kamakaia Hills.
421. Dec. 11, 12:53, moderate. 4–5 miles deep below upper end 1823 lava flow.
431. Dec. 12, 06:28, moderate. Depth shallower than preceding quakes.
448. Dec. 15, 02:13, very feeble. Kilauea.
449. Dec. 16, 07:17, feeble.
450. Dec. 18, 05:54, very feeble. Felt plainly at Naalehu. Above South Point.
451. Dec. 20, 23:19, feeble.
452. Dec. 21, 20:00, very feeble.
453. Dec. 21, 21:17, feeble.
454. Dec. 22, 03:07, slight. Felt locally. Mauna Loa.
455. Dec. 22, 04:07, very feeble. Kilauea.
456. Dec. 26, 02:55, moderate. 8 miles deep south of Kilauea Iki. Widely felt.
457. Dec. 27, 18:58, very feeble.

TELESEISMS

Oct. 5, 06:21, moderate. Costa Rica.
Oct. 7, 17:34, slight. Moluccas.
Oct. 21, 00:04, slight. West coast of Mexico.
Oct. 23, 06:24, slight. Guatemala.
Nov. 2, 05:40, moderate. Felt at Darwin, Australia.
Nov. 7, 16:28, moderate. Solomon Islands.
Nov. 9, 16:36, very slight.
Nov. 11, 00:04, very slight.
Dec. 2, 10:01, moderate. New Hebrides.
Dec. 4, 06:38, slight. New Britain.
Dec. 9, 12:26, slight.
Dec. 13, 16:00, slight.
Dec. 14, 04:40, very slight.

MICROSEISMS

Microseisms were strong on November 3, December 2–13, and December 26–31. They were of slight or moderate amplitude on other days.

CRACK MEASUREMENTS

A majority of the cracks that were measured around the rim of Halemaumau showed distinct openings. Quite likely some of the openings were due to earthquakes. Cracks on the crater floor that are more or less aligned with the southwest rift closed slightly during the sinking spell of December 8–14. During this same spell some of the old cracks by Kokoolau Crater, near where new cracks appeared at the surface, showed distinct openings.

TILTING OF THE GROUND

Seasonal northeast tilt continued until November 17 when a southwest tilt set in. This change in direction came about 1 month earlier than usual and was probably due to unusually heavy rains on November 15, 16, and 17. Seasonal southwest tilt continued through the end of the year, except for the rapid southwest tilt December 8–12.

Table of Tilt at Seismograph Vault on Northeast Rim of Kilauea Caldera.

Week Beginning	Amount Seconds	Direction
October 1	1.21	N 5° E
8	0.54	N 63° E
15	0.60	N 36° W
22	0.86	N 8° W
29	0.60	N 79° E
November 5	0.95	N 50° E
12	2.28	E
19	1.02	S 70° W
26	0.86	S 34° E
December 3	6.24	S 37° W
10	9.48	S 25° W
17	1.02	S 45° E
24	0.76	N 18° W

TEMPERATURE MEASUREMENTS

The temperature of the steam well at the Sulfur Bank varied from 204° to 204.5° F.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:
R. H. Finch, Volcanologist, Director
G. A. Macdonald, Geologist
C. K. Wentworth, Geologist, part-time
B. J. Loucks, Instrument maker
Catherine R. Hjort, Secretary

University of Hawaii:
T. A. Jaggar, Geophysicist

Seismograph Station Operators:
Hilo Station:
Brother B. T. Pleimann, Saint Joseph's School
Kealakekua Station:
H. M. Tatsuno, Konawaena School

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter**, a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

THE VOLCANO LETTER

No. 511 **U. S. Geological Survey** **January–March, 1951**

PUBLISHED BY THE UNIVERSITY OF HAWAII

BEGINNING OF GEOMAGNETIC OBSERVATIONS AT HAWAIIAN VOLCANO OBSERVATORY

By G. A. MACDONALD

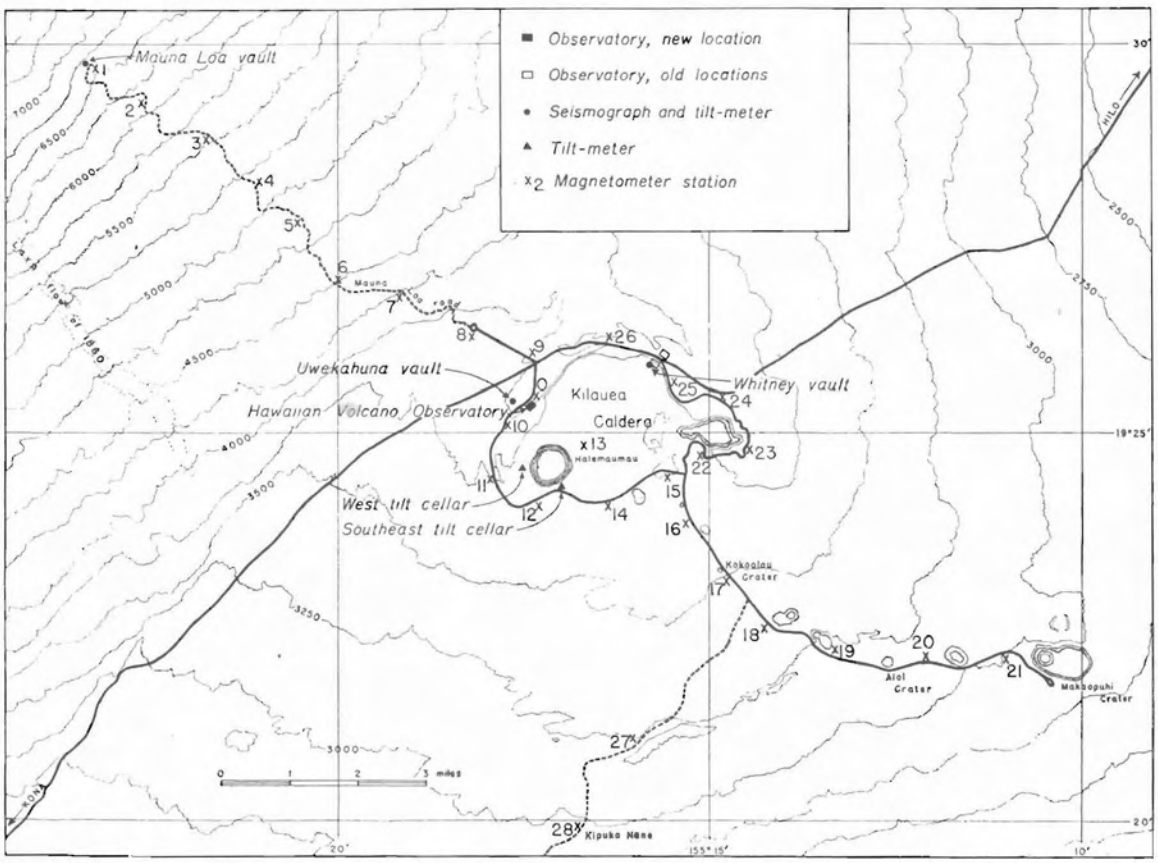

FIGURE 1. Kilauea Caldera and environs, showing locations of Observatory and permanent magnetometer stations.

For the past several years the staff of the Hawaiian Volcano Observatory has wanted to start geomagnetic measurements at Kilauea and Mauna Loa volcanoes. Results obtained by workers on volcanoes in other areas, especially Japan (Kato, 1933–35; Takahasi and Hirano, 1941), have suggested that magnetic measurements in Hawaii might give information on magmatic conditions and movements beneath the surface and, in addition, might supplement other methods in predicting eruptions. Preliminary studies by Omer (1945) suggested some correlation between volcanic conditions on the island of Hawaii and small variations in the magnetic field at Honolulu, nearly 200 miles away.

The opportunity to begin magnetic studies came early in 1950 when two Wolfson vertical magnetometers were made available to the Volcano Observatory by the Geophysics Branch of the U. S. Geological Survey. H. R. Joesting and J. H. Swartz of the Geophysics Branch, accompanied by R. E. Wilcox of the General Geology Branch of the Geological Survey, spent the first 3 weeks of February, 1950, at the Observatory setting up procedures to be followed, calibrating instruments, and instructing Observatory personnel in their use. Joesting and Swartz have kindly read and criticized the manuscript of this paper.

A series of permanent observation stations was established during February and March on Kilauea and on the lower slopes of Mauna Loa. The location of the

DIFFERENCE IN VERTICAL INTENSITY OF GEOMAGNETISM (IN GAMMAS) AT OTHER STATIONS, COMPARED TO THAT AT STATION 0.

STATION NUMBER	1950 FEB. 17	MAR. 20	APR. 3–4	MAY 9–10	JUNE 9	JUNE 12	JULY 15–16	AUG. 12–13	SEPT. 21–22	OCT. 21	NOV. 28–29	DEC. 28	1951 JAN. 20–21	FEB. 24	MAR. 20
1	.....	—683	— 744	— 828	—794	—795	— 864	— 823	— 806	—847	—1003	.....	— 821	—792	— 858
2	.....	— 37	— 54	— 18	.....	— 36	— 60	— 84	— 1	— 35	— 228	.....	— 87	+ 13	— 46
3	.....	—271	— 303	— 301	—329	—304	— 348	.....	— 300	—364	— 508	.....	— 348	—247	— 524
4	.....	—291	— 345	— 326	.....	—327	— 400	— 342	— 326	—371	— 551	.....	— 368	.....	— 486
5	.....	+ 77	+ 57	+ 62	+ 83	+112	+ 96	+ 77	+ 131	+ 26	— 85	.....	+ 73	+233	— 81
6	.....	—117	— 141	— 176	.....	—117	— 148	.....	— 136	—121	— 336	.....	— 139	.....	— 308
7	.....	— 76	— 107	— 120	—115	— 82	— 110	.....	— 79	— 75	— 339	.....	.....	— 66	.....
8	.....	—615	— 659	— 765	.....	—710	— 762	— 728	— 697	—692	— 976	—756	— 724	—625	—1060
9	.....	—714	— 758	— 899	—865	—835	— 901	— 834	— 793	—834	—1098	—869	— 912	—766	—1179
10	—681	.....	— 669	— 760	.....	.....	— 785	— 705	— 676	—676	—1019	—778	.....	—629	—1052
11	—171	.....	— 204	— 212	.....	.....	— 244	— 166	— 143	—155	— 497	—177	.....	.....	+ 290
12	—677	.....	— 676	— 745	.....	.....	— 760	— 696	— 658	—676	—1053	—700	.....	.....	— 339
13	.....	.....	— 536	— 604	.....	.....	— 588	— 559	— 541	—541	— 919	—506	.....	—431	.....
14	— 35	.....	— 69	— 45	.....	.....	— 31	— 19	— 21	— 26	— 443	— 30	.....	+ 62	+ 216
15	+416	.....	+ 433	+ 486	.....	.....	+ 452	+ 456	+ 437	+437	+ 73	+466	.....	+621	+ 788
16	.....	.....	+ 177	+ 198	.....	.....	+ 178	+ 217	+ 217	+217	+ 209	+168	+ 199	+306	+ 526
17	.....	.....	— 663	— 740	.....	.....	— 758	— 684	— 685	—732	— 672	—666	.....	—609	— 367
18	.....	.....	— 418	— 473	.....	.....	— 466	— 451	— 411	—454	— 791	—441	— 460	—345	— 178
19	.....	.....	+ 287	+ 353	.....	.....	+ 326	.....	+ 313	+352	+ 16	+332	+ 331	+414	+ 598
20	.....	.....	— 273	— 304	.....	.....	— 283	— 258	— 258	—310	— 581	—311	— 280	—180	— 18
21	.....	.....	+ 257	+ 288	.....	.....	+ 311	.....	+ 319	+294	+ 67	+274	+ 279	+398	+ 552
22	+786	.....	+ 784	+ 899	.....	.....	+ 894	.....	+ 845	.....	+ 697	+823	+1108	.....	+ 889
23	.....	.....	+1167	+1358	.....	.....	+1334	+1255	+1219	.....	+1168	.....	+1284	.....	+1278
24	.....	.....	— 46	— 45	.....	.....	— 47	— 50	— 7	.....	— 186	.....	— 8	.....	— 123
25	.....	.....	.....	+2547	.....	.....	.....	+2550	+2591	.....	+2555	.....	+2602	.....	+3843
26	.....	.....	+ 243	+ 288	.....	.....	+ 291	+ 289	+ 276	.....	+ 189	.....	+ 342	.....	.....
27	.....	.....	.....	— 872	.....	.....	— 910	— 850	— 827	—896	— 895	.....	— 924	—937	— 825
28	.....	.....	.....	— 927	.....	.....	— 921	— 925	— 897	—957	— 958	.....	— 976	—994	— 920

stations is shown in Figure 1. The number of stations is not as great as might be desired, but is limited by the amount of time available for the work.

Each station was set at a point where closely spaced set-ups of the magnetometer showed the magnetic field to be reasonably regular over an area of approximately 100 square feet. At each station three concrete hubs were set and small pits drilled in them to receive the ends of the magnetometer tripod legs. The tripod legs are kept at a fixed length when the stations are occupied, and each leg is placed on the same hub in successive readings at each station. The leveling screws also are turned out as nearly as possible to the same distance for each set-up. Thus the position of the instrument, both horizontally and vertically, is as nearly as possible the same for successive readings at a given station.

It is planned to occupy each station approximately once a month, but during some months the Observatory staff has not had time to occupy all of the stations. The stations are so widely distributed that considerable time is needed for travel between them. All the readings of each set are made on one day, or on 2 successive days.

The procedure is as follows. One instrument is set on station 0, near the Volcano Observatory at the western edge of Kilauea Caldera (Fig. 1). After the reading at station 0 is obtained, the instrument is taken to each of the other stations and readings obtained at them. Readings are made with the north end of the balance pointed first east and then west; the average of the two sets of readings is used, thus compensating for any small errors in orientation and leveling of the instrument. Immediately after the first instrument is removed from station 0, the second instrument is set up at that station and it is read at frequent intervals throughout the time the first instrument is in use at the other stations. From the readings at station 0, a curve of diurnal variation is constructed which is used in correcting the readings at the other stations. At the end of the traverse the first instrument is again set on station 0, and, after correcting for diurnal variation, any closing error is distributed linearly throughout the time of operation. The instrument is recalibrated for sensitivity in the laboratory following each series of readings. The corrected scale readings are then converted into gammas, and the strength of the magnetic attraction at each station is recorded in terms of difference in gammas from that at station 0.

In some respects the program is not ideal, but it represents the best which the limited available time and small size of the Observatory staff allow at present. If results appear to justify it, it is hoped that the program can be expanded and improved in the future. The data obtained thus far are shown in the accompanying table.

Joesting and Swartz again visited the Volcano Observatory in June, 1950, during the eruption of Mauna Loa for the purpose of checking on the progress of the investigation and the operation of the instruments. Of the measurements listed in the table, those for June 12 were made by them. The others were made by members of the Observatory staff, principally C. K. Wentworth and the writer, aided during March and April by J. B. Orr of the National Park Service. On March 8 and 9, 1951, F. C. Farnham of the Geophysics Branch made measurements with an absolute magnetometer at station 0 close to the Volcano Observatory and at a newly established station close to the seismograph station at St. Joseph's School in Hilo.

It is too soon to attempt much interpretation of the results. It is believed possible that the rise of hot magma

underground may cause a detectable change in the vertical component of the magnetic field at the surface. It will be noted in the accompanying table that several of the stations (1 to 9) which lie on the line between the Observatory and the Mauna Loa seismograph showed a decrease in magnetism as related to station 0. Mauna Loa erupted on June 1, and there is some possibility that the decrease in magnetism at these stations on Mauna Loa may have been in some way related to the then-impending eruption. However, the distance of the closest station from either the eruptive axis of the volcano (beneath the summit caldera) or the locality on the southwest rift where the eruption took place is so great (13 and 20 miles, respectively) that the apparent correlation is regarded with little confidence.

Early in July, soon after the end of the Mauna Loa eruption, a line of three stations was established running southeastward for 1.5 miles from a point on the recently active rift. It is planned to make readings at these stations at intervals of about 6 months during the next few years to determine whether any definite discernible effect results from cooling of the magma in the rift.

Variations at the stations on Kilauea have thus far been rather irregular. It appears that during the past year volcanism at Kilauea may have been at its lowest ebb in the historical period, and hence that the time of commencement of the magnetic program may have been exceptionally favorable in respect to detection of any changes which may accompany the return of surficial volcanic activity.

REFERENCES

KATO, Y. SEISMIC AND VOLCANIC ACTIVITIES AND CHANGES IN THE EARTH'S MAGNETIC FIELD. Japanese Jour. Astron. and Geophys. 10: 249–262, 1933; 12: 1–26, 1934; 12: 237–243, 1935.

OMER, G. ON MAGNETIC STUDIES. Volcano Letter 487, pp. 1–4, 1945.

TAKAHASI, R., and HIRANO, K. CHANGES IN THE VERTICAL INTENSITY OF GEOMAGNETISM THAT ACCOMPANIED THE ERUPTION [OF MIYAKE-SIMA IN 1940]. Tokyo Imp. Univ., Earthquake Res. Inst. Bul. 19: 373–380, 1941.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JANUARY–MARCH, 1951

VOLCANOLOGY

January

The year 1951 commenced with both Mauna Loa and Kilauea volcanoes quiescent. During the month of January, 18 earthquakes were recorded at the Whitney vault on the northeastern rim of Kilauea Caldera; 8 of these were recorded also on the seismograph on the lower east slope of Mauna Loa. This was the smallest number of earthquakes recorded during any month since October, 1947.

At the Whitney vault ground surface tilting was in the main southward, following the usual seasonal pattern for this time of year. From January 7 to 17, however, there was a sharp northward tilting of approximately 2 seconds of arc. Most cracks in the vicinity of Kilauea Caldera opened or closed very little. Cracks near the southeastern edge of Halemaumau continued to open.

Conspicuous steam clouds rose from Halemaumau on January 22, after heavy rains.

February

Mauna Loa and Kilauea continued quiet during February. The seismograph at the northeastern rim of Kilauea Caldera recorded 25 earthquakes during the month; 16 of these were recorded also on the Mauna Loa seismograph. An earthquake felt in the vicinity of Kapapala at 10: 55 A.M. on February 14 originated at a depth of about 7 miles on or near the Kaoiki fault zone near Ainapo on the southeastern flank of Mauna Loa. At 7: 26 on the morning of February 16 a somewhat stronger earthquake was felt from Naalehu to Hilo. It had its origin about 15 miles below a point on the northeast rift zone of Mauna Loa near Puu Ulaula. Most of the small earthquakes during the month originated at Kilauea.

Tilting of the ground at the northeast rim of Kilauea Caldera continued southward, as is normal for this season of the year. There was almost no accumulation of east–west tilt during the month. However, because there is normally a westward tilting at this time of the year, the absence of tilting may indicate a small increase of volcanic pressure beneath Mauna Loa.

The vents of the 1950 eruption of Mauna Loa were visited on February 9 and 10. Steam was issuing from the fissures from 10,200 to 11,500 feet altitude, and large amounts of sulfurous fume were being liberated in the vicinity of 10,000 feet. The source cracks were still warm, but no heat could be detected in most of the thin flows near the vents. The thick flows near the highway in Kona are still hot beneath the surface. Fume was visible on the southwest rift from the Volcano Observatory on the afternoon of February 16.

During heavy rains in late February, spectacular steam clouds rose from Halemaumau, giving evidence that the vent of Kilauea Volcano is still very hot only a short distance below the surface.

March

The period of quiet at Hawaiian volcanoes which began in late December continued through March. The seismograph at the northeast rim of Kilauea Caldera recorded 27 earthquakes during the month, 2 more than were recorded during February. Only 14 of these were recorded at the Mauna Loa station. A quake which was felt in the Volcano district and Hilo on the evening of March 14 originated at a depth of about 7 miles on the east rift zone of Kilauea, 5 miles east–northeast of Makaopuhi Crater. At 6: 41 A.M. on March 20 another earthquake was felt by a few persons in the Puueo district of Hilo. This quake had its origin about 6 miles below the eastern slope of Mauna Loa, 3 miles east of Kulani Cone. From March 15 to 19 several small earthquakes originated on the western slope of Mauna Loa near Kealakekua, possibly on the fault which runs out to sea at the northern edge of Kealakekua Bay.

Tilting of the ground surface at the northeastern rim of Kilauea Caldera continued southward through March. Southward tilting is normal during this part of the year. However, from March 7 to 17 the tilting was distinctly more rapid than normal, indicating a slight decrease of volcanic pressure beneath Kilauea Caldera. This, like the short spell of northerly tilting in January, indicates fluctuation of pressure, demonstrating that the lava column beneath Kilauea Caldera is still mobile. Slight westward tilting also occurred during the month, as is usual at this season.

Table of Tilt at Seismograph Vaults on Rim of Kilauea Caldera

Week Beginning		Whitney Vault (Northeast rim)		Uwekahuna Vault (West rim)	
		Amount	Direction	Amount	Direction
December	31	0.9″	S 45° W	0.4″	S 56° W
January	7	0.8″	N 38° E	0.7″	S 26° W
	14	0.7″	N	1.5″	N 70° W
	21	2.0″	S 35° E	2.4″	N 15° W
	28	0.6″	S 37° W	0.2″	N 27° E
February	4	1.2″	S 45° W	1.2″	S 70° E
	11	1.5″	N 38° E	1.5″	S 58° W
	18	1.5″	S 35° E	2.3″	N 78° E, S 52° W
	25	1.6″	S 42° W	2.4″	N 78° E
March	4	2.1″	S 26° W	1.5″	E
	11	4.1″	S 5° W	0.7″	S 15° E
	18	1.2″	S 16° W	0.5″	S 79° E
	25	0.6″	W	0.4″	N 63° E

TILTING OF THE GROUND

At the Whitney Laboratory of Seismology, situated at the site of the original Volcano Observatory building on the northeastern rim of Kilauea Caldera, ground tilting was in the southward direction, normal for this season of the year, except for a brief period of fairly strong northward tilting from January 7 to 17 and another less marked period of northward tilting from February 10 to 21. There was a slight eastward tilting in January and almost no accumulation of east–west tilt in February. However, since the normal seasonal tilting is westward in February, both the January and February records indicate a small increase in volcanic pressure beneath Mauna Loa. Normal westward tilting continued through the month of March. Records of tilting at the Uwekahuna vault are not yet long enough to determine the normal pattern of seasonal tilting at that locality.

CRACK MEASUREMENTS

The only crack which showed much change in width during the 3-month period preceding March 31 is the one which crosses the tourists' observation platform at the southeastern edge of Halemaumau. That crack opened 1.1 centimeters at the northern end, the amount of opening decreasing southward to zero at a point between measuring stations 8 and 9, south of the observation platform. Crack 37, on the floor of Kilauea Caldera about a quarter of a mile southeast of Halemaumau, opened 1 millimeter; crack 101-A, near Chain of Craters Road about 0.2 mile northwest of Devil's Throat, closed about the same amount.

TEMPERATURE MEASUREMENTS

The temperature of the steam well at the Sulphur Bank measured 204.5° F. on December 31 and January 30, and 205° F. on March 1 and March 31.

SEISMOLOGY

Earthquake Data, January–March, 1951

(Based on Bosch-Omori seismograph on rim of Kilauea Caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
Dec. 31	5	1	0	1	0	0	3.75	0
Jan. 7	0	0	0	0	0	0	0.0	0
Jan. 14	4	0	0	0	0	0	1.0	0
Jan. 21	5	1	0	0	0	0	1.75	0
Jan. 28	2	0	0	0	0	0	0.5	0
Feb. 4	3	0	0	0	0	0	0.75	0
Feb. 11	6	1	0	2	0	0	6.0	2
Feb. 18	1	6	0	0	0	0	3.25	1
Feb. 25	2	3	0	0	0	0	2.0	0
Mar. 4	4	5	0	0	0	0	3.5	1
Mar. 11	3	4	1	1	0	0	5.75	0
Mar. 18	5	1	1	0	0	0	2.75	0
Mar. 25	1	0	0	0	0	0	0.25	0

* For definition of local seismicity, see Volcano Letter 371.

The data for the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory. Locations given are epicenters. The arrival times are given to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year. The intensity rating (Feeble, Moderate, etc.) given is that for the Whitney Laboratory at the northeast rim of Kilauea Caldera. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney station.

1. Jan. 3, 03:39, very feeble.
2. Jan. 6, 04:58, slight. Southwest rift of Mauna Loa at about 8,000 feet altitude.
3. Jan. 26, 06:40, very feeble.
4. Feb. 14, 10:55, slight (moderate, Mauna Loa), felt at Kapapala. Kaoiki fault near Ainapo, about 7 miles deep.
5. Feb. 16, 07:26, slight (moderate, Mauna Loa), felt from Hilo to Naalehu. Northeast rift of Mauna Loa near Puu Ulaula, about 15 miles deep.
6. Feb. 16, 18:58, very feeble.
7. Feb. 20, 20:01, very feeble.
8. Feb. 20, 20:47, very feeble.
9. Feb. 20, 21:47, very feeble.
10. Feb. 21, 21:26, very feeble.
11. Feb. 23, 03:41, very feeble.
12. Feb. 24, 17:39, very feeble.
13. Feb. 26, 01:28, very feeble (feeble, Kona).
14. Feb. 26, 09:21, very feeble.
15. Feb. 28, 14:13, very feeble.
16. Mar. 5, 03:53, very feeble.
17. Mar. 5, 03:56, very feeble.
18. Mar. 5, 09:33, very feeble.
19. Mar. 5, 16:44, very feeble. Northeast rift of Mauna Loa.
20. Mar. 8, 16:30, very feeble. Nearly under Hilo, about 25 miles deep.
21. Mar. 14, 03:47, very feeble. Hilina fault, southeast of Kilauea Caldera.
22. Mar. 14, 03:48, feeble. East rift of Kilauea.
23. Mar. 14, 20:50, slight, felt in Hilo and Volcano areas. East rift of Kilauea 3 miles east–northeast of Napau Crater, about 7 miles deep.
24. Mar. 15, 04:38, very feeble (feeble, Mauna Loa). West slope of Mauna Loa near Kealakekua.
25. Mar. 15, 11:34, very feeble.
26. Mar. 15, 16:43, very feeble (slight, Kona). West slope of Mauna Loa near Kealakekua.
27. Mar. 20, 06:42, feeble, felt in Puueo. East slope of Mauna Loa 3 miles east of Kulani Cone, about 6 miles deep.
28. Mar. 24, 06:28, no record at Kilauea (very feeble, Kona). West slope of Mauna Loa.
29. Mar. 24, 22:33, very feeble.

TELESEISMS

Locations of the epicenters are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey.

Jan. 13, 12:20, slight. About 150 miles east of Alaska Peninsula.
Jan. 17, 11:17, slight. Southeastern New Guinea.
Feb. 19, 12:38, moderate. About 500 miles west of Easter Island.
Mar. 10, 12:06, slight. Fiji Islands region.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director

Chester K. Wentworth, Geologist, part-time

John C. Forbes, Laboratory Mechanic

LaVieve G. Forbes, Secretary, part-time

University of Hawaii:

T. A. Jaggar, Geophysicist

Seismograph Station Operators:
Hilo Station:

Brother B. T. Pleimann, St. Joseph's School

Kealakekua Station:

H. M. Tatsuno, Konawaena School

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter**, a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

THE VOLCANO LETTER

No. 512 **U. S. Geological Survey** **April–June, 1951**

PUBLISHED BY THE UNIVERSITY OF HAWAII

THE KILAUEA EARTHQUAKE OF APRIL 22, 1951, AND ITS AFTERSHOCKS

By GORDON A. MACDONALD

At 2:52 Hawaiian time, on the afternoon of April 22, the southern part of the island of Hawaii experienced the strongest earthquake in this area since 1929, and possibly since 1908. The epicenter of the quake lay just east of Kilauea Caldera. The intensity of V, on the modified Mercalli scale, was essentially uniform for 30 miles northeast and southwest of the epicenter, to Hilo and Naalehu, respectively. This uniformity of intensity over such a broad area indicates that the origin of the earthquake was at a considerable depth, probably 25 to 30 miles. It was impossible to determine either the epicenter or the depth of origin instrumentally, because all the seismographs of the local net were dismantled by the beginning of the preliminary waves. The operator of the Hilo seismograph station, Brother Bernard T. Pleimann of St. Joseph's School, reached the dismantled instrument and reassembled it in time to record the coda of the earthquake. Shaking continued on the Hilo instrument for 16 minutes.

The preliminary determination of epicenter, issued by the U. S. Coast and Geodetic Survey on April 24, gives the time at the origin as 00:52:21 on April 23, Greenwich time, and the magnitude on the Gutenberg-Richter scale as 6.5 as determined at Pasadena and 6.0 at Berkeley.

The earthquake was felt generally over the island of Hawaii and by many persons on the islands of Maui and Oahu. Damage resulting from the quake was slight. On the southern part of the island of Hawaii many small objects were overturned, and some dishes were broken. Many, but not all, pendulum clocks were stopped. A water pipe was broken at the Volcano Observatory, and a plate glass window at Glenwood was cracked. Water slopped over the rims of some tanks. Small earth slips occurred in road cuts between Kilauea Caldera and Hilo, and north of Hilo along the Hamakua Coast. Several rock slides occurred on the walls of Kilauea Caldera and a very large number on the unstable walls of Halemaumau crater. All the latter were small. No large blocks of the crater rim were displaced, although many cracks near the rim were widened appreciably. The crack which crosses the tourist area at the southeast rim of the crater opened 6 mm. at the time of the earthquake and 3 mm. more during the period of aftershocks. Small slides continued in Halemaumau for about a week after the big earthquake. Small rock avalanches occurred on the walls of Alae and Makaopuhi craters, on the east rift zone of Kilauea, and Superintendent F. R. Oberhansley of Hawaii National Park reported rock falls at the cliffs of Hilina Pali and Puu Kapukapu, on the southern shore of the island. Minor cracking of the highway occurred at the northeast rim of Kilauea Caldera, ¼ mile southeast of the Whitney Laboratory (Fig. 1), apparently caused by settling of a thin fill under the pavement when the block at the edge of the caldera moved forward slightly. Cracking in the soil also was observed at several places north and east of Kilauea Caldera, apparently caused by lurching of the soil. No surface faulting was observed.

The Bosch-Omori seismograph at the Whitney Laboratory on the northeast rim of Kilauea Caldera (Fig. 1) and the vertical seismograph at Uwekahuna were dismantled. The vertical seismograph was back in operation at 15:20, but resumption of recording on the Bosch-Omori seismograph was delayed until 16:45 by electric power failure caused by the earthquake. The wire suspensions on the heavy mass of one component of the Hawaiian-type seismograph at the Mauna Loa station were broken, and the mass, weighing approximately 225 pounds, was deposited on the floor of the vault, 3 feet from its proper position. At the Uwekahuna vault, the wire suspensions on both components of a semiportable tiltmeter were broken and the horizontal pendulums, each weighing 35 pounds, dropped onto the pier. The breaking of the wire suspensions, which have considerable strength under normal conditions of lateral swing of the pendulums, suggests a vertical dancing of the pendulums. This, together with the dismantling of the vertical seismograph, which is seldom dismantled even by strong earthquakes, appears to indicate a high angle of emergence of the earthquake vibrations, consonant with a deep origin nearly beneath Kilauea Caldera.

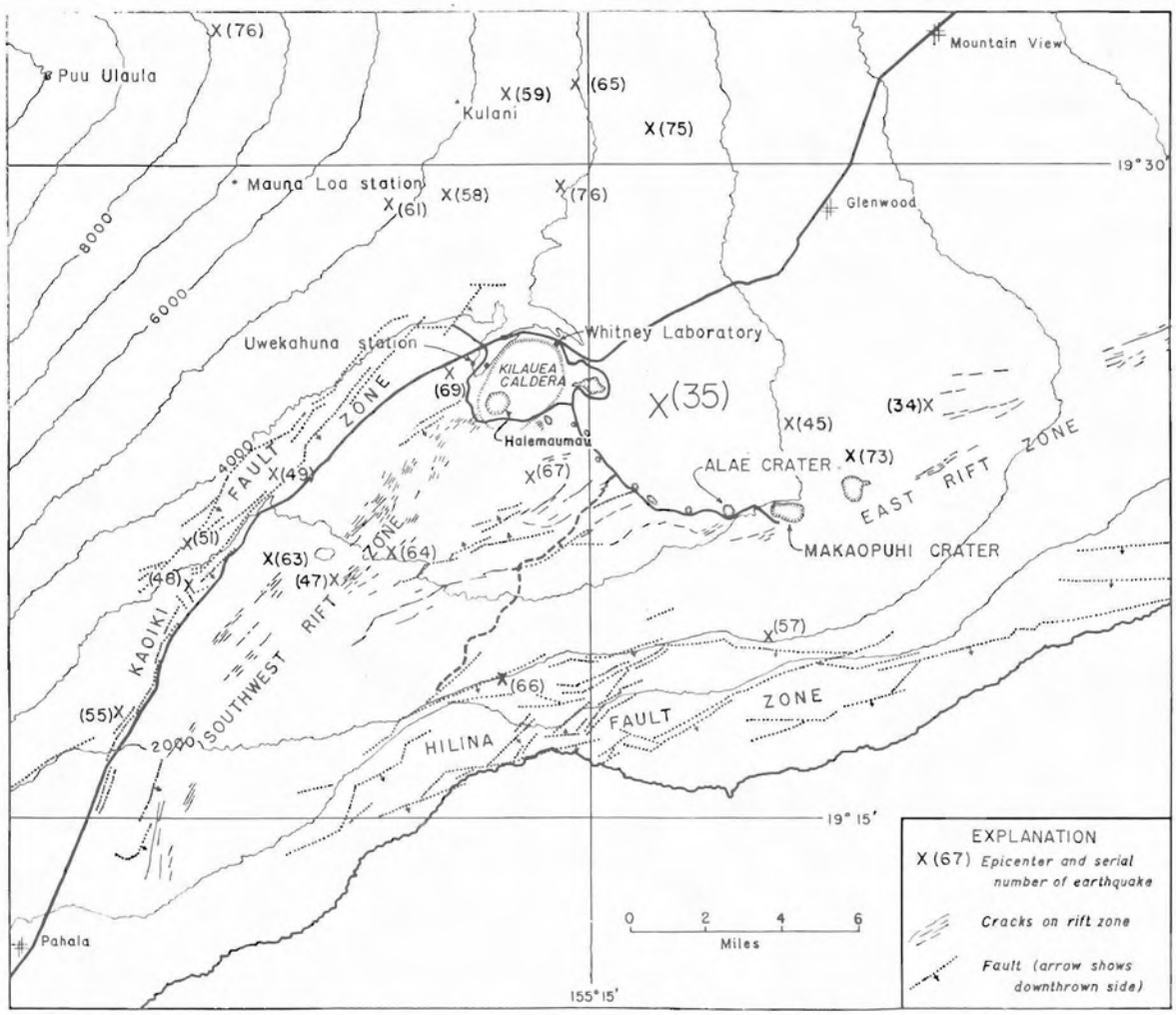

FIGURE 1. Map of Kilauea Caldera and vicinity, showing the epicenters of the large earthquake of April 22 and its aftershocks in relation to fault zones and the rift zones of Kilauea volcano. The epicenter of earthquake 35 was estimated on non-instrumental grounds and its location is only approximate.

Damage to the seismographs and tiltmeters made it impossible to determine with certainty the direction of tilt during the earthquake, but it probably was southeastward at the Whitney station and eastward at Uwekahuna. The direction of first motion of the earthquake was south and east at the Whitney station, and down at the vertical seismograph at Uwekahuna. It is believed that the earthquake accompanied a marked subsidence at Kilauea, probably caused by a decrease of volcanic pressure at depth. Subsidence is suggested by the direction of first motion, the probable direction of tilt, and the observed generalization that the strongest local earthquakes generally, if not always, accompany subsidence rather than tumescence. It is interesting that the subsidence was immediately followed by the beginning of rapid northward tilting of the ground at the Whitney station, apparently indicating restoration of the pressure. This rapid northward tilting continued until June 8 (see section on Volcanology, page 4).

At 04:53:53 H.S.T. on April 22, the major earthquake was preceded by a moderate earthquake which originated at a depth of about 21 miles on the east rift zone of Kilauea volcano, 10 miles east of the caldera (Fig. 1, location 34).

During the 7 days following the major shock, 108 earthquakes were recorded on the Volcano Observatory seismographs. Of these, 71 occurred on April 22 and 23. More than half were tremors, too small to permit identification of separate phases in the record. Figure 2 is a graph of daily seismicity from April 20 to 30, derived by assigning a numerical value to each earthquake, depending on its intensity, and totaling these values for each day. The scale of seismicity in use at the Hawaiian Volcano Observatory is an arbitrary one, based on the amplitude of the record produced by the earthquake on the seismographs. It has previously been described by A. E. Jones.[1] The grades of earthquake intensity and numerical values assigned to them are listed in the accompanying table.

As indicated in the table, earthquakes of seismicity value 1 to 4 correspond approximately to the same numerical grades in the Rossi-Forel and modified Mercalli scales of earthquake intensity. However, because the Volcano Observatory scale is based on instrumental effects, the correspondence to the other intensity scales and the descriptions of non-instrumental effects in the table are not always exact.

All earthquakes producing a double amplitude of os-

[1] JONES, A. E., CHART OF KILAUEA SEISMICITY. Volcano Letter 371: 1–3. 1932.

cillation of more than 60 mm. on the Bosch-Omori seismograph are classified as strong, and receive the same seismicity rating. Thus the big earthquake of April 22 received the same seismicity value as the much smaller "strong" earthquakes which took place on April 23 and 26. If allowance were made for this, the seismicity on April 22 would be somewhat increased. The high seismicity on April 22 and 23 results principally from the large number of very small aftershocks (tremors and very feeble earthquakes) on those days.

Most of the aftershocks were too small to be located, phase arrivals not being recognizable on the seismograms, or recognizable only on the record of one station. Only 19 could be located with reasonable certainty. The epicenters of these are shown in Figure 1, in which the number accompanying the cross indicating the epicenter is the serial number of the earthquake for the current year. The date, time, and intensity of the earthquake are given following its serial number in the table in the section on Seismology, pages 4 and 5. All the located aftershocks were of comparatively shallow origin. The deepest was that at 03:57 on April 26 (Serial No. 73), at a depth of about 11 miles on the east rift zone of Kilauea. Most of the others originated at depths of 3 to 8 miles.

In general, the aftershocks fall into two groups, one distributed along the rift zones of Kilauea volcano, and the other associated with the Kaoiki fault zone along the southeast slope of Mauna Loa and the prolongation of the Kaoiki zone northeastward beyond any recognized surface fault offsets. It is of interest to note that the northeastward continuation of the Kaoiki fault was suggested years ago by H. O. Wood,[2] who also found an apparent clustering of earthquakes along this line. The Kaoiki fault zone lies at, or close to, the surface contact between Kilauea and Mauna Loa volcanoes. The earthquake activity along this zone possibly resulted from relative downward movement of Kilauea along the Kaoiki faults in response to decrease of volcanic pressure beneath Kilauea.

[2] Wood, H. O. A consideration of recent earthquakes local to Hawaii, and of the seismological problem they indicate. Hawaiian Volcano Obs. Bul. 3(5): 56–57. 1915.

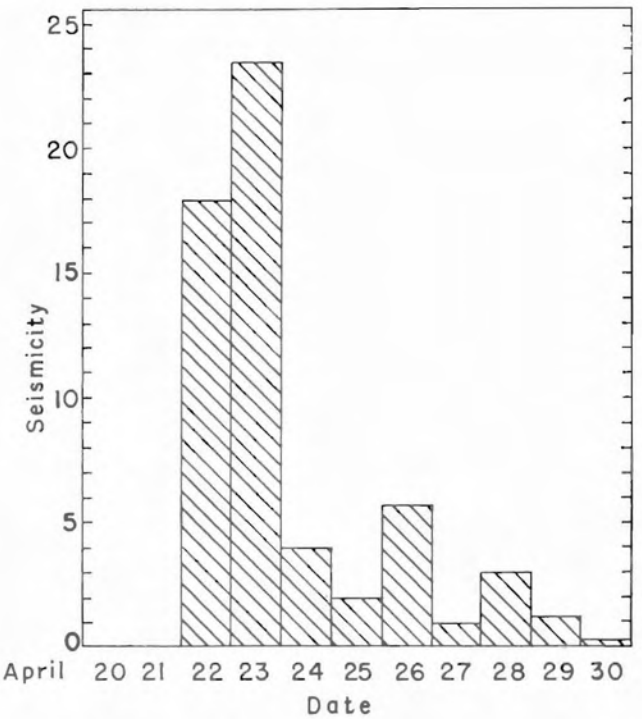

Figure 2. Graph showing seismicity at the Whitney Laboratory, at the northeast rim of Kilauea Caldera, during late April, 1951.

Many of the small aftershocks, which could not be definitely located, appear almost certainly to have originated beneath Kilauea Caldera or along one of the rift zones in the immediate vicinity of the caldera. Two of the quakes originated along the Hilina fault zone near the southern coast of Kilauea.

Comparison of earthquake intensity scales

Hawaiian Volcano Observatory scale			Description of non-instrumental effects	Approximate grade in Rossi-Forel and modified Mercalli scales
Designation	Double amplitude of motion on Bosch-Omori seismograph*	Seismicity value		
	mm.			
Tremor	< ½	¼	Not felt.	
Very feeble	½–4	½	Not felt or only very rarely felt by very few persons in especially favorable positions, usually lying down.	
Feeble	4–11	1	Not felt or felt only by a few persons in favorable positions.	I
Slight	11–25	2	Felt by many persons at rest. Hanging objects may swing.	II
Moderate	25–60	3	Felt generally, by persons in or out of doors. Hanging objects swing.	III
Strong	> 60	4	Felt by everyone or nearly everyone. Objects swing. Dishes, doors, and windows rattle. Minor damage may result.	IV–V

* Static magnification of Bosch-Omori seismograph is approximately 115.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR APRIL–JUNE, 1951

VOLCANOLOGY

April

The volcanic quiescence of the first quarter of the year continued into April. It was shattered on April 22 by the heavy earthquake and swarm of aftershocks described on previous pages. Seismographs of the Hawaiian Volcano Observatory recorded 132 earthquakes during the month of April. Of these, 108 were aftershocks of the big earthquake of April 22. The Kilauea origin of most of the shakes is shown by the fact that 125 of them were recorded on the instruments at the rim of Kilauea Caldera and only 89 of them at the Mauna Loa station.

The distinct uneasiness of Kilauea volcano was further shown by the commencement, on June 24, of fairly rapid tumescence of the volcano, expressed by northward tilting at the Whitney Laboratory at a rate considerably in excess of the normal rate for that time of year. It should be noted also that the reversal from southward to northward tilting came nearly a month earlier than usual.

May

The rapid northward tilting of the ground at the northern rim of Kilauea Caldera, which commenced in April, continued throughout May. By the end of the month a total of 6 seconds of arc of northerly tilting had accumulated. This rate is approximately twice as great as the normal rate of northward tilting at this season of the year, and indicates a continued increase of volcanic pressure beneath Kilauea. Some cracks on the floor of the caldera and along the Chain of Craters road opened slightly during the month, possibly in response to tumescence of the mountain.

Volcano Observatory seismographs recorded 41 earthquakes during May. Of these, 36 were recorded at the Whitney Laboratory and 20 at the Mauna Loa station. A feeble earthquake, felt by a few persons in the Volcano district just after noon on May 17, originated under Kilauea volcano, about 6 miles south of the crater.

June

The marked northward tilting of the ground at the northern edge of Kilauea Caldera continued into early June. After June 8, however, the rate of northward tilting decreased to about normal for this season of the year. During late May, the rate of eastward tilting was approximately normal for that season. However, on June 3, it became appreciably greater than normal and continued above normal for the remainder of the month, indicating an increase of volcanic pressure beneath the summit area of Mauna Loa.

During June, 42 earthquakes were recorded on the seismographs. Of these, 28 were recorded at the Whitney Laboratory and 29 at the Mauna Loa station. Slight earthquakes were felt by some persons from the Volcano district to Hilo at 10:49 P.M. on June 7 and 8:32 A.M. on June 11. Both originated on the east rift zone of Kilauea volcano, the first near Pauahi crater, and the second 6 miles southwest of Pahoa. A series of small earthquakes (mostly tremors) on June 18 and 19, recorded only on the Mauna Loa seismograph, indicate some movement on the northeast rift zone of Mauna Loa.

The northern end of the crack which crosses the observation area at the southeast rim of Halemaumau crater opened another 3 mm. during June. Other cracks in the vicinity also opened slightly.

The temperature of the steam at the Sulphur Bank well remained at 205° F. from March 31 to July 2.

TELESEISMS

Locations of the epicenters are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey.

April 30, 05:35, slight. Celebes region.
May 19, 04:59, slight.
May 19, 06:45, slight.
June 16, 23:54, slight. Three hundred miles off the Oregon coast.

Table of Tilt at Seismograph Vaults on Rim of Kilauea Caldera

Week Beginning	Whitney Vault (Northeast rim) Amount	Whitney Vault (Northeast rim) Direction	Uwekahuna Vault* (West rim) Amount	Uwekahuna Vault* (West rim) Direction
April 1	0.5″	N 45° W	0.9″	S 74° W
8	0.8″	S 63° E	0.3″	N 45° W
15	1.3″	S 85° W	0.2″	S 72° W
22	1.4″	N 22° E	1.4″	S 62° W
29	0.4″	N 27° W	0.6″	N 74° W
May 6	1.0″	N 7° W	1.1″	N 81° W
13	1.2″	N 17° E	.....	.....
20	1.1″	N 18° E	2.8″	S 9° E
27	1.9″	N 15° E	0.4″	S 19° E
June 3	1.0″	N 60° E	1.4″	S 17° E
10	1.6″	S 86° E	2.1″	N 3° W
17	0.4″	N 56° E	1.4″	N 17° W
24	1.4″	N 52° E	0.6″	N 53° W

* Record previous to May 13 from a small, semiportable tiltmeter. During early May, a pair of heavy, horizontal pendulums was installed, and the record after May 20 is from this new instrument. The record for the week starting May 13 is considered unreliable because of improper operation of the east-west pendulum.

SEISMOLOGY

Earthquake Data, April–June, 1951

(Based on Bosch-Omori seismograph on northeast rim of Kilauea Caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
April 1	3	1	0	0	0	0	1.25	0
8	7	1	1	0	0	0	3.25	0
15	3	1	0	0	0	0	1.25	0
22	67	26	3	4	1	3	55.75	0
29	11	1	0	0	0	0	3.25	1
May 6	0	2	2	0	0	0	3.0	0
13	8	4	1	0	0	0	5.0	1
20	5	3	0	0	0	0	2.75	0
27	1	2	0	0	0	0	1.25	0
June 3	3	0	0	1	0	0	2.75	0
10	4	2	0	1	0	0	4.0	1
17	9	2	1	0	0	0	4.25	0
24	4	1	0	0	0	0	1.5	0

* For definition of local seismicity, see Volcano Letter 371.

The data for the following local disturbances were determined from seismographs operated on the island of Hawaii by the Hawaiian Volcano Observatory. Locations given are epicenters. The arrival times are given to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich time. The number preceding each earthquake is the serial number for the current year. The intensity rating (Feeble, Moderate, etc.) given is that for the Whitney Laboratory at the northeast rim of Kilauea Caldera. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney station.

30. Apr. 4, 10:43, very feeble.
31. Apr. 13, 01:19, very feeble, felt at Waimea. About 8 miles southwest of Waimea, shallow.
32. Apr. 13, 14:53, feeble. East flank of Kilauea.
33. Apr. 15, 13:36, very feeble.
34. Apr. 22, 04:54, moderate, felt at Kapapala and from Volcano district to Hilo. East rift of Kilauea 7 miles S 15° E of Glenwood, 21 miles deep.
35. Apr. 22, 14:52, very strong, felt all over Hawaii Island and on Maui and Oahu. East rift of Kilauea near the caldera, 25 to 30 miles deep.
36. Apr. 22, 15:25, very feeble.
37. Apr. 22, 15:27, very feeble.
38. Apr. 22, 15:41, very feeble.
39. Apr. 22, 15:49, very feeble.

40. Apr. 22, 15 : 50, very feeble.
41. Apr. 22, 15 : 51, very feeble.
42. Apr. 22, 16 : 08, very feeble.
43. Apr. 22, 16 : 14, very feeble.
44. Apr. 22, 16 : 49, very feeble.
45. Apr. 22, 17 : 19, feeble. East rift of Kilauea 7 miles east of the caldera, about 8 miles deep.
46. Apr. 22, 17 : 30, very feeble.
47. Apr. 22, 18 : 46, very feeble. Southwest rift of Kilauea near Mauna Iki, about 5 miles deep.
48. Apr. 22, 20 : 30, tremor (very feeble, Mauna Loa).
49. Apr. 22, 21 : 11, tremor (very feeble, Mauna Loa).
50. Apr. 22, 23 : 30, very feeble.
51. Apr. 22, 23 : 40, very feeble. Kaoiki fault near Ainapo.
52. Apr. 23, 00 : 17, very feeble.
53. Apr. 23, 02 : 46, very feeble.
54. Apr. 23, 03 : 04, very feeble. Kaoiki fault near Kapapala.
55. Apr. 23, 03 : 27, very feeble.
56. Apr. 23, 04 : 37, very feeble.
57. Apr. 23, 04 : 40, slight. East rift of Kilauea 2 miles south of Makaopuhi, 4 miles deep.
58. Apr. 23, 04 : 41, slight. Three miles north of Kilauea Caldera, about 5 miles deep.
59. Apr. 23, 04 : 44, feeble. Near Kulani cone, about 7 miles deep.
60. Apr. 23, 05 : 24, very feeble.
61. Apr. 23, 05 : 48, slight. Five miles northwest of Kilauea Caldera, about 6 miles deep.
62. Apr. 23, 06 : 13, very feeble.
63. Apr. 23, 06 : 36, strong, felt in Volcano district. Southwest rift of Kilauea 2 miles southwest of Mauna Iki, 5 miles deep.
64. Apr. 23, 21 : 53, very feeble. Southwest rift of Kilauea near Puu Koae, about 5 miles deep.
65. Apr. 23, 22 : 16, very feeble. Two miles southwest of Kulani cone, about 5 miles deep.
66. Apr. 23, 22 : 18, very feeble.
67. Apr. 24, 01 : 14, very feeble.
68. Apr. 24, 01 : 29, very feeble.
69. Apr. 24, 11 : 30, very feeble. Near Bird Park, about 11 miles deep.
70. Apr. 25, 11 : 41, very feeble.
71. Apr. 25, 22 : 38, very feeble.
72. Apr. 26, 00 : 57, tremor (very feeble, Mauna Loa).
73. Apr. 26, 03 : 58, strong, felt in Volcano district. East rift of Kilauea near Makaopuhi, about 12 miles deep.
74. Apr. 26, 05 : 51, feeble. Waimea plain about 6 miles east of Waimea.
75. Apr. 28, 07 : 38, slight. Four miles east of Kulani cone, shallow.
76. Apr. 29, 16 : 19, very feeble. About 3 miles southeast of Kulani cone.
77. May 6, 08 : 53, very feeble, felt by one person in Volcano district, and some in Pahala and Naalehu. Kaoiki fault zone, 3 miles southwest of Pahala.
78. May 7, 12 : 36, very feeble.
79. May 8, 00 : 38, feeble.
80. May 10, 15 : 24, feeble. East rift of Kilauea near Puu Huluhulu, shallow.
81. May 13, 00 : 24, very feeble.
82. May 14, 18 : 41, very feeble. Southwest rift of Kilauea near Mauna Iki, shallow.
83. May 15, 22 : 10, very feeble.
84. May 17, 12 : 12, feeble.
85 May 18, 03 : 00, very feeble.
86. May 20, 13 : 34, very feeble.
87. May 20, 16 : 16, very feeble.
88. May 25, 03 : 10, very feeble.
89. May 30, 21 : 59, very feeble.
90. May 31, 09 : 13, very feeble.
91. June 3, 04 : 45, tremor (very feeble, Mauna Loa).
92. June 4, 14 : 36, no record at Whitney vault (very feeble, Kona).
93. June 7, 22 : 50, slight, felt in Volcano district and by a few in Hilo. East rift of Kilauea near Pauahi crater, shallow.
94. June 11, 08 : 33, slight, felt generally from Hilo to Volcano district. East rift of Kilauea 6 miles west of Pahoa, about 7 miles deep.
95. June 11, 19 : 23, tremor (very feeble, Mauna Loa).
96. June 12, 12 : 12, tremor (very feeble, Mauna Loa).
97. June 14, 11 : 12, very feeble.
98. June 15, 13 : 19, very feeble. Probably beneath Kilauea Caldera.
99. June 17, 12 : 01, very feeble (slight, Mauna Loa). Nine miles west of Mokuaweoweo, about 16 miles deep.
100. June 19, 05 : 15, feeble.
101. June 22, 08 : 11, tremor (very feeble, Mauna Loa).
102. June 23, 01 : 14, very feeble.
103. June 27, 07 : 27, very feeble.
104. June 27, 11 : 49, tremor (very feeble, Mauna Loa).

VOLCANO NOTES AND NEWS

This new feature of the VOLCANO LETTER is intended to furnish the reader with notices of recent volcanic activity all over the world, notices of recent publications of special importance to the field of volcanology, and brief statements of what other workers in volcanology are doing. No attempt will be made to be exhaustive in the treatment of any of these. Available space necessitates brevity. Accounts of volcanic activity will be credited to the person submitting them, or to the source from which they are drawn. Persons everywhere are urged to send in brief accounts of volcanic activity or statements of research programs in which they, or fellow workers, are involved. Communications should be addressed to the Director, Hawaiian Volcano Observatory, Hawaii National Park P. O., Hawaii.

ERUPTION OF OSHIMA VOLCANO

Prof. Hisashi Kuno of Tokyo University writes that the Oshima volcano became active on July 16, 1950. Oshima occupies an island of the Idzu group, about 60 miles south of Tokyo. The volcano had been dormant since 1940. The 1950 activity built a new cinder cone on the rim of the old crater of Miharayama, a large cone in the caldera of Oshima volcano. The new cinder cone reached a height of 100 meters above its base. Lava issued from the base of the new cone and filled the bottom of the old Mihara crater. On September 13, several tongues of lava overflowed the rim of Mihara crater and reached the floor of the caldera. The temperature of the lava was 1200°C. in a lava fountain, 1090° at the origin of one of the flows which spilled out of the crater, and about 900° at a point where the flow had nearly ceased moving. The viscosity of the lava was 3×10^5 c.g.s. at a point where the temperature was about 1000°. The eruption ended abruptly on September 23. The erupted lava is augite-hypersthene basalt, closely similar to that of the 1778 eruption.

The total amount of erupted material, including cinder, was estimated by S. Marauchi [*Natural Science and Museum* 17 (4) : 19. 1950] as 48,000,000 tons.

ERUPTION OF SANTIAGO VOLCANO

Santiago volcano, in southwest Nicaragua, resumed solfataric activity early in 1946, after 19 years of dormancy. The fumes, containing sulfur dioxide and sulfuric acid, have been causing great damage to near-by coffee plantations. An investigation of the activity and of the accompanying crop damage was made in April, 1951, by Ray E. Wilcox of the U. S. Geological Survey. Plans are going forward in cooperation with the U. S. Department of Agriculture for alleviation of injury to the coffee plantations by the volcanic fumes.

PERSONNEL CHANGES AT HAWAIIAN VOLCANO OBSERVATORY

Ruy H. Finch, Director of the Hawaiian Volcano Observatory since 1940, retired late in February and was succeeded by Gordon A. Macdonald. Mr. Finch first came to the Observatory in 1919, at a time when it was operated by the United States Weather Bureau. From 1919 to 1926, he served as assistant to Dr. T. A. Jaggar. When the Observatory was taken over by the Geological Survey in 1924, Finch transferred to the Survey. He was temporarily in charge of the Observatory, during the absence of Dr. Jaggar, throughout most of the great steam explosions of Kilauea volcano in 1924. We owe the excellent record of that eruption largely to his personal observations and to his organization of volunteer observers to keep a 24-hour watch on the volcano. In 1926, the Survey sent Finch to establish the volcano observatory at Mount Lassen, in northern California. From 1926 to 1935, he operated the Lassen Observatory and studied other volcanoes in the Cascade Range. In 1931 and 1932, he was the leader of expeditions to study Akutan and Shishaldin volcanoes in the Aleutian Islands. Finch left the Lassen Observatory in 1935, when it was taken over by the National Park Service, and became an apple grower near Watsonville, California. In 1940, Dr. Jaggar retired as Director of the Hawaiian Volcano Observatory, and Ruy Finch was recalled as his successor. Through the war years, the work of the Observatory was greatly curtailed by reductions in staff and other restrictions. In spite of these and other difficulties, Finch managed to keep the operations going on a basis sufficient to insure the all-important continuity of records. His prediction of the 1942 eruption of Mauna Loa was an outstanding success.

Ruy Finch's retirement culminates a lifetime of service and important contributions to the science of volcanology. Following his retirement, Finch returned with his family to Watsonville, where he is again an orchardist. His long experience and intimate knowledge of Hawaiian volcanoes, as well as his pleasant personality and keen wit, will be greatly missed by the Observatory staff. Even in retirement, Ruy's great interest in volcanoes is certain to continue, and we have every reason to expect further contributions by him to the science of volcanology.

Early in May the staff of the Hawaiian Volcano Observatory was augmented by the appointment of Dr. C. K. Wentworth as full-time geologist. From 1935 until his retirement in early May, 1951, Wentworth served as geologist for the Honolulu Board of Water Supply. Since 1949, he has held a part-time appointment at the Volcano Observatory. During the next few months his principal scientific activity is expected to lie in the Observatory's geomagnetic program, in field studies of volcanic features, and in instrumentation.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director

Chester K. Wentworth, Geologist

John C. Forbes, Laboratory Mechanic

LaVieve G. Forbes, Secretary, part-time

University of Hawaii:

T. A. Jaggar, Geophysicist

Seismograph Station Operators:
Hilo Station:

Brother B. T. Pleimann, St. Joseph's School

Kealakekua Station:

Howard M. Tatsuno, Konawaena School

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter**, a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

THE VOLCANO LETTER

No. 513 **U. S. Geological Survey** **July–September, 1951**

PUBLISHED BY THE UNIVERSITY OF HAWAII

THE KONA EARTHQUAKE OF AUGUST 21, 1951

By GORDON A. MACDONALD and CHESTER K. WENTWORTH

INTRODUCTION

The earthquake which shook the island of Hawaii early on August 21 probably was the strongest since 1868, when a series of violent earthquakes did great damage in Kau. A special study of the quake has been made by the staff of the Hawaiian Volcano Observatory, and a detailed report will be published elsewhere. Lack of space limits us to a summary here.

A great many persons have aided us in the investigation. It is impossible to mention individually all who have given us information. Special mention should be made of Howard M. Tatsuno and Sister Mary Thecla, seismograph operators at Kealakekua and Hilo, respectively; Miss Nancy R. Wallace, Mrs. Alfred E. Hansen, and Allan P. Johnston, who reported on many of the aftershocks; Homer A. Hayes, who furnished information on damage and on other subjects; Mark Sutherland, John Iwane, and Masuoka Nagai, who supplied information on damage, especially to tanks; Commander C. A. George and Roland White, of the U. S. Coast and Geodetic Survey, who supplied copies of the seismograms of the major quake at Barbers' Point, Oahu, and of the tide gauge records from Honolulu and Hilo harbors. Dr. T. A. Jaggar has read and approved the manuscript. To these and all other persons who aided the investigation, we extend our sincere thanks.

NARRATIVE

At 57 minutes past midnight on August 21, residents of the island of Hawaii were awakened by a violent earthquake. The violence was greatest in central Kona, from Kealakekua to Hookena (Fig. 1). In the vicinity of Napoopoo the initial movement appears to have been largely up and down, with some swaying in an east–west direction, changing as the quake continued to what appeared to observers to be a somewhat circular motion. Noise was intense as doors and windows rattled, dishes and furniture crashed to the floor, water tanks collapsed, and rocks rolled from banks and stone walls. Landslides rushed down the famous burial cliff, Pali

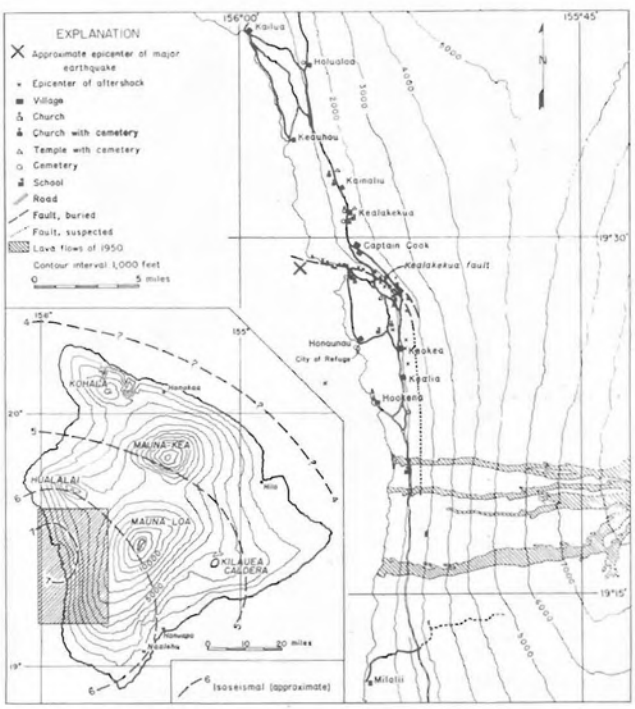

FIGURE 1. Map of the central Kona district showing the location of places mentioned in the text, the approximate locations of the epicenters of the major earthquake of August 21, 1951, and the aftershocks for which reasonably good locations were obtained. The inset map of the island of Hawaii shows the location of the area (shaded) covered by the other map and the approximate position of the isoseismal lines for the major earthquake.

Kapu o Keoua, at Kealakekua Bay. Within moments several houses, churches, and a school building were destroyed or badly damaged, many other houses slightly damaged, about 200 water tanks destroyed or damaged, many miles of stone wall thrown down, roads partly blocked by rock slides, road pavements and shoulders badly cracked, headstones in cemeteries shifted or over-

turned, and telephone and electric power lines broken. Fortunately, only two small fires broke out, and only two persons received minor injuries.

The ocean was observed withdrawing from shore at Napoopoo, and most of the inhabitants of the village were quickly evacuated to higher ground in fear of a large tsunami, or "tidal wave." A small tsunami actually did occur, but it was too small to do any damage. At Napoopoo the water surface fell about 4 feet, then rose again about 2 feet above its normal level. At Milolii the water level dropped about 3 feet, then rose 3 or 4 feet above its normal position, floating a canoe off the beach. The tide gauges at Honolulu and Hilo showed a distinct disturbance of the water in the harbors.

The earthquake was felt fairly strongly by persons on the most distant parts of the island of Hawaii and weakly by many persons on the island of Maui, and even in Honolulu, more than 180 miles from its origin. Damage extended for more than 50 miles along the highway, from Holualoa to Honuapo (Fig. 1). It was greatest in the 12-mile interval from Kealakekua to Hookena; but as far away as Naalehu, 37 miles from the epicenter of the earthquake, dishes, groceries, and bottles were thrown from shelves, stone walls collapsed, and some damage was done to structures. At Kilauea Caldera, 45 miles from the epicenter, a few objects were overturned, pavement was cracked, and numerous landslides were started on the walls of Halemaumau crater and the main caldera.

The intensity of the earthquake on the modified Mercalli scale of 1931, based on damage and other effects of the quake, was about 7 in the area near the epicenter, decreasing to 4 at the most distant parts of the island, and 2 at Honolulu. The approximate distribution of the intensity is shown by the isoseismal lines on the insert in Figure 1.

DAMAGE BY THE EARTHQUAKE

Many buildings in the Kona area were in some degree damaged by the earthquake. Most structural damage was minor, however. Some houses shifted as much as 3 or 4 inches on their foundations, and many were so twisted that it was difficult or impossible to open or close doors and windows. In nearly all houses dishes and other objects were thrown to the floor, and in stores from Holualoa to Pahala canned goods and bottles were thrown from shelves.

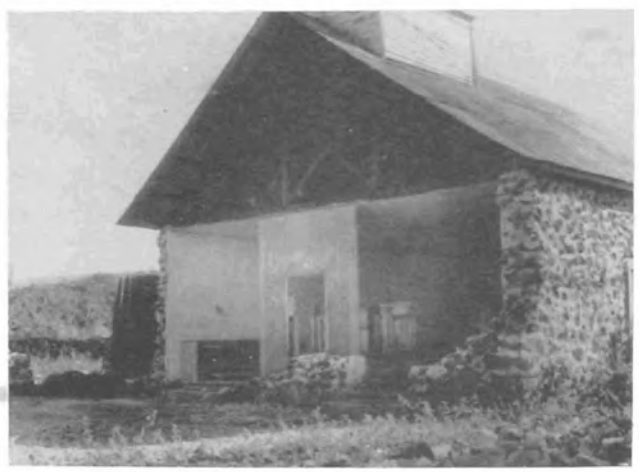

FIGURE 2. Church at Hookena Beach, the front (western) wall destroyed by the earthquake of August 21, 1951. The walls are of lava rock and coral-lime mortar. The debris of the fallen wall has been cleared away.



FIGURE 3. Honaunau School. Note the badly deformed window casings, resulting from the earthquake. In the foreground are the fragments of a large water tank.

As a class, masonry structures suffered the most damage. At Hookena the western wall of the Mission church, constructed of stone and coral-lime mortar, was thrown to the ground (Fig. 2). The upper parts of both the eastern and western walls of the Catholic church, half a mile north of Hookena, were thrown down. These walls, however, were very weakly constructed. The walls of St. Paul's Church, near Kainaliu, were badly cracked, and there was minor cracking of the lintels and interior plaster of Kahikolu Church at Napoopoo. The tower of Central Kona Church at Kealakekua separated slightly from the main building, and its plaster was cracked.

Only a few frame structures were badly damaged. At Hookena the underpinning of two old houses gave way and the houses dropped to the ground. Near Kealia two other houses were similarly damaged. At Kaimalino, 0.8 mile south of Kealia, a shop building slumped downslope when high posts supporting it at the back gave way. A service station at Keokea was damaged in the same manner. All these instances of damage to frame buildings can be traced to the failure of underpinning which was unsound because of age, poor material, or inadequate bracing. The most striking example of all was the Honaunau School, where failure of the underpinning allowed the building to collapse partly and slump to the ground, deforming it so badly that it is considered a total loss (Fig. 3). The failure there appears to have resulted from very inadequate bracing in an east–west direction, approximately parallel to the direction of sway during the earthquake.

As in big earthquakes elsewhere, a large proportion of the damage to buildings resulted from inferior or inappropriate materials, or poor construction. Unreinforced stone or brick masonry structures are especially subject to damage by strong earthquakes, though even in them the use of good mortar and adequate bracing of the structure greatly reduces the risk of damage. In frame structures footings should be firm, materials



FIGURE 4. Stone wall partly destroyed at the City of Refuge, Honaunau. The wall is approximately 10 feet high. The damaged portion is part of that rebuilt in recent years.

sound, and cross bracing, particularly of the underpinning, should be adequate in all directions. The best insurance against earthquake damage is good construction.

The most serious damage was that to water tanks. Kona's water supply comes from rain caught on roofs and stored in tub-type wooden tanks. Of a total of more than 1,000 such tanks in the heavily shaken area, about 200 were destroyed or badly damaged. The loss of water supply seriously endangered the health and comfort of the community. Tank damage extended from Keauhou to Milolii, but was most severe from Captain Cook to Hookena. Tanks showed all degrees of failure, from the development of slight leaks to complete collapse (Fig. 3).

A more detailed report on the damage to tanks will appear in the next Volcano Letter. In summary, it may be said here that the commonest features contributing to tank failure appear to have been poor footings and inadequate cross bracing of the underpinning.

Loose stone walls were greatly damaged by the earthquake. Although the principal damage occurred in the area from Keauhou to 3 miles south of Hookena, isolated instances of wall damage were observed all the way from Naalehu to Honokahau, 5 miles north of Holualoa. It is estimated that a total of many miles of wall will have to be rebuilt.

As with other types of structures, well-built walls proved surprisingly resistant to earthquake. In the construction of many of the older walls, occasional slabs of rock were laid largely or entirely through the wall, to help bind the wall together. These walls showed much less damage than those in which the loose rocks were stacked up with few or no binding slabs. It is interesting to note that the remaining portions of the well-built ancient walls of the City of Refuge, at Honaunau, were undamaged, whereas the recently reconstructed portions of the walls partly collapsed (Fig. 4).

Damage in cemeteries included the shifting, rotation, or overturning of headstones (Fig. 5) and the breaking of some grave caps. In cemeteries from Kealakekua to Honaunau most of the overturned headstones fell westward, though in a few cemeteries nearly as many fell eastward. This resulted partly from lesser stability of the stones in that direction because of the north–south orientation of the longer dimension of their bases and the general westward slope of the terrain, and partly from the east–west direction of shaking.

Damage to roads included cracking of pavement, cracking and slumping of shoulders, and caving of road banks, partly obstructing the roads. Cracking and slumping of the pavement and shoulders took place only on fills (Fig. 6). Some settling and cracking of the pavement appears to have been caused merely by compaction of the underlying fill during the jostling by the earthquake. At other places fills across small gullies were unstable because the batter (departure from vertical) of the edges of the fill were too steep, causing the downslope face of the fill to cave away. At many places the western shoulder moved slightly seaward, away from the pavement, producing cracks along the edge of the pavement or a few inches beyond the edge of the pavement and parallel to it.

A few bank cavings and pavement cracks were found as far away as Kilauea Caldera, 45 miles from the epicenter. However, most road damage is concentrated in the area near the epicenter. The distribution of damage caused by caving of banks, cracking of pavement, and collapse of stone walls along the main highway is shown graphically in Figure 7.

INSTRUMENTAL DATA

The time of occurrence of the earthquake is given by the U. S. Coast and Geodetic Survey's notice of Preliminary Determination of Epicenter at 00:56:57 H.S.T. The preliminary waves started recording on the Bosch-Omori seismograph in the Whitney Laboratory at the northeast rim of Kilauea Caldera at 00:57:09.5. The duration of the preliminary waves at the Whitney Laboratory was 9.5 seconds, corresponding with a distance of origin of approximately 47 miles. The Bosch-Omori seismograph was dismantled shortly after the arrival of the secondary waves. All other seismographs on the island of Hawaii were dismantled by the preliminary waves.



FIGURE 5. Overturned headstones in the cemetery of the Central Kona Church at Kealakekua were thrown westward from their foundations, but the base plate beneath the headstone in the foreground was shifted 2 inches eastward.

The direction of the first movement of the ground at Kilauea Caldera was east–southeast and up, that at the Mauna Loa and Kona stations was east–northeast. At the Kona station the suspensions of the east–west component of the seismograph were broken, and the weight dropped on the floor 2 feet west of the pier. Thus the only usable instrumental data we have on the location of the origin of the earthquake are a distance of approximately 47 miles from the Whitney Laboratory, and rough bearings of west–northwest from Kilauea Caldera and west–southwest from the Mauna Loa and Kona stations. These, together with the distribution of damage, are sufficient to demonstrate that the origin lay offshore west of the general Napoopoo–Honaunau area.

AFTERSHOCKS

The major earthquake was followed by a very large number of aftershocks, ranging in size from tiny tremors barely detectable by the seismographs to strong, generally felt earthquakes of an intensity as great as 4 near their epicenters. Mrs. H. Masuhara, at Keei, counted 109 felt earthquakes between 00:57 and 09:00 o'clock on August 21. The repair of damages to the Kona seismograph was not completed until 15:15 o'clock on August 23, so the total number of aftershocks during the first 2 days is not known. During the first 24 hours after it was restored to operation the Kona seismograph recorded 90 earthquakes. By midnight on August 31 it had recorded 494 quakes and by September 30 nearly a thousand. Most of the larger of these aftershocks produced good records at four or more of the five seismograph stations and could be located with fair certainty. Epicenters of 36 of these aftershocks are shown in Figure 1.

ORIGIN OF THE EARTHQUAKE

The northeastern edge of Kealakekua Bay is a scarp formed by a fault along which the lower slope of Mauna Loa has been moving downward in relation to the rest



FIGURE 6. Cracking of pavement and slumping of fill at the western edge of the highway near Hookena.

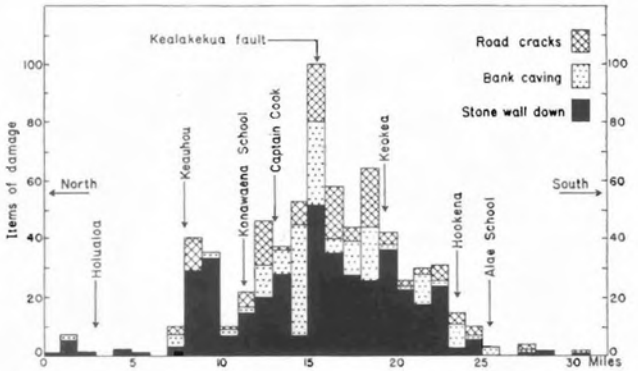

FIGURE 7. Diagram showing the frequency distribution of three of the principal types of earthquake damage along the main highway. The arrows indicate the position on the highway of villages and other features. Note the centering of damage close to Kealakekua Fault.

of the mountain. This fault has been named the Kealakekua Fault.* The total displacement on the Kealakekua Fault is not known, but it is at least 500 feet. Most of the fault scarp has been mantled with later lava flows from Mauna Loa. West–northwestward the fault disappears under the ocean (Fig. 1). Southeastward the scarp runs inland and bends southward. Beyond upper Keei the fault scarp loses its definite identity, but for several miles farther south the abnormally steep western slope of Mauna Loa is suspected, at least in part, to be a reflection of this fault scarp, deeply buried.

Most of the epicenters of the located aftershocks (Fig. 1) lie close to the known portion of the Kealakekua Fault. A few lie close to the suspected southward continuation of the fault. In view of the origin of the great majority of the aftershocks on the Kealakekua Fault, it is highly probable that the major earthquake also was caused by movement on this fault. This is confirmed by the distribution of damage caused by the earthquake. In Figure 6 the peak of the bell-shaped distribution curve corresponds closely with the location of the Kealakekua Fault. Taking into consideration the distance of origin of the earthquake from Kilauea Caldera, the probable epicenter has been placed approximately 3 miles west–northwest of Napoopoo, at north latitude 19° 29′, west longitude 155° 58′. This location is also consistent with the prevalent directions of overturning and rotation of headstones in cemeteries.

In a sense, of course, all earthquakes originating on the island of Hawaii are volcanic. The movements on the Kealakekua Fault which gave rise to the earthquakes of August and September may be related in some way to either an increase of pressure under Mauna Loa and resulting rise of the central part of the volcano, or a readjustment resulting from the great outpouring of lava in June, 1950. Any such relationship is, however, purely conjectural. There is as yet no direct evidence that the earthquakes were related to any specific eruptive episode, past or future.

* STEARNS, HAROLD T., and GORDON A. MACDONALD. GEOLOGY AND GROUND-WATER RESOURCES OF THE ISLAND OF HAWAII. Terr. of Hawaii, Dept. of Public Lands, Div. of Hydrog., Bul. 9:37. 1946.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JULY–SEPTEMBER, 1951

VOLCANOLOGY

July

Seismically, Hawaiian volcanoes were quiet during the month of July. Only 29 earthquakes were recorded on the Volcano Observatory's seismographs. One of these, a tremor recorded at 11:28 A.M. on July 28 on the seismograph operated by Howard Tatsuno at Konawaena School, was not recorded at any other station. Seventeen earthquakes were recorded at the Whitney Laboratory beneath the Volcano House, and 15 at the Mauna Loa station. A feeble earthquake at 4:07 A.M. on July 1 originated on the southwest rift of Mauna Loa beneath a point near Sulphur Cone. Another at 11:20 P.M. on July 5 originated beneath Kilauea Caldera probably within 3 miles of the surface.

Northward tilting of the ground surface at the northeastern edge of Kilauea Caldera continued throughout the month and amounted to nearly 4 seconds of arc. This rate of tilting is more than twice the average for this season of the year and indicates a continued distinct increase of volcanic pressure beneath Kilauea. Tilting in an east–west direction has shown minor oscillation during the month but no appreciable net change.

Most of the cracks on the floor of Kilauea Caldera opened or closed very little during July. However, the crack which crosses the observation area at the southeast rim of Halemaumau crater opened another 3 millimeters, making a total opening of 46.5 millimeters, or nearly 2 inches, during the past year.

On July 25 small amounts of sulphurous fume were issuing at the 1940 cinder cone in Mokuaweoweo, and a little steam was issuing near the north edge of the 1940 cone and at places on and near the 1949 cone.

August

The outstanding event of the month was the big earthquake of August 21 in Kona. This earthquake and its aftershocks have been discussed on preceding pages. During the remainder of August 21, following the major earthquake at 00:57 A.M., the seismographs at the Volcano Observatory recorded 135 earthquakes. During the month a total of 264 earthquakes was recorded at Kilauea, and 268 at the Mauna Loa station. Of these, 235 occurred after the major earthquake of August 21. The Kona seismograph recorded 494 earthquakes between the time it was repaired and restored to service at 3:15 P.M. on August 23, and midnight on August 31.

The strongest of the earlier aftershocks took place at 1:29, 4:00, 8:03, 9:57, 10:12, 18:32, and 22:48 on August 21; at 6:38 and 17:15 on August 22; and at 16:08 on August 31. Many others were felt in central Kona.

At 17:48 on August 28 a small earthquake originated beneath the east slope of Mauna Loa near Mountain View, and at 18:04 on the same day a smaller one originated just east of Kilauea Caldera. Beginning at 6:02 on the morning of August 23 the seismograph at the Whitney Laboratory of Seismology recorded 21 minutes of continuous tremor, indicating subterranean movement of magma. However, there were no other indications of volcanic unrest during the month.

Northward and eastward tilting of the ground at the Whitney Laboratory were at a rate approximately normal for that season of the year.

On August 14, Chief Ranger E. K. Field and Ranger Elroy Bohlin, of Hawaii National Park, flew over Mokuaweoweo and reported the 1940 cinder cone to be fuming mildly.

September

Earthquake activity continued abundant during September. Most of the activity centered in the Kona area. The Kona seismograph recorded 471 earthquakes during the month, bringing the total number of earthquakes since the big quake early on August 21 to 965. Most of the Kona earthquakes were too small and shallow-seated to be recorded on the seismographs at Kilauea Caldera, 42 miles away. During September the seismograph at the Whitney Laboratory recorded 110 earthquakes, and the Mauna Loa seismograph recorded 106.

Most of the Kona earthquakes originated along the fault which runs out to sea at Napoopoo, forming the great cliff at the north side of Kealakekua Bay. Several earthquakes originated beneath points along the southwest rift zone of Mauna Loa, between 9,000 feet altitude and the summit. A few had their origins beneath the crater and rift zones of Kilauea, and a small shake felt in Hilo at 11:48 P.M. on September 24 had its focus on the northeast rift of Mauna Loa. From September 23 to 26 several earthquakes originated beneath Hualalai volcano. One of these, at 7:01 P.M. September 23, was strong enough to dismantle the Kona seismograph. On September 16, about 20 earthquakes originated along the Kaoiki fault, which forms the line of cliffs northwest of the highway between Bird Park and Pahala. The one at 1:43 A.M. was felt strongly at Kapapala and less strongly at Naalehu and Pahala. Rocks were shaken down from road cuts on the Mauna Loa truck trail. Rock slides were started in Halemaumau and continued at intervals for several days.

The north end of the crack across the observation platform at the southeast rim of Halemaumau opened a quarter inch during the month. Other cracks on the floor of Kilauea Caldera showed little change in width.

Northeastward tilting continued throughout the month at the Whitney Laboratory. The direction and rate of tilting were normal for that season of the year.

The temperature of the steam at the well at Sulphur Bank, near the Volcano House, remained at 205° F. from July 2 until September 30. On September 9, temperature measurements were made on the Ohia Lodge (1950) lava flow in south Kona, near the highway. Temperatures of hot cracks, from 12 to 18 inches below the surface, ranged from 120° C. to about 400° C.

SEISMOLOGY

Earthquake Data, July–September, 1951

(Based on Bosch-Omori seismograph on northeast rim of Kilauea Caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
July 1	0	1	1	0	0	0	1.5	0
8	2	0	0	0	0	0	0.5	0
15	9	2	0	0	0	0	3.25	0
22	2	0	0	0	0	0	0.5	0
29	3	2	0	0	0	0	1.75	0
Aug. 5	4	1	1	0	0	0	1.5	0
12	2	0	0	0	0	0	0.5	0
19	128	54	10	7	3	7	120.0	0
26	31	20	1	0	0	0	18.75	1
Sept. 2	12	9	0	0	0	0	7.5	0
9	10	9	1	0	1	0	11.0	0
16	24	17	0	0	0	1	18.5	0
23	8	7	0	1	0	0	7.5	1
30	18	7	1	0	0	0	9.0	0

* For definition of local seismicity, see Volcano Letter 371.

Table of Tilt at Seismograph Vaults on Rim of Kilauea Caldera

Week Beginning	Whitney Vault (Northeast rim) Amount	Whitney Vault (Northeast rim) Direction	Uwekahuna Vault (West rim) Amount	Uwekahuna Vault (West rim) Direction
July 1	0.7″	N 9° W	0.2″	N 45° E
8	0.8″	N 16° E	1.1″	S 9° E
15	2.2″	N 6° E	3.9″	S
22	1.1″	N 26° W	2.7″	N 24° E
29	0.8″	N 18° E	1.9″	S 45° E
August 5	0.6″	N 36° E	4.2″	N 32° W
12	0.9″	N 67° E	2.4″	S 4° W
19	1.3″	N 26° W	5.0″	S 9° W
26	0.9″	N 40° E	1.8″	S 5° W
September 2	0.3″	N 27° E	2.6″	N 7° E
9	0.3″	S 34° E	0.8″	S 68° W
16	0.6″	N 67° E	5.0″	S
23	1.7″	N 10° E	2.3″	S 16° W
30	0.7″	N 10° E	2.0″	S 20° E

The data for the following local disturbances were determined from seismographs operated on the island of Hawaii by the Hawaiian Volcano Observatory. Locations given are epicenters. The arrival times are given to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich time. The number preceding each earthquake is the serial number for the current year. The intensity rating (Feeble, Moderate, etc.) given is that for the Whitney Laboratory at the northeast rim of Kilauea Caldera. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney station.

105. July 1, 04:07, very feeble. Southwest rift of Mauna Loa near Sulphur Cone.
106. July 5, 23:20, feeble. Beneath Kilauea Caldera, shallow.
107. July 17, 09:52, very feeble.
108. July 19, 19:12, very feeble.
109. Aug. 2, 19:24, very feeble.
110. Aug. 3, 01:40, very feeble.
111. Aug. 6, 23:07, very feeble.
112. Aug. 10, 04:31, feeble. East rift of Kilauea near Napau Crater.
113. Aug. 21, 00:57, strong, intensity 7, much damage in Kona. About 3 miles west-northwest of Napoopoo, probably on Kealakekua Fault.
114. Aug. 21, 01:29, strong. Felt strongly in Kona. Origin near No. 113.
115-135. Aug. 21, very feeble and feeble earthquakes, with origin in Kona.
136. Aug. 21, 03:50, slight. Kona. Felt from Kona to Volcano district.
137. Aug. 21, 04:00, moderate. Kona. Felt from Kona to Volcano district.
138-148. Aug. 21, feeble and very feeble earthquakes, with origin in Kona.
149. Aug. 21, 06:03, slight. Kona.
150-154. Aug. 21, very feeble. Kona.
155. Aug. 21, 08:03, moderate. Kona.
156-161. Aug. 21, feeble and very feeble. Kona.
162. Aug. 21, 09:38, slight. Kona.
163. Aug. 21, 09:57, strong. Felt from Kona to Volcano district. Kona.
164. Aug. 21, 10:12, strong. Kona.
165-167. Aug. 21, very feeble.
168. Aug. 21, 18:32, strong. Kona.
169. Aug. 21, 21:07, very feeble. Kona.
170. Aug. 21, 22:48, strong. Kona. Felt from Kona to the Volcano district.
171. Aug. 22, 02:14, slight. Kona.
172-174. Aug. 22, feeble and very feeble. Kona.
175. Aug. 22, 06:38, moderate. Kona. Felt from Kona to Kapapala.
176-180. Aug. 22, feeble and very feeble. Kona.
181. Aug. 22, 16:04, slight. Kona.
182. Aug. 22, 16:38, very feeble. Kona.
183. Aug. 22, 17:15, strong. Kona. Felt from Kona to Volcano district.
184. Aug. 22, 17:28, slight. Kona. Felt as far as Naalehu.
185-187. Aug. 22, feeble and very feeble. Kona.
188-190. Aug. 23, feeble and very feeble. Kona.
191. Aug. 24, 00:25, very feeble. Kona, Kealakekua Fault.
192. Aug. 24, 23:59, very feeble. Kona.
193. Aug. 25, 10:22, feeble. Kilauea.
194. Aug. 25, 11:14, very feeble (Kona feeble). Kealakekua Fault.
195. Aug. 26, 03:29, very feeble. Kealakekua Fault.
196. Aug. 26, 08:04, very feeble. Kona, Kaholo Pali.
197. Aug. 26, 08:11, very feeble (Kona slight). Kealakekua Fault.
198. Aug. 26, 19:40, very feeble. Kona, 2.3 miles S 75° E of Napoopoo.
199. Aug. 27, 04:31, very feeble (Kona feeble). Kealakekua Fault.
200. Aug. 27, 16:01, very feeble. Kealakekua Fault.
201. Aug. 27, 21:58, very feeble (Kona slight). Near Keokea.
202. Aug. 28, 11:44, very feeble. Kealakekua Fault.
203. Aug. 28, 14:24, very feeble. Kealakekua Fault.
204. Aug. 28, 17:48, feeble. About 3 miles east-southeast of Mountain View. Felt in Mountain View and Volcano district.
205. Aug. 28, 18:04, very feeble. Southwest rift of Kilauea near Kilauea Iki.
206. Aug. 28, 20:28, very feeble (Kona feeble). Kealakekua Fault.
207. Aug. 29, 06:02, very feeble (Kona feeble). Kealakekua Fault.
208. Aug. 29, 19:43, very feeble (Kona slight). Kona.
209. Aug. 29, 21:25, very feeble (Kona feeble). Kealakekua Fault. Felt in Kona.
210. Aug. 30, 07:23, very feeble (Kona moderate). Kealakekua Fault. Felt strongly in Kona.
211. Aug. 30, 14:23, very feeble. Kona.
212. Aug. 31, 16:08, very feeble (Kona strong, intensity 5). Kealakekua Fault. Felt strongly in Kona.
213. Aug. 31, 18:51, very feeble (Kona feeble). Kona, about 3.5 miles west of Hookena.
214. Sept. 1, 12:29, feeble (Kona slight). Kealakekua Fault.
215. Sept. 1, 23:21, very feeble (Kona feeble). About 0.8 mile north of Kealia.
216. Sept. 2, 18:35, very feeble (Kona feeble).
217. Sept. 3, 00:37, very feeble. Kona.
218. Sept. 4, 00:48, very feeble. Kona.
219. Sept. 4, 05:10, very feeble (Kona moderate).
220. Sept. 4, 14:13, very feeble (Kona strong, intensity 4). Felt strongly in Kona.
221. Sept. 4, 16:16, very feeble. Kilauea Caldera.
222. Sept. 4, 22:28, very feeble (Kona strong, intensity 3). Felt as far as Naalehu.
223. Sept. 6, 01:29, very feeble (Kona slight).
224. Sept. 8, 14:50, very feeble. Kilauea Caldera.
225. Sept. 8, 23:27, tremor (Kona feeble).
226. Sept. 9, 13:58, tremor (Kona moderate).
227. Sept. 10, 01:50, very feeble. Kilauea.
228. Sept. 10, 12:55, very feeble. Kona.
229. Sept. 11, 00:26, feeble. East rift of Kilauea near Puu Huluhulu.
230. Sept. 11, 12:44, very feeble. Kona.
231. Sept. 12, 01:12, very feeble (Kona slight).
232. Sept. 12, 01:27, very feeble (Kona feeble). Felt at Naalehu.
233. Sept. 12, 03:26, moderate. Southwest rift of Kilauea near Pit Craters.
234. Sept. 12, 18:55, very feeble. Kona.
235. Sept. 12, 18:56, very feeble.
236. Sept. 14, 16:49, very feeble.
237. Sept. 15, 16:45, tremor (Kona, very feeble).
238. Sept. 15, 21:33, very feeble. Southwest rift of Mauna Loa near 9,000 feet altitude.
239. Sept. 15, 23:48, very feeble. Felt at Kapapala.
240. Sept. 16, 01:43, strong, intensity 5. Kaoiki fault about 3 miles northeast of Kapapala. Felt from Kona to Hilo.
241-250. Sept. 16, very feeble. Kaoiki fault.
251. Sept. 16, 21:50, tremor (Kona feeble). Kona.
252. Sept. 16, 23:19, very feeble.
253. Sept. 17, 10:17, very feeble (Kona moderate). West slope of Mauna Loa near summit.
254. Sept. 17, 15:19, tremor (Mauna Loa very feeble).
255. Sept. 17, 18:17, very feeble (Kona feeble). Southwest rift of Mauna Loa near 11,000 feet altitude.
256. Sept. 18, 08:47, very feeble.
257. Sept. 19, 19:15, very feeble (Kona slight).
258. Sept. 20, 00:11, tremor (Mauna Loa very feeble).
259. Sept. 20, 00:25, tremor (Kona slight).
260. Sept. 20, 00:42, very feeble (Kona slight).
261. Sept. 20, 03:21, tremor (Kona very feeble).
262. Sept. 21, 07:46, very feeble.
263. Sept. 21, 12:30, tremor (Kona feeble).
264. Sept. 23, 19:01, very feeble (Kona strong). Felt strongly in Kona.
265. Sept. 24, 03:01, very feeble. Kaoiki fault 2 miles northeast of Ainapo.
266. Sept. 24, 03:13, very feeble (Kona slight). Near summit of Hualalai. Felt in Kona.
267. Sept. 24, 03:30, tremor (Kona feeble).
268. Sept. 24, 23:47, very feeble. East rift of Kilauea 10 miles east of Kapoho (?). Felt in Hilo.
269. Sept. 25, 00:56, very feeble (Kona feeble). Northwest rift of Hualalai near 5,000 feet altitude. Felt in north Kona.
270. Sept. 25, 01:23, slight (Kona moderate). Near No. 269. Generally felt in Kona.

271. Sept. 26, 20:20, very feeble (Kona slight).* South slope of Hualalai about 4 miles southeast of Holualoa. Felt in Kona.
272. Sept. 26, 23:21, very feeble.
273. Sept. 30, 06:21, very feeble. Kilauea.
274. Sept. 30, 11:17, very feeble. Kilauea.
275. Sept. 30, 16:06, very feeble. Kilauea.

TELESEISMS

Locations of the epicenters are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey. Time is Hawaiian Standard.

August 31, 23:16, slight. Easter Island region.
September 27, 09:40, moderate. Vancouver Island.

VOLCANO NOTES AND NEWS

Eruption of Oshima Volcano

The last issue of the Volcano Letter carried a brief account of the 1950 eruption of Oshima volcano, Japan. That eruption ended on September 23, 1950. A new eruption commenced early in 1951. The following notes on the new eruption were furnished by Dr. Hisashi Kuno, of Tokyo University, during a brief visit at the Hawaiian Volcano Observatory during his journey to Princeton University, where he will spend the next year in research on the pyroxene group of minerals.

The eruption started on February 4, 1951. Pyroclastic activity built a new cinder cone overlapping the northwest side of the 1950 cinder cone, on the rim of Mihara crater. On February 27 lava issued at the foot of the cone, filled the crater of Mihara-yama, and overflowed the rim. A fluid pahoehoe flow spread over the floor of the Oshima caldera. This flow continued for 2 or 3 days, then the outpouring of lava ceased, although weak Strombolian pyroclastic activity continued at the cone.

On March 10 another flow spread over the caldera floor, and barely passed the western margin of the caldera. At about this time the inhabitants of the village of Nomashi erected a wall 10 feet high across a low gap in the caldera wall in an attempt to prevent the lava from spilling out through this gap and pouring down onto the village. The lava level did not rise quite to the wall, so that the effectiveness of the wall was not tested.

On March 25 another small flow issued, pyroclastic activity continued at the cone until about June 30, but there were no more lava flows.

The old inner pit of the Mihara crater had been completely filled. Just before the end of the eruption, in June, collapse occurred at the site of the former inner pit, forming a new pit. On July 22 the volcano was quiet. The new inner pit was approximately 150 meters deep. The new cinder cone had been broken into two parts by subsidence, and the southern part had collapsed to form a small collapse crater.

Eruption in Tonga Islands

Captain R. J. Jensen, Pan American World Airways, reports observing volcanic activity on the island of Fonualei, in the Tonga group, on August 21. He writes, "The volcanic activity seemed to be located in the north-central portion of the island, with considerable smoke and a little flame. Large lava flows were evident, some of which were entering the sea. The smoke column rose to about 5,000 feet and was carried to the northwest by a southeasterly wind."

Eruption of Mt. Etna

A brief dispatch by Associated Press states that an eruption of Mt. Etna commenced on the night of September 28, 1951, at a vent about 9,300 feet above sea level. However, on September 29 the lava flow appeared to have halted. The last previous eruption of Etna was in November, 1950.

Eruption of Mt. Lamington

Reports on the catastrophic eruption of Mt. Lamington, in New Guinea, have thus far been vague and incomplete. The greatest amount of information on it yet seen by the writer is contained in an article in the June, 1951, number of *Walkabout* magazine by Dr. N. H. Fisher, chief geologist of the Australian Dominion Geological Survey and formerly in charge of the volcanological observatory at Rabaul. Accompanying the article is a series of photographs of Mt. Lamington and its vicinity, taken by the Royal Australian Air Force.

Mt. Lamington is situated near the northeast coast of Papua about N 75° E of Port Moresby. It is about 7 miles west of the west end of the Hydrographer's Range, which also is of volcanic origin. The volcanic chain extends on southeastward to Normanby and Ferguson islands. In 1943 and 1944 explosive eruptions occurred in the Goropu Mountains, 80 miles southeast of Mt. Lamington, but Lamington itself had not previously been active in historic time.

On January 21, 1951, the volcano burst into violent explosive activity. The writer has been informed that some earthquake activity preceded the outburst. Editorial comment accompanying the aerial photographs in *Walkabout* magazine states that 2,000 feet of the mountain disappeared during the eruption. It is estimated that about 4,000 persons lost their lives. Dr. Fisher briefly characterizes the eruption as a classic example of the pelean type of eruption, accompanied by glowing clouds, and he remarks on the similarity of events to those at Mount Pelée in 1902. Photographs show devastation of the type typical of glowing clouds, with trees laid over in subparallel alignment by the blasts and large areas covered with ash. An excellent photograph by G. A. Taylor on the cover of the magazine shows the fuming crater of Mt. Lamington and the dome which apparently rose in it during the eruption. Mr. Taylor, the resident volcanologist, is keeping a continuous photographic and seismic record of the eruption.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director

Chester K. Wentworth, Geologist

John C. Forbes, Laboratory Mechanic

LaVieve G. Forbes, Secretary, part-time

University of Hawaii:

T. A. Jaggar, Geophysicist

Seismograph Station Operators:
Hilo Station:

Sister M. Thecla, St. Joseph's School

Kealakekua Station:

Howard M. Tatsuno, Konawaena School

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter**, a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

THE VOLCANO LETTER

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DESTRUCTION OF WATER TANKS DURING THE KONA EARTHQUAKE OF AUGUST 21, 1951

By CHESTER K. WENTWORTH

INTRODUCTION

The following report on damage to water tanks in Kona during the earthquake of August 21, 1951, is based partly on field examination of the results of the earthquake and partly on an analysis, submitted to the Hawaiian Volcano Observatory by tank owners and builders, of 90 completed questionnaires giving data on individual damaged tanks. It is expected that much additional data will be transmitted as repairs proceed. The writer wishes to thank all those who have aided the study by submitting their reports or contributing information on tank damage. Special mention should be made of John Iwane, Extension Service, University of Hawaii; Mark Sutherland, Principal of Konawaena School; George T. Imai, Hawaii Road Department; and M. Nagai, Captain Cook Coffee Company, each of whom furnished information on a large group of tanks. The present report is only a summary statement of the results of the study. A more detailed report is planned for presentation elsewhere. For an account of other damage during the earthquake, see Volcano Letter No. 513.

WATER TANKS IN KONA

No accurate count of water tanks in Kona is known. From the recorded population of North and South Kona, which approaches 10,000, and from the total dependence on tank storage, it is a fair assumption that the number of tanks may be nearly 2,000. Many dwellings have two or more tanks. In addition to these, tanks at schools and other such buildings and tanks supplying range cattle must total several hundred.

Reliance on roof catchment and water tanks for water supply in the Kona district has been general since the building of frame structures and the replacement of native Polynesian living patterns. The native economy was supplied by a few sources of brackish water along the coast at a very small per capita daily consumption, with general use of coconut juice for drinking and of rainfall when it came. The annual rainfall along the coast is about 25 to 30 inches, but, owing to the great height and mass of Mauna Loa, the dryness of the leeward (kona) slope is ameliorated by rains due to the daytime sea-to-land breeze, which produce an annual amount of around 100 inches in a narrow belt at the 3,000 foot contour. However, the porosity of the surface rocks and the seasonality of rains are such that there are no perennial streams which reach to low altitudes, and geologic studies have indicated that adequate ground-water bodies do not exist within depths accessible under present economic conditions.

Small tanks might suffice for the few dwellings in the high-rainfall belt, but in the chief populated areas family storage of 8,000 or 10,000 gallons is usual, and many dwellings have more. Use of various urban facilities plus requirements of home gardens and attendant processing, without reference to general agriculture or stock-raising, raises the per capita consumption to 50 or more gallons per day, or perhaps 8,000 gallons per month, for a family of five. Large tanks are required to support such usage over periods when rainfall can supply only part of the required amount. Occasional water shortage, starting with larger and less foresighted families, is an almost chronic state of affairs.

DAMAGE TO TANKS

From data not yet completely gathered, it appears that about 200 tanks were seriously damaged by the earthquake. Many of these were either demolished or so displaced and distorted that they cannot be restored to use. In many cases, failure of the bottom or development of large side leaks resulted in total loss of water. Unless prompt action has been taken to repair and refill these tanks, a large proportion of them will be lost through drying and further deterioration.

The principal direct cause of damage was failure of footings. It is quite evident that the footings, while adequate to support the direct static load, were in most cases not sufficiently fixed in position, nor were the columns of the understructure adequately tied to the footings. The usual footing block is likely to move during the rocking to which the whole frame is sub-

jected during an earthquake, with progressive yielding and increase of movement to a point where the frame itself fails.

Next in importance as a cause of failure was yielding of the frame to diagonal deformation and shifting of the tank on its joists. The cylindrical, barrel-type tank depends on the tangential tension in the hoop rods both to hold the staves in watertight contact and to hold the periphery of the bottom planks tightly in the groove of the lower end of the staves. This mode of construction provides at best a very effective watertight container in continuous tension, supported directly on the joists under its floor planking. It does not provide, and would be seriously impaired by, bracing or local tying to the supports. Such a tank is best for static load; it would not be suitable for installation on a vehicle or on a ship.

MODE OF CONSTRUCTION AND PLACEMENT

The common household tank is erected with its upper edge just under the level of the eaves of the building whose roof provides the catchment. In a one-story house, the sink and wash-basin taps are often no more than 5 feet below this level, and the water of a tank more than 5 feet deep is only partly available for gravity flow to such fixtures and is not able to supply a shower bath on the same floor. Not uncommonly, small houses are built with an upper, main dwelling floor and a paved, open basement, in which laundry fixtures and a toilet or bathroom can receive water from the whole tank, even when, at some seasons, the water may be too low to supply the upstairs kitchen sink. Such hydraulic requirements necessitate placing the tank where its bottom is 6 or 8 feet and its top as much as 15 feet or more above ground.

This placement means that tanks carrying from 8 tons (2,000 gallons) to 20 tons (5,000 gallons), or even 50 tons (10,000 gallons), of water are often supported with their center of gravity 10 or 12 feet above the ground and on a base which may be little more than that dimension from side to side. A 2,000-gallon tank on six footings results in a load of about 2,700 pounds per footing; a 5,000-gallon tank on 12 footings imposes a load of about 3,300 pounds per footing. From data reported, it appears that many of the tanks of 10,000- to 25,000-gallon capacity have loads on individual footings of 4, 5, or even 6 tons! Such loads are several times that commonly carried by the columns under a small frame house, and the height of the tank is much greater in comparison to the breadth of the whole base. Tanks that are close enough to the ground to require no legs or columns may have no systematic arrangement of footings under the sills, and, in some instances, the bottom planks of the tank rest on joists (or beams) that in turn lie directly on the ground or on concrete or rock footings with no cross members parallel to the bottom planks. In such an arrangement, the bottom of the tank is in a precarious position if there is any differential movement of the footings and is ill-protected against even ordinary settling, much less a severe earthquake.

Most of the larger tanks, because of need to support the ends of the joists within the circle of the tank chimes, are supported on a sill or beam pattern that is six- or eight-sided, and the outer columns are six, eight, or more in number. These columns are usually braced from near the bottoms to the tops of adjacent columns and may or may not have bracing toward the center of the tank. Most commonly the bracing is spiked or bolted to either the outside or inside of the columns, resulting in an off-center effect which tends to develop a torque in the columns.

CAUSES OF DAMAGE

Of 90 tanks for which complete data have been received, 43 are reported demolished or totally destroyed. Of the others, a number of bottoms collapsed, other tanks developed general leakage which caused total loss of water, and many were sufficiently dislodged and deformed to necessitate complete and expensive rebuilding. In some instances, breaking of pipe fittings released all the water but could be repaired without great expense.

There is very little eye-witness account of the progressive destruction of individual tanks, but it is clear that the interrelated failure of bracing and footings was the chief cause of destruction. A few persons heard slopping of water in and from the tanks for an appreciable interval before final collapse. No marked correlation could be shown between age of the tank and damage, and only in a few instances was it clear that pre-existing impairment was responsible. So many nearly new tanks (all in good condition) were destroyed that it appears that the stresses developed by general shaking, with lateral components up to 0.2 or 0.3 of the value of gravity, could not be met by the existing bracing, and that, likewise, the footings became progressively displaced and hastened the destruction. Such stresses are comparable to tilting the tank and understructure to an angle of about 16 degrees and submitting them to repeated vertical loading and unloading. Under such conditions, it is not surprising that many of the structures failed.

The possibility of failure was further indicated by the general loads carried by the footings. In some small tanks the load per footing was as little as 1 ton, but the usual load, as in a 5,000-gallon tank on 9 footings, was 2 tons or more. In some of the larger tanks, as, for example, one at Honaunau School (Fig. 1), the load per footing was more than 12,000 pounds, or 6 tons. Lateral shaking of a mass imposing such heavy unit loads was too much for the bracing, and, after initial displacement of critical bracing or footings, the whole structure was quickly thrown down, and the tank was demolished.

RECOMMENDED CONSTRUCTION

As it is planned to present elsewhere a more detailed statement on damage to tanks and possible improvement in the design of tanks and foundation, only a few comments are included here. It is not likely that any feasible modes of construction will entirely eliminate damage from earthquakes which may occur in the Kona district. It is believed, however, that marked improvement is possible without an expenditure disproportionate to the value of the tank, if earthquake risk is kept in mind.

(1) Whenever possible, water-storage tanks should be based on the ground on a leveled, preferably concreted, surface. Founding wholly or partly on fill should



FIGURE 1. Wreckage of 23,500-gallon water tank at Honaunau School. The tank, approximately 20 years old, stood at the southwest corner of the main school building. The concrete footings seen in the background each bore a load of more than 6 tons. The tank appears to have collapsed because of failure of the supporting structure, probably due to inadequate bracing. Photo by G. A. Macdonald.

be avoided unless the entire filled area is enclosed in carefully designed, solid retaining walls and is prepared for unit loads of two or three times those from the tank. Lacking such preparation, the tank should be carried on an over-all timber crib or mat of adequate size and spacing. Increased availability of electricity and domestic-service pressure installations makes possible the basing of more large tanks on the ground.

(2) If the understructure consists of sills on columns, the lower ends of the columns should be completely tied together for compression and tension up to at least half the unit load. In the case of a simple square deck on four columns, the columns should be tied at their feet and each of the four sides braced diagonally from column bottoms to tops and through the center between opposite columns. As far as possible, bracing and cross tying should be kept in the two planes parallel to the sills and joists, respectively, with secondary truncating sills to approximate the form of a circle under large tanks. Without adequate internal bracing in the two rectangular directions, the bracing of a six- or eight-sided array of columns around the periphery results in off-center reactions and is likely to cause structural failure and destruction of the tank.

(3) Footings of concrete or large flat stones should be anchored in the ground or to the rock by imbedding them to a depth equal to their area or by rods and grouting which develop bearing resistance against lateral stresses of half the unit vertical load. Concrete piers should be tied pier to pier unless they are deeply imbedded.

(4) Wherever possible, the footing surface should be level. If this is not possible, the long columns should be tied at the level of the footings of the short columns, and the bracing should be completed at this level.

(5) Sills should be fixed at the top by drift pins, and bolts and timber fasteners should be used in the framing of supports for all but the smallest tanks. Whenever possible, braces should be paired or framed into the plane of the columns to avoid introducing torque into the stresses.

(6) Frequent inspection, painting or creosoting, and repair of defective parts will provide longer assurance of reasonable safety, as with any other structures.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR OCTOBER–DECEMBER, 1951

VOLCANOLOGY

October

Uneasiness, which was manifest at Mauna Loa during September, continued throughout October. Earthquakes originated beneath the summit area of the mountain and along both the northeast and southwest rift zones, as well as on the Kealakekua fault near Napoopoo and the Kaoiki fault from Honuapo to Ohaikea. Starting at 22:03 on October 8, Volcano Observatory seismographs recorded 16 minutes of continuous volcanic tremor probably caused by movement of molten lava underground. This was followed at 4:45 on October 9 by a moderate earthquake which appears to have originated at a depth of 25 to 30 miles beneath the summit area of Mauna Loa. This earthquake was felt by some persons in all parts of the southern portion of the island of Hawaii, from Kealakekua to Hilo. A smaller earthquake at 5:23 on the same morning originated deep beneath the upper end of the southwest rift of Mauna Loa.

During most of the month, eastward tilting at the Whitney Laboratory of Seismology at the Volcano House was at a rate about normal for that season of the year. However, from October 28 to 30 it was much more rapid than usual. The rapid tilt may have been caused by a heavy rainfall just preceding it, or it may have resulted from an increase of volcanic pressure beneath Mauna Loa. Abnormally rapid northward tilting during the same period may have been caused by an increase of pressure beneath Kilauea.

On October 24, I. C. Manus, Superintendent of Construction and Maintenance for the Kulani project, reported a long period of continuous trembling of the ground at the summit of Mauna Loa. This appeared on the seismographs as a series of closely spaced, but separate, small earthquakes. Mr. Manus also reported an apparent increase in the amount of steam being liberated at vents within Mokuaweoweo Caldera. On October 31, aircraft reported a large cloud of steam rising from the southwest rift of Mauna Loa between 8,000 and 12,000 feet altitude. This is the area in which the vents of the 1950 eruption are situated. Fume liberation at the vents has been continuous since the end of the eruption. On October 20, Acting Superintendent I. J. Castro and Ranger Elroy Bohlin, of Hawaii National Park, observed from the air steam and fume rising at eight localities along the rift between 9,000 and 12,000 feet altitude. The reported increase of the steam cloud on October 31 probably resulted from the heavy rains of October 26 to 28 coming in contact with still-hot lava near the vents, coupled with better than usual visibility of the steam because of the unusually high humidity.

During October, the seismographs at Kilauea Caldera recorded a total of 73 earthquakes. That at Konawaena School recorded 139 earthquakes, most of them aftershocks of the big earthquake of August 21.

November

Hawaiian volcanoes continued uneasy through the month of November. During the month, 73 earthquakes were recorded at the stations on the rim of Kilauea Caldera, which is more than twice the average number recorded during times of quiet. The seismograph at the Mauna Loa station recorded 53 earthquakes. Ground tilting during the month was, at an average rate, approximately normal for that season of the year. However, moderately strong oscillations of tilt in the east-west direction suggest fluctuations in pressure beneath Mauna Loa.

An earthquake of about intensity 6 in the modified Mercalli scale occurred on the morning of November 8. The time of arrival of the first waves at the Whitney Laboratory was

09 : 34 : 24, and the time of origin of the quake was approximately 09 : 34 : 12. All of the seismographs operating on the island of Hawaii were dismantled by the quake, the Mauna Loa instrument being dismantled by the preliminary waves. The earthquake was felt over all of the island, strongly over the southwest part. At Kahuku Ranch headquarters, 9.5 miles north of South Point, dishes were thrown from shelves and stone walls were extensively damaged. The intensity decreased very rapidly away from the epicenter. At South Point and at Kaalualu, 10 miles southeast of Kahuku Ranch headquarters, there was no damage to stone walls, and, even in the homestead area 4 miles southeast of ranch headquarters, the damage was very small. The decrease was even more rapid westward. Two and a half miles west of the ranch headquarters, stone walls along the highway were undamaged. Instrumental data and field investigations place the epicenter of the earthquake on the southwest rift zone of Mauna Loa at about 4,500 feet altitude, approximately 5 miles north of Kahuku Ranch headquarters. The Kahuku fault, one of the major fractures in the southwest rift zone, trends nearly north and south just west of the ranch headquarters. The area of damage to stone walls was distinctly elongated parallel to the Kahuku fault, suggesting that the earthquake was caused by movement on that fault. The rapid decrease of damage at increasing distance from the epicenter suggests a very shallow origin of the quake, but no surface fault displacement has been found.

During November, the seismograph at Konawaena School in Kealakekua recorded a total of 110 earthquakes. Most of them originated within 10 miles of the seismograph station, and the majority probably resulted from movement along the Kealakekua fault. On November 7, at 20:11, a small quake originated beneath the summit region of Hualalai volcano. On November 21, at 9:59, a small earthquake occurred beneath the Waimea Plain a few miles west of Kamuela. Nearly all the other local earthquakes recorded during the month had their origins in Kilauea and Mauna Loa volcanoes.

On November 23, two observers in the Kona area reported what appeared to them to be smoke near the summit of Mauna Loa. E. K. Field, Chief Ranger, and R. L. Jeffery, Superintendent of Construction and Maintenance, of Hawaii National Park, were at the summit of Mauna Loa at the time and reported conditions at and near the summit to be normal. The "smoke" observed from Kona appears to have been steam rising in the vicinity of the vents of the 1950 lava flows, probably caused by heavy rain on November 20 to 22.

December

The uneasiness of Mauna Loa and Kilauea during October and November persisted into early December. During the latter part of the month, the volcanoes were relatively quiet although oscillations in east-west tilting at the Whitney Laboratory still suggested some fluctuation in pressure beneath Mauna Loa.

Between December 3 and 7, the ground surface at the Whitney Laboratory tilted rapidly southward by an amount of 4.4 seconds of arc, and by December 16 an additional tilting of 0.6 seconds had taken place. This was followed, however, by a rapid partial recovery of 2.6 seconds by December 25. The net southward tilt during the month was 2.2 seconds of arc. This suggests a decrease of pressure beneath Kilauea.

During December, most of the earthquake activity originated at Kilauea volcano. The seismograph at the Whitney Laboratory, on the northeast rim of Kilauea Caldera, recorded 37 earthquakes. This number only slightly exceeds the average during quiet periods. The Mauna Loa seismograph recorded only 21 earthquakes. The Kona seismograph recorded 62 earthquakes during the month. Most of these originated close to the station, many of them probably on the Kealakekua fault.

At 20:19 on December 6, a strong earthquake was felt over all of the southeast part of the island. It originated at a depth of 3 or 4 miles on the east rift zone of Kilauea volcano, about 14 miles east of the caldera and 7 miles southwest of Pahoa.

TELESEISMS

The following earthquakes of distant origin were recorded on the seismographs of the Hawaiian Volcano Observatory. Locations of the epicenters are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey. The time given is Hawaiian Standard time.

October 21, 11 : 46, slight. Formosa.
October 21, 17 : 41, slight. Formosa.
November 6, 06 : 53, slight. Kurile Islands.
November 8, 04 : 02, moderate. Aleutian Islands.
December 7, 18 : 35, slight. Indian Ocean, about 900 miles southeast of Madagascar.
December 25, 15 : 03, slight. Off coast of southern California.
December 27, 23 : 34, slight. Guerrero, Mexico.
December 30, 12 : 50, moderate. Pacific Ocean, west of Easter Island.

The data for the following local disturbances were determined from seismographs operated on the island of Hawaii by the Hawaiian Volcano Observatory. Locations given are epicenters. The arrival times are given to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich time. The number preceding each earthquake is the serial number for the current year. The intensity rating (Feeble, Moderate, etc.) given is that for the Whitney Laboratory at the northeast rim of Kilauea Caldera. If the intensity was greater at one of the other stations, the name of that station and the intensity rating are given in parentheses after the rating at the Whitney station, except that where the earthquake was not recorded at the Whitney station the parentheses are omitted.

276. Oct. 1, 09 : 17, tremor (Kona very feeble). Central Kona.
277. Oct. 3, 22 : 56, tremor (Kona very feeble). Central Kona.
278. Oct. 4, 06 : 01, very feeble (Kona feeble). Central Kona.
279. Oct. 4, 19 : 03, tremor (Kona very feeble). Central Kona.
280. Oct. 5, 02 : 09, tremor (Kona very feeble). Central Kona.
281. Oct. 5, 08 : 42, very feeble, felt at Kapapala and Naalehu. Kaoiki fault near Hilea.
282. Oct. 6, 02 : 44, very feeble (Kona feeble). East edge of Kealakekua Bay.
283. Oct. 6, 04 : 36, feeble, felt at Kapapala and Naalehu. Kaoiki fault, about 4 miles northeast of Kapapala.
284. Oct. 6, 08 : 35, very feeble (Mauna Loa slight). Kaoiki fault, about 3 miles northeast of Kapapala.
285. Oct. 6, 13 : 34, tremor (Kona very feeble). Central Kona.
286. Oct. 7, 01 : 28, very feeble, felt at Naalehu. Near Hilea.
287. Oct. 7, 05 : 14, tremor (Kona very feeble). Central Kona.
288. Oct. 8, 07 : 16, Kona, feeble, no record on other instruments.
289. Oct. 9, 01 : 40, Kona, feeble, no record on other instruments.
290. Oct. 9, 04 : 45, slight, felt from Kona to Hilo. Central Kona.
291. Oct. 9, 05 : 23, feeble (Kona moderate), felt at Kealakekua. Central Kona.
292. Oct. 10, 02 : 31, tremor (Kona very feeble).
293. Oct. 11, 15 : 05, very feeble. Kilauea (?).
294. Oct. 11, 21 : 30, very feeble (Kona moderate), felt at Kealakekua. Central Kona.
295. Oct. 12, 10 : 12, very feeble (Kona slight). Central Kona.
296. Oct. 12, 16 : 06, tremor (Kona very feeble).
297. Oct. 14, 16 : 37, very feeble. Kilauea.
298. Oct. 14, 19 : 52, very feeble, felt at Naalehu.
299. Oct. 15, 02 : 43, very feeble. Central Kona.
300. Oct. 15, 19 : 47, very feeble.
301. Oct. 17, 08 : 49, tremor (Kona very feeble). Central Kona.
302. Oct. 17, 21 : 12, slight (Mauna Loa moderate), felt at Volcano and Hilo. Northeast rift of Mauna Loa, near the 3,000-foot contour.
303. Oct. 19, 01 : 00, very feeble, felt at Volcano. Northeast rift of Mauna Loa (?).
304. Oct. 20, 11 : 58, very feeble.
305. Oct. 20, 19 : 10, tremor (Kona very feeble).
306. Oct. 20, 21 : 01, very feeble (Kona feeble). Central Kona.
307. Oct. 23, 10 : 42, tremor (Kona slight), felt at Kealakekua. Central Kona.
308. Oct. 24, 13 : 14, very feeble (Kona feeble). Central Kona.
309. Oct. 24, 13 : 15, very feeble, felt at summit of Mauna Loa.
310. Oct. 25, 02 : 42, very feeble.
311. Oct. 25, 05 : 22, very feeble.
312. Oct. 27, 21 : 05, very feeble.
313. Oct. 28, 06 : 53, tremor (Kona very feeble). Central Kona.
314. Oct. 29, 02 : 07, very feeble. Central Kona.
315. Oct. 29, 23 : 49, very feeble. Kaoiki fault, about 3 miles northeast of Hilea.

316. Nov. 1, 20:48, very feeble.
317. Nov. 3, 06:26, very feeble.
318. Nov. 4, 19:24, very feeble. Northeast rift of Mauna Loa.
319. Nov. 6, 10:44, very feeble. Kilauea.
320. Nov. 6, 11:08, very feeble. Kilauea.
321. Nov. 7, 20:11, very feeble. Near summit of Hualalai.
322. Nov. 7, 22:46, very feeble.
323. Nov. 8, 09:34, strong. Intensity 6 at Kahuku. Felt all over southern part of island. Epicenter on southwest rift of Mauna Loa at about 4,500 feet altitude.
324. Nov. 8, 10:16, very feeble.
325. Nov. 8, 14:10, tremor (Kona slight). Central Kona.
326. Nov. 8, 14:22, very feeble, felt at Kealakekua.
327. Nov. 8, 16:33, very feeble. Kilauea.
328. Nov. 8, 23:27, tremor (Kona very feeble). Central Kona.
329. Nov. 9, 00:55, very feeble. Hilina fault, near Puu Kapukapu.
330. Nov. 10, 14:16, very feeble. Southwest rift of Mauna Loa at about 11,000 feet altitude.
331. Nov. 11, 03:52, very feeble.
332. Nov. 11, 07:08, slight, felt in Hilo. East rift of Kilauea, near Pauahi Crater.
333. Nov. 12, 07:01, very feeble. Kaoiki fault near Ainapo.
334. Nov. 13, 00:41, very feeble. Kilauea.
335. Nov. 16, 02:57, very feeble. Kilauea.
336. Nov. 16, 20:54, very feeble.
337. Nov. 17, 14:50, Kona feeble, no record on other instruments; felt in Kealakekua.
338. Nov. 18, 01:31, tremor (Kona very feeble), felt at Kealakekua.
339. Nov. 18, 02:47, tremor (Kona slight), felt at Kealakekua. Central Kona.
340. Nov. 18, 11:18, very feeble. Kilauea Caldera, near Uwekahuna.
341. Nov. 19, 18:58, very feeble.
342. Nov. 20, 17:43, tremor (Kona very feeble.) Central Kona.
343. Nov. 21, 06:22, very feeble.
344. Nov. 21, 10:00, very feeble. Waimea Plain, near Kamuela.
345. Nov. 21, 22:23, very feeble.
346. Nov. 22, 17:37, very feeble. East slope of Mauna Loa, about 3 miles east of Kulani Cone.
347. Nov. 23, 08:22, slight (Kona moderate), felt from central Kona to Kahuku. Kealakekua fault, about 5 miles west of Napoopoo.
348. Nov. 25, 06:17, tremor (Kona very feeble).
349. Nov. 25, 21:41, tremor (Kona very feeble). Central Kona.
350. Nov. 26, 12:35, very feeble. East rift of Kilauea, near Makaopuhi Crater.
351. Nov. 26, 21:25, tremor (Kona very feeble). Central Kona.
352. Nov. 28, 09:36, very feeble.
353. Nov. 28, 11:41, very feeble.
354. Dec. 1, 06:09, very feeble. Central Kona.
355. Dec. 2, 12:00, very feeble.
356. Dec. 3, 08:33, very feeble.
357. Dec. 5, 05:20, very feeble. Kilauea Caldera.
358. Dec. 6, 20:19, strong, felt from Kapapala to Hilo and east Puna. East rift of Kilauea, about 7 miles southwest of Pahoa.
359. Dec. 9, 16:37, feeble. Near Kilauea Caldera.
360. Dec. 11, 02:12, very feeble.
361. Dec. 11, 13:58, very feeble.
362. Dec. 12, 16:51, very feeble.
363. Dec. 13, 03:06, tremor (Kona feeble). Central Kona.
364. Dec. 13, 21:54, very feeble. Kilauea Caldera.
365. Dec. 14, 19:22, tremor (Kona very feeble). Central Kona.
366. Dec. 15, 01:36, very feeble.
367. Dec. 15, 23:16, very feeble.
368. Dec. 17, 15:48, very feeble.
369. Dec. 19, 05:30, very feeble.
370. Dec. 23, 09:31, very feeble. Kilauea Caldera.
371. Dec. 25, 09:50, very feeble.
372. Dec. 26, 23:06, very feeble.
373. Dec. 28, 16:17, tremor (Kona very feeble). Central Kona.
374. Dec. 29, 08:45, Kona feeble, no record on other instruments. Central Kona.
375. Dec. 29, 17:32, very feeble, felt at Naalehu and Kapapala. Kaoiki fault, near Pahala.
376. Dec. 30, 02:00, Kona feeble, no record on other instruments. Central Kona.
377. Dec. 31, 15:49, tremor (Kona feeble). Central Kona.

SEISMOLOGY

Earthquake Data, October–December, 1951

(Based on Bosch-Omori seismograph on northeast rim of Kilauea Caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
Oct. 7	6	4	1	1	0	0	6.5	0
14	3	6	0	1	0	0	5.75	0
21	10	5	0	0	0	0	5.0	2
28	16	4	1	0	0	0	7.0	0
Nov. 4	11	10	0	0	0	1	11.75	2
11	8	5	0	1	0	0	6.5	0
18	10	7	0	1	0	0	8.0	0
25	11	4	0	0	0	0	4.75	0
Dec. 2	5	3	0	0	0	1	6.75	1
9	5	6	1	0	0	0	5.25	0
16	9	2	0	0	0	0	3.25	0
23	3	4	0	0	0	0	2.75	2
30								1

* For definition of local seismicity, see Volcano Letter 371.

Table of Tilt at Seismograph Vaults on Rim of Kilauea Caldera

Week Beginning	Whitney Vault (Northeast rim) Amount	Whitney Vault (Northeast rim) Direction	Uwekahuna Vault (West rim) Amount	Uwekahuna Vault (West rim) Direction
October 7	0.3″	N 45° E	0.4″	S 45° E
14	0.7″	N	1.0″	N 18° W
21	1.2″	N 6° E	5.1″	N 22° W
28	0.7″	S 31° E	5.2″	N 10° W
November 4	0.6″	N 22° E	4.8″	S
11	0.2″	S 45° W	3.0″	S 18° E
18	0.9″	N 74° E	2.3″	N 8° W
25	1.4″	N 25° W	3.0″	S 13° E
December 2	4.2″	S 5° W	2.0″	N 10° W
9	0.9″	S 23° E	2.0″	N 10° W
16	2.8″	N 23° E	4.2″	S 5° E
23	0.4″	S 72° E	1.2″	S 34° E
30				

VOLCANO NOTES AND NEWS

ACTIVITY OF PARICUTIN VOLCANO

Paricutin volcano began its spectacular life on February 20, 1943, in the state of Michoacán, western Mexico. The new volcano is situated in the midst of a volcanic field containing hundreds of older, but geologically young, cinder cones and lava cones. During its first weeks, the activity of Paricutin was largely pyroclastic, and, by the time it was a year old, the resulting cinder cone was 1,100 feet high. Since then the upward growth of the cone has been slow, and on February 21, 1950, the summit of the cone stood approximately 1,300 feet above its original base. Lava flows commenced early in the history of the volcano and have continued intermittently ever since. At the end of June, 1950, the total area covered by Paricutin lava was about 24.2 square kilometers.*

* Carl Fries, Jr., and Celedonio Gutiérrez, activity of paricutin volcano from january 1 to june 30, 1950. Amer. Geophys. Union Trans. 32: 227–230. 1951.

Brief summaries of the activity of Paricutin volcano appear at approximately 6-month intervals in the American Geophysical Union Transactions. Carl Fries, Jr., of the U. S. Geological Survey, has kindly supplied a statement on the current state of activity of Paricutin. The Mexican Institute of Scientific Investigation and the U. S. Geological Survey are maintaining a watch over Paricutin on a cooperative basis. Two Mexican observers are constantly at the observatory, gathering data on eruptive activity, lava movement, weather, and any other pertinent occurrences. Mr. Fries visits the volcano every 2 months to gather the data sheets, make special measurements, and collect lava samples. His last visit was in mid-November, 1951.

In May, 1951, a new pyroclastic eruptive vent formed low on the northeast flank of the main cone. This new vent was very active and formed a separate crater on that flank of the cone. During the following months, the vent gradually moved up the flank, and its crater coalesced with the main crater. By November the depression on the northeast flank had been filled by deposition of pyroclastic fragments, and the profile was once again that of a simple cone.

Lava has continued to issue from the Nuevo Juatita vent at the northeast base of the cone, flowing northeastward around the Equijuata and Capatzun cinder cones. By October it had reached a point about 2½ miles from the vent, near the site of the former town of San Juan Parangaricutiro, when the flow of lava was interrupted at the vent, and the flow front ceased advancing. Solidification at the vent caused the formation of a new lava cascade just west of the former one, and during November two prongs of Lava were invading the base of Equijuata cinder cone near Tourist Lookout.

Activity of the eruptive vents in the crater of the main cone has, for the past 6 months, been of such an intermittently explosive nature that it has not been possible to climb the cone with any probability of safety. It has been dangerous even to approach the base of the cone.

ALEUTIAN-ALASKAN VOLCANO STUDIES

Dr. H. A. Powers, who is in charge of the U. S. Geological Survey's volcanological program in the Aleutian Islands, reports that the field team from the General Geology Branch, which is studying and mapping the volcanoes of the Aleutian Islands and Alaska Peninsula, completed the reconnaissance mapping of the Rat Group during the summer of 1951. This completes the mapping of all the American Aleutians west of the 180th meridian. Eastward, work has been completed on northern Kanaga, northern Adak, Great Sitkin, Umnak, and the Pavlof Group. The investigation will be continued until all the young volcanic areas have been studied.

ALEUTIAN VOLCANIC ACTIVITY

Great Sitkin volcano, in the Andreanof Group of the Aleutian Islands, has continued to steam throughout the past year, according to observations by Austin E. Jones, seismologist in charge of the seismological observatory maintained on Adak Island by the Geophysics Branch of the U. S. Geological Survey. The steam cloud is visible intermittently from Adak. It is not apparent whether this represents fluctuation in volume of steam output or fluctuation in meteorological conditions that condense the steam.

No fume or ash clouds have appeared from Great Sitkin since the series of eruptions which ended about November 29, 1950. During this eruptive period, which began November 5, 1950, several ash showers and fume were produced. Jones estimated that one ash eruption produced possibly as much as 20,000 cubic meters of ash. Flashes of light were observed several times at night by military personnel on Great Sitkin Island, but they were not seen from Adak. Prior to this activity, the last small ash falls and fume clouds were seen on December 30, 1949, and January 7, 1950.

In spite of the frequency of military air travel along the Aleutian Chain, information on minor activity of the different volcanoes is very random because the cloud and fog screen is so persistent. Minor ash showers and fume emission are known to have occurred during 1951 from Gareloi, Kanaga, Great Sitkin, Akutan, and Shishaldin. Others may have shown minor activity which has not been reported. It is certain, however, that no major eruptions have escaped notice.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director
Chester K. Wentworth, Geologist, part-time
John C. Forbes, Laboratory Mechanic
LaVieve G. Forbes, Secretary, part-time

Seismograph Station Operators:

Hilo Station:
Sister M. Thecla, St. Joseph's School

Kona Station:
Howard M. Tatsuno, Konawaena School

University of Hawaii:

T. A. Jaggar, Geophysicist

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcances in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter**, a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

THE VOLCANO LETTER

No. 515 **U. S. Geological Survey** **January–March, 1952**

PUBLISHED BY THE UNIVERSITY OF HAWAII

THE SOUTH HAWAII EARTHQUAKES OF MARCH AND APRIL, 1952

By GORDON A. MACDONALD

At 11:38 Hawaiian Standard time on March 13 a strong earthquake (Fig. 1, No. 78) originated beneath the ocean south of the island of Hawaii, 23 miles S 19° W of the coastal village of Kalapana. The earthquake was felt all over the southern portion of the island, its intensity along the south shore being estimated at 4 in the modified Mercalli scale. At 18:20 on March 14 a similar earthquake (Fig. 1, No. 80) originated in the same general area. These quakes were the forerunners of a great swarm of earthquakes that began on March 16 and continued throughout April.

On March 16 the seismographs of the Hawaiian Volcano Observatory recorded 39 earthquakes, all probably originating in the offshore area south of the island. On the following days the number of quakes rapidly increased, reaching a peak of 395 on March 20. Figure 2 indicates the daily seismicity at the Volcano Observatory through the rest of March and April. The daily seismicity was determined by assigning a seismicity value to each earthquake, depending on its size, and totaling the values for each day. Each strong earthquake was assigned a seismicity value of 4. The method is described in Volcano Letter 512.

The decrease in number of quakes from foci south of the island was less rapid than the increase and at a fairly regular declining rate. In Figure 2 the marked hump in the curve on April 5–7 is caused by a series of earthquakes originating on the east rift zone and beneath the caldera of Kilauea volcano. This swarm of Kilauea earthquakes was essentially past by April 8, although a few quakes of Kilauea origin were recorded through the remainder of April.

At the end of April the total number of earthquakes recorded since March 13 was 4,553. Most of these were small, and many were tremors too small to permit the recognition of phases in the seismogram. Based on the records from the Bosch-Omori seismograph in the Whitney Laboratory of Seismology, at the northeast rim of Kilauea Caldera, 31 are classed as moderate and 18 as strong. Several of the strong earthquakes were felt generally over the southern portion of the island. All the strong quakes and many of the smaller ones were felt in the area from Kapapala to and beyond Naalehu (Fig. 1). It is estimated that, during the height of the activity, 20 to 30 earthquakes a day were felt at Naalehu. The number of quakes felt decreased rapidly northeastward, and at Kapapala residents felt only a small proportion of those felt at Naalehu. A still smaller number was felt in the Kilauea Caldera area. It is noteworthy that very few of the earthquakes were felt at Kalapana despite the closeness of that village to the epicenters of many of the quakes. The shocks were much more generally felt in the region nearly in line with the presumed submarine fault on which they originated than they were in areas at similar distances approximately normal to the fault.

None of the earthquakes caused any important damage to property, although several of the large ones caused slight shifting or overturning of small objects on shelves. A strong quake (Fig. 1, No. 148) at 17:58 on March 17 caused a small tsunami ("tidal wave") at Kalapana. At approximately 18:00 waves swept inland about 600 feet, entering the yard of the Kalapana School. At the time, storm waves were not of sufficient size to account for the incursion of the water. This small tsunami produced no record on the tide gauge at Hilo, and no damage was done. However, the writer considered it advisable to issue a warning to all communities along the southeast shore of the island that as long as the swarm of submarine earthquakes continued there was a possibility that a large quake of shallow origin might be accompanied by a destructive tsunami. On the basis of this warning, the Department of Public Instruction ordered the Kalapana School closed and the children transported to school elsewhere until the undersea earthquakes ended.

Approximately 185 of the swarm of earthquakes yielded seismograms on which the emergence of the P and S phases could be recognized with sufficient certainty at several stations to permit reasonably certain location of the epicenter. These epicenters are indicated in Figure 1. All the epicenters were located by means of

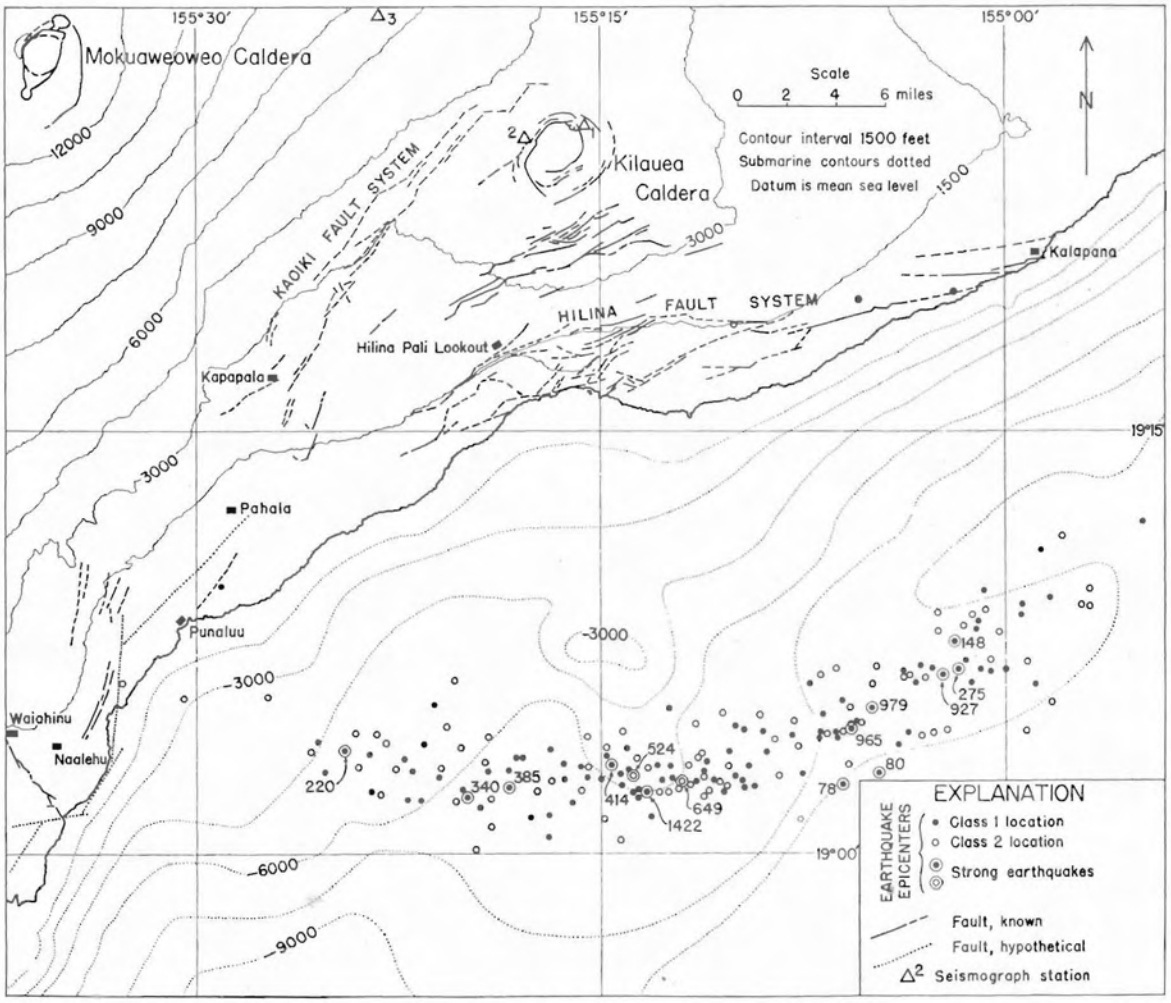

FIGURE 1. Map of part of the southeast coast of the island of Hawaii, showing the locations of epicenters of earthquakes during March and April, 1952, and the positions of known and hypothetical faults above sea level. Class 1 locations are from good agreement of all data; class 2 are satisfactory agreement of data. Serial numbers of the strong earthquakes are indicated. Seismograph stations shown are (1) Whitney Laboratory of Seismology, (2) Uwekahuna station, and (3) Mauna Loa station. The broad bulge in the submarine contours south of Kilauea Caldera probably marks a submarine shield volcano with a ridge extending eastward along a rift zone.

the distance indicated by the interval S — P, using at least three stations. Records from the Whitney Laboratory, the Mauna Loa station, and the Hilo station were used in practically all the locations, and the locations of the strong earthquakes were checked by means of the records of the Kona station. Checks on many locations were obtained from the records of the vertical seismographs and the Imamura strong-motion seismograph at Uwekahuna. In addition, a portable seismograph was operated by John C. Forbes at Naalehu on March 26, at Punaluu on March 28, and at the Hilina Pali lookout station on April 1. The writer wishes to thank Miss Constance Conard, teacher at Naalehu School, for permission to operate the seismograph in the basement of her cottage at the school, and Wayne Richardson and the Hawaiian Agricultural Company for the use of the company's beach house in which to operate the seismograph at Punaluu.

Two classes of epicentral locations are shown in Figure 1. In locations of class 1 there was good agreement of the data from all stations. In locations of class 2 the agreement was less perfect although still close. Instances in which agreement of the data was poor were rejected, and those epicenters are not shown in Figure 1. Because of the unfavorable distribution of seismograph stations in respect to the earthquake epicenters, depth determinations are too uncertain to be used for comparative purposes.

Submarine contours based on the soundings shown on U. S. Coast and Geodetic Survey chart 4115 (7th edition, June 1940) show a broad dome with its apex 21 miles nearly due south of the summit of Kilauea volcano. Soundings are inadequate to give a detailed picture of this feature, and it is highly desirable that many more soundings be obtained off the island of Hawaii. Existing soundings are, however, adequate to give a rather definite generalized picture. A few old, isolated soundings, that are not accordant with adjacent new soundings, and probably are erroneous in position, have been rejected in contouring.

The contours are shown by dotted lines in Figure 1. The dome is probably a shield volcano, lying against the side of the Kilauea shield just as Kilauea does against the side of Mauna Loa. The broad nose projecting east-

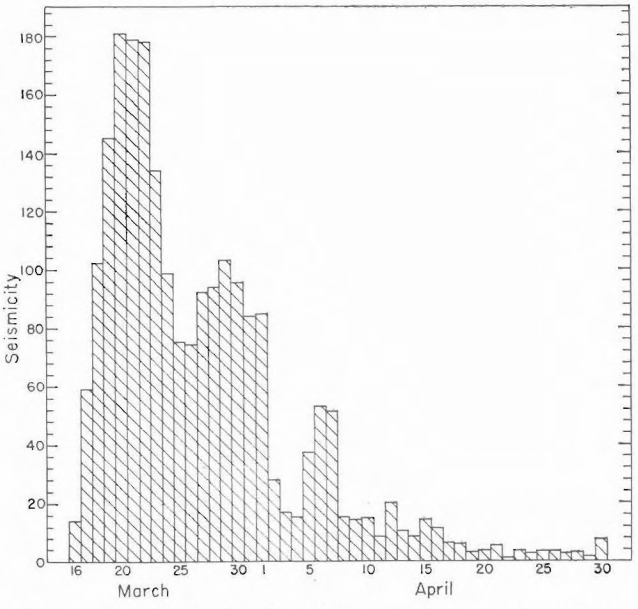

FIGURE 2. Graph showing daily seismicity at the Whitney Laboratory of Seismology from March 16 to April 30, 1952.

ward, shown by the minus-9,000-foot contour, probably is a ridge built along an eastward-trending rift zone like that of Kilauea. It is noteworthy that this probable submarine volcano lies almost exactly on a line drawn through the summits of Hualalai and Mauna Loa volcanoes.

The distribution of epicenters in Figure 1 clearly indicates that the earthquake swarm was caused by movements along a line or narrow zone nearly parallel to the south coast of the island. The eastern portion of the line lies approximately along the axis of the eastward-trending submarine ridge, and the entire line may mark a rift zone crossing south of the summit of the submarine shield, as does that of Kilauea. If so, the movements that caused the earthquakes may have accompanied subterranean magma movement or eruption of the submarine volcano. Careful watch was kept throughout the earthquake period for any signs of submarine eruption. On March 28 a cowboy employed by the Kapapala Ranch reported seeing three puffs of cloud rising from the ocean south of the island at 14:32, 14:50, and 15:10, respectively. These were not reported by any other observer. The ocean south of the island was kept under observation for the next several days from the Volcano Observatory and on March 29 and April 1 from the Hilina Pali lookout. Both binoculars and a telescope were employed. Several times puffs of cloud seen from the Observatory at first appeared to be rising from the ocean, but each time further observation showed them to be merely developing puffs of the common coastal cumulus. From Hilina Pali no clouds were seen to rise from the ocean, nor was any disturbance of the ocean surface observed.

It is, of course, entirely possible that eruption in several thousand feet of water might not produce any visible evidence at the surface. Pressure of overlying water might prevent vesiculation of sufficient degree to produce pumice or scoria light enough to float to the surface. Steam generated by contact of the hot lava with ocean water probably would be cooled and condensed as it rose through the overlying cold water, and magmatic gases might be entirely dissolved. Thus, neither floating pumice nor rising gases might be visible at the surface. On the other hand, it appears unlikely that eruption could have occurred without producing some record of volcanic tremor on the seismographs. Such tremor characteristically accompanies eruptions of Mauna Loa and Kilauea, but it was totally absent from the records during March and April, 1952. Furthermore, even in deep water the heating of the immediately surrounding water and, possibly, the introduction of toxic gases probably would cause the death of many fish, which would float ashore as they did in the vicinity of the 1950 lava flows that entered the ocean. (It is interesting to note that, although specific identifications of these fish are not yet available, many of them obviously came from depths well below those reached in ordinary fishing.)

A more probable interpretation is that the line indicated by the epicenters in Figure 1 marks a fault, or more probably a group of faults, crossing the south slope of the submarine shield volcano much as the Hilina fault system does the south slope of Kilauea volcano above sea level, and that the earthquakes were caused by movement along this fault zone. The probability is increased by the occurrence during the past year of repeated movements along the other similar fault systems on the flanks of both Kilauea and Mauna Loa. It is noteworthy that three of the located earthquakes of the March-April group originated along the Hilina fault system, probably as a result of adjustment along that system in response to movement on the faults farther south. Displacement on the faults of the Hilina system

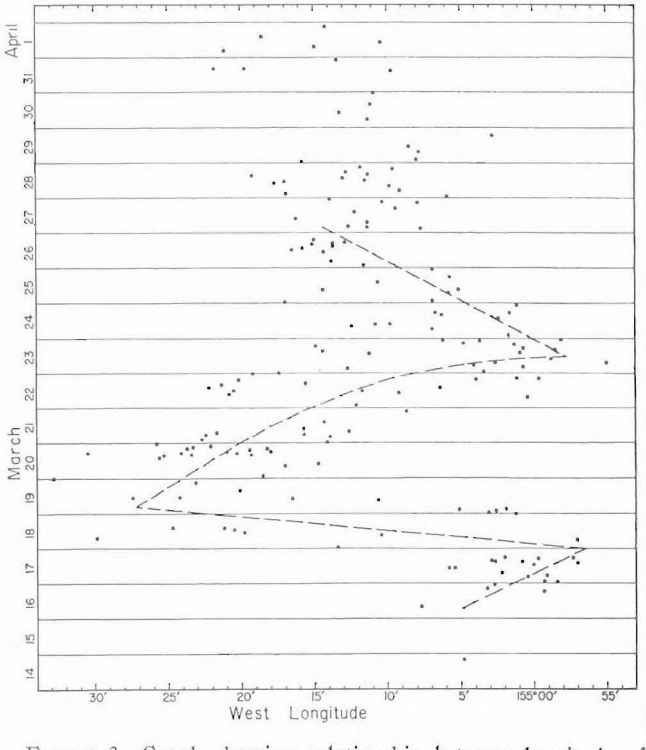

FIGURE 3. Graph showing relationship between longitude of focus and time of occurrence of the earthquakes, the epicenters of which are shown in Figure 1. The dots represent the actual earthquakes, and the dashed line shows approximate median curve.

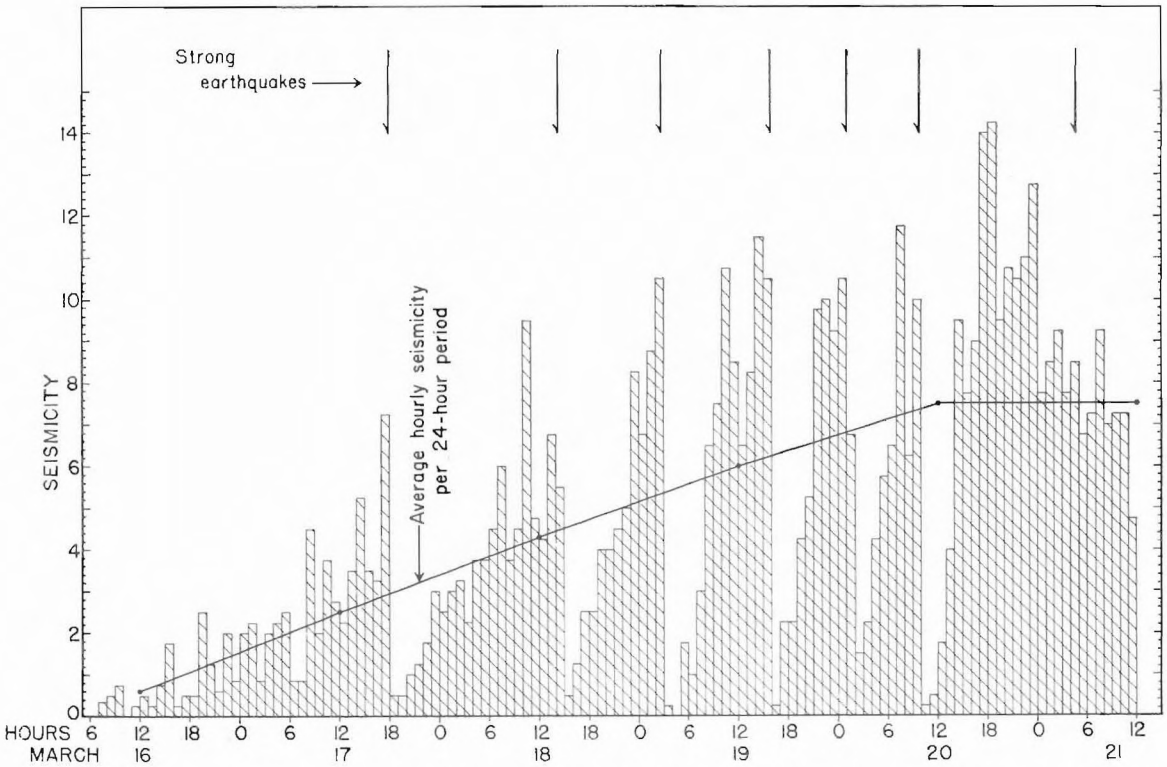

FIGURE 4. Graph showing, by means of columns, the hourly seismicity at the Whitney Laboratory of Seismology from March 16 to 21, 1952, and, by means of black dots, the average hourly seismicity for each day. The line connecting the dots indicates the trend of average hourly seismicity. The single-barbed arrows at the top of the figure indicate the time of occurrence of strong earthquakes.

has resulted in a rise of the central part of the island in relation to the undersea portion. It is probable that on the offshore faults also, the predominant movement has been a rise of the island in relation to the adjacent ocean basin.

The migration of the epicenters indicates that fault movement commenced at about longitude 155°06′W, shifted eastward to about longitude 154°57′, then westward as far as 155°32′ on March 19 and 20, then again eastward. From March 25 on, the located quakes mostly lay near the central portion of the zone of activity, with no definite shifting indicated. The migration of earthquake activity back and forth along the fault zone is shown graphically in Figure 3, in which the longitudes of the epicenters shown in Figure 1 are plotted against time.

The seismicity values may be taken as a roughly quantitative indication of the energy release by the earthquakes. During the first few days of the earthquake swarm, the average rate of energy release appears to have increased at an essentially uniform rate, suggesting a fairly uniform increase in the strain, the release of which was responsible for the earthquakes. In Figure 4, the curve representing the average hourly seismicity during each 24-hour period rises as a nearly straight line from March 16 to March 20. After March 20 the curve flattens into a nearly horizontal plateau. In detail, however, the energy release was not uniform. The plotting of hourly seismicity in the columnar graph (Fig. 4) indicates in general a succession of progressive increases of energy release, terminated by one or more strong earthquakes and followed by a period of a few hours of relative quiet. Thus, although the strain on the fault system appears to have accumulated at a fairly regular rate, the release of the strain was not regular but periodic. Probably the accumulation of strain on the faults, because of frictional resistance to movement on the fault planes, proceeded at a rate greater than the rate of release of the strain, until finally the accumulated strain was relieved by a large movement causing a large earthquake. After each fairly complete release the accumulated strain gradually increased again until another climax was reached.

The earthquake swarm of March and April, 1952, somewhat resembled that of 1868 although on a smaller scale. During late March of 1868 residents of southern Hawaii experienced great numbers of earthquakes, reportedly reaching dozens, or even hundreds, a day. They were most severe in the region from Kapapala to Waiohinu. This activity was climaxed on April 2, 1868, by a violent earthquake of about intensity 10 (Wood, 1914: 192) that leveled nearly every building in the area. The big earthquake was accompanied by a mud flow at Wood Valley, between Kapapala and Pahala, that buried a village and killed 31 persons. At the same time a great tsunami seriously damaged every coastal village along the southeast shore of the island, destroying 108 houses and the lives of 47 people (Brigham, 1909: 118). The great earthquake was followed, a few days later, by eruption of both Kilauea and Mauna Loa volcanoes.

The location of the origin of the great earthquake of April 2, 1868, is uncertain. Movement on a fault just west of Waiohinu is reported to have offset a wagon road the width of the road horizontally (Wood, 1914:

199). However, the very large tsunami that accompanied the earthquake suggests that part of the movement occurred offshore. It is not impossible that the big 1868 quake and many of its attendant smaller shocks originated on the same fault system that caused the quakes of March, 1952. It appears more probable, however, that they originated on the faults in the vicinity of Waiohinu and Naalehu and their seaward extensions.

The possibility of a train of events similar to that of 1868 was borne strongly in mind during the earthquakes of March, 1952. As already stated, the possibility of a damaging tsunami was pointed out. However, lack of strong ground tilting and the absence of earthquakes originating beneath the caldera or rift zones of either volcano during the principal part of the 1952 earthquake swarm suggested that volcanic eruption was not imminent.

REFERENCES

BRIGHAM, W. T., THE VOLCANOES OF KILAUEA AND MAUNA LOA. Bernice P. Bishop Mus. Mem. 2 (4) : 1–222. 1909.

WOOD, H. O., ON THE EARTHQUAKES OF 1868 IN HAWAII. Seismol. Soc. Amer. Bul. 4 : 169–203. 1914.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JANUARY–MARCH, 1952

By GORDON A. MACDONALD

VOLCANOLOGY

January

Hawaiian volcanoes remained quiet during January. The seismograph beneath the Volcano House, at the northeast rim of Kilauea crater, recorded a total of 54 earthquakes during the month, and the Mauna Loa seismograph recorded only 19. Thus, the number of earthquakes recorded at Kilauea was somewhat greater than the average, and earthquake activity centered at Kilauea rather than at Mauna Loa. However, most of the Kilauea earthquakes had very shallow origins and probably were related to shallow-seated readjustments rather than to deep volcanic forces. A strong earthquake at 01 :58 on the morning of January 26 originated on the group of faults near Hilina Pali, about 3 miles east of Puu Kapukapu. Slight aftershocks at 02 :52 on the same morning and 00 :07 on January 27 originated at the same locality. At 06 :26 on January 23 an earthquake, felt in the northern portion of the island, originated beneath Waimea Plain about 5 miles east-southeast of Kamuela.

Southward tilting of the ground at the northeast rim of Kilauea crater was at a rate approximately normal for this season of the year. Reversal from eastward to westward tilting took place about January 23, approximately a month later than the average, suggesting some accumulation of volcanic pressure beneath Mauna Loa during early January.

February

Earthquake activity was moderately abundant at Hawaiian volcanoes during the month of February. A total of 55 earthquakes was recorded on the seismographs of the Hawaiian Volcano Observatory. Of these, 54 were recorded at Kilauea crater and 39 at the Mauna Loa seismograph station. Thus, the earthquake activity centered at Kilauea, whereas Mauna Loa was relatively quiescent. Most of the Kilauea earthquakes originated on the east rift zone, between Makaopuhi Crater and a point 10 miles farther east. Several others originated close to Kilauea crater. All were of shallow origin.

An earthquake at 01 :16 on February 2 was felt generally in Hilo and by some persons in nearly all parts of the island. It originated at a depth of about 30 miles, nearly under Kaumana. A smaller earthquake at 20 :30 on February 1, felt by many persons in Kona, originated in central Kona, probably on the Kealakekua fault near the north edge of Kealakekua Bay. Other earthquakes on February 13 and 14 had their origin in the same general area. A quake felt at Kapapala at 22 :40 on February 23 had its epicenter on the southwest rift of Mauna Loa, near 8,500 feet elevation.

Slight westward and moderate southward tilting of the ground continued throughout the month at the seismograph station beneath the Volcano House, at the northeast edge of Kilauea crater. Both are normal for this season of the year.

Early in February a large rock slide occurred on the southwest wall of Halemaumau crater, south of the visitors' lookout point. The scar left by the slide was first observed on the morning of February 9, but the slide is believed to have taken place during or immediately following a strong earthquake at 21 :55 on February 7. Halemaumau was not visible from the Volcano Observatory on February 8 because of rain clouds filling Kilauea crater. The slide removed a layer of rock about 500 feet wide and 450 feet high from the upper part of the crater wall. It was followed by many smaller slides, the largest of which occurred near noon on February 21. Altogether, the slides deposited more than 2 million cubic feet of broken rock on the floor of Halemaumau and caused the rim of the crater to move back as much as 10 feet.

March

The outstanding event of the month of March was the beginning of the great swarm of earthquakes, originating off the south shore of the island, that is described on foregoing pages. East-west tilting at the Whitney Laboratory during March was irregular, and there was practically no accumulation of tilt in either direction. North-south tilting also was irregular, but there was an accumulation of 0.8 second of southward tilt during the month. This southward tilting was normal for that season of the year, but the rate was somewhat less than usual.

Small rock slides continued on the southeast wall of Halemaumau crater. The north end of the crack that crosses the tourist observation area opened 8 mm. during the month.

TELESEISMS

The following earthquakes of distant origin were recorded on the seismographs of the Hawaiian Volcano Observatory. Locations of the epicenters are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey. The time given is that of the first detectable emergence of the quake on the Bosch-Omori or Sprengnether vertical seismograms, in Hawaiian Standard time.

January 12, 10 : 28, slight. Fox Islands, in Aleutian Archipelago.
March 3, 15 : 33, strong. Near the east coast of Hokkaido Island, Japan.
March 5, 06 : 08, slight. Off east coast of Hokkaido.
March 9, 06 : 58, slight. Near south coast of Kamchatka.

Earthquake Data, January–March, 1952

(Based on Bosch-Omori seismograph on northeast rim of Kilauea Caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
Dec. 30	9	1	0	0	0	0	2.75	1
Jan. 6	4	4	0	0	0	0	3.00	1
13	1	2	0	0	0	0	1.25	0
20	14	13	1	1	0	1	17.00	0
27	9	5	0	1	1	0	9.75	0
Feb. 3	6	4	2	1	0	1	11.50	0
10	7	1	0	0	0	0	2.25	0
17	3	6	0	1	0	0	5.75	0
24	7	7	0	0	0	0	5.25	0
Mar. 2	10	1	1	0	0	0	4.00	2
9	13	15	1	1	0	2	21.75	1
16	1,155	487	112	79	9	8	859.25	0
23	909	313	66	90	10	3	671.75	0
30	417	245	39	39	4	2	361.75	0

* For definition of local seismicity, see Volcano Letters 371 and 512.

Table of Tilt at Seismograph Vaults on Rim of Kilauea Caldera

Week Beginning		Whitney Vault (Northeast rim)		Uwekahuna Vault (West rim)	
		Amount	Direction	Amount	Direction
December	30	1.0″	N 30° E	4.2″	N 13° W
January	6	0.4″	S 18° E	3.2″	S 6° E
	13	1.2″	S 11° W	2.2″	N 8° E
	20	1.7″	S 45° E	6.9″	N 14° W
	27	1.2″	S 37° W	1.0″	N 72° W
February	3	0.6″	W	4.2″	S 13° E
	10	1.1″	S 12° W	0.0″	.....
	17	0.5″	N 27° E	3.5″	S 5° E
	24	0.5″	S	1.4″	S 27° E
March	2	1.1″	N 7° W	1.3″	S 14° W
	9	1.0″	N 70° E	2.9″	N 6° W
	16	2.8″	S 31° W	4.2″	N 9° W
	23	0.7″	N 80° E	1.0″	S 19° W
	30	0.7″	N 45° W	2.1″	S 27° E

TEMPERATURE MEASUREMENTS

On March 20 the Territorial Highway Department installed a recording thermometer on the Ohia Lodge flow of the 1950 eruption of Mauna Loa. The thermal element is placed in a hot crack at a site just inland from the position of the old highway that was buried by the flow. The flow is approximately 50 feet thick at that point.

K. B. Hirashima, testing engineer for the Territorial Highway Department, states that a temporary installation with the thermal element at a depth of 18 inches yielded a temperature reading of 860°F. The permanent installation at a depth of 3 feet indicated a temperature of 960°. It is planned to keep a record of the rate of temperature drop over the next several years. The temperature recorded is much higher than at comparable depths over most of the flow, as has been demonstrated in cuts several feet deep excavated along the course of the new highway which crosses the flow. The high temperature at the thermometer installation is caused by gases rising from the lower part of the thick flow.

The data for the following local disturbances were determined from seismographs operated on the island of Hawaii by the Hawaiian Volcano Observatory. Locations given are epicenters. The times are arrival times at the Whitney Laboratory of Seismology, on the northeast rim of Kilauea Caldera. They are given to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich Civil time. The number preceding each earthquake is the serial number for the current year. The intensity rating (Feeble, Moderate, etc.) given is that for the Whitney Laboratory. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney station.

1. Jan. 2, 06:47, very feeble.
2. Jan. 8, 05:40, no record at Kilauea (Kona very feeble).
3. Jan. 10, 00:22, very feeble.
4. Jan. 11, 02:33, very feeble.
5. Jan. 12, 04:23, very feeble.
6. Jan. 12, 20:54, very feeble. Kilauea Caldera.
7. Jan. 15, 05:13, very feeble.
8. Jan. 17, 07:36, very feeble.
9. Jan. 23, 00:54, very feeble.
10. Jan. 23, 04:10, very feeble. Kilauea Caldera, shallow.
11. Jan. 23, 06:27, very feeble, felt at Kukuihaele. Waimea Plain, about 5 miles east-southeast of Kamuela.
12. Jan. 23, 07:54, feeble. Near Kilauea Iki.
13. Jan. 23, 11:13, very feeble. Kilauea.
14. Jan. 23, 11:54, very feeble.
15. Jan. 24, 07:03, very feeble. Kilauea.
16. Jan. 24, 07:14, very feeble.
17. Jan. 24, 13:26, very feeble. Kilauea Caldera.
18. Jan. 24, 18:24, very feeble. Kilauea Caldera.
19. Jan. 25, 03:04, very feeble. Kilauea Caldera.
20. Jan. 25, 03:06, very feeble.
21. Jan. 25, 16:53, no record at Kilauea (Kona feeble). Central Kona.
22. Jan. 25, 19:44, very feeble. Kilauea Caldera.
23. Jan. 25, 20:55, no record at Kilauea (Kona very feeble). Central Kona.
24. Jan. 26, 01:58, strong. Hilina fault system, about 3 miles east of Puu Kapukapu.
25. Jan. 26, 02:52, slight. Same as No. 24.
26. Jan. 27, 00:07, slight. Hilina fault system.
27. Jan. 27, 18:52, tremor (Kona feeble). Central Kona.
28. Jan. 27, 18:59, very feeble (Kona slight). Central Kona.
29. Feb. 1, 20:30, very feeble (Kona feeble), felt at Captain Cook. Central Kona.
30. Feb. 2, 01:16, moderate, felt over most of the island, strongly at Hilo. Nearly under Kaumana, about 30 miles deep.
31. Feb. 2, 03:46, very feeble.
32. Feb. 2, 05:58, tremor, felt in Kukuihaele.
33. Feb. 2, 06:19, very feeble.
34. Feb. 2, 13:05, very feeble.
35. Feb. 6, 06:20, very feeble.
36. Feb. 6, 18:42, feeble. East rift of Kilauea near Makaopuhi.
37. Feb. 6, 20:52, very feeble.
38. Feb. 6, 22:10, very feeble.
39. Feb. 7, 04:27, slight. East rift of Kilauea near Makaopuhi, shallow.
40. Feb. 7, 21:22, very feeble.
41. Feb. 7, 21:23, feeble. East rift of Kilauea.
42. Feb. 7, 21:55, strong. East rift zone of Kilauea, 1 mile east of Napau Crater, shallow.
43. Feb. 8, 02:02, tremor (Kona very feeble).
44. Feb. 13, 20:36, very feeble (Kona moderate). Central Kona, probably on Kealakekua fault.
45. Feb. 14, 15:46, tremor (Kona slight). Central Kona.
46. Feb. 14, 15:50, tremor (Kona slight). Central Kona.
47. Feb. 15, 14:47, tremor (Kona very feeble).
48. Feb. 15, 23:04, tremor (Kona very feeble). Central Kona.
49. Feb. 19, 11:20, very feeble, felt at Kapapala. Southeast slope of Mauna Loa near Kapapala.
50. Feb. 19, 19:26, very feeble.
51. Feb. 21, 06:15, slight, felt from Volcano district to Pepeekeo. East rift of Kilauea about 2 miles east of Napau crater, shallow.
52. Feb. 22, 17:10, very feeble. Kilauea.
53. Feb. 22, 21:34, very feeble.
54. Feb. 23, 01:47, very feeble. Kilauea.
55. Feb. 23, 22:41, very feeble, felt at Kapapala. Southwest rift of Mauna Loa at about 8,500 feet altitude.
56. Feb. 24, 10:20, very feeble (Mauna Loa feeble). North slope of Mauna Loa, about 11 miles north of Mokuaweoweo.
57. Feb. 24, 11:22, very feeble. Kilauea Caldera.
58. Feb. 24, 11:47, very feeble.
59. Feb. 24, 11:54, very feeble.
60. Feb. 25, 08:28, very feeble.
61. Feb. 26, 12:36, very feeble.
62. Mar. 1, 11:59, very feeble. Kilauea Caldera.
63. Mar. 2, 14:36, very feeble. Kilauea Caldera.
64. Mar. 6, 20:44, feeble, felt at Hilo and in Volcano district. Hilina fault system, about 2 miles northwest of Ka Lae a Puki.
65. Mar. 9, 05:59, very feeble.
66. Mar. 9, 07:51, very feeble.
67. Mar. 9, 10:51, very feeble.
68. Mar. 9, 13:57, slight. Hilina fault system, about 2.5 miles northwest of Kaena Point.
69. Mar. 9, 14:01, very feeble.
70. Mar. 10, 13:45, very feeble.
71. Mar. 11, 10:10, very feeble.
72. Mar. 12, 03:37, very feeble.
73. Mar. 12, 16:28, very feeble.
74. Mar. 12, 16:54, feeble (Kona slight). Central Kona.
75. Mar. 12, 17:07, very feeble.
76. Mar. 12, 17:11, very feeble.
77. Mar. 12, 22:17, very feeble.
78. Mar. 13, 11:38, strong, felt from Volcano district to Naalehu. Off south shore, at 19°02.4′N, 155° 06.2′W.
79. Mar. 14, 17:45, very feeble. Kilauea.
80. Mar. 14, 18:21, strong, felt from Hilo to Kapapala. Off south shore, at 19°02.8′N, 155°04.8′W.

81. Mar. 14, 19:06, very feeble.
82. Mar. 14, 19:09, very feeble.
83. Mar. 15, 22:16, very feeble. Kilauea Caldera.
84-1427. Mar. 16-31, Earthquakes originating mostly off the south shore of the island, and mostly very feeble to slight. Moderate and strong earthquakes of this group and earthquakes of other origin are listed separately below.
88. Mar. 16, 15:53, feeble, felt in Volcano district. Kilauea Caldera, shallow.
95. Mar. 16, 22:45, very feeble. Hilina fault system, 2 miles west of Kupaahu, at 19°19.7'N, 155°02.0'W.
148. Mar. 17, 17:58, strong, felt at Naalehu, caused small tsunami at Kalapana. Off south shore, at 19°07.5'N, 155°02.0'W.
167. Mar. 18, 04:50, very feeble. Kilauea.
183. Mar. 18, 08:03, very feeble. Kilauea Caldera.
199. Mar. 18, 10:53, moderate, felt at Naalehu. Off south shore, at 19°00.1'N, 155°19.8'W.
212. Mar. 18, 13:01, moderate. Off south shore at 19°06.1'N, 155°20.5'W.
220. Mar. 18, 14:18, strong. Off south shore, at 19°04.6'N, 155°24.7'W.
275. Mar. 19, 02:55, strong, felt at Naalehu. Off south shore, at 19°06.5'N, 155°01.8'W.
283. Mar. 19, 08:05, very feeble. Kilauea.
340. Mar. 19, 15:51, strong. Off south shore, at 19°02.0'N, 155°20.1'W.
385. Mar. 20, 01:22, strong. Off south shore, at 19°02.3'N, 155°18.5'W.
414. Mar. 20, 09:51, strong, felt at Naalehu. Off south shore, at 19°03.2'N, 155°14.7'W.
466. Mar. 20, 20:16, moderate, felt at Naalehu. Off south shore, at 19°03.5'N, 155°23.7'W.
494. Mar. 20, 23:48, moderate, felt at Naalehu. Off south shore, at 19°02.2'N, 155°23.6'W.
524. Mar. 21, 04:35, strong, felt at Naalehu. Off south shore, at 19°02.7'N, 155°13.9'W.
567. Mar. 21, 14:25, moderate. Off south shore, at 19°04.3'N, 155°14.3'W.
649. Mar. 22, 02:05, strong, felt at Naalehu. Off south shore, at 19°02.5'N, 155°12.1'W.
668. Mar. 22, 06:19, moderate. Off south shore, at 19°07.8'N, 155°00.4'W.
762. Mar. 22, 19:20, moderate, felt at Naalehu. Off south shore, at 19°06.4'N, 155°03.9'W.
808. Mar. 23, 06:52, moderate, felt at Naalehu and Pahala. Off south shore, at 19°11.7'N, 154°55.0'W.
842. Mar. 23, 15:05, moderate, felt at Naalehu and Kapapala. Off south shore, at 19°02.8'N, 155°14.4'W.
894. Mar. 24, 02:02, moderate, felt at Naalehu. Off south shore, at 19°08.0'N, 155°01.7'W.
927. Mar. 24, 13:29, strong, felt at Naalehu. Off south shore, at 19°06.3'N, 155°02.4'W.
954. Mar. 25, 00:30, moderate. Off south shore, at 19°01.3'N, 155°17.0'W.
965. Mar. 25, 07:04, strong, felt at Naalehu. Off south shore, at 19°04.3'N, 155°05.8'W.
979. Mar. 25, 09:17, strong, felt at Naalehu. Off south shore, at 19°05.2'N, 155°05.1'W.
1016. Mar. 26, 04:40, moderate, felt at Naalehu. Off south shore, at 19°03.3'N, 155°13.8'W.
1083. Mar. 27, 04:31, moderate, felt at Naalehu. Off south shore, at 19°03.1'N, 155°12.6'W.
1128. Mar. 27, 22:44, moderate, felt at Naalehu and Pahala. Off south shore, at 19°02.2'N, 155°13.9'W.
1166. Mar. 28, 11:57, moderate, felt at Naalehu. Off south shore, at 19°03.3'N, 155°11.5'W.
1200. Mar. 29, 02:42, moderate, felt at Naalehu. Off south shore.
1317. Mar. 30, 13:53, strong. Off south shore.
1422. Mar. 31, 22:00, strong, felt at Naalehu. Off south shore, at 19°02.2'N, 155°13.4'W.

VOLCANO NOTES AND NEWS

CONDITIONS AT PARÍCUTIN VOLCANO

A letter from Celedonio Gutierrez, the Geological Survey's permanent observer at Parícutin volcano, Mexico, addressed to Ray E. Wilcox of the Geological Survey's volcano investigations unit, tells of unprecedented absence of activity. During January and February there were several explosions stronger than any previously observed during the life of Parícutin. On February 25 eruptive activity ceased and was renewed only by a few weak surges between that time and March 4. From March 4 until the date of the letter, March 29, the volcano remained totally inactive, with not even noises or fume emission. A subsequent letter confirms total inactivity through April 29, 1952. Wilcox states that this is the first complete cessation of activity in the 9 years since the birth of Parícutin.

ALASKAN VOLCANOES

Austin E. Jones, seismologist in charge of the Geological Survey's Aleutian volcano observatory on Adak Island, has supplied the following notes obtained during January from Capt. V. Seidelhuber of a U. S. Navy tanker operating in Aleutian waters.

April 1951—On a moonlit night, glow was reflected high above Shishaldin volcano, the most active vent on Unimak Island.

October 1951—Lower slopes of Akutan showed fresh black ash on top of the snow, but the summit of the volcano was concealed in cloud.

December 20, 1951—A high column of white smoke (steam) rose above the summit of Makushin volcano, Unalaska Island, and the snow on the volcano was gray with ash.

January 17, 1952—A column of grayish-brown fume was rising from the crater on the summit of Gareloi volcano.

TSUNAMI OF MARCH 3, 1952, IN HAWAII

A violent earthquake off the east coast of the Japanese island of Hokkaido, at 01:23 on March 4 (Greenwich Civil time), caused extensive property damage and heavy casualties. It was accompanied by a tsunami ("tidal wave") which contributed greatly to the damage. This wave was recorded on the tide gauge in Honolulu harbor. According to Comdr. C. A. George, Supervisor of the Pacific District, U. S. Coast and Geodetic Survey, the arrival time at Honolulu was 11:15 Greenwich Civil time, or 23:15 on March 3 by Hawaiian Standard time, and the amplitude of the wave was about 6 inches. The wave was recorded at Hilo also, with about the same amplitude. The wave traveled from Japan to Hawaii at an average speed of approximately 450 miles an hour.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director
Chester K. Wentworth, Geologist, part-time
John C. Forbes, Laboratory Mechanic
LaVieve G. Forbes, Secretary, part-time

Seismograph Station Operators:

Hilo Station:

Sister M. Thecla, St. Joseph's School

Kona Station:

Howard M. Tatsuno, Konawaena School

University of Hawaii:

T. A. Jaggar, Geophysicist

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter**, a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

THE VOLCANO LETTER

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HIBOK-HIBOK VOLCANO, PHILIPPINE ISLANDS, AND ITS ACTIVITY SINCE 1948

By ARTURO ALCARAZ, LEOPOLDO F. ABAD, and JOSE C. QUEMA[1]

PART I

INTRODUCTION

Hibok-Hibok is one of several active volcanoes in the Philippines. Since the start of its present activity in September, 1948, it has aroused world-wide interest, not only from the scientific but also from the humanitarian point of view, because of the profound effects of the activity on the inhabitants of Camiguin Island where the volcano is located. About 500 persons died and property damage amounting to several hundred thousand pesos was sustained as a result of the most recent eruptive phase of its activity which occurred on December 4 and 6, 1951. The high loss in human lives ranks the Hibok-Hibok disaster as one of the most appalling natural disasters to have visited the Philippines in the last 40 years, since the eruption of Taal volcano on the island of Luzon in 1911.

GEOGRAPHY

Hibok-Hibok volcano is on the island of Camiguin. The island is roughly pear shaped, with its longer axis trending northwest-southeast, and lies between 9°05′N and 9°16′N, and between 124°38′E and 124°48′E (Fig. 1). Its total area is about 237 square kilometers. Camiguin is barely 10 miles off the north coast of the large island of Mindanao, and politically it is a part of the Province of Oriental Misamis in Mindanao.

At present, access to Camiguin Island is by sea transportation only, as it has no airfield. Small interisland boats call almost daily at Mambajao, which has the best port facilities on the island. However, due to the proximity of the town to Hibok-Hibok volcano, shipping activities are shifting to Binone, a barrio on the east side of Camiguin quite removed from the present dangers arising from the activity of the volcano.

[1] Geophysicist, Weather Bureau; Mining Engineer, Bureau of Mines; and Geologist, Bureau of Mines, respectively. Published by permission of the Committee on Volcanology, Department of Agriculture and Natural Resources, Philippine Islands.

The island is mountainous. Coastal plains are very narrow and in most places absent. However, because of the fertility of the volcanic soil, a large portion of the island is under cultivation. Plantations of coconut and abaca can be seen everywhere, even on the slopes of the volcanoes. The main occupations of the people are farming and fishing.

There is no real dry season in Camiguin in spite of a very pronounced maximum-rainfall period in winter. The average annual rainfall is about 97 inches. From November to April, the prevailing winds are northeasterlies; in May, the easterlies or trade winds; and from June to October, the southwesterlies. Typhoon frequency for the island is less than 7 per cent of the number that affects the Philippines annually.

According to the *Census Atlas of the Philippines* for the year 1948, the population of the island is 69,599, distributed in four municipalities as follows: Mambajao, 25,193; Sagay, 18,061; Catarman, 16,845; and Mahinog, 9,500. A fairly good road runs along the north coast, from the barrio of Naasag northeast-southeastward to Guinsiliban and then northwestward, following the south coast to barrio Bonbon, almost encompassing the island except for about 3 or 4 miles around the base of Mount Vulcan. Extension of the road from Naasag to Bonbon was under construction in 1950. However, because of the activity of Mount Hibok-Hibok, sections of the road from Baylao to Agoho, both barrios of Mambajao, are now covered by volcanic debris brought down by freshets from the slopes of the volcano and, as was the case on December 6, 1951, laid down by an ash flow.

The main topographical features of Camiguin Island are two moderately high volcanic peaks: Mount Mambajao, with an elevation of 5,620 feet, and Mount Catarman, the site of the present activity, with an elevation of 4,370 feet (Fig. 1). There are also numerous smaller peaks, all of volcanic origin. At the northwest

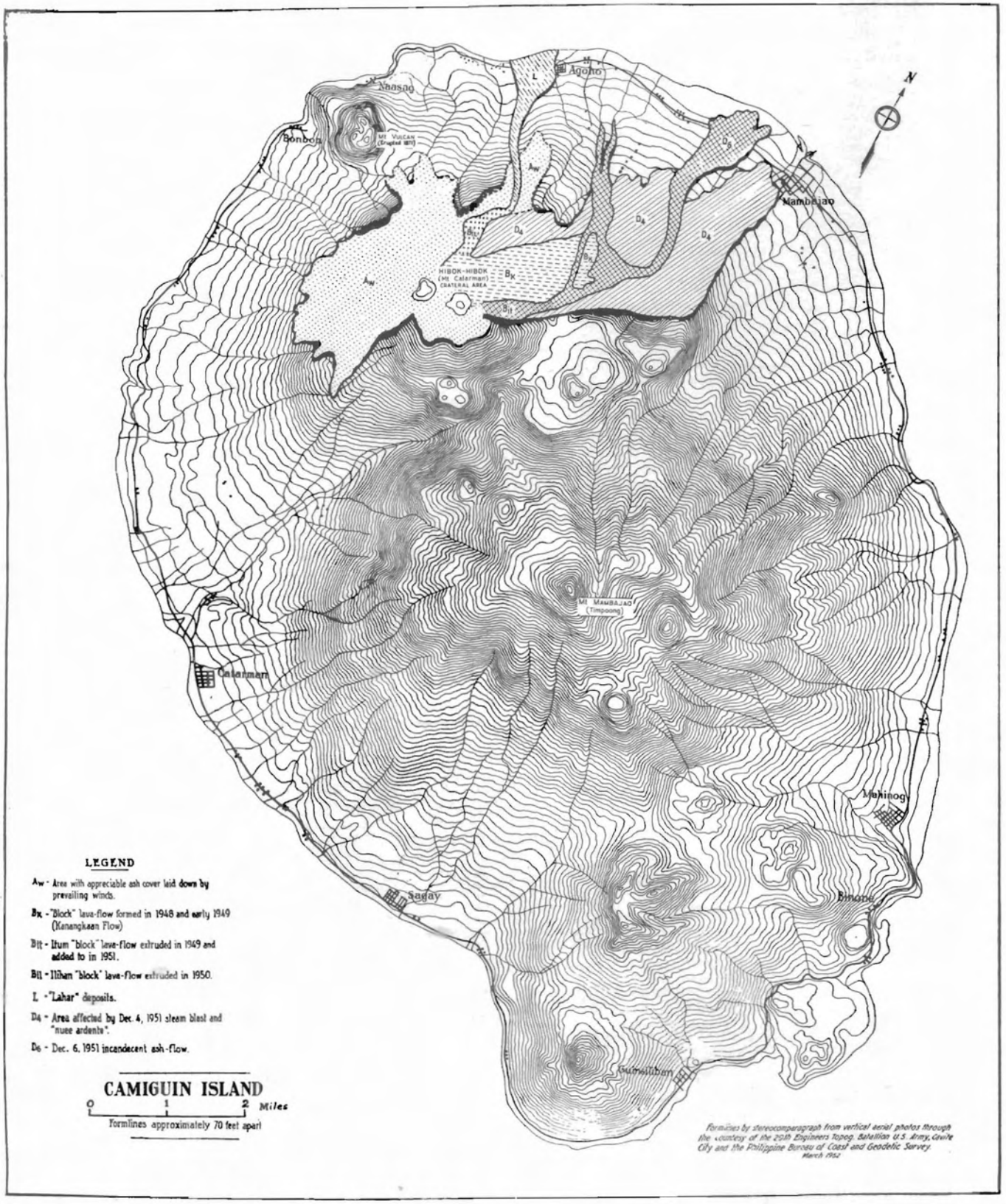

FIGURE 1. Map of Camiguin Island, showing the location of Hibok-Hibok volcano (Mt. Catarman) and the principal deposits of its recent activity.

end of the island, jutting out a little way to sea, is Mount Vulcan, a volcanic cone built up in 1871 at the base of Mount Catarman. Vulcan is about 1,500 feet high.

Hibok-Hibok is a native name given to Mount Catarman. There was really no need of any name for the volcano other than that of Mount Catarman which appears in published maps of the Archipelago, but "Hibok-Hibok" gained wide usage, and the volcano is now known locally and abroad by that name. The approximate geographical co-ordinates of the present active crater area are 9°12′N and 124°40′E.

GEOLOGY

The island of Camiguin is made up entirely of volcanic formations and was apparently built upon a submarine platform which is made evident by lines connecting isobaths at approximately the 200-fathom depth. The platform appears to be a segment or an extension of the Misamis Peninsula, from which the island is separated by 10 miles of water. The area is spotted with numerous submarine elevations, which form rocky shoals and bases of coral islets.

The rock forming the platform is not definitely known. However, there are evidences that it is probably basalt as is now to be found at southeast Camiguin and at the north tip of Misamis Peninsula. Lejay (1938) found strong positive anomalies at the tip of the peninsula and offered the explanation that the heavy materials, the presence of which is revealed by samples at the surface, must probably be in great quantity in the root. In Camiguin, however, the areal extent of the basaltic formations is limited to a sixth part of the island and can be found only in the southeastern section.

West of the basalt area from the Sagay-Mahinog line of contact are younger extrusives and most recent volcanics. They are mostly andesitic agglomerates, lava sheets, and pyroclastics and constitute the formations which built up in sequence the stratovolcanic peaks of Mambajao, Catarman, and Vulcan. The latest extrusives from Vulcan in 1871 and Hibok-Hibok in 1948 were grayish, dense to partly vesicular porphyritic andesites with numerous feldspar and ferromagnesian phenocrysts. The extrusives must have come out in a state approaching that of solids, as there is practically no evidence of any rapid cooling.

Only one hot spring is known to exist on the island. It is located at the foot of Mount Vulcan, about 1½ miles southwest of barrio Naasag. This spring is at mean sea level and thus approachable only during low tide. The water has a temperature below boiling point and comes welling out in very small quantities on the rocky beach. The water is not hard. At two places close to Mount Catarman can be found mineral springs issuing at ordinary temperature. The water tastes like the well-known Vichy mineral water of France.

PAST VOLCANIC ACTIVITY IN CAMIGUIN

The island of Camiguin bears plenty of evidences that in the past it must have been one of the more active volcanic centers of the Archipelago. Mounts Catarman and Mambajao and numerous smaller cones were built, no doubt, by past eruptions. There is no clear mention in records at hand, however, of any previous volcanic activities other than the eruption of 1871, which produced Vulcan, and the appearance of solfataras in 1897 and 1902 in the same area as the present activity. In fact, until the present activity, it was thought that Mount Catarman (Hibok-Hibok) was dormant.

The Camiguin Eruption of 1871. In January, 1871, earthquakes were felt on the north end of Camiguin Island. The number frequency and intensity of the shocks gradually increased by February, and rumbling subterranean sounds were heard to accompany the tremors. Landslides and fissuring also occurred with the earthquakes, destroying trees and plantations. On April 30, after the shocks suddenly ceased, an explosion occurred. From a spot close to the sea and north of the old town of Catarman (now known as barrio Bonbon) on the west-northwest foot of Mount Catarman, a tremendous explosion was heard, and, at the same time, a shower of stones, earth, and ashes was ejected from the recently made openings. Destruction was complete within a radius of 2 miles from the new crater. The eruption continued for about a week, after which it declined into a relatively quiet eruptive state. A volcanic cone, which was later called Camiguin volcano or Vulcan, began to form.

The activity continued for about 4 years, after which time the cone reached a height of approximately 1,500 feet, with a base nearly 1 mile in diameter. Grabau (1921) listed this eruption as one of the few occasions in historic times on which the growth and development of a volcano has been witnessed by man. It was Parícutin 72 years ahead in the Philippines.

After the eruption, the town of Catarman was rebuilt on its present site (formerly barrio Guiob), some 8 miles southeast of the old site. Vulcan is quiescent at present, with the cone partly eroded. It does not seem to be affected at all by the activity of the adjacent Hibok-Hibok. In the past decade or so, Vulcan's activity apparently has been limited to emission of an insignificant amount of steam from crevices in the crater area and visible from a distance on cold, clear mornings only.

Solfataras of 1897 and 1902. In 1897, in about the same area as the present activity of Hibok-Hibok, there issued white sulphurous vapors that caused destruction to the agricultural lands on the northeast and southwest slopes of Mount Catarman. According to the account of this activity by Reverend Saderra Maso, S.J. (1903), the solfataric activity continued up to 1902. On July 9 of that year, hollow sounds were heard coming from the mountain although there was no apparent change in the appearance of the volcano. During the night of July 27 there was a thunderstorm around Mount Catarman, and the people were surprised the following morning to note that a new solfataric vent had formed opposite the crest which separated it from the old one. The activity of the new vent lasted 8 to 10 days, during which frequent subterranean sounds were heard.

Published accounts of these solfataric activities have made no mention of associated earth tremors. However, because of recent information gathered from two old residents of Camiguin who witnessed the events in 1897 and 1902, it is now believed likely that there were local tremors associated with the activities.

PRESENT ACTIVITY

The present activity of Mount Catarman, now popularly known as Hibok-Hibok (= quivering, in dialect) volcano, may be said to have begun during the last week of August, 1948, when the vicinity of the volcano started experiencing a series of earth tremors especially perceptible at the barrios on the northeast slopes. With the local tremors, there occurred frequent slides of the soil mantle on the volcano's slopes facing the town of Mambajao. The landslides and earthquakes increased in frequency, and, on the afternoon of September 1, there occurred the first crateral outburst from the general area of the sulphur pits (most probably the vents of the 1897–1902 solfataric action of Mount Catarman). Since then, Hibok-Hibok has been in more or less continual activity punctuated by eruptive phases.

In over 3 years of activity, a certain cycle of behavior of Mount Hibok-Hibok is discernible, the cycle being (1) a short period of emission of a considerable amount of smoke from the crater and slides of volcanic materials, with or without accompanying tremors; (2) explosions, or steam blasts, concomitant with the emission of heavy clouds of steam, ashes, and other fragmentary volcanic materials, with a strong possibility of the development of "nuées ardentes d'explosion vulcanienne" (Lacroix, 1930); (3) disgorging of incandescent materials, emission of ash and smoke in large amounts, formation of agglomeratic flows, and occasional minor crateral outbursts; (4) decrease in amount of smoke and other ejecta from the crater (possibly due to engulfment of the lava column). From phase 4 the activity again goes back to phase 1, the whole cycle being completed in a period of from 9 to 14 months.

The above cycle seems to have been the pattern of behavior of Hibok-Hibok in the past 3 years, with each cycle apparently culminating in a steam blast, or blasts, of varying intensity. The period covered by each phase varies, whereas the phase itself may either be accentuated or subdued in a particular cycle. Dates of eruptions of the volcano can really be regarded as times when the cycle was at phase 2, such as September, 1948; June, 1949; September, 1950; and December, 1951.

Seismic Activity. There was no seismograph on Camiguin Island at the start of the present activity of Mount Hibok-Hibok, so the tremors that preceded the initial blast of September 1 were unrecorded. However, the tremors were of perceptible intensities and were felt by the people living close to the volcano. The distribution in time and intensity of these tremors, judging from information gathered on Camiguin Island, was one of progressively shorter intervals and increasing intensity up to the time of the initial blast, when they practically ceased, although a few weak tremors were felt in the vicinity of the volcano after September 1.

A low-magnification seismograph was installed at Mambajao in February, 1951. No unusual local seismic activity has been recorded by the instrument, however, except for occasional single tremors of volcanic origin. The absence of any swarm of tremors, macroseismic or microseismic, before the eruptive phase of later cycles is noteworthy. The December 4, 1951, steam blast, for example, was without any apparent attendant seismic activity. Why that was so is a matter for conjecture. Perhaps the seismic disturbances that may have resulted from lava surges beneath the volcano were, or are, of such small magnitude as to be undetectable by a low-magnification instrument such as had been installed at Mambajao. Nevertheless, it seems logical to expect that, toward the time of release of any large confined pressure such as must exist in the magma chamber before a steam blast, there should be tremors that are strong enough to be perceptible even without instruments.

Could it be that what Fenner (1950) wrote about the Katmai eruption finds application to paroxysmal activities of Mount Hibok-Hibok? In discussing the possibilities of exothermic reactions in magmas and the large quantities of heat that may be developed, he said that ". . . in the Katmai eruption the explosions occurred after the magma rose to the surface and was lying in an open crater, and that during this period a great amount of heat was evolved and large quantities of cold rock from the crater walls were engulfed by the magma and reacted with it. The later explosions developed in the synthetic magma so produced." If the explosions manifested by Hibok-Hibok were precipitated by exothermic reactions that took place while the magma was close to the surface, then it is not hard to see why there was no detectable seismic activity associated with those explosions. That the magma was near or in the open crater just before Hibok-Hibok explosions or steam blasts seems to be supported by the observed characteristics of phase 1, the phase preceding paroxysmal activity of the volcano.

Steam Blasts. The explosive crateral outbursts of Mount Hibok-Hibok may be termed steam blasts. There is evidence that a blast, or a series of blasts, of great violence are a characteristic feature of the present activity of the volcano.

The first steam blast happened at five o'clock in the afternoon of September 1, 1948. From eye-witness accounts, it was gathered that something (presumably a dull, explosive sound) drew people's attention to Hibok-Hibok, and they were appalled to see a dense black cloud enveloping the mountain. Its development was rapid, and within a minute or two the town of Mambajao, about 4½ miles distant, was engulfed in darkness. Pisolitic ash began to fall on the town, throwing the people into consternation. The eruption cloud dissipated in about ½ hour. The following day, September 2, there were two similar outbursts, but they were not as strong as that of the day before.

Those who saw the eruption cloud from afar were in agreement in that it was a cauliflower- or mushroom-shaped cloud that shot out from Hibok-Hibok. The destruction caused by this blast and by others later was localized in the northeast sector of the volcano, probably because of the fact that the Hibok-Hibok crater is not located at the crest of Mount Catarman but at a slightly lower elevation on its northeast flank.

The possibility of a fissure eruption of the nature suggested by Jaggar (1949) for Mount Pelée may be discounted on the basis of field evidences. Coconut trees and other vegetation were blown down or scarred, and the trees that were left standing quite close to the source



FIGURE 2. Steam blast of July 3, 1951, with its accompanying glowing cloud (nuée ardente d'explosion vulcanienne).

of the blast were flayed. Subsequent examination of the devastated area revealed rock fragments and, in one instance, a piece of stick embedded in a coconut trunk. The trees were felled with a definite directional pattern, all pointing away from the crater except for slight modifications due to topography. The area destroyed by the blast of September 1 was roughly 8 square kilometers. About 70 per cent was arable and cultivated for coconuts, hemp, and food crops. Because of the precursory tremors and landslides, occurrences entirely new to most of the island's inhabitants, people living close to the volcano left before the violent outburst, and thus there were practically no casualties. Two persons, caught at the fringe of the affected area, suffered second- and third-degree burns but survived.

In later months, other steam blasts of much lesser intensity occurred, but there were none with important consequences until 9 months later, when the cycle mentioned earlier repeated itself. In June, 1949, 9 months after the initial outburst, Hibok-Hibok again produced a number of steam-blast eruptions. They were of relatively weak intensity, however, and produced no profound effects in the vicinity of the crater. The direction of localized lateral effect of these blasts was almost due east, or about 30 degrees south of the 1948 direction. The shift may have been due to the earlier formation of an enormous black lava flow (Kanangkaan Flow) along the latter direction which may have strengthened that portion of the crater that fed the flow and produced a change of configuration at the crater that directed the new blasts in a more easterly direction.

The steam blasts corresponding to the 1950 cycle occurred in September. These blasts produced effects similar to those of 1948. There were the same directional arrangement of felled trees, the searing of vegetation, and the deposition of an appreciable ash layer inside the affected area. As in 1949, there was again a shifting of the direction of localized destruction. The devastated area was a section north of the crater, or a shift of about 45 degrees to the north of the 1948 direction. The shift was a logical one since it was the direction of easiest relief after the other portions of the Hibok-Hibok crater, away from the crest of Mount Catarman, had been bolstered by extrusions.

Up to the time of the 1950 steam blasts, the temperatures involved must have been quite low, at least not much above that which could cause the ignition of dry inflammable materials. The unfortunate victims claimed by the steam blast of September 15, 1950, died of extensive burns or asphyxiation, but their clothing did not catch fire nor did the nipa and bamboo houses within the devastated area.

The steam blasts of the 1951 cycle exceeded those of former cycles in intensity and destructiveness. Without attendant tremors or unusual crateral activity, the steam blast that caused more extensive property damage and exacted a toll of about 500 lives came during the morning of December 4, 1951 (Fig. 3). The temperature involved was much higher than in previous blasts. Trees were blown down and charred on their exposed sides, houses enveloped in the eruption cloud burst into flames, persons caught were mummified, and the thick ash layer laid down was unbearably hot below its surface even a few days later. An idea of the force of the blast may be obtained from the fact that a coconut tree 10 inches in diameter was wrapped U-shaped around a mango tree 18 inches in diameter, about 3 miles from the crater. A hill on the direct line of the blast was swept bare of vegetation and covered by a thick layer of ash, and coconut trees were blown away and piled up like match sticks at the leeward side of the hill. Furthermore, the alignment of the felled trees, the apparent ineffectiveness of topography to localize effects, and the impact pits of airborne boulders found miles away from the crater all attest to the fact that there was an explosion of considerable magnitude. The eruption cloud was visible for

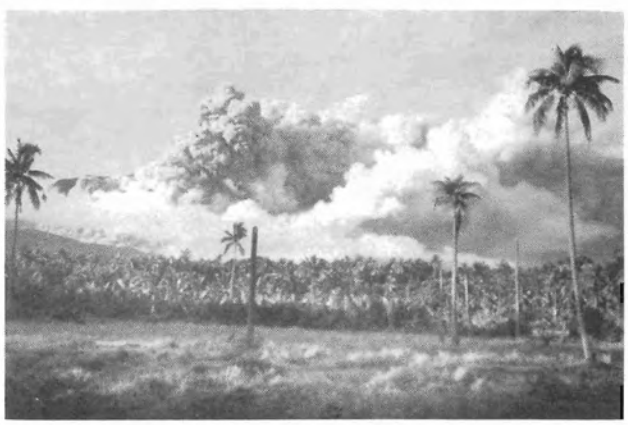

FIGURE 3. Steam blast of December 4, 1951, looking toward the southwestern outskirts of Mambajao. Photo by Hibok-Hibok Studio.

about 100 miles and, according to eye-witnesses, was remarkably like the explosion cloud of atomic bombs.

(To be continued in Volcano Letter 517)

REFERENCES

FENNER, C. N., THE CHEMICAL KINETICS OF THE KATMAI ERUPTION. Amer. Jour. Sci. 248: 593–627, 697–725. 1950.

GRABAU, A. W., TEXTBOOK OF GEOLOGY, PART 1. New York, 864 pp. 1921.

JAGGAR, T. A., STEAM BLAST VOLCANIC ERUPTIONS. Hawaiian Volcano Observatory, Fourth Special Report. Honolulu, 137 pp. 1949.

LACROIX, A., REMARQUES SUR LES MATÉRIAUX DE PROJECTION DES VOLCANS ET SUR LA GENÈSE DES ROCHES PYROCLASTIQUES QU'ILS CONSTITUENT. Soc. Géol. de France, Livre Jubilaire 1830–1930 (2): 431–472. 1930.

LEJAY, P., S. J., THE GENERAL CHARACTERISTICS OF GRAVITY IN THE PHILIPPINES. Philippine Univ. Nat. and Appl. Sci. Bul. 6 (4): 223–290. 1938.

MASO, M. SADERRA, S. J., VOLCANOES AND SEISMIC CENTERS OF THE PHILIPPINE ARCHIPELAGO. Census of the Philippine Islands, pp. 184–254. 1903.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR APRIL–JUNE, 1952

By GORDON A. MACDONALD

VOLCANOLOGY

April

The big swarm of earthquakes that started in mid-March came essentially to an end about April 20. During the period from March 13 to April 30 seismographs of the Hawaiian Volcano Observatory recorded 4,553 earthquakes. Most of them were caused by movement along a line lying south of the southeast shore of the island of Hawaii, from approximately 15 miles south of Kalapana to 11 miles southeast of Punaluu. (See Volcano Letter 515.)

Early in April a series of earthquakes commenced on the east rift of Kilauea volcano, from the caldera to a point about 8 miles southwest of Pahoa. This activity was accompanied by northward tilting of the ground at the northeast edge of the caldera, indicating a small increase of pressure beneath Kilauea. At the close of the month the uneasiness of Kilauea volcano appears to have subsided, although occasional earthquakes were still occurring both on Kilauea and off the south shore of the island.

Mauna Loa remained quiet throughout April.

May

Seismographs operated by the Hawaiian Volcano Observatory at Kilauea Caldera recorded 157 local earthquakes during May. This was a great decrease in number as compared to the 3,366 quakes recorded in March and 928 recorded in April, but it was still nearly five times the number recorded during a normal month without volcanic activity.

A few earthquakes continued to originate in the region south of the island of Hawaii, from which came a large majority of the quakes during March and April. Many small earthquakes originated at shallow depths in the vicinity of Kilauea Caldera and along the east rift zone of Kilauea near the caldera. Others, including one felt strongly at Kapapala and Naalehu on May 21, originated on the Kaoiki fault, which lies along the lower slope of Mauna Loa between Kilauea Caldera and Pahala.

Several small- to moderate-sized earthquakes originated approximately along the line connecting the summit of Mauna Loa with the submarine volcanic mountain 10 miles south of Puu Kapukapu, near the south shore of the island. That line coincides with a minor rift zone of Mauna Loa that erupted in prehistoric times but has had no historic eruptions.

The strong earthquake at 12:12 on May 23 originated on the Kealakekua fault near Napoopoo, apparently close to the place of origin of the big quake of August 21, 1951. (See Volcano Letter 513.) It was felt all over the island of Hawaii and by some persons on the island of Maui. Damage in the central Kona area included dishes, groceries, and bottles of liquor knocked from shelves, cracks in pavements, slides from roadcuts, some water tanks damaged, some windows broken, and tombstones overturned. The intensity near the epicenter was 6 in the modified Mercalli scale. The breaking of dishes extended as far as Naalehu, where the intensity was 5.

During May there was a small accumulation of northeastward ground tilting at the Whitney Laboratory of Seismology, at the northeast edge of Kilauea Caldera. The reversal from southwestward to northeastward tilting, which occurs every year in the late spring, was somewhat earlier than usual. This probably resulted from a small increase of volcanic pressure beneath Kilauea and possibly also beneath Mauna Loa.

At the end of May both volcanoes were uneasy, but as yet there was no recognized indication of eruption coming in the near future.

June

Kilauea volcano became active shortly before midnight on June 27. During the early part of June, earthquakes had been considerably more numerous than in normal, quiet times, although much less numerous than during March and early April. Many of the earthquakes originated in Kilauea volcano, but others originated in Mauna Loa and along the Kaoiki fault, and a few continued to come from the zone off the south shore of the island. The Kilauea earthquakes all were of shallow origin. Ground tilting at the northeast rim of Kilauea Caldera was weakly northward from mid-May to mid-June, at about the rate normal for that season of the year. At Uwekahuna, on the west rim of the caldera, there was weak northwestward tilting. There was an accumulation of 1.4 seconds of northward tilting at the northeast rim of the caldera between June 21 and 27. Although fairly rapid, that tilting was not greater either in amount or in rate than several similar spasms of tilting during the past several years. For the past 2 months Kilauea had been recognized to be uneasy, but during mid-June there was no indication that it was more uneasy than it had been for some time, or that it was more uneasy than Mauna Loa. No pattern of earthquake foci commencing at a depth of 20 miles or more and gradually approaching the surface, such as has been observed preceding other eruptions, was recognized, nor was there any abnormal amount of tilting. Beyond a general uneasiness of the volcano, the eruption came unheralded.

The eruption began at approximately 23:39 on June 27, with a rush of gas from a newly opened fissure extending in a northeast-southwest direction entirely across the floor of Halemaumau crater. During the first few hours, the lava fountains formed a continuous "curtain of fire" 2,700 feet long, along the opened fissure. The largest fountain was at the southwest end of the chain. At 23:50 the top of this fountain was visible above the rim of Halemaumau from the Volcano Observatory at Uwekahuna. It must then have been more than 700 feet high. Clouds of choking sulphur dioxide fume and a dense fall of pumice covered the southern portion of Kilauea Caldera.

About eight million cubic yards of lava were released during the first 6 hours of the eruption. By daylight on June 28 the new lava fill in Halemaumau was about 50 feet deep, and all signs of former features on the crater floor, including the remnants of the cones of the 1931 and 1934 eruptions, were deeply buried. After that the rate of lava extrusion greatly decreased, but extrusion continued at a rate approximating one million cubic yards a day through the rest of June and July.

The eruption will be described in detail in a future number of the Volcano Letter.

SEISMOLOGY

Teleseisms

The following earthquakes of distant origin were recorded on the seismographs of the Hawaiian Volcano Observatory. Locations of the epicenters are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey. The time given is that of the first detectable emergence of the quake on the Bosch-Omori horizontal or Sprengnether vertical seismograms, in Hawaiian Standard time.

June 10, 00 : 15, slight. Fiji Islands region.

June 22, 11 : 58, slight. Kurile Islands.

Earthquake Data April–June, 1952

(Based on Bosch-Omori seismograph on northeast rim of Kilauea Caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
April 6	213	92	16	16	6	3	177.25	0
13	78	38	5	7	1	0	60.50	0
20	32	18	2	1	1	0	24.00	0
27	28	16	0	2	1	0	19.00	0
May 4	21	15	1	0	0	1	17.75	0
11	20	10	1	1	0	0	11.00	0
18	25	11	2	2	1	1	24.75	0
25	12	17	2	0	0	0	13.50	0
June 1	17	19	0	2	1	0	20.75	0
8	20	30	1	4	0	0	29.00	1
15	31	36	6	3	1	1	44.75	0
22	1,487	60	4	2	1	0	412.75	1
29	10,080	1	3	0	0	0	2,523.5	0

* For definition of local seismicity, see Volcano Letter 371 or 512.

Local Earthquakes

The data for the following local disturbances were determined from seismographs operated on the island of Hawaii by the Hawaiian Volcano Observatory. Locations given are epicenters. In this and the previous issue of the Volcano Letter, geographical coordinates are given for some earthquakes to a tenth of a minute, but it is not intended to imply that degree of accuracy in the location. The probable error of location for those quakes is 1 to 2 minutes. The times given are arrival times at the Whitney Laboratory of Seismology on the northeast rim of Kilauea Caldera. They are stated to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich Civil time. The number preceding each earthquake is the serial number for the current year. The intensity rating (Feeble, Moderate, etc.) given is that for the Whitney Laboratory. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney station.

1428–1886. April 1–May 31. Earthquakes mostly originating off the south shore of the island and mostly very feeble to slight. Moderate and strong earthquakes of this group and earthquakes of other origin are listed separately below.

1529. April 3, 05 : 09, feeble. Kaoiki fault near Ohaikea.
1531. April 3, 06 : 23, very feeble. Kilauea, east rift.
1532. April 3, 06 : 27, very feeble. Kilauea, east rift.
1547. April 4, 11 : 09, slight. Kilauea, east rift near Napau crater.
1548. April 4, 11 : 19, feeble. Kilauea, east rift near Napau crater.
1554. April 4, 16 : 08, feeble. Kilauea Caldera, shallow.
1555. April 4, 20 : 08, feeble. Hilina fault zone, about 1.8 miles N 10° W of Ka Lae a Puki, shallow.
1569. April 5, 11 : 23, moderate. Kilauea, east rift near Makaopuhi, about 13 miles deep.
1571. April 5, 14 : 16, moderate. Off south shore of Hawaii.
1587. April 5, 21 : 04, moderate. Kilauea, east rift near Napau crater.
1596. April 6, 03 : 44, slight. Kilauea, east rift near Napau crater.
1597. April 6, 04 : 06, feeble. Kilauea, east rift about 1.5 miles west of Kalalua crater.
1612. April 6, 15 : 10, moderate. Off south shore of Hawaii.
1623. April 6, 20 : 53, slight. Kilauea Caldera, shallow.
1631. April 6, 22 : 58, strong. Kilauea Caldera, shallow. Felt generally in Volcano district.
1639. April 7, 01 : 31, feeble. Kilauea Caldera, shallow.
1640. April 7, 01 : 54, feeble. Kilauea, east rift about 1 mile east of Makaopuhi crater.
1645. April 7, 03 : 59, slight. Kilauea Caldera, shallow.
1653. April 7, 06 : 05, moderate. Kilauea, east rift near Puu Huluhulu, shallow.
1656. April 7, 06 : 44, slight. Kilauea Caldera, shallow.
1668. April 7, 12 : 15, very feeble. Kilauea, east rift near Alae crater.
1669. April 7, 12 : 53, strong. Kilauea, east rift near Makaopuhi crater, about 12 miles deep. Felt from Naalehu to Volcano.
1670. April 7, 13 : 00, moderate. Off south shore of Hawaii.
1671. April 7, 23 : 55, moderate. Kilauea, east rift near Alae crater, about 7 miles deep.
1701. April 10, 16 : 56, moderate. Hilina fault zone at Poliokeawe Pali, 3.5 miles N 45° W of Kaena Point. Felt at Naalehu.
1703. April 10, 22 : 52, slight (Mauna Loa, moderate). Deep (20 miles?) beneath the SW rift of Mauna Loa near the 9,200-foot contour. Felt strongly from Naalehu to Volcano, moderately at Hilo, and slightly as far as Paauhau and Kukuihaele.
1705. April 11, 07 : 34, feeble. Kilauea, east rift near Makaopuhi.
1711. April 12, 01 : 29, feeble. Kilauea, east rift about 2 miles east of Napau crater, shallow.
1715. April 12, 05 : 53, strong. Kilauea, east rift, 1 mile NW of Heake crater, about 13 miles deep. Felt at Naalehu and Kapapala.
1716. April 12, 06 : 22, moderate. Off south shore of Hawaii.
1719. April 12, 16 : 55, very feeble. Kilauea, east rift near Puhimau crater.
1721. April 12, 19 : 40, slight. Kilauea, east rift near Puu Huluhulu. Felt in Volcano district.
1726. April 13, 12 : 29, feeble. Kilauea, east rift near Puhimau crater.
1729. April 13, 21 : 04, very feeble. Kilauea, east rift about 2 miles east of Kalalua crater, shallow.
1734. April 14, 08 : 37, slight. Kilauea, east rift about 2 miles east of Kalalua crater, shallow.
1736. April 14, 12 : 25, very feeble. Kilauea, east rift near Kalalua crater.
1737. April 14, 16 : 56, very feeble. Kilauea, east rift near Kalalua crater.
1739. April 15, 07 : 51, feeble. East rift of Mauna Loa, shallow.
1745. April 15, 17 : 56, slight. Kilauea, 2 miles WSW of Puu Ohale, about 6 miles deep.
1746. April 15, 17 : 59, slight. Kilauea, 3 miles WSW of Puu Ohale, about 5 miles deep.
1750. April 16, 00 : 58, feeble. Kilauea, east rift near Makaopuhi crater.
1752. April 16, 07 : 08, moderate. Off south shore of Hawaii.
1780. April 21, 17 : 45, moderate. Off south shore of Hawaii, 16 miles S 10° W of Apua Point.
1813. May 3, 18 : 16, moderate. Off south shore, at 19° 12.5′ N, 155° 20.8′ W.
1816. May 6, 06 : 35, feeble. Off south shore, at 19° 09.2′ N, 155° 19.3′ W. Felt at Kapapala.
1830. May 10, 19 : 14, strong. Kilauea Caldera, about 7 miles deep.
1839. May 13, 22 : 50, slight. Southeast slope of Mauna Loa.
1842. May 15, 04 : 10, feeble. Hilina fault system, at 19° 18.4′ N, 155° 09.7′ W.
1849. May 19, 01 : 16, slight. Off south shore, at 19° 02.7′ N, 155° 07.2′ W.
1851. May 19, 04 : 08, slight. Southeast slope of Mauna Loa, at 19° 20.2′ N, 155° 28.9′ W.
1856. May 21, 17 : 13, moderate. Southeast slope of Mauna Loa, at 19° 18.1′ N, 155° 28.3′ W.

1863. May 23, 12:13, strong. Kealakekua fault, about 3.5 miles west of Napoopoo, central Kona, about 6 miles deep. Coordinates: 19° 29′ N, 155° 59′ W. Magnitude 6 assigned at Pasadena, California. Felt all over the island of Hawaii and on the island of Maui. Minor damage in central Kona.
1866. May 24, 03:32, feeble. Kilauea Caldera, shallow.
1882. May 29, 13:20, feeble. Kilauea Caldera, shallow.
1883. May 31, 05:00, very feeble. Off south shore, at 19° 02.4′ N, 155° 20.7′ W.
1884. May 31, 06:52, feeble. Southeast slope of Mauna Loa, at 19° 19.7′ N, 155° 25.9′ W.
1888. June 1, 01:05, moderate. About 4 miles NNE of Whitney Laboratory.
1895. June 3, 21:12, slight. About 4 miles NNE of Whitney Laboratory, on hypothetical extension of Kaoiki fault. Felt in Volcano district.
1919. June 10, 16:25, slight. Summit of Mauna Loa, shallow. Felt at Kapapala.
1920–1923. June 11, very feeble. Kilauea Caldera, shallow.
1924. June 11, 08:01, slight. Off south shore, at 19° 00.7′ N, 155° 16.3′ W.
1925. June 11, 08:12, feeble. Kilauea Caldera (?).
1931. June 13, 06:57, slight. About 4 miles NE of Whitney Laboratory. Felt in Volcano district.
1939. June 14, 10:44, slight. Kilauea Caldera, shallow. Felt in Volcano district.
1953. June 17, 16:37, very feeble. East slope of Mauna Loa.
1954. June 18, 05:17, slight. Off south shore, at 19° 02.1′ N, 155° 19.8′ W.
1955. June 18, 05:20, feeble. Off south shore.
1957. June 19, 16:03, strong. SW rift of Kilauea about 0.5 mile NE of Mauna Iki, shallow.
1958. June 17, 16:20, slight. SW rift of Kilauea near Ponohohoa.
1959. June 19, 16:27, moderate. Kilauea, SW rift near Kamakaia Hills.
1960–2024. June 19–26. Very feeble quakes, nearly all apparently originating in the vicinity of Kilauea Caldera at very small depths.
2025. June 26, 07:53, very feeble. Near summit of Mauna Loa.
2026. June 26, 17:23, very feeble. Near Kapapala, shallow, probably on Kaoiki fault. Felt strongly at Kapapala.
2027–2047. June 26–27. Very feeble earthquakes, apparently originating in the vicinity of Kilauea Caldera at very small depths. Continuous volcanic tremor started at approximately 23:37:30 on June 27, at about the time glow was first observed at Halemaumau, and appears to mark the beginning of eruption.
2048. June 27, 23:39, very feeble. Kilauea Caldera.
2049. June 27, 23:49, very feeble. Kilauea Caldera.
2050. June 27, 23:51, very feeble. Kilauea Caldera.
2051. June 27, 23:58, slight. Kilauea Caldera.
2052. June 28, 00:20, very feeble.
2053. June 28, 00:31, very feeble.
2054. June 28, 00:47, moderate. Kilauea Caldera.
2055–2063. June 28–30. Very feeble and feeble earthquakes accompanying the eruption of Kilauea volcano.

Table of Tilt at Seismograph Vaults on Rim of Kilauea Caldera

Week Beginning	Whitney Vault (Northeast rim)		Uwekahuna Vault (West rim)	
	Amount	Direction	Amount	Direction
April 6	1.1″	N 12° W	3.9″	S 25° E
13	0.4″	S 18° W	2.3″	S 16° E
20	0.8″	N 71° W	3.0″	S 19° E
27	0.5″	N 45° W	1.7″	N 22° W
May 4	0.4″	S 18° W	2.6″	S 13° E
11	0.6″	S 11° E	5.8″	N 9° W
18	0.7″	N 45° E	0.7″	S 64° W
25	0.4″	N 18° W	2.0″	N 9° W
June 1	0.5″	N 63° W	0.9″	N 45° E
8	0.6″	N 68° E	3.0″	N 19° W
15	1.3″	N 6° E	0.6″	W
22	1.5″	S 66° W	2.9″	N 13° E
29	1.0″	S 14° W	2.4″	S 24° E

VOLCANO NOTES AND NEWS

DIDICAS VOLCANO

During March, 1952, a passing ship reported submarine volcanic activity at Didicas Rocks, about 38 miles north of Cape Engano on northern Luzon in the Philippine Islands. Previous activity during 1856 and 1857 had resulted in the formation of a cone about 700 feet high, but the cone had been almost completely destroyed by wave erosion previous to the current eruption.

The *Manila Bulletin* for June 20, 1952, states that on March 20 the new cone was about 200 feet high. On June 17 observers were flown over the volcano in a U. S. Navy plane. The cone was then about 3,000 by 4,800 feet across and 800 feet high. At the summit of the cone the principal crater was about 0.25 mile in diameter, and a new crater had opened on the southwest flank of the cone. The column of white cloud from the volcano was visible 70 miles away.

The explosive phase of the eruption appeared to be vulcanian in character. Angular rock fragments ejected from the crater fell on the outer slopes of the cone and rolled down them, accompanied by clouds of yellowish dust. Large chunks of black material, apparently solidified lava, were observed to be perched unstably on the crater rim, occasionally falling down the outer slope or back into the crater. Ash from the volcano was falling on Calayan Island, 25 miles to the north, but not in sufficient quantity to cause damage. Photographs suggest that the structure may be a domical protrusion, with craters blasted in it by explosion and its flanks mantled with pyroclastic debris.

ALEUTIAN VOLCANOES

Austin E. Jones, seismologist in charge of the Geological Survey's observatory on Adak Island, has supplied the following notes on the activity of Aleutian volcanoes during 1951.

Gareloi, which was weakly active during 1950, was quieter during 1951. At Kanaga volcano, light wisps of steam were noted on quiet, probably humid days. At Great Sitkin a steam column, 1,000 to 2,000 feet high at times, was reported, but no ash was observed. Korovin volcano was steaming in November, 1951. G. R. MacCarthy reported a large, dense column of mingled dark fume and steam at Cleveland volcano on November 1. The volcano was also reported smoking during December. Lieutenant Sinclair, of the ship TAKL 36, reported running through muddy water for 2 miles 3.7 miles off the island of Bogoslof on September 21. G. R. MacCarthy visited Bogoslof early in November and reported that there were no signs of activity for many years past. An officer of one of the TAKL ships reported that Pogromni volcano was not active on July 2, but that it was smoking on July 5 to 7.

In July, Shishaldin volcano was reported "throwing fire and glowing." In September and probably during early October, glow was seen from ships, but on October 15 A. E. Jones could distinguish no activity from a plane passing 50 miles to the north. On October 15, a column of steam half as high as the cone stood above the crater of Frosty volcano.

Pavlof volcano was reported to be in minor explosive activity during August, 1950, the activity culminating in November and

continuing through the winter. R. D. Jones, of the Fish and Wildlife Service, saw it active on January 15, 1951. On April 1, it was reported in rhythmic explosive activity, but in mid-May R. D. Jones found it quiet and reported it as quiet until late fall. In October, fresh ash was reported on the north slope, and later R. D. Jones reported that on November 13 a sudden small explosion was seen, and it continued active through the rest of the winter.

On August 9, A. E. Jones saw the volcanoes from Pavlof to Douglas, and, although an ash fall near Katmai had been reported a few days before, he could see no signs of activity.

CATALOGUE OF VOLCANOES

Catalogue of the Active Volcanoes of Indonesia, by Dr. M. Neumann van Padang, is Part I of the *Catalogue of the Active Volcanoes of the World, including Solfatara Fields*. Published in 1951 by the International Volcanological Association, part of the cost of printing was borne by a grant-in-aid from UNESCO. It is available from Professor Francesco Signore, General Secretary of the Association, Via Tasso 199, Napoli, Italy, for the price of $5.00 (U. S.).

The project of a catalogue of the active and recently active volcanoes of the earth was initiated at the first meeting of the Association in 1922. Its execution has been long delayed for various reasons, not the least of which is the difficulty of editing in multiple languages. The decade of turmoil accompanying World War II necessitated temporary abandonment of the project. Dr. B. G. Escher, president of the Association for the period 1948–1951, deserves sincere congratulations for having successfully revivified the project so soon after the end of the war.

The volcanoes of the world have been divided geographically into 19 principal groups, which are delineated on the map accompanying *Catalogue of Active Volcanoes of the World*, by W. Q. Kennedy and J. E. Richey, issued in 1947 as a supplement to *Bulletin Volcanologique*, series 2, volume 7. The Indonesian volcanoes constitute group 6. Within the group are nine subgroups, and within each subgroup each volcano is assigned a number. Thus the volcanoes of Java are subgroup 3, and the serial number 6, 3–25 represents the volcano Merapi on Java.

Part I of the Catalogue contains 271 pages. The description of each volcano includes its name, location, and height; a short description of the form and structure of the volcano; a list of known eruptions, made compact by the use of standard symbols to describe the activity; a description of the rock types comprising the volcano and a table of chemical analyses when available; and a brief bibliography of the principal literature dealing with the volcano. Maps of the entire region and the subregions are given, as well as black and white maps, cross sections, and sketches of many of the individual volcanoes. Some of the individual maps are less distinct than could be desired, because of direct reproduction from earlier publications, without redrawing. Even so, they are of great aid in following the text, and their large number is highly commendable.

The publication will undoubtedly prove of great value as a reference work, and the author deserves the gratitude of the volcanological profession for having undertaken and accomplished the enormous task of compilation represented by it. It is sincerely hoped that additional sections of the Catalogue will appear in the near future.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director
Chester K. Wentworth, Geologist, part-time
Burton J. Loucks, Instrument Maker
John C. Forbes, Assistant Instrument Maker
LaVieve G. Forbes, Secretary, part-time

Seismograph Station Operators:

Hilo Station:

Sister M. Thecla, St. Joseph's School

Kona Station:

Howard M. Tatsuno, Konawaena School

University of Hawaii:

T. A. Jaggar, Geophysicist

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter**, a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

THE VOLCANO LETTER

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HIBOK-HIBOK VOLCANO, PHILIPPINE ISLANDS, AND ITS ACTIVITY SINCE 1948

By ARTURO ALCARAZ, LEOPOLDO F. ABAD, and JOSE C. QUEMA[1]

PART II

Glowing Clouds (nuées ardentes). Glowing clouds made up of highly heated ash, volcanic breccia, and gases have been observed at various times during the present activity of Hibok-Hibok. Three types may be distinguished: (1) small clouds of hot ash and dust, (2) "nuées ardentes d'avalanche," and (3) Lacroix's (1930) "nuées ardentes d'explosion vulcaniennes."

The "small clouds of hot ash and dust" are not really in the nuée ardente class, but they are considered here as a type so as to cover all sorts of volcanic clouds observed. They are produced when extruded lava blocks break off and fall or roll down and, darting and bounding on the steep slopes of the volcanic cone, stir up the deposited ash and other comminuted debris along their paths. This type is often observed during phase 3 of the Hibok-Hibok cycle of activity.

When, however, a large volume of material comes down from the cone, as when an unstable section gives way, an avalanche is started and a "nuée ardente d'avalanche" results. Van Bemmelen's (1949) description of this type of glowing cloud as observed in eruptions of some Indonesian volcanoes fits quite well that observed at Hibok-Hibok. According to him, such a "nuée ardente" consists of a heavy fraction of incandescent debris and an accompanying lighter fraction of hot air, volcanic gases, sand, and dust, whirling upward. The former follows depressions and gullies on the flank of the volcano, while the latter may override bounding elevations and spread over the adjacent terrain. Such most likely was what happened on September 15, 1950, during the eruptive phase of Hibok-Hibok.

The barrio of Ilihan, where the volcano claimed most of its victims in 1950, is situated at a rise fronting the mouth of a ravine on the north-northeastern slope of Hibok-Hibok. The "nuée ardente d'avalanche" followed the ravine and, upon reaching a bend, spilled over the rise and into Ilihan with still sufficient force to uproot coconut and abaca trees. Inspection of the devastated area revealed farm animals strewn around stiff in death, half-buried in volcanic dust. The houses stood defiant with their gay printed curtains and festive buntings fluttering in the breeze. The 2-inch accumulations of ash on the floor and around the yards showed the suffocating atmosphere that asphyxiated and burned so many victims. Vegetation was seared brown. The dried grasses lay flat, as if a giant roller had passed over them. Abaca and some coconut trees were blown down away from the volcano. The directional pattern of the fallen trees, the flattened grasses, and some wrecked houses strongly suggest a sudden violent blast from the direction of the volcano. And yet 50 yards downstream the grass was



FIGURE 4. Hibok-Hibok crater, looking northwest from the southern part of the island.

[1] Geophysicist, Weather Bureau; Mining Engineer, Bureau of Mines; and Geologist, Bureau of Mines, respectively. Published by permission of the Committee on Volcanology, Department of Agriculture and Natural Resources, Philippine Islands.

green, and the trees were not turned brown by heat. Chickens were scratching the ground for worms in the yard of an empty house!

At Hibok-Hibok the "nuées ardentes d'avalanche" would be most likely to occur when the cone would have built up the maximum talus, and such a condition is perhaps attained during phase 4 of the cycle of activity.

When the activity of the volcano reaches what may be termed the main or gas phase (phase 2 in the Hibok-Hibok cycle), an explosion may produce a glowing cloud that has been described as "nuée ardente d'explosion vulcanienne." This type of glowing cloud differs from "nuée ardent d'avalanche" in that it is accompanied by an upward-rising cauliflower cloud of volcanic ash and travels along the slopes and across small topographic rises with tremendous speed. The December 4, 1951, blast produced such a "nuée ardente d'explosion vulcanienne," to which can be attributed the high toll in human lives exacted by the volcano that day.

The felled coconut trees showed a radial pattern away from the volcano, indicating that the direct blast from the volcano was the active force that leveled the trees. However, on the floor of Mabini Valley (southwest of Mambajao), the axis of which lies at an angle of about 20 degrees from the direction of the crater, the trees were felled along the axis of the devastated valley (Fig. 5). The force of the blast that felled these trees must have moved along the valley axis. This inference was supported by the distribution of ash accumulations inside the valley which were thicker along the valley floor.

The writers see in the "nuée ardente d'explosion vulcanienne" produced by the steam blast of December 4, 1951, the active cause of the seemingly unrelated destructive effects observed in the devastated area. It was the dense, boiling, heavily charged, ash-laden glowing cloud that people of Mambajao witnessed developing rapidly from the volcano that fateful morning at the same time that a cauliflower-shaped cloud was seen over Camiguin Island by distant witnesses. It was the same glowing cloud that charred and mummified its victims, set fire to combustible materials along its path, felled coconut and other trees, and deposited a thick layer of incandescent ash that remained unbearably hot below its surface for days after.



FIGURE 5. Coconut trees blown down parallel to the axis of Mabini Valley by the blast of December, 1951.

At an early morning hour on December 6, 41 hours after the foregoing blast, a series of explosions rent the crater area of Hibok-Hibok and lighted up the volcano vicinity. The detonations were audible at Mambajao. With the emission of incandescent materials, a dense, dark eruption cloud formed about the volcano, made more awesome by strong electrical discharges about and within it. Almost immediately it was noted that a section from the volcano almost extending to the sea and about a kilometer or so north of Mambajao was aglow. Examination of the affected area revealed that the glow came from a very thick flow of incandescent ash and pumiceous rock boulders which had set fire to combustibles along its path. Three more victims, who remained in the danger zone in spite of warnings, were added to the number who perished on December 4.

Block Lava Flows. After the initial steam blast of September, 1948, an apparently inexhaustible amount of rock material was observed being extruded from Hibok-Hibok. This material broke off from the crater area and, coming down the volcano slope, broke further into smaller pieces as it hit protruding points or other obstacles along its descent. Nighttime observations showed the extrusives to be red-hot, and, when large fragments broke up, the fresh surfaces glowed brighter, evincing higher temperature.

The new extrusives consisted chiefly of blocky, grayish, porphyritic andesites with numerous feldspar and ferromagnesian phenocrysts. Xenoliths of the older formations traversed by the rising magma were very much in evidence in the extruded block lava, especially in those that were emitted during the first days of formation of the flow. They ranged in size from less than an inch to more than a foot in diameter and were at various stages of assimilation by the younger rock. The edges of the andesitic xenoliths were in most instances marked by a profusion of ferromagnesian minerals (predominantly hornblende). In the case of tuffaceous xenoliths, there was a tendency to form vugs or cavities, which are generally lined by fairly well-developed crystals.

The top of the flow was made up of loose, large and small, jagged and angular blocks, evidently the product of rupture of a highly viscous, almost solid, effluent magma. Some of the blocks were slightly scoriaceous, and those that may have come in contact with the soil mantle of the cone had a reddish, partly vitreous veneer. In the main, however, the blocks had smooth faces and sharp edges and were unagglutinated. This description is at variance to that of the upper part of the typical flow as observed at Hawaiian and Sicilian volcanoes. The Hibok-Hibok flows are of the type termed block lava by Finch (1933).

The lava flow that formed in 1948 and early 1949 was designated for convenience the Kanangkaan Flow (after a sitio subsequently overridden by the flow) to distinguish it from two smaller ones formed subsequently, after the former had stopped advancing.

Movement day by day, and even hour by hour, of the Kanangkaan Flow was clearly notable during its initial stages. During that period the flow was moving faster than in latter stages, and it was possible to note the forward movement of a particular block on the top of the flow within an hour's observation. Further evidence of



FIGURE 6. Coconut trunk about 10 inches in diameter bent around the trunk of a mango tree by the force of the blast of December, 1951, in Mabini Valley about 1 kilometer west of Mambajao.

motion in the Kanangkaan Flow was furnished by the extension of the flow to over 2 miles from the crater in about 8 months, or an average rate of movement of nearly 65 feet a day. The thick lower portion of the flow has not been accessible to close observation, but, judging from the absence of any notable breakthrough of the inner portion, the writers are of the opinion that, while the lava inside the blocky shell of the flow could have retained much of its original temperature for a long period, its state was closer to being plastic than fluid, and that movement of the flow had been accomplished by shearing of the highly viscous interior over a simultaneously advancing rock mat formed by the breaking and sliding down of blocks at the snout of the flow.

It is estimated that the Kanangkaan Flow in 8 months' time (September, 1948, to April, 1949) attained a volume of 900,000,000 cubic feet, or 40,000,000 tons. After advancing about 3 miles, further forward movement was arrested when the front of the flow encountered a spur of Mount Mambajao that crosses its path. The spur, however, was perhaps not the main or only reason for the halt of its advance. It is likely that the viscosity of the lava and the much gentler slope of the last mile or so had some contributory effect. At any rate, upon cessation of any forward movement of the Kanangkaan Flow, a cone was built up at the crater area whose height was limited to about 200 feet by the maximum talus possible on that part of its base resting on the Kanangkaan Flow. The formation of this cone apparently was due to a change in the direction of easiest relief for the lava that was feeding the flow. The pressure necessary to cause further forward movement of the Kanangkaan Flow undoubtedly became greater than the pressure sufficient to break through the crater end of the flow, and thus relief of the extrusive pressure was effected in the latter.

In June, 1949, a new extrusion of incandescent material from the crater area was observed to take a different direction. This time such activity was toward barrio Itum, and thus the block lava flow that was being formed in that direction was called the Itum Flow. This flow did not attain an appreciable volume or areal extent and, being close to the enormous Kanangkaan Flow, could hardly be noted in aerial maps. The Ilihan Flow, a third block lava flow from the Hibok-Hibok crater area, was formed during the activity of September, 1950. It was small, like the Itum Flow, and nowhere approached the topographic significance of the Kanangkaan Flow. However, after the direction of extrusion shifted toward Ilihan in late 1950, there was a reshifting of the activity toward Itum again in December, 1951, and as a consequence new extrusives are now being added to the 1949 Itum Flow.

Mud Flows or "Lahars." The term "lahar" as used in Indonesia refers to mud flows containing volcanic debris and breccia transported by water. As the term has gained acceptance in scientific circles, its use in this paper was deemed proper, especially since the mud flows in the Hibok-Hibok area bear very close resemblance to those described from Indonesian volcanoes.

At the onset of the Hibok-Hibok activity, danger from lahars to the communities along the drainage channels in the northeast sector of the volcano, especially after heavy rains, was suspected. Subsequent events proved this danger to be real and of definite importance in any safety consideration for the affected area. Approximately 1.5 square miles, mostly of arable land, are now covered by varying thicknesses of volcanic sediments brought down the slopes by rains. The barrio Agoho, once a thriving community, is now abandoned by its inhabitants because of the large accumulation of water-borne sediments that have buried most of the houses in the barrio (Fig. 7).

The first lahar in the Hibok-Hibok area occurred simultaneously with, or immediately after, the initial explosion of September 1, 1948. As far as could be gathered from eye witnesses, there was a wall of mud, water, and debris that came rushing down along the upper course of a water channel draining the northeast sector of Mount Catarman. In the space of a few hours the water was gone, leaving a thick deposit of mud, sand, gravel, boulders, and organic debris along the channel. This flood was noteworthy not only because of its profound effect on the old stream channel, which it widened considerably, but because it posed the question of from where the large volume of water necessary to cause the observed effects of the flow could have come. There was



FIGURE 7. Part of Agoho barrio destroyed by a lahar, as it looked on December 18, 1950.

practically no rain in the Mambajao area during the time of the eruption or for a few days preceding it. It is quite probable that some pond of water at or close to the present crater area was breached, though the existence of such a pond before the eruption could not be ascertained. Water that may have resulted from the condensation of steam released by the blast could have been a contributory source.

Subsequent floods were, more or less, related to rains. After moderate or heavy rains, especially in the vicinity of Mount Catarman, water draining from that area carried down rocks and other detrital materials and deposited them fan-wise on the gentle slopes near the sea coast. At the sea-coast barrio Agoho, the sediments from lahars have reached a depth of over 10 feet in most places, and the coastline has jutted appreciably seaward as a result of the delta being formed by the sediments carried out to sea by the floods. On a few occasions when the lahar formed soon after eruptive phases, the flow was hot and even steaming. There have been no casualties from floods, as the people living close to the channel ways were repeatedly warned of such dangers.

SUMMARIZING STATEMENTS

The continued activity of the stratovolcano Hibok-Hibok since 1948 is characterized by paroxysmal periods, each period being a part of a certain discernible cycle of behavior and featuring steam blasts that commonly produce "nuées ardentes d'explosion vulcanienne." This is the most dangerous type of glowing cloud and is capable of widespread destruction of life and property.

Glowing clouds caused by small rock slides and avalanches have not been particularly destructive unless channeled by favorable topography or given further impetus in inhabited areas by wind currents.

Precursory seismic activity was most pronounced before the initial crateral outburst in 1948 but was wanting or inappreciable in later paroxysmal periods. This observation seems to indicate that not too much reliance should be placed on seismic activity to presage further paroxysmal periods, if any, of Mount Hibok-Hibok.

Cold and hot mud flows, or lahars, have formed, especially after heavy rains, and have presented another source of danger to the inhabitants living along the drainage channels in the north and northeast sectors of the volcano.

The formation of block lava flows is another characteristic feature of Hibok-Hibok activity. The destructive effects on the arable land overrun by these lava flows present a sociological and economic problem to the people who thereby lose their agricultural means of livelihood.

The scientific investigation of the volcano is directed toward minimizing the destructive effects of subsequent eruptions on property and human lives. Therefore, the economic and social effects of the volcano's activity on the people within the area of devastation and danger are of national concern. These people should be rehabilitated and given opportunities to start anew in places removed from volcanic dangers. To remain within the danger zone of an active volcano is to live on borrowed time.

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REFERENCES

FINCH, R. H., BLOCK LAVA. Jour. Geol. 41 (7) : 769–770. 1933.

LACROIX, A., REMARQUES SUR LES MATÉRIAUX DE PROJECTION DES VOLCANS ET SUR LA GENÈSE DES ROCHES PYROCLASTIQUES QU'ILS CONSTITUENT. Soc. Géol. de France, Livre Jubilaire 1830–1930 (2) : 431–472. 1930.

VAN BEMMELEN, R. W., THE GEOLOGY OF INDONESIA, VOL. I-A, GENERAL GEOLOGY. Government Printing Office, The Hague. 1949.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JULY–SEPTEMBER, 1952

By GORDON A. MACDONALD

VOLCANOLOGY

July

The eruption of Kilauea volcano that began on the evening of June 27 continued through July, August, and September. A fuller account of the eruption will appear in the next issue of the Volcano Letter.

During early July a large fountain was active near the southwest edge of the crater, reaching its climax in size on July 3 and 4, when some bursts reached a height of 600 feet. This fountain alternated in activity with a sinkhole at the same locality into which poured a stream of lava that moved across the crater floor from the central fountains.

Fountains near the northeast edge of the crater floor continued active until July 5, building small spatter cones which later in the month were gradually obliterated, partly by collapse and partly by burial with new lava. A chain of small fountains, containing as many as 20 individual jets, extended across the southwest portion of the crater floor during the first 2 weeks of the eruption. About July 11 the activity of this fountain chain became restricted largely to the central portion of the crater, where two principal fountains began building a large spatter cone that still remains a conspicuous feature on the crater floor. The highest of the cone segments stands about 50 feet above the central pool of lava.

A circulating lake of lava developed around the central fountains. Rivers of lava issued through gaps in the central cone and spread through the lake. Where these spreading lava currents met, and along the edges of the lake, the current plunged downward. The down-plunging current carried with it fragments of the crust, and small temporary lava fountains formed where the crust was pulled under. Around the edges of the lake the spattering of these small fountains built up a wall as much as 15 feet high which confined the liquid lake lava at an elevation several feet above the surrounding black bench of solidified lava. Occasionally, the wall broke down locally and allowed a stream of molten lava to spread over the black bench.

August

Early in August the activity remained much as it had been in late July. Two large fountains played in coalescing craters in a central cinder cone about 50 feet high. The height of the fountains averaged about 40 feet, but occasional bursts reached heights of 400 feet and, rarely, as much as 550 feet. Four rivers of lava poured through gaps in the cone walls on the northeast, east, south, and west sides and fed an active lava lake with an area of about 34 acres.

On August 9 the south lava river became blocked, and the north and northeast rivers increased greatly in volume, plunging over spectacular cascades as much as 20 feet high. On August 11 the south river became re-established, and the east river was blocked by a partial collapse of the cone. By August 12 the east river was flowing again, but the northeast river had in turn been choked off. On August 13 the west and south rivers became active. These changes accompanied a gradual cooling and apparent increasing stickiness of the lava. Cessation of the south river was followed by draining of the southern portion of the lava lake, leaving a broad irregular-floored basin about 20 feet deep. On August 18 the south river again overflowed the cone wall, and new lava refilled the basin left by the earlier drainage.

Late on the evening of August 18 the northernmost of the two fountains died down greatly and by midnight it showed no signs of activity. It returned to activity early on August 19 but remained small for several days. By August 22 the height of each fountain averaged about 20 feet, with some showers of glowing fragments reaching as high as 200 feet. On August 23 lava was no longer flowing from the central cone over the surrounding crater floor, and the lava lake surrounding the cone had become inactive. The two fountains were small and sporadic, throwing showers of glowing fragments to heights of about 150 feet. They had built beehive-shaped conelets of spatter around themselves in the twin craters of the large cinder cone, and a lava lake about 120 feet across had formed in the crater of the cinder cone nearly between the two spatter conelets. This condition persisted until the end of the month.

September

From September 1 to 18 both conelets in the crater of the large cinder cone continued active, but the northern conelet was much more active than the southern one. Bursts of glowing lava fragments were thrown into the air to a height of 150 or, rarely, 200 feet. Many of these fragments fell back onto the top and sides of the conelet, gradually building it up to a height of 50 feet, overtopping the wall of the surrounding cinder cone.

Through this period the lava at the surface of the lake flowed slowly from the north to the south edge where it sank, producing fountains 10 to 15 feet high against the south bank.

Throughout the month small lava flows appeared from time to time on the floor of Halemaumau outside the big cinder cone. These welled up quietly, with very small fountains or none at all. On September 4 two of these small flows issued on the floor north and east of the cinder cone. On September 5 another appeared on the floor northwest of the cone and still another at the foot of the west wall of the crater, apparently squeezed up along the fissure between the old crater wall and the mass of new lava filling the bottom of the crater. Small flows issued on the floor southeast of the cone on September 8, northeast of the cone on September 12, at the west wall on September 16, and both northwest and northeast of the cone on September 17.

On September 19 the activity of the two conelets became reversed, with the southern one more active than the northern one. At the same time the movement of lava in the lake also reversed, rising at the south edge, to flow northward, sink, and produce fountains along the north bank. Spatter from the edge fountains and occasional small overflows had built up a low cone around the lake, the surface of which stood about 20 feet higher than the surrounding crater floor.

At 1:45 on the morning of September 20 lava started to spill over the south rim of the lake. This overflow rapidly increased in volume, breaking down the south wall of the lake cone and sending a big flow over the southern part of the floor of Halemaumau. At 10:12 A.M. the north rim of the lake also was overflowed, and a second big flow spread out to coalesce with the first one east of the cinder cone. The northeast overflow lasted only a few hours, but the southern one continued until about midnight. This outpouring of lava was the greatest since August 22.

On September 22 the northern conelet again became dominant, and the circulation in the lava lake reversed, again taking a north-south direction. Explosive activity at the southern conelet ceased entirely, and since then it has been fuming quietly. The north conelet built up to a height of 65 feet, and by September 26 its top was nearly sealed over. On that afternoon, about 4 o'clock, the top and part of the northeast side of the cone suddenly was blown off, and explosions hurled fragments of hot lava 400 feet into the air. The lava lake showed violent agitation, and its level rapidly dropped about 15 feet. Within a few minutes both lake and conelet returned to their normal state of activity, with bursts from the conelet reaching heights of 100 to 150 feet.

About 4:15 P.M. on September 27 molten lava again appeared at the foot of the northwest wall of Halemaumau, and within 2 hours a flow had spread out in both directions along the foot of the wall for a distance of 1,800 feet. By 8:00 P.M., movement in this flow had greatly decreased, but activity at both the north conelet and the lava lake was increasing markedly. At 8:35 P.M. a series of about a dozen violent blasts suddenly commenced at the north conelet, throwing incandescent cinder to a maximum height of 550 feet. The surface of the lava lake surged violently, and, following the explosions, its level gradually dropped about 15 feet, revealing glowing grottoes hung with a fringe of stalactites in the banks. As on the previous day, activity soon returned to normal.

Through the closing days of the month the northern conelet and lava lake continued moderately active, with the southern conelet fuming gently. At night, showers of glowing fragments thrown up from the north conelet could be seen to reach heights of 150 to 200 feet. Tongues of pale yellowish and

bluish flame as much as 25 feet long played above the conelet.

Measurements on September 24 indicated that the average thickness of the fill of new lava in Halemaumau produced by this eruption had reached 288 feet, and the volume of new lava was 58 million cubic yards. In comparison, the volume produced by the 1934 eruption was 9.5 million cubic yards. The average depth of the crater below the visitors' observation area is 482 feet. The rise of the floor of the crater has resulted only partly from flooding by new lava. In part the floor has been elevated bodily, apparently by the injection of new lava into the lower, still-mobile portion of the new fill.

Through the first half of September the ground at the seismograph station beneath the Volcano House tilted eastward at a rate considerably greater than normal for this season of the year. This probably resulted from a doming up of Mauna Loa caused by an increase of volcanic pressure beneath. From September 17 to 30, however, there was no further eastward tilting. Several earthquakes felt in Kona during the month appear to have originated on the Kealakekua fault in central Kona, and may have resulted from readjustments caused by changes in volcanic pressure. A quake felt widely over the southern portion of the island at 4:45 A.M. on September 2 originated in the vicinity of Kilauea crater.

SEISMOLOGY

Earthquake Data, July–September, 1952

(Based on Bosch-Omori seismograph on northeast rim of Kilauea Caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
July 6	†	1	2	3	2	0	14.5	0
13	†	0	1	0	0	0	1.0	0
20	†	0	0	0	0	0	0	1
27	†	0	1	1	0	0	3.0	1
Aug. 3	†	0	1	0	0	0	1.0	0
10	†	0	0	1	1	0	5.0	0
17	†	0	0	1	0	0	2.0	1
24	†	1	0	0	0	0	0.5	0
31	†	1	1	0	0	0	1.5	0
Sept. 7	†	0	0	0	0	0	0	1
14	†	1	0	0	0	0	0.5	0
21	†	4	0	0	0	0	2.0	0
28	†	4	1	0	0	0	3.0	0

* For definition of local seismicity see Volcano Letter 371 or 512. Each local earthquake is assigned a seismicity value according to its strength, as follows: tremor, 0.25; very feeble, 0.5; feeble, 1.0; slight, 2.0; moderate, 3.0; strong, 4.0. These values are totaled to give the weekly local seismicity. Continuous volcanic tremor is ignored in the calculation. The strength assigned to the earthquake depends on the double amplitude of the maximum oscillation it causes on the Bosch-Omori seismograph, as follows: tremor, less than 0.5 mm.; very feeble, 0.5 to 4 mm.; feeble, 4 to 11 mm.; slight, 11 to 25 mm.; moderate, 25 to 60 mm.; strong, greater than 60 mm.

† Continuous tremor.

Table of Tilt at Seismograph Vaults on Rim of Kilauea Caldera

Week Beginning	Whitney Vault (Northeast rim)		Uwekahuna Vault (West rim)	
	Amount	Direction	Amount	Direction
July 6	0.9″	N 67° W	0	—
13	0.7″	S 18° W	0.7″	S 63° E
20	0.7″	S 18° W	6.8″	S 19° E
27	1.3″	S 21° W	3.7″	S 20° E
August 3	0.7″	S 59° E	1.0″	S 18° E
10	0.5″	S	1.4″	S 63° E
17	0.5″	N 27° W	3.3″	S 29° E
24	0	—	2.3″	N 8° W
31	0.7″	S 31° E	1.0″	N 18° W
September 7	1.2″	N 74° E	0.4″	N 45° W
14	0.9″	N 40° E	3.4″	N 22° E
21	0.2″	S 45° W	1.0″	N 71° E
28	1.5″	N 55° E	4.7″	S 28° W

Distant Earthquakes

The following earthquakes of distant origin were recorded on the seismographs of the Hawaiian Volcano Observatory. Locations of the epicenters are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey. The time given is that of the first detectable emergence of the quake on the Bosch-Omori horizontal or Sprengnether vertical seismograms, in Hawaiian Standard time.

July 21, 01:59, strong. Tehachapi, California.
July 28, 22:19, slight. Southern California (?).
Aug. 20, 05:39, moderate. Off coast of Oregon.
Sept. 9, 03:29, slight. Near coast of Costa Rica.

Local Earthquakes

The data for the following local disturbances were determined from seismographs operated on the island of Hawaii by the Hawaiian Volcano Observatory. Locations given are epicenters. The times given are arrival times at the Whitney Laboratory of Seismology, on the northeast rim of Kilauea Caldera. They are stated to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich Civil time. The number preceding each earthquake is the serial number for the current year. The intensity rating (Feeble, Moderate, etc.) given is that for the Whitney Laboratory. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney station.

2064. July 1, 04:16, very feeble.
2065. July 3, 09:05, feeble (Mauna Loa, slight).
2066. July 3, 12:26, feeble (Mauna Loa, slight).
2067–2069. July 5, no record at Kilauea (Kona, very feeble). Central Kona.
2070. July 6, 15:38, very feeble (Hilo, feeble). Felt at Kukuihaele.
2071. July 6, 22:56, feeble. Felt at Kukuihaele.
2072. July 7, 04:43, slight. Felt at Hilo and Kukuihaele.
2073. July 7, 06:16, very feeble.
2074. July 9, 06:54, slight. Felt in Volcano district.
2075–2076. July 9, 08:10, slight. Twin earthquake. Felt at Hilo, Volcano, and Naalehu. Hilina fault system (?).
2077. July 12, 13:53, moderate (Kona, strong). Felt from Kona to Hilo. Origin in central Kona.
2078. July 14, 16:45, tremor (Mauna Loa, very feeble).
2079. July 16, 12:32, feeble.
2080. July 17, 17:44, tremor (Mauna Loa, very feeble).
2081. July 17, 18:14, tremor (Mauna Loa, very feeble).
2082. July 21, 11:49, tremor (Mauna Loa, very feeble).
2083. July 22, 02:46, no record at Kilauea (Kona, very feeble).
2084. July 27, 14:51, no record at Kilauea (Mauna Loa and Hilo, very feeble).
2085. July 29, 01:30, no record at Kilauea (Mauna Loa, very feeble).
2086. July 29, 10:51, no record at Kilauea (Mauna Loa, very feeble).
2087. Aug. 1, 12:33, slight.
2088. Aug. 2, 15:17, no record at Kilauea (Kona, very feeble).
2089. Aug. 2, 16:10, slight.
2090. Aug. 3, 14:49, no record at Kilauea (Kona, very feeble).
2091. Aug. 3, 18:08, no record at Kilauea (Mauna Loa, very feeble).
2092. Aug. 4, 04:00, no record at Kilauea (Kona, very feeble).
2093. Aug. 5, 18:21, tremor (Mauna Loa, very feeble).
2094. Aug. 9, 10:31, feeble (Mauna Loa and Hilo, slight).
2095. Aug. 10, 18:06, no record at Kilauea (Mauna Loa, very feeble). East rift of Mauna Loa.
2096. Aug. 11, 12:21, tremor (Mauna Loa, very feeble).
2097. Aug. 12, 20:16, tremor (Mauna Loa, Hilo, and Kona, very feeble).
2098. Aug. 13, 00:52, tremor (Mauna Loa, feeble).
2099. Aug. 14, 14:08, slight. Felt at Volcano, Kapapala, and Naalehu. Off south shore.
2100. Aug. 16, 21:07, moderate. Off south shore of Hawaii.
2101. Aug. 18, 13:59, slight (Mauna Loa, moderate). Kaoiki fault (?).

2102. Aug. 25, 21 : 20, very feeble.
2103. Aug. 30, 12 : 34, tremor (Mauna Loa, very feeble).
2104. Aug. 31, 05 : 39, very feeble.
2105. Sept. 2, 04 : 45, feeble. Felt at Glenwood, Volcano, Naalehu, Kona. Kilauea Caldera.
2106. Sept. 3, 12 : 47, tremor (Mauna Loa, very feeble).
2107. Sept. 6, 20 : 51, no record at Kilauea (Kona, feeble). Central Kona.
2108. Sept. 8, 02 : 27, no record at Kilauea (Kona, very feeble).
2109. Sept. 9, 20 : 21, no record at Kilauea (Kona, very feeble).
2110. Sept. 10, 07 : 50, no record at Kilauea (Kona, very feeble).
2111–2112. Sept. 12, no record at Kilauea (Kona, very feeble).
2113. Sept. 14, 08 : 11, very feeble. Felt at Kukuihaele.
2114. Sept. 14, 18 : 21, no record at Kilauea (Kona, very feeble).
2115. Sept. 17, 12 : 41, tremor (Kona, feeble). Felt in Kona.
2116. Sept. 18, 14 : 15, tremor (Kona, very feeble).
2117. Sept. 19, 15 : 57, no record at Kilauea (Kona, very feeble).
2118. Sept. 19, 20 : 58, no record at Kilauea (Kona, very feeble). Felt in Kona.
2119. Sept. 20, 06 : 53, no record at Kilauea (Kona, very feeble). Felt in Kona.
2120. Sept. 22, 02 : 23, very feeble.
2121. Sept. 22, 12 : 27, very feeble.
2122. Sept. 24, 11 : 45, no record at Kilauea (Kona, feeble). Felt in Kona. Origin in central Kona.
2123. Sept. 26, 14 : 56, very feeble.
2124. Sept. 27, 07 : 22, tremor (Kona, slight). Felt in Kona. Central Kona, probably Kealakekua fault.
2125. Sept. 27, 20 : 36, very feeble.
2126. Sept. 30, 04 : 10, no record at Kilauea (Kona, very feeble). Felt in Kona.
2127. Sept. 30, 20 : 57, very feeble.

VOLCANO NOTES AND NEWS

RECENT ERUPTION ON SAN BENEDICTO ISLAND, REVILLA GIGEDO GROUP, MEXICO

By HOWEL WILLIAMS

The Revilla Gigedo Islands lie 350 to 600 miles west of the Mexican mainland, approximately on latitude 19°N, in line with the principal chain of volcanoes that includes Orizaba, Popocatepetl, Nevado de Toluca, Paricutin, and Colima. All the islands, with the possible exception of one which may be composed of granite, consist of volcanic rocks. The two easternmost islands, Socorro and San Benedicto, include several volcanoes that have been active during recent geologic time. The last eruption on Socorro took place in 1848, and solfataric activity still continues there.

San Benedicto Island, site of the latest eruptions, is approximately 3 miles long in a north-south direction and ¾ mile in maximum width. The north end consists of the remnants of a group of coalescing cones of scoria, now deeply eroded and craterless. After these cones had become extinct, activity migrated southward to build a cone of white pumice, known as the Ash Heap, to a height of 975 feet. Shortly thereafter a new vent opened in the saddle between the Ash Heap and the old cone cluster. First a pumice cone was built; then a domical mass of columnar lava rose into the crater. Finally, owing to withdrawal of magma in the conduit, the top of the dome subsided to form a conical depression known as Herrera Crater.

The vent of the new volcano lies between those of the Ash Heap and Herrera Crater, on a north-south fissure that continues southward to the vents on Socorro Island. Just when activity began is uncertain but probably during July, 1952. The first eruptions to be reported were on August 12, by which time a large cone had already been formed. News of the activity reached the mainland on August 27. On September 13 Robert S. Dietz and Ruy H. Finch flew to the volcano. It was then about 1,000 feet high and almost a mile across at the base. The intensity of the eruptions had diminished greatly. Every 20 minutes or so, cauliflower clouds of steam and ash rose from the crater, and the odor of sulphuretted hydrogen was strong. On September 20 the volcano was revisited by Dr. Dietz, this time accompanied by the writer. By that time the cone was 1,500 feet high. Discharge of ash had come to an end; instead, lazy puffs of steam, mingled with hydrogen sulphide, rose only a few hundred feet above the crater rim at intervals of a few minutes, and on the floor of the crater was a small biscuit-shaped mass of blocky lava, a miniature plug. Clearly, there had been no further explosive discharge of debris since the plug rose to the surface. Apparently the volcano was approaching extinction; not only was the throat sealed by the plug, but the vapor pressure was reduced to a few atmospheres. By this time, the volcano is probably dead.

The San Benedicto eruption is especially significant as being the first historic pumice eruption in the eastern part of the Pacific Ocean. Proper identification of the nature of the pumice must await detailed microscopic study, but the white color of the ejecta and the refractive index of the glass suggest that the material is either rhyolite or dacite. Almost surely most of the new cone was built during the first few weeks, before it was seen. The first explosions seem to have been of vulcanian type, the ejecta being hurled to great heights by strong gas pressure. Subsequently, as the vapor pressure diminished, the vulcanian explosions grew weaker and were accompanied by explosions that lifted the ejecta only a short distance above the crater rim so that they then swept down the outer flanks of the cone as glowing avalanches. Finally, as the vapor pressure continued to decrease, a mass of stiff, viscous lava slowly rose from the conduit onto the crater floor. Few volcanoes have grown as rapidly; few have had such a short life.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director
Chester K. Wentworth, Geologist, part-time
Burton J. Loucks, Instrument Maker
John C. Forbes, Assistant Instrument Maker
LaVieve G. Forbes, Secretary, part-time

Seismograph Station Operators:

Hilo Station:

Sister M. Thecla, St. Joseph's School

Kona Station:

Howard M. Tatsuno, Konawaena School

University of Hawaii:

T. A. Jaggar, Geophysicist

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcances in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

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THE 1952 ERUPTION OF KILAUEA

By GORDON A. MACDONALD

OPENING PHASE OF THE ERUPTION

Late in the evening of June 27, 1952, Kilauea Volcano resumed eruptive activity after a quiescence of nearly 18 years. The last previous eruption began on September 6 and ended on October 9, 1934.

The exact time of the outbreak is uncertain, but it appears to have been very close to 11:40 P.M. Continuous volcanic tremor commenced on the Volcano Observatory seismographs at 11:37:30 P.M., and it is probable that molten lava reached the surface within a very few minutes after that. At 11:35 on June 27, Mrs. John R. Fox was awake in the living room of her home on the northeastern rim of Kilauea Caldera, from which there is an excellent view of Halemaumau Crater. She noticed nothing unusual. About 11:40 she entered another room, the window of which was open, and almost immediately heard a loud whistling roar (probably caused by the escape of gas at Halemaumau). Alarmed, she returned immediately to the living room and saw a bright orange glow over Halemaumau.

At approximately 11:40 P.M., Col. B. W. Rushton, Commanding Officer of Kilauea Military Camp, pointed out a bright reddish glow in the direction of Halemaumau to John Forbes of the Volcano Observatory staff. This, Forbes immediately identified as caused by eruption of Kilauea. John and LaVieve Forbes went immediately to the Volcano Observatory at Uwekahuna, where they telephoned me at about 11:45.

At the time the Forbes reached the Observatory, the top of a huge lava fountain was clearly visible above the rim of Halemaumau at its southwestern edge. At the beginning of the eruption the floor of Halemaumau pit was approximately 800 feet below the level of the southwestern rim; therefore, this fountain must have been more than 800 feet high! By the time I reached the Observatory, at about 11:55, the fountain itself was no longer visible, but scattered incandescent fragments still were being thrown above the rim, many of them landing outside the pit and bursting in flashes of red on the caldera floor southwest of Halemaumau.

After picking up the needed equipment, the Forbes' and I, accompanied by Cpl. Gordon Poulson of Kilauea Military Camp, proceeded immediately to Halemaumau by the road around the southwestern edge of the caldera. The fume cloud was so dense that visibility was very limited, and the fall of pumice on the road was so abundant that at times it nearly stopped the forward progress of the car. Some of the pumice blocks were as much as 10 inches across. Choking sulfur fumes were annoying but not serious so long as the car windows were kept closed.

We finally reached the southeastern rim of Halemaumau at 10 minutes past midnight. A continuous line of lava fountains, 2,600 feet in length, was playing along a fissure that extended in a northeast-southwest direction entirely across the floor of Halemaumau Crater and about 50 feet up the northeastern wall (Fig. 1-A). Most of the fountain jets ranged from 50 to 100 feet high, but at the foot of the southwestern wall was a fountain 400 feet high. Showers of liquid ejecta from the big fountain struck the adjacent wall and trickled down it in a fiery cascade. Several minor fountains, a few feet in height, were present also on the northern part of the floor in the vicinity of the 1934 cones (Fig. 1-A). Liquid lava was spreading from them as well as from the fountains along the main fissure and had already covered the entire floor of the crater.

The pool of lava was very fluid, and waves from the fountain chain swept entirely across its surface and up

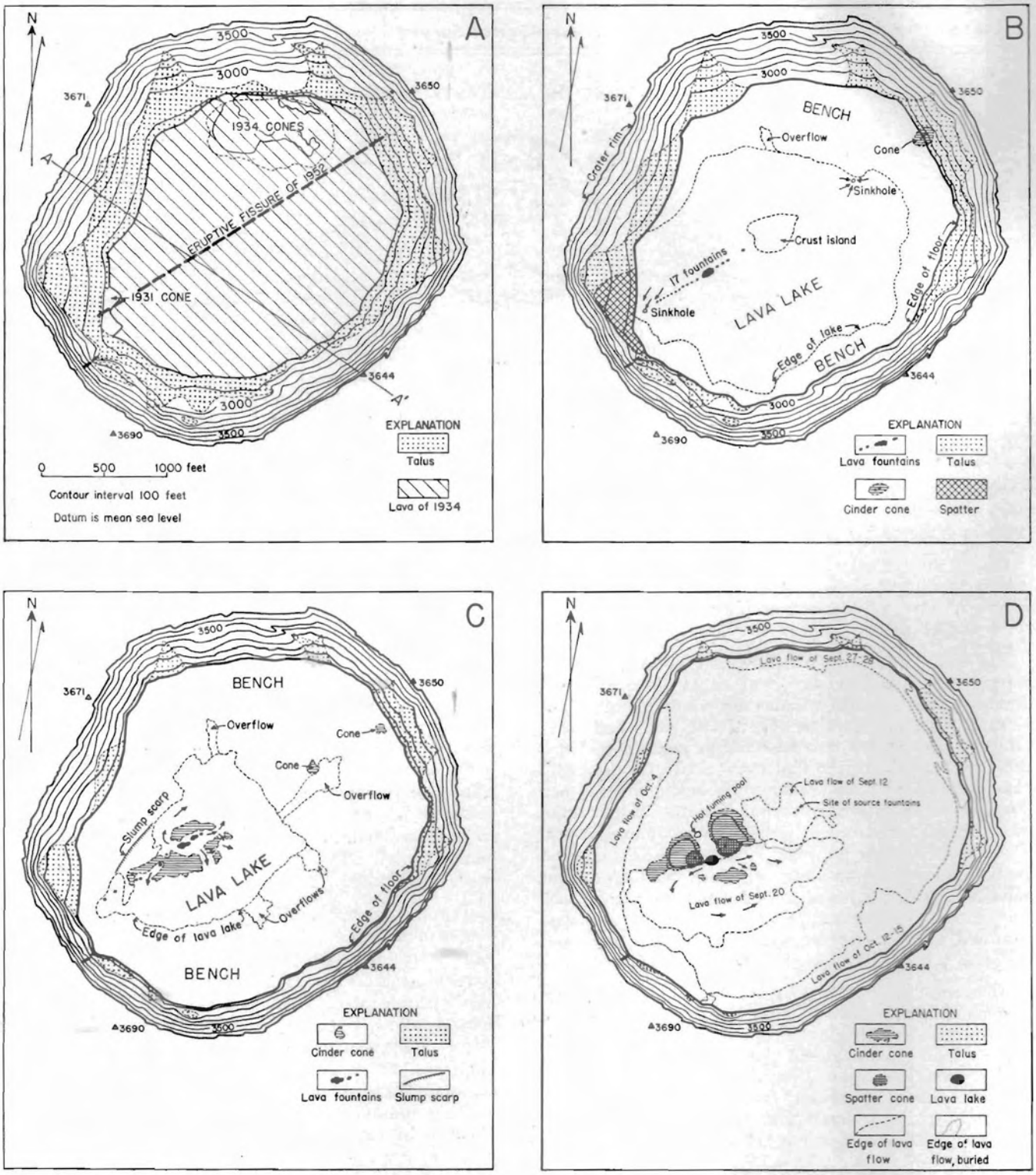

FIGURE 1. Maps of Halemaumau Crater, showing successive stages of the 1952 eruption. A. Conditions in mid-June, just before the eruption. The heavy dashed line shows the course of the fissure that opened to emit lava on the night of June 27. B. Conditions on June 30 at 1 P.M. C. Conditions on July 16. D. Conditions on October 21.

against the walls. Evanescent sinkholes developed near the edge of the pool, accompanied by small lava fountains. Each continued active for only a few minutes, then disappeared, to be replaced by another at some other point. Visibility in Halemaumau was poor because of the large amount of fume, but during brief glimpses of the northern part of the floor, the 1934 cones could not be seen. It is probable that they were already buried and that the liquid pool had attained a depth of more than 30 feet within the first half hour of the eruption. If so, the volume of lava extruded during that brief interval was at least 4,000,000 cubic yards.

The molten lava quickly crusted over, but movement of the underlying liquid tore the crust apart along myriads of lines which revealed the brightly glowing material beneath (Fig. 2). From time to time small whirlwinds moving across the lake picked up fragments of the hot crust 3 or 4 feet across, lifted them 15 or 20 feet into the air, and sent them spinning off across the surface.

The lava fountains continued to decrease rapidly in size. By 1:15 A.M. on June 28, the southwestern fountain was only 250 feet high, and by 3 o'clock it had shrunk to 100 feet (Fig. 3). At 3:15 this fountain and the southwestern part of the fountain chain for 150 feet from the wall had become inactive except for occasional very small bursts, and the next 150 feet of the fountain chain was very weak. At 4:00 the entire southwestern half of the fountain chain was totally inactive, and along the next quarter of the fissure the fountains were very small. Along the northeastern quarter of the fissure the fountains were still 50 to 75 feet high. By 4:10 the active fountains were nearly restricted to the northeasternmost eighth of the fissure, and volcanic tremor had nearly ceased recording on the seismographs. Activity had reached a very low ebb, and for a short time it looked as though the eruption might be ending.

THE PHASE OF THE LARGE LAVA LAKE

About 4:20 A.M. on June 28, small fountains resumed activity along the southwestern quarter of the fissure. These fountains were largely a mere bubbling of liquid lava, liberating very little gas, although abundant gas liberation continued at the northeastern fountains. At 5 A.M. activity was restricted to three blowing vents at the base of the northeast wall talus and the new small fountains in the southwestern part of the crater, with a few small, sporadic bursts along the intervening portion of the fissure. Very little fume was being given off. Daylight brought a clear view of the floor of the crater and confirmed the complete burial of the 1934 cones. The new lava fill was estimated to be about 50 feet thick and to have a volume of approximately 8,000,000 cubic yards.

At approximately 6 A.M. one of the small fountains near the southwestern edge of the crater floor began to grow in size. By 6:15 it was a strong dome-shaped fountain 25 feet across. The typical lava fountains are semi-explosive in nature, resembling a jet from a hose playing spasmodically into the air, and liberate a cloud of gas. This fountain, however, was nonexplosive, with little gas liberation, and resembled half an orange placed flat side down on the surface of the lava lake, appearing somewhat like the dome of water that sometimes is observed above the aperture of a freely flowing artesian well. Crusts of the surrounding lava lake were drawn in toward the fountain and foundered around its edge. By 7:15 the fountain occasionally was reaching heights as great as 50 feet (Fig. 4).

At 6:30 a double fountain jet in a small cone built on the lower slope of the northeastern talus was spurting to heights of 30 to 40 feet and throwing occasional bursts of spatter as high as 60 feet. A sluggish lava stream issued through a breach in the southeastern wall of the conelet and ran down its side at a speed of about 5 miles an hour. Another small vent 50 feet farther northeast was spurting from time to time and sending a trickle of lava down the western side of the conelet. Both vents were roaring and liberating distinctly more blue fume than the southwestern fountain. Two small fountains about 200 feet southwest of the northeastern conelet were spurting sporadically.

Through the morning of June 28, the southwestern fountains gradually increased in size, and the northeastern fountains decreased. At 11 A.M. a small flow of aa was issuing from the northeasternmost vent of the northeast conelet. This single small flow, which continued for the balance of the day, was the only aa observed during the entire eruption. By noon the northeastern fountains had become very small, and the principal southwestern fountain had grown to about 75 feet high and 100 feet across at the base. It was no longer a dome-shaped fountain of gently rising liquid but, instead, was a typical semi-explosive, flinging fountain. Fifty feet northeast of it a new small fountain played nearly continuously, and 100 feet farther northeast another played spasmodically. Around the fountain group concentric waves spread out in the crust of the lake over a radius of 500 feet. A slump scarp 10 to 15 feet high had formed around most of the circumference of the lake, a few feet to 50 feet from its margin, owing to shrinkage of the central part of the lake.

At 3 P.M. the fountains near the southwestern wall had become small and sporadic, but a new fountain just northeast of them, about 300 feet from the southwest wall, was playing to an average height of 150 feet. The amount of gas being given off had increased greatly. The northeast fountains remained about the same as they had been at noon, but about 600 feet southwest of them a prominent sinkhole had developed. Lava streamed toward it from all directions. As it was drawn toward the sinkhole, the crust was broken and torn apart, and, as the fragments reached the sink, they tilted on edge and plunged beneath the surface. Small sporadic fountains played in the sinkhole.

At many other places on the lake the crust was rifted open from time to time, often repeatedly along the same line. There, also, crust fragments were drawn in, tilted up, and plunged under. Generally, this was followed by a row of tiny fountains, lasting only a few seconds, over the place where the crust fragments disappeared.

During the evening of June 28 the fountain 300 feet from the southwest wall continued to grow, until by midnight it was playing steadily to heights around 150 feet, with occasional flings reaching 300 feet. Late in the evening a very active sinkhole developed at the southwestern edge of the lake over the course of the eruptive fissure. A river of lava about 25 feet wide flowed into it from the area of the nearby fountains, and small edge fountains played sporadically in and around it. The northeast sinkhole continued active.

By midnight the vents at the northeast edge of the crater had built narrow-throated conelets and were blowing explosively with loud booming noises, and throwing showers of ejecta to a height of 150 feet. Banners of pale-blue flame 5 to 15 feet long played intermittently over the mouth of the conelets.

Activity continued much the same through June 29 and 30. By noon of June 29, the slump scarp around the edge of the lake had been reburied, and a bench of semi-solid pahoehoe crust was beginning to grow around the edge, gradually restricting the size of the central lava lake. The bench was at about the same level as the general surface of the lake, and as the level of the latter slowly rose during the succeeding days, repeated small overflows moved out across the bench from the edge of the lake, or from fractures within the bench itself. From time to time fragments as much as 150 feet across became detached from the bench and formed islands in the lake. These islands moved across the lake toward the fountains, presumably carried along by a return circulation in the lower part of the lake. They appeared, however, to be floating, rising and falling with the level of the liquid around them.

The two prominent sinkholes continued active. Directly following the engulfment of especially large or numerous crust fragments fountaining within the sinks increased notably. However, these sinkholes appeared to be primary fountain vents in their own right as well. Small sporadic fountains played within the sink even when crustal foundering was not marked, and, from time to time, sinking gave place entirely to fountain action.

On June 29, sporadic fountains played along most of the length of the eruptive fissure southwest of the northeast sinkhole. Along this line lava moved slowly inward and sank, dragging the crust with it and producing a puckered cicatrice extending all the way from the northeast sinkhole to the big southwestern fountain.

By the afternoon of June 29, the conelet at the northeastern edge of the lake had grown to a height of about 50 feet. At 12:30 A.M. on June 30, a small glowing spot appeared on the eastern wall of the conelet, apparently caused by melting of the cone wall from within, and a few minutes later a small pahoehoe flow started to issue from this aperture. At 1:00 the walls of the conelet collapsed, liberating a small flood of very hot lava from the interior of the conelet. At the same time the northeast fountains increased in size from scattered showers of ejecta barely visible above the rim of the conelet to a strong jet about 150 feet high. The conelet quickly commenced rebuilding and by late afternoon had again nearly sealed itself. Similar activity occurred for the next several days, the cone alternately sealing nearly or completely over and reopening as the top, weakened by melting, collapsed. Occasional small flows spread over the crust bench near the conelet. The northeastern vents finally became inactive on July 6.

On June 30, a large fountain, averaging about 150 feet in height, was playing about 500 feet from the southwest edge of the lake, and on both sides of it along the line of the fissure were 16 smaller fountains (Fig. 1-B).

Early on June 29, a crust island about 150 feet across became detached from the marginal bench at the northern edge of the lake and moved slowly southward. On the evening of June 30, the island reached the main fountain area, about 800 feet northeast of the southwest sinkhole (Fig. 1-B). About 6:30 P.M. it moved over the northeasternmost small fountain and immediately started to disappear, partly by crumbling away at its edges and partly by foundering and being overflowed by fluid lava. The disintegration of the large island produced two small islands, which assumed positions just east and northwest of the principal fountain. By the night of July 1, these islands appeared to be grounded. Instead of rising and falling with the surrounding liquid, as they had previously, they remained essentially stationary. The liquid lava around them rose and fell with the surges from the fountains, alternately exposing and concealing a brightly glowing band at their bases.

The crust bench had gradually widened until by the afternoon of June 30 it was encroaching on the northeast sinkhole. On the afternoon of July 1, the sinkhole ceased to function and was replaced by a constant fountain 75 to 150 feet high. Spatter from this fountain accumulated on adjacent portions of the crust bench, and a small cone began to grow around the fountain. On July 2, the conelet was widely breached on the eastern side, and small flows from the fountains were moving over the bench nearby. On July 3, the conelet was about 20 feet high and possessed a rounded shape resembling that of a bee-hive. By July 4, the cone was nearly sealed in, and after that time it exhibited no more fountain activity.

On the morning of July 2, the activity of the southwestern sinkhole was weak. At 10:55 A.M. it suddenly reversed and became a large fountain that grew in size until, at 11:30, it was throwing ejecta regularly to a height of 200 feet and, rarely, as much as 300 feet (Fig. 5). At the same time, the central fountains increased in activity and became explosive, throwing rocket-like bursts as high as 250 feet. These bursts were accompanied by loud detonations. By mid-afternoon a large lava flow about 10 feet thick, was moving eastward from the southwest fountain along the base of the crater wall, and another was advancing northeastward between a pressure ridge on the crust bench and the central fountains. By 2:30 P.M. the whole central portion of the lake appeared to be heating up, and at 3:30 overflows from the lake were spreading over the marginal bench all around the northern and western sides. At 3:40 the southwest fountain abruptly stopped, then

spurted up briefly three times—the last spurt occurring at 3:45 . It remained inactive for the remainder of the afternoon. At 7 P.M. its site was overflowed by a southwestward spreading of the lava lake. About 9 P.M. the sinkhole resumed sluggish activity.

At 5:30 A.M. on July 3, the southwest sinkhole again suddenly became a fountain which grew rapidly to a height of 400 feet. Again, as on the previous day, the central fountains became noisily explosive. The strong fountaining lasted until about 7 A.M., then died down until all activity was very weak. By 7:30 the southwest sinkhole was again in sluggish operation, and the central fountains were gradually regaining their former size. Conditions continued much the same for the remainder of the day.

Weak sporadic fountaining began again at the southwest sinkhole at 10:15 P.M. By 10:40 the height of the fountain had increased to 100 feet, and by 11:45 it had reached 400 feet. Ranger Elroy Bohlin reported that the fountain continued big until 3:30 A.M. on July 4, playing steadily, like a jet of water from a hose, to heights of about 400 feet. Occasional bursts went above the rim of the pit—a height of more than 600 feet. Pumice fell on the road at the southwestern edge of the caldera. This was the strongest fountain activity after the first few hours of the eruption. As in the previous spasms, the central fountains were very noisy, sending long rocket-like strings of molten lava high into the air. The whole central lake and part of the marginal bench were inundated by new flows. At 3:30 both the big southwest fountain and the central fountains suddenly died down, nearly disappearing within a few minutes.

Through the morning of July 4, the southwest sinkhole was alternately moderately active and sluggish. About 3 P.M. it again became a fountain, which, by 3:30, was reaching heights similar to those of the night before. Again, the central fountains also became very active, shooting long string-like "rockets" as high as 250 feet, with loud detonations. Balloon-like balls of lava as much as 20 feet in diameter rose in the central fountain pits until they appeared to be almost detached from the underlying lava, then burst to release a large puff of pale-brown gas. The strong activity was short lived, and by 4:15 P.M. activity had returned to normal. Still another flare-up of the southwestern fountain occurred at 4 A.M. on July 5, but the fountain reached a height of only 200 feet. After that, no further big increases of the southwest fountain occurred, though for several days conditions there alternated between sinkhole and fountain activity.

The bench of semi-solid pahoehoe around the edge of the crater gradually widened, decreasing the area of the central lake of fluid lava (Fig. 1-B). On the morning of June 28, the lake extended from wall to wall of the crater and had an area of approximately 100 acres. By July 1, the bench at the north side ranged from 400 to 700 feet wide, and the area of the lava lake had been reduced to 68 acres.

CONE-BUILDING PHASE

During the first few days of the eruption, the deep pool of fluid lava around the central fountains offered no place for the accumulation of fountain ejecta, and cone building was impossible. By the night of June 30, however, there appears to have been a sufficient accumulation of pasty material in the lower part of the lake to support the crust islands on the two sides of the fountains. Spatter from the fountains accumulated on the islands, initiating the cone-building phase of the eruption. Building was slow at first, and by the morning of July 5 the island just west of the central fountain had been built up to a height of only 25 feet, partly because the underlying material was not strong enough to support it and allowed it to sink to some extent as it built up. Further evidence of the mobile character of the lake bottom is seen in the gradual southwestward shifting of the island along the edge of the fountain chain.

During the next few days, as the islands grew in height, they occasionally became unstable. The lower portion on the side toward the fountain was prevented from building and even was eaten away by the fluid lava surging against it. As the upper portion accumulated more and more spatter, the face toward the fountain became very steep, or even overhanging. Sometimes this unstable condition was relieved by a slumping off of the steep face, but at other times the entire island leaned slowly fountainward, rocked majestically in the surge, and eventually rolled slowly over.

On the afternoon of July 7, an arcuate rampart of spatter 150 feet long and 20 feet high had formed on the east side of the principal fountain, and a similar one appeared on the southwest side. By July 9, the substratum of the lake had become sufficiently firm to consistently support the accumulations of spatter that grew around the fountains, and the true phase of cone building began. By July 10, the cone surrounding the main central fountain was 30 to 50 feet high, and lava streams were spilling through gaps in it eastward and northward. The average height of the fountain within the cone was about 50 feet, but some bursts went as high as 200 feet. Southwest of the main fountain, smaller fountains were building a row of low spatter cones.

On July 5, a steep-sided wall of spatter (a so-called lava ring) started to form around the edge of the lava lake, and by July 6, the lake stood about 10 feet above the surrounding bench. At the southwestern edge of the crater floor a small, nearly circular lake 300 feet across behaved somewhat independently from the main lake. This lake was fed by the large southwest fountain at the site of the former sinkhole and a group of smaller associated fountains. Usually, the latter were arranged along an arc, concave to the northeast, extending northwestward about 75 feet from the large fountain. The southwest lake was enclosed in its own lava ring and, on the morning of July 6, stood about 10 feet above the level of the main lake.

Occasional overflows of both the main lake and the southwest lake sent tongues of lava onto the marginal bench. These overflows gradually raised the level of the

bench. As the eruption progressed, it became evident, however, that only a small part of the rise of the marginal bench was the result of overflow of lava onto its surface. Even when no overflow occurred, the bench rose at a rate approximately equal to the rise of the central lava lake. Obviously, the rise of the bench must have been caused largely by the addition of plastic material beneath it. This may have resulted from an isostatic adjustment whereby the increasing depth of the lake caused the still mobile substratum to flow outward and elevate the bench—a process that was really nothing more than the tendency of a fluid mass, however viscous, to assume a uniform surface level.

On July 12, the cone around the main central fountain was about 60 feet high, and lava rivers spilled from it both eastward and westward to feed the main lava lake. Another cone was forming around a slightly smaller fountain about 300 feet farther southwest. From this cone a lava stream escaped southward, then turned northeastward to join the lava from the larger fountain (Fig. 1-C). The southwestern pool was a true independent lava lake with a constant sinkhole at its northeastern edge around a permanent fountain, and a gradual outward movement of the lava all over the surface from the source fountains to the edge. Occasional crustal foundering and marked downflow occurred at various points all around the rim, followed by evanescent rim fountains.

Over the next few days, the two central cones grew in diameter until, by July 14, they coalesced, though the southern fountain pit remained isolated from the larger northern one. On July 17, the wall between the two pits broke down, and the central cone became a single structure having a fountain pit elongated southwestward and containing both the large central fountains. Flows continued to spill from it southward, westward, northeastward and eastward, feeding the surrounding lava lake (Fig. 6). The lake had an area of 30 acres and was very active. Currents of lava moved outward from the gaps in the cone to the edge of the lake, where they plunged downward, carrying with them fragments of the crust. Crustal engulfment occurred occasionally over all the lake surface but was commonest at two general locations, namely, at the edge of the lake, and along lines where flows from different gaps in the cone merged. The engulfment of each large crust fragment was followed by small short-lived fountains. At the edge of the lake the accumulation of spatter from these fountains built the lava ring, which, in succeeding weeks, confined the liquid of the lake at a level as much as 20 feet above the adjacent marginal bench.

On July 15, a small fountain at the northern edge of the southwest lake had built a beehive-shaped cone 30 feet high. The southwest fountains had, however, become very weak, and on July 16 the main lake overflowed into the southwest lake (Fig. 1-C). The southwest fountains again became strong on July 18, and continued active until July 22. On July 23, however, they became small and sporadic, and after July 24 they disappeared altogether, leaving the south lake as a lobe of the main lake fed by lava streaming southward from the central fountains.

A general overflow of the main lava lake began at 12:15 on July 20, and continued until midnight. Flows moved outward across the bench to, or nearly to, the crater walls on the northwest, north, and northeast sides, completing the obliteration of the cones at the former northeast sinkhole and the foot of the northeast talus, which had been partly destroyed already by collapse and burial by new lava.

On July 29, several small flows issued along the edge of the bench at, or close to, the wall of the crater. The molten lava apparently rose along the boundary of the new lava plug in the bottom of the crater. These were the first of several similar flows at intervals during most of the remainder of the eruption.

Activity continued essentially the same until August 7. The average size of the central fountains decreased to about 40 feet, but their explosiveness increased somewhat, and occasional explosive bursts reached great heights. Northrup Castle reported that, about midnight on August 5, one explosive burst from the northerly of the two fountains reached a level above the rim of the crater. Similar bursts were observed at 7:45 P.M. on August 6, and 8:30 P.M. on August 7. These bursts reached a height of about 550 feet. The greater explosiveness may have resulted from some increase in viscosity of the escaping lava. A gradual decrease in the amount of lava being poured out caused a retreat of the margins of the lava lake, which, between August 1 and 7, moved inward 50 to 75 feet.

The cone reached its maximum development early in August. On August 11, it was 65 feet high and approximately 800 feet in basal diameter.

DECLINING PHASE OF THE ERUPTION

There now began a period of fluctuating but gradually decreasing lava output. An apparent decrease in the amount of superheat in the lava caused a tendency to increased viscosity and clogging of the vents. On August 9, the southern gap in the cone became clogged, and the north and northeast lava rivers increased greatly in volume, plunging over spectacular cascades as much as 20 feet high. On August 11, the south river became re-established, and the east river was blocked by a partial collapse of the adjacent cone wall. By August 12, the east river was flowing again, but the northeast river had, in turn, been choked off. On August 13, the west and south rivers became inactive. Cessation of the south river was followed by draining of the southern lobe of the lava lake, leaving a broad basin about 20 feet deep with a nearly flat irregular floor. On August 18, lava overflowed the south wall of the cone and re-established the south river, refilling the basin.

Late in the evening of August 18, the northern of the two central fountains decreased greatly in size, and by midnight it showed no signs of activity. It returned early on August 19, but remained small for several days. By August 22, both fountains averaged about 20 feet high, with some showers of glowing ejecta reaching heights of 200 feet.

On August 23, lava was no longer flowing from the central cone, and the lava lake surrounding the cone had become inactive. The two fountains were small and sporadic, throwing showers of glowing fragments as high as 150 feet. Around themselves they had built beehive-shaped conelets of spatter 20 feet high within the crater of the cinder cone, and a nearly circular lava lake about 120 feet in diameter had formed nearly between the two conelets. This condition persisted throughout the remainder of the eruption (Figs. 1-D, 7).

By August 25, activity had become very weak, but on August 29 it began to regain its strength. In early September, it was again spectacular; loud roaring and whistling gas release accompanied explosive bursts that threw showers of glowing cinders to heights of 150 to 200 feet. On the night of September 2, small glowing spots appeared on the floor north and east of the central cinder cone, and by the morning of September 3 two flows were issuing at those localities and spreading sluggishly over the adjacent floor. The northerly flow was fed by a tiny fountain spurting 5 or 6 feet into the air about 400 feet north of the north central conelet.

From September 1 to 18, the more northerly of the two central vents was the more active, and its conelet gradually grew to a height of 50 feet, overtopping the rim of the surrounding cinder cone. Throughout this period the lava at the surface of the small lava lake flowed slowly from the north to the south edge, where it sank, producing fountains 10 to 15 feet high against the south bank. On September 19, the activity of the two conelets became reversed, with the southern one the more active. Simultaneously, the lava in the lake reversed its movement, rising at the southern edge to flow northward and sink along the north bank. Spatter from the edge fountains and occasional small overflows had built up a low, flat cone around the lake, the surface of which stood about 20 feet higher than the surrounding floor of the crater of the cinder cone.

At 1:45 A.M. on September 20, lava started to spill over the southern rim of the lake. The overflow increased rapidly in volume, breaking down the southern wall of the lava cone containing the lake and sending a big flow over the southern part of the floor of Halemaumau. At 10:12 A.M. the northeastern rim of the lake also was overflowed, and a second flow spread out to coalesce with the first one east of the cinder cone. The northeastern overflow lasted only a few hours, but the southern one continued until about midnight. This was the most voluminous single outpouring of lava after August 22.

On September 22, the northern central vent again become dominant, and again the circulation in the lava lake reversed, returning to its first direction of movement from north to south. Explosive activity at the southern conelet ceased entirely, and for the remainder of the eruption the conelet fumed quietly.

The northern conelet gradually built up to a height of 65 feet, and by September 26 its top was nearly sealed over. On that afternoon, at about 4 o'clock, the top and part of the northeastern side of the conelet suddenly were blown off. Charles Bell reported that three or four explosive bursts of ejecta reached heights of about 400 feet. This was accompanied and followed by violent oscillation of the lava in the lake, the level of which rapidly dropped about 15 feet. Within a few minutes both the lake and the conelet had returned to their normal state of activity, with bursts from the conelet reaching heights of 100 to 150 feet.

A similar series of events occurred on the evening of September 27. At 8:35 P.M. a series of about a dozen violent blasts that threw incandescent cinder to a maximum height of about 550 feet suddenly commenced at the north conelet. The surface of the lava lake surged violently, and following the explosions its level gradually dropped about 15 feet, revealing glowing grottoes hung with fringes of stalactites in the banks. As on the previous day, activity returned to normal within a few minutes.

Throughout the month of September, small flows continued to issue from time to time on the floor of Halemaumau outside the central cinder cone. These welled up quietly, with very small fountains at their vents, or none at all, and very little evidence of gas liberation. Two on September 4 have already been mentioned. On September 5, another appeared on the floor northwest of the cinder cone, and still another issued at the foot of the western wall of Halemaumau. Small flows issued on the floor southeast of the cone on September 8, northeast of the cone on September 12, at the western wall on September 16, both northwest and northeast of the cone on September 17, and at the foot of the northwestern wall on September 27. On the night of October 3, a flow broke out at the foot of the southwestern wall of Halemaumau and spread rapidly around the edge of the crater floor for a distance of 2,200 feet. The final edge flow of the eruption broke out at the foot of the southeastern wall of Halemaumau on the afternoon of October 12 and continued until October 15, eventually extending halfway around the crater, a distance of 4,600 feet (Fig. 1-D).

During the first half of October, the lava lake and the north central conelet continued active, the latter throwing frequent sporadic showers of glowing ejecta to heights of 50 to 100 and, rarely, 200 feet. On the afternoon of October 5, a series of explosive bursts similar to those of September 25 and 27 reached a height of 450 feet. Surface circulation in the lava lake continued from north to south. Fountains up to 15 feet high formed along the southern bank, where crusts were being carried down by the descending liquid, and other smaller fountains appeared from time to time at the northern edge.

Throughout the last two weeks of October, the northern conelet was largely sealed over, and only occasional small bursts of glowing fragments could be seen. The cloud of gas liberated at the conelet became markedly more conspicuous, denser, and white in color, in contrast to the thin, bluish fume liberated in earlier stages with a more open vent. At night, banners of pale blue or yellowish flame as long as 25 feet flickered over the conelet.

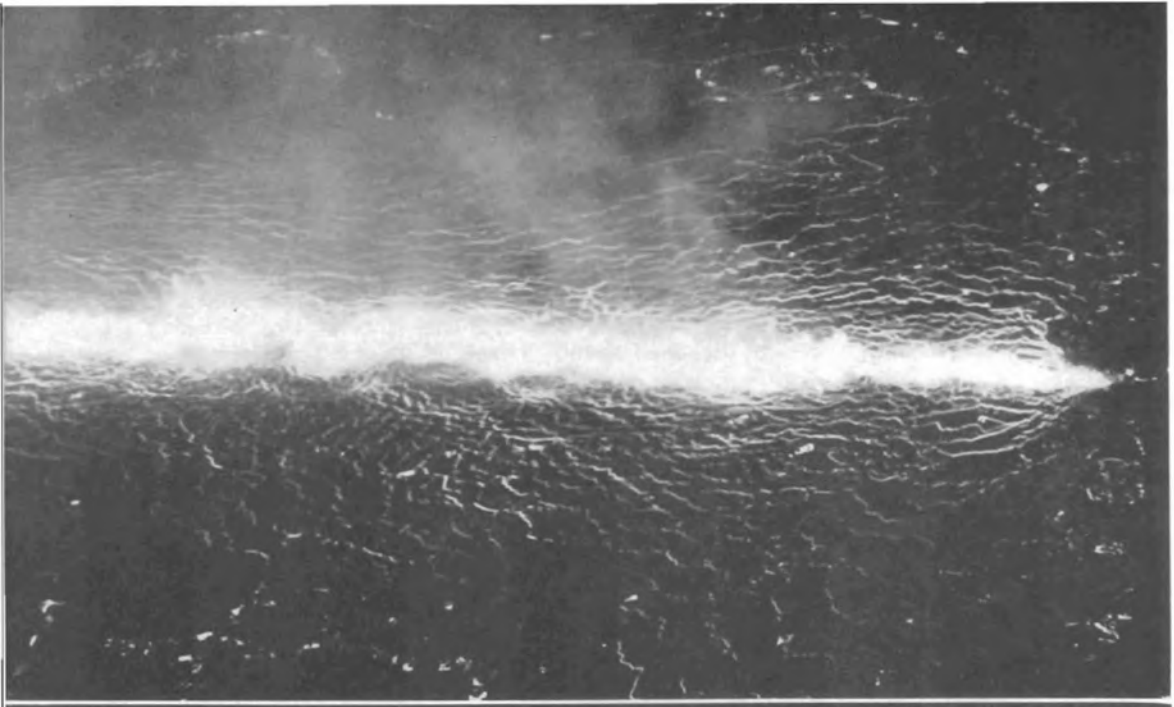

FIGURE 2. Lava fountains along the fissure in the northeastern portion of Halemaumau and brightly glowing cracks in the thin crust of the liquid lava lake, at 3 A.M. on June 28. The fountains range from about 20 to 50 feet high. Waves in the liquid can be seen near the fountains. Photo by C. K. Wentworth.

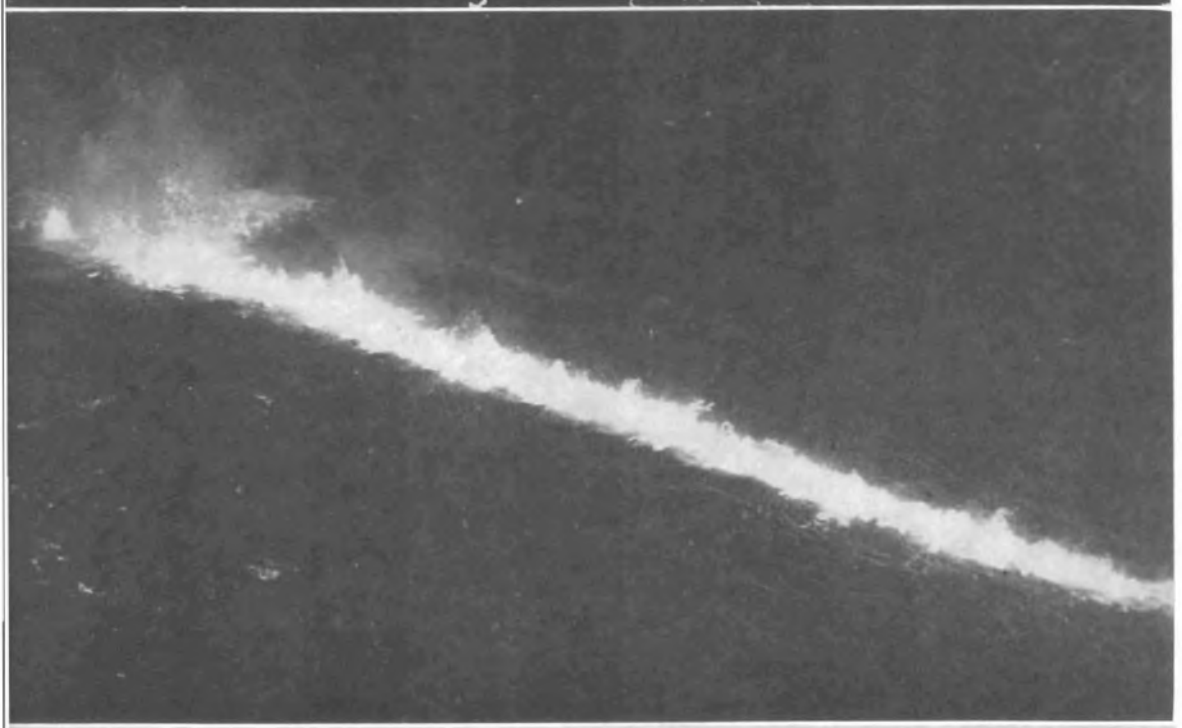

FIGURE 3. Lava fountains along the fissure across the southwestern portion of the floor of Halemaumau, at 2:15 A.M. on June 28. The large fountain at the left-hand edge is the big southwestern fountain, which had then decreased in height to about 150 feet.



FIGURE 4. The lake of liquid lava and the fountain at the southwestern edge of Halemaumau at 7:20 A.M. on June 28. The fountain is about 50 feet high. Waves in the lake are clearly visible.

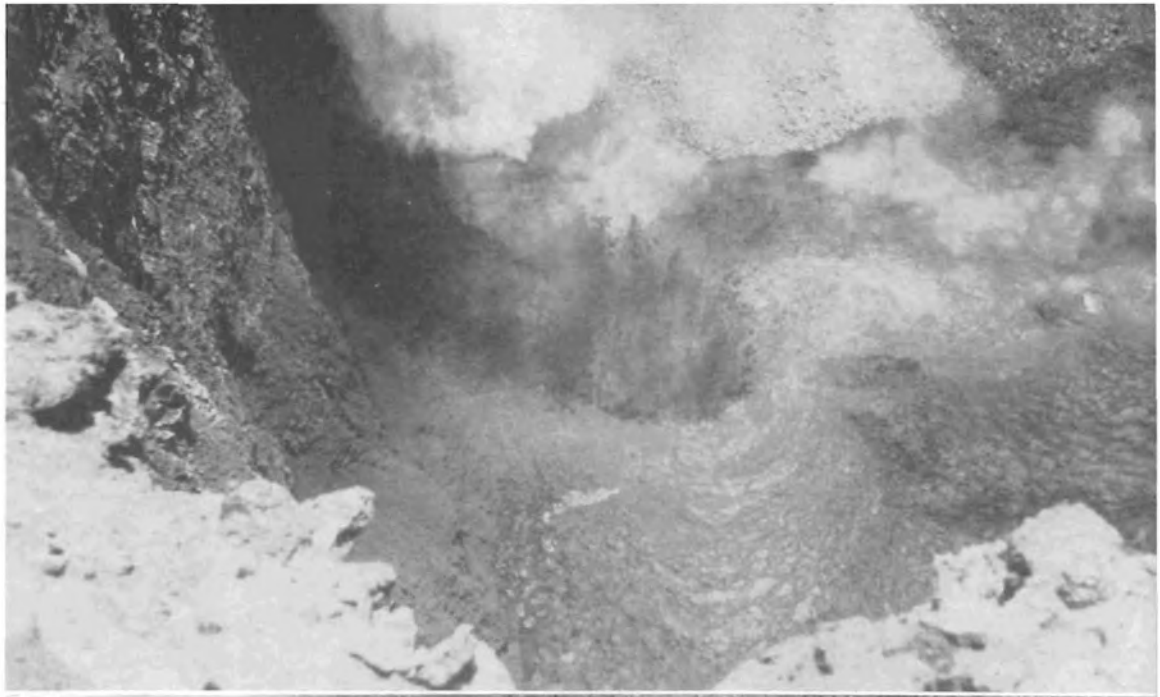

FIGURE 5. Lava fountain about 150 feet high at the southwestern edge of Halemaumau, at 11:15 A.M., July 2.



FIGURE 6. Lava fountains and cinder cone in Halemaumau on July 22. Rivers of lava are pouring out through gaps in the cone. The marginal bench along the western side of the crater floor is visible in the background. The highest cone segments are about 50 feet high.



FIGURE 7. Small spatter and cinder cones and lava lake in the crater of the large cinder cone, on September 9, looking westward from the southeast rim of Halemaumau. Comparison of the western wall of the crater with that shown in Figure 6 gives some indication of the amount of rise of the floor during the interval between the two photographs.

The end of October brought a brief revival of activity. On the night of October 31, the upper portion of the northern conelet collapsed, decreasing the height of the conelet from 65 to 35 feet, and big lava fountains veneered the outer slopes of the conelet with a thin layer of liquid spatter. On the next night, a further collapse of the conelet reduced its height to about 25 feet and broadened its wide-open crater to a diameter of about 90 feet. Lava overflowed the crater rim, completely covering the outer slopes of the conelet and extending thin flows to a point just beyond the northern edge of the cinder cone. On the south side of the conelet the flow spilled into the lava lake. With the reopening of the vent the gas cloud became thin and bluish again. As throughout much of the eruption, heat from the crater caused a convectional rise of the air above it, and condensation formed an often conspicuous cap of cumulus cloud two or three thousand feet above the crater rim.

Another overflow of the conelet, similar to that of November 1, occurred at about 10 P.M. on November 6. Within a few minutes a thin sheet of lava had covered the slopes of the conelet and the immediately adjacent region. The area of the overflow was estimated by C. K. Wentworth to be approximately 5 acres. Through early November, a small lava fountain was visible in the crater of the conelet. The fountain was generally only 15 or 20 feet in height, but it threw spasmodic bursts to heights as great as 150 feet.

The last activity of the lava lake was observed on November 9, and the last fountain activity on the morning of November 10.

Considering the eruption to have ended on November 10, its duration was 136 days. Glowing spots continued to be visible in the lava lake and north conelet until November 11, and at the south conelet and at solfataras on the crater floor northwest and south of the big cinder cone until November 18. At the end of 1952, moderate amounts of pale bluish-gray fume were still issuing at these solfataras.

THE LAVA

The total volume of the new lava fill in Halemaumau is approximately 64,000,000 cubic yards, and its average thickness is approximately 310 feet. The average depth to the crater floor from the visitors' observation area at the southeast rim of the crater is 460 feet. Figure 8 shows progressive stages in the filling of Halemaumau.

The only specimens of the erupted lava recovered are pumice. The latter has not yet been analyzed chemically, but it is basaltic in character, the refractive index of the glass being 1.598 ($\pm$.003).

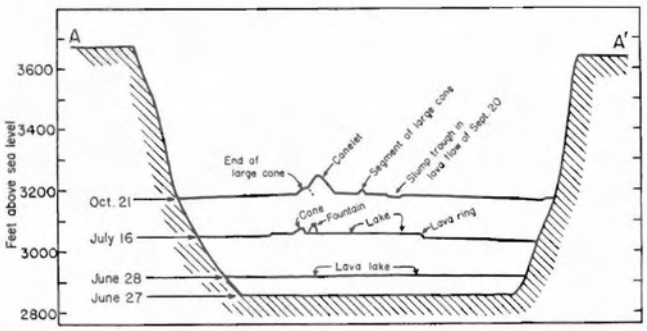

FIGURE 8. Profile across Halemaumau along line A-A′ in figure 1-A, showing successive levels of the crater floor just preceding and during the 1952 eruption. The vertical scale is twice the horizontal.

The temperature of the lava fountains was measured repeatedly with an optical pyrometer of the disappearing dot type. The reading on the hot core of the big fountains during the first month of the eruption ranged from 1030° to 1055° C., depending at least partly on the distance of the observer from the fountain. To these readings should be added a correction of about 20° for light absorption by the lava and, probably, a correction of 10° to 30° because of the fairly large distance from which readings were obtained. The actual temperature of the fountains appears, therefore, to have been in the vicinity of 1080° C. Early in August, the temperature of the fountains started to decrease. By mid-August, the corrected temperature had dropped to about 1050° C. and, by late August, to 1040°. Corrected temperature readings on active lava flows ranged from about 1030° to 920°.

The radioactivity of the erupted lava appears to have been low. Two samples of pumice ejected respectively during the first night of the eruption and at 6 A.M. on July 3, analyzed by the U. S. Geological Survey in Washington, D. C., each contained less than 5 parts per million of uranium equivalent.

ACKNOWLEDGMENTS

Many persons have contributed information on the eruption. It is impossible to mention all by name, but to all we extend our sincere thanks. Without their help it would not have been possible for the small staff of the Volcano Observatory to obtain so complete a record of the eruption. The staff of Hawaii National Park was especially helpful.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR OCTOBER–DECEMBER, 1952

By GORDON A. MACDONALD

VOLCANOLOGY

October

Kilauea Volcano continued active throughout the month of October. An account of the activity has been given in the foregoing pages.

Mauna Loa continued somewhat restless throughout October. During the month seismograph stations at the rim of Kilauea Caldera recorded 77 earthquakes, and the Mauna Loa seismograph recorded a total of 187. On October 24 and 25 the Mauna Loa instrument recorded 165 very small earthquakes originating on the northeast rift zone. Northeastward tilting of the ground at the seismograph station on the northeastern rim of Kilauea Caldera was at a rate somewhat greater than the normal, suggesting some increase of pressure beneath Kilauea and, probably, also beneath Mauna Loa.

November

The last visible lava activity in Halemaumau was on November 10. Small glowing spots continued to be visible on the crater floor until November 18. For the remainder of the month there were no signs of molten lava, and the only activity was the quiet liberation of pale bluish-gray fume at spots on the floor just south, west, and northwest of the big cinder cone. Steam issues from the talus banks at the foot of the eastern and southwestern walls of the crater, and at the top of the 1919 fissure in the southwestern wall.

Throughout November, tilting of the ground at the northeastern rim of Kilauea Caldera was northeastward at a rate approximately normal for that season of the year. This appears to indicate that there was little or no withdrawal of the molten lava, with an accompanying decrease of pressure, beneath Kilauea. Brief periods of volcanic tremor on November 19 and 29 are interpreted as indicating movement of the lava beneath the caldera. The liquid level probably still stands at a high level beneath Halemaumau, and, so long as this condition persists, lava activity may return to Halemaumau at any time with little or no warning.

Most of the earthquakes recorded during November had their origins in Kilauea Volcano. The uneasiness manifested by Mauna Loa during October did not continue. Seismographs at Kilauea Caldera recorded 56 earthquakes during the month, while the Mauna Loa seismograph recorded only 23. Several earthquakes originated in central Kona, probably on the Kealakekua fault near Napoopoo, and a few of them were felt by some persons in Kona. At 22:13 on November 27, a slight earthquake originated just west of the summit of Mauna Loa.

December

Hawaiian volcanoes were quiet throughout the month of December. Vents on the floor of Halemaumau continue to liberate moderate amounts of pale bluish-gray fume. On the morning of December 11, Ernest Morton, manager of the Kahuku Ranch, reported large clouds of steam in the vicinity of the vents of the 1950 lava flows at about 10,000 feet altitude on the southwest rift of Mauna Loa. The unusually prominent steam clouds probably resulted from unusually good visibility and high atmospheric humidity and low temperature, causing condensation.

Seismographs at Kilauea Caldera recorded 47 small earthquakes during December, and the Mauna Loa seismograph recorded 22. Several earthquakes originated in central Kona, probably on the Kealakekua fault. A few of these, together with the quake of November 27, appear to have had their foci along a line extending westward from the summit of Mauna Loa toward Kealakekua Bay and may have been caused by some shifting along the fracture along which occurred the eruption of 1877.

On December 10, at 18:01, a small earthquake was felt at Naalehu. This quake originated near the summit of Mauna Loa. On December 12, a quake, felt at 9:09 both in Naalehu and the Volcano district, originated on the Kaoiki fault about 9 miles southwest of Kilauea Caldera. A moderate earthquake, at 1:21 on December 28, appears to have had its origin beneath the summit of Hualalai.

Through most of December the ground surface at the northeastern rim of Kilauea Caldera tilted gently southwestward. The change from northeastward to southwestward tilting took place about a month earlier than usual. However, the time of reversal is rather variable from year to year, and the rate of tilting through December was about normal for the period following the usual seasonal reversal. Thus, there still appears to be little or no indication of decrease of volcanic pressure beneath Kilauea.

SEISMOLOGY

Earthquake Data, October–December, 1952

(Based on Bosch-Omori seismograph on northeast rim of Kilauea Caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
Oct. 5	†	12	0	0	0	0	6.0	0
12	†	8	0	0	0	0	4.0	0
19	†	6	1	0	0	0	4.0	0
26	†	7	0	0	0	0	3.5	0
Nov. 2	†	6	0	0	0	0	3.0	1
9	8	3	0	1	0	0	5.5	0
16	10	3	0	2	0	0	8.0	0
23	2	2	0	1	0	0	3.5	1
30	7	4	0	0	0	0	3.75	0
Dec. 7	8	5	1	0	0	0	5.5	0
14	8	2	0	0	0	0	3.0	0
21	4	1	0	0	0	0	1.5	0
28	9	3	1	0	0	0	4.75	0

* For definition of local seismicity see Volcano Letter 371 or 512. Each local earthquake is assigned a seismicity value according to its strength, as follows: tremor, 0.25; very feeble, 0.5; feeble, 1.0; slight, 2.0; moderate, 3.0; strong, 4.0. These values are totaled to give the weekly local seismicity. Continuous volcanic tremor is ignored in the calculation. The strength assigned to the earthquake depends on the double amplitude of the maximum oscillation it causes on the Bosch-Omori seismograph, as follows: tremor, less than 0.5 mm.; very feeble, 0.5 to 4 mm.; feeble, 4 to 11 mm.; slight, 11 to 25 mm.; moderate, 25 to 60 mm.; strong, greater than 60 mm.

† Continuous tremor.

Table of Tilt at Seismograph Vaults on Rim of Kilauea Caldera

Week Beginning	Whitney Vault (Northeast rim)		Uwekahuna Vault (West rim)	
	Amount	Direction	Amount	Direction
October 5	2.9″	N 22° E	1.2″	S 34° W
12	1.0″	N 69° E	4.7″	N 20° W
19	2.1″	N 13° E	1.2″	N 34° W
26	0.9″	N 23° W	2.6″	S 7° E
November 2	0.5″	S 27° E	1.4″	N 27° W
9	1.0″	N 7° E	0.3″	S
16	0.3″	S 45° E	0.3″	E
23	1.5″	N 18° W	1.0″	S 18° W
30	0.7″	N 81° W	0.3″	E
December 7	1.2″	S 18° E	0	.....
14	1.0″	S 83° W	1.6″	S 11° E
21	0.2″	W	1.2″	S 34° E
28	1.7″	S 16° E	1.4″	S 27° E

Distant Earthquakes

The following earthquakes of distant origin were recorded on the seismographs of the Hawaiian Volcano Observatory. Locations of the epicenters are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey. The time given is that of the first detectable emergence of the quake on the Bosch-Omori horizontal or Sprengnether vertical seismograms, in Hawaiian Standard time.

Nov. 4, 07:07, very strong. Near southern end of Kamchatka Peninsula. Accompanied by a tsunami that did moderate damage in the Hawaiian Islands.

Nov. 29, 14:03, slight. Off southern coast of Alaska Peninsula, at 56° N., 155° W.

Local Earthquakes

The data for the following local earthquakes were determined from seismographs operated on the island of Hawaii by the Hawaiian Volcano Observatory. Locations given are epicenters. The times given are arrival times at the Whitney Laboratory of Seismology, on the northeast rim of Kilauea Caldera. They are stated to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich Civil time. The number preceding each earthquake is the serial number for the current year. The intensity rating (Feeble, Moderate, etc.) given is that for the Whitney Laboratory. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney station.

2128. Oct. 2, 10:04, very feeble.
2129. Oct. 3, 12:12, feeble (Mauna Loa, slight). Felt at Naalehu and Kapapala.
2130. Oct. 4, 02:56, very feeble.
2131. Oct. 4, 18:32, very feeble.
2132. Oct. 5, 14:29, very feeble.
2133. Oct. 5, 16:14, very feeble.
2134. Oct. 7, 11:40, very feeble.
2135. Oct. 7, 11:54, very feeble.
2136. Oct. 8, 00:04, very feeble.
2137. Oct. 8, 05:20, very feeble.
2138. Oct. 8, 14:40, very feeble (Mauna Loa, feeble).
2139. Oct. 8, 18:59, very feeble.
2140. Oct. 9, 15:35, no record at Kilauea (Hilo, feeble).
2141. Oct. 9, 17:46, very feeble.
2142. Oct. 10, 14:14, very feeble.
2143. Oct. 11, 05:14, very feeble.
2144. Oct. 11, 19:42, very feeble.
2145. Oct. 12, 13:42, very feeble.
2146. Oct. 13, 21:53, no record at Kilauea (Mauna Loa, very feeble).
2147. Oct. 13, 23:36, very feeble.
2148. Oct. 14, 07:30, very feeble.
2149. Oct. 14, 11:52, no record at Kilauea (Mauna Loa, very feeble).
2150. Oct. 14, 21:58, no record at Kilauea (Kona, very feeble). Central Kona.
2151. Oct. 15, 06:55, very feeble.
2152. Oct. 16, 14:31, very feeble.
2153. Oct. 16, 15:37, very feeble.
2154. Oct. 18, 02:47, very feeble.
2155. Oct. 18, 17:02, very feeble. Felt at Kapapala. Kaoiki fault near Wood Valley (?).
2156. Oct. 18, 21:17, very feeble.
2157. Oct. 20, 11:25, very feeble.
2158. Oct. 21, 07:23, very feeble.
2159. Oct. 22, 01:45, no record at Kilauea (Kona, feeble).
2160. Oct. 22, 10:10, very feeble.
2161. Oct. 22, 16:39, feeble. Kaoiki fault near Bird Park (?).
2162. Oct. 23, 14:11, very feeble. Kilauea.
2163. Oct. 24, 15:00, very feeble.
2164. Oct. 25, 09:25, very feeble (Kona, slight). Felt in Kona. Central Kona.
2165. Oct. 25, 14:30, tremor (Mauna Loa, very feeble).
2166. Oct. 25, 14:44, tremor (Mauna Loa, very feeble).
2167-2175. Oct. 25, very feeble earthquakes at Mauna Loa; at other stations tremors or no record.
2176-2184. Oct. 26, same.
2185-2186. Oct. 27, same.
2187. Oct. 29, 13:39, very feeble.
2188. Oct. 30, 05:15, no record at Kilauea (Kona, very feeble).
2189. Nov. 1, 01:23, very feeble.
2190. Nov. 1, 14:11, very feeble.
2191. Nov. 2, 02:57, very feeble.
2192. Nov. 5, 12:49, very feeble. Southwest rift of Kilauea (?).
2193. Nov. 7, 22:21, very feeble.
2194. Nov. 8, 18:33, very feeble.
2195. Nov. 9, 16:56, very feeble.
2196. Nov. 10, 21:42, very feeble (Kona, moderate). Felt in Kona. Central Kona.
2197. Nov. 12, 08:05, very feeble.
2198. Nov. 12, 10:43, very feeble.
2199. Nov. 12, 17:43, very feeble.
2200. Nov. 13, 12:28, slight. Off south coast.
2201. Nov. 13, 12:54, no record at Kilauea (Kona, feeble). Central Kona.
2202. Nov. 13, 14:57, tremor (Kona, very feeble).
2203. Nov. 16, 02:40, very feeble.
2204. Nov. 16, 02:41, slight. Off south coast.
2205. Nov. 16, 09:49, very feeble.
2206. Nov. 18, 00:39, no record at Kilauea (Kona, very feeble).
2207. Nov. 19, 03:27, very feeble.
2208. Nov. 20, 10:19, very feeble. Kilauea.
2209. Nov. 22, 01:08, slight. East rift of Kilauea near Alae Crater, depth about 13 miles.
2210. Nov. 23, 18:31, very feeble.
2211. Nov. 27, 16:35, very feeble (Kona, feeble). Felt in Kona. Central Kona.
2212. Nov. 27, 22:14, slight. Felt in Kona. Near summit of Mauna Loa, 4 miles west of North Bay; 19° 29′ N., 155° 38′ W.
2213. Dec. 1, 00:30, very feeble.
2214. Dec. 1, 01:22, very feeble. Off south coast (?).
2215. Dec. 3, 01:12, tremor (Kona, feeble). Felt in Kona. West slope of Mauna Loa.
2216. Dec. 3, 09:10, no record at Kilauea (Kona, very feeble). Central Kona.
2217. Dec. 3, 20:03, no record at Kilauea (Kona, very feeble). Felt in central Kona.
2218. Dec. 5, 17:59, very feeble. Off south coast; 19° 06′ N., 155° 19′ W.
2219. Dec. 6, 09:45, very feeble. Kilauea.
2220. Dec. 7, 02:26, very feeble. West slope of Mauna Loa; at about 19° 28′ N., 155° 43′ W.
2221. Dec. 7, 11:12, very feeble.
2222. Dec. 8, 17:30, very feeble.
2223. Dec. 10, 18:01, very feeble. Felt at Naalehu. Near summit of Mauna Loa.
2224. Dec. 11, 01:06, very feeble.
2225. Dec. 12, 09:09, feeble. Felt at Naalehu and Volcano district. Kaoiki fault, south of Ainapo.
2226. Dec. 15, 18:47, very feeble. East rift of Kilauea near Puu Huluhulu, shallow.
2227. Dec. 15, 18:57, very feeble. Kilauea Caldera, 28 miles deep (?).
2228. Dec. 15, 21:11, very feeble.
2229. Dec. 17, 03:00, no record at Kilauea (Kona, very feeble).
2230. Dec. 21, 12:12, no record at Kilauea (Kona, very feeble). Central Kona.
2231. Dec. 22, 01:18, no record at Kilauea (Kona, very feeble).
2232. Dec. 23, 03:46, tremor (Kona, very feeble).
2233. Dec. 25, 00:10, very feeble. Felt in central Kona.
2234. Dec. 28, 01:22, very feeble (Kona, moderate). Felt in Kona. Beneath summit of Hualalai.
2235. Dec. 29, 20:55, no record at Kilauea (Kona, very feeble).
2236. Dec. 31, 16:00, tremor (Kona, very feeble). Central Kona.

THE TSUNAMI OF NOVEMBER 4

On November 4, 1952, a strong earthquake occurred off the southeastern coast of Kamchatka. The notice of Preliminary Determination of Epicenter issued by the U. S. Coast and Geodetic Survey gives the point of origin as 52½° N., 159° E., and the origin time as 16:58:20 Greenwich Civil time (6:58:20 Hawaiian Standard time).

The earthquake was recording on the Bosch-Omori seismograph when the record was changed at 7:45 A.M. The amplitude of the record produced was among the largest recorded at the Volcano Observatory. Quick inspection of the record indicated that it probably originated beneath the Pacific Ocean, or very close to its border, and, consequently, that it might be accompanied by a tsunami. The large size of the earthquake suggested that the tsunami might also be big.

At about 8 A.M. the Director of the Volcano Observatory notified the Hawaii Police Department in Hilo that the earthquake had occurred and suggested that they be alert for a possible "tidal wave" warning that would be issued by the Seismic Sea Wave Warning System of the Coast and Geodetic Survey. The statement was also made that it would be at least three hours from that time before the "tidal wave," if there was one, would reach Hilo.

By 9 A.M. further study of the local records and comparison of arrival times at mainland stations, received by wire from the Hilo Tribune-Herald, made it apparent that the quake had originated in the Kamchatka area and that, if a tsunami had been generated, it should reach Hilo about 13:30. Shortly afterward the actual wave warning was issued by the Coast and Geodetic Survey, based on reports of actual observed water waves.

The tsunami reached Hilo at approximately 13:30, as predicted. The record of the tide gage at Kuhio wharf shows that a rise of approximately 4 feet began at 13:32, bringing the water level to approximately 7 feet above mean lower low tide at 13:49. This was followed by a trough, bringing the water level to one foot below mean lower low tide at about 14:05. These extreme oscillations were followed by a series of diminishing oscillations, with an average period of about 17 minutes, that continued for the next several days. The dominant period of 17 minutes in these oscillations probably is approximately that of the harbor seiche.

Heights reached by the water on the Island of Hawaii were very much less than in the Aleutian tsunami of 1946. At Hilo the greatest heights measured were at Kuhio wharf, in Reeds Bay, and on Cocoanut Island. Water swept over the wharf to a depth of 11.5 feet above mean lower low tide. Near the head of Reeds Bay the high water mark ranged from 9 to 11 feet above the same datum, and on Cocoanut Island the greatest height was approximately 12 feet. Near the mouths of the Wailuku and Wailoa rivers the water reached a height of about 9 feet.

Both northward and eastward from Hilo the height reached by the water decreased rapidly, and east of Keaukaha estuary the rise was so small that it is not certain any occurred. The same condition prevailed along the southeastern, southern, and northeastern coasts of the island. Along the western coast the rise at most places ranged from 2 to 4 feet. On Hawaii, damage was restricted to the Hilo area.

Damage at Hilo included beaching of several sampans and rolling over of another on the ways in a boat-building yard; damage to buildings on Cocoanut Island and near the head of Reeds Bay; destruction of one span of the bridge to Cocoanut Island; flood damage at the Naniloa Hotel, at the wharf, and along the shore between the wharf and Reeds Bay; and destruction of a boat landing at the wharf.

Practically all of the damage observed in Hilo appeared to be the result of gentle flooding. No signs of violent impact, such as occurred in 1946, were seen. No sharp crest, or "bore" front, was reported in Hilo Bay, although an 18-inch bore was reported in the Wailoa estuary.

The boat landing, a house on a bar in Reeds Bay, and the span of the Cocoanut Island bridge appear to have merely been floated from their foundations. At least in part, the flooding from the wharf to the Wailoa River appears to have resulted from entrance of water to the portion of the bay confined by the breakwater both through the channel west of the end of the breakwater and also by flooding over the breakwater during crests of the tsunami faster than it could drain out again during troughs.

Large differences in pattern of the effects around the Island of Hawaii between the 1946 and 1952 tsunamis illustrate well the individuality of such waves, resulting from disturbances of different sizes, centering at different distances and in different directions. Such individuality makes extremely difficult prediction of the nature and size of the effects at any given locality, even when measurements are available from other areas nearer the point of origin of the waves. Many more observations, over a period of many years, will be necessary before accurate local predictions can be made, although the generally excellent operation of the Seismic Sea Wave Warning System in November, 1952, demonstrates that prediction of the general fact of the occurrence of a "tidal wave" of distant origin is now well in hand.

VOLCANO NOTES AND NEWS

DR. THOMAS A. JAGGAR

It is our sad duty to report the death of Dr. Thomas A. Jaggar, on January 17, 1953, just a week before his 82nd birthday. His loss will be keenly felt by the staff of the Volcano Observatory, and by the volcanological profession generally. Dr. Jaggar was the last of the great pioneers of volcanology as a true science. A future issue of the Volcano Letter will be devoted to a review of his work at the Hawaiian Volcano Observatory.

MYOJIN REEF

In mid-September, 1952, a volcanic eruption began in the southern Izu Islands a few miles north of the Bayonnaise Rocks and about 250 miles south of Tokyo. The following information on the eruption has been supplied by Dr. T. Minakami of the Earthquake Research Institute of Tokyo University, Drs. S. K. Neuschel and Helen L. Foster of the U. S. Geological Survey, and Dr. H. Niino of the Tokyo College of Fisheries.

The new islet, named Myojin Reef, is at 31° 56.8′ N. latitude and 139° 59.5′ E. longitude. The eruption was first observed by the crew of the fishing boat Myojin Maru on September 17. When the eruption was seen by Dr. Minakami, on September 18, explosions were occurring every few seconds in the main crater and several smaller craters, ejecting incandescent bombs, scoriae, and ash, together with heavy vapor. The island was estimated to be several hundred yards in diameter and to rise about 60 feet above sea level. Soon after that explosions and erosion by sea waves greatly reduced the area of the island above sea level, but when it was visited by Drs. Foster and Neuschel, on September 22, part of the mass still projected above sea level. A streak of yellow-colored water that extended many miles southward is believed probably to have been caused by finely comminuted rock debris.

On September 23, the Maritime Safety Board survey vessel No. 5, the Kaiyo Maru, was dispatched with a party of scientists to study the eruption. Radio contact with the ship was lost on the same night, and the ship disappeared, presumably destroyed by an explosion of the volcano, or one of the tsunamis that accompanied the explosions. Floating wreckage was found near the volcano. The Asahi Shimbun for December 24 reports that the conclusion of the investigating committee is that an explosion occurred beneath the starboard side of the vessel at about 12:20 on September 24, largely destroying the starboard side of the superstructure and causing the vessel to sink immediately. Thirty-one persons were lost. The nine scientists included two geologists, Dr. R. Tayama of the Maritime Safety Board and Prof. K. Kawada of Tokyo Education University. Dr. Tayama was well known for his work on the geology of the former Japanese Mandated Islands.

The violent explosions of September 23 and 24 largely destroyed the portion of the volcanic peak above sea level. Photographs taken by Dr. Niino on September 23, show dense cauliflower explosion clouds rising within 8 minutes to a height of about 20,000 feet. By late December, however, the island had rebuilt to a height of 150 or 200 feet. It appears probably to be a dome of viscous dacite.

Volcanic activity is not new in the general area of Myojin Reef and Bayonnaise Rocks. Sapper (Vulkankunde, p. 318) reports pumice ejection at 31° 59′ N., 140° 07′ E., in early April, 1905. According to R. Mita, in Hydrographic Bulletin No. 12, 1949, the Okinawa Maru reported a "smoke" column about 300 feet in diameter and up to 1,000 feet high in April, 1906. Submarine eruptions near the Bayonnaise Rocks were reported by the Totomi Maru in April and June, 1915. Early in February, 1946, an island about 650 feet long and 500 feet wide appeared at 31° 57′ N., 140° 01′ E., close to the location of the present Myojin Reef. In April, several spine-like islands as much as 120 feet high were reported, and, in October, the island was reported

to be 300 feet in height. It appears to have been a volcanic dome. By December, 1946, the island had been reduced to a low reef, probably by explosions and the crumbling away that characteristically takes place on volcanic domes, as well as by wave erosion.

NORTHERN MARIANAS ISLANDS

In late October, 1952, the captain of a Japanese fishing boat reported volcanic explosions sending clouds of "smoke" to a height of 1,400 feet on the island of Uracas (Farallon de Pajaros). Dr. Joshua I. Tracy, Jr., writes that Lt. G. W. Watson, U.S.N., flew over Uracas on November 22, and reported that the volcano was much more active than he had seen it during a dozen previous flights. He circled the crater for about 10 minutes and observed four or five large puffs of brown "smoke." With each puff large rock fragments were blown about 50 feet above the rim of the crater.

Dr. Tracy and Dr. J. A. Stark, both of the U. S. Geological Survey, visited Pagan Island during early November. There appears to have been no activity there since 1925, but a cinder cone 100 feet high, in the center of the crater, was fuming slightly.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director
Chester K. Wentworth, Geologist, part-time
Burton J. Loucks, Instrument Maker
John C. Forbes, Assistant Instrument Maker
Elizabeth G. Eklund, Secretary, part-time

Seismograph Station Operators:

Hilo Station:
Sister M. Thecla, St. Joseph's School

Kona Station:
Howard M. Tatsuno, Konawaena School

University of Hawaii:
T. A. Jaggar, Geophysicist

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter**, a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

THE VOLCANO LETTER

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THOMAS AUGUSTUS JAGGAR



THOMAS AUGUSTUS JAGGAR

Photo by R. H. Post, Honolulu

In Philadelphia, on January 24, 1871, Thomas Augustus Jaggar, Jr., was born to a long life of scientific adventure terminated only by his death in Honolulu on January 17, 1953. The son of a bishop of the Episcopal Church, he was educated in public and private schools in Cincinnati, Montreux, and Philadelphia. He entered Harvard University in 1889 and in 1893 graduated with the A.B. degree in geology. He received his Master of Arts degree from Harvard in 1894 and spent most of the next 2 years in Europe, studying mineralogy under Professor Paul Groth at Munich and petrography under Professor Harry Rosenbusch at Heidelberg. Returning to Harvard, he completed his work for the Doctorate of Philosophy under Professor John E. Wolff in 1897, with a dual thesis on the microscopic determination of the hardness of minerals and the geologic evidence derived from certain inclusions in dikes in the Boston area.

From 1895 to 1903, Jaggar held the position of Instructor in Geology at Harvard, and from 1903 to 1906 he was an Assistant Professor in the same department. During these years he was also a member of the United States Geological Survey, working under S. F. Emmons in the region of the Black Hills, South Dakota, and under Arnold Hague in the Yellowstone region. The work in South Dakota and adjacent parts of Wyoming led to the publication, in 1901, of his first big work, an important study of

the laccoliths of the Black Hills. A report on the petrography of the Absaroka Range was prepared for the never-published first volume of the Geological Survey's memoir on Yellowstone National Park. In 1900 and 1901, he was engaged with Charles Palache on a study of the Bradshaw Mountains in Arizona. In 1906, Jaggar was appointed Professor and Head of the Department of Geology in the Massachusetts Institute of Technology.

Dr. Jaggar's approach to geology was a dynamic one. Beginning in his student days, geological processes were his major interest. He was, of course, interested also in the results of the processes, but largely for what they could tell him of how they came about. Fired by Daubree's *Géologie expérimentale,* he set about applying the experimental methods of physics and chemistry to geology. The results of laboratory experiments on stream erosion and sedimentation appeared in print in 1908. However, he was much more interested in applying similar methods in the field, in an attempt to measure and analyze geologic processes actually in operation. The most dynamic aspects of dynamic geology are seismology and volcanology, and to Jaggar the attraction of earthquakes and volcanoes was irresistible.

In 1902, Dr. Jaggar was one of the geologists on the expedition of the S.S. "Dixie" to the Antilles to study the results of the catastrophic eruptions of Mont Pelée and La Soufrière. It was this expedition that decided him definitely on adopting the field study of geophysics as his life work. It is noteworthy that the catastrophe at St. Pierre was the factor that guided into volcanologic work the two greatest American volcanologists of the early twentieth century, Thomas Augustus Jaggar and Frank Alvord Perret.

In 1906, Dr. Jaggar visited Italy to study the eruption of Vesuvius and the damage caused by it. There he found Perret already working as a volunteer assistant to Professor Raffaele Matteucci, director of the Vesuvius Observatory. In 1907, Jaggar was the leader of the Technology Expedition to the Aleutian Islands, during which Makushin and Bogoslof volcanoes received special study. In 1909, Professor Jaggar and his colleague Professor R. A. Daly visited the Hawaiian volcanoes, and Dr. Jaggar went on to Japan to visit the laboratories and stations of the Imperial Earthquake Investigation Committee. At that time a long friendship and mutual admiration began between him and Professor F. Omori, the great leader of seismology in Japan. In 1910, Jaggar and Charles M. Spofford, Professor of Civil Engineering at M.I.T., visited Central America for the purpose of studying the volcanoes of Costa Rica and the results of the great Cartago earthquake of that year, and Jamaica to examine the work being done there in enforcing earthquake-proof construction.

These excursions served to convince Professor Jaggar of the inadequacy of the expeditionary method of studying volcanoes and earthquakes and of the necessity for permanent observatories to keep constant record, every day, year in and year out, of volcanic and seismic activity. He was impressed also by the small amount of knowledge possessed by men of science regarding the prediction or alleviation of natural disasters and by the small amount of effort being expended in the attempt to acquire that knowledge. On January 7, 1909, following the Messina earthquake disaster, he wrote in *The Nation:* "The *highest* development of geology is the unravelling of the history of the past. We haven't time to go into prediction and humanistic geology." The blame did not lie, he added, with the geologist, but with the haphazard growth of the science and the very proximity of the earth which made terrestrial observation and measurement difficult. The time had come, however, when such studies could no longer be neglected. Instruments existed for the study of the earth processes, and others could be developed. The gravest difficulty lay in the fact that the new program would call for the establishment of permanent observatories in many lands. The goals of the program should be the prediction of volcanic eruptions and earthquakes and the development of engineering and types of construction to help alleviate the consequences of such cataclysms.

On July 1, 1909, the trustees of the estates of Edward and Caroline Whitney of Boston gave $25,000 to the Massachusetts Institute of Technology to be used for research or teaching in geophysics, including seismology, with a view to the protection of human life and property. It was decided to use these funds for the establishment of a laboratory at Kilauea, Hawaii, for the study of the activity of that volcano and its earthquakes and of waves traveling through the earth from distant earthquakes. Thus did Dr. Jaggar enter upon his true life's work—the establishment and operation of the Hawaiian Volcano Observatory.

Actually, it did not fall to Dr. Jaggar's lot to perform the first work of the new program at Kilauea. During 1910 and 1911, none of the professors at M.I.T. could be spared to go to Hawaii. In the meantime, part of the Whitney Fund had been used for the construction, under the direction of Dr. A. L. Day and Dr. E. S. Shepherd of the Geophysical Laboratory of the Carnegie Institution of Washington, of special resistance thermometers for the measurement of the temperature of molten lava at Kilauea. A cableway had been designed at M.I.T. for spanning Halemaumau Crater in order to lower the thermometers into the lava lake. Dr. Shepherd's services had already been secured for the summer of 1911 to make the temperature measurements. Because Dr. Jaggar could not accompany Shepherd to Kilauea, arrangements were made with the Volcanic Research Society of Springfield, Massachusetts, for the loan of the services of Frank A. Perret, volcanologist of that society, who had been engaged in studies of the Italian volcanoes. Perret and Shepherd reached Kilauea on July 2, 1911, built an observation station at the rim of Halemaumau, and, after much difficulty, succeeded in obtaining a measurement of the temperature of the lava (1000°C.). Perret began the series of systematic records and reports on Kilauea activity that still continues. Dr. Jaggar was granted leave of absence from the Massachusetts Institute of Technology in December, 1911, and reached Kilauea on January 17, 1912.

Establishment of the Hawaiian Volcano Observatory would not have been possible without the enthusiastic aid of the people of Hawaii. The Whitney Fund provided only $3,450 per year for 5 years. During his visit in 1909, Dr. Jaggar enlisted the support of the Honolulu Chamber of Commerce and some of Hawaii's leading citizens. On October 5, 1911, L. A. Thurston gave a luncheon at the University Club in Honolulu for the purpose of organizing a Hawaiian Volcano Research Association. This association subscribed an additional

$5,000 a year, over and above the amount from the Whitney Fund, for the operation of the Volcano Observatory. The College of Hawaii, through its president, J. W. Gilmore, pledged its interest and support. Hilo people also were eager to help, and through the efforts of Demosthenes Lycurgus $1,785 was quickly gathered for the construction of the Observatory building. On March 6, Dr. Jaggar was recalled to Boston, leaving the work at Kilauea temporarily in the hands of F. B. Dodge. But on June 13 he was back again, accompanied by Dr. Harry O. Wood, who became the first seismologist of the Volcano Observatory.

From that time on, the Hawaiian Volcano Observatory was the focal point of Dr. Jaggar's interest and efforts. Financially, things were seldom easy and often extremely difficult. There were times when Dr. Jaggar served wholly without any regular salary. There were still more times when Observatory funds were inadequate to buy even the most essential materials for the work, and he had to pay for them personally out of his own slim savings or appeal again for help from such loyal friends as Frank C. Atherton and Walter F. Dillingham. To such friends Dr. Jaggar was ever grateful, not only for their help to himself, but more particularly for their aid to the growth of the new science of volcanology. It is a fine tribute to Dr. Jaggar's determination and singleness of purpose that even in the hardest and most discouraging of times he did not falter, but somehow kept the program going. After responsibility for the operation of the Volcano Observatory was assumed by the United States Government in 1919, desperately lean periods were less frequent, and there were occasional times of relative opulence. Never, however, was Dr. Jaggar content with progress. Always, over the hills and valleys of varying prosperity, he was striving for greater things for the Observatory and for the science as a whole.

Work at Kilauea was diversified. To routine seismology and the continuous record of activity of Kilauea and Mauna Loa were added observations on the rise and fall of the level of molten lava in Halemaumau, measurements of the temperature of the melt, soundings of the depth of the lava lake, experiments on the viscosity of the lava, collections of volcanic gases for chemical analysis, borings to ascertain the nature of the crater floor and the distribution of temperature in the rocks underlying it, measurements of the shifting and tilting of the ground surface both laterally and vertically, study of the different types of lavas and how they form, and petrographic studies of the rocks. No phase or feature of the volcanoes remained uninvestigated if means could be found for Jaggar or his associates to attack it. In the field of distant earthquakes, a special study was made of tsunamis, the destructive ocean waves that sometimes accompany submarine earthquakes, and possible means of predicting them.

Hawaiian work did not preclude work elsewhere. Expeditions were made to Japan in 1914 and 1923 to study the eruption of Sakurajima and the great Yokohama-Tokyo earthquake. Seeking always to expand the continuous, observatory-type study of volcanoes, Jaggar visited New Zealand in 1920, at a time when the New Zealand Government was considering the establishment of a volcano observatory. In 1924 he visited Howland and Baker Islands with the "Whippoorwill" Expedition, sponsored by the Bishop Museum and the U. S. Navy. In 1927 he was engaged in field work in the Aleutian Islands, and in 1928 he conducted the Pavlof Expedition of the National Geographic Society to the Alaska Peninsula. In 1930 he was a member of the U. S. Naval Observatory's Eclipse Expedition to Niuafo'ou Island.

In 1924 the operation of the Hawaiian Volcano Observatory passed from the U. S. Weather Bureau to the Geological Survey. In 1926 the Survey established a Section of Volcanology, with Jaggar as its Chief. Stations were established at Lassen Volcano in California and at Dutch Harbor, Alaska. Investigations of Aleutian volcanoes were begun by Jaggar in 1927 and continued by R. H. Finch, volcanologist in charge of the Lassen Observatory, in 1931 and 1932. These investigations were resumed by the Geological Survey during World War II and are now being pursued on a systematic basis under the direction of Howard A. Powers, formerly geologist for the Hawaiian Volcano Observatory.

Dr. Jaggar was one of the early advocates of a national park to include the crater areas of Kilauea and Mauna Loa, and in 1915 he made a trip to Washington for the prime purpose of pleading for its establishment. He felt that the wonders of the great Hawaiian volcanoes and the surrounding tropical beauty, which he himself loved so much, should be the property of all the American people. The vision was consummated in the establishment of Hawaii National Park the next year. In 1935 the Volcano Observatory was transferred to the National Park Service, and Jaggar became an official of the park he had helped to establish. He remained such until his retirement in 1940. After his retirement from government service, Dr. Jaggar became research associate in geophysics at the University of Hawaii and retained that position until his death.

For many years Dr. Jaggar was intensely interested in the sea bottom. This 72 per cent of the earth's surface, concealed from man's view by deep water, was a challenge to his imagination and curiosity. He advocated its exploration by any means available and was especially interested in the possibility of drilling into it from great, floating seadromes. He recognized the technical difficulties of such a procedure but was confident they could be overcome if the results would be worth it—and he was firmly convinced that they would be.

Even all this activity could not absorb all the energy of Jaggar's restless mind. He loved to work with his hands and spent much time in his machine shop. New types of seismographs and seismometers were usually under design and construction, as he carried on a constant search for instruments that could be built and installed cheaply and yet yield valuable results. Such instruments would make possible the great expansion of seismic studies that he envisioned. When Aleutian field work presented difficulties in transportation, he invented an amphibian automobile, used successfully during the Pavlof Expedition, for which he received the 1945 Franklin L. Burr Prize of the National Geographic Society. Interest in boats led to interest in navigation and the design of instruments for locating the geographical position of a ship or airplane through observation of stars at the zenith.

After his retirement he returned to one of his earliest interests, the precise measurement of hardness of minerals and other substances, and he designed and built a new instrument for hardness testing. He was interested in astronomy and spent many evenings at his telescope observing heavenly objects, especially the moon, in whose craters he saw an analogy to the great volcanic craters of the earth. He even entered the fields of philosophy and religion with essays on Jesus; the origin of the earth, life, and man; evolution; and trends of science. He was a staunch church member. While he was still at Harvard and M.I.T., he became deeply interested in the problems and methods of education. In his later life this interest was expressed through his service on the governing board of Iolani School in Honolulu.

It is difficult to evaluate properly the importance of Dr. Jaggar's work in volcanology. We are still too close to it. It is abundantly obvious, however, that its importance is very great. At the time Jaggar founded the Hawaiian Volcano Observatory, the science of volcanology was in its infancy. It has now entered a stage of adolescence where some concrete results are beginning to appear from the great amount of work put into it. Unreservedly, Jaggar may be said to have been one of the very few principal contributors to this progress.

Early results of the work at Kilauea related largely to the dual nature of the lava lake, the shallowness of the pool of pyromagma, the temperature distribution in the lake, and the composition of gases given off by it. These were important in building a picture of the physical nature of the magma column feeding the volcano. Later work added somewhat to that picture, demonstrated the swelling and shrinking of the entire volcanic edifice related apparently to changes of magmatic pressure beneath it, showed the occasional occurrence of great collapses and related thereto occasional violent steam explosions due to cracking of the surrounding rocks and entrance of ground water to the hot volcanic conduit, and built a partial picture of the earthquake activity associated with volcanic changes. Tentative correlations of volcanic events with astrophysical forces and possible cycles in time have been made and are undergoing testing. The work is far from ended, but good progress has been made.

The work has not all been done by Jaggar, of course. Contributions have been made by a whole succession of capable scientific associates, among whom may be mentioned H. O. Wood, Arnold Romberg, E. G. Wingate, A. E. Jones, H. A. Powers, and Jaggar's long-time associate and successor as director of the Volcano Observatory, R. H. Finch. And certainly he would want included among his most valuable co-workers his wife, Isabel, who shared with him the disappointments, the joys of discovery, and much of the physical work. It has been Jaggar's vision and enthusiasm, however, that has guided the work and integrated it, and a very large proportion of it actually was done by him personally.

Possibly the greatest of all Dr. Jaggar's contributions are his ideas for the protection from lava flows of cities, harbors, or other important areas, through aerial bombardment or the construction of barriers to deflect the flows. Bombing has been tried, and the general method has proved feasible and effective. There is little question that the barriers also would do their job well. These things constitute a long step toward fulfillment of the motto adopted at the founding of the Hawaiian Volcano Research Association: "Ne plus haustae aut obrutae urbes"—no more shall the cities be destroyed!

Dr. Jaggar's dream was that some day the work on Hawaiian and other Pacific volcanoes might be combined with other types of geophysical studies in a great Institute of Terrestrial Research centered in Hawaii. It is a grand dream, which may, like so many of his dreams, someday materialize.

All of us who have been associated with Tom Jaggar mourn his passing. But at the same time we are grateful, as he would have us be, for his long and full life, profitably spent, and for memories of his superb intellect combined with a gentle and modest spirit whose greatest concern was with the well-being of the rest of mankind.

—G. A. MACDONALD.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JANUARY–MARCH, 1953

By GORDON A. MACDONALD

VOLCANOLOGY

January

Hawaiian volcanoes remained fairly quiet through the month of January. Seismographs at Kilauea Crater recorded 41 earthquakes during the month, and the Mauna Loa seismograph recorded 33. This is about the usual number recorded during times of volcanic quiet. However, some of the quakes were larger than usual.

Several earthquakes were felt in Kona during the month. Most of them originated locally, on the Kealakekua fault or at sources between central Kona and the summit of Mauna Loa. A small earthquake felt at Naalehu and Kapapala at 9:08 A.M. on January 9 originated beneath the southeast slope of Mauna Loa about 8 miles northwest of Kapapala, and another at 9:10 P.M. on the same day had its epicenter about 1.5 miles closer to the summit of the mountain. The latter quake was felt quite strongly all over the southern part of the island and less strongly at least as far north as Kukuihaele.

At 2:04 A.M. on January 15 a strong earthquake originated beneath the southeast slope of Mauna Loa near the Kapapala Ranch headquarters. Objects were upset and knocked from shelves as far away as Hilo. Residents of the southern part of the island of Hawaii were generally awakened, and the quake was felt as far away as Oahu. In its epicentral area the intensity of the quake is estimated to have been about 5 on the modified Mercalli scale.

Tilting of the ground at the Volcano House was in general slightly southward during the month, at a rate about normal for this season of the year. From January 1 to 15 there was an accumulation of a little more than 1 second of eastward tilting, suggesting a small increase of pressure beneath Mauna Loa associated with the Mauna Loa earthquake activity during the early part of the month. During late January, however, the eastward tilting and, presumably, the increase of pressure beneath Mauna Loa ceased. Late in January a slight northward tilting commenced.

February

Seismic activity on the island of Hawaii during the month of February was relatively slight. Seismographs at Kilauea Crater recorded only 18 earthquakes, the smallest number since January, 1951. The Mauna Loa seismograph recorded 25 quakes during the month. Some of these originated on the west slope of Mauna Loa and others on the northeast rift zone.

At 6:44 A.M. on February 12 an earthquake with an intensity of 4 on the modified Mercalli intensity scale was felt strongly at Kapapala. Its origin was close to Kapapala, probably on the Kaoiki fault, which parallels the highway between Kilauea Crater and Pahala.

The earthquake that occurred at 1:40 A.M. (Hawaiian time) on February 26 about 650 miles north of New Caledonia, near the Santa Cruz Islands, produced only a slight record on seismographs at Kilauea.

During the month there was a small accumulation of northward tilting of the ground at the seismograph station beneath the Volcano House. There was essentially no accumulation of tilt in the east-west direction. During this season of the year tilting at the Volcano House usually is south-southwest. Therefore, the slight northward tilting and absence of westward tilting indicate some increase of volcanic pressure beneath Kilauea Crater and, possibly, also under Mauna Loa.

Late in the afternoon of February 28, the seismographs recorded 18 minutes of continuous volcanic tremor, indicating movement of magma beneath the surface at Kilauea.

March

Seismographs of the Hawaiian Volcano Observatory recorded a total of 75 earthquakes during March. Many of these were too small to be recorded at more than one station. For example, the seismograph at Konawaena School recorded four very feeble earthquakes of nearby origin that were too small to be recorded at Kilauea Crater. During the month the seismographs at Kilauea recorded 45 earthquakes, and the Mauna Loa seismograph recorded 51. The number of earthquakes at any single station was approximately normal. Although the total number of quakes was somewhat greater than normal, such a large proportion of the quakes were very small that the total seismic activity also was only about normal in amount.

On March 6, at 7:48 A.M., a slight earthquake was felt in central Kona. Its origin apparently was on the Kealakekua fault, probably near Kealia. At 2:26 P.M. on the same day an earthquake was felt throughout much of Kona and Kau. Its origin lay at a depth of about 30 miles beneath the summit area of Hualalai.

At 6:19 P.M. on March 25 a moderately strong earthquake occurred, with its epicenter on the south slope of Mauna Loa, 10 miles N 25° W of Naalehu. It was felt strongly at Naalehu, where it had an intensity of about 4 in the modified Mercalli scale. At Kapapala its intensity was 2 to 3. The quake was felt slightly over most of the island. At 1:40 A.M. on March 26 a smaller earthquake was felt quite strongly at Naalehu, where its intensity was estimated as about 2, and less strongly over much of the southwest portion of the island. Its epicenter also lay on the south slope of Mauna Loa, about 5 miles north of Naalehu.

During March, tilting of the ground surface at the Volcano House was southwestward, both the direction and the aggregate amount being approximately normal for that season of the year. Temperatures of steam at vents in the vicinity of Kilauea Crater remained unchanged. General conditions at Halemaumau also remained unaltered, with no visible activity other than steam vents and a weakly active vent liberating sulphurous fume on the floor of Halemaumau Crater northwest of the large cones of the recent eruption. During recent weeks there has been a marked increase in the volume of steam visible at the northeast wall of Puhimau Crater.

On March 14 continuous tremor was recorded on the seismographs for 16 minutes, apparently indicating movement of magma beneath Kilauea. Again on March 29 there were recorded 13 minutes of continuous tremor, possibly a succession of very small earthquakes, but appearing more probably to be volcanic tremor of the sort that accompanies magma movement. Thus far there has been no sign of abnormal tilting such as would indicate any marked decrease of pressure beneath either Mauna Loa or Kilauea. Although there has been no marked restlessness to indicate imminent eruption of either volcano, it is entirely possible that if magma stands high in the conduits, as is suggested by the evidence, eruption might occur with little or no warning.

SEISMOLOGY

Distant Earthquakes

Only one distant earthquake was recorded during the quarter. It was recorded on February 26, at 01:59 H.S.T., and produced only a slight record on the Bosch-Omori seismograph. The notice of Preliminary Determination of Epicenter issued by the U. S. Coast and Geodetic Survey places the origin of the quake in the region of the Santa Cruz Islands, at 11° S., 164.5° E., about 650 miles north of New Caledonia. Its origin time was 11:42:26 G.C.T.

Earthquake Data, January–March, 1953

(Based on Bosch-Omori seismograph on northeast rim of Kilauea Caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
Jan. 4	5	4	0	0	0	1	7.25	0
11	7	6	0	1	0	1	6.75	0
18	4	1	1	0	0	0	2.5	0
25	1	3	0	0	0	0	1.75	0
Feb. 1	0	0	0	0	0	0	0	0
8	2	5	0	0	0	0	3.0	0
15	4	2	0	0	0	0	2.0	0
22	3	1	0	1	0	0	3.75	1
Mar. 1	6	4	1	0	0	0	4.5	0
8	8	1	1	0	0	0	3.5	0
15	2	3	0	0	0	0	2.0	0
22	8	3	0	0	1	0	6.5	0
29	11	1	0	0	0	0	3.25	0

* For definition of local seismicity see Volcano Letter 371 or 512. Each local earthquake is assigned a seismicity value according to its strength, as follows: tremor, 0.25; very feeble, 0.5; feeble, 1.0; slight, 2.0; moderate, 3.0; strong, 4.0. These values are totaled to give the weekly local seismicity. Continuous volcanic tremor is ignored in the calculation. The strength assigned to an earthquake depends on the double amplitude of the maximum oscillation it causes on the Bosch-Omori seismograph, as follows: tremor, less than 0.5 mm.; very feeble, 0.5 to 4 mm.; feeble, 4 to 11 mm.; slight, 11 to 25 mm.; moderate, 25 to 60 mm.; strong, greater than 60 mm.

Table of Tilt at Seismograph Vaults on Rim of Kilauea Caldera

Week Beginning	Whitney Vault (Northeast rim)		Uwekahuna Vault (West rim)	
	Amount	Direction	Amount	Direction
January 4	0.2″	E	0.3″	N 45° W
11	1.0″	S 82° E	2.7″	N 21° E
18	0.1″	E	1.6″	S 11° W
25	0.4″	N 34° W	1.6″	N 11° E
February 1	1.2″	W	0.6″	E
8	1.0″	S 60° E	1.8″	S 9° W
15	0.6″	S 79° E	0.7″	S 27° W
22	0.8″	N 52° W	1.6″	S 11° W
March 1	0.7″	N 9° W	1.8″	S 9° W
8	0.6″	E	4.0″	S 19° W
15	0.8″	N 27° W	0.7″	N 27° W
22	1.4″	S 31° W	2.6″	S 14° E
29	1.2″	N 88° W	2.3″	S 16° E

Local Earthquakes

The data for the following local earthquakes were determined from seismographs operated on the island of Hawaii by the Hawaiian Volcano Observatory. Locations given are epicenters. The times given are arrival times at the Whitney Laboratory of Seismology, on the northeast rim of Kilauea Caldera. They are stated to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich Civil time. The number preceding each earthquake is the serial number for the current year. The intensity rating (Feeble, Moderate, etc.) given is that for the Whitney Laboratory. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney station.

1. Jan. 2, 03:32, very feeble. Near summit of Mauna Loa (?).
2. Jan. 2, 23:34, no record at Kilauea (Kona, very feeble).
3. Jan. 3, 11:31, feeble (Kona, strong). Felt strongly in Kona. Central Kona, on Kealakekua fault near Keei. 19° 28′ N., 155° 52′ W.
4. Jan. 3, 11:34, very feeble (Kona, slight). Felt in Kona (Kona aftershock).
5. Jan. 4, 23:07, very feeble. Kilauea.

6. Jan. 7, 15:58, tremor (Kona, very feeble). Felt in Kona.
7. Jan. 7, 21:31, no record at Kilauea (Kona, very feeble). Central Kona.
8. Jan. 9, 09:09, very feeble. Felt at Kapapala, Naalehu, Kona, SE slope of Mauna Loa at about 19° 22′ N., 155° 31′ W.
9. Jan. 9, 09:22, very feeble.
10. Jan. 9, 16:05, very feeble. Felt at Kapapala.
11. Jan. 9, 16:42, no record at Kilauea (Kona, very feeble). Felt in Kona. Central Kona.
12. Jan. 9, 21:10, strong. Felt strongly at Kahuku and Naalehu, moderately at Kapapala, Volcano district, Hilo, and Kona, slightly at Kukuihaele. SE slope of Mauna Loa about 4 miles SE of South Pit, at about 19° 24′ N., 155° 33′ W., about 14 miles deep.
13. Jan. 10, 06:32, tremor (Kona, very feeble). Central Kona.
14. Jan. 12, 03:27, tremor (Kona, very feeble). Central Kona.
15. Jan. 13, 04:13, slight. Four miles S 45° E of Naalehu.
16. Jan. 13, 07:29, very feeble. Felt quite strongly at Kapapala.
17. Jan. 14, 05:38, very feeble. SW rift of Kilauea (?).
18. Jan. 15, 02:05, strong. Felt strongly all over southern half of island from Hilo to Kona, and slightly as far away as Oahu. SE slope of Mauna Loa about 3 miles NNE of Kapapala Ranch headquarters, 19° 19′ N., 155° 26′ W., about 15 miles deep.
19. Jan. 15, 07:30, tremor (Kona, slight). Felt in Kona. Central Kona.
20. Jan. 16, 13:01, very feeble.
21. Jan. 16, 21:54, very feeble.
22. Jan. 17, 05:09, very feeble.
23. Jan. 17, 17:40, very feeble.
24. Jan. 18, 09:33, feeble. On SE slope of Mauna Loa near Ohaikea.
25. Jan. 21, 12:58, very feeble.
26. Jan. 23, 14:18, no record at Kilauea (Kona, very feeble). Felt in Kona. Central Kona.
27. Jan. 24, 11:14, no record at Kilauea (Kona, very feeble). Central Kona.
28. Jan. 25, 03:17, very feeble.
29. Jan. 27, 03:00, very feeble. Kilauea.
30. Jan. 29, 00:17, tremor (Kona, very feeble).
31. Jan. 30, 08:06, very feeble.
32. Jan. 30, 10:53, tremor (Kona, very feeble).
33. Feb. 3, 07:28, no record at Kilauea (Mauna Loa, tremor; Kona, feeble). Central Kona.
34. Feb. 6, 20:21, no record at Kilauea (Kona, very feeble). Central Kona.
35. Feb. 8, 18:48, tremor (Kona, very feeble).
36. Feb. 9, 22:47, very feeble (Kona, feeble). Near summit of Mauna Loa.
37. Feb. 11, 21:19, no record at Kilauea (Kona, very feeble). Central Kona.
38. Feb. 12, 04:38, no record at Kilauea (Kona, very feeble).
39. Feb. 12, 06:45, very feeble. Felt strongly at Kapapala, intensity about 4 (modified Mercalli). Kaoiki fault near Kapapala, at about 19° 17′ N., 155° 27′ W.; shallow focus.
40. Feb. 12, 14:06, no record at Kilauea (Kona, very feeble).
41. Feb. 13, 04:49, very feeble.
42. Feb. 13, 04:51, very feeble.
43. Feb. 13, 04:51, very feeble.
44. Feb. 15, 22:10, very feeble.
45. Feb. 16, 11:21, very feeble. Kaoiki fault, about 4.6 miles SW of Uwekahuna station, at about 19° 24′ N., 155° 22′ W.
46. Feb. 16, 20:20, no record at Kilauea (Kona, very feeble). Central Kona.
47. Feb. 18, 02:26, no record at Kilauea (Mauna Loa, tremor; Kona, very feeble). West flank of Mauna Loa.
48. Feb. 18, 02:30, no record at Kilauea (Mauna Loa, tremor; Kona, very feeble). West flank of Mauna Loa.
49. Feb. 20, 06:14, no record at Kilauea (Kona, very feeble). Central Kona.
50. Feb. 20, 06:16, no record at Kilauea (Kona, very feeble). Central Kona.
51. Feb. 21, 22:44, no record at Kilauea (Kona, very feeble). West slope of Mauna Loa.
52. Feb. 22, 02:40, slight. Felt in Volcano district. Kaoiki fault between Bird Park and Ohaikea.
53. Feb. 25, 15:30, very feeble.
54. Mar. 1, 22:42, very feeble. Off south shore at about 19° 00′ N., 155° 24′ W.
55. Mar. 3, 19:32, no record at Kilauea (Kona, very feeble). Central Kona.
56. Mar. 6, 04:39, feeble. Off south coast at about 19° 04′ N., 155° 25′ W.
57. Mar. 6, 06:06, very feeble.
58. Mar. 6, 07:48, very feeble (Kona, slight). Felt in central Kona. Kealakekua fault, near Kealia (?).
59. Mar. 6, 14:26, very feeble (Kona, feeble). Felt in central Kona, Naalehu, and Kapapala. Beneath summit area of Hualalai Volcano, about 30 miles deep.
60. Mar. 9, 19:27, feeble. Kilauea.
61. Mar. 10, 06:31, very feeble. North slope of Mauna Loa about 3 miles NW of Kokoolau cone, at about 19° 39′ N., 155° 37′ W.
62. Mar. 12, 18:58, tremor at Whitney Laboratory, very feeble at Uwekahuna. Kilauea.
63. Mar. 17, 03:20, no record at Kilauea (Kona, very feeble). Central Kona.
64. Mar. 18, 11:12, very feeble.
65. Mar. 18, 23:40, very feeble. Moderate distance.
66. Mar. 19, 06:45, no record at Kilauea (Kona, very feeble). Central Kona.
67. Mar. 19, 20:01, very feeble.
68. Mar. 23, 19:30, tremor (Mauna Loa and Kona, very feeble).
69. Mar. 23, 21:19, very feeble. Felt in south Kona. West slope of Mauna Loa.
70. Mar. 25, 10:50, very feeble (Mauna Loa, slight). Near summit of Mauna Loa, probably on NE rift zone.
71. Mar. 25, 18:19, moderate. Felt strongly at Naalehu and Kapapala and slightly over most of the island. South slope of Mauna Loa, at about 19° 12′ N., 155° 39′ W.
72. Mar. 26, 01:40, very feeble (Mauna Loa, feeble). Felt moderately at Naalehu and slightly as far as central Kona. South slope of Mauna Loa, at about 19° 08′ N., 155° 35′ W.
73. Mar. 27, 22:30, no record at Kilauea (Kona, very feeble). Felt in Kona. Central Kona.
74. Mar. 31, 03:54, very feeble.

VOLCANO NOTES AND NEWS

CONTINUED VOLCANIC ACTIVITY AT SAN BENEDICTO ISLAND, MEXICO

By Adrian F. Richards

Initial activity of Boqueron Volcano on San Benedicto Island, Mexico, has been described by Howel Williams in Volcano Letter 517. (The name Boqueron, meaning "Big Mouth," was suggested by Dr. Williams.)

On November 15, 1952, J. M. Snodgrass, D. L. Inman, and the writer, all of the Scripps Institution of Oceanography, flew to Boqueron Volcano in a U. S. Navy PBM. The small conical mass of lava that had plugged the conduit of the 700-foot-deep crater was observed to have increased greatly in size so that the crater had become half filled with a biscuit-shaped mass of block lava. This extrusion of lava probably took place about November 12, at which time the master of the tuna clipper "Constitution" reported to the Scripps Institution that intermittent smoke with flames shooting above the crater had been visible during the night at a distance of 40 miles from the island. No incandescence was seen on November 15. On November 19, the master of the clipper "Paramount" reported to the writer that he had seen glowing boulders hurled 200 feet above the crater at night. Based on observations of December 10, additional block lava was probably added to the crater at that time. On December 8, according to M. Silva of the "Star of the Sea," lava escaped from the flank of Boqueron Volcano at the eastern base of the cone, 60 feet above sea level.

Lewis Walker and the writer reached San Benedicto Island on December 9 for a stay of 4 days. The fissure, through which the blocky lava welled, lengthened upslope to 192 feet altitude by December 11. The temperature at the throat of the fissure was estimated by the writer to be approximately 1300°C., based on the orange-white incandescence. This lava extrusion advanced out to sea 900 feet in 2 days, during which time it grew laterally to 1,200 feet in the shape of a lobate delta. When last observed, the lava was advancing seaward at the rate of 150 feet per day.

Based on identical readings of aircraft altimeters on flights over Boqueron on November 15 and December 11, the elevation of the top of the cone of Boqueron Volcano was determined to be 1,250 feet. This figure is 250 feet less than that reported by Dr. Williams on the September 20 flight. Comparisons of September, November, and December photographs show no apparent change in the height of the rim; consequently, the 1,250-foot value is probably more nearly correct. On December 9, at intervals of approximately 1 hour, dense cauliflower clouds of steam and ash were observed to rise to 3,000 feet. On December 10, the crater rim was observed to be half a mile wide. Red incandescence of the crater lava was occasionally seen in broad daylight. On the morning of December 12, the volcanic activity increased to a continuous eruption of steam and ash from the crater. This eruption continued through December 13, when the island was seen by tuna fishermen. On January 5, Paul Lynn, master of the "Cape Beverly," reported rumbling sounds heard at a distance up to 1 mile from Boqueron, coincident with gas eruptions from the crater.

ERUPTION OF TRIDENT VOLCANO, ALASKA

Mount Trident, in Mount Katmai National Monument, erupted on February 15, 1953. Mount Trident is located near the base of the Alaska Peninsula, 110 miles northwest of Kodiak and 5 miles west-southwest of Katmai Volcano, which erupted violently in 1912. There is no previous record of activity of Trident Volcano during historic times.

On February 15 and 16, pilots of commercial and military planes reported a cloud of "smoke" rising about 30,000 feet into the air. Visibility was too poor, however, to permit precise determination of the type and place of activity. On February 18, the vent was finally located on the south slope of Trident Peak. Earlier reports that Katmai and Novarupta volcanoes were active proved false.

On February 21, seismologist Richard McDonald of the U. S. Geological Survey identified a lava flow issuing from a fissure about 1 mile southwest of the old crater of Trident Volcano. The flow was still active and was about 800 feet wide at its toe and 1,500 feet long. It had advanced about 1,000 feet since it was photographed on February 18. The eruption column rose to a height of about 11,000 feet, and a thin deposit of ash was observed over the surrounding area. The crater lake of Katmai Volcano was not frozen. Light steam rose from two craters on nearby Mageik Volcano, and steam was rising from a vent on the southeast flank of Mount Trident, about 1.5 miles east of the lava vent.

On March 11, geologist George Snyder of the U. S. Geological Survey reported Trident Volcano still active, with slow lava extrusion. Ash blanketed the area within a radius of 20 miles south and east of the volcano.

MYOJIN REEF, JAPAN

Dr. Helen Foster of the U. S. Geological Survey's office in Tokyo writes that Dr. H. Niino of the Tokyo College of Fisheries visited the area of Myojin Reef on February 1. He reported an island estimated to have a maximum diameter of 226 meters and a minimum diameter of 158 meters, in a northwest-southeast direction. The highest point was a black spine 94 meters high. There was also a grayish-white dome 54 meters high. Steam was being emitted from the spine, but there was no other sign of activity. The previous growth of the island was described in Volcano Letter 518.

The March 19 edition of the newspaper *Hawaii Hochi* reported three explosions at Myojin Reef on March 18. The eruption column was stated to reach a height of 1,000 feet.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director
Chester K. Wentworth, Geologist, part-time
Burton J. Loucks, Instrument Maker
John C. Forbes, Assistant Instrument Maker
Elizabeth G. Eklund, Secretary, part-time

Seismograph Station Operators:

Hilo Station:

Sister M. Thecla, St. Joseph's School

Kona Station:

Howard M. Tatsuno, Konawaena School

University of Hawaii:

T. A. Jaggar, Geophysicist

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcances in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter**, a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

THE VOLCANO LETTER

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NOTES ON THE 1880–81 LAVA FLOW FROM MAUNA LOA

By E. D. BALDWIN[1]

At Honolulu in November, 1880, we were under a strict smallpox quarantine, no one being allowed to leave the Island of Oahu for fear of carrying the disease to the other islands. It was then that we received word that at 9 P.M. on November 5 a great lava flow had broken out on the top of the Mauna Loa divide about a mile above Puu Ulaula. One branch of the lava flow was heading northward toward Mauna Kea. The main branch was advancing rapidly down the mountainside south of the 1855 lava flow. It had often been remarked at Hilo that, if a great lava stream should flow down on the Puna (south) side of the 1855 lava flow, Hilo would be doomed. Here was a massive aa lava stream that in a few days had flowed with great speed down the steep part of the Mauna Loa slopes and then made a turn toward Hilo, on the Puna side of the 1855 lava flow.

A third flow started southward into Kau at 8 P.M. on November 9.

The great lava flows of Mauna Loa commonly are aa at first, changing to pahoehoe after a period of 2 or 3 weeks if the flow continues that long.[2] This fact was well known to all our old Hilo settlers. With the rapid advance of this great aa flow and the knowledge that at any moment the more rapid pahoehoe flow might start, one can easily imagine the nervous excitement of the Hilo residents. They appealed to the authorities at Honolulu for advice and suggested that Professor W. D. Alexander, Surveyor General of the Kingdom of Hawaii, be sent to Hilo to report on the lava flow. The Government acted immediately and passed Professor Alexander through the quarantine and on to the Island of Hawaii.

The writer was then a young man, living in Professor Alexander's home and just beginning his apprenticeship in the Government Survey. Consequently, after Professor Alexander's return from Hilo, the writer had the pleasure of listening to his brilliant account of the lava flow.

One of Hilo's greatest mountaineers, Judge D. H. Hitchcock, was assigned to guide Professor Alexander to the flow. The party started on horseback at daybreak on November 29, spent the night at Hitchcock's Kipuka Ahina camp, then continued to the lava flow on foot the next day. They first visited the western branch of the flow, which Professor Alexander stated was a red-hot stream of aa, then turned back downslope and visited the Hilo branch of the flow. The latter, he stated, was running liquid aa, with its front near the Mawae corner of the Piihonua land division.

Professor Alexander described the lava flow as appearing very liquid at its front, but so viscous that they were unable to drive a stick into it or get any of the molten lava on a stick to shape it into souvenirs, as they

[1] Mr. E. D. Baldwin, for 28 years surveyor and civil engineer in the Hawaiian Government Survey, under the Kingdom, the Republic, and the Territory, had a life-long interest in Hawaiian volcanoes. The present article was written in 1933, after his retirement and shortly before his death. His daughter, Mrs. Jessie Baldwin Hardy, referred it to K. P. Emory of Bernice P. Bishop Museum who in turn referred it to T. A. Jaggar and G. A. Macdonald. The map accompanying the article was prepared by Macdonald.

The article contains much of interest that does not appear to have been published previously. The accounts of the two barriers to protect Hilo from the 1881 lava flow are of special interest in connection with recently proposed barriers. As Mr. Baldwin points out, the wall built to protect the Waiakea mill certainly would not have been effective, as the lava soon would have overtopped the wall and continued on its course. The great earthen embankment along the edge of the Alenaio Gulch, proposed but not constructed, might well have saved the center of Hilo if the flow had continued. It would not, however, have saved the harbor, and it would not be adequate to protect the much expanded Hilo of today.—G. A. M.

[2] It should be noted that this succession of pahoehoe following aa as the eruption progresses is the result of a change in condition of the lava being poured out at the vent, resulting in a new pahoehoe flow flooding over and beyond an earlier aa flow, and not an example of change of aa to pahoehoe in a single flow as it progresses down slope.—G. A. M.

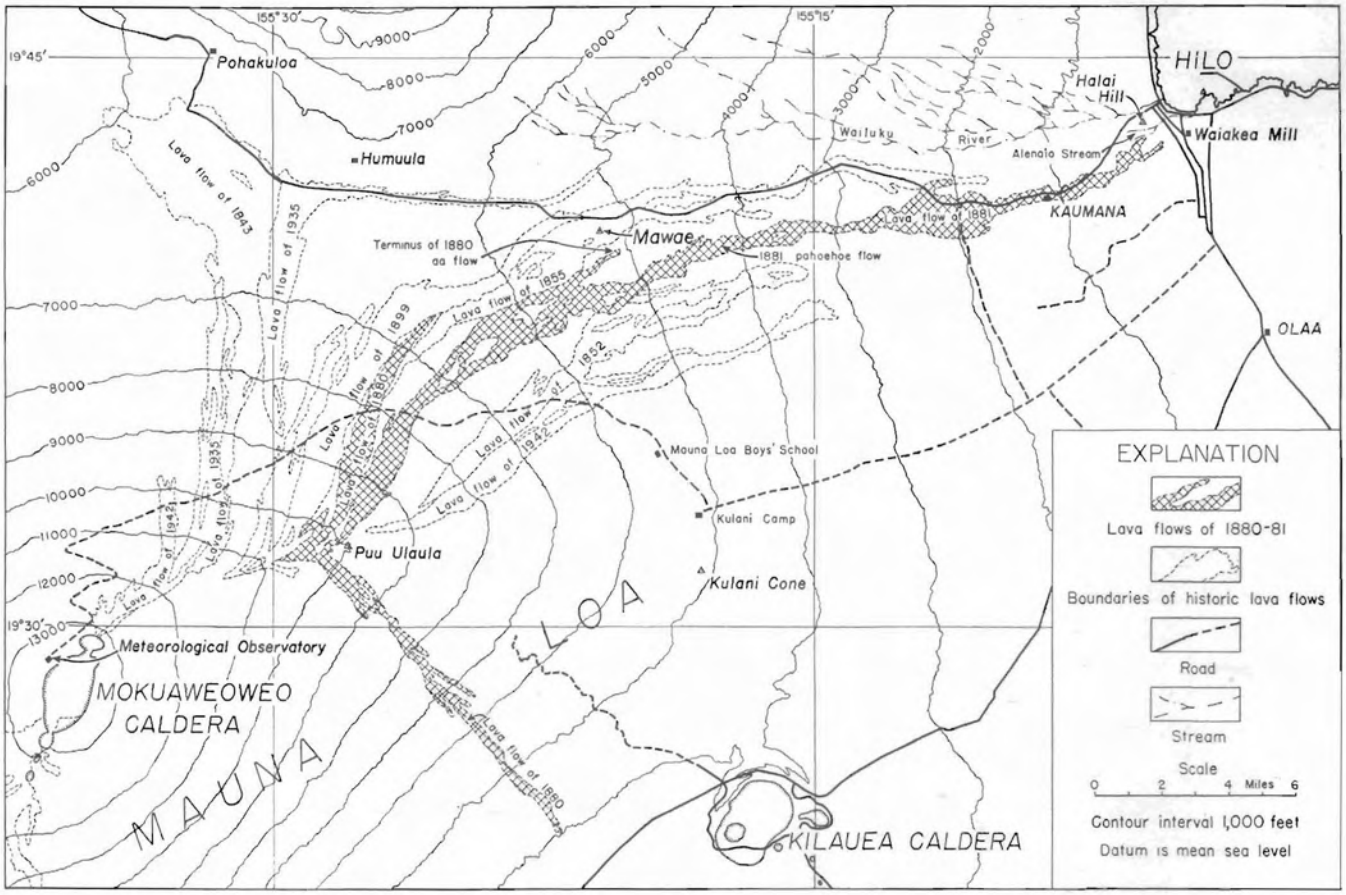

FIGURE 1. Map of the eastern portion of Mauna Loa, showing the 1880–81 lava flows.

were accustomed to do with molten pahoehoe. They cut a long pole from a tree and rushed with it against the most molten portion of the front of the flowing lava, but could make no impression on it.

Mr. Hitchcock has stated to the writer that he had visited the source of the flow a short time after it started and that it was aa all the way from its source to the point where Professor Alexander saw it. The aa flow continued for a short distance below that point, eventually stopping about 20 miles from Hilo. Shortly after Alexander's visit, however, the lava changed to pahoehoe at its source. According to Mr. Hitchcock, the pahoehoe flowed out of the same vent as the aa and flooded down over the aa, almost obliterating it.

For 7½ months the advance of the pahoehoe was slow, averaging only about ½ mile a month. Above Kaumana Woods the flow averaged about a mile wide. On June 30, 1881, the front of the flow was reported to be just above John Hall's house, near the upper edge of the woods about 5 miles from Hilo. As the flow moved through Kaumana Woods, it narrowed until it was hardly ¼ mile wide, and its speed increased greatly, to an average of about 4 miles a month. Almost before the Hilo people were aware of it, the lava suddenly appeared in a narrow stream coming down through the Kaumana lands at the seaward edge of the woods.

Finally the smallpox quarantine in Honolulu was lifted, and on July 12 the writer and a group of other boys took the first steamer for Hilo. The group included Willie and Arthur Alexander, sons of Professor Alexander; John Bishop, son of S. E. Bishop; Horace Chamberlain, son of Warren Chamberlain; and Henry Hyde, son of the Reverend Dr. Hyde. We reached Hilo on the morning of July 14, and as our steamer approached the port we had a fine view of the whole line of the flow, from its source to within a few miles of Hilo town. At the source two columns of dense smoke were rising.

We found the front of the flow about 3 miles from Hilo. When we first reached it, it appeared dead, and a stream of cold water was coming from under it. We traveled up along the flow looking for a suitable camping site and came to a place where it was in action. The pahoehoe lava was flowing into and burning a thick grove of sumach trees (called by the natives *neneleau*). We were new to a live lava flow and did not dare go near it. This amused us soon afterward, as we practically lived on the flow for 2 weeks.

On July 15 we camped at the Natural Bridge, about 4 miles from Hilo. Just below the Natural Bridge the flow had crossed the Alenaio Stream and formed a natural dam and reservoir in which one could enjoy any kind of bath, from cold to scalding hot. We cooked every meal on the lava flow. We found a place where the lava was oozing out in a small way and on this set our pots and fried our pancakes. Occasionally our fry-

ing pan floated down with the lava.

At several places there were openings in the top of the flow that exposed the tunnel of red-hot, flowing lava beneath. At one of these, on the steep slope near Kaumana, we threw stones on the flowing lava and timed their passage; we found that the stream of lava was traveling at an average rate of 40 miles an hour in its confining tunnel. This seemed astounding at first, but when one considers that the flow was then more than ½ mile wide at its advancing front, the lava would have to be traveling very fast in its narrow channels higher up to supply the broad spread of lava at the front of the flow.

The central supply tunnel was probably 20 to 50 feet wide, with numerous smaller branch tunnels extending from the main tunnel. Often these supply tunnels became blocked; then there would be a sudden outburst of lava, throwing great blocks of the cooled lava, with the molten lava, into the air.

After camping near the Natural Bridge for about a week, we went down to the front of the flow again and found it very active. On the side toward Hilo a great, red, molten stream was flowing down Alenaio Gulch. Another very active branch of the flow was pushing off toward Waiakea. We rounded the Alenaio flow and went over to the Waiakea branch. On returning, we found that the Alenaio flow had advanced so rapidly that we were cut off from our former trail. Our alternative was to break through a dense grove of hau trees or run across a tongue of lava about 30 feet wide and 1.5 feet thick that had flowed out only a few minutes before. The tongue was red hot, just beginning to turn black on top. After testing the tongue of new lava by throwing heavy stones on it and observing that the stones rolled over it as if it were solid, we sprang over it with as few steps as possible, only slightly scorching our shoes.

A pahoehoe lava flow in full motion is a very interesting sight. At the advancing front the lava seems to come out of its tunnel and flow in an open red river of fire as much as several hundred feet long. This then appears to clog up and cool on top, and the lava pushes out in great and small lobes, piling one over the other and eventually forming a new tunnel underneath for the molten lava. The latter will then again break out and go through the same process as before.

After 2 weeks we reluctantly packed up our camp and started on our return trip to Honolulu. As we passed down toward Hilo we could see the lava flow making a rapid advance toward the town and the Waiakea sugar mill. On passing upper Halai Hill we noticed Princess Ruth Keelikolani sitting on the brow of the hill with her retainers, all decked out in red bandanas. The report is that she broke a bottle of champagne and made other sacrifices to Pele. The natives give Princess Ruth credit for stopping the flow.

When we left Hilo, about July 29, the lava was approximately 1.5 miles from the main part of the town. Again the Hilo people appealed to the authorities at Honolulu for help. At that time Professor Alexander had in his employ Mr. W. R. Lawrence, a former military engineer and practical civil engineer. He sent Mr. Lawrence to Hilo to survey the front of the lava flow and suggest any method that might be used to prevent the flow from entering the main portion of the town.

It was evident that the main flow of molten lava, like water, was seeking the lowest level and following the bed of Alenaio Stream. Mr. Lawrence recommended building a massive embankment along the town side of Alenaio Gulch. At Honolulu, the writer had been loaned to the Interior Department to assist in reading proof of the 12 volumes of a new copy of the Land Commission Awards and was working in the telephone room of the Interior Office. There he had the pleasure of hearing Mr. H. A. P. Carter, Minister of Foreign Affairs, telephoning to a Honolulu business firm to order a thousand picks, shovels, hoes, wheelbarrows, etc. The Government was arranging to set 1,000 men to work building the embankment to protect Hilo. But the work was never actually started, as the next steamer brought word that the lava had stopped flowing on August 9.

The people of Waiakea Plantation had built an ordinary stone wall across the front of the Waiakea branch of the flow in an effort to protect the Waiakea mill and claimed that the Waiakea flow was stopped by that wall. The writer later visited the wall and found that a small tongue of lava had piled up a few feet along it. Fortunately the eruption ended just at that time, as in the opinion of the writer the stone wall could not have stopped the flow.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR APRIL–JUNE, 1953

By GORDON A. MACDONALD

VOLCANOLOGY

April

Hawaiian volcanoes were quiet throughout the month of April, and seismic activity was approximately normal in amount. Seismographs at the rim of Kilauea Caldera recorded 50 earthquakes during the month, and the Mauna Loa seismograph recorded 33. Thus, Kilauea showed somewhat more activity than Mauna Loa. The Kona seismograph recorded 19 small earthquakes not recorded at any other station. These originated in central Kona close to the station. Probably some or all of them resulted from small movements on the Kealakekua fault, which runs out to sea along the northern edge of Kealakekua Bay.

A feeble earthquake felt in the Volcano area at 11:09 A.M. on April 10 had its origin beneath the east slope of Mauna Loa. A quake at 2:20 A.M. on April 14 recorded as very feeble on the seismograph but was felt by several persons in central Kona. Another feeble quake originated beneath the southwest slope of Mauna Loa at 1:42 A.M. on April 24 and was felt in Kona and in the Volcano district. Moderate earthquakes at 8:50 and 11:03 A.M. on April 29 probably had their origin on the Kaoiki fault, which separates Kilauea and Mauna Loa west of Kilauea Crater.

Tilting of the ground surface at the northeast rim of Kilauea Caldera normally is toward the southwest throughout the month of April. This year, the southward component of tilting was approximately normal in amount, suggesting essentially no change in volcanic pressure beneath Kilauea. Westward tilting, however, was at a rate somewhat greater than normal, suggesting the possibility of some reduction of pressure beneath Mauna Loa.

May

During early May, Hawaiian volcanoes were fairly quiet. From May 1 to 17 ground tilting at the northeast rim of Kilauea Caldera was approximately normal, both in direction and

amount, for that season of the year. The number of earthquakes recorded was nearly twice the normal number, but most of them were very small.

On May 17 the ground surface at the northeast rim of the caldera began tilting rapidly northward, and northward tilting continued at a rate notably greater than normal throughout the rest of May. On May 20 the number of earthquakes recorded at Kilauea Crater increased greatly and through the rest of the month averaged about 20 per day, bringing the total number recorded during May to 259. Of these, about 90 percent had their origin beneath or near Kilauea Crater.

Several small earthquakes were felt in Kona during the month. All these except one originated in the Kona area, some of them probably on the Kealakekua fault. At 4:59 A.M. on May 29 a strong quake originated on the Kealakekua fault. This earthquake dismantled one component of the seismograph at Konawaena School. It was felt strongly in central Kona and weakly over much of the rest of the island.

At 2:44 A.M. on May 24 a moderate earthquake originating beneath the east flank of Mauna Loa was felt over much of the island. A sharp earthquake felt at Kapapala at 7:33 P.M. on May 27 probably had its origin on the Kaoiki fault.

June

Kilauea Volcano remained notably restless throughout the month of June. Of the 184 earthquakes recorded by seismographs at Kilauea Crater during the month, the great majority originated in Kilauea Volcano. The total number of earthquakes was more than four times the usual number recorded during times of volcanic quiet. Northward tilting of the ground surface at the northeast rim of Kilauea Crater during June amounted to 4 seconds of arc. This rate of tilting is about five times as rapid as the average for this season and demonstrates a distinct increase of volcanic pressure beneath Kilauea.

Several earthquakes originating beneath the slopes of Mauna Loa and along its northeast rift zone indicate some uneasiness of that volcano also. However, ground titling in the east-west azimuth at the northeast rim of Kilauea Crater was slightly westward at a rate approximately normal for this season of the year. This suggests a lack of any marked change of volcanic pressure beneath Mauna Loa.

A feeble earthquake felt in Hilo and the Volcano district at 8:38 P.M. on June 15 appears to have had its origin beneath the east flank of Mauna Loa, about 3 miles north-northeast of the Whitney Laboratory of Seismology. Another, felt in the same areas at 10:47 A.M. on June 27, originated beneath the east slope of Mauna Loa about 3 miles S60°E of Puu Kulua. A slight earthquake at 12:49 A.M. on June 9, felt in Hilo but not reported felt in the Volcano area, apparently had its origin beneath the crater region of Kilauea Volcano.

The seismograph at Konawaena School recorded 17 earthquakes during June. Most of them originated in central Kona close to the seismograph, probably on the Kealakekua fault.

LANDSLIDE ON THE HAMAKUA COAST

A small landslide took place on the sea cliff near the mouth of Manowaiopae Stream, just south of Laupahoehoe (Hamakua Coast), early on the morning of May 28. According to Joe Jose, who lives near the site of the slide, a small slip occurred at 3:00 A.M., followed by a larger one at 5:00 A.M. Seismographs on the Island of Hawaii recorded no earthquakes at those times, so the slides apparently were not set off by earthquakes. At the foot of the sea cliff the slides built a small peninsula; this was immediately attacked by waves which rapidly removed a large portion of it.

Such landslides are not uncommon along the sea cliffs of Hawaii, especially along the windward coast of Kohala. According to William Ellis (*Journal of a Tour around Hawaii*, Boston, 1825), similar landslides occurred late in 1822 or early in 1823 between Pololu and Honokane valleys and at a locality known as Laupahoehoe, about 1½ miles northwest of Waimanu Valley. Another landslide may have occurred at the latter locality during the violent earthquake of April 2, 1868. A large slide occurred on the sea cliff just east of the mouth of Honopue Valley during heavy rains in January, 1941 (Stearns and Macdonald, *Geology and Ground Water Resources of the Island of Hawaii*, 1946, p. 51). All these slides built debris fans at the base of the cliff, but only the Laupahoehoe fan was large enough to survive for long the attack of waves.

SEISMOLOGY

Local Earthquakes

The data for the following local earthquakes were determined from seismographs on the Island of Hawaii operated by the Hawaiian Volcano Observatory. Locations given are epicenters. The times given are arrival times at the Whitney Laboratory of Seismology, on the northeast rim of Kilauea Caldera. They are stated to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich Civil time. The number preceding each earthquake is the serial number for the current year. The intensity rating (Feeble, Moderate, etc.) given is that for the Whitney Laboratory. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney station.

75. Apr. 2, 02:59, no record at Kilauea (Kona, very feeble). Central Kona.
76. Apr. 7, 23:37, tremor (Kona, very feeble).
77. Apr. 10, 11:09, feeble (Mauna Loa, slight). Felt in Volcano district. Northeast slope of Mauna Loa.
78. Apr. 13, 18:00, no record at Kilauea (Kona, very feeble).
79. Apr. 14, 02:20, tremor (Kona, very feeble). Felt in Kona. Central Kona.
80. Apr. 16, 14:36, no record at Kilauea (Kona, very feeble).
81. Apr. 17, 09:35, very feeble. Kilauea.
82. Apr. 22, 15:28, very feeble.
83. Apr. 24, 01:42, feeble. Felt in Volcano district, south Kona, and Kohala. Southwest slope of Mauna Loa, near 19°20′N., 155°47′W.
84. Apr. 24, 05:44, very feeble.
85. Apr. 29, 08:50, moderate. Southwest rift of Kilauea (?).
86. Apr. 29, 11:03, moderate. Kilauea.
87. Apr. 29, 13:00, slight. Southwest rift of Kilauea (?)
88. May 3, 23:50, no record at Kilauea (Kona, very feeble).
89. May 6, 17:59, tremor (Kona, very feeble).
90. May 7, 14:43, no record at Kilauea (Kona, very feeble).
91. May 8, 01:18, no record at Kilauea (Kona, very feeble).
92. May 8, 16:19, tremor (Kona, very feeble).
93. May 8, 17:53, tremor (Kona, very feeble).
94. May 11, 08:48, slight. Kilauea (east rift zone ?).
95. May 13, 08:25, very feeble.
96. May 13, 12:10, very feeble.
97. May 15, 13:31, very feeble.
98. May 16, 10:31, very feeble.
99. May 17, 09:30, no record at Kilauea (Kona, very feeble).
100. May 17, 13:48, very feeble.
101. May 18, 03:05, very feeble.
102. May 19, 18:02, tremor (Kona, very feeble). Felt in south Kona.
103. May 20, 13:05, very feeble.
104. May 21, 14:12, very feeble.
105. May 22, 23:22, very feeble (Kona, feeble). Felt in central Kona. Kealakekua fault (?).
106. May 24, 02:05, slight. Felt in Volcano district. Kilauea.
107. May 24, 02:12, very feeble. Kilauea.
108. May 24, 02:44, moderate. Felt over much of Hawaii Island as far north as Kukuihaele. East slope of Mauna Loa near 19°26′N., 155°27′W.
109. May 24, 13:15, tremor (Uwekahuna, very feeble).
110. May 25, 10:17, tremor (Kona, very feeble). Felt in south Kona.
111. May 26, 06:26, feeble. Felt at Naalehu.
112. May 27, 19:33, tremor. Felt at Kapapala.
113. May 29, 04:59, slight (Kona, strong). Felt in central and south Kona, Naalehu, and Volcano district. Kealakekua fault at north side of Kealakekua Bay, near 19°29′N., 155°56′W.
114. May 29, 05:08, tremor (Kona, very feeble). Central Kona.
115. May 29, 07:47, no record at Kilauea (Kona, very feeble). Central Kona.
116. May 29, 10:21, no record at Kilauea (Kona, very feeble). Central Kona.
117. May 30, 05:16, very feeble.
118. May 31, 04:13, very feeble.
119. June 4, 01:14, very feeble.
120. June 4, 17:01, very feeble.
121. June 4, 18:48, very feeble. Felt fairly strongly at Kapapala. Southeast slope of Mauna Loa near Kapapala.

122. June 5, 11:23, very feeble.
123. June 6, 04:48, very feeble. Kilauea.
124. June 8, 16:58, very feeble.
125. June 9, 00:44, very feeble.
126. June 9, 00:49, slight. Felt in Hilo. Kilauea (?).
127. June 10, 00:40, very feeble. Kilauea.
128. June 11, 21:27, no record at Kilauea (Kona, very feeble). Central Kona.
129. June 15, 03:24, no record at Kilauea (Kona, feeble). Central Kona.
130. June 15, 20:34, feeble. Felt in Hilo and Volcano district. Northeast slope of Mauna Loa about 3 miles N 30° E of Volcano House, near 19°29′N., 155°14′W.
131. June 16, 11:10, no record at Kilauea (Kona, very feeble). Central Kona.
132. June 17, 02:27, no record at Kilauea (Kona, very feeble). West slope of Mauna Loa.
133. June 18, 03:05, very feeble.
134. June 20, 20:55, tremor (Kona, very feeble).
135. June 21, 07:20, no record at Kilauea (Kona, very feeble).
136. June 23, 17:50, very feeble (Kona, slight). Central Kona.
137. June 23, 17:53, no record at Kilauea (Kona, very feeble).
138. June 26, 17:53, no record at Kilauea (Kona, very feeble).
139. June 26, 20:24, very feeble (Kona, feeble). Central Kona.
140. June 26, 20:54, tremor (Kona, very feeble).
141. June 27, 10:47, moderate. Felt in Volcano district. East slope of Mauna Loa about 3 miles S 60° E of Puu Kulua, near 19°31′N., 155°23′W.
142. June 27, 23:12, tremor (Kona, very feeble).
143. June 28, 20:20, very feeble.
144. June 30, 00:45, tremor (Kona, very feeble). Central Kona.
145. June 30, 06:37, tremor (Kona, very feeble). Central Kona.

Distant Earthquakes

The following earthquakes of distant origin were recorded on the seismographs of the Hawaiian Volcano Observatory. Locations of the epicenters are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey. The time given is that of the first detectable emergence of the quake on the Bosch-Omori horizontal or Sprengnether vertical seismograms, in Hawaiian Standard time.

April 5, 14:48, slight. Banda Sea, at 7°S., 132°E.
April 18, 13:48, slight. Off south coast of Mexico, at 10°N., 102°W.
April 23, 06:34, slight. New Britain region, at 4°S., 154°E.
June 15, 08:05, slight. Near south coast of Kodiak Island, Alaska, at 56½°N., 154°W.

Earthquake Data, April–June, 1953

(Based on Bosch-Omori seismograph on northeast rim of Kilauea Caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
April 5	6	0	1	0	0	0	2.5	1
12	5	1	0	0	0	0	1.75	1
19	12	0	1	0	0	0	4.0	1
26	17	0	0	1	2	0	9.25	0
May 3	11	0	0	0	0	0	2.75	0
10	15	2	0	1	0	0	6.75	0
17	73	0	0	0	0	0	18.25	0
24	149	3	0	2	1	0	45.75	0
31	38	6	0	0	0	0	12.5	0
June 7	30	3	0	1	0	0	11.0	0
14	48	1	1	0	0	0	13.5	1
21	58	2	0	0	1	0	18.5	0
28	15	2	0	0	0	0	4.75	0

* For definition of local seismicity see Volcano Letter 371 or 512. Each local earthquake is assigned a seismicity value according to its strength, as follows: tremor, 0.25; very feeble, 0.5; feeble, 1.0; slight, 2.0; moderate, 3.0; strong, 4.0. These values are totaled to give the weekly local seismicity. Continuous volcanic tremor is ignored in the calculation. The strength assigned to the earthquake depends on the double amplitude of the maximum oscillation it causes on the Bosch-Omori seismograph, as follows: tremor, less than 0.5 mm.; very feeble, 0.5 to 4 mm.; feeble, 4 to 11 mm.; slight, 11 to 25 mm.; moderate, 25 to 60 mm.; strong, greater than 60 mm.

Table of Tilt at Seismograph Stations on Rim of Kilauea Caldera

Week Beginning	Whitney Station (Northeast rim)		Uwekahuna Station (West rim)	
	Amount	Direction	Amount	Direction
April 5	1.4″	S 38° W	0.6″	N
12	0.9″	N 56° E	1.3″	S 37° E
19	1.3″	S 63° W	0.4″	N 45° E
26	1.3″	S 80° W	0.7″	N 27° W
May 3	0.6″	N 79° E	1.6″	N 12° W
10	0.4″	S 72° E	2.6″	S 14° E
17	1.5″	N 14° W	2.2″	S
24	1.3″	N 34° E	2.4″	N 23° W
31	1.2″	N 17° W	1.3″	S 14° W
June 7	1.0″	N 7° E	0	0
14	0.1″	W	0.7″	N 26° E
21	0.7″	N 9° E	1.4″	S 27° E
28	1.8″	N 20° W	0.4″	N 45° E

VOLCANO NOTES AND NEWS

VOLCANOLOGICAL SURVEY OF INDONESIA

The Volcanological Survey of Indonesia (Dinas Gunung Berapi Indonesia) is carrying on the work started by the Netherlands East Indies Volcanological Survey. Directly after the war the work was handicapped by a lack of funds and adequate personnel. Since 1950, however, rapid advances have been made in reconnaissance and mapping of volcanic districts, some of them previously unknown. Much of this has been made possible through the co-operation of the Air Force of the Republic of Indonesia. A summary account of the progress up to the end of 1952 is contained in *Berita Gunung Berapi (Communications of the Volcanological Survey of Indonesia)* 1 (1–2), Sept.–Dec., 1952.

Following the transfer of Sovereignty, Dr. G. A. deNeve became director of the Volcanological Survey, succeeding W. A. Petroeschevsky in September, 1950. It was decided that aerial reconnaissance offered the most expeditious way of obtaining a general view of the volcanic activity of the whole of Indonesia and determining which volcanoes are most urgently in need of more detailed examination. This reconnaissance was largely accomplished by mid-1951, and ground examinations and mapping had been carried on in some areas. As a result of this work 15 new active volcanic centers have been found on Sumatra, northern Celebes, and Flores, bringing the total number of active volcanoes and solfatara and fumarole fields in Indonesia to 167, in place of the 152 listed by C. H. Stehn in 1940.

Additional work was done during 1952 by teams of investigators transported to and from their respective areas of study in Catalina amphibian planes. Special studies have been carried out on Semeru to delineate the areas in danger from cold lahars (mud flows) and at Kelud for the restoration of the tunnels constructed to drain the crater lake.

This energetic resumption of work on Indonesian volcanoes is deserving of great praise, and it is to be hoped that the work can be continued in a similar manner and its scope increased still further.

ACTIVITY OF TRIDENT VOLCANO

Trident Volcano, in Alaska, continues in mild activity. The lava flow issuing about a mile southwest of the old crater of Trident continued to grow slowly until June 2. George Snyder, geologist of the U. S. Geological Survey, reports that between June 2 and June 17 the rate of growth of the flow increased markedly. He estimated the thickness of the flow in the vicinity of the vent to be about 1,000 feet on June 17. The rate of gas emission is much decreased over that during March. Snyder

reports there were two large explosions and constant gas liberation during an hour's observation on June 17. Steam is issuing from the crater of nearby Mageik Volcano. Robert R. Coats reports (U. S. Geological Survey Bulletin 974-B) that Mageik Volcano and the neighboring volcanoes Katmai, Martin, and Novarupta have been steaming almost constantly since 1912. A small cinder cone is reported to have been built on the southwest flank of Novarupta, in the Valley of Ten Thousand Smokes, in July, 1950 (Lowell Sumner, Sierra Club Bul. 37 (10) : 45, Dec., 1952). George Snyder states (Preliminary Report of Mt. Trident Eruption) that according to the *Kodiak Mirror* for Feb. 21, 1953, Mageik Volcano last erupted in 1951.

The accompanying photograph shows the lava flow on the southwest flank of Trident Volcano on February 21 and the cloud of ash and fume rising at the vent from which the flow is issuing.

Snyder estimates that from the beginning of the eruption until March 11 the volume of lava and ash liberated by Trident Volcano was between 2.2 and 4.5 billion cubic feet (0.015 to 0.03 cubic mile) and that between March 11 and June 17 from 1 to 2.5 billion cubic feet of additional lava was extruded. Compared with this, the volume of ash and other fragmental material produced by the great eruption of Katmai Volcano in 1912 has been estimated at 6 to 7 cubic miles.

R. E. Wilcox writes that the last significant ash eruption of Trident Volcano was on June 30.

ACTIVITY OF GREAT SITKIN VOLCANO

Richard McDonald, seismologist of the U. S. Geological Survey, reports that on May 11, 1953, the Coast and Geodetic Survey ship *Pioneer* observed a spectacular column of steam rising an estimated 5,000 feet above Great Sitkin Volcano, in the Aleutian Islands. The steam column lasted about an hour. An earthquake felt at Adak on May 12, with an intensity of 5 on the modified Mercalli scale, had its epicenter on a line passing through Great Sitkin. On the afternoon of May 14 a steam cloud was seen to rise about 4,000 feet above the crater rim of Great Sitkin, and during the evening another earthquake occurred, slightly less severe than that of May 12, with its epicenter on the same line. Both quakes apparently were more severe on Great Sitkin than on Adak. When next observed, on May 19, the steaming of Great Sitkin Volcano was much diminished but still greater than normal. Subsequent observations on May 23, June 5, and June 7 showed only weak emission of steam. No ash eruption was observed during the period from May 11 to June 7, nor did the form of the basalt dome in the crater of Great Sitkin change appreciably.



FIGURE 2. Trident Volcano, Mount Katmai National Monument, in eruption on February 21, 1953. The cloud of ash and fume is rising from a vent on the southwest slope of Trident, and a small lava flow also is issuing from the same vent. Knife Peak Volcano appears on the left of the view, and Katmai Volcano, with its summit caldera formed during the great eruption of 1912, is on the right. Official U. S. Navy photograph.

ACTIVITY IN THE MARIANA AND VOLCANO ISLANDS

Charles G. Johnson, of the U. S. Geological Survey's Military Geology Branch, has forwarded a report from the 54th Strategic Reconnaissance Squadron, USAF, on aerial reconnaissance of activity on Farallon de Pajaros, in the Mariana Islands, and submarine volcanic activity near Minami Iwo Jima, in the Volcano Islands.

During late March the Farallon de Pajaros volcano was in mild explosive activity. On March 25, Major J. F. Fagan reported small puffs of smoke from the crater at intervals of 2 to 3 minutes. On March 26, Lt. J. D. Long counted eight explosions in 11 minutes, during which rocks estimated to be as much as 3 feet in diameter were thrown an estimated 30 feet above the crater rim. On March 27, Capt. C. G. Cook observed only two belches of smoke containing only small fragments in a period of 20 minutes. On March 28, Capt. K. S. Durham observed puffs of smoke rising about 300 feet above the crater every 65 to 70 seconds. Similar activity was reported on March 30 and 31.

About 1.5 miles north-northeast of Minami Iwo Jima submarine volcanic activity produced a small area of very light green water.

ACTIVITY ON SAN BENEDICTO ISLAND

Adrian F. Richards, of the Scripps Institution of Oceanography, again visited the Revilla Gigedo Islands in March, 1953. At that time Boqueron Crater on San Benedicto Island was quiet. The lava in the crater was cool at the surface but gave vent to numerous active fumaroles. The delta of blocky lava at the eastern base of the cone was about three times as large as it had been during December, 1952, extending seaward about 2,100 feet beyond the old shoreline and providing a good small-boat harbor on its south side. Information from fishermen leads Richards to believe that the flow probably ceased its forward growth during January.

Richards also reports an area of active fumaroles covering nearly 2 acres near the peak on the north and northeast sides of Mount Evermann, on Socorro Island. Many small, boiling mud pots were observed.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director
Chester K. Wentworth, Geologist, part-time
Burton J. Loucks, Instrument Maker
John C. Forbes, Assistant Instrument Maker
Elizabeth G. Eklund, Secretary, part-time

Seismograph Station Operators:

Hilo Station:
Sister M. Thecla, St. Joseph's School

Kona Station.
Howard M. Tatsuno, Konawaena School

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcances in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations.

The **Volcano Letter**, a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

THE VOLCANO LETTER

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CONDITION OF ACTIVE VOLCANOES OF ITALY IN 1952

By FRED M. BULLARD
University of Texas

Although there are many volcanoes in Italy which have been active in very recent geologic time, the number which have been active in historic time is quite limited, even considering the fact that recorded history in this region goes back to around 800 B.C., when the first Greek colonies were established in the region. Today active vents are located in only three areas: (1) the Naples area, including Vesuvius and the Solfatara of Pozzouli, (2) the Eolian Islands, represented by Stromboli and Vulcano, and (3) Mt. Etna in Sicily.

The writer was privileged to spend most of 1952 in a study of the active and recently extinct volcanoes of Italy. The purpose of this brief paper is to set forth the state of activity during 1952 of the so-called active vents.

VESUVIUS

It should be kept in mind that Vesuvius is but one of a number of volcanoes in the Naples area which have been active in recent geologic time. Probably the oldest of these is Epomeo on the island of Ischia which last erupted in 1302. A very severe earthquake in 1883 at Casamiccola (Ischia) indicates that the volcanic energy is not entirely dead. In the Phlegrean Fields, on the shore of the Bay of Naples, there are no less than 19 separate craters, the last activity being the birth of the new crater, Monte Nuovo, in 1538. The Solfatara, one of the craters in the Phlegrean Fields, just west of Naples (Fig. 1), maintains a constant emission of hot gases from which the name "Solfatara" is derived. The activity of the Solfatara, with the exception of an eruption in 1198 in which lava poured, has been in about its present state since the earliest records.

The great eruption of Vesuvius in 79 A.D., in which Pompeii and Herculaneum were destroyed, blew away a large part of the old cone, and a new cone, the present Vesuvius, was built, its center being somewhat removed from the center of the old cone. The remnants of the old cone, which still partly encircle Vesuvius, are known as Monte Somma (Fig. 2).

Following the eruption of 79 A.D., the activity of Vesuvius appears to have been very irregular, with long

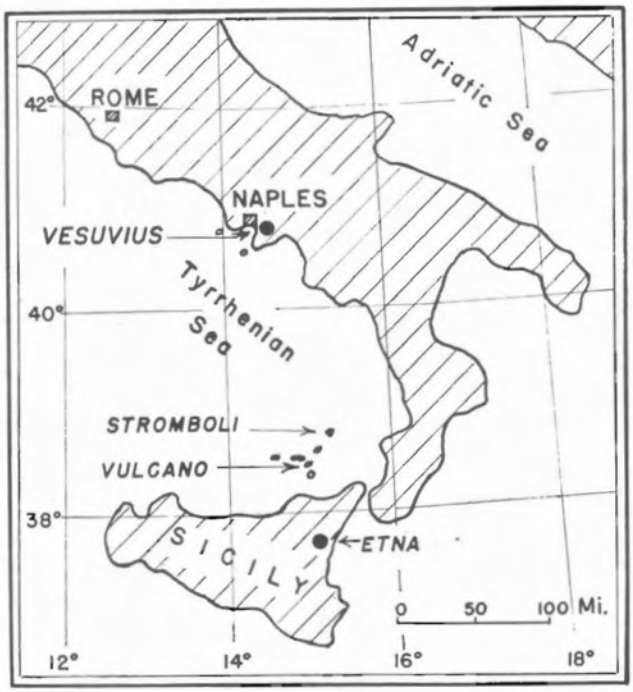

FIGURE 1. Map of southern Italy, showing the location of the principal volcanoes mentioned in the text.

intervals between eruptions, until the grand eruption of 1631. This eruption, one of the greatest in the entire history of Vesuvius, marks a new era in the activity of the volcano. Since 1631 Vesuvius has been in an almost constant state of activity. This activity, which may be described as cyclic, is marked by eruptive periods in which moderate activity is climaxed by a grand eruption which ends a cycle, the new cycle beginning with a repose period. Mercalli has published a list of 12 eruptive periods since 1700, each culminating with a paroxysm followed by a distinct interval of complete inactivity (repose period), the duration of which varied from 2 to 7 years. The repose period is marked by simple emanations of gaseous material. It is the period during



FIGURE 2. Vesuvius during 1952, with the Bay of Naples in the foreground. The present cone of Vesuvius is on the right. The peak at the left is a high portion of the encircling remnant of Monte Somma. Photo by author.

which the magma acquires a gas-saturated condition required for the next eruption.

The great eruption of 1906 closed a cycle, and the repose period which marked the beginning of the new cycle lasted until 1913 (some slight activity in 1911 is interpreted by some writers as marking the end of the repose phase), a period of 7 years. In the following years Vesuvius was in an almost continuous state of moderate activity until the grand eruption of 1944 which marked the end of the cycle. The 1944 eruption began on March 18 and lasted 11 days. Extensive lava flows covered the towns of Massa and San Sebastiano, as well as destroying a portion of the Vesuvius railway line. The new cycle was initiated by a repose phase which has continued to the present time. As the repose phase of Vesuvius has rarely exceeded 7 years, and it is now in its ninth year, it is obvious that a renewal of activity may be expected at any time.

At the end of the 1944 eruption the crater was an elliptical-shaped basin with a maximum depth of about 900 feet below the west rim. Since the 1944 eruption, the crater has been gradually filling by avalanches from the sides. Its depth in July, 1952, was estimated to be about 700 feet. As the sides avalanche, they not only fill up the bottom of the crater but also enlarge the upper rim. As some of the large avalanches crash into the crater, a great cloud of dust, resembling a cauliflower in appearance, boils out of the crater. Frequently, such clouds are reported in the press as eruptions.

The greatest thermal activity at present is on the eastern side, 200 to 300 feet below the rim on the outer slope. For the past year or so this has been a "hot" spot, and recent press reports list temperatures in excess of 650°C. Whether this indicates that the next outbreak will occur at this point cannot, of course, be determined, but it is at least suggestive. Numerous steam fumaroles rise from points on the interior walls of the crater. There is a considerable accumulation of sulphur around fumaroles on the inner slope of the northeast rim, which is the highest point on the crater.

If the renewal of activity at Vesuvius follows the pattern of the previous eruptive cycles, the first activity will begin with the opening of a *bocca* in the bottom of the crater and the development of a small cinder cone. Later, lava will appear as intercrater flows, perhaps filling the crater and overflowing the rim or issuing from cracks near the top as slow outpourings of lava.

STROMBOLI

The Eolian Islands (Lipari Islands), in the Mediterranean sea off the southern coast of Italy and directly north of Sicily, consist of a number of volcanoes, two of which (Stromboli and Vulcano) are considered active. Stromboli is a large volcano, rising from the floor of the Mediterranean Sea in water between 6,000 and 7,000 feet deep and reaching a height of approximately 3,000 feet above sea level. Its total height from its submarine base is 3,200 meters; by comparison, Mt. Etna reaches a height of only 2,900 meters. Thus Professor G. Ponte was not entirely incorrect when, in a recent paper, he described Stromboli as the highest active volcano in Europe.

Normally, the lava column stands very high in the conduit, and frequent gas explosions hurl quantities of red-hot scoria several hundred feet into the air. The explosions occur at intervals of 15 to 30 minutes, and at each outburst a red glow is reflected on the rising gas column, gradually dying out as the lava crusts over. This red glow, coming and going at more or less regular intervals, has given to this volcano the name, "Lighthouse of the Mediterranean." So characteristic of Stromboli is the throwing out of incandescent scoria that it has been selected as one of the types of volcanoes. Although the so-called Strombolian type of activity is characteristic of Stromboli, the volcano also exhibits rare but violent explosive eruptions accompanied by large *pino* (pine-tree shaped) clouds, which spread ash



FIGURE 3. Stromboli, from the north. The eccentric crater is about 600 feet below the summit. The talus-like slope extending from the crater to the sea is the Sciarra del Fuoco. Photo by the author.

and cinders widely. Effusive lava flows are also much more common than has been generally accredited, and because of this fact it must be recognized that Stromboli, like most volcanoes, exhibits various eruptive phases and is not limited to the so-called Strombolian type.

The writer made three visits to Stromboli in 1952: in June, again on December 1–3, and during the week of December 12–19. As one approaches Stromboli by ship (it is an overnight trip from Naples) in the early morning, the symmetrically shaped cone with a white vapor column rising from the crater can be seen for some time before the ship is close enough to enable one to distinguish the big scar on the side of the cone, known as the Sciarra del Fuoco (Fig. 3). On the first trip to Stromboli in June, 1952, numerous columns of white vapor were observed rising from the crater, and at infrequent intervals a dense, yellowish-brown gas issued. There was no noise, and no red glow was observed. The cone was climbed on June 21 and the activity observed from the top of the north peak, from which vantage point one is able to look down into the crater some 600 feet below. The first view into the crater is a thrilling sight.

The crater is a large, oval-shaped basin, about 500 feet in its longest dimension, about 600 feet below the summit of the mountain. It is separated into two sections by a low ridge of debris. Extending from the northwest edge of the crater to the sea is the Sciarra del Fuoco. In June, 1952, there were within the crater two active vents and possibly a third. The vent nearest the edge of the Sciarra del Fuoco was an oval-shaped crater, possibly 30 to 40 feet in diameter, from which issued a grayish gas and, at intervals, a dense white cauliflower cloud of steam. There was no noise associated with this vent.

At the opposite end of the oval-shaped crater was the most active vent. From it a grayish-white vapor issued which frequently filled the entire crater, obscuring everything. There was a continuous roar, more of a chugging or "sloushing" noise, comparable to that made by a locomotive when the engineer slides the wheels in starting, or to the unrhythmical exhaust of a pump station in an oil field. At intervals of 15 to 30 minutes this exhaust was interrupted by more violent outbursts (not an explosion but a tremendous outrush of gas) which hurled rocks (scoria) from 600 to 1,000 feet above the crater floor. They were not incandescent, and most of them fell back into the crater, the noise continuing until another outburst took place. There appeared to be a third vent, approximately midway between the two described. This vent could not be seen clearly from the vantage point, but a gas column was observed rising from this point from time to time. Active avalanching was taking place on the opposite wall of the crater. At irregular intervals avalanches slid from the wall, giving rise to dense, yellowish-brown cauliflower clouds which filled the crater and spread a rain of fine ash over the upper part of the cone.

Lava flow of June 6, 1952. This flow apparently began without any preliminary explosions or *pino* clouds which normally accompany an outflow, as the inhabitants of San Vincenzo were not aware of the flow until a tourist, arriving by ship, commented on the lava flowing down the Sciarra del Fuoco. The flow appears to have started on June 6 and to have continued for several days. The lava reached the sea at the base of the Sciarra del Fuoco, building out two small projections into the sea which were still steaming when visited by the writer on June 22.

The cone was not ascended on the December 1–3 visit to Stromboli because of bad weather conditions. However, from the deck of the ship, as the writer was leaving Stromboli for Naples late in the evening of December 3, a red glow was noted which faded and reappeared. Suddenly, with a brilliant glare, a tremendous explosion hurled fragments into the air which could be clearly distinguished even at a distance of a number of miles. The glare which illuminated the lower part of the cone was a whitish red, the upper part a



FIGURE 4. Vulcano, from Quattr'ochi, Lipari. The low rim encircling the highest cone is the remnant of an earlier cone. Photo by the author.

bright red. Two such explosions occurred during the hour the "Lighthouse of the Mediterranean" was watched from the deck of the ship before it disappeared over the horizon.

Two visits to the crater were made on the third trip to Stromboli in mid-December. On the first ascent (December 14) the conditions were generally the same as in June, except that the steam column was much denser (probably due to colder air temperature) and the visibility, as a result, much poorer. The west vent, as usual, was the most active and was accompanied by the chugging or exhaust noise as in June. When a second ascent was made on December 18, the conditions were somewhat different. From the west vent, at intervals of 20 to 30 minutes, showers of red-hot scoria were thrown to a height of around 600 feet. The outbursts, although definite explosions, were more like an exhaust with a hissing noise, or like the outrush of gas under high pressure. The scoria fragments were mostly flat and appeared to represent the thin crust from a bubble, which on bursting showered fragments into the air. All the scoria fell back into the cavity, none reaching the Sciarra del Fuoco. The chugging, so prominent on previous visits, was entirely absent, and between outbursts there was a silent emission of steam. The eastern vent (adjacent to Sciarra del Fuoco) continued to send up large quantities of steam, and at irregular intervals, probably 30 to 40 minutes, it exploded with a shrill, whistling noise. There was no apparent relationship between the activity of the two vents.

VULCANO

Vulcano is one of the Eolian Islands, immediately adjacent to Lipari, famous in classic mythology as the site of Vulcan's forge (Fig. 4). It was quite active in the early centuries of the Christian era but has been less active in recent times. The last eruption was in 1888–90. Since that time it has been in a solfataric state of activity. When the writer visited Vulcano in late November, 1952, it appeared to be in about the same state of activity as described in the literature of the past 10 to 20 years. Abundant fumaroles were active on the upper half of the inner slope of the west wall of the crater. Deposits of sulphur were abundant around all the openings. Strangely enough, no fumaroles occur on the floor of the crater, and there is no evidence in deposits to indicate that any ever were present.

Another active fumarole area is at the west base of the main cone, known as Faraglioni di Levante, or Porto di Levante. The mining of sulphur was carried on here for years, but no work is now being done. The sulphur occurs as impregnations in the porous tuffs. Active fumaroles occur along the beach and in the shallow water near shore, as well as on the land a few yards back of the beach. There are several active, boiling mud pits similar to those at the Solfatara of Pozzouli. Drilling is under way in this area in an effort to obtain natural steam for the generation of electricity.

MT. ETNA

Located on the east coast of Sicily, Mt. Etna is the greatest volcanic mass in Europe and one of the large volcanoes of the world. It has the shape of an enormous cone truncated at a height of 9,190 feet by a plateau on which stands the summit cone, which reaches a height of 10,742 feet. The regularity of the slope is marred by about 200 parasitic cones which mark the site of previous eruptions. On the east slope of the cone is the tremendous depression or valley known as the Valle del Bove.

Mt. Etna has been known as an active volcano from the earliest times. One of the greatest eruptions of Mt. Etna was in 1669, when the city of Catania was destroyed by a lava flow. From 1669 to 1951 there have been 35 eruptions, separated by an average interval of 8 years. The most recent eruptions were in 1923, 1928, 1942, and 1950–51.

The summit crater is a circular depression, some 2,000 feet in diameter. Numerous steam columns rise from

the floor and sides of the crater, but sublimate deposits are insignificant. Prior to 1942 the crater was a cone-shaped depression nearly 1,000 feet deep, with many steam vents and small cones on the floor. In 1942 there was an eruption within the crater, and it filled to its present level, which is about 300 feet below the rim. A low cinder cone, from which abundant steam issues, occupies a portion of the crater floor. On the northeast edge of the crater floor there is a circular depression (small-scale replica of Halemaumau on the floor of Kilauea) which was formed by subsidence of the crater floor in 1945. On the northeast edge of the summit crater and outside the rim is the Northeast Bocca (also known as the northeast subterminal crater). It is a cone formed during the eruption of 1911, partly merged with the present summit crater but some 200 feet below and on the outer slope. From this opening great volumes of steam and occasionally other gases issue. This is the vent which supplies the vapor column rising constantly from Mt. Etna. The vent can be well observed from a vantage point on the main crater rim. Large clouds of white steam boil out with a hissing noise, accompanied by a roar which resembles the continuous roll of thunder. The guide reported that the thunder-like noise is present only when the vapor is white (i.e., steam). If it is dark (ash-filled) there is no noise. A similar relationship between the composition of the eruption cloud and noise was noted at Paricutin Volcano, Mexico.

The last eruption of Mt. Etna began on November 25, 1950, preceded by intense activity at the northeast subterminal crater. Large quantities of fluid lava issued from the east base of the summit cone near the 9,000-foot level and flowed into Valle del Bove. This great expanse of fresh, black lava forms a striking floor in the Valle del Bove today.

A very sharp earthquake damaged a number of towns on the eastern slope of Mt. Etna on March 22, 1952. The greatest damage centered around San Venerina, where 400 families were left homeless. Whether this is to be the point of a future outbreak is, of course, not known, but it is interesting to point out the possibility of such being the case.

References

ALFANO, G. B., and I. FRIEDLAENDER. LA STORIA DEL VESUVIO. Naples, 1928.

D'ARRIGO, AGATINO. LA RECENTE ERUZIONE DELL' ETNA. Inst. Geog. Mil., Rev. 31(2), 1951.

IMBO, G. PAROSSIMO DI STROMBOLI NEL SETTEMBRE 1930. Bul. Vulcanologique, 1928.

——— VARIAZIONE CICLICHE NELLA SUCCESSIVE DEI PERIODI DI REPOSO ETNEI. Bul. Vulcanologique, 1928.

——— L'ATTIVITA ERUTTIVA VESUVIANA, PT. 1. Annali dell'Osservatorie Vesuviano, ser. 5, vol. 1, 1951.

PERRET, F. A. THE VESUVIUS ERUPTION OF 1906. Carnegie Inst. Wash., Pub. 339, 1924.

PONTE, G., G. IMBO, and others. LO STROMBOLI. Dell' Associazione Internationali dei Vulcanologi. Messina, 1952.

SICARDI, LUDOVICO. IL RECENTE CICLO DELL' ATTIVA FUMAROLICA DELL ISOLA DI VULCANO. Bul. Vulcanologique, ser. 2, vol. 7, pp. 86–140, 1940.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JULY–SEPTEMBER, 1953

By GORDON A. MACDONALD

VOLCANOLOGY

July

Seismographs of the Hawaiian Volcano Observatory recorded 82 earthquakes during July. Of these, 44 were recorded at Kilauea caldera and 58 at the Mauna Loa station. Many, of course, were recorded at both stations, but an unusually large proportion were too small to be recorded at any but the closest. The number of earthquakes was somewhat greater than usual, but only two were large enough to be felt. On July 26 at 1:52 P.M., a moderate quake was felt from central Kona to Hawi. It appears to have originated in the vicinity of Hualalai. At 10:24 P.M. on July 28, a quake felt lightly in central Kona probably was of nearby origin.

During the month, tilting of the ground at the northeast rim of Kilauea caldera was northward at a rate slightly greater than normal. There appears to have been little change of volcanic pressure at Kilauea. From July 22 to 31 there was a marked westward tilting. This, together with northwestward tilting at the Mauna Loa station, suggests a decrease of pressure beneath Mauna Loa, accompanied by some subsidence of the mountain.

August

Hawaiian volcanoes continued moderately uneasy throughout August. Observatory seismographs recorded 79 earthquakes during the month. Of these, 47 were recorded at the stations on the rim of Kilauea caldera, and 58 at the Mauna Loa station. Most of the quakes came from shallow foci on the northeast rift zone of Mauna Loa or in the vicinity of Kilauea Crater.

Earthquakes felt strongly at Kapapala and slightly from Naalehu to the Volcano district, at 6:48 A.M. on August 1, 5:20 P.M. on August 4, and 12:46 A.M. on August 6, originated on the southwest rift zone of Kilauea a short distance southwest of Mauna Iki. A quake felt strongly in central Kona at 3:00 A.M. on August 8 originated nearby, probably on the Kealakekua fault.

An earthquake felt all over the island of Hawaii and by many persons on Maui and Oahu, at 7:46 P.M. on August 21, appears to have originated beneath the north slope of Hualalai volcano in the vicinity of Puu Waawaa. This is the area from which came more than 6,000 earthquakes during September and October, 1929. Another earthquake, felt strongly in Kona and lightly over most of the rest of the island at 12:53 A.M. on August 23, originated beneath the southwest slope of Hualalai, east of Holualoa.

Through August the ground surface at the northeast rim of Kilauea Crater tilted northward at a rate somewhat greater than normal and westward in place of the eastward tilting normal during that season of the year. Some of this abnormal tilting may have been caused by the load imposed on the ground by the weight of the new addition to the Volcano House, then under construction. It appears probable, however, that much of it was of volcanic origin, resulting from a decrease of volcanic pressure beneath Mauna Loa and an increase beneath Kilauea.

September

Hawaiian volcanoes continued to be seismically restless during the month of September. A large number of very small earthquakes was recorded. Many of them apparently originated on or near the zone just south of the island from which came the great number of quakes during March and April, 1952, preceding the eruption of Kilauea. (See Volcano Letter 515.) Several other quakes had their origins along the Kaoiki fault zone near Ainapo and in central Kona. Two of the latter, at 3:00 P.M. on September 23 and 1:20 P.M. on September 27, were felt in Kona.

The ground surface at the northeast rim of Kilauea caldera tilted northward throughout the month at a rate slightly greater than normal for this season of the year. Eastward tilting was at approximately the normal seasonal rate. The possible small increase of volcanic pressure under Kilauea, suggested by the northward tilting, tends to be confirmed by the slight opening of cracks on the crater floor.

SEISMOLOGY

Local Earthquakes

The data for the following local earthquakes were determined from seismographs on the island of Hawaii operated by the Hawaiian Volcano Observatory. Locations given are epicenters. The times given are arrival times at the Whitney Laboratory of Seismology on the northeast rim of Kilauea caldera. They are stated to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich Civil time. The number preceding each earthquake is the serial number for the current year. The intensity rating (Feeble, Moderate, etc.) given is that for the Whitney Laboratory. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney station.

146. July 1, 15:14, tremor (Mauna Loa, very feeble). Northeast rift of Mauna Loa.
147. July 2, 00:12, very feeble.
148. July 2, 05:34, no record at Kilauea (Mauna Loa, very feeble). Northeast rift of Mauna Loa.
149. July 2, 07:09, tremor (Mauna Loa, very feeble). Northeast rift of Mauna Loa.
150. July 2, 11:58, no record at Kilauea (Mauna Loa, very feeble).
151. July 6, 02:51, very feeble, west slope of Mauna Loa.
152. July 6, 07:19, very feeble, northeast rift of Mauna Loa.
153. July 6, 15:07, tremor (Mauna Loa, very feeble).
154. July 6, 20:26, slight. Beneath southwest edge of Kilauea caldera.
155. July 6, 23:55, very feeble.
156. July 7, 15:59, tremor (Uwekahuna, very feeble).
157. July 7, 17:55, very feeble.
158. July 9, 09:21, tremor (Uwekahuna, very feeble).
159. July 10, 10:07, tremor (Mauna Loa, very feeble).
160. July 13, 15:56, very feeble.
161. July 14, 12:37, tremor (Mauna Loa, very feeble).
162. July 15, 04:59, very feeble. Felt at Kapapala.
163. July 19, 13:24, tremor (Mauna Loa, very feeble).
164. July 20, 18:07, very feeble (Mauna Loa, feeble). East slope of Mauna Loa.
165. July 21, 17:30, tremor (Mauna Loa, very feeble).
166. July 24, 02:29, tremor (Uwekahuna, very feeble).
167. July 26, 10:18, no record at Kilauea (Kona, very feeble). Felt in central Kona.
168. July 26, 13:52, tremor (Kona, very feeble). Felt in central Kona and at Hawi.
169. July 26, 21:47, tremor (Mauna Loa, very feeble).
170. July 26, 22:44, very feeble.
171. July 28, 22:24, tremor (Kona, feeble). Felt in central Kona. Central Kona.
172. July 30, 14:30, tremor (Mauna Loa, very feeble). Probably Kaoiki fault.
173. July 31, 13:07, very feeble.
174. July 31, 23:44, very feeble.
175. Aug. 1, 06:48, very feeble (Mauna Loa, feeble). Felt at Pahala. Southwest rift of Kilauea near 19° 20'N., 155°21'W.
176. Aug. 1, 08:13, 20'N., 155°21'W.
177. Aug. 1, 23:39, tremor (Mauna Loa, very feeble).
178. Aug. 2, 02:31, very feeble.
179. Aug. 4, 11:10, very feeble.
180. Aug. 4, 17:20, very feeble.
very feeble (Mauna Loa, feeble). Felt: Kapapala, strong; Volcano, Naalehu, slight. Southwest rift of Kilauea near 19°20'N., 155°23'W.
181. Aug. 5, 02:46, tremor (Mauna Loa, very feeble). Mauna Loa, northeast rift.
182. Aug. 6, 00:47, very feeble (Mauna Loa, slight). Felt at Kapapala. Southwest rift of Kilauea near 19°22'N., 155°21'W.
183. Aug. 6, 14:39, very feeble.
184. Aug. 6, 18:47, very feeble.
185. Aug. 6, 21:08, tremor (Mauna Loa, very feeble).
186. Aug. 7, 02:17, very feeble.
187. Aug. 7, 05:53, very feeble.
188. Aug. 8, 00:37, tremor (Mauna Loa, very feeble).
189. Aug. 8, 03:00, very feeble. Felt strongly in central Kona.
190. Aug. 11, 07:12, very feeble.
191. Aug. 11, 09:16, very feeble. Kilauea.
192. Aug. 11, 12:39, very feeble. Kilauea.
193. Aug. 12, 08:38, very feeble.
194. Aug. 13, 05:55, very feeble (Uwekahuna, feeble).
195. Aug. 14, 18:20, tremor (Mauna Loa, very feeble).
196. Aug. 14, 22:14, very feeble.
197. Aug. 15, 10:33, tremor (Mauna Loa, very feeble).
198. Aug. 15, 12:04, tremor (Mauna Loa, very feeble).
199. Aug. 15, 16:27, no record at Kilauea (Kona, very feeble). Kona.
200. Aug. 16, 20:53, no record at Kilauea (Kona, very feeble). Central Kona.
201. Aug. 18, 17:47, no record at Kilauea (Mauna Loa, very feeble).
202. Aug. 20, 12:56, tremor (Mauna Loa, very feeble).
203. Aug. 21, 19:47, slight (Mauna Loa, Kona, and Hilo, strong). Felt all over island of Hawaii and as far away as Honolulu. Felt on Maui, generally weakly, but strong in Haleakala Crater. North slope of Hualalai near Puu Waawaa.
204. Aug. 21, 21:07, very feeble. Felt in Kona.
205. Aug. 23, 00:53, strong. Felt: Kona strong; Naalehu and Kapapala, moderate; Volcano, slight. Beneath southwest slope of Hualalai about 3 miles east of Holualoa.
206. Aug. 24, 23:05, no record at Kilauea (Kona, very feeble). Felt slightly in central Kona. Central Kona.
207. Aug. 25, 14:54, tremor (Mauna Loa, very feeble).
208. Aug. 27, 09:44, tremor (Mauna Loa, very feeble).
209. Aug. 27, 10:49, tremor (Mauna Loa, very feeble).
210. Aug. 29, 06:16, tremor (Mauna Loa, very feeble).
211. Sept. 1, 04:07, very feeble.
212. Sept. 1, 15:31, very feeble (Mauna Loa, feeble).
213. Sept. 1, 15:36, tremor (Mauna Loa, very feeble).
214. Sept. 2, 06:24, tremor (Mauna Loa, very feeble).
215. Sept. 3, 04:42, very feeble. Felt at Hawaii National Park. Kilauea.
216. Sept. 4, 05:58, no record at Kilauea (Kona, very feeble).
217. Sept. 4, 15:40, no record at Kilauea (Mauna Loa, very feeble).
218. Sept. 10, 07:00, tremor (Mauna Loa, very feeble).
219. Sept. 10, 20:02, no record at Kilauea (Mauna Loa, very feeble).
220. Sept. 12, 01:58, very feeble.
221. Sept. 12, 06:57, very feeble.
222. Sept. 13, 07:16, very feeble.
223. Sept. 13, 16:35, tremor (Mauna Loa, very feeble).
224. Sept. 14, 14:03, tremor (Mauna Loa, very feeble).
225. Sept. 15, 02:37, no record at Kilauea (Kona, very feeble). Kona.
226. Sept. 15, 10:57, tremor (Mauna Loa, very feeble).
227. Sept. 16, 04:22, tremor (Mauna Loa, very feeble).
228. Sept. 17, 19:34, very feeble.
229. Sept. 23, 07:50, tremor (Mauna Loa, very feeble).
230. Sept. 23, 14:50, very feeble (Kona, slight). Felt in central Kona. Central Kona.
231. Sept. 24, 02:09, no record at Kilauea (Mauna Loa, very feeble).
232. Sept. 25, 09:40, tremor (Mauna Loa, very feeble).
233. Sept. 25, 11:46, tremor (Mauna Loa, very feeble).
234. Sept. 25, 12:00, tremor (Mauna Loa, very feeble).
235. Sept. 25, 12:19, tremor (Mauna Loa, very feeble).
236. Sept. 25, 13:10, tremor (Mauna Loa, very feeble).
237. Sept. 25, 16:33, tremor (Mauna Loa, very feeble).
238. Sept. 25, 17:13, tremor (Mauna Loa, very feeble).
239. Sept. 26, 11:04, no record at Kilauea (Mauna Loa, very feeble).
240. Sept. 26, 12:16, no record at Kilauea (Mauna Loa, very feeble).
241. Sept. 26, 12:57, no record at Kilauea (Mauna Loa, very feeble).
242. Sept. 26, 13:02, no record at Kilauea (Mauna Loa, very feeble).
243. Sept. 26, 13:43, tremor (Mauna Loa, very feeble).
244. Sept. 26, 17:25, no record at Kilauea (Mauna Loa, very feeble).
245. Sept. 26, 20:11, no record at Kilauea (Mauna Loa, very feeble).
246. Sept. 27, 06:08, very feeble. Probably Kaoiki fault.
247. Sept. 27, 13:20, no record at Kilauea (Kona, feeble). Felt in central Kona.

Earthquake Data, July–September, 1953

(Based on Bosch-Omori seismograph on northeast rim of Kilauea caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
July 5	10	4	0	1	0	0	4.5	0
12	7	2	0	0	0	0	2.75	0
19	6	1	0	0	0	0	2.0	0
26	6	5	0	0	0	0	4.0	0
Aug. 2	8	9	0	0	0	0	6.5	0
9	5	6	0	0	0	0	4.25	0
16	3	1	0	1	0	0	3.25	0
23	6	0	0	0	0	1	5.5	0
30	5	3	0	0	0	0	2.75	0
Sept. 6	2	3	0	0	0	0	2.0	0
13	3	2	0	0	0	0	1.75	1
20	33	2	0	0	0	0	9.25	0
27	8	2	0	0	0	0	3.0	2

* For definition of local seismicity see Volcano Letter 371 or 512. Each local earthquake is assigned a seismicity value according to its strength, as follows: tremor, 0.25; very feeble, 0.5; feeble, 1.0; slight, 2.0; moderate, 3.0; strong, 4.0. These values are totaled to give the weekly local seismicity. Continuous volcanic tremor is ignored in the calculation. The strength assigned to the earthquake depends on the double amplitude of the maximum oscillation it causes on the Bosch-Omori seismograph, as follows: tremor, less than 0.5 mm.; very feeble, 0.5 to 4 mm.; feeble, 4 to 11 mm.; slight, 11 to 25 mm.; moderate, 25 to 60 mm.; strong, greater than 60 mm.

Table of Tilt at Seismograph Stations on Rim of Kilauea Caldera

Week Beginning	Whitney Station (Northeast rim)		Uwekahuna Station (West rim)	
	Amount	Direction	Amount	Direction
July 5	1.4″	N 42° W	4.8″	S 8° E
12	0.3″	S 45° W	1.6″	N 12° E
19	1.6″	N 9° W	0.4″	S 45° W
26	2.7″	N 69° W	1.6″	N 12° W
August 2	1.8″	W	2.9″	N 27° W
9	1.1″	N 64° W	1.1″	S 34° E
16	1.8″	N 4° W	3.4″	S 12° E
23	0.9″	N 16° E	3.4″	S 12° E
30	1.0″	S 61° E	1.0″	N 72° E
September 6	1.0″	N 70° E	0.3″	N
13	1.2″	N 5° E	2.6″	N 7° W
20	1.8″	N 4° E	1.4″	S 27° E
27	1.4″	S 85° E	3.5″	N 22° W

New Seismographs

On June 26, 1953, the old Hawaiian-type seismograph at the Mauna Loa station was replaced by a new Loucks-Omori seismograph. The station had been out of operation for about 3 weeks during renovation of the vault and installation of the new instrument. The Loucks-Omori seismograph is an Omori-type seismograph developed at the Hawaiian Volcano Observatory as a result of gradual and long-continued modification of the Bosch-Omori instrument. Built by Burton J. Loucks and John C. Forbes in the Observatory's instrument shop, it consists of two heavy horizontal pendulums hung respectively north-south and east-west, operating at an undamped period of 3 seconds, with a static magnification of 200.

The seismograph station on Haleakala, island of Maui, had been out of operation since the early part of World War II. On August 20, 1953, a new Loucks-Omori seismograph was installed in the Haleakala station. Like the Mauna Loa instrument, it has a static magnification of 200 and is being operated at a period of 3 seconds. The station is situated in the headquarters area of the Haleakala Section of Hawaii National Park, at 20°45′57″N. and 156°14′58″W. It is operated by the National Park staff under the direction of Mr. Eugene Barton, Assistant Superintendent. Records are sent to the Hawaiian Volcano Observatory for interpretation.

New buildings for seismograph stations were completed during July on the grounds of the Waimea School at Kamuela, the Naalehu School at Naalehu, and the Pahoa School at Pahoa, island of Hawaii. These new stations will be operated in cooperation with the Territory of Hawaii Department of Public Instruction. It is expected that seismographs will be installed in them within the next few months.

Distant Earthquakes

The following earthquakes of distant origin were recorded on the seismographs of the Hawaiian Volcano Observatory. Locations of the epicenters are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey. The time given is that of the first detectable emergence of the quake on the Bosch-Omori horizontal or Sprengnether vertical seismograms, in Hawaiian Standard time.

July 1, 21 : 05,	slight. New Hebrides Islands, 18½°S., 169°E.
Sept. 13, 14 : 46,	slight. Fiji Islands, 18½°S., 178½°E. Accompanied by a tsunami. Several persons killed, and extensive property damage.
Sept. 28, 15 : 46,	slight. Origin probably within a few hundred miles.
Sept. 30, 13 : 23,	moderate.

VOLCANO NOTES AND NEWS

ACTIVITY AT NGAURUHOE, NEW ZEALAND NOVEMBER, 1952, TO JULY, 1953

By J. Healy

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On November 29, 1952, Ngauruhoe volcano erupted clouds of ash 6,000 feet into the air in what the manager of the Chateau, Mr. L. S. Dennis, described as the most intense activity for many months. The mountain had erupted at intervals of several months during the previous 2 years, but now activity mounted, and for a period of nearly 3 months it continued in violent eruption for most of the time. Unfortunately, the weather was not good and only spasmodic observations were possible.

The eruption of ash in billowing, cauliflower-shaped clouds characterized the eruptive activity, and was accompanied by thunderous explosions, frequently heard at the Chateau at a distance of 8 miles. Toward the end of January the climax was reached, and for several days windows and doors at the Chateau were rattled by the closely spaced detonations. Guests on the evening of January 23 watched white-hot blocks being thrown from the crater, fall beyond its rim, and roll down the mountain slopes, while the entire crest was illuminated by a bright red glow that dilated at short intervals as big "shots" went up. Considerable noise like thunder and drums was heard during this period. At this distance the visibility of discrete blocks being erupted through the air testified to their large size. The periodicity of large explosions at this stage was about 8 to 10 minutes, whereas earlier it had been up to a half hour. Later the periodicity again increased as the eruptive activity waned.

Strong activity continued until the middle of February, after which active periods became shorter and more widely spaced. On March 27 a single eruption of a black ash cloud to an estimated height of 20,000 feet was reported, but since that date eruptions have been few. One was reported on July 28.

The writer inspected the crater from the air on February 4, 1953, but clouds kept the plane at about the level of the west rim. Steam was on that occasion issuing from vents near that rim, but from a vent farther east a straight plume of light-brown ash was rising. A climber had previously reported on January 30 the emission of "brown, semi-transparent substance several hundred feet into the air" and had stated that this was falling back to build up the cone around the vent. He also reported the discharge of masses of molten, orange-colored lava, so it appears most likely that this light-brown emission consisted of red-hot ash and scoria.

Ngauruhoe is an andesite volcano with perfect conical symmetry, and the summit, which is a little over a quarter mile in diameter, was divided prior to 1949 into three units. The main crateral floor occupied the eastern half, with the precipitous east rim rising above it. On the western side were two contiguous subcraters—a smaller one on the north, and a larger active one on the south. The crater at that time and the eruptive activity of 1948 have been described by Allen (1). In the eruption of 1949, which has been described by Battey (2) and Cloud (3),

the active subcrater was filled with lava in the early stages but finally became a shallow pit floored with loose pyroclastic material. Its earlier rim, which separated it from the main crater floor on the east, was obliterated, and the foot of the east wall was buried.

The latest activity was similar to that described by Allen in the account of the 1948 eruption, and the crater now shows a return to the earlier conditions. The active subcrater on the southwest has again been deepened, and a rim of pyroclastic material has again been built up between it and the wide floor of the main eastern half of the summit. A difference has remained, however. The 1949 eruption apparently weakened the northwest rim and permitted small fumaroles to emerge on the outer slopes. During the winters since then a large patch outside the northwest rim has been observed to remain free of snow, due to the presence of warm ground.

References

1. ALLEN, L. R. ACTIVITY AT NGAURUHOE, APRIL–MAY, 1948. N. Z. Jour. Sci. and Technol. 30B: 187–193, 1948.
2. BATTEY, M. H. THE RECENT ERUPTION OF NGAURUHOE. Rec. Auck. Inst. Mus. 3(6): 387–395, 1949.
3. CLOUD, P. E. THE 1949 ERUPTION OF NGAURUHOE. Sci. Monthly LXXII, 4: 241–251, 1951.

ERUPTION OF MOUNT SPURR, ALASKA

By Ray E. Wilcox

Mount Spurr is the northeasternmost of a chain of many active volcanoes comprising the Aleutian volcanic arc. The explosive outbreak of Mount Spurr which took place early on July 9, 1953, was its first strong activity during the 200 years of recorded history of that area.

The eruption took place from an old ice-filled vent at an altitude of about 7,000 feet on the south shoulder of Mount Spurr. Reports of concurrent eruptions from other points on Mount Spurr and Mount Torbert appear to have been erroneous, as also do reports of eruption in the Lake Beluga-Mount Susitna area, 30 miles east of Mount Spurr, on July 10. The eruption was observed by Werner Juhle and Henry Coulter, of the U. S. Geological Survey, from July 11 to 14, and by the writer from July 12 to 27.

The earliest observations of the eruption were made by airplane pilots at 5:05 A.M., July 9, apparently only minutes after the initial outbreak. From a distance of 60 miles they noted the eruptive cloud rising through the overcast to a height of about 15,000 feet and a width of about ⅛ mile, growing rapidly. By 5:25 A.M. the cloud had risen to the 30,000-foot level and had begun to mushroom. At 5:40 A.M. the mushrooming portion extended from an altitude of 32,000 feet to 60,000 or 70,000 feet, with an estimated diameter of 30 miles. Its stalk was estimated to have a diameter of about a mile. Electrical discharges were seen at intervals of about 3 seconds throughout the mushroomed portion. By 6:00 A.M. falling ash obscured the area below the expanded portion of the cloud, and the stalk was lost from sight.

A report by a pilot at 9:00 A.M. indicated that the ash still was erupting in large quantities and that the radius of the mushroom cloud had increased to 40 to 60 miles at 27,000 feet altitude. At noon the activity was greatly diminished, but by 3:30 P.M. moderately strong eruption had resumed and, apparently, continued through the afternoon and evening. On the morning of July 10 the vent was steaming only, but at 3:30 P.M. an especially strong surge of ash-laden steam rose to 20,000 feet. From July 11 to 14 the activity consisted of the liberation of moderately large quantities of steam, with little or no ash. The intensity of the steam eruption in general diminished from day to day, with the exception of one stronger surge of steam and minor ash at 2:00 P.M. on July 13. This trend of gradually diminishing intensity continued through the rest of July.

No lava flows were produced during the eruption. Immense floods and mud flows did occur on July 9 or 10, however, the water for which no doubt stemmed from the melting of the ice in the crater and, possibly, from local torrential rains associated with the strong ash eruption. Thousands of cubic yards of debris of all sizes up to several yards in diameter were carried down the south flank of the mountain to pile up in the Chakachatna River and form a dam, behind which the water backed up for a distance of about 5 miles, nearly to Chakachamna Lake.

The huge ash cloud from the first surges of the eruption moved slowly eastward, and by 11:00 A.M. its leading edge had spread over Anchorage, 80 miles east of the volcano. Street lights in Anchorage came on automatically at 11:00 A.M., due to the increasing darkness, and by noon ash was falling abundantly, accompanied by a perceptible odor of gas. Complete darkness lasted from 1:00 to 3:00 P.M. Ash continued to fall through the remainder of the afternoon and evening, but by early morning on July 10 only a haze of dust hung over the area. No significant amount of new ash appears to have reached the Anchorage area after that. At Anchorage the measured thickness of ash ranged from ⅛ to ¼ inch. In the Beluga Lake area the ash deposit may have ranged from 1 inch to several inches in thickness, judging from the large number of trees and bushes bent down by the load. On the southeast slope of Mount Spurr, Juhle found only a couple of inches of coarse debris. Westward the ash deposit thinned rapidly, and little or no ash could be seen on the snow a mile or two west of the active vent.

[Sometime in the last week of August, Dr. R. Werner Juhle, who made some of the observations of activity of Mount Spurr presented above, lost his life in Knife Creek in (the Valley of Ten Thousand Smokes) Katmai National Monument, Alaska. He had gone out alone from the base camp on a traverse planned to take several days. When he failed to return at the appointed time, an exhaustive search by planes and by men on foot aided by bloodhounds (flown up from San Francisco for the search) discovered his footprints leading up to and disappearing on the bank of a narrow, deep rapids of Knife Creek. His pack and exposure meter were found on the oposite bank of the rapids but prolonged search failed to find any further trace. Dr. Juhle, one of the outstanding recent graduates in geology from Johns Hopkins University, had done his Doctor's thesis on Iliamna Volcano, Alaska, and was engaged during the 1953 field season in the study of Katmai Volcano and the Valley of Ten Thousand Smokes as part of the co-operative investigation of Katmai National Monument by the National Park Service, Geological Survey, and other organizations.—*H. A. Powers.*]

J. P. EATON JOINS HVO STAFF

On September 15, Dr. Jerry P. Eaton joined the staff of the Hawaiian Volcano Observatory as Seismologist. Dr. Eaton has just completed his work for the degree of Doctor of Philosophy at the University of California, with a thesis on "The Theory of the Electromagnetic Seismograph." The thesis deals in large part with the response characteristics of Sprengnether seismographs, one of which is being operated at the Observatory's Uwekahuna station. Dr. Eaton is assuming charge of the seismological work, and most other geophysical work, of the Volcano Observatory.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

Gordon A. Macdonald, Volcanologist, Director
Jerry P. Eaton, Seismologist
Chester K. Wentworth, Geologist, part-time
Burton J. Loucks, Instrument Maker
John C. Forbes, Assistant Instrument Maker
Elizabeth G. Eklund, Secretary, part-time

Seismograph Station Operators

Hilo Station:
Sister M. Thecla, St. Joseph's School

Kona Station:
Howard M. Tatsuno, Konawaena School

Haleakala Station:
Hawaii National Park Staff

THE VOLCANO LETTER

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A SUGGESTED EXPLANATION OF THE ALTERNATION OF ACTIVITY BETWEEN TWO VENTS AT KILAUEA VOLCANO

By CHESTER K. WENTWORTH

After the first month of the eruption of Kilauea in 1952 and for several weeks thereafter, visible outflow of lava took place from one or both of two vents somewhat southwest of the center of the Halemaumau pit. At first both vents were active centers of fountaining, with one or the other more active, but in late August and early September one or the other would remain crusted over and almost dead while the other would be quite vigorous and even spectacular in its action for several hours to a day or more. Then the inactive one would come to life and rival its twin while the latter in turn became quiet. Such alternations took place a number of times, were observed by many persons who were able to visit the eruption repeatedly, and came to be predicted confidently by various observers.

Such behavior, among the many other points of interest, aroused speculation as to its cause, and the following note offers a tentative explanation, after a brief additional description. The two vents, during the early part of the period under discussion, were the sources of fountains which bubbled through a common liquid pool of lava. With some variation, the centers were about 150 to 175 feet apart, and in the later stages there had been built two merged ring cones that generally were maintained some 50 or 60 feet above the central lake, and which together had roughly the shape of a figure eight. At various times this bilobate lake had as many as six outlet lava rivers which streamed through breaks in the ring cones and formed ever-changing and often merging fans on the low dome of the rising floor of Halemaumau. In later stages the outlet rivers were only three, two, or one in number. In the last case the lava output from both fountains, if any, passed out by the one outlet. With only slight differences, the liquid level was commonly about the same throughout the lake. Most of the features of the filling crater and the character of the fountains have been described elsewhere.[1] It is only necessary here to mention certain conditions which may bear on the alternation of activity.

[1] G. A. MACDONALD, THE 1952 ERUPTION OF KILAUEA, Volcano Letter 518: 1–10. 1952.

First, we must keep in mind that the two vents maintained their approximate positions during the last 100 feet or more of rise of the lava fill and were, as far as we can see, the same as two of the most prominent of the vents along the initial rift in the floor which survived after the sheet fountaining of the first few hours. Second, it is to be presumed from the evident circulation of liquid in the pool, the peripheral breaking and exposure of bright lava, and the rise of the chilled floor without change of pattern that the larger part of the lava fill had remained very hot but was far from a homogeneous liquid. It seems quite certain that the two vents were branches from the same source at no very great depth.

Essential to the postulated mechanism is recognition of two sorts of physical condition in and around a vent conduit. We assume that, when lava outflow from a given vent is continuous and active, there must be a heating of the surrounding solid rock and an injection of all openings near the conduit so that the whole column represents an active, live, bulb-like pressure and heat system which would quickly make a liquid response and invade any adjacent opening. The pressure of the liquid must be at least slightly in excess of that required by the level of the vent pool through which it issues.

If such a conduit becomes inactive, cooling will result, the liquid parts will become less mobile, and the whole will presently lose its capacity for a quick hydraulic response to an opening. On the other hand, cooling will result eventually in shrinking, possibly in the production of actual openings, and moreover, if stresses are transmitted, the response of the mass is likely to be by rupture rather than by flow. It is not a contradiction to suggest the possible growth of linear stresses while at the same time postulating shrinkage, because we have to consider the possibility of juxtaposition of two interconnected conduits in alternating phase.

Assume, for instance, that arm A of such a dual system for some reason commences to chill and becomes less fluid. It will gradually lose its capacity for liquid

pressure behavior and approach and enter the rupture stage. If arm B continues active, building slightly higher pressures as the pool rises and maintaining or raising the surrounding throat temperature and liquidity, it can be able at some common point to apply stress in the form of liquid pressure to a part of arm A which may be in the rupture state. The result could be a breaking through of liquid, rise of the column, and renewal of activity in vent A. If such breaking through into vent A saps the hydraulic and thermal activity of vent B sufficiently, it is plausible that conduit B might then, in time, cool toward the rupture state. If this takes place while vent A goes through its phase of fully injecting the rupture system adjacent to its main conduit, the time may come after some hours when the hot, swelling, hydraulic phase of conduit A will develop sufficient boundary stress to invade the rupturing realm of conduit B and bring that vent to a renewed phase of liquid activity, thus completing a cycle. The period of such a cycle would depend essentially on volumes and cooling rates.

It is not possible or necessary to define or describe what degree of solidity is reached in the rupture stage if it is once accepted that there can be a relative contrast between the mobile, liquid pressure of the hydraulic phase and the firm, or pasty but crackable, condition of the rupture phase. The contrast is one of response to stresses that operate over a few minutes or hours; it is one of rigidity rather than strength. The contrast is related to but not of the same dimensions as the well-known contrast between zones of flow and of rupture in the parlance of structural geologists.

It appears that the alternation is related to a rate of outflow of lava and heat which can maintain one active vent but probably not two and thus leads to waning of one when the other waxes. It seems also that the postulated tendency can operate in varying degrees from sharp, accurately timed alternation (though this would hardly be the normal) to a more irregular, somewhat diffuse, and not always completed alternation, perhaps with a considerable amount of overlapping. It should also be recognized that the pressure built in the liquid phase need not be strictly hydrostatic or uniform, merely that it be effectively continuous throughout the volume involved. Neither must it be measured exactly by the fluid level of the pool; it will obviously be higher in the active conduit than in the connected but recently inactivated conduit which was formerly feeding the same pool at a slightly lower level.

THE PHILIPPINE COMMISSION ON VOLCANOLOGY

During 1952, the Congress of the Republic of the Philippines established by legislative act a five-man Commission on Volcanology. The Commission is composed of Dr. Jose M. Feliciano, Head of the Department of Geology and Geography of the University of the Philippines, Chairman; Dr. Casimiro del Rosario, Director of the Weather Bureau; Mr. Benjamin Gozon, Director of the Bureau of Mines; Professor Ramon Abarquez, Chairman of the Section on Geology, Seismology, and Volcanology of the National Research Council; and Mr. Jose C. Quema, representative of the Philippine Geological Society. The purposes of the Commission are:

1. To conduct studies of all active Philippine volcanoes.
2. To establish necessary facilities in order to predict volcanic eruption if possible.
3. To formulate in advance and in detail specific plans of action and of relief in the event of eruption.
4. To recommend to the President of the Philippines such measures as may be necessary to protect life and property in areas which may be affected by volcanic eruptions, including the declaration of certain areas as closed to human habitation or subject to regulation.
5. To study the economic importance of Philippine volcanism.

A working staff has been established by the Commismission, with its headquarters at the University of the Philippines in Quezon City, near Manila. The staff consists of Mr. Arturo Alcaraz, Geologist-in-Charge; Mr. Gregorio A. Andal, Assistant Geologist; Mr. Benigno Yambao, Junior Geologist; Mr. Eugenio Omahoy, Volcanological Observer on Camiguin Island; and Miss Annie C. Aterrado, Secretary. A seismograph station is being operated at the town of Mambajao on Camiguin Island, close to the base of the volcano; field studies are in progress at both Hibok-Hibok and Taal volcanoes. Daily reports are received on volcanic conditions at Taal and Hibok-Hibok. A seismograph station at Taal volcano is being operated by the Weather Bureau, in close co-operation with the Commission on Volcanology. A bibliography on Philippine volcanoes and solfataric areas has been compiled and was presented to the Eighth Pacific Science Congress in November, 1953.

Detailed topographic and geologic mapping of all active Philippine volcanoes is planned, and it is hoped to establish additional seismograph and tilt-measuring stations in the near future. At present, a Loucks-Omori two-component horizontal seismograph, with static magnification of 200, is being operated at Hibok-Hibok volcano. The seismograph at Taal is a Wiechert inverted pendulum, also with a magnification of 200. Dr. Gordon A. Macdonald of the United States Geological Survey, Director of the Hawaiian Volcano Observatory, is spending approximately three months in the Philippine Islands, aiding in the work of the Commission on Volcanology. During the Eighth Pacific Science Congress very helpful advice was received by the Commission from Dr. G. A. de Nevé, Director of the Volcanological Survey of Indonesia; Mr. James Healy, Chief of volcanological investigations for the New Zealand Geological Survey; and Professor Howel Williams of the University of California.—G. A. MACDONALD.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR OCTOBER–DECEMBER, 1953

By JERRY P. EATON

VOLCANOLOGY

October

Seismic unrest at Mauna Loa and Kilauea continued through October. A series of sharp earthquakes on October 26, 27, and 28 caused some excitement at the Observatory. Four of these quakes, which originated under the east rift of Kilauea, were felt in the Volcano area at 1:07 A.M., 3:36 A.M., and 4:30 A.M. on the twenty-seventh, and at 10:58 P.M. on the twenty-eighth. A continuous watch was maintained at Halemaumau crater from 4:30 A.M. on October 27 until late in the afternoon of the same day, when it appeared that the seismic crisis had passed.

Of about 20 small to moderate earthquakes originating along the southwest rift of Kilauea and the Kaoiki fault, one was felt at Pahala on October 9 at 6:15 A.M., one was felt at Naalehu on October 27 at 8:02 A.M., and three were felt at the Kapapala Ranch on October 28 at 3:50 P.M., 5:03 P.M., and 9:15 P.M.

Thirteen earthquakes were centered in Kona. Of these, five were felt: October 2 at 10:06 P.M., October 8 at 9:22 A.M., October 15 at 5:10 P.M., October 19 at 2:33 A.M., and October 31 at 6:15 A.M. In addition, earthquakes felt at Pepeekeo on October 23 at 2:02 P.M. and at Kukuihaele, in Kohala, on October 9 at 6:15 A.M. were recorded by the Observatory's seismographs.

Although the number of earthquakes recorded during October was not unusually large, a surprising number of these were felt.

Northward tilting of the earth's surface at the Volcano House on the northeast rim of Kilauea Crater continued at a rate slightly greater than normal for this season of the year. Eastward tilting was at the normal seasonal rate. An increase of pressure under Kilauea indicated by this excessive northward tilting was not confirmed by the further opening of cracks in the floor of the crater.

November

Seismic activity centered at Kilauea during the month of November. Of the 44 earthquakes rated as very feeble or larger which were recorded during November, 21 originated on Kilauea, 8 originated on Mauna Loa, and 15 recorded too weakly to be located.

Twelve of the Kilauea earthquakes centered very near the Observatory, four being felt weakly in the Volcano area at 9:32 P.M. on November 22, at 3:38 P.M. on November 28, at 7:44 P.M. on November 29, and at 1:04 P.M. on November 30. The largest earthquake of the month was felt quite generally in the Puna and Hilo districts and weakly as far as Kealakekua, Kona, and Kukuihaele, North Hamakua. It occurred on November 29 at 8:43 P.M. and originated on the east rift of Kilauea 10 miles from the Observatory at a depth of about 10 miles.

A feeble earthquake recorded at 8:37 P.M. on November 8 was felt at Naalehu and probably centered along the coast south of Kilauea. Slight earthquakes were felt in Kealakekua at 8:35 P.M. on November 4 and in Kamuela at 9:45 A.M. on November 16, but neither was recorded at the Observatory.

Northward tilting of the ground at the Volcano House on the north rim of Kilauea Crater continued at a rate slightly greater than normal for this season of the year, indicating continuing high pressure under Kilauea.

December

Many small earthquakes originating under Kilauea and Mauna Loa during December indicated that the Hawaiian volcanoes remained in a state of unrest. Of 51 quakes rated as very feeble or larger recorded by the Observatory's seismographs during the month, 17 originated at Kilauea, 8 at Mauna Loa, 1 at Kohala, and 25 were recorded too feebly to be located.

Between November 30 and December 6 a large number of tremors was recorded by the Mauna Loa seismograph. One of the larger earthquakes accompanying this swarm of tremors was felt in Hilo at 1:56 A.M. on December 1. It is probable that the tremors stemmed from foci near the focus of this larger earthquake, deep under the northeast rift of Mauna Loa.

Two quakes originated on the southeast flank of Mauna Loa between its summit and the Kaoiki fault. Two of the five quakes occurring on the Kona side of Mauna Loa were felt, one in Kalihiki at 4:16 P.M. on December 14, the other in Captain Cook at 1:00 P.M. on December 16.

Seismic activity at Kilauea continued to center around the caldera. Twelve of the 17 quakes occurring on Kilauea originated within a few miles of the Observatory. In addition, two quakes proceeded from epicenters on the southwest rift of Kilauea, two others from epicenters along the coast south of Kilauea.

Earthquakes were felt in the Kohala district at 7:42 P.M. on December 11, 2:53 A.M. on December 12, and 7:11 P.M. on December 17. The second of these was not recorded on any of the Observatory's seismographs.

The rate of northward tilting of the earth's surface at the Volcano House on the northeast rim of Kilauea caldera decreased, as is usual at this time of the year. Eastward tilting, however, proceeded at the same moderate rate which had prevailed since mid-August. The failure of eastward tilting to slacken and reverse during December suggested an increase in pressure under Mauna Loa. No other evidence was available, however, to check this conclusion.

SEISMOLOGY

Local Earthquakes

The data for the following local earthquakes were determined from seismographs on the islands of Hawaii and Maui operated by the Hawaiian Volcano Observatory. Locations given are epicenters. The times given are arrival times at the Whitney Laboratory of Seismology, on the northeast rim of Kilauea caldera. They are stated to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich Civil time. The number preceding each earthquake is the serial number for the current year. The intensity rating (Feeble, Moderate, etc.) given is that for the Whitney Laboratory. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney station.

248. Oct. 1, 09:23, tremor (Mauna Loa, slight). Kaoiki fault.
249. Oct. 1, 22:02, very feeble.
250. Oct. 2, 20:18, tremor (Mauna Loa, very feeble). Southwest rift of Kilauea 2 miles east of Kapapala Ranch.
251. Oct. 2, 20:36, tremor (Mauna Loa, very feeble). Kaoiki fault.
252. Oct. 2, 22:06, no record at Kilauea (Kona, very feeble). Felt in Capt. Cook. Central Kona.
253. Oct. 4, 22:27, tremor (Mauna Loa, very feeble).
254. Oct. 5, 01:20, very feeble.
255. Oct. 5, 11:21, very feeble. Kilauea.
256. Oct. 8, 09:22, feeble (Mauna Loa, moderate). Felt in central Kona. Nine miles east of Hainoa Crater on Hualalai.
257. Oct. 9, 06:16, very feeble. Felt at Kukuihaele. Kohala.
258. Oct. 9, 16:26, no record at Whitney Laboratory (Mauna Loa, very feeble).
259. Oct. 9, 16:28, no record at Whitney Laboratory (Mauna Loa, very feeble).
260. Oct. 9, 19:03, no record at Whitney Laboratory (Kona, very feeble). Central Kona.
261. Oct. 9, 21:11, tremor (Mauna Loa, very feeble).
262. Oct. 9, 21:53, tremor (Mauna Loa, very feeble). Felt at Pahala. Mauna Loa.
263. Oct. 10, 02:04, tremor (Mauna Loa, very feeble).
264. Oct. 10, 02:51, very feeble. East rift of Kilauea at Alae Crater.
265. Oct. 14, 17:23, tremor (Mauna Loa, very feeble). Kaoiki fault.
266. Oct. 14, 18:28, tremor (Mauna Loa, very feeble). Five miles east of Hainoa Crater on Hualalai.
267. Oct. 15, 07:11, very feeble. Kilauea.

268. Oct. 15, 17:10, very feeble (Kona, feeble). Felt in Capt. Cook. Central Kona.
269. Oct. 16, 00:33, very feeble. South flank of Mauna Loa near Anipeahi.
270. Oct. 17, 18:09, very feeble. South flank of Mauna Loa.
271. Oct. 18, 00:57, very feeble. Kilauea.
272. Oct. 18, 15:16, very feeble. East rift of Kilauea.
273. Oct. 19, 02:33, no record at Kilauea (Mauna Loa, very feeble). Central Kona.
274. Oct. 20, 06:15, tremor (Mauna Loa, very feeble). Kaoiki fault.
275. Oct. 22, 14:00, no record at Kilauea (Kona, very feeble).
276. Oct. 22, 14:02, very feeble (Mauna Loa, feeble). Felt at Pepeekeo. East flank of Mauna Kea.
277. Oct. 23, 14:49, no record at Whitney Laboratory (Mauna Loa, very feeble).
278. Oct. 25, 00:53, no record at Kilauea (Mauna Loa, very feeble).
279. Oct. 25, 01:23, very feeble.
280. Oct. 25, 04:17, very feeble. Makaopuhi Crater.
281. Oct. 25, 10:42, tremor (Uwekahuna, very feeble). East rift of Kilauea near Napau Crater.
282. Oct. 26, 14:13, very feeble. East rift of Kilauea near Napau Crater.
283. Oct. 26, 17:46, slight. East rift of Kilauea south of Alae Crater.
284. Oct. 26, 17:50, slight. East rift of Kilauea south of Alae Crater.
285. Oct. 26, 17:51, slight. East rift of Kilauea.
286. Oct. 26, 17:53, very feeble.
287. Oct. 27, 00:22, feeble.
288. Oct. 27, 01:07, strong. Felt at Volcano. East rift of Kilauea south of Aloi Crater near Ainahou.
289. Oct. 27, 01:10, very feeble.
290. Oct. 27, 01:38, slight.
291. Oct. 27, 03:37, strong. Felt at Volcano. East rift of Kilauea south of Makaopuhi Crater.
292. Oct. 27, 04:30, strong. Felt at Volcano. East rift of Kilauea near Alae Crater.
293. Oct. 27, 06:20, strong. East rift of Kilauea south of Napau Crater.
294. Oct. 27, 08:02, very feeble. Felt at Naalehu. Southwest rift of Mauna Loa near Alika Cone.
295. Oct. 27, 23:56, tremor (Uwekahuna, very feeble).
296. Oct. 28, 06:44, tremor (Uwekahuna, very feeble). Kaoiki fault near Halfway House.
297. Oct. 28, 07:21, very feeble. Kaoiki fault near Halfway House.
298. Oct. 28, 15:50, very feeble. Felt at Kapapala. Hilina Pali.
299. Oct. 28, 17:03, very feeble. Felt at Kapapala. Southwest rift of Kilauea near Ponohohoa Chasms.
300. Oct. 28, 21:15, very feeble. Felt at Kapapala. South flank of Mauna Loa.
301. Oct. 28, 22:58, very feeble. Felt at Volcano. East rift of Kilauea near Aloi Crater.
302. Oct. 29, 04:47, very feeble. Southwest flank of Kilauea.
303. Oct. 29, 05:40, very feeble.
304. Oct. 30, 08:16, tremor (Uwekahuna, very feeble). Kilauea caldera.
305. Oct. 31, 06:08, tremor (Kona, feeble). Felt in North Kona and North Kohala. North flank of Hualalai.
306. Oct. 31, 12:26, very feeble. Southwest flank of Kilauea.
307. Oct. 31, 13:22, very feeble. Southwest flank of Kilauea.
308. Nov. 1, 03:22, no record at Whitney Laboratory (Uwekahuna, very feeble).
309. Nov. 1, 14:42, very feeble. Southwest flank of Kilauea near Maunaiki.
310. Nov. 3, 10:14, tremor (Uwekahuna, very feeble). Southwest rift of Kilauea.
311. Nov. 5, 00:16, tremor (Mauna Loa, very feeble).
312. Nov. 5, 07:55, tremor (Mauna Loa, very feeble). Mauna Loa.
313. Nov. 5, 23:47, very feeble. Southwest rift of Mauna Loa.
314. Nov. 6, 02:30, feeble (Mauna Loa, slight). Mauna Loa, 3 miles south of the Mauna Loa seismograph.
315. Nov. 6, 11:24, tremor (Mauna Loa, very feeble).
316. Nov. 8, 18:14, very feeble.
317. Nov. 8, 20:37, very feeble. Coast south of Kilauea.
318. Nov. 10, 13:48, tremor (Uwekahuna, very feeble).
319. Nov. 12, 09:37, tremor (Mauna Loa, very feeble).
320. Nov. 14, 04:55, very feeble. Coast south of Kilauea.
321. Nov. 14, 05:12, very feeble. Coast south of Kilauea.
322. Nov. 19, 03:20, no record at Kilauea (Mauna Loa, very feeble).
323. Nov. 19, 05:36, tremor (Uwekahuna, very feeble).
324. Nov. 20, 05:10, tremor (Uwekahuna, very feeble).
325. Nov. 21, 11:26, very feeble (Mauna Loa, feeble). Red Hill.
326. Nov. 21, 15:23, very feeble (Uwekahuna, feeble). Kilauea.
327. Nov. 21, 16:11, very feeble. Mauna Loa.
328. Nov. 22, 21:32, moderate. Felt in Hawaii National Park and at Volcano. Kilauea caldera.
329. Nov. 23, 17:26, very feeble. Near Kilauea caldera.
330. Nov. 25, 07:07, no record at Whitney Laboratory (Uwekahuna, very feeble).
331. Nov. 25, 12:42, tremor (Uwekahuna, very feeble).
332. Nov. 26, 02:09, no record at Kilauea (Mauna Loa, very feeble).
333. Nov. 26, 03:09, very feeble.
334. Nov. 26, 05:52, very feeble (Mauna Loa, feeble). Red Hill.
335. Nov. 26, 13:54, very feeble (Uwekahuna, feeble). Near Kilauea caldera.
336. Nov. 26, 13:55, very feeble (Uwekahuna, feeble). Near Kilauea caldera.
337. Nov. 26, 16:58, very feeble. Near Kilauea caldera.
338. Nov. 27, 19:25, very feeble. Kilauea.
339. Nov. 28, 08:11, very feeble. Kilauea.
340. Nov. 28, 15:38, moderate. Felt in Hawaii National Park. Near Kilauea caldera.
341. Nov. 28, 20:46, no record at Kilauea (Mauna Loa, very feeble).
342. Nov. 29, 03:05, very feeble. Near Kilauea caldera.
343. Nov. 29, 03:49, no record at Kilauea (Kona, very feeble). Kona.
344. Nov. 29, 07:36, tremor (Uwekahuna, very feeble). Near Kilauea caldera.
345. Nov. 29, 19:44, moderate. Felt in Hawaii National Park. Near Kilauea caldera.
346. Nov. 29, 20:43, strong. Felt from Hawaii National Park to Hilo. East rift of Kilauea near Napau Crater.
347. Nov. 29, 21:18, very feeble.
348. Nov. 29, 23:18, no record at Whitney Laboratory (Uwekahuna, very feeble).
349. Nov. 30, 13:02, tremor (Uwekahuna, very feeble).
350. Nov. 30, 13:04, slight. Felt in Hawaii National Park. Near Kilauea caldera.
351. Nov. 30, 13:30, no record at Whitney Laboratory (Uwekahuna, very feeble).
352. Dec. 1, 01:56, tremor (Mauna Loa, very feeble). Felt in Hilo. Northeast rift of Mauna Loa.
353. Dec. 1, 02:01, no record at Kilauea (Mauna Loa, very feeble).
354. Dec. 1, 03:20, no record at Kilauea (Mauna Loa, very feeble).
355. Dec. 1, 03:21, no record at Kilauea (Mauna Loa, very feeble).
356. Dec. 1, 04:17, no record at Kilauea (Mauna Loa, very feeble).
357. Dec. 1, 04:20, tremor (Mauna Loa, very feeble).
358. Dec. 1, 04:24, tremor (Mauna Loa, very feeble).
359. Dec. 1, 08:46, no record at Kilauea (Mauna Loa, very feeble).
360. Dec. 1, 09:09, tremor (Mauna Loa, very feeble).
361. Dec. 1, 10:54, tremor (Mauna Loa, very feeble).
362. Dec. 1, 12:34, no record at Kilauea (Mauna Loa, very feeble).
363. Dec. 1, 12:43, tremor (Mauna Loa, very feeble).
364. Dec. 1, 12:45, tremor (Mauna Loa, very feeble).
365. Dec. 1, 13:13, tremor (Mauna Loa, very feeble).
366. Dec. 1, 13:20, no record at Kilauea (Mauna Loa, very feeble).
367. Dec. 1, 14:12, tremor (Uwekahuna, very feeble).
368. Dec. 1, 16:27, tremor (Mauna Loa, very feeble).
369. Dec. 1, 21:23, no record at Kilauea (Mauna Loa, very feeble).

370. Dec. 2, 23:19, tremor (Mauna Loa, very feeble).
371. Dec. 3, 01:54, no record at Whitney Laboratory (Mauna Loa, very feeble).
372. Dec. 3, 01:59, tremor (Mauna Loa, very feeble).
373. Dec. 6, 21:02, feeble. Near Halfway House on the south flank of Mauna Loa.
374. Dec. 8, 03:29, no record at Whitney Laboratory (Uwekahuna, very feeble). Near Kilauea caldera.
375. Dec. 8, 14:00, very feeble. Kilauea caldera.
376. Dec. 8, 23:59, very feeble. Kilauea caldera.
377. Dec. 9, 01:13, slight. Felt in Hawaii National Park. Kilauea caldera.
378. Dec. 9, 01:18, slight. Kilauea caldera.
379. Dec. 9, 01:56, slight. Kilauea caldera.
380. Dec. 9, 10:03, very feeble. Kilauea caldera.
381. Dec. 9, 10:43, very feeble. Kilauea caldera.
382. Dec. 11, 12:27, no record at Kilauea (Kona, very feeble).
383. Dec. 12, 08:56, very feeble. Southwest rift of Kilauea near the Ponohohoa Chasms.
384. Dec. 12, 15:15, tremor (Uwekahuna, very feeble). Near the coast south of Kilauea.
385. Dec. 13, 02:53, very feeble.
386. Dec. 14, 04:08, very feeble.
387. Dec. 14, 08:15, very feeble.
388. Dec. 14, 12:39, very feeble. Kilauea caldera.
389. Dec. 14, 14:54, very feeble.
390. Dec. 15, 21:08, no record at Kilauea (Kona, very feeble).
391. Dec. 16, 13:00, no record at Kilauea (Kona very feeble). Felt in Capt. Cook. Kona.
392. Dec. 16, 17:01, very feeble.
393. Dec. 17, 19:11, very feeble. Kohala.
394. Dec. 20, 04:11, very feeble (Uwekahuna, feeble). Southeast flank of Kilauea near Kalapana.
395. Dec. 21, 12:24, tremor (Mauna Loa, very feeble). East rift of Kilauea.
396. Dec. 21, 12:40, tremor (Uwekahuna, very feeble). Kilauea caldera.
397. Dec. 28, 22:24, no record at Whitney Laboratory (Uwekahuna, very feeble). Kilauea caldera.
398. Dec. 29, 06:01, tremor (Uwekahuna, very feeble). Kilauea caldera.
399. Dec. 30, 08:05, tremor (Uwekahuna, very feeble).
400. Dec. 31, 16:53, very feeble. Kilauea caldera.
401. Dec. 31, 19:54, very feeble.
402. Dec. 31, 20:50, no record at Kilauea (Kona, very feeble). Kona.
403. Dec. 31, 22:55, very feeble.

Distant Earthquakes

The following earthquakes of distant origin were recorded on the seismographs of the Hawaiian Volcano Observatory. Locations of the epicenters are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey. The time given is that of the first detectable emergence of the quake on the Bosch-Omori horizontal or Sprengnether vertical seismograms, in Hawaiian Standard time.

Nov. 3, 17:59, slight. New Hebrides Islands, 12½°S., 166½°E.
Nov. 17, 03:55, slight. Near coast of Guatemala, 14°N., 92°W.
Nov. 25, 07:59, moderate. Near south coast of Honshu, Japan, 34°N., 141°E. Felt Honshu and Hokkaido. Seismic sea wave.
Dec. 4, 05:11, strong. Off coast of Vancouver Island, 49½°N., 129°W.
Dec. 12, 07:53, feeble. Near coast of Peru, 3½°S., 81°W. Several killed and heavy property damage in Tumbes and Corrales.

Earthquake Data, October–December, 1953

(Based on Bosch-Omori seismograph on northeast rim of Kilauea caldera)

Week Beginning		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
Oct.	4	10	11	0	0	1	0	11.0	0
	11	21	5	1	0	0	0	8.75	0
	18	16	6	1	0	0	0	8.0	0
	25	40	19	3	4	0	4	46.5	0
Nov.	1	8	7	0	1	0	0	7.5	1
	8	17	6	0	0	0	0	7.25	0
	15	30	4	2	0	0	0	11.5	1
	22	39	9	3	0	2	0	23.25	1
	29	732	28	0	1	1	1	211.0	1
Dec.	6	22	8	1	3	0	0	16.5	1
	13	42	9	0	0	0	0	15.0	0
	20	6	2	1	0	0	0	3.5	0
	27	9	7	0	0	0	0	5.75	0

* For definition of local seismicity see Volcano Letter 371 or 512. Each local earthquake is assigned a seismicity value according to its strength, as follows: tremor, 0.25; very feeble, 0.5; feeble, 1.0; slight, 2.0; moderate, 3.0; strong, 4.0. These values are totaled to give the weekly local seismicity. Continuous volcanic tremor is ignored in the calculation. The strength assigned to the earthquake depends on the double amplitude of the maximum oscillation it causes on the Bosch-Omori seismograph, as follows: tremor, less than 0.5 mm.; very feeble, 0.5 to 4 mm.; feeble, 4 to 11 mm.; slight, 11 to 25 mm.; moderate, 25 to 60 mm.; strong, greater than 60 mm.

Table of Tilt at Seismograph Stations on Rim of Kilauea Caldera

Week Beginning		Whitney Station (Northeast rim)		Uwekahuna Station (West rim)	
		Amount	Direction	Amount	Direction
October	4	1.3″	N 41° W	4.8″	S 20° E
	11	1.1″	N 72° W	1.0″	N 72° E
	18	1.0″	S 54° E	1.3″	N 14° W
	25	2.9″	N 7° W	3.0″	S 18° E
November	1	0.6″	S 67° E	2.2″	N
	8	1.2″	N 84° E	2.4″	S 23° E
	15	1.0″	N 21° E	3.9″	N 24° W
	22	0.5″	N 45° E	1.8″	N 45° W
	29	0.7″	N 9° W	2.6″	N 14° W
December	6	0.8″	S 72° E	0.3″	S
	13	1.2″	S 45° E	1.0″	S 18° E
	20	0.3″	N 63° W	0.3″	E
	27	1.5″	N 72° E	4.2″	N 23° W

VOLCANO NOTES AND NEWS

ERUPTIONS OF MIHARA-YAMA, O-SHIMA, AND ASAMA-YAMA, JAPAN

By Helen L. Foster

(From data supplied by Central Meteorological Observatory, Tokyo, Japan)

Mihara-yama, O-shima: October 5, 1953 to January 6, 1954. Mihara-yama, O-shima, erupted from July 16, 1950, to September 24, 1950. It was then quiescent until February 4, 1951, when eruption recommenced and lasted until June 28, although the activity in April, May, and June was intermittent. The volcano was again quiescent until October 5, 1953, when activity commenced again, heralded by minor earth tremors and rumbling sounds. The first explosion was heard at 8:32 A.M. on October 5. A new vent about 1.5 meters in diameter opened on the inner south wall of the larger cinder cone formed in the 1951 eruption. Lava fragments as large as 1 foot in diameter were hurled to a height of 50 or 60 meters above the vent. Explosions continued intermittently until October 13, when activity subsided after 7:30 P.M. Although emission of gas clouds occurred at intervals, no further explosions were recorded until November 10. On November 11 lava flows and fragments were emitted from two new vents in the crater of the 1951 cinder cone. Only steam and gases were emitted from the vent, which had been active in October. By November 14 a small cone about 3 meters high had formed around the active vents. The volcano was quiescent again during most of the remainder of November, although steam and other gas fumes were emitted.

On December 1 eruptions began again and continued intermittently until December 18, 1953. Gas, ash, and ejecta were emitted from the November vents and from a new vent which opened between those formed in October and November.

Observations on December 24 determined that in the vicinity of the vents which were active in October there was a crater 40 meters long, 20 meters wide, and 8 meters deep which had two vents. In the area of the vents active in November there was a crater 70 meters long and 40 meters wide, with two vents.

Eruption recommenced on December 29 at 3:27 A.M. Activity continued through December 31, 1953. Slight activity was again recorded on January 4, 5, and 6, 1954, when explosions hurled bombs 200 meters high and horizontal distances of 400 meters. Minor topographic changes were taking place in and around the old 1951 cinder cone as the result of collapse and the accumulation of new ejecta.

All the new activity of Mihara-yama in 1953 and 1954 has been on a small scale as compared with the eruptions of 1950 and 1951. Only small quantities of lava and ejecta have been emitted, all of which have been within the crater of the 1951 cinder cone, with the exception of a few pieces of ejecta which have been thrown beyond the 1951 cinder cone crater.

Asama-yama: December 27, 1953 to January 7, 1954. A series of small explosions of Asama-yama began on December 27, 1953. The volcano had been quiescent since June, 1952.

Explosions occurred on December 27 at 1:41 P.M. and 4:45 P.M. and on December 29 at 8:40 A.M. and 10:23 A.M., and on December 30 small ash falls from minor explosions occurred, beginning at 8:00 P.M.

Another explosion occurred on January 3, 1954, and a cloud, probably ash-laden, rose to a height of 600 meters.

On January 7 explosions occurred at 3:30 P.M. and 3:34 P.M., and an ash cloud rose to a height of 700 meters. These explosions were the largest of the series of about 10 which have occurred since December 27, 1953.

CURRENT ACTIVITY OF ALEUTIAN VOLCANOES

By H. A. Powers

There has been but slight activity at most Aleutian volcanoes during the fall of 1953. Observations are being made by members of the Armed Forces and by Austin Jones, Seismologist of the Geophysics Branch, U. S. Geological Survey.

Trident. During July and August a tongue of lava flowed as much as 3 miles, starting from the northwest side of the original vent and following the west margin of the June flows. It terminated in two broad lobes, one crossing the south-flowing stream from Katmai Pass where it dammed a small lake at about 2,000 feet altitude, the other extending a half mile farther south into the Pass drainage at a lower altitude. The new lava flow did not increase visibly in area during the fall months, but was still steaming in December. The vent is sporadically erupting small bursts of ash, and constantly fuming and steaming.

Spurr volcano has been steaming but has had no renewal of ash eruption since the July explosions.

Shishaldin erupted hot ash during the first week of October.

Pavlov was seen "glowing" on November 25 by the personnel of the *Penguin*, sailing from the Pribilof Islands.

Steam plumes but no new ash on the recent snows are reported at various December dates from Gareloi, Kanaga, Great Sitkin, Cleveland, and Makushin.

SECTION OF VOLCANOLOGY EIGHTH PACIFIC SCIENCE CONGRESS

A highly successful meeting of the section of volcanology of the Eighth Pacific Science Congress was held on November 17, 1953, at the University of the Philippines. The meeting opened with the presentation of the report of the Standing Committee on Volcanology of the Pacific Area, by J. Healy, Chairman of the Committee. The report was presented only in brief at the meeting, but the full report was distributed to those present, and copies were sent to contributors who were not present. The 33-page mimeographed report contains accounts of volcanic and thermal activity and investigations in Canada, Hawaii, Alaska, continental United States, Mexico, Guatemala, San Salvador, Nicaragua, South America, New Zealand, Australian territories, Philippines, Japan, Fiji, Solomon Islands, and Indonesia. A 22-page appendix contains a list of volcanological and allied research workers in all these countries. Mr. Healy deserves, and received, the sincere thanks of his fellow workers for his excellent report and organization of the meeting itself.

Following presentation of the Chairman's report, a symposium on Volcanology of the Pacific was convened by Mr. Healy. Chairmanship of the morning session, which was devoted to *nuées ardentes* and related phenomena, was turned over to Mr. Arturo Alcaraz of the Philippine Commission on Volcanology, with Mr. Jose C. Quema of the Philippine Bureau of Mines as secretary. Papers presented during the morning session were: Glowing Avalanche Deposits of Central America, by Howel Williams; Mount Katmai and the Valley of Ten Thousand Smokes, Alaska (a new interpretation of the great eruptions of 1912), by Howel Williams, Garniss Curtis, and Werner Juhle; An Outline of Mount Lamington Phenomena, by G. A. Taylor (presented by J. Thompson); Volcanic Activity of Catarman and Hibok-Hibok, by V. R. Pelaez; Recent Volcanicity at Taupo, New Zealand, by I. L. Baumgart and J. Healy; Some Problems of Welded-Lava and Welded-Tuff Related with the Sunken Calderas in Japan, by T. Matumoto, T. Isikawa, and M. Minato (presented by Howel Williams).

The afternoon session was devoted to descriptive volcanology, petrology of volcanic rocks, and geophysics, under the chairmanship of G. A. Macdonald of the U. S. Geological Survey. Fourteen papers were presented, as follows: The Didicas Submarine Volcano, by A. Alcaraz, L. F. Abad, and M. H. Tupas; Eruption on San Benedicto Island, Mexico, 1952, by R. S. Dietz and A. F. Richards; Combined Air- and Terrain-Reconnaissances Carried out by the Volcanological Survey in the Indonesian Archipelago, and Its Program for Future Research, by G. A. de Nevé; Seventy Years Krakatoa and Twenty-Five Years Anak Krakatoa, with a Communication Concerning the Latest Investigation in October, 1953, by G. A. de Nevé; Volcanic Activity in New Guinea, by J. G. Best (presented by J. Thompson); A Cluster of Little-Known Philippine Volcanoes, by A. Alvir; The Significance of Pillow Lavas in Pacific Islands, by H. T. Stearns (read by title only); The Difference of Chemical Composition between Japanese and Manchurian Volcanic Rocks, by I. Iwasaki and T. Katsura (presented by Y. Miyake); Preliminary Account of the Hydrothermal Condition at Wairakei, New Zealand, by J. Healy; Geochemical Investigation of Geysers in Japan, by K. Noguchi (presented by Y. Miyake); Volcanic Activities in Japan During 1949–1953, by T. Minakami and R. Morimoto (presented by G. A. Macdonald); Transpacific Detection by Underwater Sound of Myojin

Volcanic Explosions, by R. S. Dietz and M. J. Sheehy; The New Seismological Equipment for the Permanent Conservation-Posts of the Volcanological Survey of Indonesia, by G. A. de Nevé; Rehabilitation of the Guarding-System of the Volcanological Survey, by G. A. de Nevé.

A public lecture on Hawaiian volcanoes, illustrated with color movies of the 1949 and 1950 eruptions of Mauna Loa and 1952 eruption of Kilauea, was given by G. A. Macdonald on the evening of November 18, in the auditorium of the Philippine General Hospital.

On November 15, the delegates to the Division of Geology and Geophysics took part in a field trip to Taal volcano. Volcano Island, in the midst of Taal Lake, and the crater from which occurred the disastrous explosions of 1911 were visited. Further glimpses of Taal volcano and the structure of the surrounding region were obtained on a field trip to Tagaytay Ridge on November 19, under the auspices of the Philippine Geological Society and the Philippine Association of Mining, Metallurgical, and Geological Engineers. Following the meetings of the Congress, a group of 15 persons from the Division of Geology and Geophysics participated in a field trip to the southern part of the Philippines, during which both Hibok-Hibok and Mayon volcanoes were visited. Both volcanoes were fuming, but no other activity was visible.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director
Jerry P. Eaton, Seismologist
Chester K. Wentworth, Geologist, part-time
Burton J. Loucks, Instrument Maker
John C. Forbes, Assistant Instrument Maker
Elizabeth G. Eklund, Secretary, part-time

Seismograph Station Operators:

Hilo Station:
Sister M. Thecla, St. Joseph's School

Kona Station:
Howard M. Tatsuno, Konawaena School

Haleakala Station:
Hawaii National Park Staff

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PHILIPPINE VOLCANOES DURING 1953 AND EARLY 1954

By GORDON A. MACDONALD and ARTURO ALCARAZ

The work of the Philippine Commission on Volcanology, created in mid-1952, includes continuous watch over volcanoes that are in eruption or show indications of possible impending eruption, periodic examinations of other active volcanoes (not in eruption), and, as time permits, studies of the dormant and extinct volcanoes of the archipelago. During 1953 and early 1954 continuous observations were made at Hibok-Hibok and Taal volcanoes and short investigations at Didicas and Mayon volcanoes. Canlaon and Bulusan volcanoes were viewed from a distance.

Arturo Alcaraz has been in charge of the field operations of the Commission on Volcanology since December, 1952. Gordon A. Macdonald spent December, 1953, and January and early February, 1954, in the Philippines assisting in the work of the Commission. We wish to express our thanks to the members of the Commission and to the U. S. Geological Survey for making our respective work possible; and to our coworkers, Gregorio A. Andal, Benigno Yambao, and Eugenio Omahoy, for much assistance and pleasant companionship in the field.

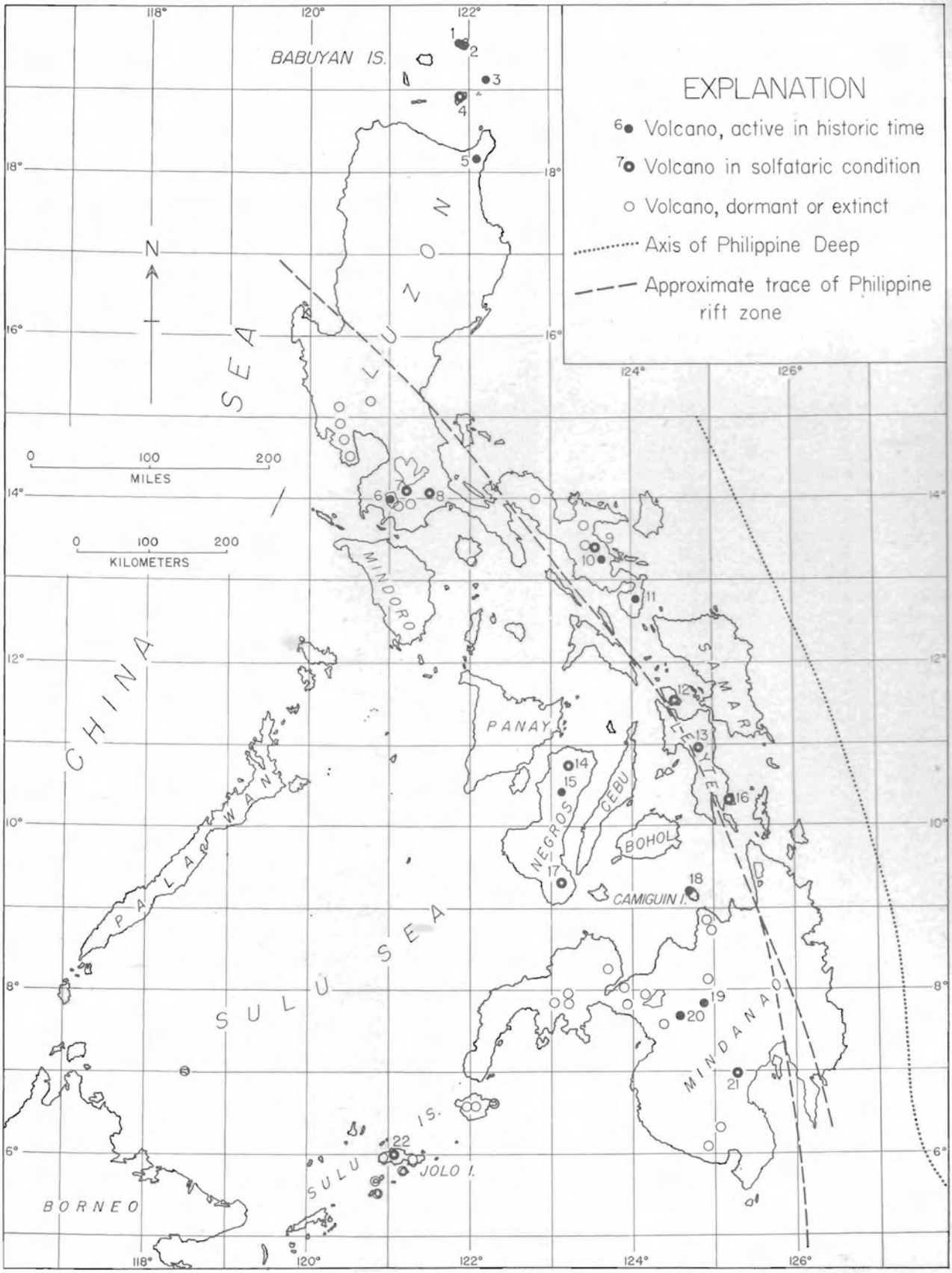
Throughout the known part of geologic time, volcanoes have played an important part in the development of the Philippine Archipelago. Volcanic rocks of uncertain age appear among the metamorphosed basement rocks in the Northwestern Cordillera, Mountain Provinces, and Sierra Madre of Luzon Island; on Marinduque and Masbate islands; on the islands of the Palawan group; on Panay, Cebu, Bohol, Samar, and Mindanao islands; and on islands of the Sulu group (Irving, 1951). Volcanic rocks known or believed to be of Tertiary age are exposed at various places from central Luzon to Zamboanga (Irving, 1953). But it is with the volcanoes of Pleistocene and Recent age that we are principally concerned.

The new geologic map of the Philippines (Irving, 1953) shows numerous areas of Quaternary volcanic rocks, scattered all the way from the Babuyan Islands, north of Luzon, to the Sulu Islands, south of Mindanao. Of the major islands in the archipelago, only Palawan, Panay, Cebu, Bohol, Masbate, and Samar lack Quaternary volcanics. Many of the cones, probably of Pleistocene age, are moderately dissected by erosion. Examples of these include Mariveles Mountain on the Bataan Peninsula, Mount Arayat in the central plain of Luzon, Mount Macolod at the southeastern edge of Lake Taal in Batangas Province, Mounts Isarog and Iriga in Camarines Sur Province, the small cone at the southern end of Marinduque Island, Mount Mambajao on Camiguin Island, and many others. In the vicinity of the city of San Pablo, in the area between Mounts Banahaw and Malepunyo, there are many small depressions, several of them occupied by crater lakes. These appear to be diatremes, formed by short-lived volcanic explosions with or without accompanying collapse, perforating the plateau of Quaternary tuff.

Eleven Philippine volcanoes have erupted during historic times. Thirteen others show solfataric activity. These active and solfataric volcanoes are listed in the accompanying table and shown on the map (Fig. 1). Data concerning historic eruptions have been assembled by Andal and Yambao (1953).

Mount Santo Tomas, or Tonglon, near the city of Baguio, has in the past been listed as a volcano in solfataric condition, or even as having erupted in 1641 (Musper and Neumann van Padang, 1937; Andal and Yambao, 1953). These reports must, however, refer to some other locality, because examination of Mount Santo Tomas during February, 1954, showed it to consist of ancient, interstratified volcanic and sedimentary rocks of probable Tertiary age.

Didicas volcano, in the Babuyan Islands north of Luzon, resumed eruption in March, 1952, after a period of quiescence lasting nearly a century. Eruptive activity between 1856 and 1860 had built a mountain that rose some 700 feet above sea level, but subsequent wave action had reduced it to three small rock masses 200 to 270 feet high. Relatively quiet eruption resulted in the building of a blocky dome, from which escaped large volumes of steam and sulfurous gases. The new Didicas dome covered the former rock masses, and by late 1953 the top of the dome was about 830 feet above sea level (Alcaraz, Abad, and Tupas, 1953). Mild vulcanian explosions at the summit of the dome were reported during the early stages of the activity. Ash fell on Calayan Island, 25 miles to the north, but in quantities


EXPLANATION
Volcano, active in historic time
Volcano in solfataric condition
Volcano, dormant or extinct
Axis of Philippine Deep
Approximate trace of Philippine rift zone
BABUYAN IS.
LUZON
SEA
CHINA
PALAWAN
MINDORO
PANAY
NEGROS
CEBU
BOHOL
LEYTE
SAMAR
CAMIGUIN I.
MINDANAO
SULU SEA
SULU IS.
JOLO I.
BORNEO
N
0 100 200
MILES
0 100 200
KILOMETERS
118°
120°
122°
124°
126°
18°
16°
14°
12°
10°
8°
6°

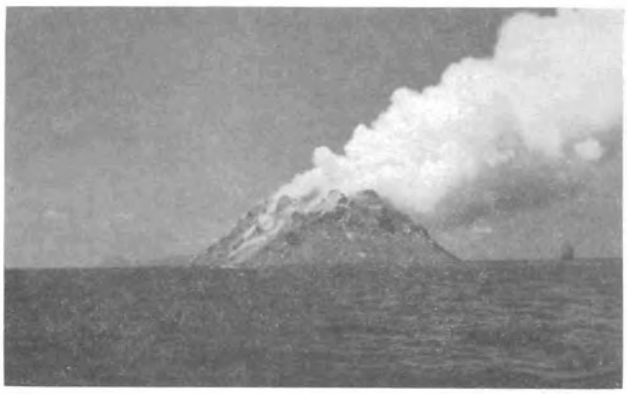


FIGURE 2. Didicas volcano from a point 0.25 mile to the east-northeast, on March 30, 1952. The blocky character of the dome and the banks of crumble breccia on its flanks are clearly visible. One of the old Didicas Rocks can be seen at the right. Photo by Arturo Alcaraz.

too small to cause damage (Andal and Yambao, 1953). In June, 1953, G. A. Andal and L. F. Abad were able to land on the dome and reported that the activity had subsided appreciably.

After its catastrophic eruption in 1911, Taal volcano remained entirely quiet until early 1953. During February, 1953, reports were received of signs of renewed activity, but examinations of the volcano on February 12 and 19 revealed no sign of change from the conditions observed during a survey of the volcano in February, 1949. The temperature of the water of the crater lake was found to be 32°C. In May, 1953, steam vents and hot springs became active in a zone about 100 meters long at and near the southwestern shore of the crater lake. Some sulfur gas is present in the steam. On May 19 the temperature of the steam was 98°C., and the temperature of the crater lake had risen to 36°C. By mid-June the temperature of the steam had increased to 101°C., but since then it has remained stable, with occasional decreases to about 100°C. During the remainder of 1953 the volume of steam fluctuated, but generally it was somewhat less than during May and June. There was a slight northwestward shifting of the active area. In early 1954 there has again been some increase in the apparent volume of steam, which in early March was about twice that observed in May, 1953.

The renewal and gradual increase of solfataric activity at Taal volcano seems unquestionably to indicate a rise of magma at depth or some other change in subsurface conditions resulting in a greater supply of heat to the volcanic vent. No other signs of impending eruption have been observed, and people are still being permitted to reside on Volcano Island, though some have left voluntarily. Close watch is being kept for increased earthquake activity or other signs of eruption; residents of Volcano Island have been informed of the possibility of eruption, and a plan for possible evacuation of the island and areas along the shore of Taal Lake has been prepared.

Mayon volcano, in Albay Province, is the most frequently active volcano in the Philippines and is believed to have the most perfectly symmetrical cone in the world. Since 1800, Mayon has had 31 recorded eruptions, with an average interval of one each 4.9 years. The actual interval has varied, however, from less than 1 to 26 years. The 1928 and earlier eruptions have been described by Faustino (1929). Since that time, eruptions have occurred in 1938, 1939 (a single brief explosion), 1943, and 1947. During late 1953 and early 1954 Mayon volcano was fuming quietly. Most of the fume rose from fissures in and around the small, blocky mass of 1947 lava in the small crater.

Mayon volcano is a composite strato-volcano, composed dominantly of pyroclastics but with numerous interbedded lava flows. The flows are of block-lava type, transitional toward aa. Pyroclastic beds on the northern slope of the volcano above the Mayon resthouse consist largely of Strombolian cinder. Abundant mudflows have formed a broad apron completely around the base of the cone and have been responsible for most of the damage to life and property during historic times.

Bulusan volcano, in Sorsogon Province, has not erupted in recent years. The last eruptive period began on January 18, 1916, and continued intermittently until 1922. During that period there were 17 separate mild explosions, each lasting only a few minutes. Ash fell on towns west, southwest, and south of the volcano, but not in sufficient amount to cause damage. Maso (1928: 765) describes what appears to have been a block-lava flow in the crater during November and December, 1918. The flow pushed its snout out through a breach in the crater rim, and from the snout fragments rolled down the ravine below the breach, black by day but exhibiting dull red incandescence at night. He also describes what

FIGURE 3. Fumaroles at the southwestern edge of the crater lake of Taal volcano, January 3, 1954. Photo by G. A. Macdonald.



FIGURE 1. Map of the Philippine Islands, showing the location of volcanoes active in historic time, those in solfataric condition but not historically active, and known volcanoes of probable Quaternary age that have shown neither eruptive nor solfataric activity during historic times. The latter are taken from the new geologic map of the Philippines (Irving, 1953). The active and solfataric volcanoes are numbered on the map as follows: 1, Smith; 2, Babuyan Claro; 3, Didicas; 4, Camiguin de Babuyanes; 5, Cagua; 6, Taal; 7, Maquiling; 8, Banahaw; 9, Malinao; 10, Mayon; 11, Bulusan; 12, Biliran; 13, Burauen area; 14, Silay; 15, Canlaon; 16, Cabalian; 17, Magaso; 18, Catarman (Hibok-Hibok); 19, Calayo; 20, Ragang; 21, Apo; 22, Bud Dajo.



FIGURE 4. The dome of Hibok-Hibok volcano seen from the top of the 1948 lava flow, December 19, 1953. Part of the old crater wall is visible on the left skyline. The dome is nearly buried by its long slopes of talus (crumble breccia). Photo by G. A. Macdonald.

appear to have been small, avalanche-type *nuées ardentes*. In his own words, "Sometimes instead of rocks a mass not unlike mud detached itself from the said hot base and showed a great effervescence while sliding down the ravine and raised a white yellowish cloud which had a great ascensional force. After the effervescence had ceased the bottom of the ravine and the vegetation on its sides was seen covered with white dust. . . ."

The last known eruption of Canlaon volcano, on Negros Island, occurred during 1906. The volcano was viewed from the air on January 22, 1954. The mountain has two principal peaks. The northern peak is vegetated to its top, is moderately eroded, and does not appear to have been recently active. The southern peak appears to be a rounded cinder cone, little vegetated and entirely uneroded, sitting on a forested and moderately eroded base which is probably a composite cone. A prominent crater is present in the southern peak. No fumarolic activity was visible.

Calayo and Ragang volcanoes, on Mindanao Island, were not visited during 1953 or early 1954. The last recorded eruption of the former was in 1887 (Andal and Yambao, 1953: 22), while the latter was reported to be active in 1915 (Smith, 1924: 216). Makaturing volcano, also in Mindanao, has been listed by several writers as active. However, there is serious doubt that it ever was active within historic times. Maso (1922: 142) wrote, "Considering the different actual conditions of the Makaturing and of the Ragang one is inclined to believe that all the historic eruptions attributed to the former occurred in the latter. Writers give the years 1834, 1840, 1858, 1871 and 1873, but nearly all these dates are somewhat doubtful because of the lack of reliable particulars and of the fact that the writers are at variance about the same."

Hibok-Hibok volcano, on the northern end of Camiguin Island, just north of Mindanao, was in eruption from 1948 to early 1953. During that period two block-lava flows were extruded on the eastern flank of the mountain, mudflows devastated an area on the northern slope, a dome was built in the summit crater partly overlapping onto the flanks of the mountain, and destructive *nuées ardentes* took the lives of about 500 persons in the sector northeast of the summit (Alcaraz, Abad, and Quema, 1952). As a result of this, the zone around the volcano was closed to public occupation by Presidential order, until such time as the danger from the volcano should subside.

Three visits were made to Hibok-Hibok during December, 1953, and January, 1954. Records from a new, more sensitive seismograph installed in the town of Mambajao, near the base of the volcano, indicated that very few earthquakes were originating beneath the volcano. There had been no ash eruptions since July 14, and no large avalanches from the dome had been reported since May. Eugenio Omahoy, the volcanological observer stationed in Mambajao, had detected no changes in the size or outline of the dome since May, except for the collapse of one prominent spine. In December the dome was examined from the upper part of the valley down which had rushed the *nuées ardentes* of December, 1951, and many smaller, later avalanches. In January the dome itself was climbed and examined at close hand. The dome was fuming quite strongly, but there was no sign of present or recent active growth. Talus banks extended far up the flanks of the dome, in places nearly to its summit. Except in small local areas, the rock ribs between the talus banks had been reduced by crumbling to a slope of stability. Several small spines were present on the dome, and at the summit there was a narrow spine, about 100 feet high, that appeared from some angles to be curved like the dorsal fin of a shark. Some of the spines, including the eastern end of the large spine at the summit, appeared about to collapse. These collapses undoubtedly will cause small avalanches, but it is unlikely that the avalanches will travel far enough to cause damage to inhabited areas. Deposits of recent avalanches are all small and extend little beyond the edge of the dome itself.

Therefore, it appears that, barring renewal of eruptive activity, danger from the dome is over. On that basis, it was recommended that the ban on occupation of the town of Mambajao and the agricultural lands

FIGURE 5. The summit of the Hibok-Hibok dome, seen from the southeast, January 26, 1954. The spine at the top of the dome is badly fissured. The mass in the left foreground was formed in an early stage of the dome growth. Later, activity shifted slightly northeastward and produced the more recently active mass in the background. Photo by G. A. Macdonald.



around the foot of the volcano be abolished, but a new, smaller restricted zone with a radius of 3 kilometers be established around the summit of the volcano, in which no residence would be permitted. These recommendations have been acted upon. At the same time, the dangers of residing upon an active volcano were pointed out to the local populace. A close watch is being kept on the volcano for any signs of renewal of eruptive activity.

REFERENCES CITED

ALCARAZ, A., L. F. ABAD, and J. C. QUEMA. HIBOK-HIBOK VOLCANO, PHILIPPINE ISLANDS, AND ITS ACTIVITY SINCE 1948. Volcano Letter 516: 1–6; 517: 1–4, 1952.

——— and M. H. TUPAS. THE DIDICAS SUBMARINE VOLCANO. Eighth Pacific Science Congress, Abstracts of Papers, p. 4, 1953.

ANDAL, G. A., and B. YAMBAO. PHILIPPINE VOLCANOES AND SOLFATARIC AREAS. Mimeographed, 34 pp., distributed during sessions of Eighth Pacific Science Congress, Manila, 1953.

FAUSTINO, L. A. MAYON VOLCANO AND ITS ERUPTIONS. Philippine Jour. Sci. 40: 1–47, 1929.

IRVING, E. M. REVIEW OF PHILIPPINE BASEMENT GEOLOGY AND ITS PROBLEMS. Philippine Bur. Sci. 79(3): 267–307, 1950.

———(compiler). GEOLOGIC MAP (BIOSTRATIGRAPHIC-LITHOLOGIC) OF THE PHILIPPINES. Philippine Bureau of Mines and U. S. Geological Survey, 1953.

MASO, M. S. ACTIVE PHILIPPINE VOLCANOES. Weather Bureau Bulletin for April, 1922, Bureau of Printing, Manila, p. 141, 1924.

——— STEAM AS IMMEDIATE CAUSE OF THE LAST ERUPTIONS OF TAAL AND BULUSAN VOLCANOES. Third Pacific Science Congress, Proc. 1: 761–767, 1928.

MUSPER, K. A. F. R., and M. NEUMANN VAN PADANG. NEUE ÜBERSICHT DER TÄTIGEN VULKANE UND SOLFATARENFELDER IN DEN PHILIPPINEN. De Ingenieur in Nederlandsche-Indie 4 (5): 67–85, 1937.

SMITH, W. D. GEOLOGY AND MINERAL RESOURCES OF THE PHILIPPINE ISLANDS. Bureau of Printing, Manila, p. 216, 1924.

PHILIPPINE VOLCANOES (LISTED FROM NORTH TO SOUTH)

ISLAND	NAME OF VOLCANO	
	Active during historic time	Solfataric
Babuyan Islands	Smith Babuyan Claro (?) Didicas	Camiguin de Babuyanes
Luzon	Cagua Taal Mayon Bulusan	Maquiling Banahaw (possibly active in 1730) Malinao
Visayan Islands		
Biliran		Biliran
Leyte		Mt. Danan, Casiboi Crater } Burauen area Cabalian
Negros	Canlaon	Silay Magaso (Cuernos de Negros)
Camiguin	Hibok-Hibok (Catarman)	
Mindanao	Calayo (Masuan) Ragang	Apo
Jolo (Sulu Archipelago)		Bud Dajo (possibly active in 1641)

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JANUARY–MARCH, 1954

By JERRY P. EATON

VOLCANOLOGY

January

January was a quiet month for Hawaiian volcanoes. Only 27 earthquakes were recorded by seismographs of the Hawaiian Volcano Observatory. Seven of them originated under Kilauea, 12 under Mauna Loa, and 8 recorded too weakly to be located.

An earthquake at 9:39 P.M. on January 20, issuing from a focus 10 miles deep under Red Hill on the northeast rift of Mauna Loa, was felt in the Volcano district, Hilo, Pepeekeo, Kukuihaele, and Papaloa, Kona. Two smaller earthquakes from foci under the east rift of Kilauea were felt in Hilo; the first at 4:36 A.M. on January 24 and the second at 11:48 A.M. on January 31. At 2:27 A.M. on January 17 a slight earthquake was felt at Kalahiki, Kona.

Tilting of the earth's surface measured at the Volcano House on the northeast rim of Kilauea caldera was southwestward at a rate which is normal for this season of the year. Measurements of cracks in the floor of Kilauea do not show any significant change in the volcanic pressure under the volcano.

February

Hawaiian volcanoes remained quiet during February. Only 3 of the 27 earthquakes recorded by the Hawaiian Volcano Observatory seismographs were felt. Fourteen earthquakes originated on Mauna Loa, including those at 3:59 P.M. on February 6, 3:15 A.M. on February 16, and 5:32 P.M. on February 22, which were felt in Kona. Kilauea was shaken by six earthquakes, none of which was felt. Seven of the recorded earthquakes were too feeble to be located.

Tilting of the earth's surface at the northeast rim of Kilauea caldera proceeded in a southwesterly direction at a rate approximately normal for this season of the year.

March

Thirty-six earthquakes were recorded by seismographs of the Hawaiian Volcano Observatory during March. During most of the month seismic activity remained at the low level established during January and February; only 15 earthquakes were recorded from March 1 to March 29. Nine of them originated at Kilauea. The remaining six, including the earthquake at 4:19 P.M. on March 16, which was felt in Captain Cook, issued from Mauna Loa.

A series of small tremors felt in Hawi at about 8:30 P.M. on March 23 was not recorded on any of the Observatory's seismographs.

Two strong earthquakes, which originated at a depth of about 15 miles on the east rift zone of Kilauea or the eastward extension of the Hilina fault system between the rift zone and the south shore in the vicinity of Kalapana, rocked the Island of Hawaii early on the morning of March 30. The first shock was recorded on the seismographs at the Volcano Observatory at 6:40:07 A.M.; the second at 8:42:01 A.M.

Both earthquakes were felt over the entire Island of Hawaii, and at least the second, which was the larger of the two, was felt on parts of Maui. Extensive, but mostly moderate, damage was caused in the Hilo and Puna districts. Although the shaking was most intense in the Puna district, where water tanks were thrown down and stone fences were damaged, the most spectacular damage occurred in and near Hilo, where many windows were broken and portions of a few houses were deranged or thrown down.

On March 30 and 31 a total of 16 aftershocks, several of which were felt in Puna and Hilo, stemmed from the same region as the two large quakes. The largest of these occurred at 6:57 A.M. on March 30 and at 3:04 P.M. and 4:00 P.M. on March 31. The

aftershock sequence extended into April, with small earthquakes at 3:57 P.M. on April 1 and 2:05 P.M. on April 8.

Concurrent with the large earthquakes in Puna and the associated aftershocks, seismic activity increased near Kilauea caldera. Four quakes originated in this region on March 30 and 31, and two more occurred on April 1. Of these six earthquakes, those at 11:19 A.M. on March 30 and 6:35 A.M. on April 1 were felt in the Volcano area.

The normal seasonal southwestward tilting at the Volcano House on the northeast rim of Kilauea caldera reversed for about 1 week at the time of the Puna earthquakes. Subsequently, southwestward tilting normal for this season has been re-established.

No general change in the width of cracks in Kilauea caldera, which might indicate changing pressure under the volcano, accompanied the Puna earthquakes.

SEISMOLOGY

Earthquake Data, January–March, 1954

(Based on Bosch-Omori seismograph on northeast rim of Kilauea caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
Jan. 3	2	3	0	0	0	0	2.0	0
10	3	4	0	0	0	0	2.75	0
17	5	3	1	0	0	0	3.75	1
24	4	2	0	1	0	0	4.0	0
31	3	1	0	1	0	0	3.75	4
Feb. 7	6	3	0	0	0	0	3.0	0
14	7	0	0	0	0	0	1.75	4
21	6	0	0	0	0	0	1.5	0
28	1	2	0	0	0	0	1.5	1
Mar. 7	8	2	0	0	0	0	3.0	0
14	3	1	0	0	0	0	1.25	1
21	1	2	0	0	0	0	1.25	1
28	25	10	2	2	1	4	36.25	4

* For definition of local seismicity see Volcano Letter 371 or 512. Each local earthquake is assigned a seismicity value according to its strength, as follows: tremor, 0.25; very feeble, 0.5; feeble, 1.0; slight, 2.0; moderate, 3.0; strong, 4.0. These values are totaled to give the weekly local seismicity. Continuous volcanic tremor is ignored in the calculation. The strength assigned to the earthquake depends on the double amplitude of the maximum oscillation it causes on the Bosch-Omori seismograph, as follows: tremor, less than 0.5 mm.; very feeble, 0.5 to 4 mm.; feeble, 4 to 11 mm.; slight, 11 to 25 mm.; moderate, 25 to 60 mm.; strong, greater than 60 mm.

Table of Tilt at Seismograph Stations on Rim of Kilauea Caldera

Week Beginning	Whitney Station (Northeast rim)		Uwekahuna Station (West rim)	
	Amount	Direction	Amount	Direction
January 3	0.5″	E 14° S	1.3″	S 14° W
10	1.2″	S 6° E	1.2″	S 34° W
17	0.1″	S 21° E	0.5″	N 45° W
24	0.8″	S 18° W	0.6″	E
31	1.5″	S 29° W	1.6″	N
February 7	0.8″	S 18° W	1.3″	S 14° E
14	0.2″	S 45° W	1.9″	S 9° E
21	0.9″	W 16° S	4.2″	N 33° W
28	1.4″	S 45° W	1.2″	N 34° W
March 7	0.8″	S 45° W	1.2″	S 34° E
14	1.1″	S 13° W	1.6″	N 11° W
21	1.2″	S	0.3″	N
28	0.7″	N 9° W	2.9″	S 27° W

Local Earthquakes

The data for the following local earthquakes were determined from seismographs on the islands of Hawaii and Maui operated by the Hawaiian Volcano Observatory. Locations given are epicenters. The times given are arrival times at the Whitney Laboratory of Seismology, on the northeast rim of Kilauea caldera. They are stated to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich Civil time. The number preceding each earthquake is the serial number for the current year. The intensity rating (Feeble, Moderate, etc.) given is that for the Whitney Laboratory. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney station.

1. Jan. 3, 03:06, very feeble. Kilauea caldera.
2. Jan. 6, 09:11, very feeble.
3. Jan. 9, 03:17, very feeble (Mauna Loa, feeble). Southeast flank of Mauna Loa 3 miles west of Halfway House.
4. Jan. 9, 13:57, very feeble. Southeast flank of Mauna Loa 5 miles southeast of Halfway House.
5. Jan. 10, 00:19, very feeble.
6. Jan. 12, 08:01, very feeble (Mauna Loa, feeble). Southeast flank of Mauna Loa.
7. Jan. 13, 04:30, tremor (Mauna Loa, very feeble). Southeast flank of Mauna Loa near Halfway House.
8. Jan. 13, 22:48, very feeble.
9. Jan. 14, 17:28, not recorded at Kilauea (Mauna Loa, very feeble).
10. Jan. 14, 03:04, very feeble.
11. Jan. 15, 13:17, tremor (Uwekahuna, very feeble). Kilauea caldera.
12. Jan. 16, 12:49, not recorded at Kilauea (Kona, very feeble). Kona.
13. Jan. 17, 02:27, tremor (Uwekahuna, very feeble). Felt in Kalihiki, Kona. Kona.
14. Jan. 17, 05:29, very feeble.
15. Jan. 17, 15:39, Kilauea.
16. Jan. 17, 17:17, not recorded at Kilauea (Kona, very feeble). Kona.
17. Jan. 19, 12:11, tremor (Mauna Loa, very feeble). Southeast flank of Mauna Loa.
18. Jan. 20, 21:39, tremor (Uwekahuna, very feeble). Hilina Pali.
19. Jan. 20, 21:39, feeble (Mauna Loa, slight). Felt in Papaloa, Kona; Hawaii National Park; and Kukuihaele, North Hamakua. Ten miles deep under Red Hill on the northeast rift of Mauna Loa.
20. Jan. 20, 21:40, very feeble.
21. Jan. 22, 03:13, tremor (Uwekahuna, very feeble).
22. Jan. 24, 04:36, slight. Felt in Hilo. Twelve miles deep under Alae crater on the east rift of Kilauea.
23. Jan. 26, 06:48, tremor (Mauna Loa, very feeble).
24. Jan. 28, 13:15, not recorded at Kilauea (Kona, very feeble). Kona.
25. Jan. 29, 22:54, very feeble. Kaoiki fault.
26. Jan. 30, 08:31, very feeble. Southwest rift of Kilauea near the coast.
27. Jan. 31, 11:48, slight. Felt in Hilo. East rift of Kilauea about 6 miles from the Observatory.
28. Feb. 6, 15:59, tremor (Mauna Loa, very feeble). Felt in Kalihiki, Kona. Kona.
29. Feb. 6, 20:41, tremor (Mauna Loa, very feeble). Southeast flank of Mauna Loa.
30. Feb. 7, 14:15, tremor (Mauna Loa, very feeble). Deep under the summit of Mauna Loa.
31. Feb. 7, 19:50, tremor (Uwekahuna, very feeble). Kilauea caldera.
32. Feb. 10, 22:14, very feeble (Mauna Loa, feeble). Southeast flank of Mauna Loa.
33. Feb. 12, 03:24, tremor (Uwekahuna, very feeble).
34. Feb. 12, 03:51, very feeble. Kilauea.
35. Feb. 12, 13:10, not recorded at Kilauea (Kona, very feeble). Kona.
36. Feb. 12, 15:30, not recorded at Kilauea (Hilo, very feeble). Near Hilo.
37. Feb. 13, 13:01, tremor (Uwekahuna, very feeble).
38. Feb. 13, 23:44, very feeble. Kilauea.
39. Feb. 16, 03:15, not recorded at Kilauea (Kona, feeble). Felt in Captain Cook. Kona.
40. Feb. 16, 08:31, not recorded at Kilauea (Mauna Loa, very feeble). Northeast rift of Mauna Loa.
41. Feb. 18, 14:39, not recorded at the Whitney Laboratory (Mauna Loa, very feeble).

42. Feb. 19, 06:31, not recorded at the Whitney Laboratory (Uwekahuna, very feeble). Southwest rift of Kilauea.
43. Feb. 19, 21:27, not recorded at Kilauea (Mauna Loa, very feeble). Mauna Loa.
44. Feb. 20, 02:33, not recorded at the Whitney Laboratory (Mauna Loa, very feeble). Summit of Mauna Loa.
45. Feb. 22, 17:32, not recorded at the Whitney Laboratory (Mauna Loa, very feeble). Felt at Kalihiki, Kona. Kona.
46. Feb. 23, 16:50, not recorded at the Whitney Laboratory (Mauna Loa, very feeble). Southeast flank of Mauna Loa.
47. Feb. 24, 01:04, tremor (Uwekahuna, very feeble).
48. Feb. 24, 03:36, not recorded at the Whitney Laboratory (Mauna Loa, very feeble).
49. Feb. 25, 15:38, not recorded at the Whitney Laboratory (Mauna Loa, very feeble). Southeast flank of Mauna Loa.
50. Feb. 26, 09:50, not recorded at Kilauea (Mauna Loa, very feeble).
51. Feb. 26, 14:15, tremor (Mauna Loa, very feeble). Mauna Loa.
52. Feb. 26, 14:16, not recorded at Kilauea (Mauna Loa, very feeble). Mauna Loa.
53. Feb. 27, 14:53, tremor (Uwekahuna, very feeble). Kilauea.
54. Mar. 3, 23:30, not recorded at the Whitney Laboratory (Uwekahuna, very feeble). Kilauea.
55. Mar. 6, 02:35, very feeble. East rift of Kilauea.
56. Mar. 6, 21:49, very feeble. Kilauea.
57. Mar. 9, 02:51, very feeble. Kilauea caldera.
58. Mar. 9, 03:22, very feeble. Kilauea caldera.
59. Mar. 12, 15:32, not recorded at the Whitney Laboratory (Hilo, very feeble). Near Hilo.
60. Mar. 15, 06:50, very feeble. Kilauea caldera.
61. Mar. 16, 16:19, tremor (Kona, feeble). Kealakekua fault.
62. Mar. 19, 00:23, tremor (Mauna Loa, very feeble). Southeast flank of Mauna Loa.
63. Mar. 24, 07:25, very feeble. East rift of Kilauea near Alae Crater.
64. Mar. 26, 00:28, very feeble. Southwest rift of Kilauea 4 miles southeast of Kapapala Ranch.
65. Mar. 26, 03:08, not recorded at the Whitney Laboratory (Mauna Loa, very feeble). Southeast flank of Mauna Loa.
66. Mar. 26, 15:02, not recorded at the Whitney Laboratory (Uwekahuna, very feeble). Kilauea caldera.
67. Mar. 26, 16:07, not recorded at the Whitney Laboratory (Mauna Loa, feeble). Northeast rift of Mauna Loa near the Mauna Loa seismograph.
68. Mar. 29, 19:31, tremor (Mauna Loa, very feeble). Deep under the northeast rift of Mauna Loa.
69. Mar. 30, 06:40, strong. About 15 miles deep between the east rift of Kilauea and the sea near Kalapana.
70. Mar. 30, 06:57, slight. Aftershock of No. 69.
71. Mar. 30, 07:02, tremor (Uwekahuna, very feeble). Kilauea caldera.
72. Mar. 30, 07:38, very feeble. Aftershock of No. 69.
73. Mar. 30, 08:42, strong. About 15 miles deep between the east rift of Kilauea and the sea near Kalapana.
74. Mar. 30, 09:08, very feeble. Aftershock of No. 73.
75. Mar. 30, 10:08, tremor (Uwekahuna, very feeble). Aftershock of No. 73.
76. Mar. 30, 10:17, very feeble. Aftershock of No. 73.
77. Mar. 30, 10:26, very feeble. East rift of Kilauea.
78. Mar. 30, 11:19, strong. Felt in Hawaii National Park. Kilauea caldera.
79. Mar. 30, 12:13, tremor (Mauna Loa, very feeble). Aftershock of No. 73.
80. Mar. 30, 13:31, tremor (Uwekahuna, very feeble). Aftershock of No. 73.
81. Mar. 30, 14:44, tremor (Mauna Loa, very feeble). Aftershock of No. 73.
82. Mar. 30, 15:42, very feeble. Aftershock of No. 73.
83. Mar. 30, 18:15, very feeble. Aftershock of No. 73.
84. Mar. 31, 00:30, very feeble. Aftershock of No. 73.
85. Mar. 31, 01:09, tremor (Uwekahuna, very feeble). Aftershock of No. 73.
86. Mar. 31, 01:30, very feeble. Kilauea caldera.
87. Mar. 31, 05:46, very feeble. Kilauea caldera.
88. Mar. 31, 15:04, feeble. Aftershock of No. 73.
89. Mar. 31, 15:48, very feeble. Aftershock of No. 73.
90. Mar. 31, 16:00, moderate. Aftershock of No. 73.

Distant Earthquakes

The following earthquakes of distant origin were recorded on the seismographs of the Hawaiian Volcano Observatory. Locations of the epicenters and the magnitudes are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey. The time given is that of the first detectable emergence of the quake on the Bosch-Omori horizontal or Sprengnether vertical seismograms, in Hawaiian Standard time.

Jan. 19, 18:40:00. Pacific Ocean south of Mexico, 8½°N., 103½°W., magnitude 6.

Jan. 31, 15:16:40. Volcano Islands, 24½°N., 142½°E., magnitude 7¼.

Feb. 4, 23:29:31. Off coast of New Britain, 4½°S., 153°E., magnitude 6¼–7.

Feb. 6, 14:28:01.

Feb. 6, 20:24:15. New Hebrides Islands, 15°S., 167½°E., magnitude 6–6½.

Feb. 10, 14:43:07. Ningsia Province, China, 39½°N., 101°E., magnitude 7–7½.

Feb. 18, 14:51:22. Off coast of Nicaragua, 11½° N., 87½°W., magnitude 6¾–7.

Feb. 19, 09:17:17. Kermadec Islands, 30°S., 178°W., magnitude 7–7½.

Feb. 19, 11:45:33. Coast of Nicaragua, 12½°N., 87½°W., magnitude 6¾–7. Felt at Managua.

Feb. 20, 08:46:36. Flores Sea, 7°S., 124½°E., magnitude 6½–6¾.

Mar. 2, 20:13:50. New Guinea, 5½°S., 142½°E., magnitude 7–7¼.

Mar. 19, 00:12:00. Santa Rosa Mountains, California, 33.3°N., 116.1°W., magnitude 6–6¼. Slight property damage.

Mar. 21, 13:55:34. Northwestern Burma, 24½°N., 95°E., magnitude 7–7¼. Felt in Eastern India.

Mar. 28, 10:44:04. Rat Islands, Aleutian Islands, 52°N., 176°E., magnitude 6½.

Mar. 28, 18:13:13. Near north coast of Luzon Island, Philippine Islands, 19½°N., 121½°E.

Mar. 28, 20:34:45. Near south coast of Spain, 37°N., 3½°W., magnitude 7¼–7½. Extensive property damage at Granada and Malaga.

VOLCANO NOTES AND NEWS

RABAUL OBSERVATORY

The following notes are abstracted from an account of the Volcanological Observatory at Rabaul and its operations, prepared by Mr. J. G. Best, volcanologist at the Observatory, and forwarded through the kindness of Dr. N. H. Fisher, Chief Geologist of the Bureau of Mineral Resources, Commonwealth of Australia.

The Volcanological Observatory at Rabaul is built on the northern rim of the Blanche Bay caldera, 600 feet above sea level. The site overlooks the township of Rabaul and affords an excellent view of the various craters within Blanche Bay.

The Observatory was completed shortly before the capture of Rabaul by the Japanese in early 1942. Subsequently, however, the upper portion of the building, together with all records, was destroyed, and all instruments and fittings removed from the instrument cellar. In December, 1951, work was commenced on reconstruction of the Observatory. The upper portion of the building was restored and now contains a laboratory, records room, and office, as well as temporary housing for the staff.

Upon the erection of permanent housing for the staff, these living quarters will be converted for use as a museum, photographic dark room, and workshop.

The instrument cellar is beneath the office building. It is 25 feet long, 15 feet wide, and 9 feet deep, and is concrete lined. Four concrete instrument piers are set well below the floor of the cellar and are based on the surface of a lava flow which lies 8 feet below the cellar floor. A 3-inch gap, loosely filled with soil and covered with tarred paper, is left between the piers and the cellar floor.

Three Benioff seismometers, a Benioff recorder, and two tiltmeters have been installed in the instrument cellar. The start of recording with the Benioff instruments has been held up through lack of accessories.

At Rapindik, 3¼ miles southeast of the Observatory, an Omori-type seismograph with low magnification and mechanical recording was installed in May, 1950. It is so placed to detect seismic activity of volcanic origin at the active centers in Blanche Bay.

The two tiltmeters at the Observatory are normally read daily and the readings plotted graphically. Temperatures of hot springs, wells, fumaroles, and solfataras at 51 points in the Blanche Bay area are taken weekly and recorded graphically. In the event of an upward trend in temperature, the frequency of the readings would be increased. Analysis of volcanic exhalations is to become routine, being done jointly with the weekly temperature readings. Photographic records of selected fumaroles and other thermal points also are to become a routine feature. The Commonwealth Department of Public Works operates a Stevens continuous-recording water gauge in Simpson Harbour and the volcanological staff have access to this instrument for any information required. In addition, tide poles are installed at selected points around Blanche Bay and are read weekly, so that changes in the level of the strandline can be detected.

A systematic investigation is to be made of all volcanic areas in the Territory of Papua and New Guinea, and eventually regular inspections will be made of the more active areas. Preliminary investigations of several areas have already been made.

To keep in touch with events at other centers, a system of reporting seismic and volcanic phenomena has been introduced. This involves the reporting by radio of all important earthquakes and changes in volcanic activity. Monthly reports of all relevant information from outside areas are forwarded to the Observatory by government stations through the Territory.

ACTIVITY OF MOUNT ASAMA

By T. Minakami

Asama volcano resumed activity on December 27, 1953, after a complete quiescence of 38 months. The usual Asama eruptions are Vulcanian in type and of explosive character, with furious detonations lasting several minutes throwing up abundant ejecta including numerous lava blocks and bombs. The interval between successive eruptions is usually several days, even during such markedly active periods as 1935–38. The present activity differs from this in that each explosion is on an extremely small scale compared with the usual ones and occur very frequently. During the period from the beginning of the eruption to the end of February, 1954, the number of separate explosions observed has ranged from 0 to 10 per day, and because observation is not possible during hours of darkness the total number of explosions probably is about 30 per cent greater than this. The kinetic energies of individual explosions during the present activity are estimated to range from 10^{14} to 10^{16} ergs, whereas those of the ordinary explosions of Asama are estimated to be nearly 10^{19} ergs. The explosions have ejected volcanic ash and pumice-like gravel. No serious damage has resulted, although ice skating at rinks at Karuizawa, near the southeastern foot of the volcano, was disturbed by the fall of fine ash.

Highly sensitive seismographs at the Asama Volcano Observatory indicated an increase in frequency and amplitude of microearthquakes originating from Asama volcano during the late summer and autumn of 1953. On August 2 and 3 a swarm of at least 200 microearthquakes originated in the neighborhood of the summit crater. After that, the emission of vapor (including volcanic gases such as SO_2) from the crater became very irregular in quantity. At times the gas was very abundant, and at other times it was very sparse. This is a common occurrence at Asama preceding and during eruption. On November 5, when the summit of the mountain was visited by a party including the writer and Dr. G. A. Macdonald of the Hawaiian Volcano Observatory, vapor was so abundant that the crater floor was invisible. Rumblings from the crater were heard at the Volcano Observatory on December 20, a week before the outbreak.

ACTIVITY OF OTHER JAPANESE VOLCANOES

Early in February newspapers reported a submarine disturbance observed by crews of MATS aircraft in the vicinity of Minami Iwo Jima, about 30 miles south-southeast of Iwo Jima in the Volcano Islands group. The surface of the ocean was reported to be boiling and steaming, presumably as a result of volcanic eruption in the ocean. Activity in the same general area was reported in March, 1953 (Volcano Letter 520: 7).

Charles G. Johnson, of the U. S. Geological Survey, Pacific Geological Surveys, reports that volcanic explosions began on Suwanose Island in the northern Ryukyu group at about 12:30 P.M. on February 22. Ash fell as far as 20 nautical miles south-southwest of the island.

Mr. Johnson also reports that the activity of O-shima volcano, which began on December 29, 1953 (Volcano Letter 522: 6), ceased, at least temporarily, about February 15. The last strong activity was on January 27, when bombs were reported hurled 1,000 feet into the air, and a small lava flow covered part of the crater floor. This violent activity subsided about 4:30 P.M. on January 27. Small explosions occurred for about 6 minutes on January 31 and intermittently for about 2 hours on February 1, followed by intermittent small-scale activity until February 15.

ERUPTION OF MERAPI VOLCANO

Merapi volcano, in east-central Java, probably is the most dangerous volcano in Indonesia, partly because of the type of its activity, and partly because of the concentration of a dense agricultural population of some 3 million persons in the area close around its base. For several months the Volcanological Survey of Indonesia had been calling attention to the restlessness of the volcano, and warning that it might erupt. The eruption came on January 18. Scant newspaper reports state that the outbreak came in the form of a violent explosion, and that it was preceded by two perceptible earthquakes. The press descriptions suggest that *nuées ardentes* may have formed on the flanks of the mountain. On January 20 the reported casualties were 68 known dead and 145 injured. Many thousands of people were being evacuated from danger areas.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director
Jerry P. Eaton, Seismologist
Chester K. Wentworth, Geologist, part-time
Burton J. Loucks, Instrument Maker
John C. Forbes, Assistant Instrument Maker
Elizabeth G. Eklund, Secretary, part-time

Seismograph Station Operators:

Hilo Station:
Sister M. Thecla, St. Joseph's School

Kona Station:
Howard M. Tatsuno, Konawaena School

Haleakala Station:
Hawaii National Park Staff

THE VOLCANO LETTER

No. 524 **U. S. Geological Survey** **April–June, 1954**

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THE ERUPTION OF KILAUEA VOLCANO IN MAY, 1954

By GORDON A. MACDONALD and JERRY P. EATON

INTRODUCTION

Kilauea Volcano erupted early on the morning of May 31, 1954, after a dormancy of 18½ months. Although it could not be specifically predicted, the eruption was not unexpected. The termination of activity at Kilauea in November, 1952, was neither accompanied nor followed by any abnormal tilting that would suggest reduction of volcanic pressure beneath the volcano. On the contrary, during 1953 there was an accumulation of approximately 12 seconds of northward tilting at the Whitney Laboratory of Seismology on the northeastern rim of Kilauea caldera, in excess of the usual seasonal tilting. This suggested an actual increase of volcanic pressure beneath the caldera, resulting in a tumescence of Kilauea Volcano. Short periods of volcanic tremor during February and March, 1953, indicated subsurface movement of lava at Kilauea. All indications were that molten lava continued to stand at a high level within the conduit. In the report on activity of Hawaiian volcanoes during 1953 (Macdonald and Eaton, in preparation), submitted to the U. S. Geological Survey in mid-May, 1954, it was stated: "Under such conditions, eruption might come with very little forewarning."

Kilauea continued restless through the early months of 1954, but although eruption remained a possibility at any time, there was no evidence that appeared adequate for the basis of a prediction of an outbreak at any specific time.

NARRATIVE OF THE ERUPTION

Numerous small earthquakes occurred during the night of May 30–31. Slight earthquakes were recorded at 3:42 and 3:47 A.M. These wakened many persons, including the writers, in the region near Kilauea caldera. Shortly afterward Macdonald became conscious of a faint, persistent low-pitched roaring, almost a felt vibration rather than a recognizable sound, somewhat resembling the vibration caused by a heavy truck in low gear climbing a distant hill. The sensation continued as long as the observer remained motionless. A moderate earthquake occurred at 3:51 A.M., followed by a strong quake at 3:54 A.M. The latter was violent enough to dismantle the Bosch-Omori seismograph, and immediately both of us went to the Whitney Laboratory of Seismology to restore the instrument to operation.

Halemaumau had been visited at approximately 3:30 A.M. by G. H. Ruhle, Naturalist of Hawaii National Park, who reports that complete darkness reigned and everything appeared as usual. When we reached the seismograph vault, at approximately 4:03 A.M., there still was no sign of glow at Halemaumau. The seismograph was restored to operation, and a drum bearing a new record sheet placed on the instrument at 4:08 A.M. At 4:09 A.M. we observed the beginning of registration of volcanic tremor on the seismograph. Rushing from the vault, we observed (at approximately 4:10 A.M.) a bright glow at Halemaumau, reflected on a rising cloud of gas that already had reached a height of about 2,000 feet above the crater rim. The fume cloud continued to expand upward. About daylight the pilot of a plane inbound to Hilo reported it to have reached a height of 30,000 feet, where it was spreading out like a great mushroom.

We reached the Volcano Observatory at about 4:20 A.M. Half a mile away, a dense column of fume was rising from the northeastern part of Halemaumau Crater, nearly hiding the top of a giant lava fountain that appeared from time to time, with its top about 100 feet above the rim of the crater. This fountain rose from the crater floor, 470 feet below the rim. Thus, its total height was between 550 and 600 feet. Thin fume rose from the entire area of the crater, and a second principal fume column rose near the southwestern edge. These columns of fume rose nearly vertically above the crater. There was little low-lying fume, such as made approach to the lee side of the crater almost impossible in June, 1952.

At 4:27 A.M. the eruptive activity was entirely confined to Halemaumau Crater. Between 4:30 and 4:35

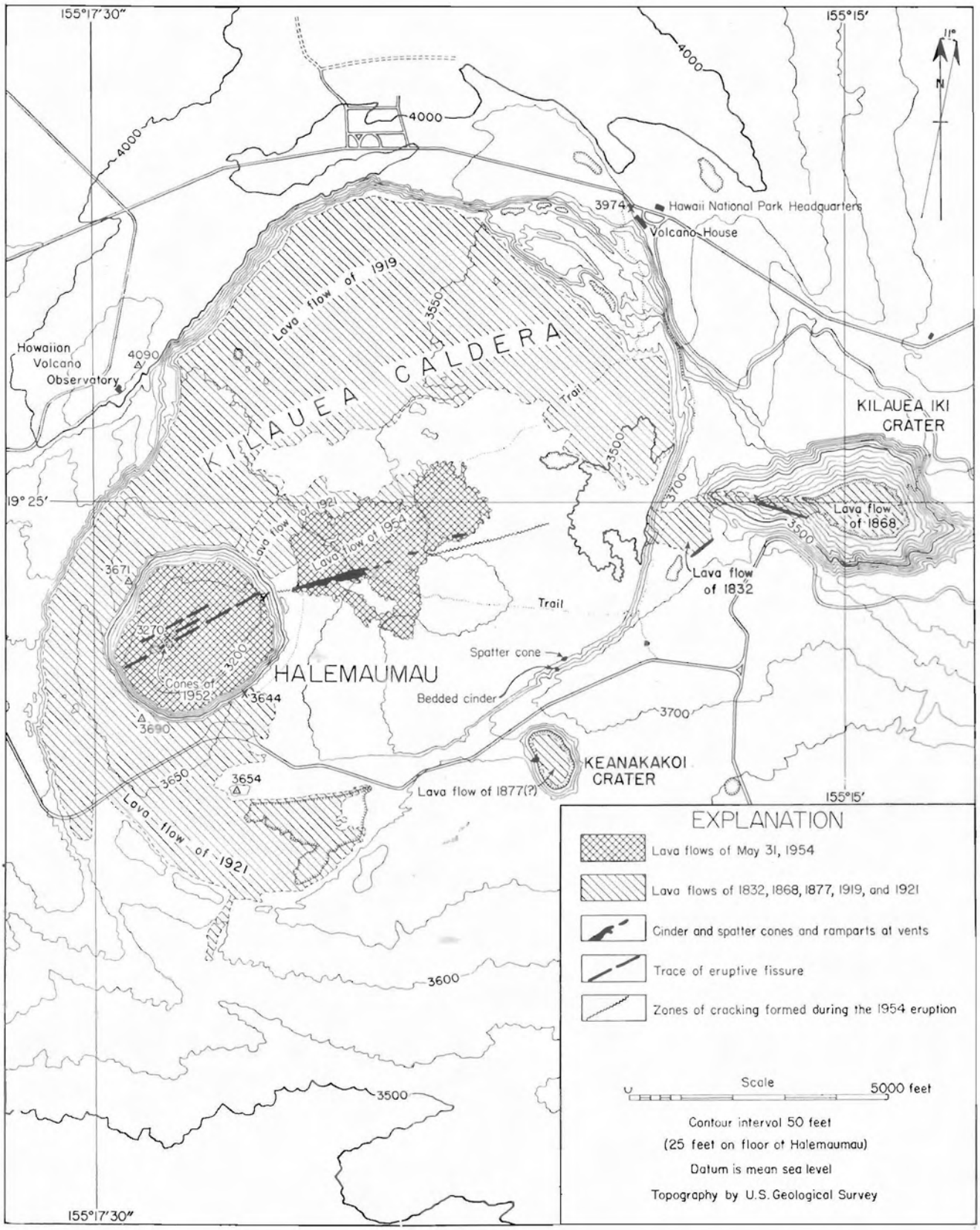

FIGURE 1. Map of Kilauea caldera, showing the location of the eruptive fissures and lava flows of the 1954 eruption, and some older flows outside Halemaumau.

A.M. lava issued from a fissure on the floor of Kilauea caldera northeast of Halemaumau. Ranger D. J. Tobin, Jr., of Hawaii National Park, viewed this event from a point near Kilauea Iki, nearly in line with the opening fissure. He states that at first the incandescent lava welled out gently, with little or no fountaining, followed by a gradual waxing of the fountains to a height of 50 to 100 feet. Because of the cloud of fume rising from Halemaumau immediately behind the new outbreak, he was unable to tell whether the arrival of lava at the surface was preceded by an outburst of fume from the fissure outside Halemaumau.

At 4:35 A.M. the line of fountains on the caldera floor northeast of Halemaumau was estimated to be 300 feet long, with its western end about 300 feet from the rim of Halemaumau. During the next few minutes the fountain chain spread rapidly, mostly eastward but also slightly toward the west. By 4:50 A.M. the principal chain was 1,400 feet long. Three other shorter chains were active farther east-northeast (Figs. 1 & 2). Very active flows of pahoehoe were spreading from the base of the fountains, and had already reached lengths as great as 1,000 feet.

We reached the rim of Halemaumau Crater at approximately 4:55 A.M. The entire crater floor was covered with a pond of incandescent lava. Across the floor diagonally from east-northeast to west-southwest, approximately along the line of the eruptive fissure of 1952, stretched a row of lava fountains from a few feet to more than 100 feet high (Fig. 1). The fissure bisected the cones left by the 1952 eruption, and lava poured from the cones into the surrounding pool. At the southwestern end of the line, approximately in the position occupied by the principal fountain during the early days of the 1952 eruption (Macdonald, 1952), was a fountain 250 to 300 feet high (Fig. 3). At the northeastern end the huge fountain visible earlier from the Volcano Observatory continued to play to a height at least 100 feet above the observers' heads (Fig. 4). Between these two end fountains the row of smaller fountains was nearly continuous.

Northwest of the principal row of fountains lay another shorter row, parallel to the first, and extending just northwest of the 1952 cones. Between these two rows of fountains was a third short row of three fountains, just northeast of the 1952 cones (Fig. 1). All of the fountains of the second and third rows were small. Few of them exceeded 10 feet, and none exceeded 25 feet in height.

Possibly the most spectacular feature of the eruption was the cascade of brilliant, orange-yellow lava that poured from the eruptive fissure 300 feet above the floor, on the northeastern wall of the crater (Fig. 4). Plunging down the wall, this "fire-fall" of incandescent liquid joined the turbulent pool around the base of the northeastern fountain. The lava issued at the head of the cascade quietly, with little spattering and no fountaining, as though it were poor in gas. At the base of the cascade a row of small fountains issued from the eruptive fissure, merging southward with the big northeast fountain.

Spreading out from the rows of source fountains, the lava was quickly covered with a thin black crust that was rifted apart by movement to reveal in a network of cracks the bright orange liquid beneath. Distinct waves, set up by surging at the fountains, swept outward across the surface of the lake. At the foot of the crater walls, the surging liquid alternately covered and revealed a bright band 5 to 10 feet in height. Locally, foundering of fragments of the crust resulted in small secondary fountains, apparently caused by release of air and other gases carried down by the sinking crusts. Many of the secondary fountains were evanescent, and shifting in position. Others, however, occurred persistently along certain lines, apparently determined by the boundaries of flow units. The most prominent line of that sort extended from the southeast to northwest edges of the lake, passing just northeast of the 1952 cones, and apparently marked the boundary between two principal convective cells surrounding the southwest and northeast fountains respectively.

A gap of 200 feet separated the westernmost fountains on the caldera floor from the rim of Halemaumau Crater (Fig. 1). By 5:40 A.M., lava liberation had nearly ceased along the westernmost 100 feet of the fountain chain, and activity at those vents consisted largely of roaring gas release, accompanied by showers of incandescent ejecta. The preponderance of gas at these vents, together with the gas-poor character of the lava forming the cascade on the adjacent wall of Halemaumau, suggests that in the section of the fissure near Halemaumau there was a partial separation of the gas and liquid phases, the gas-rich portion rising nearly vertically to feed the westernmost vents of the fountain chain on the caldera floor, and the liquid largely draining into Halemaumau, forming the cascade.

No conspicuous crack was visible on the wall of Halemaumau above the head of the cascade, or between the rim of Halemaumau and the end of the fountain chain to the east. In the latter gap there were many cracks in a zone about 50 feet wide along the projected course of the eruptive fissure farther east, but none of them were continuous for more than a few feet, or were more than 2 or 3 mm. wide.

Eastward, the principal line of fountains was approximately 1,400 feet long, and essentially continuous. The fountains forming this "curtain of fire" were a few feet to about 100 feet high, and the accumulation of ejecta from them was rapidly building a spatter rampart. Fragments of ejected pumice were drifted southwestward by the trade wind, partly mantling the southern slope of the spatter rampart and the adjacent lava. Along its southwestern part the rampart was breached, and several flow units were escaping northwestward, merging into a single, very active flow of pahoehoe. A smaller flow moved southeastward on the southern side of the rampart. A large river issued from the fountain pit at the eastern end of the spatter rampart and moved southeastward, spreading out to form a broad flow that merged with the lava flowing eastward north of the spatter rampart and with other lava from vents farther east.

Three other short rows of small fountains, less than 20 feet high, lay respectively 200, 400, and 900 feet east of the principal fountain chain. These also built small ramparts and cones of spatter, and liberated small flows. A somewhat more conspicuous row of fountains, 300 feet long, lay 1,800 feet east of the principal fountain chain.

All of these short rows of fountains were essentially parallel to the principal chain, but were offset en echelon from it. West of the easternmost row, a zone of narrow, diagonal cracks extends across an embayment in the new flow toward the next group of vents. Another zone of narrow cracks extends eastward for about 900 feet beyond the new lava, as a prolongation of the line of the principal fountain-chain (Fig. 1).

By 6:45 A.M. new lava had accumulated to a depth of more than 50 feet in Halemaumau Crater, nearly burying the cones of the 1952 eruption. Dense, bluish-white fume filled the crater, nearly obscuring the floor. Two principal fume columns rose from the northeast and southwest fountains. Strong winds, which were directed centripetally entirely around the crater, blew these fume columns inward, causing them to meet a few hundred feet above the crater rim. Above that level the fume cloud rose nearly vertically. No doubt the violent centripetal winds were caused by the strong convective rise of warm air and fume above the crater. Small, violent whirlwinds caused dust-devils around the edge of the crater, and swept across the crater floor, carrying off whirling fragments of the thin crust of the lava lake.

At 7:10 A.M. a good view of the northeastern portion of the crater floor was obtained by Eaton from the northern rim. The northeast fountain consisted of a surging, dense, domical core rising about 200 feet above the crater floor, with frequent bursts of scattered incandescent ejecta as high as the crater rim. The main outward flowage from the base of the fountain was southward. Concentric lobe-shaped markings on the crust of the new lava developed around the base of the fountain. These were stretched outward as the current spread from the fountain source at a velocity of 5 to 10 miles per hour. The circulation appeared to move in a circle and return toward the northwest base of the fountain, but dense fume caused poor visibility of that part of the floor.

At 7:30 A.M. fountain activity, both in Halemaumau and on the caldera floor to the northeast, was decreasing. The largest fountains northeast of Halemaumau were only about 75 feet high, and the westernmost 200 feet of the eruptive fissure was almost dead. The southwest fountain in Halemaumau was about 150 feet high, with occasional bursts reaching 200 feet. The northeast fountain was about 450 feet high. Other small fountains, 10 to 50 feet high, were active in the central part of the floor. The cascade had dwindled to a mere trickle, and by 8:00 A.M. it was entirely inactive.

Between 8:00 and 9:00 A.M. the flow on the caldera floor was still advancing slowly, but had reached nearly its full extent. The three segments of eruptive fissure east of the principal cone chain were nearly inactive, and at the fourth (easternmost) segment activity was very weak. At the latter the repetitive pattern of behavior consisted of a few seconds of quiet followed by loud hissing, culminating in a dull, hissing explosion that threw fragments of pasty lava 15 feet in the air. Along the main section of the active fissure lava fountains still played to heights of 50 to 75 feet.

Between 10:00 and 11:00 A.M. activity within Halemaumau was restricted largely to the northeast and southwest fountains. A prominent sinkhole was active from time to time near the northeastern end of the 1952 cones. Many small avalanches were occurring on the crater walls. Striking the fluid lava of the lake, these caused violent splashing and sank quickly out of sight, to be followed for several minutes by a group of small, secondary fountains. The lava fountains northeast of Halemaumau continued to decrease in size, and by 11:00 A.M. were essentially inactive. By 1:00 P.M. the southwest fountain in Halemaumau had decreased to a height of only 50 feet, and the northeast fountain was throwing only occasional showers of spatter to heights of less than 25 feet. A slump scarp was starting to form around the edge of the crater floor.

At 1:30 P.M. fountains along the central part of the chain northeast of Halemaumau again became weakly active, throwing sporadic showers of incandescent ejecta to heights as great as 25 feet. This revival was brief. By 4:00 P.M., the fountain activity outside Halemaumau was completely ended except for occasional very weak flings and weak, whistling gas release. A little sluggish movement continued in the flow until evening, and glow was visible in the throats of the cones until the night of June 1.

By 3:00 P.M. the northeast fountain in Halemaumau was completely inactive, and the southwest fountain was throwing weak, sporadic bursts of ejecta to heights up to

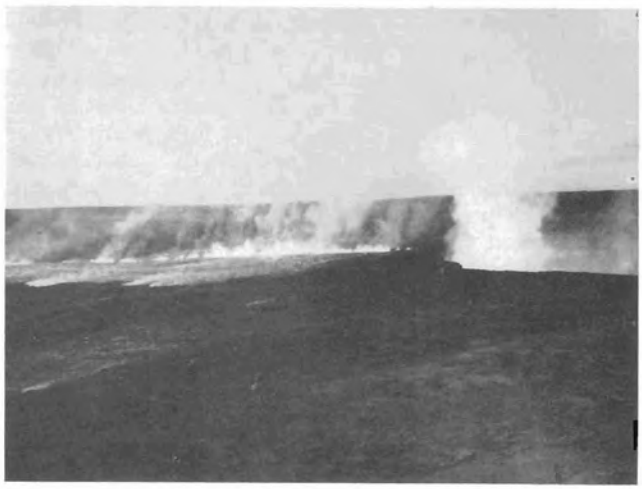

FIGURE 2. Lava fountains along the fissure northeast of Halemaumau and flow spreading from them. At the right, fume rises from the northeastern edge of Halemaumau. Photo from Uwekahuna about 6 A.M., by Ralph T. Kanemori, Modern Camera Center, Hilo.

25 feet. Similar, but smaller fountains were active in the pit of the principal 1952 cone and just northeast of the 1952 cone group. The slump scarp around the edge of the floor continued to grow in height. By 4:00 P.M. it averaged about 25 feet high, and by the morning of June 1 its height was estimated at 40 feet.

During the evening of May 31 occasional small showers of red-hot cinders were being thrown from the throat of the 1952 cone, but the principal activity was at a vent about 500 feet northeast of the 1952 cones (Fig. 1). At intervals of a few minutes noisy, semi-explosive bursts from that vent threw showers of incandescent ejecta to heights of about 100 feet. The ejecta falling and accumulating around the vent were building a small cone. The vent continued in similar activity until the

afternoon of June 3. During daylight hours each blast was seen to be accompanied by a puff of bluish-white fume.

On the morning of June 1 two small flows were active near the northeast and east-northeast edges of the floor of Halemaumau, and occasional weak lava movement was visible near the southwestern edge. This condition continued throughout the day. During the afternoon a tiny lava fountain, about two feet high, was visible at the head of the east-northeast flow. On June 2 the southwest and east-northeast flows had ceased, but the northeast flow continued active and was developing into a small lava lake. This lake was approximately 300 feet long and 100 feet wide, and was situated on the course of the eruptive fissure. Slow circulation in it, from east to west, was accompanied by occasional disintegration and foundering of the crust and small secondary fountains. No primary fountaining was visible. The lake became inactive about 3:00 A.M. on June 3. The last weak blasts from the semi-explosive central vent were observed at about 6:00 P.M., June 3. Thus, the duration of the eruption was approximately three and one-half days.

Gradual shrinkage of the new lava fill in Halemaumau continued through the eruption and for several days thereafter. Old features, such as the 1952 cones and the prominent fault scarp running northwestward from them, temporarily buried by the new lava, reappeared. The slump scarp around the edge of the crater floor eventually reached a height of approximately 45 feet.



FIGURE 3. Southwest fountain in Halemaumau, seen from the east rim about 6:30 A.M., May 31. To the right small fountains are playing along fissures that cross the 1952 cones. The bright lines on the crater floor are cracks in the dark lava crust, revealing the incandescent material beneath. Photo by Ralph T. Kanemori, Modern Camera Center, Hilo.

THE LAVA

The lava poured out onto the caldera floor northeast of Halemaumau is basalt containing only 1 to 2 per cent olivine. The olivine is present both as scattered phenocrysts up to about 2 mm. across, and as microlites visible only under the microscope.

The flow consists almost entirely of pahoehoe. Aa is present in small patches only locally. A particularly interesting feature is the development of typical clinkery aa in narrow bands, generally less than a foot wide, along the lines of principal shear near and parallel to the margins of lava streams. Part of the pahoehoe, especially that liberated late in the eruption, is dense, but much of it is very vesicular and shelly. Many toes near the edge of the flow are hollow, consisting of a thin crust 2 to 6 inches thick, covering a central opening as much as 2 feet in diameter. These toes appear to have been inflated by gas, like balloons.

An upper layer of vesicular pahoehoe crust, generally 1 to 3 inches thick, appears to have been essentially isolated from the underlying flow by a layer of gas bubbles. This crust behaved semi-independently from the flow beneath it, being dragged along by movement of the underlying liquid, folded and rolled into ropy forms, and locally fractured and tilted. At the edges of the flow this crust was in places thrust out as much as 3 or 4 feet over the adjacent rocks.

The area covered by the flow northeast of Halemaumau is approximately 139 acres, and the volume of the flow is approximately 1.5 million cubic yards.

The rapid gush of liquid lava into Halemaumau during the first eight hours of the eruption produced a fill averaging 63 feet in thickness, with a volume of approximately 15 million cubic yards. Most of the lava was extruded during the first two hours. About noon on May 31, there began a rapid sinking of the lava level over the entire floor of Halemaumau, leaving a narrow band of congealed lava clinging to the crater walls. By the evening of May 31 the slump scarp thus produced around the edge of the floor was about 25 feet in height, and by the end of the eruption the scarp had increased to an average of 32 feet. Thus the permanent fill of new lava in Halemaumau had an average thickness of 31 feet, and a volume of approximately 7 million cubic yards.

In Hawaii, shrinkage of ponded lavas on cooling and loss of gas commonly produces slump scarps, indicating a decrease of volume of as much as 20 per cent (Macdonald, 1954). However, the decrease of volume of the new fill in Halemaumau was approximately 52 per cent. This proportion appears to be far too great to have resulted from shrinkage due to loss of gas and cooling. Furthermore, the major part of the sinking of the new lava surface was too rapid to have resulted from those causes. The conclusion appears inescapable that some of the new lava disappeared downward, presumably draining back into the fissures through which it had previously risen. The slower sinking, of approximately 7 feet, after the evening of May 31, may have resulted partly from additional draining away of the liquid, but unquestionably also in part from loss of gas and cooling.

RADIOACTIVITY

An attempt to determine the degree of radioactivity of the fume was only partly successful. An hour after the outbreak of the eruption Macdonald took a Geiger-Muller counter into the fume cloud at the southwestern edge of Halemaumau. The fume was rising almost directly upward, however, and only occasionally did moderately dense clouds blow momentarily over the ground at the rim. At no time was it possible to keep the counter

tube in dense fume for long periods. Two counts for periods of only one minute each were obtained. A third count was made in fume rising from a crack several feet away from the crater rim. All of these counts were within the range normally obtained in the Kilauea area at times of no surface volcanic activity, and counts made on the caldera floor away from the crater rim on the morning of May 31. Thus, the counts obtained give no evidence of any concentration of radioactive material in the fume cloud, just as earlier counts have revealed no concentration in active flows or pumice ejected by the lava fountains (Macdonald and Orr, 1950, p. 24; Finch and Macdonald, 1953, p. 76).

EARTHQUAKES ASSOCIATED WITH THE ERUPTION

Following the cessation of the last eruption of Kilauea in November 1952, seismic activity remained at a low level for about five months. On April 29, 1953, three moderate earthquakes originating on the southwest rift of Kilauea initiated a mild resurgence of seismic activity which continued through May, June, and July. August, September, and most of October were extremely quiet months at Kilauea.

A sequence of moderate to strong earthquakes on October 26 and 27 stemming from the upper part of Kilauea's east rift was the first major seismic event at the volcano following the 1952 eruption. After another three weeks of quiet there began a series of frequent, small earthquakes originating at Kilauea caldera which continued until the end of the year.

The first three months of 1954 were very quiet. Coincident with the occurrence of two large earthquakes



FIGURE 4. Northeast fountain in Halemaumau, seen from the east rim about 6:30 A.M., May 31. The cascade on the crater wall is visible just to the right of the fountain. The crater wall to the right is approximately 400 feet high. Photo by Ralph T. Kanemori, Modern Camera Center, Hilo.

along the east rift of Kilauea between Pahoa and Kalapana on March 30, the series of frequent, small to moderate quakes stemming from Kilauea caldera began again. This series continued until the outbreak of the eruption on May 31.

The majority of these earthquakes were of shallow origin, not more than three to five miles deep, although between May 13 and 18 four quakes originated under the caldera region at depths of 15 to 25 miles. Predominantly, these quakes were small, only eight being felt in spite of the shallow focal depths. From March 30 through May 31 about 90 quakes were large enough to be identified as being of Kilauean origin, while almost 900 quakes, too small to locate but apparently from Kilauea, were recorded at the Uwekahuna station. Like the larger members of the same group these small quakes appear to have been predominantly of shallow origin. Two characteristic types occurred. One had very sharp preliminary phases and an S-P interval of between 0.2 and 1.5 seconds. The other had no identifiable phases; it consisted only of a train of very irregular waves. Both types were recorded only by instruments around Kilauea caldera and, undoubtedly, were of local origin.

At 3:26 A.M. on May 31 intermittent, high-frequency spasmodic tremor began recording on the Sprengnether vertical seismograph at Uwekahuna. About 3:37 A.M. a series of small, sharp quakes began recording at a rate of about one per minute, the records of the quakes superimposed on the now continuous spasmodic tremor. After 3:42 A.M. these frequent quakes and the continuous spasmodic tremor became so large that the Sprengnether record was unreadable.

Between 3:37 A.M. and the beginning of harmonic tremor at 4:09 A.M., 33 quakes, several of which were felt, were recorded on seismographs around Kilauea caldera. The large quake at 3:54 A.M., which originated at a shallow depth just east of Halemaumau, awakened people generally in the vicinity of the caldera.

It appears probable that the spasmodic tremor and earthquake sequence immediately preceding the eruption were caused by the splitting open of the eruptive fissure and the intrusive rise of the fluid lava through the opening fissure at moderate to shallow depths in the volcano. When the lava reached the surface and the sporadic rise through the opening fissure gave way to a free and voluminous outflow of lava at the surface, harmonic tremor with approximately 10 times the amplitude of the preceding spasmodic tremor suddenly appeared on the seismographs.

Less than one minute after the sharp beginning of strong harmonic tremor on the Bosch-Omori seismograph, the authors rushed from the seismograph vault and found Kilauea already in eruption. This sharp beginning of harmonic tremor and its coincidence in time with the beginning of the eruption is a further check on the long-standing belief that harmonic tremor is generated by the movement of magma through fissures feeding the eruption. The intensity of harmonic tremor recorded by instruments around the caldera correlated closely with the rate of outpouring of lava by the volcano. Continuous harmonic tremor ceased when lava fountaining died out about 2:00 P.M. on May 31. Following the cessation of lava fountaining in Halemaumau and along the rift on the caldera floor, several small vents on the floor of Halemaumau continued in mild gas and cinder activity. One of these continued to throw up occasional showers of cinders until the afternoon of June 3. Associated with the mild explosions from these vents frequent packets of harmonic waves, each about 15 seconds in duration and closely resembling harmonic

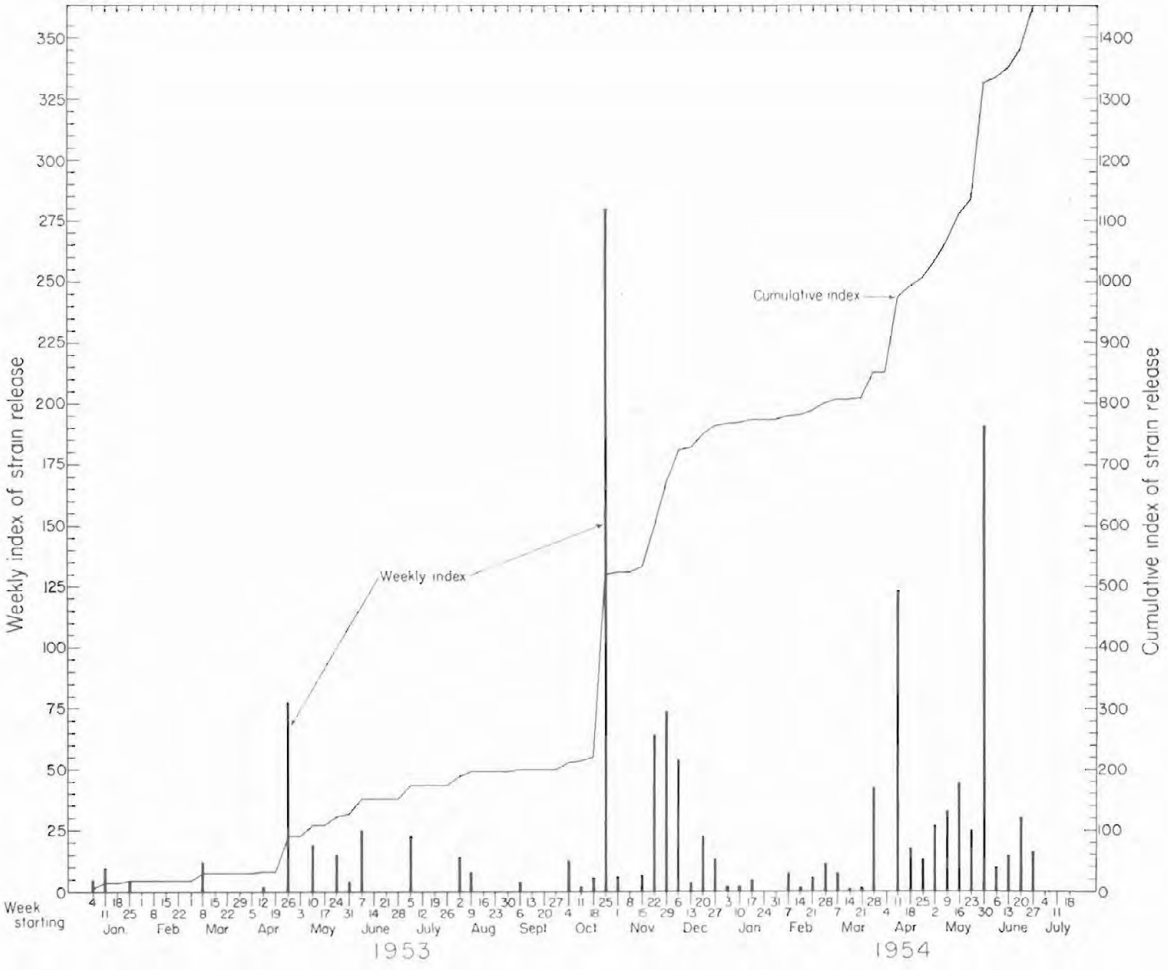

FIGURE 5. Graph showing weekly strain release index (vertical bars) and cumulative strain release index (continuous curve) for the Kilauea caldera region from January 1953 to mid-July 1954. An increase in steepness of rise of the cumulative curve represents an increase in rate of strain release through earthquakes.

tremor, were recorded by the Sprengnether vertical seismograph. These packets, about 3,700 in all, increased and decreased in frequency of occurrence in rather close correspondence to the frequency of explosions at the cinder vents although no coincidence in time between vent explosion and recorded packet could be demonstrated.

STRAIN-RELEASE INDEX

Benioff (1954) has pointed out that, under certain simplifying assumptions, if a uniformly strained body be released suddenly from its strained state by faulting, a fraction of the energy so released radiating outward as seismic waves, the amount of strain released is proportional to the square root of the energy released. If magnitudes of the earthquakes considered are available this energy can be obtained from the Gutenberg-Richter (1942) magnitude-energy formula. To date, determination of magnitudes of local Hawaiian earthquakes has been impeded by proximity of recording stations to the epicenters and variable focal depths. Pending a solution of this problem an approach somewhat different from Benioff's will be followed.

Supposing that we are dealing with regular, sinusoidal, body waves in a homogeneous medium, at any distance from the focus the S-P interval multiplied by the amplitude of the largest wave is constant and is proportional to the square root of the energy in the earthquake. For earthquakes of moderate range in size recorded at small epicentral distances the above relationship permits us to calculate a quantity proportional to the strain release without knowing the earthquake's magnitude.

Dealing only with local earthquakes, we can adopt one instrument as standard and avoid the reduction of recorded amplitudes to earth amplitudes. Thus, the product (S-P) x A, where S-P and A are, respectively, the S-P interval and the maximum amplitude of a given earthquake recorded on the Sprengnether vertical seismograph at Uwekahuna, is a measure of the strain release or the faulting or fracturing which generated the earthquake.

Because of the extreme difference between the energy released by a large earthquake and that released by a small one, (S-P) x A shows a great variation from large to small earthquakes. Since the many small earth-

quakes which precede eruptions of Hawaiian volcanoes and which appear to be a significant premonitory symptom of eruption are dwarfed relative to the infrequent, much larger earthquakes occurring at times remote from eruptions, an additional weighting device is employed. The strain release index of a given earthquake is defined as: S-R Index $= \sqrt{(S\text{-}P)}\ A$, where S-P and A are as defined above.

To obtain geologic units small enough that its rocks may be considered to be acted upon by a single system of forces it is necessary to divide the volcanoes into units, guided insofar as possible by the known geology. For the present purpose the Kilauean unit is taken as the volcano Kilauea minus the eastern half of its long east rift zone. S-R Indices for earthquakes larger than tremors originating in this unit were computed for 1953 and the first half of 1954. When records from the standard instrument, the Sprengnether vertical seismograph at Uwekahuna, were not available records from other instruments located around Kilauea caldera were used. In such cases, empirically determined amplitude correction factors were applied to obtain S-R Indices corresponding to those from the Sprengnether seismograph.

In Figure 5 are plotted weekly S-R Indices (the sum of the S-R Indices of earthquakes occurring during a given week) and cumulative weekly S-R Indices. The slope, not the height, of the latter curve is significant: it is a measure of the rate of strain release in the volcano.

CONCLUSION

The 1954 eruption of Kilauea is one of the shortest on record, being exceeded in brevity during recent years only by that of February, 1929, which lasted two days. The total final volume of lava left in Halemaumau and on the caldera floor was only about one-twelfth that extruded during 1952, but the rate of lava output during the first few hours of the eruption was very high, approximately equal to that during the corresponding part of the 1952 eruption.

The fissure eruption on the caldera floor east-northeast of Halemaumau appears to have been unique in the recent history of Kilauea caldera. A search of the literature reveals no record of similar activity at least since 1877. Before that, the records are too incomplete to constitute any good basis for comparison. The eruptive fissure extends almost directly toward the vents of the eruptions of 1832 and 1868. Neither of these eruptions was on the caldera floor. The eruption of 1832 occurred on the Byron Ledge, spilling lava both into the caldera and into Kilauea Iki Crater. That of 1868 occurred on the wall of Kilauea Iki and sent no lava into the caldera proper. Both, however, were intimately associated with caldera activity, and the alignment of the 1954 fissure with these earlier vents suggests that this is an important zone of weakness across the caldera floor.

On or about May 4, 1877, an eruption occurred along a fissure at the southeastern edge of Kilauea caldera. An entry by Thomas E. Cook in the Volcano House record book, under the date of May 21, 1877, states that the fissure from which the flow of lava took place commenced at the caldera wall and extended up to within 20 or 30 feet of the top of the wall (Brigham, 1909, p. 132). Under the date of May 6, 1877, Sanford B. Dole states, also in the Volcano House record book, that the lava spouted from the fissure to heights of 50 to 150 feet (Brigham, 1909, p. 131). Activity appears to have lasted only a few hours, but lava covered several acres of the caldera floor. The eruption was accompanied by draining of Halemaumau, leaving a fuming pit about 250 feet deep. The large size of the fountains and the location of the fissure indicate quite certainly that the eruption came from a primary, deep-seated vent, and was not merely an overflow from Halemaumau.

Eruption may have occurred in Keanakakoi Crater at about the same time. There appears, however, to be considerable doubt regarding the date of the lava that forms the floor of Keanakakoi (Stearns and Clark, 1930, p. 79).

The location of the eruptive fissure of 1877 is not known with certainty. H. A. Powers suggests (personal communication) that the small spatter cone at the southeast edge of Kilauea caldera just north of Keanakakoi (Fig. 1) may have been formed at that time. The suggestion is highly plausible, but cannot be confirmed. Both the spatter cone and a 2-foot bed of cinder on the caldera wall south of it, 150 feet above the caldera floor, may have been formed during the 1877 eruption.

None of the lava outpourings on the caldera floor between 1877 and 1954 appear to have been from primary, deep-seated vents. In 1884 and 1885 lava flowed northeastward from Halemaumau to the caldera wall near Kilauea Iki, building a small cone, known as Little Beggar, near its point of emergence. Little Beggar was a well-known landmark on the floor of Kilauea caldera until it was buried by the 1954 eruption. It was a "rootless" driblet cone (Wentworth and Macdonald, 1953, p. 52) built by spatter from an opening in the roof of a lava tube. L. A. Thurston believed that overflows during 1894 destroyed the original Little Beggar cone, and built another in its place (Stearns and Clark, 1930, p. 79). However, comparison of a photograph of Little Beggar in 1889 published by Brigham (1909, p. 157), with others taken during recent years indicate that it probably was the same cone. If there were two Little Beggars they were very closely similar in form and identical in origin. It appears probable that the 1884–85 flow was simply a drainage from the Halemaumau lake, through fissures in the edge of the broad, shield-shaped Halemaumau cone. Certainly no strong lava fountaining occurred at the 1884 vent. The 1894 lava flooding in the same general area undoubtedly was merely an overflow from the Halemaumau lake.

The outpourings of 1918 and 1919 also were obviously merely overflows from the Halemaumau lake, even though the latter sent a big stream of lava all the way to the northern wall of the caldera. The 1921 flow, over the southern portion of the caldera, issued from cracks southwest of Halemaumau formed at the time of the 1919–20 outbreak in the Kau Desert. Two prominent conelets were formed at the points of issue of the lava. However, the fountains at these vents were low and poor in gas, and photographs of the conelets show them to have been driblet cones. Almost surely, the eruption of 1921, like those of 1884, 1894, 1918, and 1919, was merely an overflow from the Halemaumau lake.

Persons familiar with the behavior of Kilauea previous to the great collapse in 1924 have remarked on the dis-

tinct change in character of its behavior during the 1952 and 1954 eruptions (Isabel P. Jaggar, personal communication). Unquestionably, these last two eruptions have resembled much more closely the eruptive habit of Mauna Loa than that of Kilauea during the 19th, and early part of the 20th centuries. Probably, however, the change does not represent any fundamental alteration in the eruptive habit of Kilauea, but rather merely reflects the absence of an open vent between eruptions (or lava overflows). The open conduit, marked by the presence of the active lava lake most of the time from 1823 to 1924, prevented the accumulation of any large "head" of gas on the magma column, and consequently the formation of large gas-rich fountains such as have characterized the activity of Mauna Loa and the 1952 and 1954 eruptions of Kilauea. There is no good reason to believe, however, that the "permanent" lava lake and open conduit have been characteristic of Kilauea volcano throughout its period of growth. Its geologic structure and the formations at prehistoric vents indicate, on the contrary, that throughout most of its growth it has closely resembled Mauna Loa. The century of nearly constant lava lake activity, which ushered in our knowledge of Kilauea, may well have been an unusual period in the long-term history of the volcano.

REFERENCES

BENIOFF, H. 1954. OROGENESIS AND DEEP CRUSTAL STRUCTURE—ADDITIONAL EVIDENCE FROM SEISMOLOGY. Geol. Soc. Amer. Bul., vol. 65, pp. 385–400.

BRIGHAM, W. T. 1909. THE VOLCANOES OF KILAUEA AND MAUNA LOA ON THE ISLAND OF HAWAII. Bernice P. Bishop Mus. Mem., vol. 2, no. 4, 222 pp.

FINCH, R. H., AND G. A. MACDONALD. 1953. HAWAIIAN VOLCANOES DURING 1950. U. S. Geol. Survey Bul. 996-B, pp. 27–89.

GUTENBERG, B., AND C. F. RICHTER. 1942. EARTHQUAKE MAGNITUDE, INTENSITY, ENERGY, AND ACCELERATION. Seismol. Soc. Amer. Bul., vol. 32, pp. 163–191.

MACDONALD, G. A., AND J. B. ORR. 1950. THE 1949 SUMMIT ERUPTION OF MAUNA LOA. U. S. Geol. Survey Bul. 974-A, pp. 1–33.

MACDONALD, G. A. 1954. ACTIVITY OF HAWAIIAN VOLCANOES DURING THE YEARS 1940–1950. Bul. Volcanologique, ser. 2, vol. 15, pp. 120–179.

STEARNS, H. T., AND W. O. CLARK. 1930. GEOLOGY AND WATER RESOURCES OF THE KAU DISTRICT, HAWAII. U. S. Geol. Survey Water-Supply Paper 616, 194 pp.

WENTWORTH, C. K., AND G. A. MACDONALD. 1953. STRUCTURES AND FORMS OF BASALTIC ROCKS IN HAWAII. U. S. Geol. Survey Bul. 994, 98 pp.

REPORT OF THE HAWAIIAN VOLCANO OBSERVATORY FOR APRIL–JUNE, 1954

By GORDON A. MACDONALD

April

Seismic activity on the island of Hawaii was appreciably greater than normal during the month of April. A total of 69 earthquakes larger than tremors was recorded on seismographs operated by the Volcano Observatory on the island of Hawaii. Of these, 44 originated in Kilauea Volcano, 19 of them in or near the crater area, and most of the rest along the east rift zone, which extends from the crater eastward through Puna to Cape Kumukahi. Three of these earthquakes were felt in the Volcano district on April 15, and one each on April 1 and 22. The quake felt in Hilo on April 8 was an aftershock of the large quakes that originated in Puna on March 30. Another, felt in Hilo on April 26, had its focus on the east rift zone of Kilauea near Napau Crater.

Only six earthquakes were definitely related to Mauna Loa, although the origins of 14 others could not be located with certainty. On April 23 and 24, three small quakes originated beneath the western slope of Hualalai Volcano.

Tilting of the ground surface at the northeastern rim of Kilauea caldera was southwestward, but at a rate somewhat less than normal. This apparently represented a slight increase of volcanic pressure beneath Kilauea.

Although Kilauea Volcano was definitely restless, there was as yet no indication of imminent eruption.

A new seismograph station at Pahoa, in eastern Puna, was put into operation on April 1. The station is situated on the grounds of the Pahoa school, through a cooperative agreement with the School Department of the County of Hawaii. The station is equipped with a Loucks-Omori two-component horizontal seismograph, with static magnification of 250, recording on smoked paper with a recorder speed of 60 mm. per minute. Time marks on the record originate from an I.B.M. master clock in the station. The clock time is corrected by means of the Bureau of Standards time signal, broadcast over station WWV, and marked directly on the record by means of a device constructed by Jerry P. Eaton. The station operator is Kongo Kimura.

May

The outstanding event of the month was the outbreak of Kilauea on May 31, described in preceding pages.

Earthquake activity at Kilauea remained greater than usual throughout May. Both the total number of quakes recorded and the weekly seismicity index ranged from two to four times the normal. Thus the volcano was obviously uneasy, but no single event or pattern of events was recognized that would make possible a definite prediction of coming eruption. A large number of very small earthquakes recorded on the Sprengnether vertical seismograph at the Uwekahuna station may, on further analysis, prove to have characteristics that would aid prediction if similar swarms occur in the future. This is the first pre-eruption seismic activity recorded on seismographs of high sensitivity in Hawaii.

Ground tilting at the northeastern rim of Kilauea caldera was approximately normal during May. The seasonal reversal from southward to northward tilting took place a little earlier than usual, and as a result there was a slightly larger than usual accumulation of northward tilting during the month. It was, however, well within the limits of variation of non-eruption years. Thus there was little or no evidence of change of magmatic pressure beneath Kilauea during the months just preceding the eruption.

June

The eruption of Kilauea that began at 4:09 A.M., May 31, ended late in the afternoon of June 3. No eruptive activity occurred during the remainder of the month.

Seismic activity at Kilauea remained somewhat greater than normal through the month of June. The seismograph at the Whitney Laboratory of Seismology recorded a total of 65 earthquakes. Most of these came from a depth of several miles beneath the Kilauea crater area, and represented continued uneasiness of Kilauea volcano. Ground tilting was normal for this season of the year, indicating no marked change of volcanic pressure during or following the eruption.

From June 16 to 20 a swarm of small quakes originated apparently at a depth of about 25 miles in the vicinity of the Mauna Loa seismograph station. Many of these were felt at Umikoa, and some at other localities on the north and east flanks of Mauna Kea.

Several small quakes were felt in Kona during June. Two of these, on June 1 and 16, dismantled the seismograph at Konawaena school. The quakes originated in central Kona, probably on the Kealakekua fault.

Starting early on the morning of May 31, and continuing throughout June, a very large number of landslides occurred on the walls of Halemaumau Crater. More broken rock accumulated at the foot of the wall during the month of June than during the entire interval between the 1952 and 1954 eruptions. Several segments of the crater rim collapsed. One of these was almost directly in front of the visitors' overlook, but the greatest instability was on the northern wall. There, an average width of about 10 feet of the rim collapsed over a distance of several hundred feet, taking with it one benchmark and several other surveying stations used by the Volcano Observatory. Cracks near the northern rim show an aggregate opening of about one foot. Less-pronounced cracking occurred on the caldera floor southeast, south, and west of Halemaumau. The crack at station 40, west of the west tilt cellar, opened 9 mm. during June.

The summit region and northeast rift zone of Mauna Loa were examined on June 24 to 27. No signs of any unusual conditions were detected. There have been no apparent changes in Mokuaweoweo caldera since the end of the 1949 eruption.

A new seismograph station at Kamuela, on the northern part of the island of Hawaii, was put into operation on June 9. It is situated on the grounds of the Waimea school, and is equipped in the same manner as the Pahoa station (see above). The station operator is Thomas C. Mills.

SEISMOLOGY

Earthquake Data, April–June, 1954

(Based on Bosch-Omori seismograph on northeast rim of Kilauea caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
April 4	0	3	0	0	0	0	1.50	0
11	6	9	0	2	0	1	14.00	1
18	3	1	1	1	0	0	4.25	0
25	4	5	0	0	0	0	3.50	3
May 2	7	9	0	0	0	0	6.25	1
9	7	5	1	0	0	0	4.25	2
16	12	10	2	1	0	0	12.00	0
23	13	9	2	0	0	0	9.75	0
30	984	22	2	1	1	1	268.00	1
June 6	20	8	0	0	0	0	9.00	3
13	815	16	0	0	0	0	212.00	2
20	5	12	1	0	0	0	8.25	1
27	5	11	3	0	0	1	13.75	1

* For definition of local seismicity see Volcano Letter 371 or 512. Each local earthquake is assigned a seismicity value according to its strength, as follows: tremor, 0.25; very feeble, 0.5; feeble, 1.0; slight, 2.0; moderate, 3.0; strong, 4.0. These values are totaled to give the weekly local seismicity. Continuous volcanic tremor is ignored in the calculation. The strength assigned to the earthquake depends on the double amplitude of the maximum oscillation it causes on the Bosch-Omori seismograph, as follows: tremor, less than 0.5 mm.; very feeble, 0.5 to 4 mm.; feeble, 4 to 11 mm.; slight, 11 to 25 mm.; moderate, 25 to 60 mm.; strong, greater than 60 mm.

Table of Tilt at Seismograph Stations on Rim of Kilauea Caldera

Week Beginning	Whitney Station (Northeast rim)		Uwekahuna Station (West rim)	
	Amount	Direction	Amount	Direction
April 4	1.03″	W 36° S	1.32″	N 14° W
11	0.36″	E	2.58″	S 7° E
18	0.60″	W 37° S	0.32″	S
25	0.61″	W 11° N	2.74″	N 21° W
May 2	0.60″	N 37° E	1.72″	S 22° E
9	0.42″	W 34° S	2.58″	N 30° W
16	0.61″	N 11° W	1.43″	N 27° W
23	1.18″	N 24° E	0.96″	S
30	1.03″	W 24° N	5.30″	N 25° W
June 6	1.08″	N	0.72″	N 27° W
13	0.24″	E	1.60″	S
20	1.23″	N 29° W	1.43″	S 27° E
27	0.72″	N	1.36″	SE

Local Earthquakes

The data for the following local earthquakes were determined from seismographs on the islands of Hawaii and Maui operated by the Hawaiian Volcano Observatory. The number preceding each quake is the serial number for the current year. Only earthquakes classed as feeble or larger are included in the list. Many very feeble quakes, to which serial numbers are assigned also, are omitted. Locations given are epicenters. Except where otherwise indicated, the times given are arrival times at the Uwekahuna station, on the western rim of Kilauea caldera. They are stated in Hawaiian standard time, which is 10 hours behind Greenwich civil time. The intensity rating (Feeble, Moderate, etc.) given is based on the Bosch-Omori seismograph at the Whitney Laboratory of Seismology. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney station.

92. Apr. 1, 06:34:49, strong. Felt in Hawaii National Park. Kilauea caldera.
93. Apr. 1, 15:56:42, slight. Felt in Puna. East Puna.
94. Apr. 1, 17:52:30, feeble. Kilauea caldera.
101. Apr. 11, 02:20, not recorded at the Whitney Laboratory (Pahoa, slight). East Puna.
116. Apr. 15, 06:27:11, very feeble (Uwekahuna, feeble). Kilauea caldera.
117. Apr. 15, 06:27:50, slight (Uwekahuna, moderate). Felt in Hawaii National Park. Kilauea caldera.
118. Apr. 15, 06:43:03, very feeble (Uwekahuna, feeble). Kilauea caldera.
119. Apr. 15, 07:01:11, slight (Uwekahuna, moderate). Felt in Hawaii National Park. Kilauea caldera.
120. Apr. 15, 07:15:00, strong. Felt in Hawaii National Park. Kilauea caldera.
123. Apr. 15, 19:19:53, not recorded at the Whitney Laboratory (Pahoa, feeble). East Puna.
131. Apr. 17, 17:25:34, very feeble (Uwekahuna, feeble). Kilauea caldera.
138. Apr. 22, 14:31:54, slight. Felt in Hawaii National Park. Kilauea caldera.
141. Apr. 23, 16:13:23, feeble. Kaoiki fault.
143. Apr. 23, 23:14, not recorded at the Whitney Laboratory (Kona, feeble). Kona.
149. Apr. 25, 11:22:17, not recorded at the Whitney Laboratory (Pahoa, feeble). East Puna.
177. May 6, 20:31:41, very feeble (Mauna Loa, feeble). Northeast rift of Mauna Loa near Puu Ulaula.
190. May 14, 07:53:19, not recorded at the Whitney Laboratory (Pahoa, feeble). East Puna.
192. May 15, 01:45:36, feeble. Three miles south of Uwekahuna at a depth of 15 miles.
197. May 18, 03:34:34, feeble. Kilauea caldera.
198. May 18, 10:36:40, feeble. Six miles south of Uwekahuna at a depth of 20 miles.
199. May 18, 16:56:48, very feeble (Kona, strong). Felt in Kealakekua and Capt. Cook, Kona. Kona.

203. May 20, 20 : 40 : 03, slight. Kilauea caldera.
212. May 24, 09 : 11 : 56, feeble (Uwekahuna, slight). Kilauea caldera.
218. May 26, 16 : 39 : 42, feeble (Mauna Loa, strong). Kaoiki fault near Halfway House at a depth of 6 miles.
233. May 31, 03 : 42 : 32, slight (Uwekahuna, moderate). Kilauea caldera.
236. May 31, 03 : 46 : 57, very feeble (Uwekahuna, feeble). Kilauea caldera.
237. May 31, 03 : 47 : 38, very feeble (Uwekahuna, feeble). Kilauea caldera.
238. May 31, 03 : 48 : 06, very feeble (Uwekahuna, feeble). Kilauea caldera.
239. May 31, 03 : 48 : 16, feeble. Kilauea caldera.
246. May 31, 03 : 50 : 44, moderate (Uwekahuna, strong). Felt in Hawaii National Park. Kilauea caldera.
247. May 31, 03 : 50 : 59, very feeble (Uwekahuna, feeble). Kilauea caldera.
253. May 31, 03 : 54 : 05, strong. Felt in Hawaii National Park. Kilauea caldera just east of Halemaumau.
258. May 31, 14 : 45 : 40, very feeble (Uwekahuna, feeble). Kilauea caldera.
266. June 1, 20 : 42 : 53, very feeble (Kona, strong). Felt in Kona. Kona.
267. June 2, 00 : 03 : 03, feeble. Kilauea caldera.
289. June 16, 09 : 42 : 28, very feeble (Pahoa, feeble). East rift of Kilauea.
299. June 18, 03 : 00 : 03, very feeble (Mauna Loa, feeble). Approximately under the Mauna Loa seismograph station at a depth of about 25 miles. This is one of the largest of a series of more than 100 very feeble quakes and innumerable tremors originating from this focus on June 18, 19, 20, and 21. Many of these quakes were felt at Umikoa on the northeast flank of Mauna Kea, and several were felt at Kamuela and Hilo.
429. June 23, 02 : 03 : 09, feeble. Kilauea caldera.
445. June 29, 02 : 35 : 27, very feeble (Mauna Loa, slight). Same epicenter as No. 299.
456. June 30, 17 : 20 : 11, feeble. Kilauea caldera.

Distant Earthquakes

The following earthquakes of distant origin were recorded on the seismographs of the Hawaiian Volcano Observatory. Locations of the epicenters and the magnitudes are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey. The time given is that of the first detectable emergence of the quake on the Sprengnether vertical seismograms, in Hawaiian standard time.

Apr. 2, eP 05 : 07 : 35, 28½° S., 177° W. Kermadec Islands.
Apr. 17, iP 10 : 17 : 51.4, 51½° N., 179° W. Andreanof Islands, Aleutian Islands. Felt on Adak. Magnitude 6¾–7.
Apr. 26, eP 10 : 33 : 29.4, 51° N., 158½° E. Off southeast coast of Kamchatka. Magnitude 6½–6¾.
Apr. 29, eP 00 : 57 : 15.3, 29½° N., 112½° W. Gulf of California. Magnitude 7¼–7½.
Apr. 29, eP 01 : 42 : 11.2, 29½° N., 112½° W. Gulf of California. Minor damage in Western Mexico. Magnitude 7½–7¾.
May 5, iP 23 : 10 : 59.4, 27½° N., 112½° W. Gulf of California. Magnitude 6¾.
May 9, eP 20 : 53 : 03.4
May 13, iP 04 : 56 : 12.6, 17° N., 95½° W., Oaxaca, Mexico. Minor damage. Magnitude 6–6½.
May 14, iP 12 : 49 : 13.7, 36° N., 137° E. Near coast of Honshu, Japan. Felt in Eastern Honshu. Magnitude 7.
June 3, eP 21 : 01 : 29.0, ½° S., 91½° W. Galapagos Islands. Magnitude 6¼–6¾.
June 6, eP 07 : 02 : 04, 3½° S., 136½° E. Western New Guinea. Magnitude 7.
June 7, eP 00 : 24 : 37.5, 3½° S., 152° E. New Britain Region. Depth 450 km. Magnitude 6¾.
June 11, iP 19 : 42 : 34.4, 18° S., 179° W. Fiji Islands. Depth 550 km. Magnitude 6½.
June 15, eP 03 : 41 : 02.6, 5° S., 77° W. Northern Peru. Magnitude 6½–7.
June 16, iP 15 : 49 : 31.5, 56° N., 159½° W. Off south coast of Kodiak Island. Magnitude 6½.
June 23, eP 22 : 07 : 28.2, 18½° N., 145½° E. Marianas Islands.

VOLCANO NOTES AND NEWS

TANGIWAI RAILWAY DISASTER

Christmas Eve of 1953, and the visit of Queen Elizabeth to New Zealand, were marred by disaster. Shortly after 10:20 P.M. on December 24, the Wellington-Auckland express train plunged into the gorge of the Whangaehu River near Tangiwai station. Casualties numbered 151, of which 131 are known dead, and 20 are missing. The immediate cause of the catastrophe was the destruction of the railway bridge by a large mudflow (lahar) originating on Ruapehu volcano and rushing down the Whangaehu River. The following account of the causes of the catastrophe is derived largely from a report by James Healy, Supervising Geologist of the Geological Survey Branch, New Zealand Department of Scientific and Industrial Research. The report is contained in a longer report of the Board of Inquiry into the Tangiwai Railway Disaster (Government Printer, Wellington, 31 pp., 1954).

Ruapehu is a composite volcanic cone south of Lake Taupo, in the central part of the North Island of New Zealand. At its summit is a broad crater, a mile long and half a mile wide, within which is an inner cone with a crater containing a small lake. The central cone is surrounded on three sides by fields of snow and ice, occupying the larger crater. On the east, however, the central cone slopes directly down to the Whangaehu Glacier, on the outer flank of the mountain. The crater lake is generally unfrozen, being warmed by rising volcanic steam. The water of the lake may rise until it spills out through the lowest notch in the crater rim, melts a channel beneath the adjacent ice field, and finally emerges to form a branch of the Whangaehu River. Recent activity of Ruapehu has been restricted largely to the inner cone. During the last eruption a dome of lava grew in the crater during March and April, 1945, followed by explosions that continued until early 1946. The explosions left a crater 1,000 feet deep, and covered the summit of the mountain with loose ash and larger ejecta.

In prehistoric times large mudflows buried much of the region around the base of Ruapehu. Mudflows down the Whangaehu River occurred on four previous occasions during the past century. Those of 1889 and 1895 resulted from eruptions in the crater lake; those of 1861 and 1925 were cold mudflows result-

ing from release of the water of the lake below the glacier. None appears to have equaled in size that of 1953.

After the end of explosive activity in 1946, the crater began to refill with water, and by August 1953 the lake level had again stabilized and the outlet tunnel under the glacier had been re-established. The new lake level was 20 to 25 feet higher than before 1945. Water appears to have been seeping through a barrier of ash and scoria alongside the outlet tunnel, to form another channel beneath the ice at a lower level.

No new volcanic activity appears to have contributed to the origin of the 1953 mudflow. The cause of the sudden release of water from the crater lake, which resulted in the disastrous mudflow, appears to have been fissuring, and collapse of the barrier of ash at one side of the entrance of the outlet tunnel. Collapse of the barrier may have resulted partly from erosion by the stream of water in the hidden channel beneath the ice, and partly from weakening of the barrier by seepage of water through it (Healy, 1954). The lake level dropped 26 feet, and the rate of discharge is believed to have reached 30,000 cubic feet per second. As the flood moved down the Whangaehu Valley it brought with it huge quantities of loose ash and boulders, together with blocks of ice from the glacier. At the lower end of the Whangaehu Gorge the flood, at its maximum, filled a channel 105 feet wide to a depth of 22 feet (as compared to the river flow on December 28, which occupied a channel only 20 feet wide and 1.5 feet deep).

Mudflows, both hot and cold, are a common cause of disaster in volcanic regions, and methods for warning and control of mudflows are one of the most pressing problems in practical volcanology. During the past few months two persons were killed by mudflows on the slopes of Hibok-Hibok volcano in the Philippines. These mudflows resulted from torrential typhoon rains falling on the loose debris left on the upper slopes of the volcano by the recent eruptions. On January 23, 1954, A. Alcaraz and G. A. Macdonald warned the municipal council of Mambajao of the possibility of such mudflows, and advised that local people should not live within a few feet of stream courses.

UNITED NATIONS TRAINEE IN VOLCANOLOGY

Gregorio A. Andal, assistant geologist of the Philippine Commission on Volcanology, arrived at the Hawaiian Volcano Observatory on June 7 for a stay of nearly two months. Mr. Andal's visit is under the auspices of the United Nations Technical Training Program. He will spend his time in Hawaii studying Hawaiian volcanoes and volcano observatory methods. On his departure from Hawaii, early in August, he plans to spend an additional two months on similar study in Japan.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director
Jerry P. Eaton, Seismologist
Chester K. Wentworth, Geologist, part-time
Burton J. Loucks, Instrument Maker
John C. Forbes, Assistant Instrument Maker
Elizabeth G. Eklund, Secretary, part-time

Seismograph Station Operators:

Hilo Station:
Sister M. Thecla, St. Joseph's School

Kona Station:
Howard M. Tatsuno, Konawaena School

Pahoa Station:
Kongo Kimura, Pahoa School

Kamuela Station:
Thomas C. Mills, Waimea School

Haleakala Station:
Hawaii National Park Staff

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VOLCANIC ERUPTIONS OF 1953 AND 1948 ON ISABELA ISLAND, GALAPAGOS ISLANDS, ECUADOR[1]

By ADRIAN F. RICHARDS[2]

1953 FLANK ERUPTION OF SIERRA NEGRA (Volcan Grande)

On August 27, 1953, the northern flank of Sierra Negra (Volcan Grande), situated on southern Isabela (Albemarle) Island, the largest of the Galapagos Islands, was reported in a state of eruption. The reports were contained in radio messages sent by the captains of several tuna clippers to the Scripps Institution of Oceanography, University of California, and the U. S. Hydrographic Office (Notice to shipmasters, volcanic activity, Pacific Ocean: U. S. Hydrog. Office, Hydrographic Bul. No. 36, Sept. 5, 1953). Joe Marques, Master, and Robert Robbins, Navigator and Radio Operator, of the "Normandie," and Captain George Zeluff of the "Paramount" have furnished the writer with their observations of the beginning of this eruption.

During the afternoon of August 27 a presumedly new lateral fissure, believed to trend northeast-southwest and estimated to be two miles long, opened about three-fourths of the way up the northern side of Sierra Negra, at an approximate altitude of 3,700 feet. The beginning of the eruption was witnessed from the "Paramount," located in Bolivar Canal nearly 30 nautical miles north of the fissure site. A very large, light-colored eruption column was observed to ascend to a height of more than 30,000 feet, and voluminous flows of lava started to issue from the ends of the fissure and flow north towards Elizabeth Bay.

During the night of August 28 a bright red reflection in the sky was observed from the "Normandie," which was then off the west end of San Cristobal (Chatham) Island, approximately 90 miles east of the volcano. On the 29th the eruption was viewed from the "Normandie" in Elizabeth Bay, about 20 miles from the fissure. Unfortunately much "smoke"—slightly darker than the fog—and haze obscured the site of the eruption. However, at night visibility improved, and cherry-red lava could be seen flowing down the northern side of Sierra Negra. Lava from the north end of the fissure appeared to flow due north, to the shore of Elizabeth Bay, about 5 miles from the fissure. It is not known whether or not the lava flowed into the bay. From the southern end of the fissure the lava stream apparently divided and flowed toward both sides of Point Moreno, which is located approximately 10 miles northwest of the fissure. "Red eruptions," probably lava fountains or showers of incandescent cinder, ascended an estimated 400 feet (as seen from 20 miles away) above the fissure at intervals of seven to eight minutes. Most of the visible activity appeared at the northern extremity of the fissure.

On August 31 a bright reddish glow, reflected from low clouds, was seen from James Bay on the western side of San Salvador or Santiago (James) Island, nearly 40 miles north-northeast of the volcano. On September 10 the "Normandie" was near Webb Cove, about 15 miles west of the fissure. Volcanic activity, if present, was not observed, due to heavy fog, mist, and clouds which obscured the island from view.

Ray Maderis, Navigator of the "Equator," has informed the writer that on October 7 volcanic activity on southern Isabela Island was observed from Baltra Island, about 60 miles to the northeast.

At the end of January, 1954, the "Paramount" again visited Isabela Island. Visibility from Elizabeth Bay was

[1] Contribution from Scripps Institution of Oceanography, New Series, No. 741.

[2] Scripps Institution of Oceanography, La Jolla, California. The writer wishes to express his appreciation to all of the men of the tuna fishing fleet who have contributed the information which has made this report possible. The assistance of Professors F. P. Shepard and Chas. H. Behre, Jr., who have critically read the manuscript, is also appreciated. Professor Behre has also aided the writer with the nomenclature of the Isabela Island volcanoes.

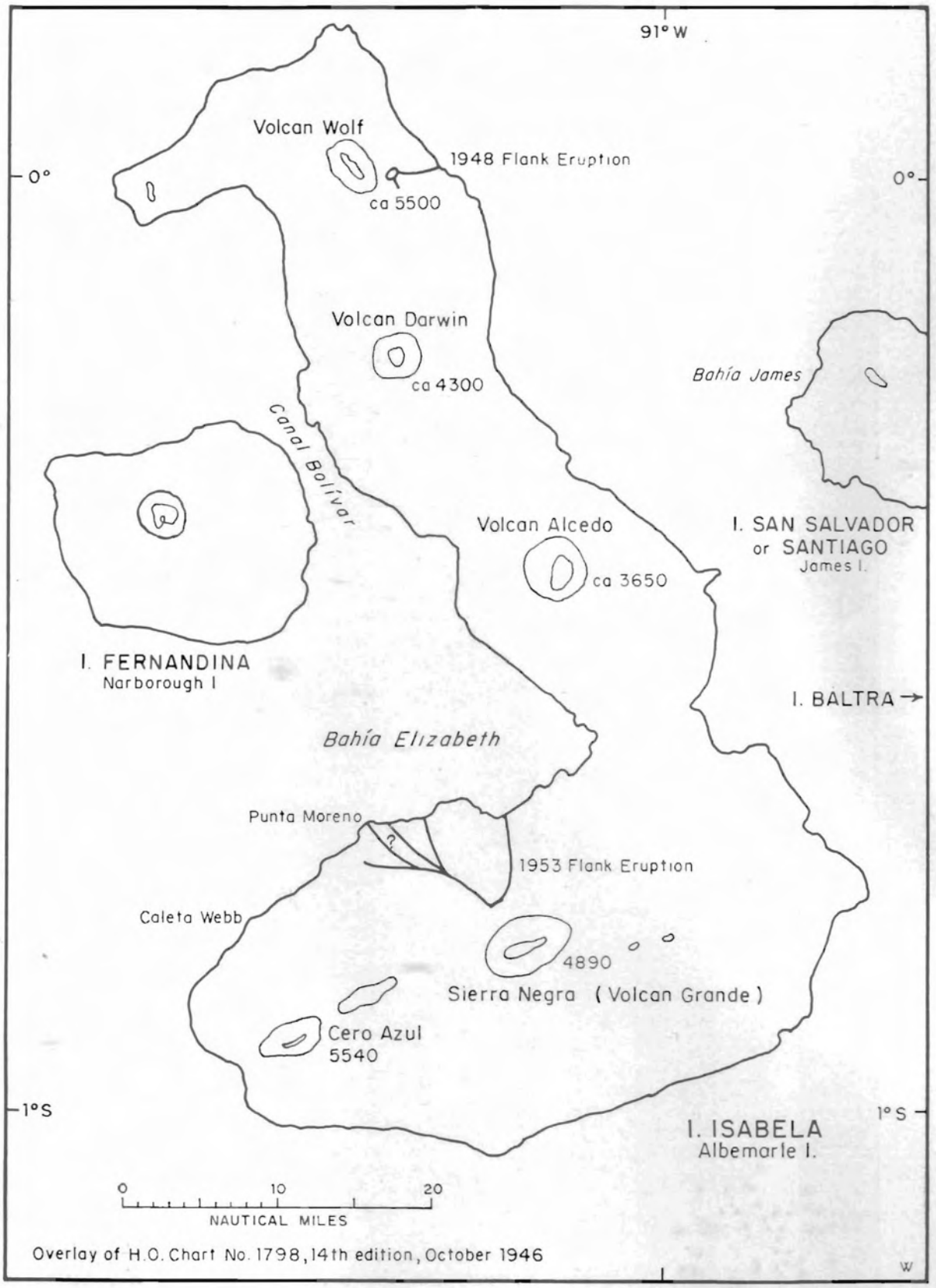

FIGURE 1. Location of the 1948 and 1953 flank eruptions on Isabela Island.

excellent and Captain Zeluff reported that he observed the lava flows to be located approximately as shown in Figure 1. No cone was seen at the site of the fissure, where fumarolic activity was observed. The violent phase of the eruption ceased between October 7 and the end of January, 1954. The exact date is unknown.

1948 FLANK ERUPTION OF VOLCAN WOLF

According to notations made in the log book of the "Paramount," and information obtained from Joseph Madruga, Master of the "Paramount" at that time, an eruption occurred on January 24, 1948, from a new peripheral vent near the east summit of Volcan Wolf on northern Isabela Island. To the writer's knowledge this eruption has not been previously recorded in the literature.

At the beginning of the eruption Volcan Wolf was observed from Banks Bay, about 11 nautical miles southwest of the volcano. A light-colored eruption column originating from the new vent was observed to ascend more than 10,000 feet above sea level. Throughout the time that the "Paramount" was in the vicinity of the volcano, an intermittent rumbling noise was heard. At night red incandescent bombs were seen ejected an estimated 200 to 300 feet above the vent, and Banks Bay was illuminated by the volcanic activity as brightly as during a night with a full moon.

On the 25th Madruga was flown near the eruption site in the fish-spotting Piper Cub belonging to the "Paramount." A small cone, estimated to be about 100 feet high, was seen forming on the southeastern side of the volcano near the peak, at an altitude of approximately 4,000 feet. The crater of the cone glowed cherry-red, and lava appeared to be flowing over the rim. However, the base of the cone could not be clearly seen, and consequently it is possible that the lava could have been emerging from a fissure in the cone instead of flowing over the rim. Large bombs or blocks of lava were also seen shooting skyward.

A single stream of lava from the crater of the parasitic cone was observed flowing very slowly down the flank of the volcano. Several days later, according to Madruga, other fishermen noticed that steam was rising from the shore, and it appears probable that the lava had reached the sea, about 3.5 miles from the cone. On the day of the flight a small second stream of lava was observed flowing a short distance south from the cone. The approximate position of the cone and two flows, based on the data given by Madruga, are shown in Figure 1.

The violent phase of the activity continued for at least four or five days before the "Paramount" left Isabela Island. At the end of January, or early in February, the ship was at Wolf (Wenman) Island, 85 miles north of the volcano, and a red glow from the eruption was clearly visible at night. The date of the end of the eruptive activity is not known to the writer.

REFERENCE

Report of the M. V. ROYAL PACIFIC: U. S. Hydrographic Office, Bul. 36, Sept. 5, 1953.

A METHOD FOR RECORDING RADIO TIME SIGNALS ON SEISMOGRAMS

By JERRY P. EATON

One of the most exacting requirements in seismology is the accurate timing of seismic events. For earthquake work the precision in timing currently sought is one-tenth of a second. To attain this precision an accurate time base must be provided on the seismogram. The usual procedure is to maintain a station clock, capable of running at a very uniform rate, which is equipped with contacts for marking minutes and hours on the seismogram. Time indicated by this clock is then checked periodically against the accurate radio time signals broadcast by the National Bureau of Standards Stations WWV or WWVH; by one of the U. S. Naval Radio Stations NSS, NPG, NPM, or NBA; or by similar institutions abroad.

Granted that a reliable station clock is available, the accuracy of the seismogram time base is limited by the accuracy of the radio time signal and the accuracy of the comparison of clock and radio time. Of the American stations, WWV, WWVH, and NSS broadcast time signals accurate at least to a few hundredths of a second. Signals broadcast by NPM and NPG appear to be accurate to within about one-tenth of a second. Thus, any of these stations provides time precise enough for the needs of earthquake seismology.

The most satisfactory method for comparing radio and clock time is to record the radio time signal directly on the seismogram, permitting a clock correction to be measured with at least as great a precision as that attainable in measuring individual seismic events on the seismogram. Special receivers built to close a relay in the seismograph timing circuit in response to the make-break continuous wave signals sent out by the Naval Radio Stations are usually employed for this purpose.

At the Hawaiian Volcano Observatory the need arose to adapt a small commercial communications receiver (Hallicrafters S-38C) to the task of closing a relay in response either to the NPM (Oahu) continuous wave signal or to the WWVH (Maui) modulated signal. A diagram of the rather simple and inexpensive solution to this problem is given in Figure 2. The audio frequency emf appearing across the speaker transformer primary, *T*, is rectified in a voltage-doubling circuit employing two germanium diodes, *D*. The output of this system is applied to the coil of a plate circuit relay, *Rel*. With the

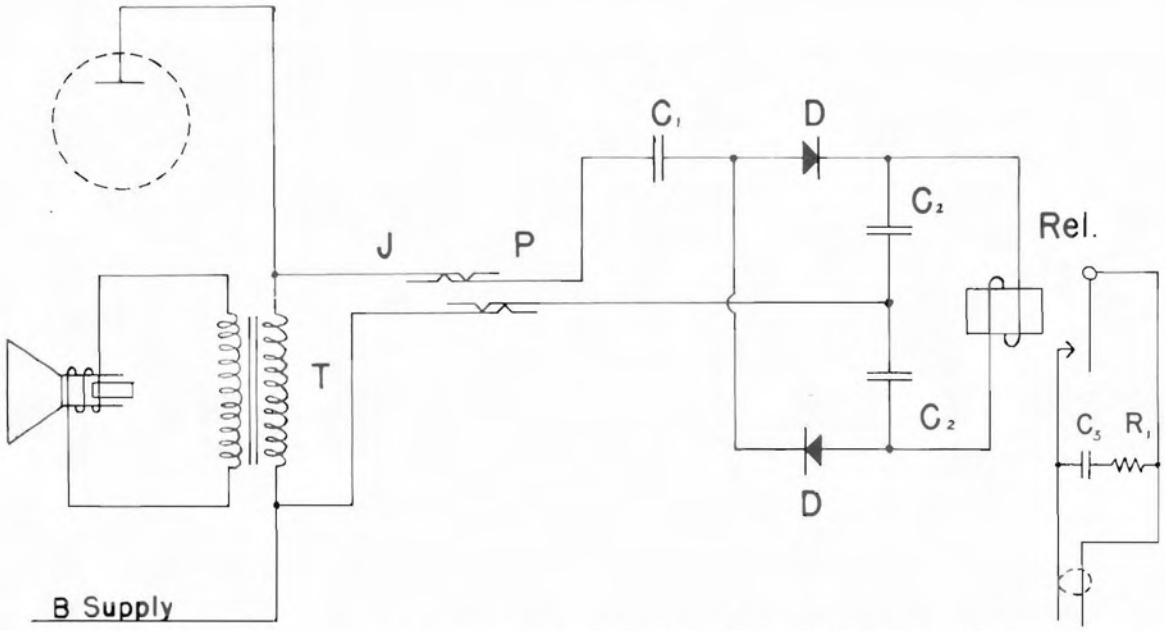

FIGURE 2. Radio adapter for recording time signals. T—Speaker transformer, J—Phone jack, P—Phone plug, C_1—2μF capacitor, C_2—1μF capacitor, C_3—0.25μF capacitor, D—Germanium diode (G.E.1N91 or 1N34A), Rel.—Plate circuit relay (Potter-Brumfield LS-5, 5000Ω coil), R_1—20 to 50Ω 1 watt carbon resistor. The 1μF and 2μF capacitors preferably should be pyranol, but electrolytic capacitors are satisfactory if polarization is maintained.

circuit components used the relay closes on about 10 volts, whereas a good, strong signal develops up to 60 volts across the relay. Since this recording device requires no operating power supply, the relay, two diodes, four condensers, and one resistor required in its construction are simply mounted on a 1 × 4 × 10 inch wooden block. The device is attached to the radio circuit by means of a phone plug and jack so that it need not interfere with other use of the receiver.

Signals broadcast on any frequency which can be tuned by the receiver can be used provided the structure of the signal is suitable for recording. At the Volcano Observatory the signal from WWVH has proved to be most useful. Beginning on the hour, WWV broadcasts a 600 cps audio frequency and a one cps modulation consisting of five 1000 cps pulses at the beginning of each second. This one cps modulation, or "tick," as it sounds on the receiver, is omitted on the 59th second of each minute. During the fourth minute of the hour the audio frequency is omitted; code, voice announcements, and the one cps modulation are broadcast during this minute. At exactly five minutes after the hour a 440 cps audio frequency comes on. This frequency and the one cps modulation continue for four minutes, then the 440 cps tone goes off and another minute of code, voice announcements, and "ticks" follows. The foregoing 10-minute cycle is repeated six times per hour and continues day and night. Except for minor periodic interruptions, the WWVH signal is the same as that of WWV. The adapter described above closes the relay during period of audio frequency, code, voice announcements, and, with moderate signal strength, at each of the one cps "ticks." The timing event most clearly recordable is the return of the audio frequency after the one minute of audio frequency silence.

If photographic recording is employed the adapter relay contacts can be placed in parallel with the clock relay contacts to permit the radio time signal to be re-

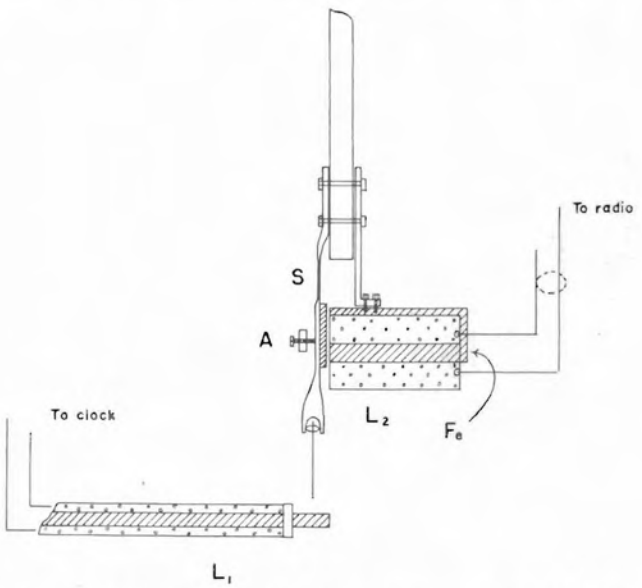

FIGURE 3. Radio time-signal marking pen for mechanical recorder. L_1—Pen lift magnet, L_2—Pen deflector magnet, Fe—Iron core and armature, A—Amplitude adjustment screw, S—Flexible pen arm.

corded by the minute-mark deflector system. If mechanical recording is used and the writing points are lifted to record time marks, it is convenient to record the radio time signal by a separate writing point which is deflected horizontally by the radio signal and is lifted from the paper by the clock signal. In practice the clock correction is obtained once a day when the record is changed. The operator drops the timing needle onto the drum and tunes the radio to record the signal. After the signal has been recorded he lifts the timing pen to avoid interference with the seismograph pens during the registration of earthquakes.

Figure 3 is a diagram of the time marker used with the mechanically recording Loucks-Omori seismographs built at the Observatory. The pen is lifted by the regular pen-lift magnet used to record clock time. In addition the pen is carried on a flexible arm which is deflected horizontally by another electromagnet controlled by the radio.

One difficulty encountered in the use of this time-marking system originated in the "feedback" through the receiver of the static generated at the relay contacts. This difficulty was overcome by employing a half-wave doublet antenna with a twin-line lead-in to the receiver; by placing a simple capacity-resistance filter across the relay contacts and near each heavy inductance in the time-signal marking circuit; and by using shielded conductors in this circuit.

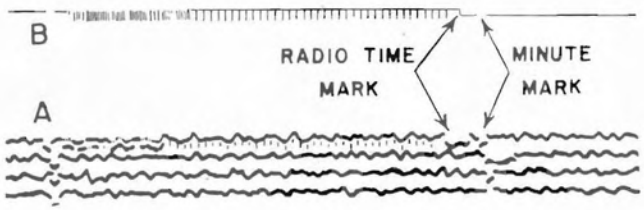

FIGURE 4. WWVH time signals recorded on an optical (A) and mechanical (B) seismograph.

Figure 4 illustrates WWVH time signals recorded on the photographic record of the Sprengnether and on the smoked-paper record of the Loucks-Omori.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JULY-SEPTEMBER, 1954

By GORDON A. MACDONALD and JERRY P. EATON

VOLCANOLOGY

July

Earthquake activity on the island of Hawaii continued somewhat greater than usual throughout July. The seismograph at the Whitney Laboratory of Seismology, on the northeast rim of Kilauea caldera, recorded 58 quakes during the month. This is approximately twice the number usual during times of volcanic quiet. The more sensitive Sprengnether seismograph at Uwekahuna recorded a much larger number of very small earthquakes.

Most of the quakes originated within a few miles of the Whitney and Uwekahuna stations, probably beneath Kilauea caldera and the east rift zone near the caldera. On July 3, at 11:53 A.M., a strong earthquake was widely felt over the southern part of the island, and did minor damage in Hilo. Its epicenter was about a mile north of Alae Crater, five miles southeast of the caldera. J. B. Wosky, Superintendent of Hawaii National Park, reported that during and after the quake numerous heavy rock falls occurred on the seaward face of Puu Kapukapu, in the vicinity of Halape, at the coast south of Kilauea caldera. Other small shocks of this group were felt lightly in the Volcano district on July 25 and 26.

Several small earthquakes, originating farther east on the Kilauea rift zone, were recorded at the Pahoa station. A light quake, probably of local origin, was felt in central Kona on July 29.

Tilting of the ground surface at the northeastern edge of Kilauea caldera was northward at a rate only slightly greater than usual at that time of year. There did not appear to be any marked change in volcanic pressure, indicated by ground tilting.

Occasional rock falls continued on the walls of Halemaumau Crater, but their frequency during the latter half of July was somewhat less than during June. Fresh cracking of the ground surface was observed near the west, southeast, and north rims of Halemaumau.

August

Kilauea Volcano continued somewhat uneasy during August. The seismograph at the Whitney Laboratory of Seismology recorded 46 earthquakes during the month. This is somewhat more than the number normally recorded in times of volcanic quiet. Most of the quakes originated beneath or near Kilauea caldera. Tilting of the ground at the northeastern rim of the caldera was northward at a rate slightly greater than usual at that season. There was no indication of any decrease of volcanic pressure beneath Kilauea.

A sharp earthquake was felt in Kona at 11:27 P.M. on August 1. Its origin was within a few miles of the seismograph station at Konawaena school, probably on the Kealakekua fault near the northern edge of Kealakekua Bay. At 2:27 P.M. on August 7 a strong quake originated beneath Kilauea caldera. It was felt by many persons in the Volcano area, and by some in Hilo and Kona. A moderate quake at 11:16 P.M. on August 30, felt by residents of the Volcano area, also originated beneath Kilauea caldera.

September

The seismograph at the Whitney Laboratory of Seismology recorded 94 earthquakes during the month, approximately three times the number recorded during normal times of volcanic quiet. During the week starting September 12 alone, 56 quakes were recorded. Most of the earthquakes appear to have originated beneath the Kilauea caldera area or the adjacent part of the east rift zone. Several during mid-September appeared to originate at depths of 25 to 30 miles beneath the caldera or the nearby slope of Mauna Loa. One at 2:43 A.M. on September 13 was felt in Hilo.

Several quakes were felt in Kona during early September. These originated on the western slope of Mauna Loa, probably on the Kealakekua fault. No other signs of uneasiness of Mauna Loa were noted.

Tilting of the ground at the northeast rim of Kilauea caldera was approximately normal in direction and amount for that season of the year. Thus no marked change in volcanic pressure beneath Kilauea was indicated.

Neither during the May-June eruption of Kilauea, nor in the four months following the eruption, has there been any indication of reduction of volcanic pressure beneath Kilauea Volcano. Magma appears probably to be still standing at a high level in the conduit. Under such conditions, eruption may occur with little or no warning other than the numerous earthquakes that indicate continued uneasiness of the volcano.

SEISMOLOGY

Local Earthquake Data, July-September, 1954

(Based on Bosch-Omori seismograph on northeast rim of Kilauea caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Total	Local Seismicity*
July 4	2	4	0	0	0	0	6	2.50
11	10	15	2	0	0	0	27	12.00
18	6	6	1	0	0	0	13	5.50
25	1	9	0	2	0	0	12	8.75
Aug. 1	1	9	0	1	0	0	11	6.75
8	6	6	0	0	0	2	14	12.50
15	1	4	0	0	0	0	5	2.25
22	3	5	2	2	0	0	12	9.25
29	7	7	0	0	1	0	15	8.25
Sept. 5	3	4	1	0	0	0	8	3.75
12	32	19	3	2	0	0	56	21.00
19	9	9	0	1	0	0	19	8.75
26	5	8	1	0	0	0	14	6.25

* For definition of local seismicity see Volcano Letter 371 or 512. Each local earthquake is assigned a seismicity value according to its strength, as follows: tremor, 0.25; very feeble, 0.5; feeble, 1.0; slight, 2.0; moderate, 3.0; strong, 4.0. These values are totaled to give the weekly local seismicity. Continuous volcanic tremor is ignored in the calculation. The strength assigned to the earthquake depends on the double amplitude of the maximum oscillation it causes on the Bosch-Omori seismograph, as follows: tremor, less than 0.5 mm.; very feeble, 0.5 to 4 mm.; feeble, 4 to 11 mm.; slight, 11 to 25 mm.; moderate, 25 to 60 mm.; strong, greater than 60 mm.

Table of Tilt at Seismograph Stations on Rim of Kilauea Caldera

Week Beginning	Whitney Station (Northeast rim)		Uwekahuna Station (West rim)	
	Amount	Direction	Amount	Direction
July 4	0.4″	S 56° W	1.8″	S 31° E
11	1.0″	N	1.3″	S
18	1.3″	N 30° E	2.7″	S 21° E
25	0.4″	N 18° W	3.0″	N 19° W
Aug. 1	0.8″	N 18° W	2.2″	N 26° W
8	1.0″	N 21° W	1.7″	N 22° W
15	0.9″	N 56° E	0.3″	N
22	0.4″	S 33° W	0.4″	N 45° E
29	1.3″	N 21° E	2.9″	S 12° E
Sept. 5	0.4″	N 18° E	2.1″	S 26° E
12	1.0″	N 53° E	1.0″	S 18° W
19	0.2″	N 45° W	2.3″	N 17° W
26	0.6″	S 37° E	1.0″	N

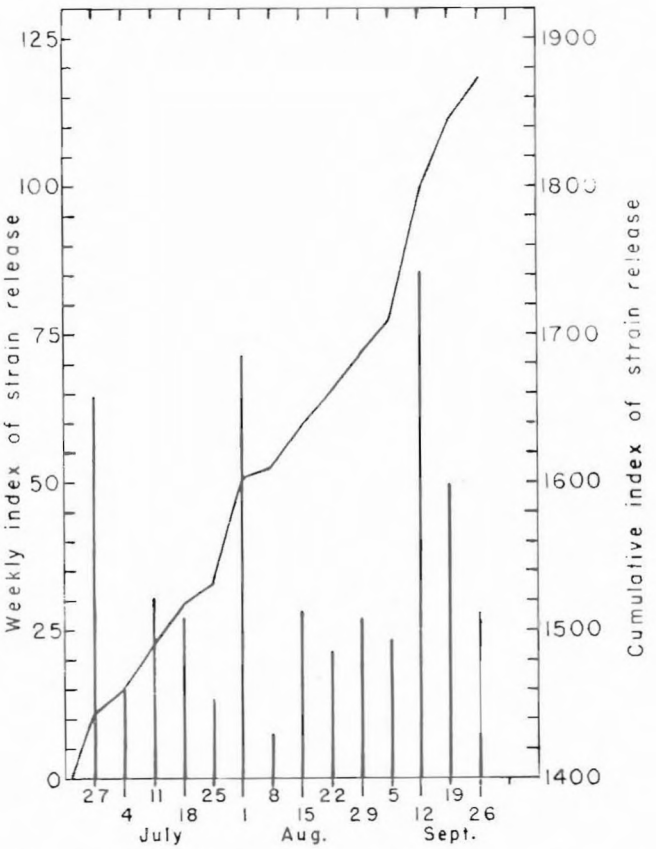

FIGURE 5. Graph showing weekly strain release index (vertical bars) and cumulative strain release index (continuous curve) for the Kilauea caldera region from late June through September, 1954. An increase in steepness of rise of the cumulative curve represents an increase in rate of strain release through earthquakes.

Local Earthquakes

The data for the following local earthquakes were determined from seismographs on the islands of Hawaii and Maui operated by the Hawaiian Volcano Observatory. The number preceding each quake is the serial number for the current year. Only earthquakes classed as feeble or larger are included in the list. Many very feeble quakes, to which serial numbers are assigned also, are omitted. Locations given are epicenters. Except where otherwise indicated, the times given are arrival times at the Uwekahuna station, on the western rim of Kilauea caldera. They are stated in Hawaiian standard time, which is 10 hours behind Greenwich civil time. The intensity rating (Feeble, Moderate, etc.) given is based on the Bosch-Omori seismograph at the Whitney Laboratory of Seismology. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney Station.

461. July 1, 09:06, feeble (Mauna Loa, moderate). Felt in Hawaii National Park. About 10 km deep under Kilauea caldera.
462. July 2, 06:00, feeble. Kilauea caldera.
465. July 3, 11:52:35, strong. Felt quite generally over southern half of Hawaii. About 12 km deep under Alae Crater on the east rift of Kilauea.
476. July 11, 12:07:26, feeble. East rift of Kilauea near Napau Crater.
486. July 15, 17:10:07, feeble. Kilauea caldera.
500. July 22, 13:35 (Pahoa), not recorded at Kilauea (Pahoa, feeble). East rift of Kilauea near Pahoa.

501. July 22, 15 : 38 (Pahoa), not recorded at Kilauea (Pahoa, feeble). East rift of Kilauea near Pahoa.
502. July 22, 20 : 36 : 50, feeble. Kilauea caldera.
506. July 25, 18 : 17 : 55, slight. Felt in Hawaii National Park. Near Mauna Loa seismograph station about 10 km deep.
508. July 26, 00 : 51 : 44, slight. Felt in Hawaii National Park and in central Kona. Along the Kaoiki fault west of the Observatory at a depth of 10 km.
520. Aug. 1, 23 : 27 : 48, not recorded at the Whitney Laboratory (Kona, feeble). Felt in central Kona. Central Kona.
521. Aug. 2, 13 : 40 : 33, strong. Felt in Volcano area. About 15 km deep under Alae Crater on the east rift of Kilauea.
523. Aug. 7, 14 : 26 : 17, strong. Felt generally over central Hawaii. 25 km deep under Kilauea caldera.
536. Aug. 16, 04 : 45 : 33 (Pahoa), not recorded at Kilauea (Pahoa, feeble). East rift of Kilauea near Pahoa.
540. Aug. 18, 07 : 13 : 56, slight. Kilauea caldera.
542. Aug. 20, 01 : 58 : 54, feeble. East rift of Kilauea near Makaopuhi Crater.
559. Aug. 30, 23 : 17 : 04, moderate. Felt in Volcano area. 20 km deep under Makaopuhi Crater.
564. Sept. 1, 15 : 17 : 49, not recorded at the Whitney Laboratory (Kona, slight). Felt in central Kona. Central Kona.
570. Sept. 7, 14 : 48 : 36, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
576. Sept. 8, 23 : 03 : 52, feeble. Kilauea caldera.
588. Sept. 12, 21 : 58 : 59, slight. Under Kilauea caldera at a depth of 20 km.
590. Sept. 12, 23 : 08 : 26, tremor (Mauna Loa, very feeble). This very feeble earthquake is included in the list because it is typical of about 250 earthquakes (tremor and very feeble in strength) which originated on Sept. 12 and Sept. 13 at a depth of about 45 km below the southeast flank of Mauna Loa between the Mauna Loa seismograph station and the Volcano Observatory.
595. Sept. 13, 02 : 42 : 53, feeble. Felt in Hilo. 5 km east of Puu Kapukapu along south coast of Kilauea at a depth of about 15 km.
598. Sept. 13, 18 : 22 : 05, feeble. 20 km deep under east rift of Kilauea near Makaopuhi Crater.
602. Sept. 15, 01 : 23 : 06, feeble. Kilauea caldera.
604. Sept. 16, 08 : 15 : 04, slight. Kilauea caldera.
622. Sept. 22, 00 : 19 : 35, slight. Kilauea caldera, 15 km deep.
630. Sept. 25, 21 : 12 : 07, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.

Distant Earthquakes

The following earthquakes of distant origin were recorded on the seismographs of the Hawaiian Volcano Observatory. Locations of the epicenters and the magnitudes are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey. The time given is that of the first detectable emergence of the quake on the Sprengnether vertical seismograms, in Hawaiian standard time.

July 1, eP 16 : 51, 13½° N., 123½° E. Southeastern Luzon, P. I. Many casualties and extensive property damage. Mag. 6¾–7¼.
July 5, eP 22 : 13 : 27.6, 46½° N., 153½° E. Kurile Islands. Mag. 6½–7.
July 6, eP 01 : 20 : 35.3, 39½° N., 118½° W. Near Fallon, Nevada. Several injured and moderate property damage. Mag. 6¾–7.
July 6, eP 12 : 14 : 58.6, Fallon, Nevada, aftershock. Mag. 6¼–6¾.
July 17, eP 23 : 17 : 39.4, 35½° N., 140½° E. Near east coast of Honshu, Japan. Felt. Mag. 6½.
July 30, eP 15 : 12 : 46.3, 39° N., 140° E. Ningsia province, China. Mag. 6½.
July 31, eP 17 : 33 : 41.0, 3° S., 140° E. Northern New Guinea.
Aug. 4, eP 22 : 57 : 26.1, 52° N., 176° E. Rat Islands, Aleutian Islands. Mag. 6–6¼. Depth 60 km.
Aug. 9, eP 09 : 25 : 26.7, 53° N., 161° E. Off east coast of Kamchatka. Mag. 6½–6¾. Depth 60 km.
Aug. 17, iP 18 : 50 : 26.9, 21½° S., 176° W. Tonga Islands. Mag. 7–7¼. Depth about 150 km.
Aug. 23, eP 19 : 58 : 52.1, 39½° N., 118½° W. Near Fallon, Nevada. Minor property damage at Fallon and Lovelock. Mag. 6½–6¾.
Aug. 27, eP 01 : 04 : 41.5, 24½° N., 143° E. Volcano Islands. Mag. 6¾. Depth about 100 km.
Aug. 31, eL 12 : 30, Fallon, Nevada, aftershock. Mag. 5½–6½.
Sept. 2, eP 09 : 00 : 08.4, 10° S., 166° E. Santa Cruz Islands. Depth about 100 km.
Sept. 3, eP 17 : 39 : 32.9, 3° S., 139½° E. Northern New Guinea. Mag. 6¼. Depth about 60 km.
Sept. 4, eP 21 : 54 : 18.5, 19° S., 176° E. Fiji Islands region. Mag. 6½.
Sept. 6, eP 08 : 39 : 35.0, 51° N., 158° E. Near southeast coast of Kamchatka. Mag. 6½. Depth about 60 km.
Sept. 12, eP 16 : 18 : 01.7, 21° S., 175½° W. Tonga Islands. Mag. 6¾. Depth about 150 km.
Sept. 15, iP 08 : 03 : 27.2, 18° S., 178½° W. Fiji Islands. Mag. 7. Depth about 600 km.
Sept. 17, iP 01 : 11 : 18.3, 20½° S., 177½° W. Fiji Islands region. Mag. 7–7¼. Depth about 250 km.
Sept. 19, eP 14 : 52 : 10.8, 1½° S., 120½° E. Celebes. Mag. 5¾–6.
Sept. 30, eP 17 : 03 : 21.0, 11° S., 166° E. Santa Cruz Islands. Mag. 6½–7.

VOLCANO NOTES AND NEWS

ERUPTION OF NGAURUHOE

Ngauruhoe Volcano, on the North Island of New Zealand, broke into violent eruption on June 4. The volcano is a conical mountain 7,515 feet in altitude, 175 miles southeast of Auckland. The following information was furnished by James Healy, New Zealand Government volcanologist, and Brenda Bishop, Secretary of the Pacific Science Council.

The volcano had been in activity for some time, sending big ash clouds high into the air. On the morning of June 4 the entire top of the mountain was reported to be aglow even in daylight. Flying over the volcano, Healy found the crater full of lava, with spurts of orange-red lava going some 500 feet into the air, and two lava flows moving down the slopes of the mountain. One flow came down directly on top of the lava flow

of 1949, and the other a little farther south. Very little ash was being liberated. The lava flows were visited on June 5. They had nearly come to rest, but large blocks were rolling down the mountainside following numerous explosions at the crater. On June 6 activity was more explosive and more ash was being liberated. The explosive phase continued for several days, but on a lesser scale than in 1949.

Another increase of activity occurred on the night of June 9. Spectacular flows of lava were visible from Chateau Tongariro during the evening, but by 3 A.M. on June 10 the spurt of activity was nearly over. The lava flow is reported to be of aa type, and in places to exceed 70 feet in thickness. A cinder cone built in the crater of the volcano was reported to have reached a height of 200 feet on June 9, and to be breached toward the west where the lava flows escaped.

In September Ngauruhoe was still active. Strong explosions took place on the night of September 2. Several lava flows have been reported on the flanks of the cone during June, July, and August. One of the largest occurred on August 18.

Ruapehu Volcano, 12 miles southwest of Ngauruhoe, was reported steaming in early October. Healy flew over the crater on October 8, and reported that the steam was thick enough to obscure part of the crater lake. Ruapehu Volcano erupted in 1895. Another eruption in 1945 caused the temporary drying up of the crater lake. During that eruption a small lava dome was built in the crater.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director
Jerry P. Eaton, Seismologist
Chester K. Wentworth, Geologist, part-time
Burton J. Loucks, Instrument Maker
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Elizabeth G. Eklund, Secretary

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Sister M. Thecla, St. Joseph's School

Kona Station:
Howard M. Tatsuno, Konawaena School

Pahoa Station:
Kongo Kimura, Pahoa School

Kamuela Station:
Thomas C. Mills, Waimea School

Haleakala Station:
Hawaii National Park Staff

Naalehu Station:
Alfred K. Kahakua, Naalehu School

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KAUAI, AN ANCIENT HAWAIIAN VOLCANO

By G. A. MACDONALD[1], D. A. DAVIS[1], and D. C. COX[2]

Kauai is one of the oldest, and structurally the most complicated of the Hawaiian Islands. Like the others, it consists principally of a huge dome-shaped shield volcano, built up from the sea floor by many thousands of thin flows of basaltic lava. The volume of this great shield was on the order of 7,000 cubic miles. Through much of its growth it must have resembled rather closely the presently active shield volcano Mauna Loa, on the island of Hawaii. When the Kauai volcano started its growth is not known with certainty. It is believed that activity started late in the Tertiary period of geologic time, possibly in the early or middle part of the Pliocene epoch, some 8 to 10 million years ago. Growth of the shield was rapid in the geological sense, and probably was completed before the end of the Pliocene epoch.

Toward the end of the growth of the shield, its summit collapsed to form a broad caldera, the largest that has been found in the Hawaiian Islands. Like the calderas of Kilauea and Mauna Loa, that of Kauai had boundaries which were rather indefinite in part. The principal central depression was bordered by less depressed fault blocks, some of which merged imperceptibly with the outer slopes of the volcano. Elsewhere the caldera rim was low, and flows spilled over it onto the outer slopes. The well-defined central depression of the major Kauai caldera was approximately 10 to 12 miles across.

At about the same time as the formation of the major caldera, another smaller caldera was formed by collapse around a minor eruptive center on the southeastern side of the Kauai shield. Lavas accumulated in the calderas, gradually filling them, and burying talus that formed along the foot of the boundary cliffs. These lava flows differed from those that built the major portion of the shield in being much thicker and more massive, as a result of ponding in the depressions. The petrographic types are for the most part the same throughout. Both the flank flows that built most of the shield, and the flows that filled the calderas, are predominantly olivine basalt. Picrite-basalt (oceanite), with very abundant large phenocrysts of olivine, and basalt containing little or no olivine are present, but together comprise less than 10 percent of the whole. Late in the period of filling of the major caldera a small amount of basaltic andesine andesite was extruded.

Near the end of the period of filling of the major caldera further collapse occurred, forming a large triangular graben (down-faulted trough) on the southwestern side of the shield. Lava flows erupted within the caldera poured southwestward over the cliff bounding the graben and spread over the gently sloping graben floor. Other flows were erupted along the fault forming the northeast edge of the graben. Near the present Waimea Canyon their advance was obstructed by the fault scarp at the western edge of the graben. The cliff along the northeastern edge of the graben eventually was buried by lava flows from within the caldera, but that along the western edge continued to stand above the level of the flows in the graben. The flows accumulated in the graben are of the same types as those that filled the caldera, and like them are mostly thick and massive because of ponding and the gentle slopes over which they spread.

The rocks of the major Kauai shield volcano are known as the Waimea Canyon volcanic series. The thin flows that accumulated on the flanks of the shield, and that comprise the major portion of the volcanic edifice,

[1] U. S. Geological Survey.
[2] Experiment Station, Hawaiian Sugar Planters' Association.

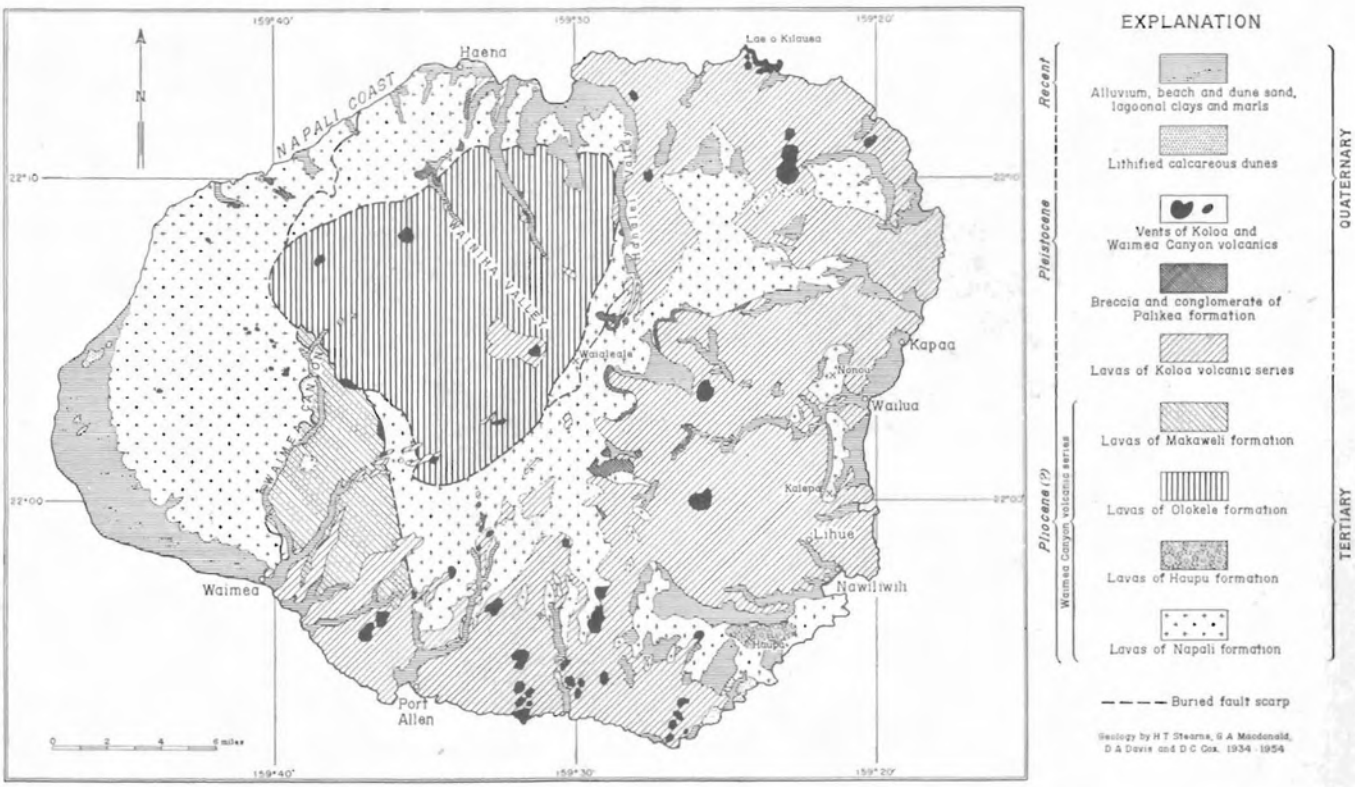

FIGURE 1. Generalized geologic map of the island of Kauai.

are named the Olokele formation, and those that filled the small caldera are named the Napali formation. The rocks that accumulated in the big summit caldera on the southeastern slope of the shield are named the Haupu formation. The volcanic rocks accumulated in the graben on the southwestern side of the shield are named the Makaweli formation, and sedimentary rocks interbedded with them are known as the Mokuone formation. These formations are formally defined and described in detail in the forthcoming Bulletin 13 of the Hawaii Division of Hydrography. The relationships of the rock units are shown in generalized fashion in (Fig. 1).

About the end of eruption of the Waimea Canyon volcanic series, or shortly afterward, another great collapse took place on the eastern flank of the volcano. A subcircular graben 6 or 7 miles across sank several thousand feet, forming a broad depression between the Waialeale massif on the west and Kalepa and Nonou ridges on the east. This collapsed structure cannot be demonstrated as clearly as the Makaweli graben, on the southwest side of the shield, because its walls have been greatly eroded and its floor is deeply buried by lavas of the later Koloa volcanic series. It appears, however, to be the most reasonable explanation of the physiography of the eastern side of the island (Fig. 2).

Following the building of the great Kauai shield came a long period of volcanic quiescence in which erosion carved deeply into the island. Waves cut high sea cliffs, and streams cut grand canyons as much as 3,000 feet deep. The course of the most magnificent of these, Waimea Canyon, was governed by the partly buried eroded fault scarp along the western edge of the Makaweli graben. The massive caldera-filling lavas were more resistant to erosion than the thinner flank flows, and the caldera fills stand in relief above the eroded flanks of the volcano. The Haupu mass is a prominent landmark from both the Lihue and Koloa areas, and along the northern side of the island the eroded edge of the caldera fill forms an imposing escarpment culminating in Puu Iliahi, Mamalahoa, and Hihimanu peaks.

During this period of erosion sea level was several hundred feet below the present level. Test holes have passed through younger rocks to more than 200 feet below sea level on the south side of the island, and more than 300 feet below sea level on the east side of the island, without entering rocks of the Waimea Canyon volcanic series. Probably this early sea level on Kauai was as far below the present sea level as the minus-1200-foot shoreline recognized on Oahu. The later rocks of the Koloa volcanic series probably rest in part on a platform formed by wave erosion during this early low stand of the sea.

After a period of quiescence long enough for deep soil to form over much of the mountain and erosion to carve the shield nearly to its present degree of dissection, volcanism was renewed. Eruption occurred from a series of minor vents arranged in nearly north-south and

northeast-southwest lines across the eastern two-thirds of the island. The lavas, cinder cones, and ash beds of this period of volcanism are known as the Koloa volcanic series. The Koloa lavas include olivine basalt, picrite-basalt of mimosite type with few phenocrysts of olivine, basanite, nepheline basalt, melilite-nepheline basalt, and ankaratrite (nepheline basalt very rich in pyroxene and olivine). Inclusions of dunite, composed almost entirely of olivine, are common in the Koloa flows. Just before and during the eruption of the Koloa volcanics, voluminous landslides and mudflows brought down a large amount of rock debris and soil from the steep slopes of the mountainous central upland and deposited it as breccias at the foot of the steep slopes in valley heads and along the border of the marginal lowland. Streams distributed part of the material across the lowland. The breccias and conglomerates thus formed, and later buried by Koloa lavas, are named the Palikea formation.

The structures formed at Koloa vents include cinder cones, one tuff cone, and lava cones. The latter are miniature shields resembling the major Kauai shield volcano, and like it formed by repeated outpourings of fluid lava. The tuff cone, at Lae o Kilauea, was formed by phreatomagmatic explosions caused by rising magma coming in contact with water-saturated rocks. It resembles Diamond Head and Punchbowl cones on the island of Oahu.

Koloa volcanism continued for a long period. It was not, however, continuous over the entire eastern part of the island. Locally long periods of quiet occurred, allowing streams to re-excavate some of the canyons filled by earlier Koloa lavas, and weathering to form deep soils later buried by new Koloa flows. Some of the canyons formed by erosion between Koloa eruptions were several hundred feet deep. Koloa eruptions probably continued through the Pleistocene and into the Recent epoch. The latest Koloa flow appears very recent. The lava is essentially unweathered and the surface features of the flow are well preserved. It overlies lithified calcareous sand dunes formed during a low stand of the sea, probably at the time of the last advance of the Pleistocene glaciers.

At times during the Pleistocene epoch lowered sea levels permitted erosion of stream valleys and sea cliffs to more than 200 feet below present sea level. Coral reefs were formed during some of these low stands of the sea and calcareous beaches accumulated. A test boring about 1.5 miles north of Kapaa penetrated a calcareous beach buried 240 feet below present sea level beneath Koloa lavas. Calcareous sand dunes also were formed, and now stand with their bases submerged in the ocean. The tuff cone at Lae o Kilauea was formed by phreatomagmatic explosions caused by rising hot magma encountering water-saturated rocks. The explosions threw up fragments of reef limestone. Much of the apron of Koloa lavas around the northeast side of the island probably rests on a platform formed below present sea level by wave erosion and the growth of coral reef.

At other times during the Pleistocene the sea stood higher than at present. Some stream terraces may be graded to a stand of the sea as high as 260 feet above present sea level, but no positive evidence for stands higher than 40 feet have been found. Well-preserved shorelines are recognized approximately 40, 25, and 5 feet above sea level. Some of the present coral reef probably was formed when the sea stood about 5 feet higher than now, and has been planed down to its present level by solution and wave erosion.

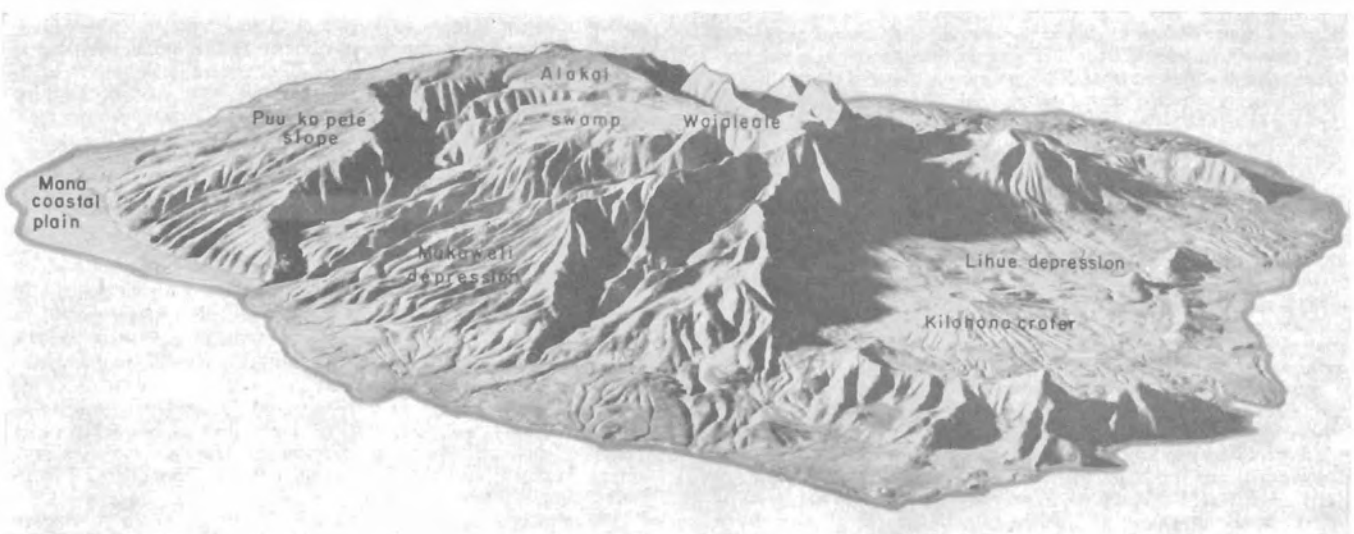

FIGURE 2. Photograph of a topographic model of Kauai, at the University of Hawaii. The model is viewed from the south, and shows at the right the Lihue basin, on the eastern side of the island. In the left center is the Makaweli graben, with Waimea Canyon at its western edge.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR OCTOBER-DECEMBER, 1954

By GORDON A. MACDONALD and JERRY P. EATON

VOLCANOLOGY

October

Kilauea volcano remained in a restless condition during October. About two-thirds of the 70 earthquakes recorded on the seismograph at the Whitney Laboratory of Seismology stemmed from the region of Kilauea caldera and the adjacent portion of the east rift zone. None of these earthquakes was reported felt.

Approximately one-third of the earthquakes recorded during the month originated beneath Mauna Loa. Among these were the four earthquakes reported felt on Hawaii during October. At 8:50 P.M. on October 7 the southern part of the island was shaken by an earthquake from an epicenter about 10 miles north of Naalehu. The largest quake of the month, which occurred near Hookena at 6:26 A.M. on October 11, was felt over most of the island. Two aftershocks, the first at 6:39 A.M. and the second at 6:52 A.M. on October 11, were felt in South Kona.

Tilting of the ground at the northeast rim of Kilauea caldera was approximately normal in direction and amount for this season of the year.

November

Kilauea volcano continued moderately uneasy through November. The seismograph at the Whitney Laboratory of Seismology recorded 72 earthquakes during the month. The more sensitive seismograph at the Uwekahuna station recorded approximately 385 quakes. Both the total number of earthquakes and the amount of energy released in earthquakes, which is represented in a general way by the seismicity index, were approximately three times as great as during periods of volcanic quiet.

Most of the earthquakes that could be located came from points of origin near Kilauea caldera. Two of these, at 11:09 P.M. on November 23 and 11:34 A.M. on November 26, were felt in Hawaii National Park. Two other quakes, felt at Kamuela at 10:56 A.M. on November 19 and 3:02 P.M. on November 20, appear to have come from a depth of about 20 miles beneath the northwest flank of Mauna Kea, 10 miles southeast of Kamuela. On November 21, a small quake came from a shallow focus 3 miles south-southeast of the summit of Mauna Loa.

Tilting of the ground at the northeastern rim of Kilauea caldera was approximately normal during most of the month. However, from November 27 to 30 it was northeastward at a rate decidedly greater than normal. This may have been related to heavy rains rather than to changes of volcanic pressure.

December

Kilauea volcano continued uneasy through the month of December. The seismograph at the Whitney Laboratory recorded 91 earthquakes during the month, more than twice the number normally recorded during times of volcanic quiet. The local seismicity, which is a rough indication of the amount of energy released by the earthquakes, was more than three times as great as that normally experienced during quiet periods. The more sensitive seismograph at the Uwekahuna station recorded 353 earthquakes during December. Most of the quakes originated at or close to Kilauea caldera. Several interesting quakes came from foci approximately 28 miles deep beneath the caldera. Others were of exceedingly shallow origin.

Many earthquakes originated also along the east rift zone of Kilauea volcano both in the vicinity of the Chain of Craters Road in Hawaii National Park, and in east Puna. A large number of small quakes, and a few fairly large ones, came from foci only about 5 miles from the Pahoa seismograph station. The Pahoa seismograph was dismantled by these quakes several times during the month. Two of the quakes, at 11:00 A.M. and 4:02 P.M. on December 14, were felt quite strongly 4.5 miles east-southeast of Pahoa.

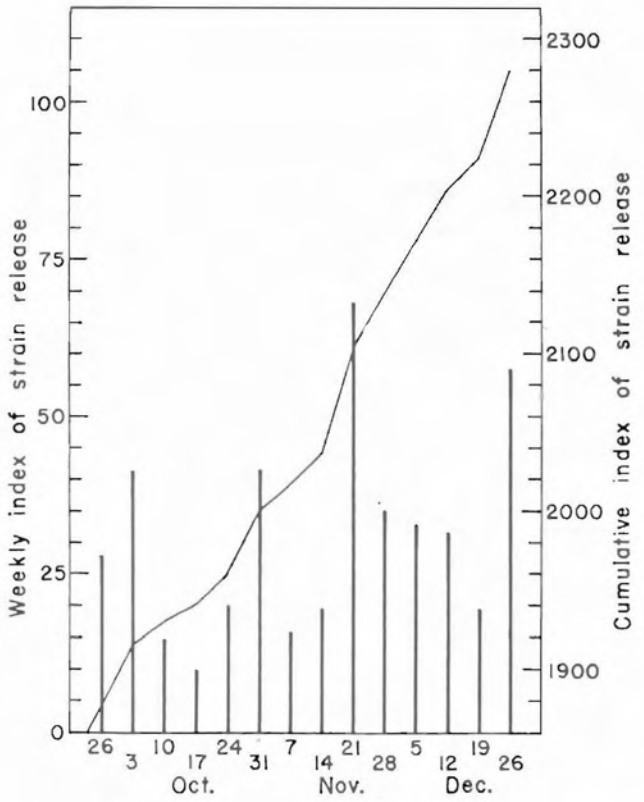

FIGURE 3. Graph showing weekly strain release index (vertical bars) and cumulative strain release index (continuous curve) for the Kilauea caldera region from October through December, 1954. An increase in steepness of rise of the cumulative curve represents an increase in rate of strain release through earthquakes. Earthquakes on the Kilauea rift zone east of Kalalua Crater and on the Hilina and Kaoiki fault zones are not included.

An earthquake at 2:30 P.M. on December 4, felt by some persons from Hilo to Pahala, originated at a depth of about 10 miles beneath the south flank of Kilauea just south of the caldera. A quake felt slightly at Captain Cook and Pahala at 8:59 P.M. on December 5, and another felt in the Volcano district at 10:26 P.M. on December 14, originated beneath the Kilauea caldera area. Another, felt in the Volcano district at 8:49 A.M. on the 28th, appears to have stemmed from the Kaoiki fault, which separates Kilauea and Mauna Loa.

Quakes felt in Kona at 7:15 P.M. on December 6, 6:00 P.M. on December 11, and 9:10 P.M. on December 24, probably came from foci beneath the western flank of Mauna Loa. A quake felt in Kamuela and Hawi at 12:46 P.M. on December 23, originated near Kamuela.

Particularly noteworthy volcanologically, although they were felt by no one, were several periods of almost continuous small earthquakes recorded at the Mauna Loa and Uwekahuna stations. The longest of these periods extended from 2:00 P.M. on December 3 to 9:45 A.M. on December 4. Other shorter periods of this continuous spasmodic tremor, from 10 minutes

to more than one-half hour in duration, occurred at intervals from November 30 to December 5, and on December 21. These quakes appear to have come from a depth of 25 to 30 miles beneath the Kilauea caldera area.

Tilting of the ground surface at the northeastern edge of Kilauea caldera was slightly southwestward during the month. Because the normal tilting at this season is slightly northeastward, this suggests the possibility of a slight decrease in volcanic pressure beneath Kilauea. However, the reversal to southwestward tilting normally takes place in January, and exceptionally heavy rains during December may have had enough effect on the temperature of the rocks near the seismograph station to cause the reversal to southwestward tilting to occur a little earlier than usual, independently of any volcanic effect. Tiltmeters at Uwekahuna and on the caldera floor showed no marked centripetal tilting.

Although Kilauea volcano shows definite signs of uneasiness, there is at the end of December no definite evidence that eruption is imminent. However, conditions somewhat resemble those preceding the eruption on May 31, and there is little or no evidence of any reduction in pressure since before the May eruption. Molten lava may still be standing at high levels in the conduit of the volcano, and it is not unlikely that eruption might again occur with little or no additional forewarning.

SEISMOLOGY

Local Earthquake Data, October-December, 1954

(Based on Bosch-Omori seismograph on northeast rim of Kilauea caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Total	Local Seismicity*
Oct. 3	5	9	2	0	1	1	18	14.75
10	5	7	1	0	1	0	14	8.75
17	3	6	1	0	0	0	10	4.75
24	6	9	1	0	0	0	16	7.0
31	4	9	0	0	2	0	15	6.5
Nov. 7	4	5	0	1	0	0	10	5.5
14	1	6	3	0	0	0	10	4.75
21	7	19	2	1	0	0	29	15.25
28	11	14	1	1	0	0	27	12.75
Dec. 5	10	13	1	0	0	0	24	10.0
12	4	8	1	1	0	0	14	8.0
19	6	7	1	0	0	0	14	6.0
26	6	14	3	2	0	0	25	15.5

Table of Tilt at Seismograph Stations on Rim of Kilauea Caldera

Week Beginning	Whitney Station (Northeast rim)		Uwekahuna Station (West rim)	
	Amount	Direction	Amount	Direction
Oct. 3	0.3″	N 45° E	2.9″	S 12° E
10	0.9″	N 40° E	3.0″	S 32° E
17	0.1″	E	0.7″	S 27° E
24	1.0″	N 76° E	0.7″	N 27° W
31	0.3″	S 63° E	0.6″	E
Nov. 7	0.3″	S 63° E	1.3″	S 17° E
14	0.6″	N 22° E	0.4″	N 45° E
21	1.2″	N 29° W	1.1″	S 33° W
28	2.2″	N 61° E	2.3″	N 34° W
Dec. 5	0.5″	N 26° E	0.6″	S
12	0.7″	S 59° E	1.4″	N 63° W
19	1.8″	S 42° W	2.6″	N 7° W
26	0.8″	S	1.6″	N 36° W

* For definition of local seismicity see Volcano Letter 371 or 512. Each local earthquake is assigned a seismicity value according to its strength, as follows: tremor, 0.25; very feeble, 0.5; feeble, 1.0; slight, 2.0; moderate, 3.0; strong, 4.0. These values are totaled to give the weekly local seismicity. Continuous volcanic tremor is ignored in the calculation. The strength assigned to the earthquake depends on the double amplitude of the maximum oscillation it causes on the Bosch-Omori seismograph, as follows: tremor, less than 0.5 mm.; very feeble, 0.5 to 4 mm.; feeble, 4 to 11 mm.; slight, 11 to 25 mm.; moderate, 25 to 60 mm.; strong, greater than 60 mm.

Local Earthquakes

The data for the following local earthquakes were determined from seismographs on the islands of Hawaii and Maui operated by the Hawaiian Volcano Observatory. The number preceding each quake is the serial number for the current year. Only earthquakes classed as feeble or larger are included in the list. Many very feeble quakes, to which serial numbers are assigned also, are omitted. Locations given are epicenters. Except where otherwise indicated, the times given are arrival times at the Uwekahuna station, on the western rim of Kilauea caldera. They are stated in Hawaiian standard time, which is 10 hours behind Greenwich civil time. The intensity rating (Feeble, Moderate, etc.) given is based on the Bosch-Omori seismograph at the Whitney Laboratory of Seismology. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney Station.

641. Oct. 1, 14:49:57, feeble. East rift of Kilauea near Kilauea caldera.
648. Oct. 2, 22:22:54, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
649. Oct. 3, 11:09:02, feeble. Near Kilauea caldera at a depth of 20 km.
653. Oct. 5, 12:23:54, very feeble (Mauna Loa, feeble). Felt in Hawaii National Park. Northeast rift of Mauna Loa near Puu Ulaula.
658. Oct. 6, 13:42:46, feeble. Near Kilauea caldera.
661. Oct. 7, 18:43:22, moderate. East rift of Kilauea near Pauahi Crater at a depth of about 10 km.
662. Oct. 7, 20:56:25, moderate (Naalehu, strong). Felt Kalahiki, Capt. Cook, and Hawaii National Park. Southeast flank of Mauna Loa about 20 km. north of Naalehu.
664. Oct. 8, 11:56:39, very feeble (Mauna Loa, feeble). Southeast flank of Mauna Loa near the Mauna Loa seismograph station.
665. Oct. 9, 04:20, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
666. Oct. 11, 01:18:41, feeble. Near Kilauea caldera.
667. Oct. 11, 06:26:33, strong. Felt in Kalahiki, Capt. Cook, Kamuela, Hawaii National Park, Hilo, and Honokohau. West shore of Mauna Loa near Hookena.
677. Oct. 15, 23:16:50, feeble. Near Kilauea caldera.
679. Oct. 16, 06:16:32, not recorded at the Whitney Laboratory (Pahoa, feeble).
684. Oct. 18, 23:07:05, tremor (Kamuela, feeble). West flank of Mauna Kea.
686. Oct. 19, 01:25:41, feeble. Near Kilauea caldera.
698. Oct. 27, 13:30:14, feeble. Near Kilauea caldera.
708. Nov. 4, 04:49:21, moderate. Near Napau Crater on the east rift of Kilauea at a depth of about 10 km.
714. Nov. 6, 16:04:36, moderate. Felt in Hawaii National Park. Near Kilauea caldera at a depth of about 20 km.
723. Nov. 11, 01:53:43, slight. Near Kilauea caldera at a depth of about 15 km.
737. Nov. 17, 04:30:48, feeble. Near Kilauea caldera.
738. Nov. 18, 19:30:39, not recorded at the Whitney Laboratory (Naalehu, feeble). Near the summit of Mauna Loa.
743. Nov. 19, 10:55:34, feeble (Kamuela, strong). Felt in Kamuela. Fifteen km. southeast of Kamuela at a depth of about 35 km.
745. Nov. 20, 15:02:51, very feeble (Mauna Loa, slight). Felt in Kamuela. Ten km. west of Pohakuloa at a depth of about 30 km.
748. Nov. 21, 19:32:55, very feeble (Mauna Loa, feeble). Ten km. southeast of Mokuaweoweo at a depth of 10 km.

753. Nov. 23, 07 : 47 : 54, not recorded at the Whitney Laboratory (Pahoa, moderate). East rift of Kilauea near Pahoa.
756. Nov. 23, 08 : 21 : 25, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
763. Nov. 23, 23 : 08 : 35, slight. Kilauea caldera.
771. Nov. 26, 02 : 20 : 19, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
773. Nov. 26, 02 : 30, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
776. Nov. 26, 05 : 50 : 24, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
779. Nov. 26, 11 : 34 : 05, feeble. Felt in Hawaii National Park. East rift of Kilauea near Kilauea caldera.
786. Nov. 26, 15 : 37 : 59, feeble. Near Kilauea caldera.
789. Nov. 27, 08 : 04 : 58, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
797. Dec. 1, 17 : 27 : 34, feeble. Near Kilauea caldera.
811. Dec. 4, 06 : 35 : 56, not recorded at the Whitney Laboratory (Mauna Loa, feeble). About 45 km. deep in the vicinity of Kilauea caldera.
815. Dec. 4, 08 : 49, not recorded at the Whitney Laboratory (Mauna Loa, feeble). About 45 km. deep in the vicinity of Kilauea caldera.
818. Dec. 4, 14 : 29 : 36, slight. Felt in Hilo and Pahala. Hilina Pali.
833. Dec. 5, 10 : 46 : 42, feeble. East rift of Kilauea near Napau Crater.
837. Dec. 5, 20 : 59 : 15, tremor (Pahoa, feeble; Kona and Mauna Loa, very feeble). Felt in Capt. Cook and Pahala. About 45 km. deep in the vicinity of Kilauea caldera. This is the largest of a swarm of more than 200 small earthquakes originating at about the same place on Dec. 4 and 5.
840. Dec. 6, 08 : 55 : 07, not recorded at the Whitney Laboratory (Kona, feeble). Offshore west of Hualalai.
841. Dec. 6, 19 : 15, not recorded at the Whitney Laboratory (Kona, feeble). Felt in Capt. Cook.
848. Dec. 9, 16 : 02 : 18, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
863. Dec. 14, 11 : 01 : 04, not recorded at the Whitney Laboratory (Pahoa, moderate). East rift of Kilauea near Pahoa.
866. Dec. 14, 17 : 35 : 26, very feeble (Kamuela, feeble). Between Mauna Loa and Hualalai at a depth of about 15 km.
867. Dec. 14, 22 : 25 : 52, moderate. Felt in the Volcano area. Kilauea caldera.
868. Dec. 15, 11 : 21 : 30, feeble. Near Kilauea caldera.
887. Dec. 22, 02 : 50 : 52, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
889. Dec. 23, 12 : 45 : 54, not recorded at the Whitney Laboratory (Kamuela, moderate). Felt at Kamuela and Hawi. About 25 km. deep near Kamuela.
899. Dec. 27, 03 : 19 : 30, tremor (Pahoa, feeble). East rift of Kilauea near Pahoa.
904. Dec. 28, 03 : 06 : 36, moderate. Just south of Kilauea caldera. Shallow.
905. Dec. 28, 03 : 31 : 26, slight. Just south of Kilauea caldera. Shallow.
906. Dec. 28, 07 : 26 : 22, slight. Just south of Kilauea caldera. Shallow.
907. Dec. 28, 08 : 49 : 17, feeble (Mauna Loa, slight). Felt in the Volcano area. Kaoiki fault near Halfway House at a depth of 15 km.

Distant Earthquakes

The following earthquakes of distant origin were recorded on the seismographs at the Hawaiian Volcano Observatory (19° 25.4′ N. latitude, 155° 17.7′ W. longitude). Beginnings of phases are given in Hawaiian standard time, which is 10 hours slower than Greenwich civil time. Locations of epicenters, magnitudes, and depths of focus are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey.

Oct. 2, eP 16 : 56 : 10.9, 10° S., 166° E. Santa Cruz Islands. Magnitude 6¾–7.
Oct. 3, iP 01 : 26 : 28.2, 60° N., 151° W. Kenai Peninsula, Alaska. Minor damage at Anchorage, Seward, Valdez and Homer. Magnitude 6½–7. Depth about 100 km.
Oct. 3, eP 13 : 33 : 53.4, ½° S., 127° E. Molucca Islands.
Oct. 17, eL 13 : 13, 13½° N., 116½° W. Lower California. Felt in San Diego and Imperial Valley, California. Magnitude 6.
Oct. 20, eP 21 : 02 : 05, 14° N., 90½° W. Guatemala. Magnitude 6½.
Nov. 1, eP 18 : 13 : 42
Nov. 1, eP 22 : 36 : 16.7, 7½° S., 119° E. Sumbawa Island region. Magnitude 6½–6¾.
Nov. 12, eP 02 : 34 : 06, 31½° N., 116° W. Lower California. Felt in San Diego and El Centro, California. Magnitude 6–6½.
Nov. 12, eP 11 : 56 : 15, 15½° S., 174° W. Tonga Islands.
Nov. 15, iP 06 : 36 : 01.5, 19½° N., 145½° E. Marianas Islands. Magnitude 6½–6¾. Depth 200 km.
Nov. 18, eP 20 : 05 : 49.1, 41° N., 131½° E. Sea of Japan. Magnitude 6½–6¾. Depth about 600 km.
Nov. 25, iP 01 : 23 : 12.9, 40½° N., 126° W. Off Cape Mendocino, California.
eT 01 : 55 : 40, Felt in Northern California. Magnitude 6¼–6½.
Nov. 25, iP 11 : 41 : 20.5, 21½° S., 179° E. Fiji Islands region. Magnitude 6½. Depth about 650 km.
Dec. 16, iP 01 : 14 : 32.0, 39½° N., 118° W. Near Fallon, Nevada. Moderate property damage. Magnitude 6¾–7¼.
Dec. 21, iP 10 : 03 : 14.7, 41° N., 124° W. Humboldt County, California.
eT 10 : 38 : 26, Several injured and extensive property damage. Magnitude 6¼–6¾.
Dec. 26, eP 19 : 40 : 15.2, 19° S., 178° W. Fiji Islands. Depth about 500 km.
Dec. 26, eP 20 : 59 : 26.2, 4½° S., 130° E. Banda Sea.
Dec. 27, eP 15 : 10 : 28.8, 5° S., 152½° E. New Britain region.
Dec. 30, eP 01 : 39 : 10.1, 53° N., 168° W. Fox Islands, Aleutian Islands. Felt on Unalaska. Magnitude 6½–6¾. Depth about 60 km.

VOLCANO NOTES AND NEWS

VOLCANIC ACTIVITY IN JAPAN

By Helen L. Foster

(From personal observations and data supplied by Central Meteorological Observatory, Tokyo.)

Mihara-yama, O-shima.—Mihara-yama, on O-shima, has been quiescent since February, 1954, although steam and other gases have been emitted continuously from various parts of the crater in varying amounts. At times steam and gas emission has been quite heavy with billowing clouds rising 100 to 300 meters into the air.

Volcanic tremors were recorded at intervals in April, June, and on September 25. At 4:25 P.M. on September 24 an earthquake originated beneath O-shima which, on the island, had an intensity of II on the scale of VII used by Central Meteorological Observatory, Japan.

On November 2, 1954 at 5:45 A.M. volcanic tremors were recorded for periods of about 12 minutes at 30-minute intervals. On November 6 and 7 when the crater was visited volcanic tremors were continuing, and steam and gas emission had increased considerably. At times, steam clouds rose to a height of 500 meters. Ground temperatures in the crater area seemed higher than in previous months. Sublimates were being deposited in increased amounts in many places in the crater. Numerous new fissures, particularly in the remnants of the 1951 cinder cone, were observed. Some old fissures had opened wider and were emitting steam. A small cone formed in January, 1954, was considerably broken, partly by fissures which opened in August and partly by new collapses.

On November 9 the volcanic tremors again ceased and steam and gas emission decreased.

1954 Eruptions of Asama-yama.—The 1953 and January and February, 1954, activity of Asama-yama was reported in Nos. 522 and 523 of the *Volcano Letter*. Since then small explosions have continued. The Karuizawa Weather Station recorded about 50 small explosions in January, about 70 in February, 31 in March, 17 in April, 19 in May, 4 in June, 6 in the latter part of July, 4 in August, and 2 on September 6 including quite a large explosion at 5:58 P.M.

After an inactive period in September and October a small explosion occurred at 1:45 P.M. on November 2 and another at 1:50 P.M. on November 4. A small amount of ash was ejected on November 4.

Volcanic ash has been ejected during many of the explosions, but no serious damage has been reported. All of the explosions have been comparatively small.

Submarine Eruption of Myojin-sho.—Myojin-sho is a rock bank in the Beyoneisu-retsugan (Bayonnaise Rocks), about 50 kilometers south of Aoga-shima, Izu Islands. It was the site of violent volcanic eruptions in 1952 and 1953 and became especially well known because of the loss of the Kaiyo-maru, a patrol ship of the Japanese Hydrographic Office, in an eruption on September 24, 1952. (See *Volcano Letter* No. 518.)

Renewed eruption at Myojin-sho has been reported by a fishing boat, the Eikichi-maru. Members of the crew witnessed two explosions between 2:00 and 3:00 P.M. on November 4, 1954. The eruptions were not recorded on the seismograph or wave-recorded at Aoga-shima and no steam cloud was seen from there.

The Tori-shima Weather Station, about 160 kilometers south of Myojin-sho, reported several ocean swells during a 3-hour period on November 5 which might have been caused by eruptions at Myojin-sho.

CATALOGUE OF PHILIPPINE VOLCANOES

Late in 1953 appeared Part II of the *Catalogue of the active volcanoes of the world, including solfatara fields. Part II, Philippine Islands and Cochin China*, by M. Neumann van Padang, closely follows the plan of Part I. (See *Volcano Letter* No. 516.) In 49 pages, it lists and briefly describes 41 volcanoes and solfatara fields in the Philippine Archipelago, and 2 in Cochin China. Of the Philippine volcanoes, 16 have had historic activity, 12 are in a solfataric and fumarolic state, and 3 are solfatara and fumarole fields not belonging to any well-defined volcano. Both the Cochin China volcanoes have been active in historic time. Like Part I, this new section of the Catalogue will be of great value as a reference work.

The Catalogue is being published by the International Volcanological Association, part of the cost of printing of Parts I and II being borne by a grant-in-aid from UNESCO. A limited number of copies of Part II are available from Professor Francesco Signore, General Secretary of the Association, Via Tasso 199, Napoli, Italy, for $3.60 (U.S.).

ERUPTION IN THE GALAPAGOS ISLANDS

Alcedo Volcano, in the central part of Isabela (Albermarle) Island, erupted on November 9. According to Adrian Richards, of the Scripps Institution of Oceanography, fume rose from the crater and from numerous fissures on the east flank of the cone. The eruptive activity of Alcedo on the first day was reported to be less intense than that of Sierra Negra (Volcan Grande), on the south end of Isabela Island, during 1953 (see *Volcano Letter* No. 525). Later (exact date unknown) a small flow of lava was reported high on the north-northwest side of the cone, and shimmering heat waves were observed above the crater during daylight and a bright glow from the crater at night.

Richards states that the eruption of Alcedo was preceded in late 1953 or early 1954 by upheaval of the shore in the vicinity of Bahia Urvina and for three miles southward. The upheaval raised the reef surface as much as 15 feet, and caused the shoreline to migrate about 2,400 feet seaward. The raised area is on the western flank of the Alcedo cone.

This appears to be the first recorded eruption of Alcedo volcano, although eruptions elsewhere on the island occurred in 1797, 1800, 1813, and 1847. An eruption in the northern part of Isabela Island in April, 1925, was recorded by William Beebe; and eruptions occurred at Wolf volcano in 1948 and at Sierra Negra volcano in 1953. The latter two eruptions, in the northern and southern parts of Isabela Island, respectively, are described by Richards in *Volcano Letter* No. 525.

FRENCH BIBLIOGRAPHICAL DIGEST

Just received is the third issue of the second series of the French Bibliographical Digest, devoted to Geology. This series is intended to make French scientific work better known in the United States, and numbers are sent free of charge upon request. Correspondents are asked to specify the subjects in which they are interested. Requests should be addressed to the Cultural Division of the French Embassy, 972 Fifth Avenue, New York 21, N. Y. The present number of the Digest contains 102 pages, and lists approximately 500 titles, most of them accompanied by brief abstracts. One of the several sections deals with volcanology and paleovolcanology. Another volume in preparation will include papers on geophysics.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director
Jerry P. Eaton, Seismologist
Chester K. Wentworth, Geologist, part-time
Burton J. Loucks, Instrument Maker
John C. Forbes, Assistant Instrument Maker
Elizabeth G. Eklund, Secretary

Seismograph Station Operators:

Hilo Station:

Sister M. Thecla, St. Joseph's School

Kona Station:

Howard M. Tatsuno, Konawaena School

Pahoa Station:

Kongo Kimura, Pahoa School

Kamuela Station:

Thomas C. Mills, Waimea School

Haleakala Station:

Hawaii National Park Staff

Naalehu Station:

Alfred K. Kahakua, Naalehu School

THE VOLCANO LETTER

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RECENT VOLCANIC ACTIVITY IN CENTRAL AMERICA

By A. R. McBIRNEY

Although the years 1952, 1953, and 1954 have seen little primary activity in the Central American volcanoes, there have been several interesting events that merit recording. In general, activity through this period has been characterized by low temperature steam and gas emissions often of violent nature, and little if any juvenile material has been erupted. The locations of the volcanoes are shown in Figure 1.

Starting in the northernmost extremity of the Central American volcanic chain, in Guatemala conditions have remained more or less unchanged during the last five years. Tacaná, which erupted in 1950, is quiet and shows not even fumarolic activity. Santa Maria continues to give off a respectable amount of steam and gas, but there is no sign of significant growth in the protrusive spine. Fuego has been quiet, and aside from a steady mild fuming around the circumference of the summit crater, has given off nothing of note. Fumaroles are reported active on Zuñil, Pacaya, Atitlán, and Acatenango.

In El Salvador, Izalco has been the only volcano to show activity. During 1953 and early 1954 it erupted with remarkable regularity, blowing off puffs of steam and dust at intervals of 20 to 90 minutes, but this declined around the middle of 1954 and finally stopped. Early in 1955 (probably in February) Izalco again became active, with strong explosive discharges of gas and incandescent bombs every 5 to 10 minutes. Other recently active volcanoes in El Salvador have shown only fumarolic activity.

Nicaragua still has the greatest concentration of active vents along the chain. Old Telica continues to send up a steady cloud of gases of considerable volume, although no ash or lava has been given off for several years. Cerro Negro has been quiet since the spectacular outburst of 1950, but when I visited it last around the end of August, 1954, I noticed several active fumarolic vents on the summit and along a set of parallel north-south lines on the north side of the cone. Las Pilas has developed into a vent of major importance. It opened on the 23rd of October, 1952, with a fissure approximately a kilometer in length running north-south across the top and down both flanks. Steam, gas, and lithic dust from wall rocks were blown out along the entire length of the fissure, but soon the activity became centralized on the south side of the peak. Apart from a short period of quiet between December, 1952, and February, 1953, the volume of gases has continued to increase and the centralized vent has been widened. Following a period of very heavy rainfall, it erupted a considerable amount of ash (accessory wall rock material) for three days starting the 31st of October, 1954, and blanketed the town of Leon, 23 kilometers to the west, with a thin layer of dust.

Momotombo continues to steam quietly, as it has since the last important eruption of cinders and lava in 1905. The Santiago vent of Masaya, which probably has given off more steam and gas during the last eight years than any other volcano of the world, has increased its rate of gas emission. I made a descent into the 680-foot deep crater during the first week of October, 1954, and found that the concentric faulting around the floor close to the vertical walls has reached a maximum downthrow of

16 feet. A new collapse appears to be imminent. The activity of the volcano Concepcion on the island of Ometepe resembles that of Izalco in El Salvador. It sends up large puffs of steam and dust at intervals varying from seven minutes to several hours, and for nearly three years its spectacular performance has delighted travelers on the air plane flights south of Managua.

In Costa Rica, Poás has been the only volcano to show much activity. The present cycle started in February of 1953 when eruptions under the crater lake finally vaporized the water and began, in March of that year, to hurl incandescent bombs in Strombolian fashion nearly a thousand feet into the air. When I visited it in September, 1953, the strength of the steam blast was very impressive, and the roar from the vents could be heard for several miles down the mountain side. It began building a small cinder cone in the bottom of the crater, and Fred M. Bullard, who visited it in August of 1954, told me that the cone had been well formed around a single vent, which still gives off large quantities of steam. The remaining active volcanoes in Costa Rica—Rincon de la Vieja, Irazú, and Turrialba, have not shown more than fumarolic activity.

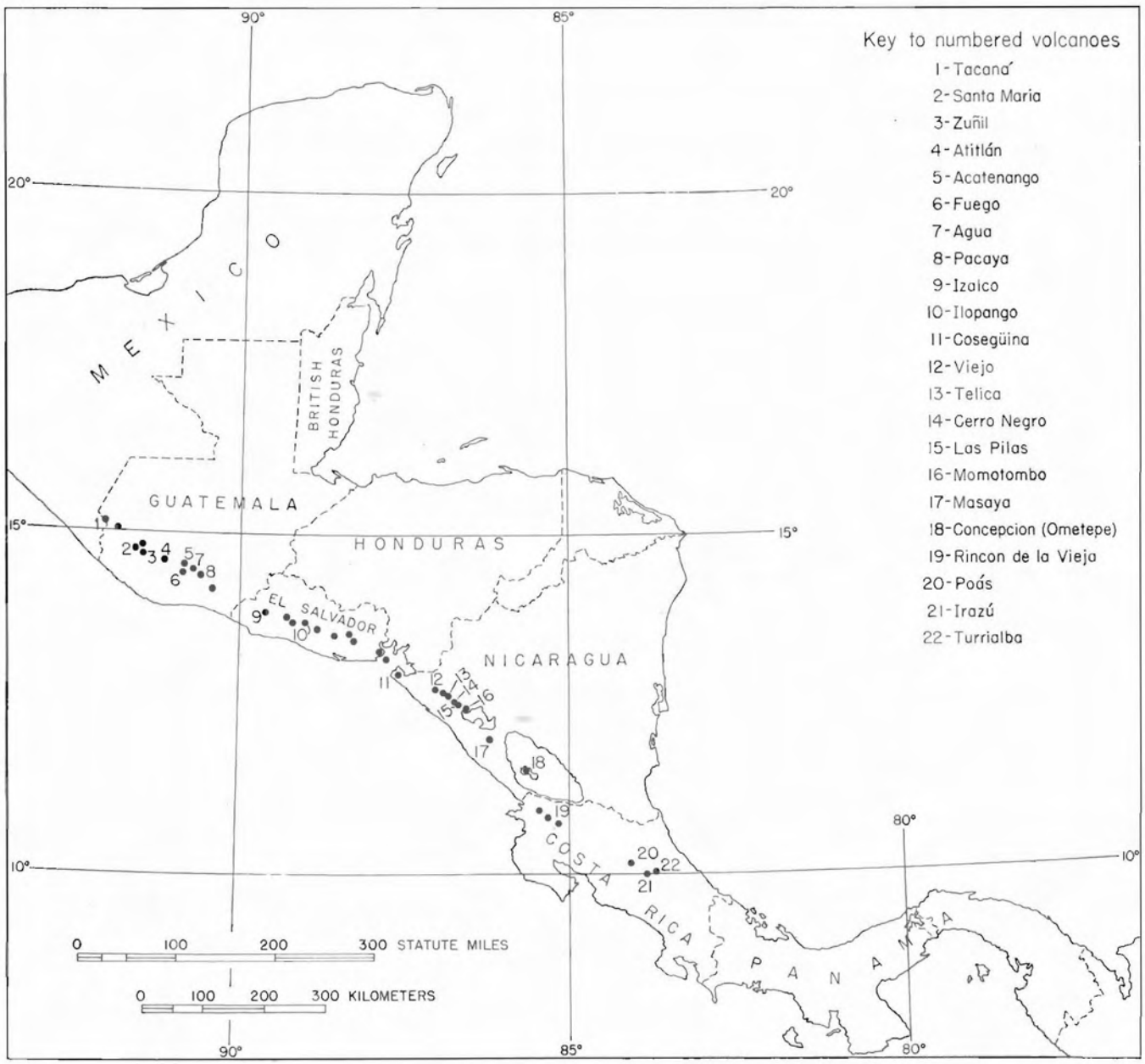

FIGURE 1. Map of Central America showing the location of volcanoes mentioned in the text. Black dots indicate volcanoes that have been active in historic time.

A NEW DATE IN KILAUEA'S HISTORY

By HOWARD A. POWERS

An old fern forest growing on the northeast rim of Kilauea was killed and buried under a layer of hot pumice and Pele's hair about 2,500 years ago. Much charcoal from this old forest has been found in excavations in the vicinity of the Volcano House since the original Hawaiian Volcano Observatory buildings were erected in 1912, and the date of the death of the forest has been found by measuring the amount of carbon 14 isotope in the charcoal.

Carbon 14 is a radioactive form of carbon that is present in small quantities compared to the inert form, carbon 12. The proportion of these two sorts of carbon remains the same so long as the plant or animal is living. At the death of the organism, the carbon 14 begins to break down to carbon 12 at a known rate, and if the amount of radioactive carbon 14 in a sample of dead carbon is measured, the number of years that the carbon has been dead can be determined with reasonable accuracy. This important detective tool was discovered and made useful by W. F. Libbey of the University of Chicago, and has been employed to determine the age of many events in both human and geological history that occurred between about 25,000 B.C. and the beginning of written history.

This carbon date at Kilauea makes it possible to extend backward the history of volcanic activity with considerable certainty. The high spots probably were about as follows:

Kilauea was exceedingly active several thousand years before the birth of Christ and overflowed its crater frequently, building the broad dome of the volcano. Activity slowed down and a caldera formed. (The Volcano House is on the rim of that caldera.) A steam blast eruption, perhaps similar to the one of 1924, plastered the rim with a layer of mud and boulders, on which later a fern forest grew while activity in the crater remained moderately quiet.

About 500 B.C., lava returned to form a lava lake with fountaining that probably rarely has been equalled since. The Pele's hair and pumice fell over the countryside forming a deposit several inches thick a mile away from the crater on the windward rim, killing the forest. Downwind, in the Kau desert, pumice and glassy ash piled up more than 30 feet thick. Several small overflows of the crater rim took place.

At the time of Hawaiian occupation overflows were continuing, according to information given by Hawaiians to Ellis in 1823. He said: ". . . it had been burning from time immemorial . . . and had overflowed some part of the (adjacent) country during the reign of every king that had governed Hawaii." (Ellis, W. 1917. *A narrative of a tour through Hawaii.* P. 184. Honolulu.)

A change of activity from overflow to collapse with many explosive eruptions is recorded in the rock record and also by Hawaiian verbal history. Ellis goes on to say (p. 184): ". . . for many kings' reigns past, it had kept below the level of the surrounding plain, continually extending its surface and increasing its depth, and occasionally throwing up, with violent explosion, huge rocks or red-hot stones." In the rock section, this change in nature of activity is well marked, and it is quite possible that datable charcoal may be found also among the buried remains of the forest that was killed by these later explosive eruptions.

This period of collapse and explosive activity probably culminated in the explosion of 1790, vividly described by the Hawaiians. Since that time, Kilauea has changed again to a stage of voluminous lava eruption that has filled the greater crater up to a point where overflows to the desert again are possible.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JANUARY–MARCH, 1955

By GORDON A. MACDONALD and JERRY P. EATON

VOLCANOLOGY

January

Kilauea volcano continued markedly uneasy through most of January. The Bosch-Omori seismograph at the Whitney Laboratory of Seismology, on the northeastern rim of Kilauea caldera, recorded 94 earthquakes during the month. This is nearly the same number as recorded in December, 1954, and between two and three times the number normally recorded during times of volcanic quiet. The local seismicity was more than four times as great as that normally experienced during quiet periods. The more sensitive Sprengnether seismograph at the Uwekahuna station recorded 316 earthquakes during January, a few less than during December. Most of the quakes originated in or very close to the Kilauea caldera region, probably on the east rift zone or the zone of faults that extends westward from it 2 to 4 miles south of the caldera.

Even greater restlessness was displayed by the Pahoa station, where 140 quakes were recorded on the Loucks-Omori seismo-

graph as compared to 127 during December. Most of the quakes originated on the east rift zone of Kilauea within 6 miles of the station.

Tilting of the ground surface at the northeast rim of Kilauea caldera was south-southwestward at a rate normal for that season of the year.

February

The uneasiness of the east rift zone of Kilauea volcano increased throughout February. From February 1 to 23, the Pahoa seismograph recorded an average of 6 earthquakes a day, excluding swarms on February 12 and 17. On February 12 a swarm of 50 small quakes was recorded, and on the 17th a swarm of 173. On February 24 the instrument recorded 130 quakes. On subsequent days the number increased rapidly to 350 on the 25th, 600 on the 26th, and 700 on the 27th. The last three numbers are estimates because the seismograph was dismantled for several short periods. Most of the earthquakes originated within 10 miles of the station.

The seismic uneasiness of the east rift zone began in November, 1954, and continued with general slight increase through December, January, and February. It was accompanied by similar uneasiness in the caldera region. This uneasiness was pointed out in press releases in November, December, January, and early February, and in *Volcano Letter* 526 (pp. 4-5). Early on the morning of February 28, it was culminated by eruption of the volcano on the east rift near the southern base of Puu Honuaula, 6 miles west-southwest of Cape Kumukahi (East Cape). The eruption will be described in detail in a later issue of the *Volcano Letter*.

Throughout most of February tilting of the ground surface at the northeastern rim of Kilauea caldera was south-southwestward at a rate approximately normal for that season of the year. Beginning about February 20, however, the rate of southwestward tilting increased markedly, indicating a decrease of volcanic pressure beneath the caldera region.

Neither tilting nor earthquakes gave any indication of uneasiness of Mauna Loa associated with that of Kilauea.

March

The lava extrusion that began near Puu Honuaula on the morning of February 28 ceased abruptly just after noon of March 1. It was followed during the next few hours by voluminous steam liberation accompanied by small phreatic explosions.

On March 2, cracks started to open in the ground farther northeast, in the area between Puu Honuaula and Kapoho. The cracks closely followed the zone of cracking of the 1924 disturbance. Sharp earthquakes of very shallow origin accompanied the formation of small fault scarps. Early on the afternoon of March 2 lava broke out along a fissure near the south base of Kaholua o Kahawali hill, 4.5 miles west-southwest of Cape Kumukahi. During that afternoon and night, and through March 3, the eruptive fissures spread both southwestward and northeastward, and on the evening of March 3 lava fountains broke out in the outskirts of Kapoho village. The evacuation of Kapoho had already been recommended on March 1, and by afternoon of March 3 it was essentially completed.

Activity in the zone between Kapoho and Puu Honuaula continued strong until March 6, but by evening of that day lava eruption had ceased. On March 7 earthquakes again became very numerous on the Pahoa seismograms, with a total of 326 recorded in 24 hours. On March 8 the number increased to 596, and on March 9 to 1,392. Most of these quakes originated along the rift zone from 8 to 16 miles west-southwest of Cape Kumukahi, and it became apparent that eruption probably would occur somewhere in that region. Early on the morning of March 12 cracks appeared in the Kalapana road 3 to 3.5 miles south of Pahoa, and in the late afternoon fume, followed by lava fountains, appeared near the south base of Puu Kaliu. The next morning lava broke out in the vicinity of the Kalapana road. On March 14 a large lava fountain developed between Puu Kaliu and the Kalapana road, and on March 16 the lava flow reached the ocean 1.5 miles southwest of Opihikao. At 2 P.M. on March 16, a lava outbreak occurred east of the old Iilewa Crater, about 3,000 feet southwest of the Kalapana road outbreaks. On March 19 another outbreak occurred about 1.3 miles farther southwest. The vent near Iilewa Crater continued active until March 27, and on March 26 another vent became active about a quarter of a mile farther southwest. Flows from this new vent reached the ocean on March 28 and April 2. At the end of March the lava fountains at the vent about 0.6 mile south of old Iilewa Crater were still very active.

South-southeastward tilting at the northeastern rim of Kilauea caldera continued from late February into March, and on March 7 the rate of tilting became very much accelerated. Throughout the remainder of the month the ground tilting was rapid, indicating a sinking of the floor of Kilauea caldera. Apparently there occurred a withdrawal of magma from beneath the caldera to compensate for the extrusion of lava 20 miles to the eastward. The tilting at the Whitney Laboratory totaled 34 seconds of arc between February 20 and April 10, and during the same period tilting of 30 seconds of arc occurred at the Uwekahuna station. Using the azimuths of tilting determined at those two stations, the point of maximum subsidence on the caldera floor is found to lie approximately 4,700 feet N. 77° E. of the center of Halemaumau, and assuming uniform tilting from the stations to that point the amount of sinking is calculated to have been approximately 1.2 feet. The point of maximum subsidence is close to that indicated by tilting at the same two stations during the subsidence of December 1950, and is in the same general region as the zone of maximum subsidence in 1924 as determined by R. M. Wilson by differential leveling.

The sinking was accompanied by very numerous earthquakes. During the week starting March 20, the Bosch-Omori seismograph at the Whitney Laboratory recorded approximately 2,667 earthquakes, and during the following week approximately 778. An even greater number was recorded on the more sensitive seismographs. At 4 P.M. on March 27, an earthquake of about intensity 5 broke water lines and cracked houses in the residence area of Hawaii National Park, and opened cracks across the Mamalahoa Highway about 1,000 feet east of Park Headquarters.

Assuming the cone of depression to have had the same area as that of 1924, as delineated by Wilson, and using the ratio of the maximum subsidence to that of 1924 in the same region, the volume of the subsidence has been calculated to be of the order of 220 million cubic yards. This is of the same order of magnitude as the volume of lava extruded in east Puna during the eruption.

Over the rest of the island seismic activity was low during March. Mauna Loa continued to show no signs of uneasiness.

SEISMOLOGY

Local Earthquake Data, January–March, 1955

(Based on Bosch-Omori seismograph on northeast rim of Kilauea caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Total	Local Seismicity*
Jan. 2	10	8	0	1	0	0	19	8.5
9	0	5	0	0	0	0	5	2.5
16	7	29	5	3	0	0	44	27.25
23	4	11	2	1	0	0	18	10.5
30	9	8	0	0	0	0	17	6.25
Feb. 6	13	9	1	0	0	0	23	8.75
13	14	6	0	0	0	0	20	6.5
20	53	13	1	4	0	0	71	28.75
27	128	0	1	0	0	2	131	41.0
Mar. 6	15	8	4	2	1	2	31	26.75
13	38	42	6	1	5	0	92	53.5
20	**2600±	55	5	5	2	0	2667±	698.5±
27	** 700±	69	6	0	1	2	778±	220.5±

* For definition of local seismicity see *Volcano Letter* 371 or 512. Each local earthquake is assigned a seismicity value according to its strength, as follows: tremor, 0.25; very feeble, 0.5; feeble, 1.0; slight, 2.0; moderate, 3.0; strong, 4.0. These values are totaled to give the weekly local seismicity. Continuous volcanic tremor ("harmonic tremor") is ignored in the calculation. The strength assigned to the earthquake depends on the double amplitude of the maximum oscillation it causes on the Bosch-Omori seismograph, as follows: tremor, less than 0.5 mm.; very feeble, 0.5 to 4 mm.; feeble, 4 to 11 mm.; slight, 11 to 25 mm.; moderate, 25 to 60 mm.; strong, greater than 60 mm.

** Number of tremors partly estimated.

Table of Tilt at Seismograph Stations on Rim of Kilauea Caldera

Week Beginning	Whitney Station (Northeast rim)		Uwekahuna Station (West rim)	
	Amount	Direction	Amount	Direction
Jan. 2	1.4″	S 59° E	1.2″	N 34° W
9	1.4″	S 20° W	0.9″	S 45° E
16	0.2″	S	1.0″	W
23	0.1″	N	3.9″	S 25° E
30	1.1″	S	2.3″	N 8° W
Feb. 6	0.6″	S 37° W	1.6″	N 37° W
13	0.3″	S 45° E	2.6″	S 14° E
20	1.3″	S 22° W	3.3″	N 17° W
27	1.2″	S 11° W	1.3″	N 14° W
Mar. 6	11.0″	S 36° W	12.5″	S 61° E
13	11.1″	S 31° W	11.2″	S 53° E
20	6.2″	S 34° W	4.6″	S 56° E
27	3.6″	S 16° W	4.9″	S 58° E

Local Earthquakes

The data for the following local earthquakes were determined from seismographs on the islands of Hawaii and Maui operated by the Hawaiian Volcano Observatory. Except for smaller earthquakes of special interest, only earthquakes classed as slight or larger were included in the list. The intensity ratings assigned are based on the Bosch-Omori seismograph at the Whitney Laboratory. This intensity scale has been extended empirically to permit its use with the Loucks-Omori and Sprengnether seismographs. The entries for a given earthquake are: date, time of arrival at the nearest station (Hawaiian standard time), intensity at the nearest station, name of the nearest station, epicenter, and general remarks.

A large fraction of the earthquakes occurring on the east rift of Kilauea near Pahoa were felt in the epicentral area. The number felt was so large that no attempt was made to keep an accurate record of those felt. It may be assumed that all of the quakes from the Pahoa area which are listed below either were felt or could have been felt by a favorably situated observer.

Jan. 5, 00:16:43, slight at Pahoa. East rift of Kilauea near Pahoa.
Jan. 6, 15:44:07, slight at Uwekahuna. East rift of Kilauea near Napau Crater.
Jan. 6, 18:33:55, slight at Pahoa. East rift of Kilauea near Heiheiahulu at a depth of about 5 km.
Jan. 8, 17:33:33, slight at Pahoa. East rift of Kilauea southeast of Pahoa.
Jan. 8, 18:20:03, Ditto
Jan. 11, 11:03:27, Ditto
Jan. 17, 03:49:16, slight at Mauna Loa. Kaoiki fault near Halfway House at a depth of about 15 km.
Jan. 18, 13:33:55, slight at Kamuela. Near Kamuela at a depth of about 20 km.
Jan. 21, 02:54:09, slight at Uwekahuna. East rift of Kilauea near Kalalua Crater.
Jan. 21, 07:56:01, slight at Uwekahuna. East rift of Kilauea near Napau Crater.
Jan. 21, 22:00:41, slight at Uwekahuna. East rift of Kilauea near Kalalua Crater.
Jan. 22, 09:01:02, moderate at Pahoa. East rift of Kilauea southeast of Pahoa.
Jan. 25, 05:08:10, slight at Pahoa. East rift of Kilauea near Pahoa.
Jan. 27, 06:18:43, slight at Uwekahuna. East rift of Kilauea near Napau Crater at a depth of about 5 km.
Feb. 21, 19:17:45, slight at Uwekahuna. East of Puu Kapukapu at a depth of about 5 km. Felt in the Volcano area.
Feb. 23, 13:58:49, slight at Uwekahuna (slight at Mauna Loa and Pahoa, very feeble at Hilo, Naalehu, and Kamuela). East rift of Kilauea near Makaopuhi Crater at a depth of about 25 km. Felt in Hawaii National Park, the Volcano area, and Pepeekeo.
Feb. 24, 15:06:17, slight at Pahoa. East rift of Kilauea southeast of Pahoa.
Feb. 24, 18:46:22, moderate at Pahoa. East rift of Kilauea near Puu Honuaula at a depth of about 5 km.
Feb. 24, 21:23:28, slight at Pahoa. East rift of Kilauea southeast of Pahoa.
Feb. 25, 01:34:43, Ditto
Feb. 25, 05:50:34, Ditto
Feb. 25, 06:11:25, moderate at Pahoa. East rift of Kilauea southeast of Pahoa.
Feb. 25, 13:19:21, slight at Pahoa. East rift of Kilauea near Pahoa.
Feb. 25, 15:19:56, slight at Pahoa. East rift of Kilauea near Pahoa.
Feb. 25, 22:01:50, moderate at Pahoa. East rift of Kilauea near Pahoa.
Feb. 26, 07:30:43, slight at Pahoa. East rift of Kilauea near Pahoa.
Feb. 26, 08:47, Ditto
Feb. 26, 10:37:13, slight at Uwekahuna (Pahoa seismograph out of operation. Estimated moderate at Pahoa). East rift of Kilauea near Puu Kepaka.
Feb. 26, 12:22:05, slight at Pahoa. East rift of Kilauea near Pahoa.
Feb. 26, 15:40:18, Ditto
Feb. 26, 18:56:33, Ditto
Feb. 27, 00:37:24, Ditto
Feb. 27, 13:42:23, Ditto
Feb. 27, 17:00:30, Ditto
Feb. 27, 17:22:06, Ditto
Feb. 27, 17:56:53, very feeble at Hilo (Pahoa seismograph out of operation. Estimated moderate at Pahoa). East rift of Kilauea near Pahoa.
Feb. 27, 18:07:29, slight at Pahoa. East rift of Kilauea near Pahoa.
Feb. 27, 20:15:03, Ditto
Feb. 27, 23:12:02, Ditto
Mar. 1, 09:06:43, Ditto
Mar. 1, 14:21:30, strong at Pahoa. East rift of Kilauea near Kalalua Crater. Felt in the Volcano area.
Mar. 4, 14:32, slight at Uwekahuna. East rift of Kilauea near Kilauea caldera.
Mar. 5, At 12:30 a series of earthquakes which was recorded at all stations on the islands of Hawaii and Maui began. These earthquakes originated at a shallow depth on the east rift of Kilauea between Napau Crater and Kalalua Crater. For the first hour and a half the seismograms at Uwekahuna and the Whitney Laboratory were so disturbed by spasmodic tremor that arrival times of individual earthquakes could not be determined. During this interval, arrival times and intensities recorded at the Pahoa station will be given although Uwekahuna might be a few km. closer to the epicenters of some of the earthquakes.
Mar. 5, 12:39:08, strong at Pahoa. Four km. east of Napau Crater. Felt in Hilo.
Mar. 5, 12:46:53, moderate at Pahoa. Near Kalalua Crater.
Mar. 5, 12:48:37, Ditto
Mar. 5, 12:53:21, slight at Pahoa. Near Kalalua Crater.
Mar. 5, 12:53:44, strong at Pahoa. Near Kalalua Crater.
Mar. 5, 12:54:43, moderate at Pahoa. Near Kalalua Crater.
Mar. 5, 12:58:26, strong at Pahoa. Four km. west of Kalalua Crater. Largest earthquake of series.
Mar. 5, 14:13:51, moderate at Pahoa. Near Kalalua Crater.
Mar. 5, 14:22:08, strong at Pahoa. Near Kalalua Crater.
Mar. 5, 14:56:57, slight at Uwekahuna. Near Kalalua Crater.
Mar. 5, 15:19:04, Ditto
Mar. 5, 15:29:40, slight at Uwekahuna. Near Kalalua Crater.
Mar. 5, 15:54:30, slight at Uwekahuna. Near Kalalua Crater.
Mar. 5, 16:11:23, moderate at Pahoa. Near Kalalua Crater.
Mar. 5, 17:00:01, slight at Uwekahuna. Near Kalalua Crater.
Mar. 5, 17:59:08, moderate at Pahoa. Near Kalalua Crater.
Mar. 5, 18:35:35, slight at Uwekahuna. Near Kalalua Crater.
Mar. 5, 19:44:00, Ditto
Mar. 5, 20:08:14, Ditto
Mar. 5, 23:29:15, Ditto
Mar. 6, 05:24:47, moderate at Pahoa. Near Kalalua Crater.

Mar. 6, 09 : 58 : 37, slight at Pahoa. Near Kalalua Crater.
Mar. 6, 11 : 45 : 06, strong at Pahoa. Near Kalalua Crater.
Mar. 6, 12 : 47 : 45, slight at Mauna Loa. Near the Mauna Loa seismograph at a depth of about 5 km.
Mar. 7, 22 : 21 : 31, strong at Pahoa. Near Heiheiahulu. Felt over the entire southern half of the island of Hawaii.
Mar. 7, 22 : 43 : 50, slight at Uwekahuna (Pahoa seismograph out of operation. Estimated moderate at Pahoa). Near Heiheiahulu. Felt in Pahoa, Hilo, and Hawaii National Park.
Mar. 7, 22 : 57 : 38, strong at Pahoa. Near Heiheiahulu. Felt in Pahoa, Hilo, Hawaii National Park, and Capt. Cook.
Mar. 7, 23 : 32 : 41, strong at Pahoa. Near Heiheiahulu. Felt in Pahoa, Hilo, and Hawaii National Park.
Mar. 8, 20 : 03 : 36, slight at Pahoa. East rift of Kilauea near Pahoa.
Mar. 9, (17 earthquakes), slight at Pahoa. East rift of Kilauea near Pahoa.
Mar. 9, 09 : 16 : 55, slight at Pahoa. South coast of Kilauea near Kalapana.
Mar. 10, (15 earthquakes), slight at Pahoa. East rift of Kilauea near Pahoa.
Mar. 11, (11 earthquakes), Ditto
Mar. 12, (9 earthquakes), Ditto
Mar. 13, (6 earthquakes), Ditto
Mar. 14, (7 earthquakes), Ditto
Mar. 15, (4 earthquakes), Ditto
Mar. 15, 19 : 01 : 27, slight at Uwekahuna. Kilauea caldera.
Mar. 15, 19 : 02 : 55, slight at Uwekahuna. Kilauea caldera.
Mar. 16, (3 earthquakes), slight at Pahoa. East rift of Kilauea near Pahoa.
Mar. 17, (4 earthquakes), slight at Pahoa. East rift of Kilauea near Pahoa.
Mar. 17, 01 : 00 : 52, slight at Uwekahuna. Kilauea caldera.
Mar. 17, 01 : 06 : 04, Ditto
Mar. 17, 05 : 54 : 40, Ditto
Mar. 17, 08 : 23 : 37, Ditto
Mar. 17, 13 : 32 : 23, moderate at Uwekahuna. Kilauea caldera.
Mar. 17, 13 : 35 : 47, Ditto
Mar. 18, (7 earthquakes), slight at Pahoa. East rift of Kilauea near Pahoa.
Mar. 18, 09 : 54 : 30, moderate at Uwekahuna. Kilauea caldera.
Mar. 18, 15 : 25 : 15, Ditto
Mar. 18, 22 : 43 : 03, Ditto
Mar. 19, 12 : 09 : 40, slight at Pahoa. East rift of Kilauea near Pahoa.
Mar. 19, 18 : 03 : 33, moderate at Uwekahuna. Kilauea caldera.
Mar. 20, 18 : 10 : 42, slight at Pahoa. East rift of Kilauea near Pahoa.
Mar. 22, 00 : 42 : 54, Ditto
Mar. 22, 20 : 46 : 27, Ditto
Mar. 22, 23 : 57 : 06, slight at Uwekahuna. Kilauea caldera.
Mar. 23, 00 : 01 : 21, Ditto
Mar. 23, 02 : 06 : 30, slight at Pahoa. East rift of Kilauea near Pahoa.
Mar. 23, 03 : 42 : 12, Ditto
Mar. 23, 07 : 53 : 59, slight at Uwekahuna. Kilauea caldera.
Mar. 23, 12 : 08 : 52, slight at Pahoa. East rift of Kilauea near Pahoa.
Mar. 24, 05 : 23 : 46, slight at Pahoa. East rift of Kilauea near Pahoa.
Mar. 24, 06 : 56 : 11, slight at the Whitney Laboratory. Kilauea caldera. Felt in Hawaii National Park.
Mar. 24, 06 : 59 : 27, Ditto
Mar. 24, 07 : 05 : 32, Ditto
Mar. 24, 10 : 27 : 38, slight at Uwekahuna. Kilauea caldera. Felt in Hawaii National Park.
Mar. 24, 11 : 02 : 26, slight at Pahoa. East rift of Kilauea near Pahoa.
Mar. 24, 18 : 22 : 59, moderate at Uwekahuna. Kilauea caldera.
Mar. 24, 23 : 26 : 20, slight at Uwekahuna. Kilauea caldera at a depth of 20 km.
Mar. 25, 04 : 27 : 33, moderate at Uwekahuna. Kilauea caldera.
Mar. 25, 05 : 42 : 49, Ditto
Mar. 25, 06 : 26 : 10, slight at Pahoa. East rift of Kilauea near Pahoa.
Mar. 25, 07 : 13 : 23, slight at Uwekahuna. Kilauea caldera.
Mar. 25, 07 : 34 : 28, Ditto
Mar. 25, 07 : 40 : 42, Ditto
Mar. 25, 07 : 41 : 24, Ditto
Mar. 25, 08 : 07 : 08, Ditto
Mar. 25, 08 : 54 : 49, Ditto
Mar. 25, 08 : 55 : 19, Ditto
Mar. 25, 20 : 17 : 00, very feeble at Mauna Loa. About 10 km. north of Kilauea caldera at a depth of about 40 km. This earthquake and the next are representative of a large number of small earthquakes originating in this region on March 25, March 26, and March 27.
Mar. 26, 06 : 34 : 08, very feeble at Mauna Loa. About 10 km. north of Kilauea caldera at a depth of about 50 km.
Mar. 27, 09 : 23 : 43, strong at the Whitney Laboratory. Kilauea caldera. Felt in Hawaii National Park.
Mar. 27, 16 : 02 : 20, strong at the Whitney Laboratory. Kilauea caldera. Felt strongly in Hawaii National Park. Water lines broken and roads cracked in Hawaii National Park.
Mar. 28, 20 : 39 : 00, slight at Uwekahuna. Kilauea caldera.
Mar. 30, 13 : 41 : 31, moderate at Naalehu. Southwest rift of Mauna Loa about 15 km. northeast of Puu Keokeo.
Mar. 30, 16 : 57 : 23, Moderate at the Whitney Laboratory. Kilauea caldera.

Distant Earthquakes

The following earthquakes of distant origin were recorded on the seismographs at the Hawaiian Volcano Observatory (19° 25.4′ N. latitude, 155° 17.7′ W. longitude). Beginnings of phases are given in Greenwich civil time, which is 10 hours faster than Hawaiian standard time. Locations of epicenters, magnitudes, and depths of focus are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey.

Jan. 5, eP 01 : 02 : 19.6, 50° S., 162½° E. Off coast of South Island, New Zealand. Magnitude 6½–6¾.
Jan. 5, eP 17 : 57 : 51.0, 16° S., 167½° E. New Hebrides Islands. Magnitude 6¾.
Jan. 5, eP 23 : 51 : 13.5, 16° S., 167½° E. New Hebrides Islands. Damage at Malekula. Magnitude 6¾–7.
Jan. 8, eP 07 : 42 : 29.3, 11½° S., 166½° E. Santa Cruz Islands. Depth about 60 km. Magnitude 6¾–7.
Jan. 13, eP 02 : 10 : 37.5, 53° N., 167½° W. Fox Islands, Aleutian Islands. Felt on Unalaska.
eT 03 : 00 : 44,
Jan. 13, eP 02 : 42 : 38.8, Fox Islands aftershock.
eT 03 : 34 : 02,
Jan. 31, eP 16 : 11 : 05.7, 46½° N., 153° E. Kurile Islands. Magnitude 6¼–6½.
Feb. 27, iP 20 : 52 : 30.6, 27½° S., 176° W. Kermadec Islands region. Magnitude 7¾–8.
Mar. 14, iP 13 : 19 : 01.8, 52½° N., 173½° W. Andreanof Islands, Aleutian Islands. Magnitude 6¾–7. Depth about 100 km.
Mar. 18, eP 00 : 15 : 28.4, 54½° N., 161° E. Near east coast of Kamchatka.
Mar. 31, eP 18 : 29 : 08.2, 8° N., 124° E. Near northwest coast of Mindanao, P. I. About 425 killed. Magnitude 7½.
Mar. 31, iP 21 : 04 : 54.7, 8° N., 124½° E. Mindanao aftershock. Felt.

VOLCANO NOTES AND NEWS

ERUPTION OF STROMBOLI

Following a series of strong earthquakes in its vicinity, Stromboli volcano erupted in late December, 1954. On December 29, United Press reported a stream of lava entering the sea near the village of Ginostra, and ash falls over other parts of the island. The earthquakes caused a large amount of damage on the island of Salina, 20 miles from Stromboli. It was stated that no house was left habitable on Salina Island, and many of the inhabitants were evacuated. Etna also was reported fuming heavily.

ASSOCIATION OF PHYSICAL VOLCANOLOGY OF JAPAN

Letters from Akira Suwa, Chief of the Volcanological Subsection of the Central Meteorological Observatory, and Prof. Sakuma of Hokkaido University announce the formation of an Association of Physical Volcanology. At the end of December the Association had about 240 members. Chairman of the committee for the Association is Prof. T. Minakami, of the Earthquake Research Institute of Tokyo University.

SUBMARINE ERUPTION IN THE CELEBES SEA

On February 13 the crew of a Japanese fishing boat reported a submarine eruption south of the Philippine Islands. Black "smoke," probably an ash-laden cloud of fume and steam, at first rose from the sea to a height of 200 to 300 meters. Five minutes later the cloud became white, probably largely steam. The cloud rose from an area of about 1,800 square meters of sea surface.

According to Mr. Arturo Alcaraz, Geologist in Charge, Philippine Commission on Volcanology, the eruption probably took place at or near a known submarine volcano that lies about 130 kilometers west-northwest of Great Sangihe Island in the northern part of the Celebes Archipelago, about 250 kilometers southwest of the Davao Peninsula on the island of Mindanao, Philippines. (Lat. 3° 58′ N., Long. 124° 10′ E.) The volcano, which last erupted early in 1922, is unnamed. It bears the serial number 6,7-5 in M. Neumann van Padang's *Catalogue of the Active Volcanoes of Indonesia.*

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director
Jerry P. Eaton, Seismologist
Chester K. Wentworth, Geologist, part-time
Burton J. Loucks, Instrument Maker
John C. Forbes, Assistant Instrument Maker
Elizabeth G. Eklund, Secretary

Seismograph Station Operators:

Hilo Station:

Sister M. Thecla, St. Joseph's School

Kona Station:

Howard M. Tatsuno, Konawaena School

Pahoa Station:

Kongo Kimura, Pahoa School

Kamuela Station:

Thomas C. Mills, Waimea School

Haleakala Station:

Hawaii National Park Staff

Naalehu Station:

Alfred K. Kahakua, Naalehu School

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DISTRIBUTION OF AREAS OF PNEUMATOLYTIC DEPOSITION ON THE FLOOR OF KILAUEA CALDERA

By GORDON A. MACDONALD

Gases rising through innumerable fissures in the lavas that floor Kilauea caldera have formed white deposits on the surface of the lava. These deposits are not distributed uniformly over the caldera floor, but are concentrated in narrow bands and irregular patches. For the most part, the active steam vents are confined to the same areas. With certain qualities of lighting, the areas of deposition show up clearly to the eye in the field, from the caldera rim, and in aerial photographs. I commenced the mapping of these areas by plane table in 1951, but the mapping was interrupted by the heavy earthquake of August 21, in Kona. The mapping was completed in January 1955, by use of a photo-mosaic compiled by E. K. Field, former chief ranger of Hawaii National Park, from aerial photographs taken in 1944. Thanks are extended to Elroy Bohlin, acting chief ranger, for permission to use the mosaic.

Gases issuing at the two solfataras, known respectively as Sulphur Bank and Southeast Sulphur Bank (Fig. 1), contain sulphur dioxide and carbon dioxide. In those two areas of acid gas release the rocks are much altered to iron oxides and clay minerals, and leached to form pseudomorphs of opaline silica (Macdonald, G. A. 1944. Solfataric alteration of rocks at Kilauea volcano. *Amer. Jour. Sci.* 242: 496-505). For the most part, however, the fumarole gases in and near Kilauea caldera consist largely or entirely of steam and air. Gas was collected by Kazuji Terada from a vent on the eruptive fissure of the 1954 lava flow on June 23, and from a vent on the northern part of the caldera floor on July 16, 1954. The latter vent (A, Fig. 1) is at or near the site of the former prominent conelet known as the Perret cone, buried by the lava flow of 1919. The gases were analyzed by Terada for the Geological Survey, and found to contain only water vapor and air. Gas from a vent on the flat above the Steaming Bluffs, 0.4 mile southwest of Sulphur Bank, contained a very small amount of carbon dioxide, possibly as a result of contamination by vegetable matter along the fissure (Terada, K. Unpublished report to U. S. Geological Survey, 1954).

Along the source fissure of the 1954 lava flow on the caldera floor northeast of Halemaumau (Fig. 1) small deposits of thenardite (Na_2SO_4) are found, associated with a little opal. These resemble deposits along eruptive fissures on Mauna Loa (Macdonald, G. A., and C. K. Wentworth. 1954. Hawaiian volcanoes during 1951. *U. S. Geol. Survey, Bul. 996d*: 180). At other areas within Kilauea caldera the deposits appear to be entirely opal. The opal is white and powdery, and forms thin crusts commonly in mammilary, botryoidal, and stalagmitic forms, and rarely miniature conelets resembling geyser cones but less than a centimeter high. Below the crust the lava rocks are generally partly altered to clay minerals and iron oxides for thicknesses of a few millimeters or a few centimeters. Generally the line of demarcation between the altered rock and the overlying crust is very sharp. The silica has clearly been transported and deposited by the rising steam, though it probably was derived by leaching of the altered rocks along the walls of the channel rather than from any deep-seated magmatic source.

Most of the areas of pneumatolytic deposition on the caldera floor show a strikingly arcuate arrangement (Fig. 1). With little question, these arcuate traces mark the buried margins of the sunken central basins that existed in the caldera during the nineteenth century. The buried scarps that bounded the basins, and the faults beneath them on which the sinking took place, still constitute pathways that guide the rise of steam from greater depths.

Comparison with Figure 2 demonstrates that trace 1 (Fig. 1) coincides approximately with the margin of the inner basin of 1840. Trace 2 nearly corresponds with the ridge of talus pushed up by bodily elevation of the

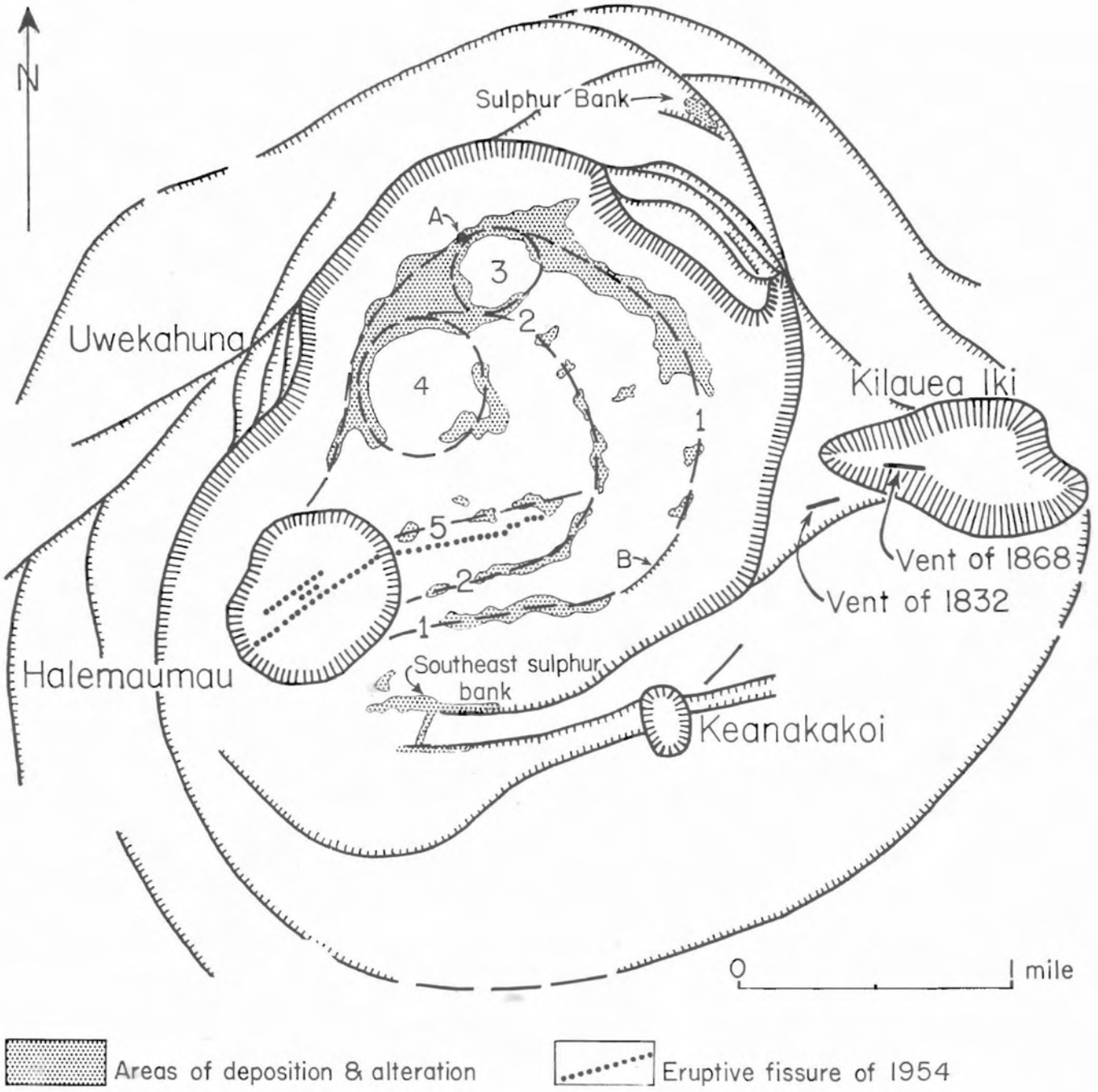

FIGURE 1. Map of Kilauea caldera, showing areas of deposition and alteration, the Perret steam vent (A), and a small monoclinal scarp (B) on one of the arcuate lineaments marked by the areas of deposition.

central part of the caldera floor in 1845 and 1846, and may correspond with the central basin of 1868. Trace 3 coincides in position with the embayment at the north edge of the inner basin in 1825 (Fig. 2), and 1841 (Wilkes, Charles. 1845. *Narrative of United States Exploring Expedition During the Years 1838-1842*. Vol. 4. Map facing p. 165). Trace 4 appears probably to reflect the position of another small pit, possibly the lake shown north of Halemaumau in Malden's map of 1825, and the sketch by Captains Parker and Chase in 1838 (Brigham, W. T. 1909. The volcanoes of Kilauea and Mauna Loa. *Bernice P. Bishop Mus., Mem.* 2(4) : 45-48), and the embayment on the west side of the central basin shown in Wilkes' map of 1841.

Along trace 1, in the southeastern part of the caldera, a scarp (B, Fig. 1) as much as 10 feet high formed

principally by flexing of the lavas, with cracking and minor faulting, has resulted from uplift of the central portion of the crater floor in relation to the margin. This uplift probably took place since 1884, because the lavas covering that portion of the floor probably are of that date.

Trace 5 appears to be essentially straight, rather than arcuate. It coincides closely in direction, and very nearly in position, with the eruptive fissure of the 1954 lava flow, and probably represents the northeast rift zone crossing the caldera floor. The eruptions of 1832 and 1868 no doubt represent activity on this rift zone.

Strikingly linear also is the arrangement of the three small circular structures, pits 3 and 4 and Halemaumau. The trend of this lineament departs somewhat from that of the southwest rift zone, and even more from that of the northeast rift. It is, however, approximately the same as that of two dikes cropping out in the caldera wall west of the fault blocks at the northeastern edge of the caldera. These dikes are the only ones exposed in the walls of Kilauea caldera other than those in Halemaumau.

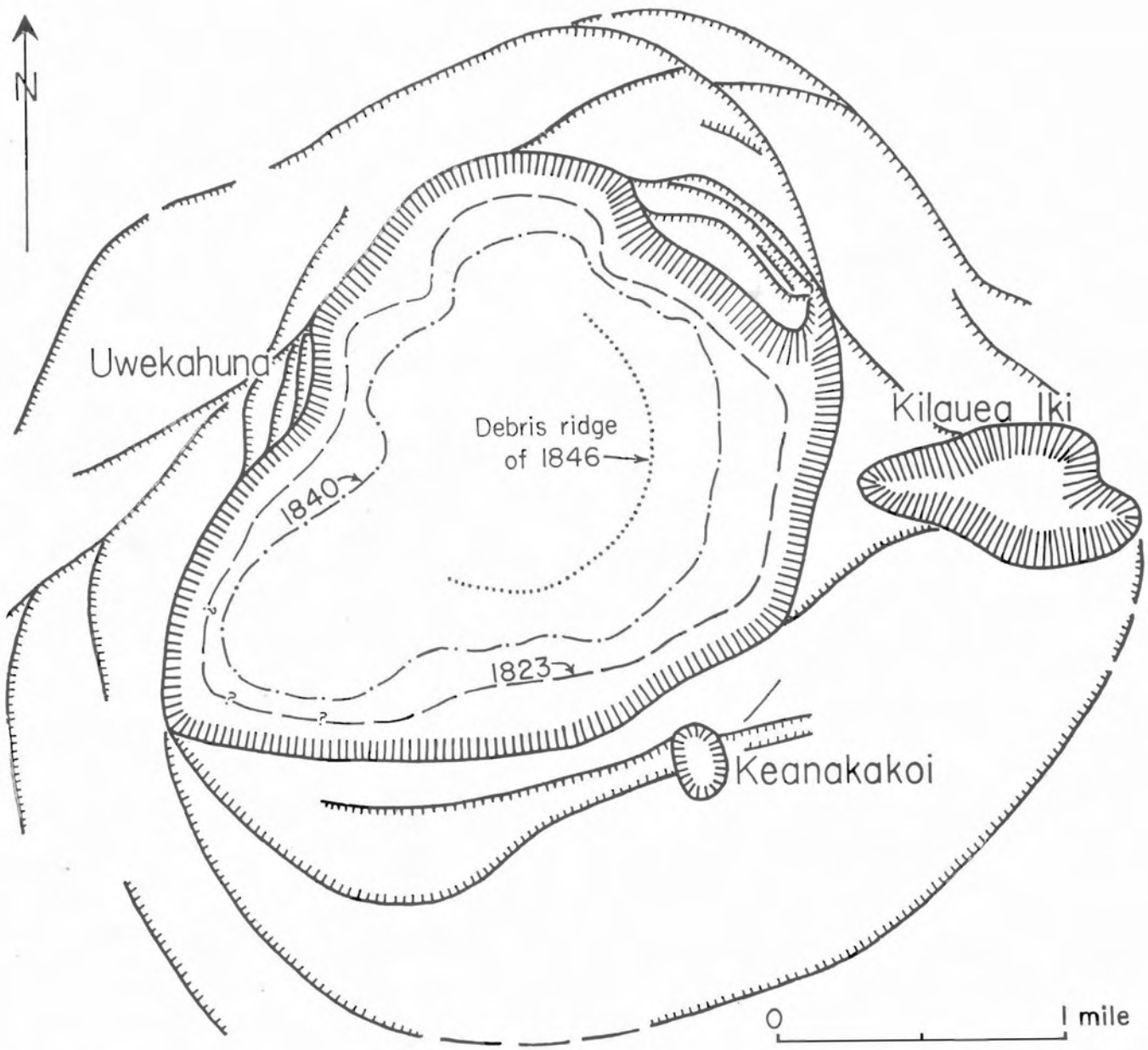

FIGURE 2. Map of Kilauea caldera showing the approximate margin of the inner depression of 1823 (adapted from the map by Malden in 1825), and 1840 (after Wilkes), and the approximate position of the ridge of elevated talus in 1846 (after C. S. Lyman).

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR APRIL–JUNE, 1955

By GORDON A. MACDONALD and JERRY P. EATON

VOLCANOLOGY

April

The volcanic activity on the east rift zone of Kilauea volcano, in eastern Puna, that had begun on February 28, continued into early April. The vents in the vicinity of the prehistoric Iilewa Crater continued fountaining, and liberating lava flows. A second flow from these vents entered the ocean on the evening of April 2. Lava extrusion stopped early on the morning of April 8. For the next two weeks the southwestern vents near Iilewa Crater continued to fume moderately to heavily, and a small pit on the northeast side of the southwesternmost vent glowed brightly, but there was no surface extrusion of lava.

On April 24 a short period of weak fountain activity occurred in the crater of the northeasternmost new cone near Iilewa Crater, and a small lava flow poured into the crater of the cone. Another small fountain and flow broke out in the same crater on the afternoon of April 26, but continued only a few hours. On the afternoon of April 27 a small lava flow broke out at a fissure in an older flow 1,000 feet southeast of the cone, and continued until the afternoon of the 28th. On April 30 activity resumed at the small pit just northeast of the southwesternmost cone of the Iilewa group, with small lava fountains, and pahoehoe flows spreading around the vent.

Volcanic tremor of the "harmonic" type was weak and irregular on the Pahoa seismograms from the beginning of the month until April 7. The resumption of weak activity at the vents near Iilewa Crater from April 24 to 30 was not accompanied by any detectable tremor.

At 4:25 A.M. on April 1 a strong earthquake occurred deep under the Kilauea caldera region. It was widely felt on the island of Hawaii, but did no damage. Very numerous earthquakes continued at Kilauea caldera throughout the month, but with gradually decreasing frequency (see table of local earthquake data). These accompanied a south-southwestward tilting of the ground at the northeast edge of the caldera totaling about 4.4 seconds of arc. At the west edge of the caldera the tilting was about 6 seconds of arc in a south-southeasterly direction. This tilting clearly indicated a sinking of the caldera floor, presumably resulting from decrease of magmatic pressure because of the release of lava in east Puna. The sinking was a continuation of the much more marked sinking of late March. (See *Volcano Letter* 527.)

The eruption in east Puna, and the accompanying effects at Kilauea caldera, will be described in detail in forthcoming issues of the *Volcano Letter*.

May

The activity that resumed at the southwestern vents of the Iilewa group on April 30 continued with gradually increasing strength into May. At first fountaining was low, and small sluggish flows were restricted to the area within about 1,000 feet of the vents. On May 16 occurred a marked recrudescence of activity. Lava fountaining became strong, and voluminous extrusion formed a broad pool of pahoehoe northeast of the vents, which drained southeastward toward the old Kalapana-Pahoa road and the coast. On May 19 a flow threatened the Iwasaki camp, and evacuation of the camp was started. (The camp had been evacuated during March, but had been partly reoccupied during the lull in activity in April.) On May 24 and 25 flows buried the upper portion of the Kamaili road and the Iwasaki camp area. All lava activity at the vent ceased suddenly at approximately 11:15 A.M. on May 26.

Harmonic tremor resumed on the Pahoa seismograph on May 4, and continued very weakly until May 9. No tremor was detected on May 10 and 11, but it resumed on May 12. It continued to be very weak until 8:30 P.M. on May 16, when it suddenly increased in strength, though it was still rather weak. It continued until May 26, when it ceased very abruptly at 11:13:47 A.M. The latter time coincided closely with the end of visible activity at the vents south of Iilewa Crater.

During the rest of May the vents near Iilewa Crater, those at and near the old Kalapana road 3.6 miles south of Pahoa, and those southwest of Puu Kii continued to fume lightly to moderately, but there was no further lava extrusion. Blue flames, possibly burning sulphur, were observed at cracks in the ground along the old Kalapana road.

Seismic activity was at a low level both in east Puna and in the Kilauea caldera area. The Pahoa seismograph recorded only 25 earthquakes during May, and only 35 were recorded by the Bosch-Omori seismograph at the northeast rim of the caldera. Westward tilting of the ground at the northeast rim of the caldera was about normal in direction and amount for that season of the year, but southward tilting continued at a moderate rate well beyond the normal time of reversal to northward tilting. This may indicate a continued sinking of the caldera floor, but may on the other hand represent merely an unusually late seasonal reversal. The Mauna Loa seismograph recorded 56 earthquakes during May.

June

The month of June was quiet both volcanically and seismically. Quiet release of volcanic fume and steam continued at the vents of the recent eruption in east Puna, and blue flames were occasionally visible at cracks along the old Kalapana road near the former Nii residence. The amount of visible steam varied greatly, probably in large part because of variations in the amount of rainfall, and temperature and humidity of the atmosphere.

The Bosch-Omori seismograph in the Whitney Laboratory of Seismology, on the northeast rim of Kilauea caldera, recorded only 18 earthquakes during June. This is the smallest number recorded since February 1953. The Pahoa seismograph recorded 28 quakes, three more than in May. The Mauna Loa seismograph recorded 52 quakes, four less than in May. Some of the quakes recorded at the Mauna Loa station originated at Kilauea, others on the Kaoiki fault zone between Kilauea and Mauna Loa, and others on Mauna Loa, probably on the east rift zone. No harmonic tremor was recorded on any of the seismographs.

A sharp earthquake felt from Naalehu to the Volcano district at 9:16 P.M. on June 12 probably originated on the Kaoiki fault. A quake of local origin rattled windows in the Waimea area at 7:11 A.M. on June 29.

During June the ground surface at the Whitney Laboratory of Seismology tilted slightly southeastward. Normally at that season of the year the direction of tilting should be northeastward. The abnormal direction of tilting may indicate a continued slight reduction of volcanic pressure beneath Kilauea caldera, but the time of the seasonal reversal from southward to northward tilting varies as much as two months and the continued southward tilting may represent merely an unusually late seasonal reversal. If so, the reversal from westward to eastward tilting in advance of the south to north reversal (it usually follows the latter by about a month) may indicate either an increase of pressure beneath Mauna Loa to the west, or a reduction of pressure beneath the Puna area to the east. The number and distribution of tilt measuring stations is inadequate to furnish the answer to this and similar problems, and the number of stations is being increased as rapidly as possible.

SEISMOLOGY

Local Earthquake Data, April–June, 1955

(Based on Bosch-Omori seismograph on northeast rim of Kilauea caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Total	Local Seismicity*
Apr. 3	230	24	3	2	2	0	261	82.5
10	198	1	0	0	2	0	201	56.0
17	28	3	1	0	0	0	32	9.5
24	3	3	0	1	1	0	8	7.25
May 1	0	1	0	0	0	0	1	0.5
8	0	3	0	3	3	0	9	16.5
15	1	0	1	1	0	0	3	3.25
22	2	5	3	0	0	0	10	6.0
29	4	2	0	2	3	0	11	15.0
June 5	1	1	0	0	0	0	2	0.75
12	0	2	0	0	1	0	3	4.0
19	1	0	0	0	0	0	1	0.25
26	2	2	0	0	0	0	4	1.5

* For definition of local seismicity see *Volcano Letter* 371 or 512. Each local earthquake is assigned a seismicity value according to its strength, as follows: tremor, 0.25; very feeble, 0.5; feeble, 1.0; slight, 2.0; moderate, 3.0; strong, 4.0. These values are totaled to give the weekly local seismicity. Continuous volcanic tremor ("harmonic tremor") is ignored in the calculation. The strength assigned to the earthquake depends on the double amplitude of the maximum oscillation it causes on the Bosch-Omori seismograph, as follows: tremor, less than 0.5 mm.; very feeble, 0.5 to 4 mm.; feeble, 4 to 11 mm.; slight, 11 to 25 mm.; moderate, 25 to 60 mm.; strong, greater than 60 mm.

Table of Tilt at Seismograph Stations on Rim of Kilauea Caldera

Week Beginning	Whitney Station (Northeast rim)		Uwekahuna Station (West rim)	
	Amount	Direction	Amount	Direction
Apr. 3	2.8″	S 18° W	3.3″	S 29° E
10	0.4″	S	3.2″	S 12° E
17	0.3″	S 27° W	1.0″	S 18° E
24	0.9″	S 15° W	1.4″	N 27° W
May 1	0.3″	S 27° E	1.3″	S
8	0.7″	S 31° E	0.6″	S
15	1.4″	S 38° W	0.3″	N
22	1.2″	S 36° W	0.3″	E
29	0.4″	N 81° E	1.6″	S
June 5	0.4″	S 18° E	2.7″	S 21° E
12	0.4″	N 81° E	2.3″	S 9° E
19	0.5″	S 14° W	0.9″	S 45° E
26	0.4″	N 81° W	2.6″	S 7° E

Local Earthquakes

The data for the following local earthquakes were determined from seismographs on the islands of Hawaii and Maui operated by the Hawaiian Volcano Observatory. Except for smaller earthquakes of special interest, only earthquakes classed as slight or larger were included in the list. The intensity ratings assigned are based on the Bosch-Omori seismograph at the Whitney Laboratory. This intensity scale has been extended empirically to permit its use with the Loucks-Omori and Sprengnether seismographs. The entries for a given earthquake are: date, time of arrival at the nearest station (Hawaiian standard time), intensity at the nearest station, name of the nearest station, epicenter, and general remarks.

Apr. 1, 04:24:28, Strong at Uwekahuna. Under the south rim of Kilauea caldera at a depth of about 10 km. Felt generally over the entire island of Hawaii and by a few observers on the islands of Maui and Oahu.

Apr. 2, 05:09:24, slight at Uwekahuna. Kilauea caldera.
Apr. 2, 06:37:56, Ditto
Apr. 4, 13:28:44, Ditto
Apr. 4, 13:34:14, Ditto
Apr. 6, 14:33:35, moderate at Uwekahuna. Near Kilauea caldera.
Apr. 6, 15:59:34, Ditto
Apr. 7, 01:27:22, slight at Uwekahuna. Near Hilina Pali at a depth of about 25 km.
Apr. 7, 15:48:54, slight at Uwekahuna. Near Kilauea caldera.
Apr. 9, 18:08:30, moderate at Uwekahuna. Near Kilauea caldera.
Apr. 10, 09:45:02, feeble at Uwekahuna. Southwest rift of Kilauea near the Ponohohoa Chasms at a depth of about 15 km.
Apr. 12, 08:25:44, moderate at the Whitney Laboratory. East rim of Kilauea caldera. Felt in Hawaii National Park.
Apr. 12, 12:49:56, Ditto
Apr. 22, 05:47:16, moderate at Pahoa. East rift of Kilauea near Pahoa.
Apr. 23, 07:33:51, moderate at Mauna Loa. Ten km. north of Halfway House at a depth of about 15 km. Felt at Hilo, Hawaii National Park, and Naalehu.
Apr. 24, 13:19:08, moderate at Uwekahuna. Kilauea caldera. Felt at Hawaii National Park.
Apr. 24, 09:06:19, slight at Uwekahuna. Five km. north of Halfway House at a depth of about 25 km. Felt at Hilo, Pahoa, and the Volcano area.
May 8, 16:01:57, moderate at Uwekahuna. Near Puu Kapukapu. Felt at Pahoa and Pepeekeo.
May 9, 05:44:51, slight at the Whitney Laboratory. East rim of Kilauea caldera. Felt at Hawaii National Park.
May 9, 09:35:38, Ditto
May 11, 09:06:53, moderate at Uwekahuna. Near Kilauea caldera.
May 12, 10:30:40, slight at the Whitney Laboratory. Near Kilauea caldera.
May 14, 10:34:23, slight at Uwekahuna. Near Kilauea caldera.
May 15, 02:42:23, feeble at Uwekahuna. Under Kilauea caldera at a depth of about 40 km.
May 16, 23:26:17, slight at Uwekahuna. Kilauea caldera.
May 23, 01:40:47, Ditto
May 29, 05:34:11, moderate at Uwekahuna. Near Kilauea caldera.
June 1, 01:59:50, moderate at the Whitney Laboratory. East rim of Kilauea caldera.
June 1, 03:50:50, Ditto
June 5, 17:02:11, very feeble at Naalehu. Near Pahala at a depth of about 75 km.
June 12, 21:15:56, slight at Mauna Loa. Near the Mauna Loa seismograph station at a depth of about 15 km. Felt at Pahala, Naalehu, and Hawaii National Park.
June 14, 14:29:35, slight at Mauna Loa. Near the Mauna Loa seismograph station at a depth of about 15 km.
June 27, 03:51:27, slight at Pahoa. East rift of Kilauea near Pahoa.

Distant Earthquakes

The following earthquakes of distant origin were recorded on the seismographs at the Hawaiian Volcano Observatory (19° 25.4′ N. latitude, 155° 17.7′ W. longitude). Beginnings of phases are given in Greenwich civil time, which is 10 hours faster than Hawaiian standard time. Locations of epicenters, magnitudes, and depths of focus are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey.

Apr. 5, eI, 15:29:50, 25° N., 110° W. Gulf of California. Magnitude about 7.

Apr. 10, eP 17:50:19.8, 8° N., 125° E. Philippines aftershock. Many injured, moderate damage in Lanao province.

Apr. 19, eP 20:38:19.6, 30° S., 72° W. Near coast of Central Chile. Extensive damage from water waves at Tongoy and La Serena. Magnitude 7.

Apr. 23, iP 18:38:58.1, 24½° S., 113° W. Easter Islands region. Magnitude 6¾.

Apr. 28, eP 19:12:11.6, eT 19:50:27.1, 51° N., 178½° W. Felt: Adak. Magnitude 6½.

May 14, iP 06:13:34.1, 28° N., 139½° E. Bonin Islands region. Depth about 500 km. Magnitude 6¾.

May 30, iP 12:40:42.2, 24½° N., 142½° E. Volcano Islands. Depth about 600 km. Magnitude 7¼. Felt: Tokyo.

May 30, eP 23:39:10.8, 3° S., 137° E. Western New Guinea. Magnitude 6½.

May 31, eP 09:39:44.7, 27° S., 177½° W. Kermadec Islands region. Depth about 100 km. Magnitude 6¾.

June 2, eP 00:26:11.0, 51½° N., 180°. Andreanof Islands, Aleutian Islands. Magnitude 6¾.

June 12, eP 20:39:35.2, 49° N., 155° E. Kurile Islands.

June 14, eP 06:19:46.4, 20° N., 107° W. Off coast of Colima, Mexico. Magnitude 7.

June 20, iP 12:14:42.2, eT 12:53:15, 51½° N., 180°. Andreanof Islands, Aleutian Islands. Magnitude 6¾—7¼.

VOLCANO NOTES AND NEWS

THE LANAO EARTHQUAKE, PHILIPPINES

On April 1, at 2:15 A.M. (Philippine time), a very strong earthquake occurred in the central western part of Mindanao Island. Soon afterward the volcano Makaturing was reported in eruption.

The earthquake is briefly described by Arturo Alcaraz, in *The Philippine Geologist* (9(2):48-49). It was among the most severe experienced in the Philippines during this century. The epicenter lay between Lake Lanao and Panguil Bay. An intensity of VIII in the Rossi-Forel scale was attained in the epicentral area. The effects included fissuring and slumping in filled ground, differential settling in alluvial ground, sand boils, landslides, and a strong seiche in Lake Lanao. Many houses and public buildings were damaged. About 400 persons were killed. Of these, 174 were drowned when a large portion of Tugaya village slumped as much as 40 feet downward into the lake.

Makaturing is a dormant or extinct volcano situated south of Lake Lanao (*Volcano Letter* 523, p. 4). Mr. Alcaraz writes (personal communication) that aerial examination of the mountain in April indicates the news reports of eruption to have been incorrect. Two or three small landslides on the mountain slopes probably resulted from the earthquake of April 1.

ERUPTION OF MT. ASAMA, JAPAN

Newspapers reported a brief explosive eruption of Asama volcano at 7:46 P.M. on June 11. The eruption was stated to have lasted only about 3 minutes. It was accompanied by a loud roar, and black ash fell over neighboring areas, including the popular resort town of Karuizawa. No casualties were reported. The mountain lies in the Asama National Park, and normally during summer week ends many climbers are on its slopes. Fortunately, on June 11 visitors were discouraged by heavy rains.

The last previous activity of Asama consisted of small explosions on November 2 and 4, 1954 (*Volcano Letter* 526, p. 7).

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director
Jerry P. Eaton, Seismologist
Chester K. Wentworth, Geologist, part-time
Burton J. Loucks, Instrument Maker
John C. Forbes, Assistant Instrument Maker
Akira Yamamoto, Secretary

Seismograph Station Operators:

Hilo Station:

Sister M. Thecla, St. Joseph's School

Kona Station:

Howard M. Tatsuno, Konawaena School

Pahoa Station:

Kongo Kimura, Pahoa School

Kamuela Station:

Thomas C. Mills, Waimea School

Haleakala Station:

Hawaii National Park Staff

Naalehu Station:

Alfred K. Kahakua, Naalehu School

THE VOLCANO LETTER

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THE 1955 ERUPTION OF KILAUEA VOLCANO

By GORDON A. MACDONALD and JERRY P. EATON

INTRODUCTION

The 1955 eruption, on the east rift zone of Kilauea volcano in the eastern part of the Puna District, was unique in several respects and unusual in others. It was the first flank eruption of Kilauea since 1923, and the first eruption in eastern Puna since 1840. In some respects it had the aspects of three separate eruptions, each accompanied by its premonitory earthquakes. It was unusual in that the opening of the eruptive fissures in part progressed up slope, toward the central vent of the volcano, and also in the irregular manner in which activity shifted from one vent area to another. For the first time in Hawaii, and probably anywhere else, scientists were able to observe and photograph at close range the entire sequence of the development of volcanic vents, from the first opening of the fissure in the ground, through the appearance of lava, the formation of cones and flows, and the cessation of activity. Also for the first time in Hawaii, we observed the formation of a pit crater. Unusually good opportunities were presented to observe active flow fronts at close range and study the mechanics of their movement; and to obtain temperature measurements both on flow fronts and in the lava fountains.

The 1955 eruption was the first to occur in any populous area in American territory. For the first time it was necessary to evacuate fairly large numbers of people, with their movable belongings, because of volcanic danger. The staff of the Hawaiian Volcano Observatory worked in close cooperation with the Civil Defense Agency, the Police and Fire departments, the National Guard, the American Red Cross, and the Department of Public Instruction, in handling the disaster. In this connection, the responsibility of the Observatory staff was principally for prediction of the location of new points of outbreak and of the course of the flows. All orders of evacuation were issued by the Disaster Council of the County of Hawaii, with advice from the Observatory staff; and evacuation was on a purely voluntary basis. The eruption also saw the first modern attempts in Hawaii to construct barriers to deflect lava flows from certain areas. The barriers will be discussed in the detailed report on the eruption. The experience obtained with problems of human safety is of great value to all of us, particularly in view of the possibility of the development of even more serious situations in future Hawaiian eruptions.

Space here does not permit a full account of the eruption. The following pages contain only a brief summary of events. A detailed report will be published later as a bulletin of the United States Geological Survey.

ACKNOWLEDGMENTS

It is impossible to credit here all the individuals who aided us during the eruption, but to all we extend our sincere thanks. Among those who may be mentioned are: Deputy Director Peter Pakele, Edward Bento, Raymond Suefuji, Richard Chinen, Albert Kudo, Albert Wilson, and Edward Wingate, of the Civil Defense

Publication of the *Volcano Letter* will be discontinued with this issue. Beginning in January, 1956, the quarterly report of the Hawaiian Volcano Observatory will be published by the United States Geological Survey. The reports will be distributed free of charge. Persons desiring to receive the reports as they are published should request them from the Director, U. S. Geological Survey, Washington 25, D. C.

Agency; Col. Michael Roman, Captains Elroy Bohlin and Ken Cheney, and the men of the National Guard radio crews; Manager John Rolfes and Robert Spence of the American Red Cross; Principal Raymond Torii, and other teachers of Pahoa School; Deputy Chief George Martin, Captain William Kamau, and many other officers of the Hawaii Police Department; Manager C. E. S. Burns, Jr., and Myron Isherwood, of Olaa Sugar Co.; County Supervisor Richard Lyman; Chief Robert Kahakua, and other members of the Hawaii Fire Department. Special thanks are due Curtis Kamai, of the Territorial Highway Department, who worked with us constantly in the field through the first phases of the eruption, keeping flow maps up to date and aiding in many other ways; and to Arthur Lyman, of Olaa Sugar Co., whose phenomenal knowledge of the area and ever-willing counsel aided immensely in keeping track of volcanic events.

NARRATIVE OF THE ERUPTION

The events leading to the eruption may be considered to have commenced with the two strong earthquakes centered in eastern Puna on March 30, 1954. The quakes came from a focus about 12 miles deep nearly south of Pahoa, between the surface trace of the east rift zone of Kilauea volcano and the southern shore of the island. Throughout the rest of the year many earthquakes originated at centers along the east rift zone and in the caldera area. At the same time, tilting of the ground surface in the vicinity of the caldera indicated a swelling of the mountain, apparently caused by an increase of volcanic pressure beneath. The brief eruption in Kilauea caldera, from May 31 to June 3, 1954, had scarcely any effect either on the tilting of the ground surface or the sequence of earthquakes. Both continued uninterrupted through the rest of the year.

Repeatedly from November 1954 through February 1955 press releases from the Volcano Observatory called attention to the restlessness of the volcano. The possibility of eruption without appreciable further warning was pointed out, but the evidence was not sufficient to allow us to state definitely that the volcano was going to erupt, or if it did erupt, just when or where the outbreak would occur. Finally, in late February, earthquake activity increased greatly and centered in eastern Puna. Mr. and Mrs. Harold Warner reported that they were feeling large numbers of quakes, many of them accompanied by booming sounds, and that their dogs were much excited and digging persistently in the ground at their ranch, 5 miles S. 72° E. of Pahoa (Fig. 1). We spent most of February 27 at the Warner ranch, studying the phenomena. By that evening it was evident that eruption was imminent and that the outbreak would almost certainly take place in the area close to the Warner ranch. But our conservatism had caused us to wait too long. Before the prediction could be published, the eruption began.

The initial outbreak occurred within a few minutes of 8 A.M. on February 28, within a quarter of a mile of the Warner ranch house. Small lava fountains played along fissures in the ohia forest just north of the road to Pohoiki (Fig. 1-A). Two principal fissures, each about 300 feet long, trended N. 65° E., and were arranged en echelon with the more easterly fissure offset slightly to the north. A fuming fissure extended southwestward from them across the road. Farther east-northeast, two other short rows of fountains played from fissures on the south slope of the old cinder cone, Puu Honuaula (Fig. 1-B). The lava fountains were 50–150 feet high, and from them a rather sluggish lava flow spread southeastward between the base of Puu Honuaula and the road.

At approximately 2 P.M. a new group of small fountains developed farther east-northeast, in the saddle between Puu Honuaula and the next hill to the east (Fig. 1-C), and where the fissure crossed a cane-field road just west of the fountains the upper edge of a dike of incandescent lava was visible a foot or two below the ground surface. Bursts of gas from the top of the dike threw showers of glowing lapilli into the air.

The extension of the erupting fissures lay along a line trending almost directly toward the village of Kapoho, 3 miles distant, and in a hurried conference with Defense officials it was decided that Kapoho should be evacuated. By 5 P.M. the evacuation was already well under way. At 4:10 P.M. the lava flow from the vents on the south side of Puu Honuaula reached the Pohoiki road, and by 4:30 the road was completely blocked.

Activity in vent area C had essentially ceased by 4:30 P.M., but it resumed about 7:30, with the development of a chain of fountains in the area where the glowing dike had been visible earlier. A lava flow from them advanced rapidly southeastward into the cane fields.

Conditions continued essentially the same, though with fluctuations in the intensity of the lava fountaining, throughout the night and into the morning of March 1. By midmorning, activity had ceased at the vent area C, but continued at vents A and B. At 12:15 P.M. the lava fountains suddenly started to decrease rapidly in size, and by 12:20 they were completely dead. Immediately afterward, a great cloud of steam started to roll from vents B and C but not from the vents at A (Fig. 1). At most places the emission was rather gentle, and the cloud consisted entirely of white steam. Along the western portion of the row of vents at B, however, the steam roared out violently, carrying with it a cloud of black sand-sized ash. There was no trace of salt and very little trace of sulfur in the steam cloud. Apparently the rapid withdrawal of molten lava from the upper part of the eruptive conduits had allowed ground water to enter the conduits from the surrounding rocks, and contact of the water with the hot conduit walls resulted in the rapid generation of large volumes of steam. The ash was largely lithic, and apparently resulted from corrasion of the walls of the conduits by the outrushing steam.

The violent escape of steam continued until about 2:30 P.M., when it started to diminish. Gradually lessening amounts of steam poured out of the vents throughout the remainder of the afternoon and night. Lava activity at the vents was over, but lava continued to drain from tubes and open channels in the flow until about midnight.

At about 4 P.M. a small brief outbreak of lava occurred in the saddle between two unnamed hills 3,500 feet east-

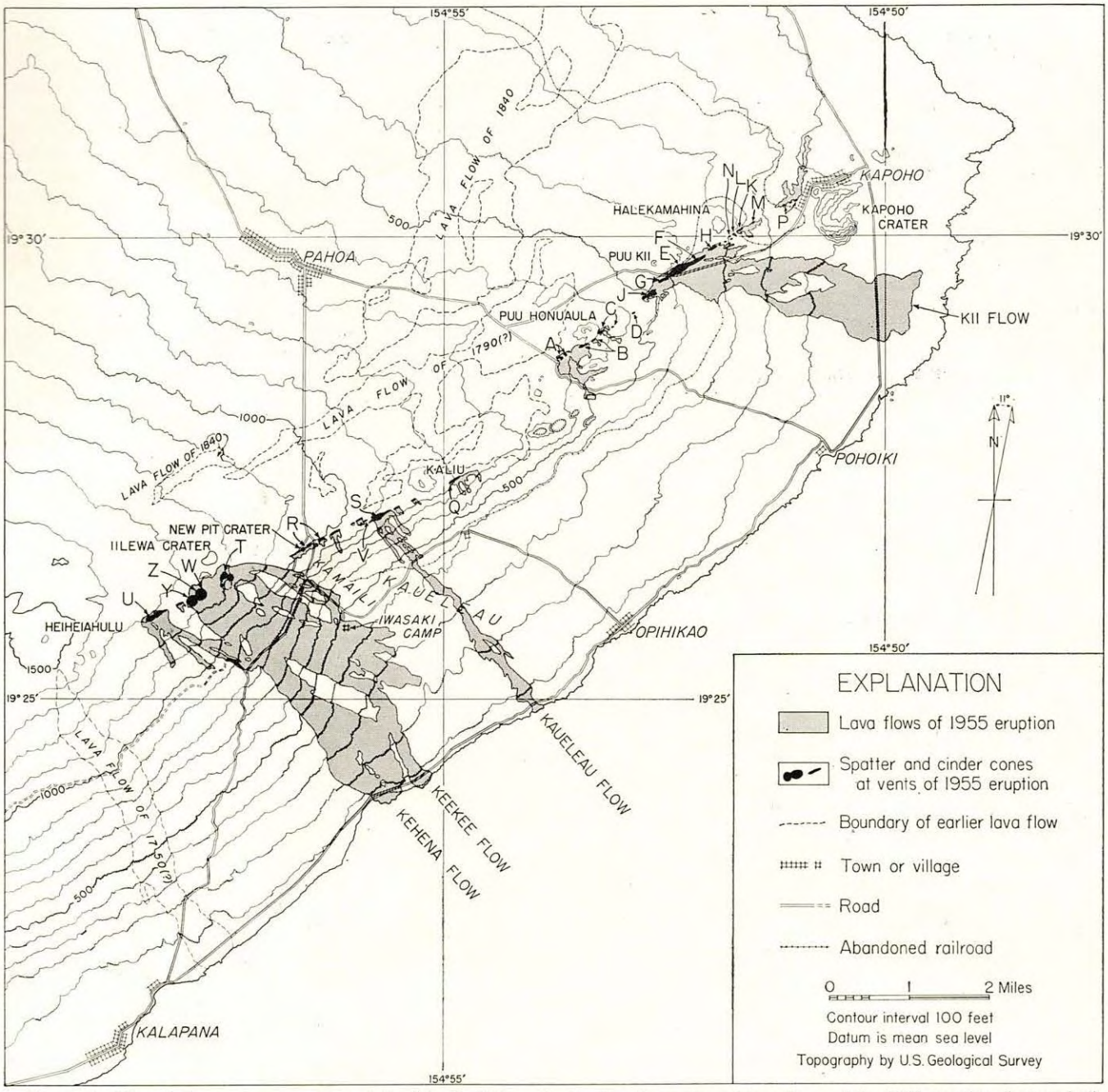

FIGURE 1. Map of the southeastern part of the island of Hawaii, showing the vents and lava flows of the 1955 eruption. Letters indicate the location of vents mentioned in the text in the order of their outbreak.

northeast of Puu Honuaula (Fig. 1-D). It lasted only a few minutes, and the flow formed in the cane field was less than 50 feet long.

The quiet condition of the vents suggested that the eruption might be over, but the continuation of large numbers of small earthquakes indicated that that was not the case. During the morning of March 2, new cracks appeared in the ground near the Pahoa-Kapoho road, 1.25 miles east-northeast of Puu Honuaula and 0.2 mile southeast of the old cinder cone, Puu Kii. The road was broken by a southeast-facing fault scarp 18 inches high, which continued east-northeastward along the bed of the old railroad with displacement as great as 3 feet. These fissures and fault scarps developed while we watched them, by a series of slow gradual movements accompanied by sharp small earthquakes of very local origin. Plantation officials were advised to move cane-field workers out of the area just southeast of the opening fissures, and the evacuation of Kapoho village (already largely accomplished) was speeded up. By 1 P.M. the fissures had spread northeastward to the vicinity of Halekamahina hill, a mile from Puu Kii, and less than a mile from the outskirts of Kapoho. The fissuring was following closely the zone of fractures formed during

the great swarm of earthquakes in the spring of 1924.

At 2:15 P.M. lava broke out in the cane field north of the Kapoho–Pahoa road (Fig. 1-E), 0.1 mile northeast of the initial fissuring across the road, and only about 250 feet from where Macdonald and B. J. Loucks were watching the development of fissures along the old railroad bed. First a cloud of dense white fume appeared, then after an interval of two or three minutes clots of incandescent lava started to shoot above the tops of the cane. Within 5 minutes of the first appearance of lava the line of fountains had increased in length to a quarter of a mile, the fountains had grown to a height of 50 feet, and very active flows of pahoehoe were spreading outward at a rate of about 40 feet a minute.

At approximately 4 P.M. the erupting portion of the fissure again lengthened downhill (Fig. 1-F). About 6:30 P.M. new vents extended the erupting fissure up slope, across the Kapoho–Pahoa road (Fig. 1-G). From 7:15 to 7:25 P.M. the eruptive fissure again lengthened 500 feet down slope east of vent F. At 8 P.M. another line of fountains broke out at H, east of vent F, and a new flow started to advance just north of the earlier flow. The fountains at vent H lasted only about 2 hours. At approximately 9 P.M. still another group of vents became active southwest of the Pahoa–Kapoho road (Fig. 1-J).

At 12:35 A.M. on March 3 a row of small lava fountains broke out on the lower southeast slope of Halekamahina hill (Fig. 1-K). At 1:30 A.M. another small outbreak occurred just to the west (Fig. 1-L), and at 2:41 still another outbreak occurred to the east (Fig. 1-M), only half a mile from the outskirts of Kapoho village. None of these groups of fountains lasted more than 2 hours. At 5:10 A.M. a small fountain broke out at N (Fig. 1), but lasted only about 45 minutes.

Vents J, G, and E were longer lived than the other vents, and became the principal vents of the eruption between March 3 and 10. They lay on fissures arranged en echelon, with each fissure offset to the left (north) in relation to the preceding one. The largest fountain was at vent E, close to the locus of the initial outbreak at 2:15 P.M. on March 2. By the early hours of daylight on March 3 this fountain averaged about 200 feet in height, and occasional bursts of cinder reached heights of 350 or 400 feet. The three groups of fountains fed a very active flow of aa. At 6:30 A.M. on March 3 the principal lobe of this flow was advancing 300 feet per hour over a front 500 feet wide, just south of the Kapoho road. Another less active lobe lay further south.

About 7 P.M. new fissures appeared in the old railroad bed at the western edge of Kapoho, and within a short time had extended through the center of the village itself. A police detail was still stationed in Kapoho, and a few people were still loading heavy appliances and the remainder of store stocks into trucks. These persons were immediately evacuated from the village, and the headquarters of the police detail was moved southward to a point on the coastal road 2.5 miles south of Kapoho.

Lava fountains broke out in the outskirts of Kapoho (Fig. 1-P) at approximately 9:30 P.M., and it seemed as though the village was doomed. By great good fortune, however, fountain activity was restricted to the westernmost part of the line of fissures, and a low ridge turned the flow of lava northward, away from the main portion of the village. Several houses in the outer part of the village were destroyed, but most of the village remained unharmed. Like that near Halekamahina, activity at the Kapoho vents was short lived. By 7:30 A.M. on March 4 lava activity at the easternmost vent had been replaced by a cloud of steam similar to those at Puu Honuaula on March 1, and by 8 A.M. activity at the Kapoho vents was over.

Still another threat to Kapoho had developed on the evening of March 3, when the big flow from the vents near Puu Kii reached the head of a shallow valley that led to the village. Although the main portion of the flow was directed down a larger valley farther south, it appeared probable that part of the flow would spill over the low divide and go down the valley toward Kapoho. However, the head of the valley was blocked by a fill on the old railroad grade, and although the lava piled up to a height of 15 to 20 feet above the level of the top of the fill, the lower mobile portion of the flow was deflected southward by the fill and none of the flow spilled into the valley toward Kapoho.

The flow crossed the coast road on the evening of March 4. On that day and the next the lava fountain at vent E reached a height of nearly 800 feet! On March 6, however, the fountains rapidly died down. By evening there was no sign of activity at the vents, and the big flow was stagnating without having reached the ocean.

Again it looked briefly as though the eruption might be over. The seismographs indicated otherwise, however. By the morning of March 7 another series of earthquakes was under way, this time originating in a zone southwest of the Puu Honuaula vents, within a mile or two on each side of the road from Pahoa to Kalapana. A new outbreak in that area appeared probable. For nearly a week we waited, while earthquakes occurred as frequently as two a minute for hour after hour. Eruption appeared more and more certain, but we could not be sure just where it would take place. The east rift zone of Kilauea lies along the top of a broad ridge, the crest of which lies about three miles south of Pahoa. If eruption occurred on the north side of the ridge, the town of Pahoa might be in immediate and drastic danger. The evacuation of Pahoa was not advised, because it appeared almost certain that the outbreak would be on the south side of the ridge; but under the direction of Richard Lyman, plans were laid for the construction by bulldozers of an earthen wall to try to divert the lava from the town if it should prove necessary. The Observatory staff took part in the planning, and the scheme had the complete approval of the citizens of Pahoa.

Finally, on the morning of March 12, cracks opened across the Pahoa–Kalapana road south of the crest of the ridge, 3.5 miles south of Pahoa. The town of Pahoa appeared to be out of danger, but the Kaueleau and Kamaili areas were in immediate jeopardy. Most persons had already left those areas, and residents of the Kalapana and Opihikao areas also had been evacuated because of the probability of isolation of those areas from food supplies and medical aid should eruption occur.

On the evening of March 12, lava broke out near Puu Kaliu (Fig. 1-Q), 2 miles east of the Kalapana road;



FIGURE 2. Fume issuing from a new fissure in vent area R, adjacent to the Kalapana road, on March 13, 1955. Lava reached the surface at this point a few minutes later. This illustrates the first phase in the formation of a new volcanic vent.



FIGURE 3. Viscous lava appearing at the surface in a new fissure across the Kalapana road, in vent area R, on the afternoon of March 13, 1955. Small explosive fountains burst through the top of the bulge of lava a minute or two later.



FIGURE 4. Spatter cone forming around a lava fountain at the new vent shown in Figure 3, about 16 hours later (morning of March 14).

and on the morning of March 13 a series of outbreaks occurred just east of the road (Fig. 1-R). Persons living in the area had already moved away, and the absence of any immediate threat to human life or movable property allowed us to spend a fascinating day watching and photographing for the first time in history the complete sequence of the development of new volcanic vents.

First, hairline cracks opened in the ground, gradually widening to 2 or 3 inches. Then from the crack there poured out a cloud of white choking sulfur dioxide fume (Fig. 2). This was followed a few minutes later by the ejection of scattered tiny fragments of red hot lava, and then the appearance at the surface of a small bulb of viscous molten lava (Fig. 3). The bulb gradually swelled to a diameter of 1 to 1.5 feet, and started to spread laterally to form a lava flow. From the top of the bulb there developed a fountain of molten lava which gradually built around itself a cone of solidified spatter (Fig. 4). The same general sequence was observed at three separate points during the day.

During the afternoon, activity spread southwestward across the Kalapana road, and by the morning of March 14 a spatter cone 30 feet high stood athwart the road.

On March 14 a lava fountain 400 feet high developed about a mile east of the Kalapana road (Fig. 1-S). Favorable conditions of wind and topography allowed us to approach within 100 feet of the base of this fountain and an unusually clear line of sight made possible excellent temperature measurements at night with an optical pyrometer. The temperature in the core of the fountain was close to 2,000° F. A lava flow from the fountain swept down through Kaueleau. On March 16 it entered the ocean, sending up great clouds of steam. Kalapana village was completely isolated.

During the afternoon of March 16 a new outbreak (Fig. 1-T) occurred south of the old Iilewa Crater, a mile southwest of the scene of the March 13 activity at the Kalapana road. Another took place two miles southwest of the road (Fig. 1-U) on March 19. Flows from the latter vents crossed the Kalapana road on the evening of March 19, but the activity of the vents lasted only about a day.

On March 20 activity increased at vent T. The lava fountain reached a height of 600 to 750 feet, and flows from it advanced into the Kamaili area. Pumice and Pele's hair fell abundantly in Pahoa, 5 miles away. A cone of pumice, cinder, and welded spatter 1,000 feet across and about 100 feet high was built around the fountain. On the morning of March 21 a tongue of one of the flows from vent T entered the head of a small valley that led directly to a small plantation camp owned by Koji Iwasaki. In an effort to keep the flow from reaching the camp, a wall about 1,000 feet long and 10 feet high was hurriedly thrown up by bulldozers working under the direction of Arthur Lyman, with Eaton's advice. During the afternoon the flow reached the barrier and was turned by it, but advanced along it only about 50 feet before the supply of lava was cut off and all movement in that tongue stopped.

The next day Robert Yamada, of Hilo, started construction of another series of short barriers to try to divert another portion of the flow from his coffee plantation. The walls were only partly successful, but did demonstrate certain valuable principles relating to the diversion of lava flows.

At 4:03 P.M. on March 20 a sharp explosion from vent area R, only about 150 feet east of the Kalapana road, threw dark ash 500 feet into the air. Several similar explosions followed within the next two hours. Air reconnaissance revealed a nearly circular pit with a mouth about 30 feet in diameter and a brightly glowing interior (Fig. 5). The walls were overhanging, the diameter of the base of the pit being at least twice that of the mouth. A tongue of pale blue and yellow flame played over the aperture at night, and the temperature of the interior was estimated on the basis of color to be at least 100° F. hotter than the cores of the lava fountains, presumably because of combustion of volcanic gas

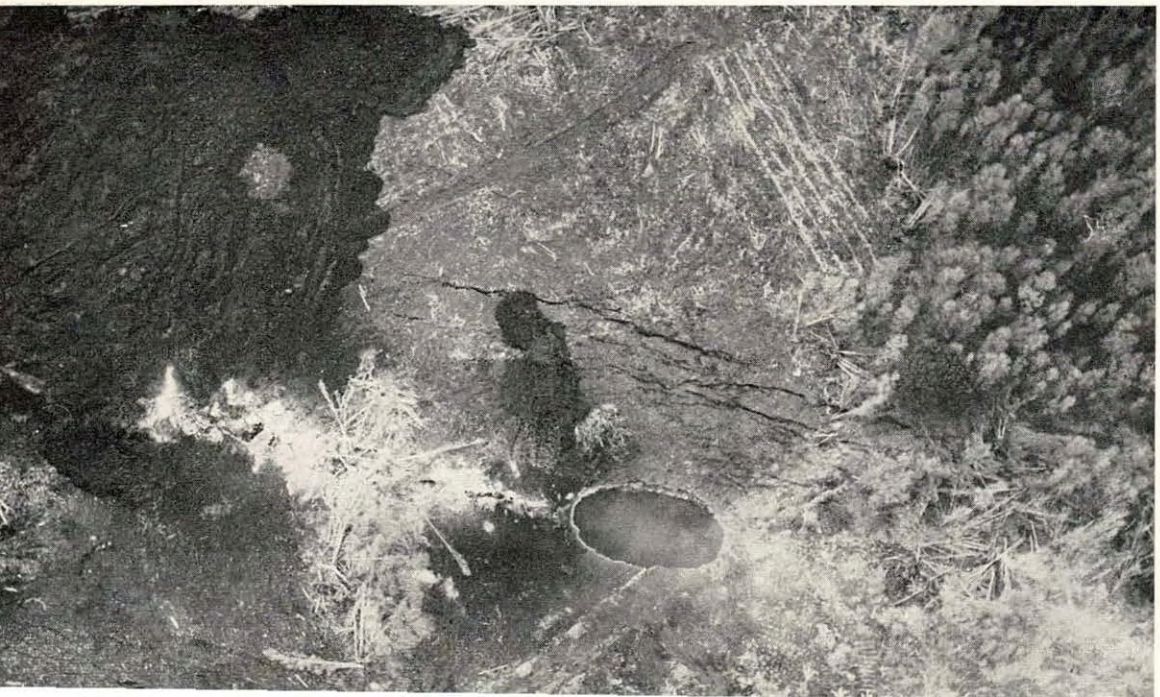

FIGURE 5. Aerial photograph showing the small pit crater formed in vent area R (Fig. 1) on the afternoon of March 20. Lava flows erupted on March 13 are visible on the left. The eruptive fissure extends across the picture from middle left to lower right.

in the pit. The edges of the pit caved back rapidly during the next few days, revealing it to be about 135 feet deep, floored with talus from the collapsing rim. The walls were covered with a tapestry of stalactites formed by melting and dripping of the old rocks under the intense heat of the burning gas. This pit is a small pit crater, similar to those along the Chain of Craters road in Hawaii National Park. The volume of ash ejected by the explosions was much less than the volume of the crater. Obviously, the crater was formed principally by collapse, probably as the result of withdrawal of molten lava beneath.

At 9 A.M. on March 25 a small outbreak occurred 0.7 mile east of the Kalapana road (Fig. 1-V). It was short-lived, however. The lava flow advanced less than 500 feet from the vent, and by early afternoon the activity was completely over.

At 8 P.M. on March 26 a new outbreak occurred 1,500 feet southwest of vent T. From this new vent (Fig. 1-W) a rapid aa flow advanced seaward along the south side of the earlier flows, and on March 28 spread across the Yamada coffee plantation and entered the sea. Small explosions caused by sea water coming in contact with the fluid hot lava threw up showers of sand of the sort that forms beaches such as the famous black sand beach of Kalapana. The fountains at cone T became inactive at 2 A.M. on March 27, though occasional roaring gas release continued at a vent on the northeast side of the cone. Early on the morning of March 27 still another vent became active at Y (Fig. 1).

On March 30 a lava fountain developed at the roaring vent on the northeast side of cone T, and a cinder and spatter cone was built around it, overlapping the adjacent older cone. On March 31 a small flow from this vent stopped only 2,000 feet from the Iwasaki camp. A flow that had started from vent Y on March 28 continued slowly down the southern edge of the previous flows and entered the ocean at Kehena on April 2. The lava fountains at vents T and Y gradually declined through April 3 to 5, and on April 6 became intermittent. Just after midnight on April 7 all lava activity ceased.

Then for more than 2 weeks things were completely quiet except for a glowing pit 10 feet across at the northeast base of cone Y and liberation of clouds of white sulphurous fume and steam from other vents. Earthquakes were very few and small. Apparently, however, molten lava continued to stand high in the conduits, for activity resumed quietly and without forewarning.

On April 24 a weak lava fountain broke out again in the crater of the first cone at vent T. It continued to play for only a few hours. Similar activity again appeared on April 26. For 3 or 4 hours scattered bursts of spatter were thrown to a height of 50 feet, and a small lava flow trickled into the bowl of the crater. The next day a flow of sluggish dense pahoehoe issued from fissures in lavas of the earlier part of the eruption about 1,000 feet southeast of the crater of cone T, and advanced 1,500 feet seaward before coming to a stop on April 28.

On April 30 weak fountaining and lava extrusion resumed at the site of the glowing pit at the base of cone Y. From then until May 16 activity at that site gradually increased. Semi-explosive ejections built a cone of loose cinder 75 feet high between cones W and Y, and close to its northeast base two small spatter cones were built. Lava spread around the vents. Then on May 16 a marked recrudescence of activity took place. The showers of discrete cinders were replaced by voluminous lava fountaining at the site of one of the two small spatter cones, and in the crater of the cinder cone. A large cone of welded spatter (Fig. 1-Z) rapidly grew around the two fountains, reaching a height of 150 feet and burying the cinder cone, the two small spatter cones, and the remnant of cone W. East of the cone was formed a broad pool of lava that spilled southeastward toward the ocean and northeastward into the crater of cone T. On May 19 the Observatory staff issued a warning of renewed danger to the Iwasaki camp; the camp, which had been reoccupied after the cessation of activity in early April, was again evacuated. At 9 P.M. lava entered the camp, destroying about half the buildings, but not until essentially all their contents had been removed.

On May 18 lava had started to spill from the pond northeast of cone Z into the valley northwest of cone T. Other small overflows into the valley occurred on subsequent days. At 11:30 P.M. on May 23 a great flood of lava broke over the divide into the head of the valley, and quickly formed another broad pond of lava north of cone T. This pond continued to grow through May 24, fed by a spectacular cascade in which the lava attained rates of flow estimated as more than 30 miles per hour. A flow worked northeastward from the pond along a line of old cracks leading toward vent area R. At 9:45 P.M. on May 24 a tongue from this flow spilled southeastward, and swept at great speed down across the intersection of the Kalapana and Kamaili roads. About 3½ hours later another similar spill-over sent lava across the Kamaili road 1,500 feet below the Kalapana road. This flow joined another slower aa flow that had spilled out of the pond near cone Z, and together they advanced on the remnant of the Iwasaki camp. One of the houses spared by the flow of May 19 had been moved away, and the metal roofing had been removed from another, but the remainder of the camp was totally destroyed in the early morning of May 25.

It almost seemed as though, with the final destruction of the camp, the volcano goddess felt her work was ended! At 11:15 A.M. on May 26, lava fountain activity ceased very abruptly, almost as though a valve had been closed in the conduit bringing the lava to the surface, and by the morning of May 27 all movement in the flows had stopped. Since then steam and sulfur gases have continued to escape from the vents, especially in vent areas J, R, and T, but there has been no other volcanic activity.

VOLUME AND COMPOSITION OF THE LAVAS

The flows and cones of the 1955 eruption cover an area of approximately 6.1 square miles, or 3,900 acres. Of this, about 1,100 acres were under cultivation. The estimated volume of the flows above sea level is approximately 111,000,000 cubic yards. The amount of lava that disappeared below sea level is unknown, but is estimated to be 5 to 10 million cubic yards. The total volume of

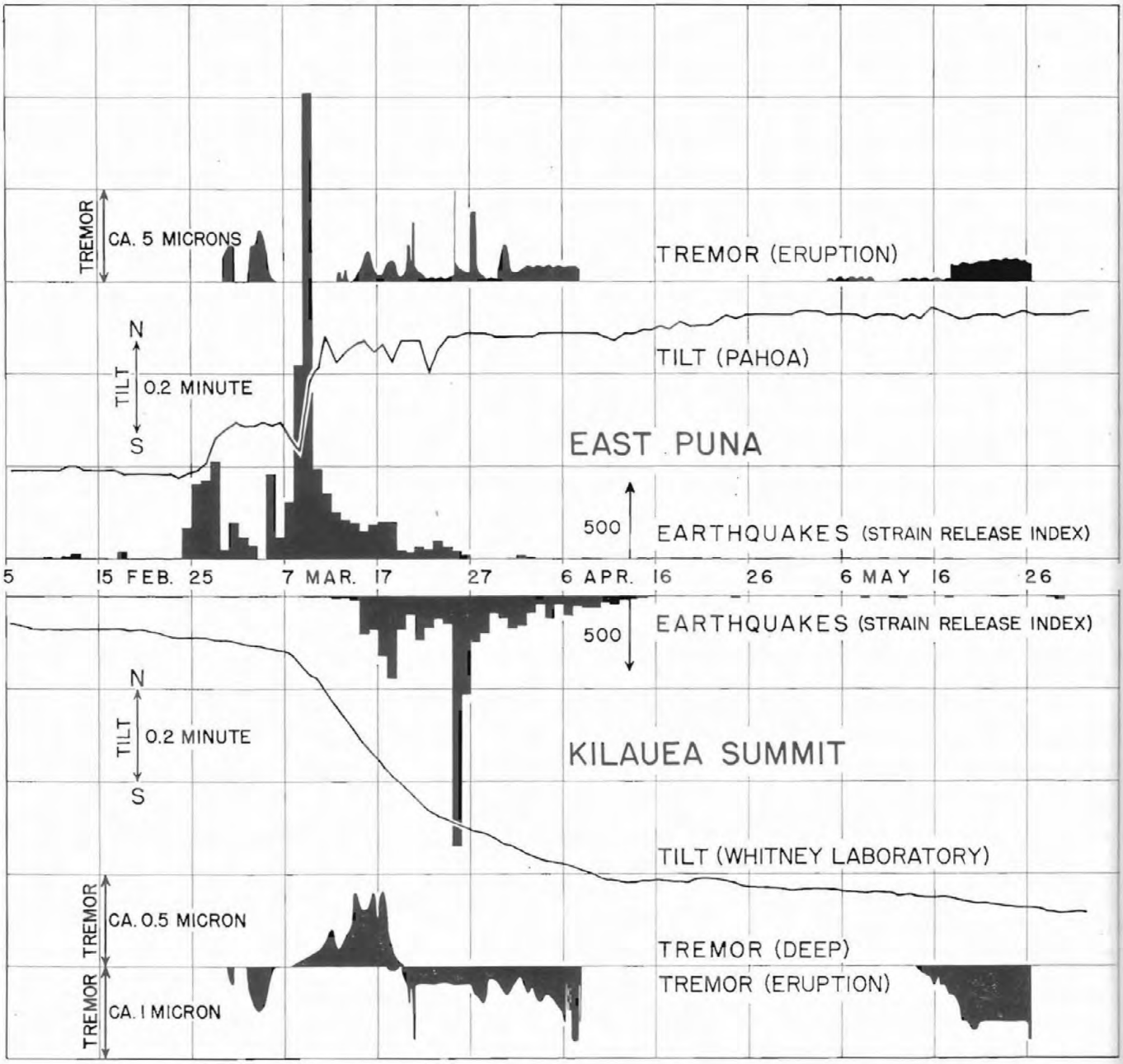

FIGURE 6. Graph showing ground tilting, strain release index, and amplitude of volcanic tremor in the eastern Puna and Kilauea summit regions during and just preceding the 1955 eruption. In the lower part of the graph tremor of deep origin is plotted above the line and tremor of shallow origin probably generated by flow of lava through the conduit near the surface is plotted below the line.

the cinder and spatter cones is approximately 2.5 million cubic yards. Thus the total volume of material extruded is approximately 120 million cubic yards. This is about twice the volume of material extruded during the 1952 eruption in Kilauea caldera, but is less than half the estimated volume of the nearby lava flow of 1840, and only about one-fifth that of the material extruded during the 1950 eruption of Mauna Loa.

The lava is basalt, containing moderately abundant phenocrysts of plagioclase. A few phenocrysts of olivine also are present in most specimens, but eight chemical analyses of the lavas made in the laboratories of the U. S. Geological Survey all show a slight excess of normative silica. The percentage of silica shows a general decrease through the course of the eruption, ranging from 51.24 in the earliest flow to 50.53 in the latest. Similarly, there was a slight decrease in the proportion of soda, and increase of magnesia and lime through the course of the eruption.

EARTHQUAKES, TILTS, AND HARMONIC TREMOR

The strain release index previously defined for the

short period, vertical Sprengnether seismograph at Uwekahuna (*Volcano Letter* 524), was extended empirically to permit its use with a Loucks-Omori seismograph. For a group of earthquakes recorded during October, 1954, on the Sprengnether and on a Loucks-Omori temporarily set up beside it, the average ratio of the maximum amplitude on the Sprengnether to that on the Loucks-Omori was 6.5. Using this ratio we can write:

S-R index $= \sqrt{(S\text{-}P)\ A} = \sqrt{(S\text{-}P)\ 6.5\ a}$, where S-P is the duration in seconds of the preliminary tremor, A is the maximum double amplitude in mm. on the Sprengnether record, and a is the maximum double amplitude in mm. on the Loucks-Omori record.

Two units into which it is convenient to divide Kilauea for a seismometric study of the eruption are east Puna (Kilauea volcano east of the bend in the east rift zone 2 miles east of Napau Crater) and Kilauea summit (Kilauea volcano minus the Puna unit defined above).

Because of the great uncertainty in reading and locating very small earthquakes, strain release indices were tabulated only for earthquakes having an index of $\sqrt{5}$ or larger. Since the significance of earthquakes occurring at abnormally large depths (greater than 25 km.) under the caldera and its environs is as yet poorly understood, and the epicenters of these earthquakes are very difficult to determine, such earthquakes were not included in the computation of strain release indices for the Kilauea summit unit.

In Figure 6 daily strain release indices from February 5 to May 31 for east Puna (based on the Loucks-Omori seismograph at Pahoa) and for Kilauea summit (based on the Sprengnether seismograph at Uwekahuna) are presented graphically. The daily strain release index for a given unit is the sum of the strain release indices of the earthquakes occurring during the day in that unit.

During the eruption sharp changes in the inclination of the earth's surface (tilt) were recorded both at Pahoa and at Kilauea caldera. At Pahoa, which lies about 5 km. northwest of the initial 1955 outbreak, the north-south component shows the clearest changes. Northward tilting at Pahoa results from a swelling of the rift zone southeast of the station. All of the tiltmeters and horizontal pendulum seismographs around Kilauea caldera recorded a large subsidence of the top of the volcano centered just east-northeast of Halemaumau. At the Whitney Laboratory, which lies about 3 km. N. 30° E. of this center of subsidence, the southward tilting recorded on the north-south component corresponds to subsidence of the caldera.

The north-south components of tilt recorded at Pahoa and at the Whitney Laboratory are plotted in Figure 6.

A gross measure of the rate of lava extrusion is provided by the amplitude of the harmonic tremor generated by the lava moving up through the feeding channels. The amplitudes of this tremor recorded on the Loucks-Omori seismograph at Pahoa and on a modified, short period, horizontal component Sprengnether seismograph operated in a basement on the east rim of Kilauea caldera also are presented in Figure 6. In addition, the amplitude of the short period tremor supposedly of deep origin recorded on the latter seismograph is given in the same figure.

This graph constitutes a summation of the most important data on earthquakes and tilt accompanying the eruption and presents this data for comparison with the time and intensity of lava extrusion (as measured by the harmonic tremor generated). The discussion of the relationship between earthquakes, tilt, and lava extrusion which follows is largely an interpretation of this graph.

Following the two big earthquakes near Kalapana on March 30, 1954, the only seismic activity which persisted in east Puna issued from the east rift zone near Pahoa. Tiny, sharp, shallow earthquakes at an average rate of about 25 per month stemmed from this region through the spring, summer, and fall of 1954. Late in the year the frequency of these earthquakes began to increase. A total of 67 occurred in November; 81, in December; 185 in January, 1955; and 350 between February 1 and February 23, 1955.

On February 23 a sharp earthquake of moderate size occurred at a depth of about 25 km. under the east rift zone of Kilauea near Makaopuhi Crater. After that date the number of earthquakes stemming from the east rift zone southeast of Pahoa rose sharply. Only 13 earthquakes from this region were recorded on February 23. This number increased rapidly to 130 on the 24th, 350 on the 25th, 600 on the 26th, and 700 on the 27th. Early on February 28 the frequency of earthquakes dropped off sharply; and at 7:45 A.M. the first harmonic tremor, heralding the beginning of a rapid flow of lava up through feeding channels, appeared on the Pahoa seismogram. The eruption had begun.

Northward tilting recorded at Pahoa between February 24 and March 1 indicates that the east rift zone was inflated during the swarm of earthquakes preceding the initial outbreak and during the brief life of the eruption on the flank of Puu Honuaula (Fig. 1, vents A-C).

While the eruption was in progress and lava was pouring out freely at the surface, very few earthquakes were recorded. Immediately after the cessation of activity at the Puu Honuaula vents (Fig. 1, A-C), earthquakes started again. The frequency of earthquakes slowly diminished after the outbreak at vent E (Fig. 1) on March 2 and as the opening of new vents came to a halt on March 3. While the most spectacular lava fountaining of the whole eruption was in progress at vent E on March 4, virtually no earthquakes were recorded.

By noon on March 5 the fountain at vent E was greatly reduced in size, and earthquakes in the eruption area had almost ceased. At about 12:30 a spectacular swarm of earthquakes began at a source near Kalalua Crater (9 miles west of the Pahoa–Kalapana road). For several hours all seismographs on Hawaii were in incessant motion. With diminishing intensity and frequency of earthquakes, this swarm lasted for about 24 hours. These earthquakes typically showed rather long period, dispersive, surface wave trains following preliminary phases which were relatively small and wholly lacking in short periods. They appear to have originated at shallow depth, perhaps about 5 kilometers.

On March 7 the Kilauea summit region began to respond to changes of the previous week in east Puna.

This response probably was made possible by splitting open of the east rift zone at depth near Kalalua Crater two days earlier. Although no increase in seismic activity at Kilauea caldera began until March 12, on March 7 the top of the volcano began to subside rapidly. At the same time a minute short period harmonic tremor closely resembling tremor from eruptions at Kilauea caldera began to record on a short period, horizontal component Sprengnether seismograph on the east rim of Kilauea caldera.

At Pahoa a brief southward tilting was under way by March 7 (Fig. 6). Several strong earthquakes originated south of the east rift zone, near Kalapana, and the number of earthquakes from the east rift itself began to increase rapidly on the same day.

On March 8 the tilting at Pahoa reversed, and a rapid inflation of the east rift zone south of Pahoa began. The dramatic swarm of earthquakes from the east rift zone intensified on March 8 and reached a maximum on March 9 when almost 1,400 earthquakes were recorded. On subsequent days the frequency of earthquakes from the east rift diminished gradually. Rapid tumescence of the east rift stopped on March 11. For the next two weeks only erratic back and forth tilting was recorded at Pahoa.

From March 7 to March 12, as the short period harmonic tremor usually associated with the outpouring of lava at Kilauea caldera steadily increased in amplitude, rapid subsidence of the caldera continued. During this interval no lava was extruded, but the east rift zone south of Pahoa was inflated to the accompaniment of an impressive swarm of earthquakes. This evidence suggests that plastic magma at depth (10 to 20 km., perhaps) oozed out from under the caldera and welled up beneath the badly fractured east rift zone.

Following the outbreak of lava on the east rift south of Pahoa on March 12, seismic activity in east Puna continued as long as new sections of the rift were being split open and new vents formed. After the last new section of the rift opened on March 26 seismic activity in Puna dropped to a very low level, where it remained for the rest of the eruption.

After a weak beginning on March 12 a swarm of earthquakes at Kilauea caldera suddenly built up to major proportions on March 15. This swarm reached a first maximum on March 18 and then declined slowly. Earthquakes of this group were mostly quite small and shallow. They appear to have originated within a few kilometers of the Uwekahuna station.

A sharp revival of earthquakes at Kilauea caldera on March 25 sent the number for the day to almost 1,100. Although the average size of the earthquakes diminished, an even greater number (almost 1,300) was recorded on March 26.

On the afternoon of March 27 a sharp shallow earthquake originating near the east rim of the caldera opened a crack across the Mamalahoa highway east of Hawaii National Park headquarters and cracked water lines in the park housing area. From March 25 to March 28 the focal zone of these earthquakes extended to depths as great as 45 km. From this same zone, about 45 km. deep under Kilauea caldera, several remarkable series of small earthquakes and spasmodic tremor were recorded prior to the 1955 eruption. The largest such series occurred from June 18 to June 21, 1954, shortly after the 1954 eruption in Kilauea caldera (see *Volcano Letter* 524).

Early on the morning of April 1, 1955, the largest earthquake that occurred during the eruption originated at a depth of about 10 km. near the south rim of Kilauea caldera.

The subsidence of the caldera which began on March 7 continued until the end of the swarm of earthquakes in the summit region in mid-April, although the rate of subsidence decreased on March 23 and again on April 10. After a very weak reversal of tilt between April 13 and April 22, slow subsidence of the caldera started once more and continued until the end of the year. Assuming the area of sinking to have been the same as that in 1924 (Wilson, R. M., 1935. *Ground surface movements at Kilauea volcano, Hawaii.* Hawaii Univ. Res. Pub. 10, pp. 54-55, fig. 8), and the amount of sinking throughout the area to have had the same proportions as in 1924, the volume of sinking in the summit region from February 20 to April 10 has been calculated to be about 216,000,000 cubic yards. This is of the same order of magnitude as the volume of lava extruded in eastern Puna during the same interval.

After the cessation of eruptive activity in Puna on April 7, the east rift zone again began to swell slowly. Only a few tiny earthquakes occurred in this region between April 7 and the revival of activity at an earlier vent on April 23. This swelling which stopped again with the revival of activity on April 23, was the only forerunner of the final phase of the eruption. The channels had remained open, and when more lava became available, perhaps oozing out from under the caldera, it simply welled up and poured out without the premonitory earthquakes resulting from further opening of the rift.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JULY–DECEMBER, 1955

By GORDON A. MACDONALD and JERRY P. EATON

VOLCANOLOGY

July

The month of July was seismically and volcanically quiet on the island of Hawaii. The seismograph in the Whitney Laboratory of Seismology, at the northeast edge of Kilauea caldera, recorded only 21 earthquakes, most of them very small. The Mauna Loa seismograph recorded 40 quakes during the month, 12 less than during June. There also, most were very small.

The seismograph at Pahoa School recorded 29 earthquakes during July, as compared with 28 during June. Most of the quakes were small, and probably originated along the part of the east rift zone of Kilauea volcano affected by the recent eruption. At 10:23 P.M. on July 23 a quake felt strongly on the rift zone at the Pahoa–Kalapana road was felt only weakly in Pahoa and

Kaueleau. It originated at a very shallow focus near Iilewa Crater.

The ground surface at the northeast rim of Kilauea caldera tilted slightly eastward during the month. Normally during this season of the year the tilting is northeastward. The absence of northward tilting probably indicates a slight continuation of the decrease of volcanic pressure beneath the caldera that was conspicuous during the eruption in east Puna.

Volcanic activity at the surface was confined to mild steaming and fuming at the vents of the recent eruption in east Puna. On several days steam release was strong near the Nii house on the old Kalapana road, and at the vents on Namba's hill southwest of Puu Kii. However, this appeared to result from heavy rains. At one vent the sound of steam bubbling through accumulated rain water could be heard. Gas flames no longer were observed along the Kalapana road.

Except for the occasional periods of voluminous steaming resulting from heavy rains, there appears to have been a gradual, slight but definite, decrease in temperature and fume release at the east Puna vents during June and July. That, together with the low level of seismic activity, appeared to indicate that the east Puna eruption was over.

August

Volcanoes on the island of Hawaii remained fairly quiet throughout the month of August, although two deep earthquakes were felt lightly over a large part of the island group. The seismograph in the Whitney Laboratory of Seismology recorded only 23 earthquakes, two more than during the month of July. The seismograph at Pahoa School recorded 39 quakes, 10 more than during July.

Most of the seismic activity was recorded at the Mauna Loa station. Throughout most of the month activity at that station also was small, but between 11 A.M. on August 9 and midnight on August 10 more than 600 very small earthquakes were recorded. The origin of these quakes is not known with certainty, but they probably came from the nearby northeast rift of Mauna Loa.

At 7:18 A.M. on August 7 an earthquake was felt generally on the islands of Hawaii and Maui, and by many people on Oahu. It originated at a depth of about 25 miles beneath the Waimea area on the island of Hawaii. Another quake, felt to about the same degree over the same area at 2:28 A.M. on August 14, originated at a depth of about 22 miles beneath the Hilina Pali area, on the south slope of Kilauea volcano. A slight earthquake was felt at 5:27 A.M., August 19, in the volcano area. On August 29, at 2:41 and 2:44 A.M., slight quakes were felt at Nanawale Ranch, 3 miles east of Pahoa. They had their origin on the east rift zone of Kilauea.

Tilting of the ground surface at the northeast edge of Kilauea caldera was eastward, rather than north-northeastward, as is normal at that time of the year. This probably indicates a decrease of pressure beneath the volcanic structure to the south and southeast of the Whitney Laboratory.

Liberation of steam and sulfurous fume continued weak to moderate along the vent fissures of the recent eruption in east Puna. There was no sign of any resumption of volcanic activity in east Puna, or elsewhere.

September

Volcanoes on the island of Hawaii remained quiet during the month of September. The Bosch-Omori seismograph in the Whitney Laboratory of Seismology recorded only 22 earthquakes. This was one less than during August, and one more than during July. The more sensitive Sprengnether vertical seismograph at the Uwekahuna station recorded 164 quakes during the month. The Mauna Loa seismograph recorded 47, and the seismograph at Pahoa School recorded 38 quakes.

At 2:16 on the morning of September 26 an earthquake was felt strongly at the Kapapala Ranch, and weakly all over the southern part of the island, from Kalapana to south Kona. It originated on the southwest rift zone of Mauna Loa two or three miles south of Puu o Keokeo. No damage was reported.

Eastward tilting of the ground surface at the northeast rim of Kilauea caldera was approximately normal, but northward tilting was much less than usual during that season of the year. This appears to represent a small reduction in volcanic pressure beneath Kilauea and adjacent parts of the east rift zone.

October

During the month of October earthquake activity on the island of Hawaii increased somewhat over that of preceding months. The Bosch-Omori seismograph at the Whitney Laboratory of Seismology recorded 79 earthquakes, as compared with 22 during the month of September. The more sensitive Sprengnether vertical seismograph at Uwekahuna recorded 327 quakes.

Most of the earthquakes originated at or near Kilauea caldera, and probably were related to the slight sinking of the caldera region (indicated by tilting of the ground surface) that had continued ever since the end of the Puna eruption in late May. The quake felt in the Volcano district at 12:42 on the morning of October 12 came from a depth of about 15 miles beneath Kilauea caldera. Another, felt in Hilo at 10:07 P.M. on October 29, probably came from the same region. A quake felt in the Volcano district and at Pahala at 4:33 P.M. on October 24 originated near the mouth of Wood Valley, probably on the Kaoiki fault zone. Earthquakes felt at Kamuela and Umikoa at 5:17 and 11:45 P.M. on October 24 came from a depth of about 18 miles beneath the Waimea region.

The strongest earthquake of the month occurred at 4:56 P.M. on October 26, and originated near the summit of Mauna Loa. Several smaller quakes also came from Mauna Loa. Eastward tilting of the ground surface at the edge of Kilauea caldera, accompanied by less than normal northward tilting, may have indicated a small increase of volcanic pressure beneath Mauna Loa.

A series of landslides on the southwest wall of Halemaumau crater began in late September and continued into October. A large segment of the crater rim, estimated to be 100 feet long, 75 feet high, and 5 to 10 feet thick, fell into the crater during the night of October 1. The last large slide occurred on October 10, but occasional small slides continued throughout the rest of the month.

November

The Hawaiian volcanoes were very quiet through the month of November. The Bosch-Omori seismograph in the Whitney Laboratory, on the northeast rim of Kilauea caldera, recorded only 19 earthquakes during the month, the smallest number since February, 1953. The Sprengnether vertical seismograph at Uwekahuna recorded 100 quakes during November. The Loucks-Omori seismograph in the Mauna Loa station recorded 47 quakes, most of them very small.

An earthquake at 10:37 A.M. on November 2 was reported felt at Hilo, Pahoa, and in the Volcano district. It originated at a depth of about 10 miles on the east rift zone of Kilauea, near the caldera. On November 3 and 4 several tiny quakes felt in Naalehu originated very close to that town. A quake felt in central Kona at 8:16 A.M. on November 13 had its origin near Kealakekua, probably on the Kealakekua fault. At 3 P.M. on November 21 a sharp earthquake was felt only at the Volcano House and the nearby headquarters building of Hawaii National Park. Its origin was beneath the northeastern edge of Kilauea caldera.

The Pahoa seismograph recorded 17 earthquakes during November. One of these, at 8:15 P.M. on November 29, was felt at Pahoa School. It originated at a depth of about 3 miles on the east rift zone of Kilauea southeast of Pahoa. Steam and sulfur gas continued to escape from the vents of the 1955 eruption, particularly those at the old Kalapana road, those south-southeast of old Iilewa Crater, and those south of the Kapoho road. There had been essentially no change in the temperature of the escaping steam since shortly after the end of the eruption. Several places in the last flows southwest of the Kamaili–Opihikao road remained very hot. At one of them the temperature was still about 870° F. There were no signs whatever of any renewal of volcanic activity in Puna.

Tilting of the ground surface at the Whitney Laboratory was almost due eastward throughout the month. Normally at that season of the year the tilting is north-northeastward. The absence of northward tilting during November appeared still to be

the result of a slow sinking of the top of Kilauea volcano south of the Whitney Laboratory that had continued ever since the end of the Puna eruption. The sinking is believed to have been caused by a small reduction in volcanic pressure beneath the volcano. The eastward tilting, combined with an absence of northward tilting, may indicate a slight swelling of Mauna Loa volcano, but the evidence is inconclusive.

December

Except for the continued liberation of steam along the vents of the 1955 eruption, Hawaiian volcanoes remained quiet during December.

Twenty-nine earthquakes, about the average for months of volcanic quiet, were recorded during December at the Whitney Laboratory. Only 10 earthquakes from the Puna area were recorded at Pahoa during December.

On December 12 and 13 a swarm of tiny earthquakes originated about 45 km. beneath Kilauea caldera. The sensitive Sprengnether seismograph at Uwekahuna recorded about 200 earthquakes from that source on those two days. A total of 307 earthquakes, mostly very small, were registered on the Sprengnether seismograph during the month.

A small earthquake which probably originated in the Hualalai volcano was felt at Honokohau at 3:15 P.M. on December 7. The earthquake felt on the island of Oahu at 2:23 P.M. on December 26, was recorded feebly on the Uwekahuna seismograph. At 2:14 P.M. on December 28 an earthquake originating along the southwest rift of Kilauea was felt at the Kapapala ranch. Later the same day, at 6:02 P.M., an earthquake stemming from the north rim of Kilauea caldera at a very shallow depth was felt at Kilauea Military Camp.

SEISMOLOGY

Local Earthquake Data, July–December, 1955

(Based on Bosch-Omori seismograph on northeast rim of Kilauea caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Total	Local Seismicity*
July 3	2	2	1	0	0	0	5	2.5
10	1	1	0	1	0	0	3	2.75
17	1	1	0	1	0	0	3	2.75
24	2	3	2	0	0	0	7	4.0
31	3	4	0	0	0	0	7	2.75
Aug. 7	4	2	0	0	0	1	7	6.0
14	2	4	0	0	0	1	7	6.5
21	1	3	0	0	0	0	4	1.75
28	1	1	0	0	0	0	2	0.75
Sept. 4	2	2	0	0	0	0	4	1.5
11	1	2	0	0	0	0	3	1.25
18	4	4	0	1	0	0	9	5.0
25	6	4	0	0	1	0	11	6.5
Oct. 2	3	2	0	0	0	0	5	1.75
9	14	9	1	1	0	0	25	11.0
16	17	3	1	0	0	0	21	6.75
23	10	8	2	0	0	1	21	12.5
30	4	1	0	1	0	0	6	3.5
Nov. 6	2	2	0	0	0	0	4	1.5
13	1	1	0	1	0	0	3	2.75
20	1	1	0	1	0	0	3	2.75
27	2	1	0	0	0	0	3	1.0
Dec. 4	1	4	0	0	0	0	5	2.25
11	13	4	0	0	0	0	17	5.25
18	0	0	0	0	0	0	0	0.0
25	2	4	0	0	1	0	7	5.5

* For definition of local seismicity see *Volcano Letter* 371 or 512. Each local earthquake is assigned a seismicity value according to its strength, as follows: tremor, 0.25; very feeble, 0.5; feeble, 1.0; slight, 2.0; moderate, 3.0; strong, 4.0. These values are totaled to give the weekly local seismicity. Continuous volcanic tremor ("harmonic tremor") is ignored in the calculation. The strength assigned to the earthquake depends on the double amplitude of the maximum oscillation it causes on the Bosch-Omori seismograph, as follows: tremor, less than 0.5 mm.; very feeble, 0.5 to 4 mm.; feeble, 4 to 11 mm.; slight, 11 to 25 mm.; moderate, 25 to 60 mm.; strong, greater than 60 mm.

Table of Tilt at Seismograph Stations on Rim of Kilauea Caldera

Week Beginning	Whitney Station (Northeast rim) Amount	Whitney Station (Northeast rim) Direction	Uwekahuna Station (West rim) Amount	Uwekahuna Station (West rim) Direction
July 3	0.4″	S 18° W	1.0″	S 18° E
10	0.5″	N 45° E	1.4″	S 27° E
17	0.8″	E	1.3″	S 14° E
24	0.4″	N 18° E	1.6″	N 11° W
31	0.1″	W	1.3″	N 14° W
Aug. 7	0.3″	N 27° E	0.6″	N
14	0.3″	S 45° E	0.4″	N 45° W
21	0.9″	N 67° E	0.6″	S
28	0.6″	N 79° E	0.9″	S 45° E
Sept. 4	0.8″	E	0.7″	N 63° W
11	0.1″	N	1.0″	S 18° E
18	1.2″	N 84° E	1.4″	N 27° W
25	0.3″	N 45° E	0.7″	S 27° E
Oct. 2	0.3″	N 26° E	1.0″	S
9	0.4″	S 57° E	2.4″	N 23° W
16	0.4″	S	2.0″	N 9° W
23	0.9″	N 33° E	0.0″	....
30	0.4″	E	1.6″	S 11° E
Nov. 6	0.5″	E	1.9″	N 31° W
13	0.6″	N 37° E	2.3″	S 8° E
20	0.0″	....	2.3″	N 8° W
27	0.4″	S 19° E	1.4″	N 27° W
Dec. 4	0.4″	S 34° E	1.0″	S
11	0.5″	S 89° E	2.9″	S 6° E
18	2.6″	S 60° E	5.1″	N 21° W
25	0.7″	S 31° W	0.9″	N 45° W

Local Earthquakes

The data for the following local earthquakes were determined from seismographs on the islands of Hawaii and Maui operated by the Hawaiian Volcano Observatory. Except for smaller earthquakes of special interest, only earthquakes classed as slight or larger were included in the list. The intensity ratings assigned are based on the Bosch-Omori seismograph at the Whitney Laboratory. This intensity scale has been extended empirically to permit its use with the Loucks-Omori and Sprengnether seismographs. The entries for a given earthquake are: date, time of arrival at the nearest station (Hawaiian standard time), intensity at the nearest station, name of the nearest station, epicenter, and general remarks.

July 3, 10:40:18, slight at Uwekahuna. Kilauea caldera.

July 10, 14:34:49, slight at Uwekahuna. Five km. north of Apua Point.

July 23, 11:27:16, moderate at Uwekahuna. Just south of Makaopuhi Crater. Felt in Hilo.

July 23, 22:03:17, moderate at Pahoa. East rift of Kilauea near Pahoa.

July 25, 07:50:34, feeble at Naalehu. Off south shore of Hawaii at 19° N., 155° 10′ W.

July 27, 02:58, slight at Kona. Near Keahole Pt. Felt over northwest one third of the island of Hawaii.

Aug. 7, 07:17:44, strong at Kamuela. Five km. northeast of Kamuela at a depth of 40 km. Felt over the entire island of Hawaii, on Maui, and on Oahu.

Aug. 9, 21:33:25, very feeble at Uwekahuna. About 60 km. deep in the vicinity of Kilauea caldera. This earthquake is the largest of several hundred originating in the same region on Aug. 9 and Aug. 10.

Aug. 14, 02:28:05, strong at Uwekahuna. On the Hilina fault system south of the Volcano Observatory at a depth of about 25 km. Felt over the entire island of Hawaii, on Maui, on Oahu, and by a few persons on Kauai.

Sept. 19, 14:01:54, slight at Pahoa. East rift of Kilauea near Pahoa.

Sept. 26, 02:16:00, strong at Naalehu. Southwest rift of Mauna

Loa near Puu Keokeo. Felt over the southwest half of the island of Hawaii.

Oct. 12, 00 : 41 : 42, slight at Uwekahuna. Under Kilauea caldera at a depth of about 25 km. Felt at Hawaii National Park.

Oct. 24, 17 : 16 : 53, slight at Kamuela. Near Kamuela at a depth of about 25 km.

Oct. 26, 16 : 55 : 45, strong at Mauna Loa. Near the northeast end of Mokuaweoweo. Felt at Hawaii National Park.

Nov. 2, 10 : 36 : 44, slight at Uwekahuna. East rift of Kilauea near Kilauea caldera at a depth of about 15 km. Felt at Volcano, Pahoa, and Hilo.

Nov. 13, 08 : 16 : 24, (time at Uwekahuna), strong at Kona. Near Kealakekua. Felt in central Kona.

Nov. 21, 14 : 59 : 54, slight at the Whitney Laboratory. Northeast rim of Kilauea caldera. Felt at Hawaii National Park Headquarters.

Nov. 29, 20 : 15 : 20, (time at Uwekahuna), feeble at Pahoa. East rift of Kilauea southeast of Pahoa at a depth of about 5 km. Felt at Pahoa.

Dec. 12, 12 : 33 : 12, tremor at Uwekahuna (very feeble at Mauna Loa). Under Kilauea caldera at a depth of about 45 km. This earthquake is one of the largest of a swarm of about 200 earthquakes stemming from this focus on Dec. 12 and 13.

Dec. 26, 14 : 23 : 34, (time at Uwekahuna), very feeble at Haleakala. Near the north coast of Molokai. Felt on Oahu.

Dec. 28, 18 : 02 : 25, moderate at the Whitney Laboratory. Near the north rim of Kilauea caldera. Felt at Kilauea Military Camp.

Distant Earthquakes

The following earthquakes of distant origin were recorded on the seismographs at the Hawaiian Volcano Observatory (19° 25.4′ N. latitude, 155° 17.7′ W. longitude). Beginnings of phases are given in Greenwich civil time, which is 10 hours faster than Hawaiian standard time. Locations of epicenters, magnitudes, and depths of focus are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey.

July 3, eP 14 : 33 : 56.7, 52° N., 178° E. Rat Islands, Aleutian Islands.

July 4, eP 14 : 27 : 09.8, 51½° N., 177° E. Rat Island, Aleutian Islands. Magnitude 6½—6¾.

July 6, eP 02 : 03 : 03.9, 51° N., 158° E. Kamchatka. Magnitude 6¾.

July 20, eL 00 : 11 : 15, 56½° N., 153° W. Near south coast of Kodiak Island. Magnitude 6.

July 21, eP 11 : 58 : 56.4, 25° S., 74° W. Southern Peru. Magnitude 6¾. Depth about 100 km.

July 24, iP 16 : 31 : 58.2, 24° N., 122° E. Near east coast of Formosa. Felt at Hualien and Shinko.

July 26, eL 04 : 24 : 34, 56½° N., 153° W. Kodiak Island foreshock. Magnitude 6.

July 27, eP 18 : 26 : 29.0, 56½° N., 153° W. Near south coast of Kodiak Island. Magnitude 6¼.

Aug. 6. iP 08 : 39 : 19.5, 21½° S., 177½° W. Tonga Islands region. Magnitude 6¾. Depth about 350 km.

Aug. 16, iP 11 : 56 : 17.4, 6° S., 155° E. Solomon Islands. Magnitude 7¼. Depth about 200 km.

Aug. 21, iP 17 : 45 : 14.5, 3° S., 137½° E. New Guinea. Magnitude 6¾—7.

Aug. 23, eP 15 : 39 : 21.6, 43½° N., 128° W. About 170 miles
eT 16 : 13 : 57, off coast of Oregon. Magnitude 6—6½.

Aug. 24, eL 07 : 12 : 26, 44½° N., 129½° W. Off coast of Oregon.
eT 07 : 36 : 47,

Aug. 28, eP 20 : 23 : 48.9, 14° N., 91° W. Near coast of Guatemala. Magnitude 6¾. Depth about 60 km.

Sept. 3, eP 12 : 46 : 34.8, 14° N., 91° W. Guatemala. Felt. Magnitude 6½. Depth about 100 km.

Sept. 3, iP 16 : 35 : 21.7, 1° N., 123° E. Celebes.

Sept. 8, eP 03 : 36 : 56.3, 7° S., 155½° E. Solomon Islands.

Sept. 13, eP 02 : 07 : 44.8, 52° N., 176° W. Andreanof Islands,
eT ?02 : 45 : 48, Aleutian Islands. Magnitude 5¾—6. Depth about 60 km.

Sept. 15, eP 12 : 42 : 06.1, 5° S., 134½° E. Off coast of western New Guinea. Magnitude 6¾.

Sept. 20, eP 13 : 30 : 00.2, 32° S., 178° W. Kermadec Islands. Magnitude 6½.

Sept. 22, eP 03 : 36 : 55.0, 24° N., 123° E. Off east coast of Formosa. Felt: Taipeh.

Sept. 25, eP 19 : 11 : 13.9, 6° N., 127½° E. Off east coast of Mindanao, Philippine Islands. Felt: Mindanao. Magnitude 6½. Depth about 100 km.

Sept. 26, iP 08 : 38 : 17.7, 15½° N., 92½° W. Chiapas, Mexico. Magnitude 6¾. Depth about 200 km.

Oct. 5, eP 09 : 06 : 47.9, 53½° N., 161° E. Near east coast of Kamchatka.

Oct. 10, eP 09 : 07 : 33.1, 5° S., 153° E. New Britain. Magnitude
eL 09 : 25 : 45, 7¼.

Oct. 13, iP 09 : 35 : 58.6, 9½° S., 161° E. Solomon Islands. Magnitude 7.

Oct. 14, eL 09 : 09 : 44. 3° S., 103½° W. Pacific Ocean, west of Galapagos Islands. Magnitude 6—6¼.

Oct. 21, iP 19 : 10 : 14.4, 21° S., 179° W. Fiji Islands. Depth about 650 km. Magnitude 6¼.

Oct. 21, eP 23 : 22 : 08.6, ½° S., 123½° E. Northern Celebes.

Nov. 10, iP 01 : 51 : 32.3, 15° S., 174° W. Samoa Islands. Depth about 100 km. Magnitude 7¼—7½.

Nov. 14, eP 13 : 32 : 36.1, 17½° N., 145½° E. Marianas Islands. Depth about 150 km.

Nov. 15, eP 10 : 13 : 49.2, 55½° N., 155° W. Off south coast of
eT 10 : 51 : 03, Alaska Peninsula. Magnitude 6—6¼.

Nov. 22, eP 03 : 33 : 37.1, 24½° S., 123° W. Eastern Tuamotu
eS 03 : 41 : 14.1, Archipelago. Magnitude 6¾—7.
eL 03 : 52 : 16.1,
eT 04 : 30 : 51,

Nov. 23, eP 06 : 38 : 32.2, 50½° N., 157° E. Near south coast of
eL 06 : 52 : 33, Kamchatka. Depth about 60 km. Magnitude 7—7¼.

Dec. 19, eP 03 : 25 : 42.1, 8½° N., 127° E. Near east coast of Mindanao Island, Philippine Islands.

Dec. 27. iP 17 : 29 : 48.4, 32° S., 180°. Kermadec Islands. Depth about 400 km.

VOLCANO NOTES AND NEWS

CHANGE IN VOLCANO OBSERVATORY STAFF

On December 12, Dr. Jerry P. Eaton replaced Gordon A. Macdonald as Director of the Hawaiian Volcano Observatory. The rest of the staff remains unchanged. Dr. Macdonald will be transferred to the United States mainland in the summer of 1956, and will be attached to the Denver office of the General Geology Branch of the Geological Survey. No replacement for him has yet been named.

ERROR IN Volcano Letter 526, "KAUAI, AN ANCIENT HAWAIIAN VOLCANO"

A phrase was omitted in the first sentence on page 2 of *Volcano Letter* 526. The sentence should read: "The rocks that accumulated in the big summit caldera are named the Olokele formation, and those that filled the small caldera on the southeastern slope of the shield are named the Haupu formation."

POSSIBLE ERUPTIONS NEAR NECKER ISLAND AND WEST OF THE HAWAIIAN CHAIN

On August 20 the crew and passengers of a M.A.T.S. plane sighted an oval area of steaming turbulent water, about a mile across, between Necker and Nihoa Islands in the northern part of the Hawaiian chain. The patch was surrounded by a thin line of yellowish surf, and near one end of the oval was what appeared to be an acre or two of dry land. Yellowish water drifted off down current. The next day all this had disappeared, and there was left only a slick appearance of the water surface where the turbulence had been, and a series of large waves sweeping outward away from the area.

The description is typical of submarine eruptions, and it appears probable that a brief submarine eruption did occur. The supposed dry land that disappeared so quickly probably was a raft of floating pumice. Hawaiian pumice is so permeable that it floats only a very short time.

The eruption occurred in a part of the Hawaiian Islands in which there has been no known previous volcanic activity during historic times. It is quite possible, however, that such activity may have occurred. The nearby islands are uninhabited. The area lies away from the regular shipping lanes, and although it is visited nowadays by many fishing boats, this is a rather recent development. Eruptions could easily have occurred in that area during the 19th century without being observed by anyone. Even today, with frequent air travel over the area, only one plane chanced to see it.

Although it was not specifically foreseen, the eruption is not surprising. The entire Hawaiian ridge, from Kure and Midway Islands on the northwest to Hawaii on the southeast, is volcanic. The northwestern islands are mostly old and deeply eroded, but geologically young lava flows are found on both Oahu and Kauai. Geologists working in the islands have long recognized the possibility that volcanic activity might occur again on those islands. The probability is small. It has not occurred during all the time the Hawaiian people have lived in the islands, and it is not likely to occur in the lifetime of any living person. But it is nevertheless a distinct possibility.

On September 22 planes reported brown and yellow streaks in the ocean and smoke rising from the water about 385 miles due west of Honolulu (205 miles south of Necker Island). The reports made a much less definite picture than those of August 20, and it is not at all certain that the disturbance was of volcanic origin.

VOLCANIC ACTIVITY IN OTHER PARTS OF THE WORLD

Volcanoes in many parts of the world have been active in recent months. Mount Etna, in Sicily, was active in late June and July, and lava flows threatened several villages. On September 3 an outbreak 14 miles south of Mexicali, in northern Lower California, Mexico, appears to have been a low temperature eruption related to mud volcanoes and geysers rather than to ordinary volcanic eruptions. A similar eruption appears to have occurred in the same region in 1877. In October a ship passing through the Philippine Sea reported boiling water about 600 miles east of the Didicas Rocks, where volcanic activity built a dome in 1952 and 1953. This position is at approximately 19° 10′ N., and 132° 15′ E., nearly due south of the Daito Islands, and a little south and west of a point where a submarine eruption was reported in 1854 (Sapper, K., Vulkankunde, p. 320). On October 22 long-dormant Bezymyanny volcano in Kamchatka erupted, and continued active into late November.

Particularly abundant activity occurred in Japan. The following information was supplied by Mr. Akira Suwa, Chief of the Volcanological Subsection of the Central Meteorological Observatory. On July 24 Naka-dake, one of the vents of Aso volcano in central Kyushu, broke into strombolian eruption, throwing incandescent bombs to a height of 200 to 300 meters above the crater rim. On October 13 eruption commenced at the South Peak of Sakurajima, near the southern end of Kyushu. Activity continued until the end of the month. On November 19 a minor explosion occurred at Me-akan-dake, near the Akan caldera in eastern Hokkaido.

Stromboli, off the western coast of Italy, was reported in eruption on January 3, 1956. On January 4 Merapi volcano, in central Java, erupted, sending glowing clouds down the mountainside toward populous districts at the base of the volcano.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director
Jerry P. Eaton, Seismologist
Chester K. Wentworth, Geologist, part-time
Burton J. Loucks, Instrument Maker
John C. Forbes, Assistant Instrument Maker
Akira Yamamoto, Secretary

Seismograph Station Operators:

Hilo Station:
Sister M. Thecla, St. Joseph's School

Kona Station:
Howard M. Tatsuno, Konawaena School

Pahoa Station:
Kongo Kimura, Pahoa School

Kamuela Station:
Thomas C. Mills, Waimea School

Haleakala Station:
Hawaii National Park Staff

Naalehu Station:
Alfred K. Kahakua, Naalehu School