PREFACE

The Volcano Letter was an informal publication issued at irregular intervals by the Hawaiian Volcano Observatory (HVO) during the years 1925 to 1955. Individual issues contain information on volcanic activity, volcano research, and volcano monitoring in Hawaii. Information on volcanic activity at other locations is also occasionally included.

To increase accessibility of this resource, previously only available in print format, this compilation was scanned from the highest quality Volcano Letter originals in the HVO archives. Optical Character Recognition (OCR) was run on the entire file. In addition, the file size was reduced by making it compatible with only Adobe Reader v. 8 and later. The scanning was done by Jim Kauahikaua and the quality control and posting was done by Katie Mulliken, both current staff at the Hawaiian Volcano Observatory.

Originals of the first three Volcano Letters could not be found so copies plus the Title Page and Index for 1925 have been extracted from an excellent scan of Volcano Letters for 1925 to 1929 available in Books.Google.com

The Volcano Letter was published by HVO through multiple changes in administration, including the Hawaiian Volcano Research Association (1925-1932), the U.S. Geological Survey (1932-1935), the Department of the Interior (1935-1938), and the University of Hawaiʻi (1938-1955). Issues 1–262 were published weekly from January 1, 1925, to January 2, 1930, and consisted of a single page of text. Issues 263–384, also published weekly, from January 9, 1930–May 5, 1932, were generally longer—four-pages—and provided more detail on volcanic activity, including photographs, maps, and plots. Weekly issues 385–387, published May 12–26, 1932, were a single page of text due to budget reductions brought on by the Great Depression. Budget restrictions reduced the publishing frequency to monthly for issues 388–428, covering the period of June 1932 to October 1935; these issues were generally shorter, 1–2 pages, and sometimes featured figures. From November 1935 to July 1938, issues 429–461 remained monthly but increased in length (generally eight pages) and featured figures frequently. Issues 462–530, published over the period of August 1938–December 1955, varied in length from 2–15 pages, but were published quarterly, rather than monthly.

Six of the letters are misnumbered:
Jan. 21, 1926 number is 55 though it should 56
July 29, 1926 number is 82 though it should be 83
Feb. 16, 1928 number is 161 though it should be 164
May 31, 1928 number is 197 though it should be 179
Nov. 29, 1928 number is 204 though it should be 205

For background information on the Hawaiian Volcano Observatory: https://pubs.usgs.gov/gip/135/

The Volcano Letter publications are also available in print:

Fiske, R.S., Simkin, T., and Nielsen, E.A., eds.,1987, The Volcano Letter, No. 1-530. See https://www.si.edu/object/siris_sil_328087

April 2023

The Volcano Letter

Two dollars per year **Ten cents per copy**

No. 314—Weekly Hawaiian Volcano Observatory, National Park, Hawaii January 1, 1931

One of Dr. Stone's photographs made during his ascent of Calbuco January 19, 1930, a year after the eruption described by Dr. Reichert on January 6, 1929. This is looking down into the new crater of the volcano, from the north side of the summit, showing thick white fume issuing from the bottom.

1929 ERUPTION OF CALBUCO, CHILE

By Dr. Federico Reichert

(Translated by J. B. Stone from Riel y Fomento, No. 87, July 1929).

It was in the afternoon of the 5th of January, 1929, when, accompanied by a friend, I undertook to climb the peak Derrumbo situated to the south of Lake Todos los Santos, a body of water well known to those making the trip between Bariloche and Puerto Montt. On the accompanying map of the Pacific Ocean these places may be found just where the longshore islands begin on the west side of South America, in the great valley of Chile, about 600 miles south of Valparaiso.

The prospect for the projected climb was very favorable. The sky was completely clear. The sun was brilliant and the calm absolute. Only the barometer marked an extraordinary and inexplicable minimum. In spite of this abnormal low pressure we resolved to begin the trip, and were able to climb that afternoon to an altitude of approximately 1,200 meters, where we stopped and were overtaken by night.

At about 2 o'clock of the following morning we were awakened by a strange noise and, on looking toward the horizon, we saw a thick mass of clouds, which was approaching rapidly from the west. The rarefaction of the atmosphere was clearly manifested. We supposed that a storm was approaching, a phenomenon often occurring in these regions. The stars still shone. Believing that it was a temporary atmospheric disturbance, we decided to wait until the clouds should discharge themselves, and then continue the interrupted ascent.

But this plan was rudely changed at 5 a. m. when we saw that the clouds were taking forms ever more curious and strange, and were approaching our position like phantasms, threatening to envelop the whole neighborhood and the summit of the peak we were trying to scale. At the same time there was heard a distant detonation different from the report of thunder, and the sky darkened thickly. We thought it would rain, but it did not do so. We decided then to abandon our plan and to return to the shore of the lake, where we had left a boat tied. This we did.

After setting out downhill and about 7 a. m., we found ourselves faced by a strange condition. At first we had the sensation that it was raining, but very quickly found we were mistaken. We looked up and verified the fact that it was a volcanic eruption, which in my judgment proceeded from the mountain Calbuco, situated some fifteen or twenty kilometers distant from the spot, and the only volcano at that time characterized by periodic activity in this region.

Little by little the sky was darkening more. The south

Overturned trees in the valley of Rio Caliente half buried in ash and swept by the blast that had rushed out from the eruption of Calbuco. Just such effects were found on the west side of Sakurajima in 1914. Photo Stone.

cove of Lake Todos los Santos was wrapped in an impenetrable blackness. Only in the north there were seen patches of faint light which quickly disappeared. At 9 a. m. we reached our moored boat. Meanwhile volcanic ash fell intermittently. We embarked at once bound for the south corner of the lake to seek refuge. We rode ten minutes and found ourselves in the dark, as in the middle of a starless night. Something marvelous! In the north, too, were extinguished the little lights gleaming until then in the bosom of the cloud masses. Under such conditions like blind men we kept on rowing anxious to gain the shore.

Ordinarily this could be done in 20 minutes, but now we rowed madly for two hours and a half. We seemed to navigate in a vacuum. The rain of ash bathed our bodies and faces and hindered our looking upward. The situation became complicated a little later by another pheonomenon no less strange. We were wrapped in the "fire of Saint Elmo" produced by the high electric tension. From our clothes and flesh we gave off sparks, and our heads seemed to be surrounded with aureoles. Suddenly the lightning flashed, followed immediately by thunder. The light of the celestial dischange, however, was not bright enough to tear the curtain of ash and nocturnal darkness which covered everything. Simultaneously the discharges from our bodies stopped and we found ourselves again in a chaos. We went on for a stretch and the phenomenon of the "fires" was repeated.

Without warning we reached the shore. To orient ourselves we lit matches and debarked not without difficulty. We were absolutely ignorant of the point where we had arrived. At last at 11:30 a. m. the sky began to clear and we distinguished smokily some outlines of the vicinity. To our surprise we found that we were scarcely 100 meters from the place where we had set out.

The spectacle which presented itself to our gaze was breath-taking. All the landscape, usually so magnificent, was covered by the gray colors of mourning. The fresh green forest had disappeared under cloaks of volcanic ash. The panorama was like a desert. The summits of the mountains Osorno, Puntiagudo, and Tronador, so majestic, had also received the rain of ash from the volcano. The snowy whiteness of their snow-clad peaks was now blackened. Carried by the blast from Calbuco the ash had traveled to the end of the state railways of Argentina, covering all the region of Lakes, Gutierrez and Mascardi of the Argentine Southern National Park. An area consequently of thousands of square kilometers.

Our expedition had aspects, therefore, that were unexpectedly dramatic, but it served for scientific observations. We analyzed the ash which had encircled us for so many hours, to see if it contained fertilizing substances. From this study we can say that it has a specific gravity of 2.66, and that the average thickness of the blanket was 1.5 centimeters. Thus every square meter of surface received about 40 kilograms of ash, contributing lime and phosphoric acid in appreciable quantities. For the 40 kilograms of crude ash will eventually add to every square meter of ground 740 grams of lime and 84 grams of phosphoric acid in the form of easily assimilable compounds.

(Dr. Stone points out that no rain fell at Calbuco for two weeks after this eruption, confirming Finch's conclusion (Amer. Jour. Sci. Feb. 1930) that steam from volcanoes is not the cause of accompanying showers, which depend rather on atmospheric humidity.)

VOLCANOES AND VOLCANOLOGY IN KAMCHATKA

The following is summarized from an interesting letter sent by Dr. P. T. Novograblenof, Director of the Kamchatka Museum, Petropaulovsk, Kamchatka, U. S. S. R.

Writing May 5, 1930, he states that in September, 1929, a great eruption began of Gorely Volcano, a peak 1,830 meters high lying 85 kilometers southwest from Petropaulovsk. The eruption reached its maximum December 30-January 2, and ended in March, 1930, lasting nearly seven months. Gorely, like most of the Kamchatka volcanoes or "sopka" as they are called there, is in uninhabited country. The result of this eruption was that a large area of southern Kamchatka was covered with ash. This is not to be confused with Gareloi of the Aleutian Islands.

Kluchevskaya Volcano, the Vesuvius of Kamchatka, was in a severely active condition throughout the whole of 1929. There were, however, no considerable earthquakes at Petropaulovsk. There are 18 active volcanoes in the peninsula and one in eastern Kamchatka. In the beginning of 1930 the massive northerly volcano Shiveluch, 3,291 meters high, began to throw up clouds of ash and lapilli. It is not known whether there were lava flows.

The Academy of Sciences of U. S. S. R. proposes to establish two volcano observatories in Kamchatka, one near Avachinsky Volcano, the other near Kluchevskaya. The Geological Committee of the Union has informed the Kamchatka Scientific Society that a volcanological expedition is being sent to Kamchatka under Professor A. N. Zavaritsky for exploring Avanchinsky Volcano (elevation 2,720 m.) and Koriatsky (3,462 m.), both these cones being near Petropaulovsk. This expedition will work for two years. It will be the second volcano expedition sent to Kamchatka, as the first one under Conradi and Kehll worked there in 1908-10. T.A.J.

KILAUEA REPORT No. 988

WEEK ENDING DECEMBER 28, 1930

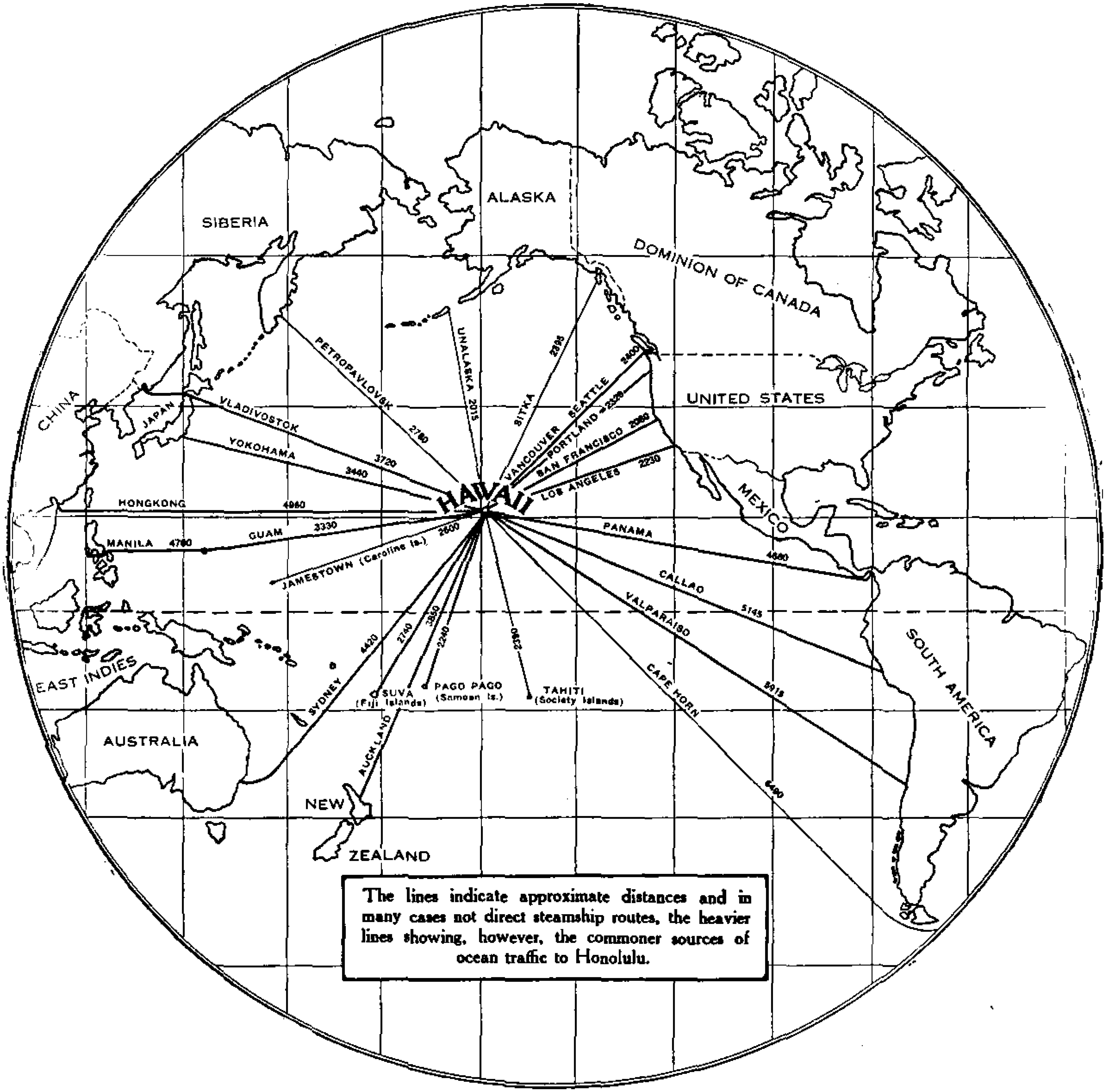
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The situation at Halemaumau pit after the recent eruption of lava which filled the bottom and ceased activity December 7, 1930, still suggests continued upward pressure of the lava without sufficient gas potential to make it break out with visible lava flowing. This is indicated by tilt eastward at the pit seismograph and northward at the Observatory instruments, both of these directions implying a tipping away from the volcanic center; also bluish sulphur fume continues to rise.

December 24 the fume had greatly diminished in quantity as seen at 9:15 a. m. when one looked down at the side of the new cone and the sulphur crack at the southeast edge of the new floor. The lava December 26 seemed to have settled and cracked a little at the aa area. The pit seismograph showed tilt away from the center. December 28 at 4 p. m. fresh red debris was conspicuous on the north and east taluses. The pit as seen from a distance showed faint blue fume rising, otherwise was clear. This was identified as coming actively from the base of the outer ridge around the new lava cone, from the southern end of the sulphur crack, and from whitish spots at the southwest. The lava lake area has slumped as much as would be expected from loss of gas in the underlying lava pool.

The seismographs have registered 42 tremors, two of them continuous for several minutes, and two accompanied by easterly tilt. One feeble earthquake was registered at 12:55 a. m. December 25. Tilt at the Observatory was moderate north and microseismic motion was slight.

The eruption of Calbuco January 6, 1929, looking east from Puerto Varas on the morning of the day described by Dr. Reichert. Puerto Varas is on the railway at the south end of Lake Llanquihue, and the pall of ash is here shown at the north in the direction of Lake Todos los Santos. Photo Karl.



This map of the Pacific Ocean shows one radius leading to Petropaulovsk 2,780 nautical miles from Honolulu, and another to Valparaiso which is 600 miles north of Calbuco Volcano. Niuafoou, described in Volcano Letter No. 312, is midway between Suva and Pago Pago.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 315—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | January 8, 1931

The eruption in Halemaumau November 19, 1930, at about 5 p. m. The smaller fountains directly in front of the large talus in the center background, and the main fountain to the left, are pouring out lava which is rapidly spreading over the old floor formed in July, 1929. Photo Maehara.

LAVA IN HALEMAUMAU SINCE MAY. 1924

It may be of interest at this time to review briefly the stages of the volcanic activity of Halemaumau since the great explosive eruption and collapse of May, 1924.

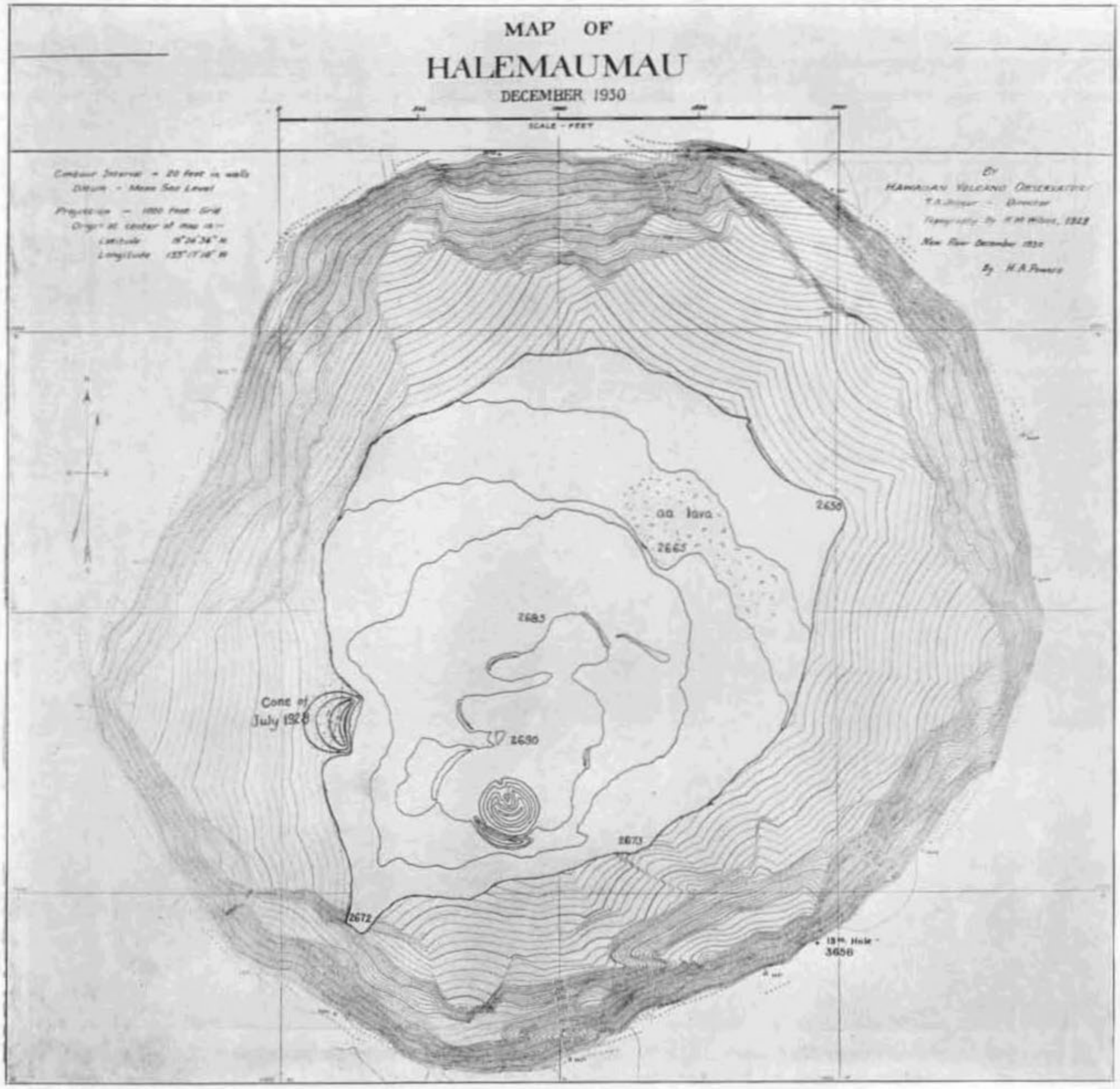
At the end of this explosive phase, no live lava was visible in the pit. Its appearance may be described by quoting from the Monthly Bulletin of the Hawaiian Volcano Observatory for July, 1924:

"The cauldron left by the May eruption was at the upper rim by measurements platted early in July, 3,400 feet long northeast-southwest by 3,000 feet wide. It remained an irregular oval with edges that had gone back about equally in all directions. The lowest part of the bottom flat was towards the north apporximately 1,335 feet below a datum station on the eastern rim. This bottom area was diamond-shaped and gravelly, of dimensions 1,000 by 700 feet. . . . . The site of the center of the new pit was indentical with the old Halemaumau, which had merely been enlarged and deepened."

Shortly after 1 o'clock on the afternoon of July 19, 1924, live lava appeared in the new pit, breaking out in a source fountain through the west talus at a point about 125 feet higher than the bottom of the pit. The lava flowed from the source fountain down the talus slope and then outward over the floor of the pit. This activity continued 10 days, until July 29. The new lava floor built by this eruption was 1,100 feet long by 800 feet wide. The center of the floor had piled up some 25 feet higher than the margins to a point 1,305 feet below the station on the east rim or about 2,390 feet above sea level. Thus the new lava floor was 35 feet thick in the center over the lowest point of the old rock floor.

Lava did not reappear in the pit until July 7, 1927, almost exactly three years later, but during all of this interval the pit was being enlarged by cracking and avalanching of the rim.

About 1 o'clock the morning of July 7, 1927, lava broke out in four fountains aligned along the edge of the 1924 lava floor at the base of the southwest talus. The southern-



Map of Halemaumau revised to show the shape and elevation of the 1930 lava floor.

most fountain broke through the talus above its base in the manner of the 1924 fountain. This eruption came to an end on July 19, after 12 days of moderate but continuous activity. The new floor formed by the lava which poured over the bottom of the pit was 1,700 feet long and about 1,400 feet wide at its greatest dimensions, with its long axis lying in a northeast-southwest direction. It covered a space of approximately 30 acres. An average elevation of the center of the floor was 2,515 feet above sea level. Thus somewhat over 100 feet of new lava had been deposited on top of the old floor by this eruption.

The last of the year (1927) was marked by a series of very heavy avalanches. After one enormous slide from the north wall of the pit, live lava oozed out from several cracks in the floor at the edge of the avalanche debris. No fountaining accompanied this gush of lava, and many other facts seemed to indicate that the activity was no more than a squeezing-up by pressure of remnant liquid lava from the July eruption. This gush of lava took place on January 11, 1928.

The collapse of the rim of the pit by avalanching continued with some violence during the early months of 1928. In the summer of 1928 a survey of the pit by Mr. Wilson showed that it had changed somewhat in shape since the summer of 1924. Quoting from the Volcano Letter No. 184: "In its (the pit's) present condition it is almost circular in shape, though the northeast-southwest diameter is slightly greater. Its diameters are 3,240 by 2,980 feet. The perimeter is 1.96 miles. The depth of the lowest part of the floor below the average rim elevation is 1,170 feet. The area of exposed lava floor and the cones with their spatter is now about 19 acres. The horizontally projected area of all the taluses is 87 acres, and the area of the horizontal projection of all the walls is 81 acres; the slope areas are of course much greater. This makes the total area of the pit 187 acres.

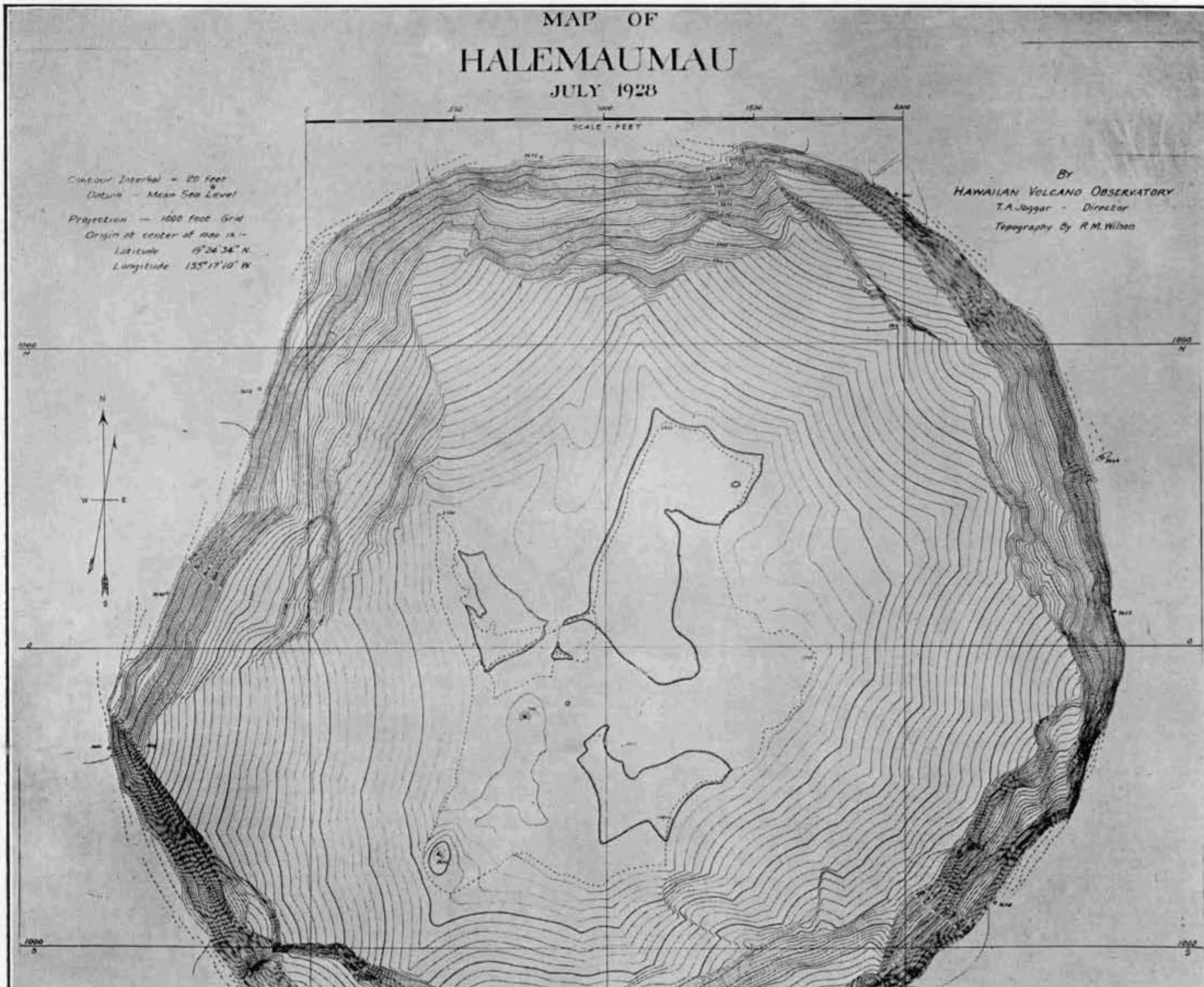
Lava reappeared in the pit at 12:45 a. m. February 20, 1929, and the fountaining occurred along a thousand-foot rift in the old floor trending N. 63° E. about 270 feet out from and parallel to the northwest edge of the floor. The activity continued until 1:15 p. m. February 21, about 36 hours. The new lava spread completely over the old floor and extended itself up on the bounding talus slopes.

At the end of the eruption the new lava fill had an average diameter of 1,600 feet and covered 40.5 acres. After solidification of the new fill, the surface averaged 45 feet above the average surface of 1927 lava.

After a much shorter period of repose. fountaining lava again appeared in the bottom of the pit about 6 a. m. July 25, 1929, the source fountains breaking through the southwest edge of the old floor near the big talus very close to the center of the 1927 fountaining area. Lava flowed from the source fountains until 7:42 p. m. July 28. During the first 24 hours the lava rose 44 feet above the level of the old floor. At the end of 48 hours, the depth had increased to 77 feet, and on the morning of the fourth day. July 28, the pit had been filled 88 feet. The maximum elevation of the surface of new lava was reached at the end of 85 hours activity, 94 feet above the old floor and 2,640 feet above sea level. Withdrawal of some molten lava, and shrinkage due to crystallization. caused some collapse of the surface of the new lava after the eruption stopped. The final cooled fill of new lava had a surface area of 55 acres and an average depth of 55 feet. The average elevation of its surface was 2,600 feet above sea level.

The recent activity, November 19 to December 7, 1930, has been the longest of this series of intermittent eruptions, and it has also brought a much greater amount of lava into the bottom of the pit. The new floor formed during this activity covers 62 acres and has an average depth of about 70 feet. It was estimated that somewhat over 15.000,000 tons or about 229,000,000 cubic feet of new lava is contained in this fill. The surface of the new fill varies from 2,650 to 2,690 feet above sea level.

In the six years from 1924 to 1930 the dimensions of the flat bottom of the pit have been increased from 1,000



Map of Halemaumau as drawn in 1928, showing the elevation s and shape of the floor of lava formed by the 1927 eruption.

New National Park Service lookout house on Mount Harkness, California. The Lassen Volcano Observatory has installed a two-component seismograph in the basement of this building. (See Volcano Letter No. 305, October 30, 1930.) Photo Finch

by 700 feet to 2,200 by 1,700 feet by the rise of the level of the lava fill. The elevation of the lowest point of the bottom has changed from 2,360 to 2,650 feet above sea level, giving a lava fill of 290 feet. Thus a total volume of over 463,000,000 cubic feet of lava has been poured into Halemaumau by the five eruptions which have a combined duration of 46 days of activity. In a circular pit 1,000 feet in diameter, about the size of Halemaumau before 1920, this volume of lava would make a column about 600 feet deep. H.A.P.

KILAUEA REPORT No. 989

WEEK ENDING JANUARY 4, 1931

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

The strong trade winds blowing across the dry crater and the edge of the Kau Desert during the first three days of the week whipped up huge clouds of dust which gave a fair imitation of the dust clouds from Halemaumau during the explosive eruptions of May, 1924. Then during the latter part of the week, beautiful cumulus clouds formed above the pit at night which lacked only the glow on their under side to duplicate the steam cloud of the recent eruption. Within the pit the emission of blue fume from the fountain site has ceased entirely, and but a small amount of steam is now being given off from the cracks in the new lava floor. Steaming was fairly strong from the south talus and the big southwest talus during the later part of the week.

One feeble quake was recorded on the Observatory seismographs at 4:01 p. m. December 30 which had a distance to its origin of 9 miles; and one very feeble shock was registered on January 4 at 9:33 p. m. On January 1 the seismograph was disturbed at 11:39 p. m. by the preliminary wave from a distant earthquake, and the stronger shock waves from this quake kept the pens in motion for 55 minutes. The Observatory instruments recorded 56 small tremors of probable volcanic origin during the week. The non-volcanic microseismic motion was moderate during the first three days, then dwindled to slight intensity for the last four days.

The average of the tilt record for the week shows a very slight inclination to the west since last week. This average gain was made up of several slight tiltings in various directions, showing that no single strong factor is controlling the tilt at the present time. There still has been no sign of a notable decrease in the pressure under Kilauea since the end of the last eruption which would have been indicated by a notable tilting of the ground in toward the pit.

THE VOLCANO LETTER

The Volcano Letter combines, after January 1, 1930, the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

The Volcano Letter

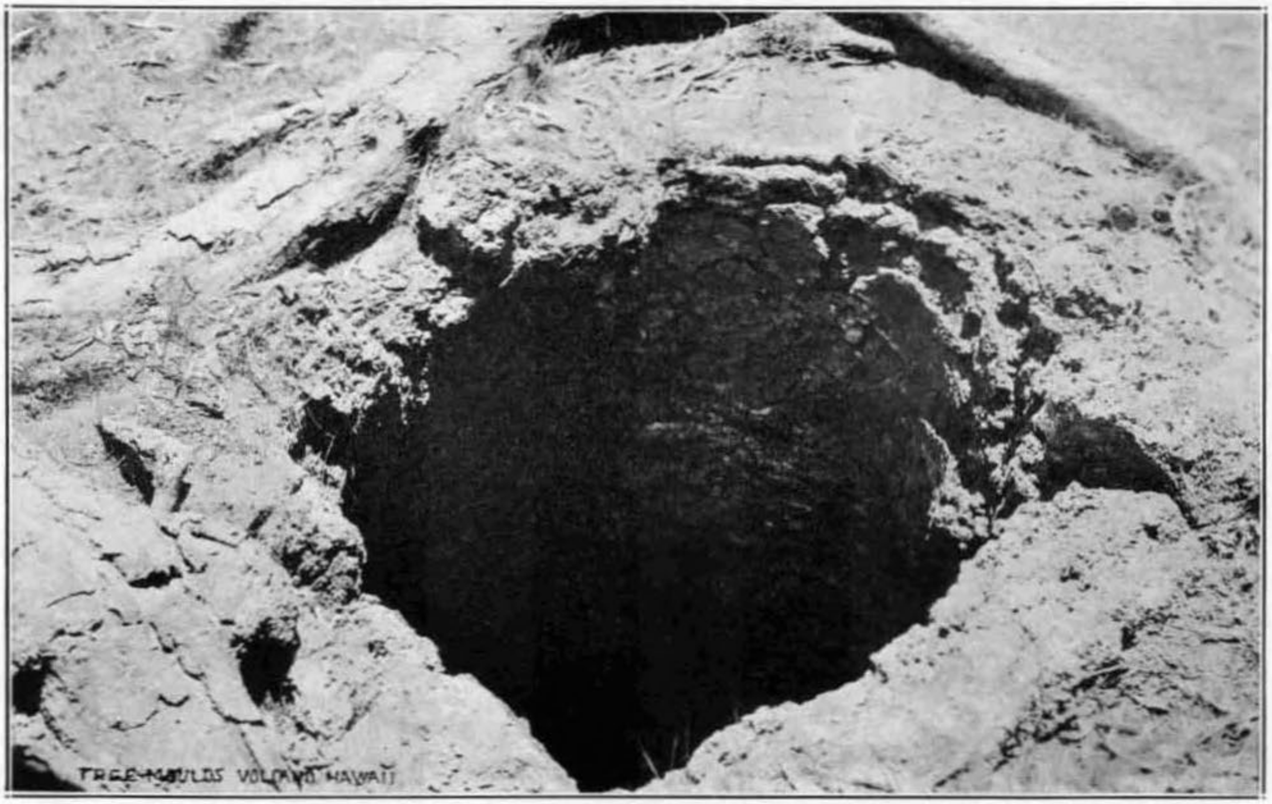
Two dollars per year Ten cents per copy

No. 316—Weekly Hawaiian Volcano Observatory, National Park, Hawaii January 15, 1931

Lava tree with wooden trunk still standing in it, formed by flow enwrapping the base of tree from left to right and then lowering. 1923 flow from Kilauea, Chain of Craters Road. Photo Boles.

LAVA TREE CASTS AND TREE MOLDS

Lava trees, Figure 1, and tree molds, Figure 2, are very much the same thing, but the one stands in relief, while the other is left a hole in the ground. To understand these tree molds we must remember that lava is very stiff and plastic when it is flowing, like molasses candy, and that contact with any cool substance like wood may, it is true, set fire to the substance, but none the less the lava will instantly congeal. It is really a glass, and molten glass solidifies very quickly. When the wood which is surrounded by lava flames up and burns away, the glass mold may retain very perfectly the pattern of the bark (see Volcano Letter No. 212, Page Three). Both lava trees and tree-molds contain cavities where the wood has burned out. There is a possible third type which would be formed where fresh lava filled up one of these cavities and made a true cast or stone tree by utilizing the natural mold created by the earlier lava flow. A fourth type was described by Mr. Bartrum in Monthly Bulletin of the Hawaiian Volcano Observatory for July, 1925. Here in the North Auckland district of New Zealand a carbonized tree trunk had been trapped by very liquid lava, by shrinkage radial cracks had developed the ring structure and radiation



Tree cast making a well three feet across, with bark pattern molded on the walls. Roots of a modern tree shown above. Here the lava surrounded a tree that burned out. Golf links at Kilauea Volcano. Photo Kanemori.

structure of the wood, the molten glass had penetrated these cracks forming lamellae of finely vesicular basalt in a sort of honeycomb preserving the texture of the original tree. Some of the partitions are no thicker than a sheet of paper.

Both lava trees and tree-mold wells are formed when a fluid lava flow invades a tree-covered area. The lava is chilled upon surrounding a tree and solidifies. If the flow is one of great fluidity, the level of the lava surface is apt to lower greatly after the source of supply has given out. This is because the flowing does not cease, out from under the high crust first attained. Consequently this flood level of the lava in the forest leaves its mark on all the trees, and its mark is nothing less than a casing or shell around each trunk. The original crust over the flow as a whole sinks much lower than the level where it stood when the hot lava was impeded by the forest. The outer edges of the flow during the closing stages sent out tongues which drained away the under substance. Hence the casts of trees, or better the frozen shell of lava around trees, remain to mark the original height of the flow.

Figure 3 shows the southern edge of the floor of Kilauea Crater in March, 1921, where the level of the lava was adjusted after the source fountain ceased action. No trees were present, but the lava plaster on the cliff marks the height of the flood when the fill was made. The cliff is composed of old horizontally bedded ash layers. At the foot is seen the downward broken or slumped field of lava, robbed of its under substance by outflow from under the crust.

If a flow is not so fluid and there is no way for the lava to escape around the edges, the surface does not lower so much after activity at the source has ceased, and instead of a plastered rock tree above the surface, there may be left merely a well or hole in the rock, molding the tree that has burned or rotted away after being surrounded by the melt. Figure 1 shows the wooden bole of the tree still standing in the embrace of the plastered layers of lava which are wrapped around its base.

Occasionally tall lava trees are found on hillsides for which fantastic explanations have been offered. It must be remembered that a grove of trees is a substantial and resistant object in a landscape. A lava flow is a sluggish mass of porridge which will pile up against such an obstruction. This is illustrated by Figure 4 where the obstruction was a cone on the southwest slope of Kilauea. The flow of 1823 plastered the slope of the cone to a considerable height as the flood divided around it. The cone is about 30 feet high and if trees had existed at its base so as to be trapped in the lava, these might have been molded and stand as monoliths today of considerable elevation, while but a few feet away other trees might have escaped uninjured.

Tree casts and molds are found in many places. In the Craters of the Moon National Monument in Idaho there are excellent examples. In the "Burnt Lava Flow" south of Glass Mountain in northern California there are several tree casts, most of which were pushed over by later flows. These casts of woody matter by lava are not confined to recent volcanic activity, for they are found preserved in ancient volcanic strata.

The tree molds near the golf links at Kilauea Volcano are wells lined with a selvage of glassy lava which often preserves the pattern of the bark of the koa trees which were molded by an ancient Kilauea flow. These wells where the tree has burned out are from 6 inches to 6 feet in diameter and from 3 to 12 feet deep. The ground round about is covered with ash soil, and this somewhat obscures the real significance of these molds. This ash was the fallen volcanic dust of the explosive eruption of Kilauea in 1790. Where the original lava shells around the trees stood slightly in relief in these places, the ash drifted over the country in sufficient volume to fill up the ground around the tree casts, but not sufficient to fill up the holes themselves. Therefore the shells do not appear to stand up, but are preserved merely as pits in the ground modelled after the original single, double, or triple trees whose roots were far below where the tourist stands today. On the nearby slopes of Mauna Loa there are some of these tree molds shaped like a trough, where the lava trapped a fallen or recumbent tree, and the divergent roots at the end are now marked by divergent tubes where the roots were modelled in stone and then burned away to ashes.

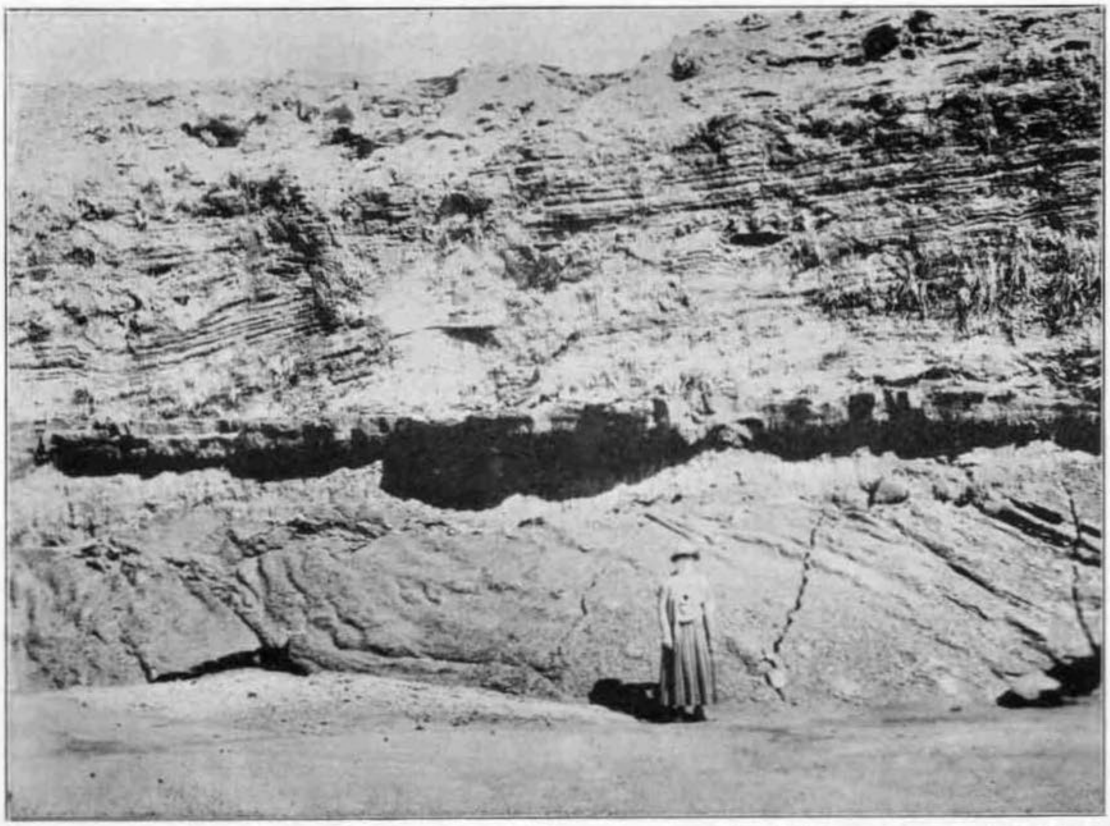
R.H.F.

TILTING OF THE GROUND FOR DECEMBER

The tilting movement of the ground under the Hawaiian Volcano Observatory during the month of December, 1930, and following the eruption of lava in the bottom of Halemaumau pit beginning November 19 and ending December 7, has amounted to more than 5 seconds of arc in a northeasterly direction. This is a tilt away from the pit and it will be seen that it increased during the eruption and increased greatly the second week after the eruption. While still being northerly the tilt had a westward trend during the last week of December. The suggestion is strong that the upward pressure of the lava continued after the visible outflow ceased. There has been nothing around Halemaumau as yet to indicate that the lava column is lowering.

The following figures show the net amount of tilt on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms, by platting a curve smoothed by overlapping progressive seven-day averages.

November 24-30	1.2 seconds NNE
December 1-7	1.8 seconds NNE
December 8-14	0.2 second NNE
December 15-21	2.5 seconds NE
December 22-28	1.2 seconds WNW



Lava bench at base of ash cliff, south bay of Kilauea Crater. The 1921 flow slumped after rising to the level of this bench, as the feeding source had become inactive. Photo Finch.

Lava plastered cone where the 1823 Keaiwa flow from Kilauea piled up on the hillside and then lowered. Photo Emerson.

KILAUEA REPORT No. 990

WEEK ENDING JANUARY 11, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

There have been no changes at Halemaumau during the week. Steam is as usual at the vapor vents. No renewal of fume has occurred.

The instruments at the Observatory recorded a total of 28 seismic disturbances. Of these 25 were tremors and 3 were very feeble local earthquakes, all unfelt. One shock occurred at 6:27 p. m. January 6 with indicated distance 18 miles; another was at 7:38 p. m. January 7, indicated distance 37 miles.

Tilt for the week accumulated moderately strong SSW, a change from the prevailing northerly direction during previous weeks. Microseismic motion was stronger than normal, probably due to high winds at the end of the week.

THE VOLCANO LETTER

The Volcano Letter combines, after January 1, 1930, the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

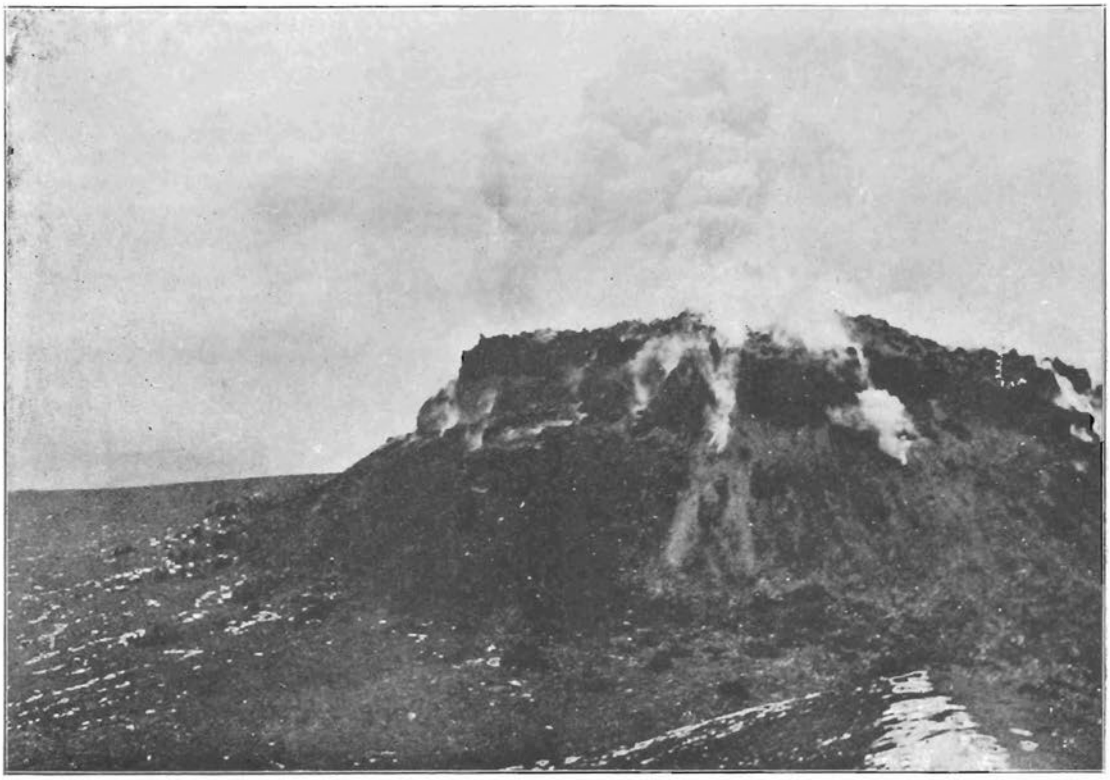
The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year Ten cents per copy

No. 317—Weekly Hawaiian Volcano Observatory, National Park, Hawaii January 22, 1931



Lava dome of Tarumai Volcano in Hokkaido, the north island of Japan, two hours after the eruption of October 30, 1926. The dome was formed in 1909, but was rent asunder by a new gas eruption in 1926. Photo K. Shibahara.

THE LAVA DOME ERUPTION OF TARUMAI

In Volcano Letter No. 276 an airplane photograph of 1926 was shown exhibiting a new gas outbreak through the crater dome of Tarumai Volcano in Hokkaido, the north island of Japan. Tarumai is 3,300 feet high amid the forests and lakes of the "Canadian" wilderness of Japan. The map on Page Three shows the four islands of Japan and the black lines represent the arcuate rifts in the crust of the earth along which are grouped the belts of active volcanoes. The southwestern curved line follows the arc of the Riu Kiu islands, which passes through Sakurajima Volcano in the southernmost bay of Kiushu (Volcano Letter No. 308). This ends with subordinate offshoots in the west end of Japan proper, and then comes the arc of that island, with eastern and western belts of volcanoes at the north. These belts converge at Yakedake Volcano (Y in cut), and there meet the great arc extending to the south which passes through Asama Volcano in central Japan. (Volcano Letter No. 297) Fujiyama, (F in cut), Oshima in Sagami Bay southwest of Tokyo (T in cut, see Volcano Letter No. 299), and the Ogasawara volcano islands and the Bonin group far to the south in the direction of Guam. Another bend starts a new arc in western Hokkaido and this extends outside of the map to the northeast along the line of the Kurile island volcanoes which lead in turn to a new arc in Kamchatka. Tarumai is at the southwestern end of the black line marking the Kurile arc, and not far east from Usu Volcano, described in Volcano Letters 298 and 302. (See Simotomai, Zeitchr. fur Erdkunde zu Berlin, No. 9, 1912).

The eruption which lifted the crater floor of Tarumai and converted it into a lava dome occurred in the spring of 1909, and the writer was privileged to make the ascent of the mountain and study the dome while it was still hot and steaming on May 9 of that year. He carried with him a Bristol pyrometer for measuring high temperatures in the cracks of the lava dome. He was accompanied by Professors Oinoue, Sato, and H. Tanakadate, who furnished valuable photographs and information. He stayed at the sawmill and match factory in the forest at the base of the mountain, operated by Mr. Haruta, who had watched the activity from its beginning.

We arrived by rail May 8th at Nishitap near the south shore of Hokkaido, and walked two miles across open flats to the mill which is on a brawling trout stream. The valley is enclosed by a marked marine terrace at least 200 feet above sea level. In the afternoon the clouds rose and showed the east rampart of Tarumai to be saddle-shaped, with pure white steam clouds rising behind it. The mill is 7 miles from the crater, and its function is to make thin strips of pine for match boxes.

At 6:30 a. m. we started on foot through the woods for the mountain, and after leaving the forest crossed several step-like ridges at the base of the outer cone, these being followed by a 35° slope of pumice and cinder which made laborious climbing. Arrived at the high rim of the outer crater we were surrounded by clouds, but saw a great fallen block of andesite in the inner crater. In the afternoon the summit cleared and the huge lava dome was revealed 1500 by 1800 feet in diameters and 600 feet high above its visible base. There was an inner crater pit 2200 by 1300 feet in diameters, and the dome of the new lava was west of the center of this inner crater with its talus overlapping the crater edge on the southwest. The whole surface of the dome was pinnacled with many small pillars rising all over it. These dimensions were from a survey by Oinoue of April 23 and there had been some changes during the fortnight succeeding. The picture on Page One shows the general aspect of the dome, but with much more talus than was present at first. The writer had studied the dome of Bogoslof in 1907, and was impressed by the greater height and steepness of the Tarumai dome, and the protruding crags of hot lava.

At the north where the lava dome was rounded and did not overlap the rim of the inner crater, no falling of rocks was observed, but at the south the dome was very steep and overlapped the rim, there were great fallen blocks at its base, and Dr. Oinoue reported he had seen a block 30 feet in diameter come down. Several rocks were heard falling. At a sulphur patch amid the cracked andesite of the dome, a maximum temperature of 457° C. was measured, while the steam temperature gave 430° when the terminal did not touch the rock.

The history of the eruption was as follows: On the night of January 11, 1909, a column of fire rose over the crater, in the night of January 22 ash fell on the snow at the mill, in the morning of February 6 there was an ash fall and smoke was visible over the mountain, and at 3 p. m. February 10 sounds were heard twice, much steam arose, and ash fell. At 1 p. m. February 18 much steam was visible, and on March 3 rumbling noises were heard three times by the miller Haruta. In the morning of March 30th detonations began at 7:18 a. m., rumbling continued for an hour, stones fell the size of peas, and the smoke from the crater rose in a very slender whitish column which later became darker. After an hour the activity diminished, and in the afternoon the eruption ceased.

April 12 at 11:40 p. m. came loud rumbling and lightnings, at a place two and a half miles from the crater stones fell 5 to 7 inches in diameter, and an earthquake occurred lasting two minutes. April 15 and 17 the column of brown smoke was seen at Sapporo in central Hokkaido. Close at hand strong rumblings, smoke, and glow were perceived, and April 18 with southerly wind the ash fell to leeward 25 to 30 miles away. The cauliflower clouds rising above the mountain assumed wonderful spiral form. There was no life lost in the eruption. The glow increased and the explosive activity dwindled to steam jets April 22.

April 23 Oinoue climbed the mountain, found the steaming dome, and made photographs and sketches. The dome had first been noticed by a fisherman on Lake Shikots on April 20 and had developed at some time after the explosions of April 12 and 17. On April 4 the inner crater pit had been 200 feet deep, floored with gravel, the floor sloping gently toward the north, and steaming chiefly around the west and southwest borders. The pit had shown lava sheets in its wall. There was a small depression in the northern part of the bottom. The lava dome had come up through this bottom. Mr. Oinoue observed glow in the crevices of the dome. Several cracks were found in the rim of the inner crater near the edge of the dome. Rocks were constantly falling off the western side from the many pinnacles of this rude aa of andesite lava, of which the dome was formed. When a huge block fell away from the upper part of the dome a glowing spot was left where it broke off.

On May 1 a sketch from the western mountain showed increased talus all around the dome, except on the northeast side where the jagged rock ledge extended all the way to the base. The profile had become flatter on top, but still showed pinnacles, and an inner comb or fin rose slightly above the flat top. There were many immense fallen blocks, but the slides of rock matter were small and few.

When I saw the dome on May 9 the sulphur-coated blocks of rock near the level of the edge of the crater on the south side of the dome averaged 2 to 3 feet in diameter and the odor was of sulphur dioxide. Quiet steam was rising. There was an area of sulphur stains 30 feet across. The wind was from the south, and a faint crackling was audible in the hot rocks.

The following notes on temperature of crevices in the dome, made with the thermo-couple, indicate the heat at this time:

(1) The base-metal couple was inserted without touching the rock one foot into a cavity nine inches in diameter full of rising steam. The terminal was at least three inches from the rock in four directions. Temperature 430° C.

(2) A narrow steaming fissure was measured, the terminals touching the rock, and inserted 24 inches from the outer surface. Temperature 450° C.

(3) A big wedge-shaped cavity was measured, under a large bowlder, with a very large opening on the outside. Temperature 390° C.

(4) A small cavity, lower down the slope under No. 2 above, received the terminals 12 inches inside laid against the rock. Temperature 457° C.

(5) A small cavity 6 inches across the mouth, admitted the terminal for a distance of 4 feet. Temperature 398° C.

(6) A small area of secondary solfataric action, stained rocks across an area 7 feet in diameter, a 2-inch fissure among the fragments, the terminal inserted one foot. Temperature 200° C.

This volcano is famous for the large amount of pumice which it has ejected. It has an outer ring wall like Somma at Vesuvius. There was a faintly defined inner cone surrounding the inner pit. In July of 1739 the mountain rumbled and emitted fire, volcanic ash fell heavily during two or three days and nights, all this being preceded by a shock of earthquake. In 1804-17 there was a great eruption of fire, sand, and ash, many lives were lost and some people were wounded, and the emission of smoke continued for 40 years. (This record is somewhat doubted.) December 25, 1871, Tarumai vomited sand and ash for three days and two nights; this destroyed a small cone on top, left a cavity 100 meters deep with a small pond in the bottom, and changed the summit in other respects. February 8, 1874, there was another eruption lasting three days with a revival February 16. Ash fell in Sapporo November 5, 1883, from another eruption, and there were two other outbreaks during that decade. There was unusual black smoke August 17, 1894, and thereafter there was always steam at the crater until the big eruption of 1909. T.A.J.

KILAUEA REPORT No. 991

WEEK ENDING JANUARY 18, 1931

Section of Volcanology, U. S. Geological Survey

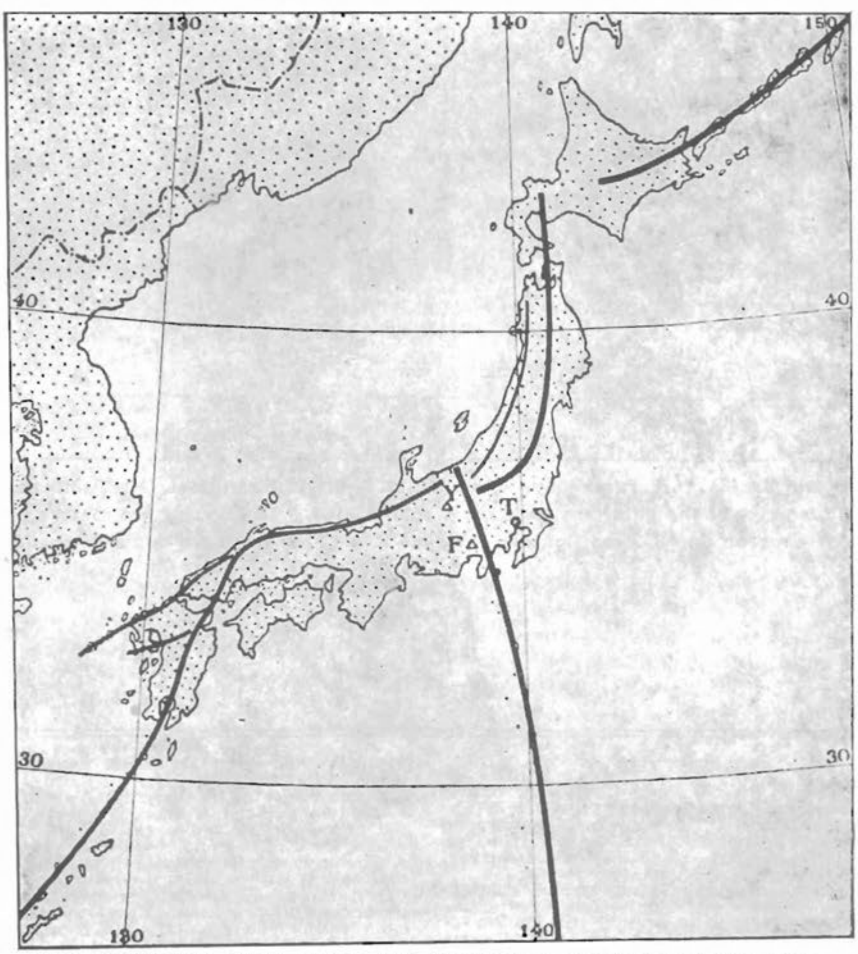
T. A. Jaggar. Volcanologist in Charge

Few notable changes have occurred at Halemaumau during the week. Fume remains absent at the 1930 vents. There are many scattered sulphur areas with whitish coatings, but the main area southeast is bright yellow. On the 14th steam was strong on the south talus.

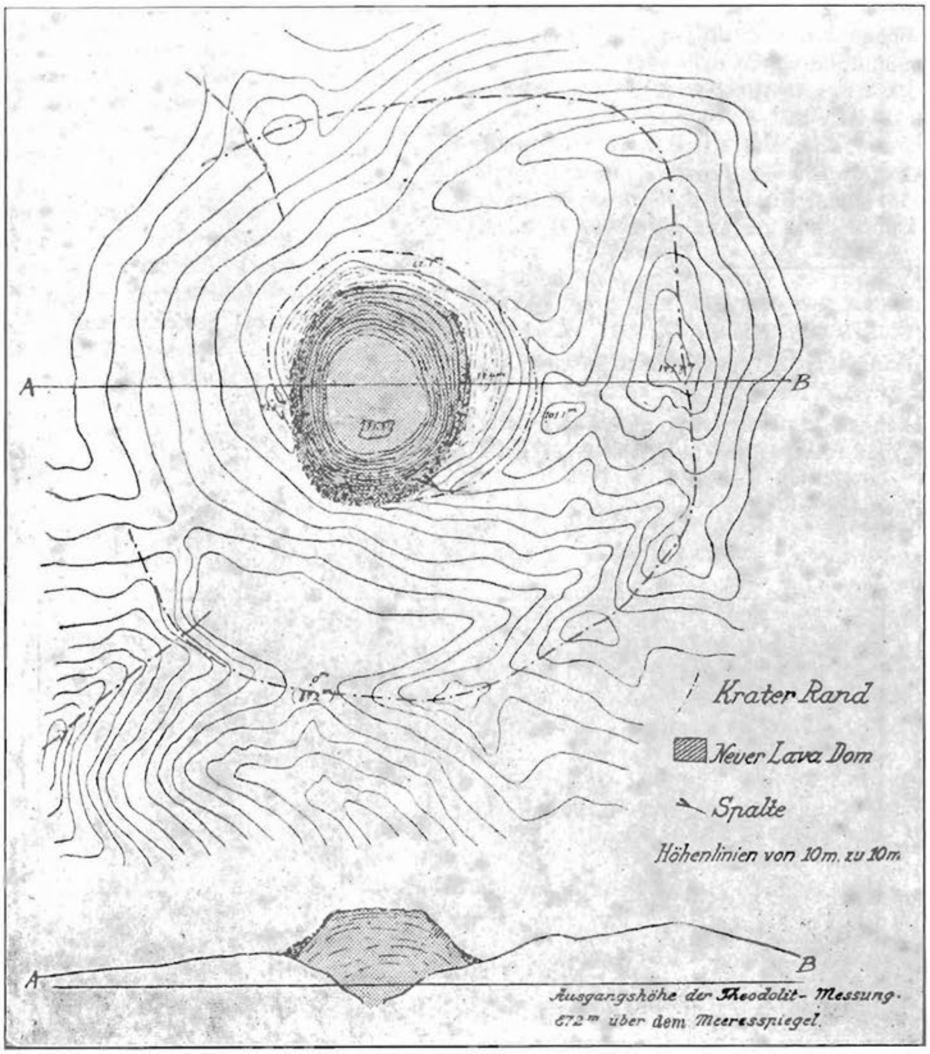
Thick dust clouds over the region southwest of the fire pit, caused by extremely high trade gales, gave rise to rumor of an eruption January 12.

The seismographs registered 29 local tremors and earthquakes and 2 teleseisms during the seven-day period ending at midnight January 18. Two of the first group had indicated distance to origin 18 miles, and another (3:03 a. m. January 12) was reported felt in Hilo. A local earthquake at 8:44 p. m. the 16th originated 30 miles from the Observatory, apparently under the center of the island. It was felt generally, and was more perceptible in Hilo and Hamakua districts than elsewhere. The first of the two teleseisms registered 3:31 p. m. to 4:04 p. m. the 14th; its indicated distance was about 6,000 km. ESE (Oaxaca, Mexico). The second recorded feebly 4:40 p. m. the 16th, duration 21 minutes.

The direction of tilt again changed, accumulating slight NNE. Microseisms were moderate at the beginning of the week, decreasing to slight.



Map of Riu Kiu, Japan, Bonin, and Kurile arcs and their volcanic rifts. T=Tokyo, F=Fujiyama, Y=Yakedake. After Omori.



Map and profile of Tarumai lava dome of 1909, after Simotomai (H. Tanakadate). The diameter of the outer crater is more than a mile. The figures are meters above the contour line 872 m. Contour interval 10m. The new lava dome is shaded

THE VOLCANO LETTER

The Volcano Letter combines, after January 1, 1930, the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

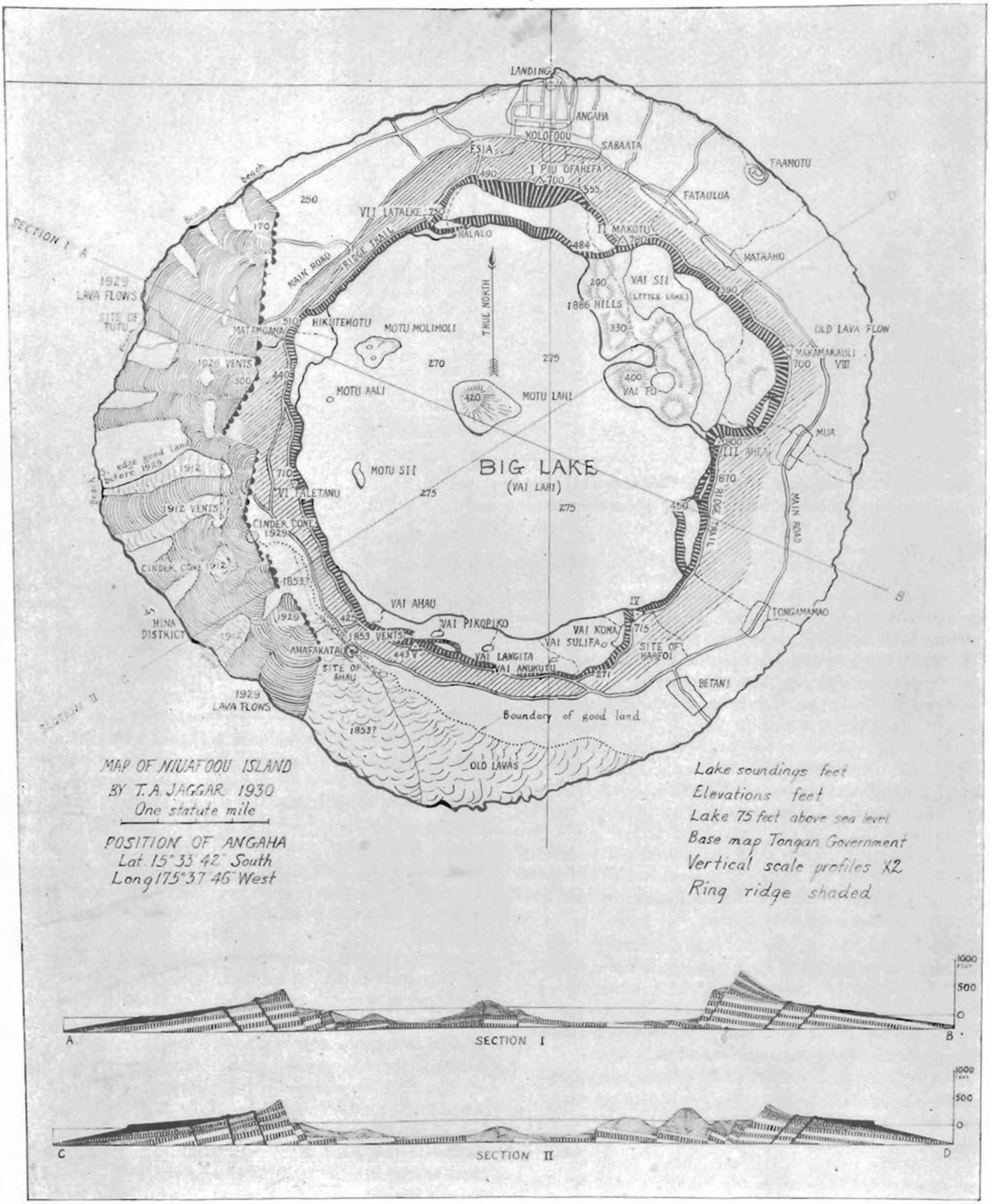
The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

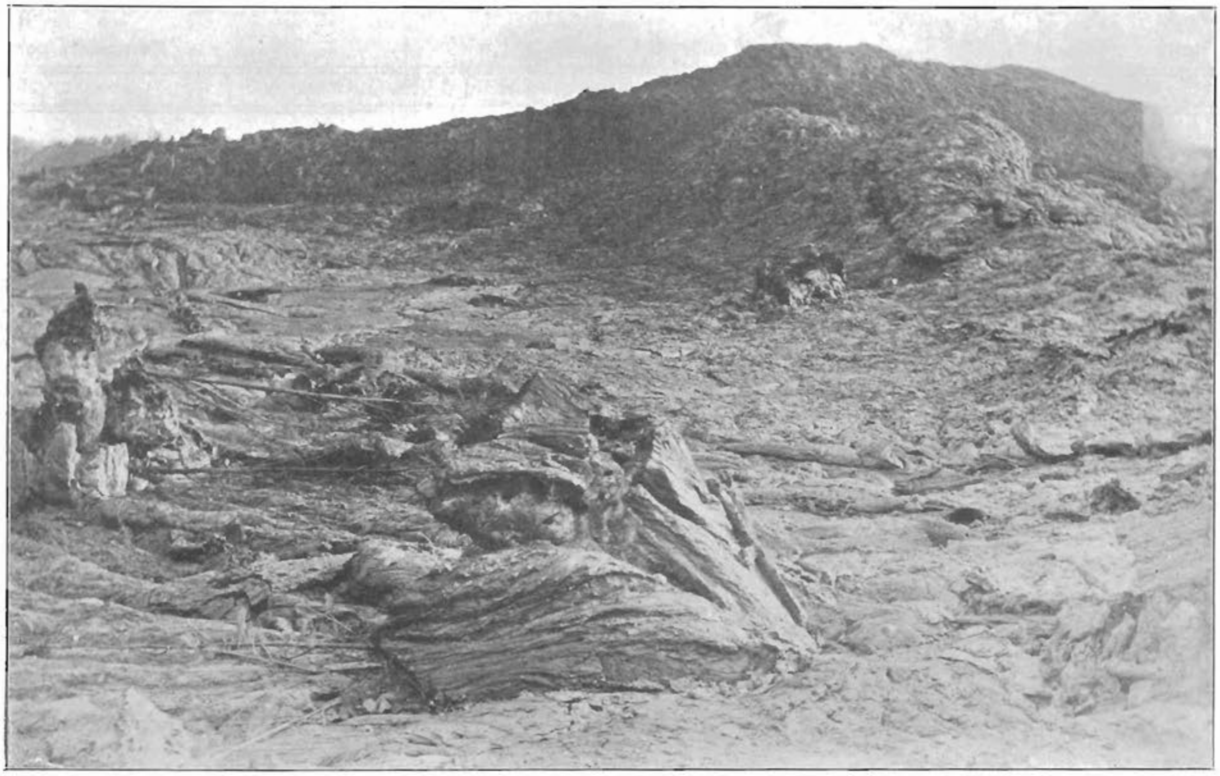
The Volcano Letter

Two dollars per year | Ten cents per copy

No. 318—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | January 29, 1931



Volcanologic map of Niuafoou Volcano, a ring island in the Pacific Ocean visited by the U. S. Naval Observatory Eclipse Expedition in 1930. Shows profile structure sections, the positions of the villages, roads and trails, and the lake soundings and land elevations in feet. Survey by T. A. Jaggar.



Pahoehoe lava and spatter ridge, with some coconut tree molds of 1912, photographed in 1913 when the lava was fresh. Compare 1929 eruption Volcano Letter No. 312. Photo from Captain Crawford.

GEOLOGY AND GEOGRAPHY OF NIUAFOOU VOCANO

The accompanying map and profiles were made by the writer on the basis of a recent outline map of the Tongan government and serve to show the perfect ring shape of the island Niuafoou, which as described in previous numbers of the Volcano Letter (265 and 312) is a prosperous copra island in the triangular space of the South Pacific Ocean between Samoa, Fiji, and Vavau. The big lake in Niuafoou is a crater sink fed by rain water and made somewhat brackish by hot volcanic gas springs, by evaporation, and probably by more or less connection with sea water. The lake is 275 feet deep and stands only 75 feet above sea level, so that 200 feet of its waters are below the ocean level, and that in a porous basaltic dome greatly cracked. As there is no drainage, and salt water is heavier than rain water, the bottom of the lake might be salt without that fact showing on the surface.

It will be seen by the profiles that the structure of the island, here shown with the slopes and dips exaggerated to double their normal inclination, and the heights to double the true elevation with reference to the horizontal scale, is that of a very flat lava dome. The island is entirely basaltic and the submarine slope seaward is from 4° to 7°. The cross sections of the inner cliffs around the lake show very massive columnar sheets of basalt at the bottom of deep sections 600 feet thick. The upper ring ridge shows mixed eruption with alternations of about 20 feet of ash and agglomerate representing one phase, followed by 20 feet of thin-bedded lava flows representing another phase. These upper beds have dips of from 13° to 18°, whereas the lava layers seen in the sea cliffs of the border platform dip radially away from the center at from 4° to 8°.

This implies that the lower dome of Niuafoou was built up of heavy sheets of liquid basalt, and that the development of explosive eruption was a later feature recorded chiefly in the upper layers. The angle between outer platform and ring ridge is accented by the modern flows of lava which have come up concentric fractures as shown in the profile, but this angle is also produced structurally by the presence of the steeper mixed cone of the ring ridge resting on an older dome pediment of lava, like the present Vesuvian cone. This angle is probably a belt of weakness concentric to the crater lake, as indicated by the western 1929 fractures shown on the map with lines of black half-domes along the rift fissures from which the flows poured to the sea.

In the ejecta of the two most modern eruptions of Niuafoou, those of 1912 and 1929, both of which emerged through what appear to be tension fractures of northerly trend on the southwest side of the island, pieces of coral were thrown up. This ejection was during a minor steam-blast phase at one locality ("cinder cone" on map), all the rest being pure lava flow. The coral fragments are mixed with dike rocks and lava clinker, at cinder cones containing unusually deep circular pits along the line of lava source vents, and at the 1929 locality three-quarters of a mile from the sea. Ash and sand accumulated to leeward. This ejection of coral fragments recalls Vesuvius, which flings up limestone, and the 1823 explosions along the lava rift near the sea at Kilauea. The coral at Niuafoou indicates that coral rock exists under the southwest slope of the island, though there is no coral reef around the island at the present day. Coral does not occur in the explosive fragments of the 1886 hills, produced by the big eruption of that year northeast of the lake. There may have been a fringing reef at some inactive stage when the island was smaller. The elevations of the two vents where the coral fragments were found are approximately 150 and 200 feet above sea level.

The cross section of the island shows an outer lava slope all around, (black in the profiles) the ring ridge, the inner cliff, three platforms of explosive materials making islands and sandy hills at the lake level, and the lake bottom. The latter is probably floored with down-sunken blocks of the former cone, overlaid by explosive fragments and sand. This material is shown in heaps in the sections. The outer lava slope at the west and south is modern. It will be seen that each of the three inner lake shore lowlands, including the islands as attached to the northwestern one, is backed by a notching outward of the ring of cliffs. Each of these lowlands stands for an explosive eruption, the northwestern one prehistoric, the southern one probably 1814, and the northeastern one 1886. These steam blasts probably represented subsidences of the lava column at the end of a cycle of upward pressure and outflow. Ground water entered the void, the retreat of the lava into the depths being along the wall-crack of the more or less circular plug under the lake, steam blast shot up and loosened fault blocks, and the sinking of these notched the ring of cliffs outward. The biggest notch is that back of the 1886 hills.

The modern lava flows of the last century started at the south and extended the process of opening fissures northward up the west side of the island. The mechanism of breakage of the cone appears to be by lava flows outside the ring ridge and engulfment eruptions of steam inside of it. There are no fresh lava flows on the lake side of the ring ridge. There are only minor evidences, as cited above, of steam-blast cinder cones on the ocean side of the ring ridge. The cycle at Kilauea appears to involve shorter pulsations of lava flow at 11-year intervals, and a longer cycle of six or twelve of these (66 or 132 years). This longer cycle may culminate in explosion, which means lava subsidence. Something of the same sort exists at Niuafoou.

Summarizing the list of eruptions of Niuafoou we find known outbreaks in 1814 (steam blast), 1853 and 1867 (lava flows), 1886-87 (steam blast), 1912 and 1929 (lava flows). Apparently the 1814 eruption was a steam-blast phenomenon, and it seems likely that its center was at Vai Kona, on the south side of the lake, for there are still warm gases there smelling of hydrogen sulphide, depositing alum, and bubbling up through lagoon waters. Like the Kilauea eruptions of 1790 and 1924, the years 1814 and 1886 may mark the opposite ends of one supercycle, in which case the next explosive eruption for Niuafoou might be expected 72 years after 1886, or about 1958.

It will be seen that the doubt about lava flows on Niuafoou (Thomson, N. Z. Jour. Sci. Tech. 1926, p. 369) is definitely dismissed. The modern lava flows of 1853 and 1867 were at the south (see map), 1912 farther north, and 1929 much farther north. Naturally the clustered settlement at Angaha is anxious about the next eruption, which is likely to extend the concentric fractures around the northwest side of the island in the direction of the villages. The explosive eruption of 1886 notched the rim of the big crater outward where that rim was highest, and therefore heaviest (over 800 feet above sea level). It followed lava flows of the 19th century on exactly the opposite side of the island. If this mechanism maintains a balance of concentric breakage about a cone, it is logical for the explosive eruption about 1958 to follow after flank outflows on the opposite side of the volcano. The highest and heaviest rim of the caldera next to be expected to subside in a steam-blast eruption is southeast (870 feet high). The flank outflows then to be expected between now and 1958 will be at the northwest. As the maximum lava gushing of 1929 was west-northwest, and the trend of a century appears to be extension of cracks northward, there appears to be every reason to expect the next lava eruption to invade the lands west of Angaha.

Sapper (Vulkankunde, p. 336) cites a doubtful date 1840 for a Niuafoou eruption. Supposing this to have been a lava flow, there were six volcanic events in the 115 years following 1814, with intervals respectively:

After 1814 explosive eruption: 26, 13, 14, 19, years

After 1886 explosive eruption: 26, 17, ? ? years

It thus appears that an extra long interval may follow an explosive eruption, and this is true of other volcanoes. The average interval otherwise for Niuafoou by this table is 16 years. This would place the next probable lava flow following 1929 about the year 1945. If the eruption is normal it will fracture open a fissure about a mile long, and if it should start at the big steam vent back of Futu, and spread a mile to the northeast, it would do no damage to Esia, nor to Angaha, but it would be much too close for safety. The next eruption after that is likely to be ejection of steam and ash about 1958, possibly at the Ahea ridge, with damage like that of 1886. The records are very imperfect and it should be understood that there is a range of from three to five years on each side of the year mentioned for the expectancy based on statistics.

These forecasts are not accurate, for our knowledge of the 19th century is very imperfect. They are merely suggestive experiments in volcanologic reasoning, based on such imperfect data as those figures by which the 1924 explosive eruption of Kilauea was forecast on historical data in 1918, with an error of four years (Bull. Hawn. Volc. Obsy., Jan. 1918, p. 17). They may rightly be used by those governing Niuafoou as stating facts based on past statistics.

T.A.J.

KILAUEA REPORT No. 992

WEEK ENDING JANUARY 25, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar. Volcanologist in Charge

On January 19 no changes were observed at Halemaumau and steam rose from the south talus as usual. The pit seismograph indicates that conditions are quiet. A little dust rose from the north rim of the pit at 3:45 p. m. January 22. This was seen to have been a slide at the north talus and on January 24 a little fume rose at the southeastern sulphur crack and the pit seismograph showed a few volcanic tremors.

The Observatory seismographs for the week ending midnight January 25 registered 30 tremors, one of which lasted two minutes. Fourteen very feeble local earthquakes occurred, three of them on January 25 indicating origin about 30 miles from the station. Tilting of the ground was slight to the WSW, and microseismic motion was slight.

Map of the Pacific Ocean. Niuafoou is between Pago Pago and Suva.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volacno Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

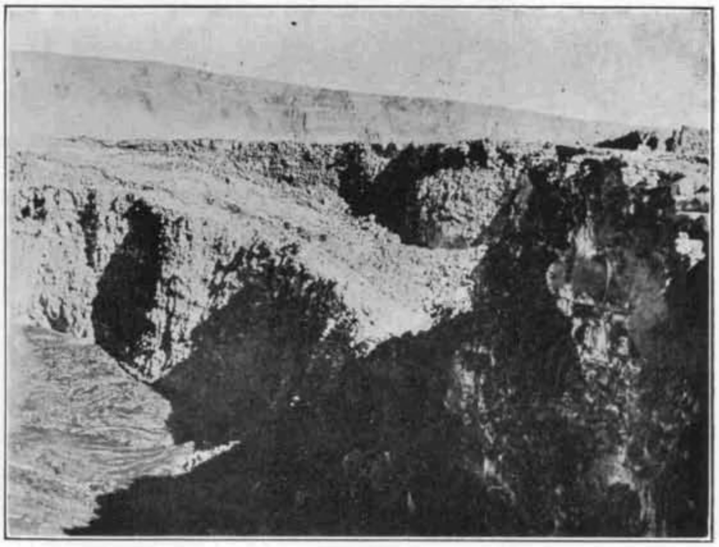
Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 319—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | February 5, 1931



Halemaumau looking north from the southeast rim December 15, 1916, showing the northeastern inner shelf which had been left for many years as a feature of the pit rim by the collapse of 1894. The pit circle measured only 13C0 by 1400 feet at this time. The inner lava is seen below, and in the background is Uwekahuna bluff of Kilauea Crater. Photo Jaggar.

TWENTY YEARS OF HAWAIIAN ERUPTIONS

The Hawaiian Volcano Observatory, which was first financed in 1909 and began research in the summer of 1911, has observed about twenty important crises in the three volcanoes Kilauea, Mauna Loa, and Hualalai in the course of twenty years. This means an average of one a year, and with each new event the public is apt to forget the vastly important and exciting events that went before. Therefore very briefly we recount here the sequence.

Kilauea Activity of 1909-13

After the southwestern Mauna Loa flow of 1907, lava rose and fell in Halemaumau pit, then much smaller than at present, at depths 200 to 300 feet below the rim. In 1910 and 1912 three remarkable risings occurred with hundreds of roaring liquid lava fountains. Then came subsidence with much smoke, the lava 600 feet down, from May 1913 to May 1914.

Mauna Loa Summit Eruption 1914

Slowly the melt rose with glowing trickles, sputter, and fume in Halemaumau. In November 1914 Mokuaweoweo, the summit crater of Mauna Loa, suddenly split athwart its bottom and gave vent for two months to high spurting fountain jets of frothy lava, which flowed in the crater only, and became dormant.

Kilauea's Rising 1914-16

Halemaumau now began a cycle of steadily increasing inflow of lava, which was destined to last for 10 years. There was sinking just after the Mauna Loa event, then the upbuilding of a lake in the Kilauea pit, with overflow floor, crags and islands.

Southwest Flow Mauna Loa 1916

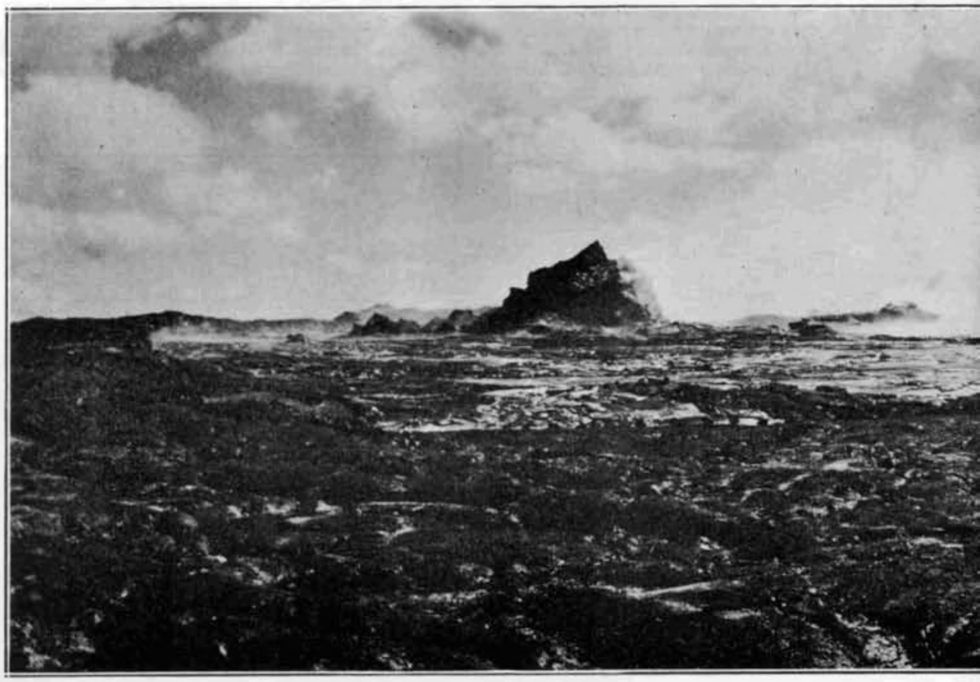
With an astonishingly beautiful mushroom of fume that shot up from about the 10,000-foot level southwest on Mauna Loa May 19, 1916, a new lava flow began making short streams of aa into the forest of Kahuku and Honomalino. This never reached the road and ceased about June 5.

Kilauea Subsidence and Recovery 1916-18

On the same day the lava of Halemaumau, which had just shown a spurt of rising, with the Mauna Loa eruption, sank nearly 400 feet in 24 hours with a magnificient display of red-hot avalanches tumbling into the void 673 feet deep. Immediately lava boiled up in the bottom, and with chiefly rising tendency built up lakes, platforms and crags to the point of overflowing the rim of Halemaumau in February 1918.

Overflows Into Kilauea Crater 1918-19

These two years exhibited the lava in Halemaumau with huge craggy peaks of uplifted floor between the lakes, and whenever there was overflow, reactions of subsidence followed. Overflowing was continuous for seven months in 1919, flooding the Kilauea floor north.



Halemaumau brim full of lava December 31, 1920. This photograph shows the whole pi
toward the south. Where the photographer was standing would now be about 600 fe

Alika Flow Mauna Loa 1919: peak of the Cycle 1913-1924

Kilauea flows spurted when Mauna Loa erupted again September-November, 1919, beginning with gushing near Mauna Loa summit southwest. The Mauna Loa flows came out about the 8000-foot level above Puu o Keokeo and poured to the sea at Alika in south Kona.

Kilauea Grand Subsidence 1919

About when Mauna Loa ceased action, Halemaumau, when full to the top, on November 28, 1919 suddenly withdrew its lava column like a piston into a cyclinder 400 feet in an hour. The lava lowered farther for a few hours, immediately recovered, then rose 30 feet a day.

Kau Desert Outflow Kilauea 1919-20

Halemaumau lava rose to the top again December 15, 1919, flooded the southwestern Kilauea floor, burst open the mountain in the Kau desert 6 miles away, and during the next 8 months built the slagheap hill there Mauna Iki, making aa and pahoehoe flows five miles long. Lava in Halemaumau lowered.

Kilauea's Great Overflows March 1921

From 320 feet below rim Halemaumau executed a tremendous rise again for its inner lava lakes between October 1920 and March 1921. There was increasing effervescence, gigantic fountains spouted up in myriads, crags, floors, lakes and wells rose en masse, and the pit overflowed to the Kilauea floor in three great floodings with 5 overflows at one time on March 18, 1921. A small flow went out through the southern Kilauea wall to the desert.

Chain of Craters Outbreak from Kilauea 1922

Kilauea lava subsided three times, with intervening rises, during 1921-22, the last being the greatest engulfment of the Halemaumau walls which had yet occurred in this century. This in May 13-27, 1922, enlarged the pit from a diameter of 1400 feet to 2000 feet. Then May 28-29 came short-lived outflow in Makaopuhi and Napau pits in Puna 9 miles from Halemaumau.

Second Chain of Craters Outflow 1923

Kilauea pit was dormant until lava burst from the talus and began to fill Halemaumau July 17 and September 2, 1922. Then came pulsations of rising to a point 127 feet below rim July 4, 1923, followed by another big subsidence in August and an outflow up a long crack in the forest near Chain of Craters trail west of Makaopuhi. This is the flow shown to tourists where the vent is still hot and lava spatter clings to the trees.

Great Rise and Collapse of Kilauea 1923-24

These oscillations of rising and sinking at Halemaumau, with outflow somewhere down the mountain, reached a grand climax in 1924. This was the end of the eleven-year cycle, and this cycle was the end of an 134-year super-cycle. In the pit greatly enlarged by numerous collapses, the lava rose to within 121 feet of the rim January 27, 1924, making the largest continuous sea of lava ever measured by the Observatory. Then it lowered to dormancy February 15-21, 1924, left a collapsed tumble with a glowing hole about 400 feet down, leading to a demonstration on the eastern or Puna rift of Kilauea Mountain.

Kapoho Coast Subsidence April 1924

This eastern rift crack extends beyond the Chain of Craters through the forest to be crowned with a line of clinker cones 30 miles east of Kilauea. Here at Kapoho April 21, 1929, began continuous shaking, then extensive

rim with the enclosed liquid lava lake and a high crag standing in its midst, looking
t inside the north rim of the present pit, and 30 feet up in the air. Photo Jaggar.

cracks opened with settling of the country along a four-mile strip to the coast. There was possibly slight increase of steam there at the always steaming Puulena pit craters. No heat was detected in 20 new chasms. The country sank 11 feet, at the ocean a new salt water lagoon extended 200 feet inland, and coconut trees stood in eight feet of water.

Kilauea Explosive Eruption 1924

The series of subsidences in Halemaumau was now breaking down the mountain, the lava retreated into a deep void, and immediately after the eastern rift subsidence Halemaumau pit began to cave in with increasing avalanches beginning April 28, 1924. Through the cloud of rising dust steam blasts began to fling up rocks May 11, this accentuated the collapse of the funnel and the breaking down of the walls, and a grand climax of explosive eruption was reached May 18. The steam blasts came in pulsations like geyser eruptions every few hours. One man was killed through being too venturesome. The pit was enlarged from 2000 feet to 3500 feet diameter and was left 1300 feet deep. Red-hot walls were revealed below. Steam blasts ended May 27.

Return of Lava July 1924

Except for avalanches Kilauea was dormant until July 19, 1924, when frothy pumiceous lava shot up through the talus of the bottom of Halemaumau with much burning gas, made torrents of melt into the cup of debris at the bottom of the pit, and kept up the action gradually declining for two weeks. This was followed by prolonged dormancy at Kilauea for three years. T.A.J.

(To be continued)

KILAUEA REPORT No. 993

WEEK ENDING FEBRUARY 1, 1931

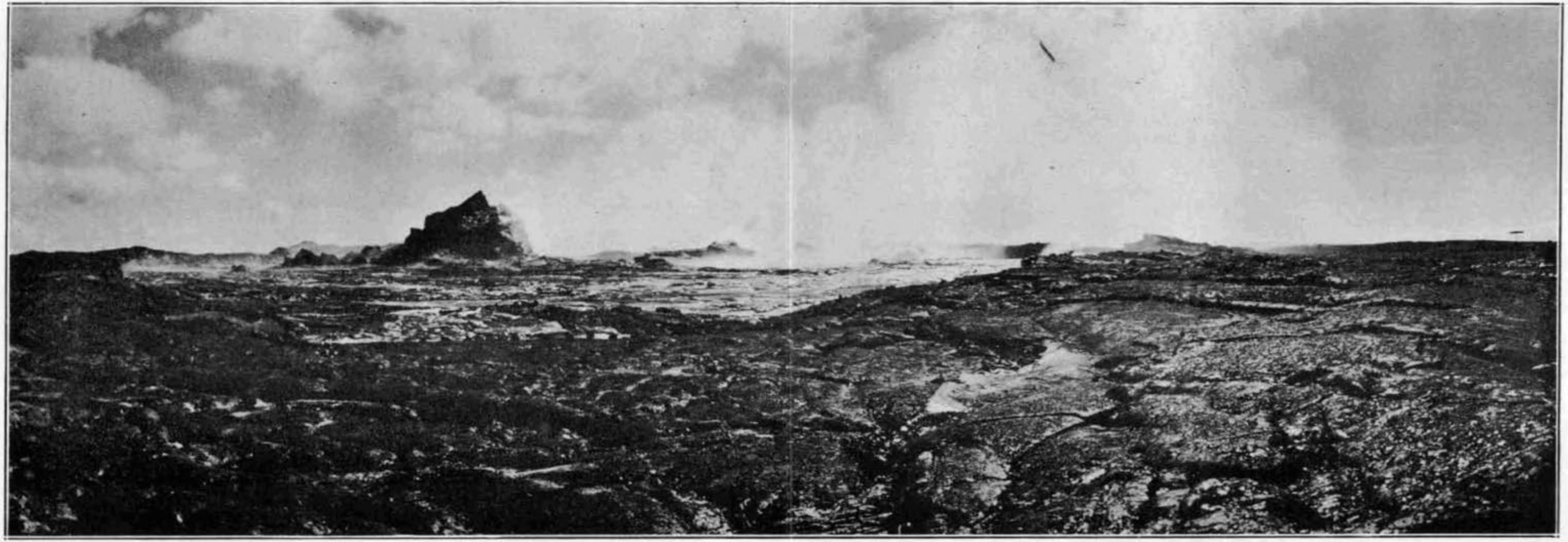
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The week was notable on Hawaii for two felt earthquakes noticed generally all over the island suggesting origins under Mauna Loa. These in sequence upon the similar earthquake of January 16, which by careful analysis showed signs of originating deep under the northeastern slope of Mauna Loa, make the watching of that mountain for possible volcanic activity a matter of interest in the near future.

During the prolonged slight earthquake of 11:39 p. m. January 29 rocks were heard falling in the direction of Halemaumau. Prior to that time there were no changes at the pit, but the seismograph there had recorded a few slow-period tremors. At 9:30 a. m. January 30 a few rocks fell from the north wall of the pit where there was a small red scar from earlier falls. The steaming at the south talus was slight and no fume was detected at the sulphur crack south.

The seismographs at the Observatory registered 1 slight earthquake January 29, 11:39 p. m., 1 classed as feeble 11:56 a. m. February 1, the former showing distance 14 miles, the latter 55 miles. Very feeble shocks were registered to the number of 26 as well as 39 tremors. Ten of the minor shocks indicated distances around 30 miles, as in the case of the earthquake of January 16. The increase of total frequency over the preceding week is from 44 to 67 disturbances. Microseismic motion for the week changed from moderate to very slight. Tilting of the ground was strong to the east.

THE VOLCANO LETTER



Halemaumau brim full of lava December 31, 1920. This photograph shows the whole pit rim with the enclosed liquid lava lake and a high crag standing in its midst, looking toward the south. Where the photographer was standing would now be about 600 feet inside the north rim of the present pit, and 30 feet up in the air. Photo Jaggar.

Halemaumau on the forenoon of November 28, 1919, just after the early morning subsidence which had lowered lakes and crags like a piston drawn into a cylinder. The previous evening the lava had been up to the level of the rim shown so that one could walk out on the inner floor. Ridge in background was the pressure rim crushed up during the previous year. Photo Jaggar.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volacno Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year — Ten cents per copy

No. 320—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — February 12, 1931

How the old lava mountain of the Kau Desert split open December 22, 1919 through sand and rock and the roots of a tree, in order to give vent to the lava which later piled up into Mauna Iki.

TWENTY YEARS OF HAWAIIAN ERUPTIONS
(Continued)

Hoopuloa Lava Flow Mauna Loa 1926

While Kilauea remained dormant, Mauna Loa on April 10, 1926, opened its southwestern rift about 3 a. m., with lava splitting its way upward and gushing at first just outside of the summit crater. Frothy pahoehoe flows from this summit source poured several miles southward. Then at about 8,000 feet elevation and east of the Alika source cones of 1919 three cups opened along the southwestern rift of Mauna Loa, a big brown fume column shot up, and lava flows started along the rift 15 miles southwest of the Mauna Loa summit. The flood of slag spread both east and west from the rift crack, the western flow finally taking control, pouring down through the forest in South Kona, crossing the main road at 12:22 p. m. April 16, pooling back of Hoopuloa village at the coast as a mass of heavy aa, and completely burying the village, wharf, and harbor between 4 and 9 a. m. April 18.

The source region on top of the southwest ridge of Mauna Loa had developed a line of activity along the rift five miles long with cones and fountains 50 to 100 feet high, the activity progressing along the crack from above downward, and settling down to steady flow at one of the lower cones. Flowing stopped at the Hoopuloa shore April 19, but continued in new streams in the upper Honomalino forest until April 30, when the eruption ceased. There were swarms of earthquakes during and after the outbreak, the frequency diminishing after April 17.

Return of Lava Kilauea July 1927

Halemaumau remained dormant until July 7, 1927, when lava returned to the bottom of the pit, declining in activity to dormancy July 20. The spraying fountains of pumiceous lava attracted attention by their illumination at 1 a. m., and were found to be in a line of four vents trending northeast-southwest across the lava floor of 1924. The persistent vent which became the main source of the bottom fill originated up the southwestern talus and built a pumice cone. About 100 feet of new lava was deposited over an area in the bottom of the pit 1700 feet long northeast-southwest by 1400 feet wide.

Return of Lava Kilauea January 1928

After a series of heavy avalanches in Halemaumau culminating in a monstrous one which caused the north-

Halemaumau Pit during its recovery September 7, 1920, showing the rising pahoehoe liq
Taken from an inner sl

western talus to develop into a landslip over the lava floor at 12:26 a. m. January 11, 1928, glow suddenly appeared at the pit coincident with this landslip. New lava had spouted up cracks in the 1927 floor which was brightly incandescent at first, but the rosy over the pit disappeared in 20 minutes. By 1 a. m. the glowing areas indicated cooling flows with a hint of blue flame at a northern cone vent, but there was no observable motion. Slides from the walls continued on all sides. There was no fountaining seen, but no observer was present during the first half hour.

This upflow was believed at the time to be the result of loading down the crust of July 1927, and squeezing up the lava that remained still fluid below. This explanation is doubtful as the frequency of volcanic earthquakes had been unusual for two months, and an eruption was expected.

Return of Lava Kilauea February 1929

Halemaumau was dormant until February 20, 1929, when inflow of lava in the bottom of the pit lasted a day and a half. This was heralded by a striking record of tilt with small earthquakes at the pit seismograph. The ground suddenly tilted away from the pit, and at the end of the eruption tilted back again. Again the outbreak was just after midnight, in the early morning hours of February 20 along a fracture in a straight line across the northwestern side of the bottom lava in Halemaumau. As the landslip of January 1928 had diminished the size of the cup of talus, the new fill, only 45 feet deep, was smaller than that of 1927, measuring only 1600 feet in diameter. The action was marked by a line of continuous fountains with a big fountain of the Mauna Loa type shooting up frothy lava 200 feet at the north end of the live crack, and making a streaming with bright line pattern out into the lake which covered the bottom. There was a steady roar, blue fume arose, while pumice and Pele's needles fell outside of the pit. There was almost no avalanching. The northern fountain built up a pumice and lava heap from which cascades poured down, and this broke down to an "arm-chair niche" at the end.

Return of Lava Kilauea July 1929

After a shorter period of dormancy Halemaumau again produced a spurting eruption in its bottom lasting three days July 25-28, 1929, so as to diminish the depth of the pit by another layer of lava 55 feet deep. This left Halemaumau approximately 1,000 feet deep. Again the outbreak was in the early morning. The time was about 4:35 a. m. as shown by sudden tilt and earthquakes. The center of activity was a fracture through the western talus tangential to the bottom plug. Big fountains spouted up there, and the seismograph at the pit showed inward tilt toward the center on the first day, followed by outward tilt thereafter. In all these short eruptions of lava in Halemaumau a characteristic harmonic tremor of the ground was registered at the Observatory during the days of actual fountaining, and was absent before and afterwards. At the end of July there remained visible glow from cracks in the floor for a few days, as usual with these eruptions, but none of these outbreaks left hissing gas or other signs of continued activity. The eruption stopped abruptly and the new lava solidified.

id lava of the lakes making overflow platforms as the lake lava gained upon the crags.
elf looking south.

Hualalai Earthquake Crisis Autumn 1929

Suddenly small earthquakes began to be felt in North Kona near Hualalai Volcano September 19, 1929, though Kilauea remained dormant, and no volcanic activity appeared elsewhere. Puuwaawaa, a large cone on the north flank of Hualalai, became the center of maximum motion. Large destructive earthquakes about Grade IX Rossi-Forel occurred September 25 and October 5. Six thousand two hundred eleven earthquakes were registered in Kona between September 21 and October 16. Great damage was done though no lives were lost: houses, roads, stone fences, fills, tanks, and masonry of every description were broken. Everything indicated that this seismic spasm was connected with volcanic movement of lava underground tending to shift from the Mauna Loa region to the Hualalai region. An Hualalai outbreak was expected, for this volcano had been active in 1800. No lava flow came and the seismic movements gradually died away in November.

Return of Lava Kilauea November 1930

Another eruption began in the bottom of Halemaumau at 1:29 p. m. November 19, 1930, and this proved to be the longest of this series of intermittent eruptions, bringing also a much greater amount of lava into the bottom of the pit. The activity lasted until December 7 and added a layer to the bottom averaging 70 feet deep. The bottom floor was greatly enlarged to become a leaf-shaped structure 2200 feet long northeast-southwest by 1700 feet wide with a large source cone near its southern margin. The remnant half cone of July 1929 still persists at the base of the western talus.

The new lava fountains broke through the floor in front of the grotto niches of 1929 and several fountains developed, one dominating the others as usual, and this in the region of the south edge of the 1929 floor. Here there were developed spraying jets 100 feet or more high, pumice and Pele's hair fell outside of the pit, a crescent heap was built around the south side of the fountain and this gradually enlarged to become a big cone more than 100 feet high. A lake was developed north of the source cone with changing ramparts around its margin, and this at the top of a slag heap which constituted the entire fill of 1930. From the lake the slag heap sloped down in all directions, steeply at the south and more gradually at the north. The activity developed streaming across the lake from the source cone, and trickling flows now here, now there, from the lake out to the margin of the fill. The decline of activity was gradual, and the region of lake and source cone was left thicker and higher than the border fill. Halemaumau was now 930 feet deep, and at the top 3400 feet long by 3000 feet wide.

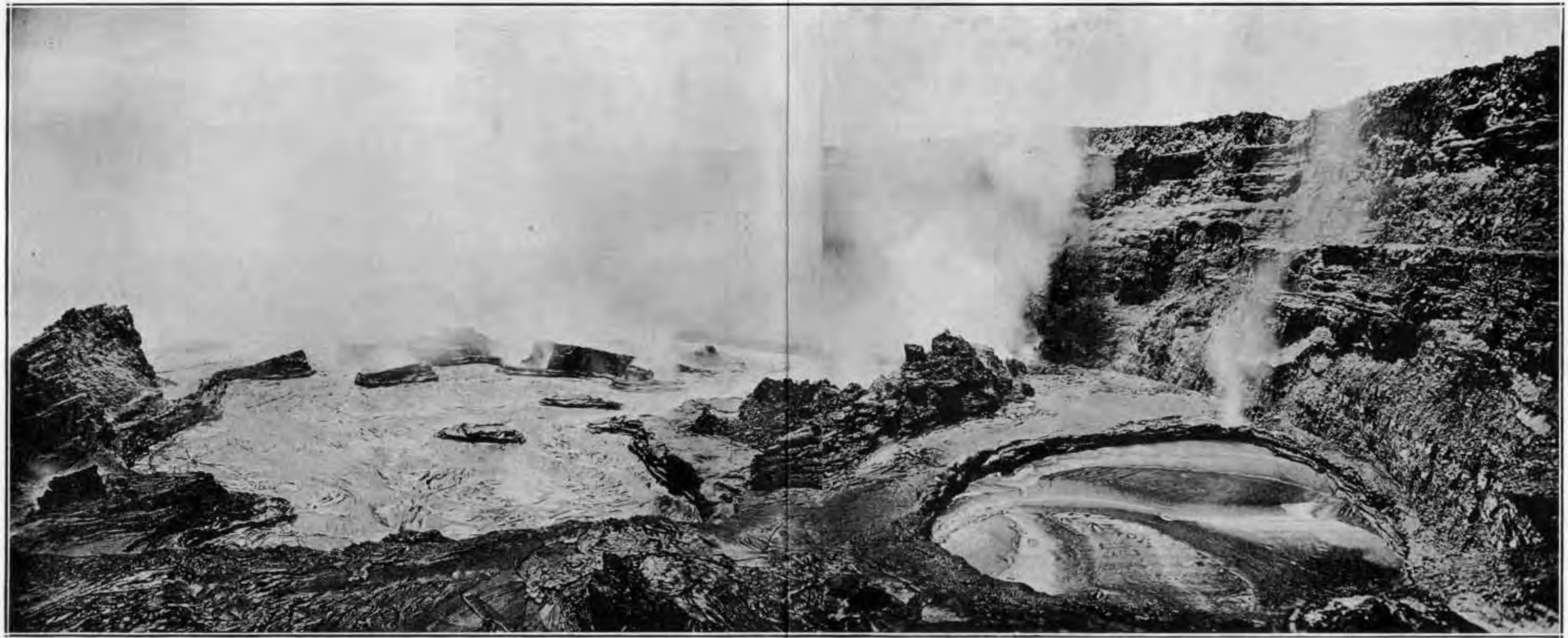
T.A.J.

KILAUEA REPORT No. 994

WEEK ENDING FEBRUARY 8, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Conditions at Halemaumau remained without change during the week. A few quick-period tremors recorded on the pit seismograph early in the week.



Halemaumau Pit during its recovery September 7, 1920, showing the rising pahoehoe liquid lava of the lakes making overflow platforms as the lake lava gained upon the crags. Taken from an inner shelf looking south.

Upper part of one of the flows from Mauna Iki January 9, 1920, showing a bend in the lava stream, placidly flowing along like a river. This lava had come out of the same crack shown on Page One, and six miles away was draining the pit shown on Pages 2-3. Photos Jaggar.

Fourteen local disturbances and one distant shock were recorded on the instruments at the Observatory, the former classified as follows: 11 tremors, 2 very feeble seisms, and 1 feeble seism. The feeble shock occurred at 7:10 p. m. February 4 and had an indicated distance of 23 miles from the Observatory. It was felt at Kapapala, Hilo, and vicinities.

The teleseism, which began recording at 12:27 p. m. February 2, had an indicated distance of 8,040 kilometers; direction as determined by the record of the vertical component was south-southwest (New Zealand disaster).

Tilt for the week accumulated strong northwest Microseismic motion mas slight.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volacno Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

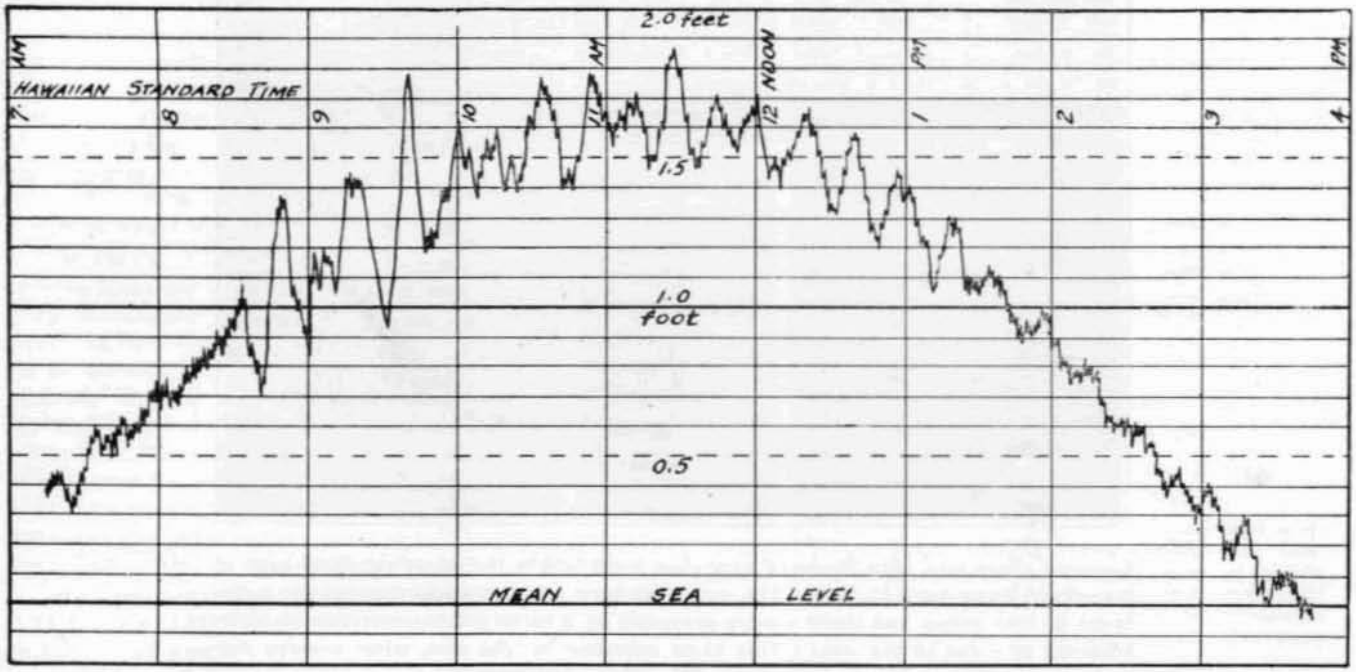
The Board of Directors includes Lorrin A. Thurston, President; Frank C. Atherton and Walter Dillingham, Vice-Presidents; L. Tenny Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year — Ten cents per copy

No. 321—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — February 19, 1931



TIDAL WAVE, NOVEMBER 4 1927
HILO, HAWAII.

Tide gauge record showing the beginning of an earthquake wave series at 8:30 a. m. with maximum range of about a foot, from an earthquake under the sea off the coast of California November 4, 1927. This earthquake was 3,925 km. from Hilo, and the sea wave traveled 7.8 statute miles per minute, The quake was felt in California and on a ship at sea.

HAWAIIAN DAMAGE FROM TIDAL WAVES

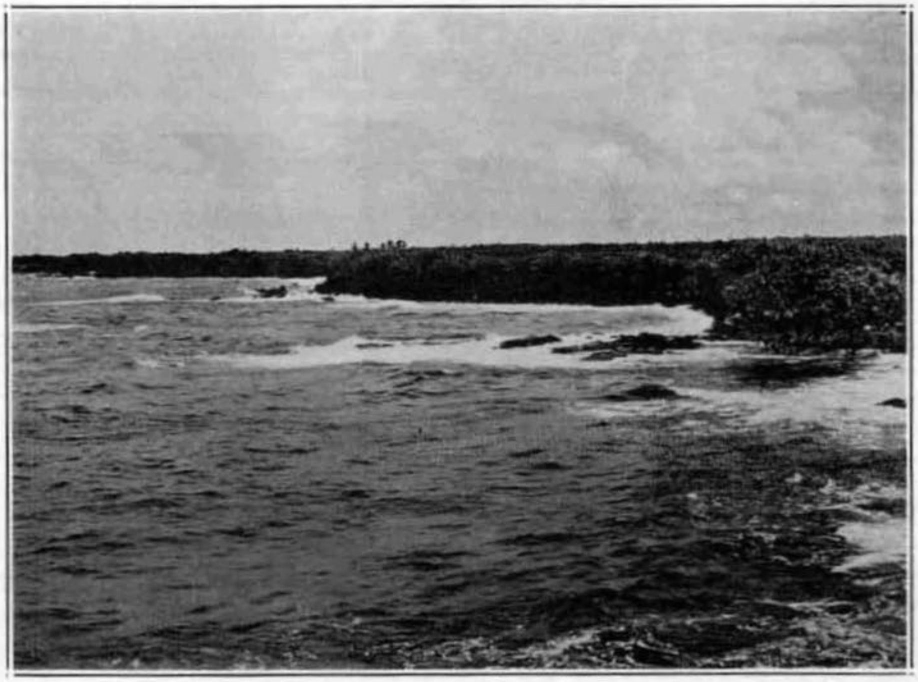
In Volcano Letter No. 274 the general conditions, under which a "tsunami" or earthquake wave is generated by a seismic movement of the sea bottom, are reviewed. These are commonly called tidal waves, a name protested by geologists, but after all not wholly inappropriate, for tides do enter into resonance with the harmonic oscillations of water that make catastrophes popularly called tidal waves. Moreover not all such damaging movements are due to earthquakes, as this piling-up of rhythms to make flood on a shelving shore may be due to landslip, to volcanic engulfment under the sea, to submarine lava flow, or to hurricane. In the earthquake wave proper, a sea-bottom shift like the dropping of a fault block of earth crust sends an impulse across the deep ocean, the trough or crest of which travels from 300 to 500 miles an hour, and so is quite comparable to the travel of the crest of the tide actuated by the pull of the moon. We have proved here in Hawaii that two tremendous deep-sea earthquakes off the Aleutian Islands in one case made disaster in Kahului and Hilo, in the other did not. Both made measurable waves, but probably the one augmented a tide, and the other was in some way compensated by a tide.

Facts about tsunami in Hawaii may be found in the well known books of Brigham, 1866 (Mem. Bost. Soc. Nat. Hist., Vol. I, pt. 3), Hitchcock, Hawaii and Its Volcanoes (Honolulu, 1911), and Brigham, Kilauea and Mauna Loa (Bishop Museum 1909).

In May 1819 the ocean was seen to recede in Hawaii and executed about 13 oscillations before it came to rest again.

On November 7, 1837, a big earthquake off the Chile coast made a disastrous wave about the shores of the Pacific Ocean which was described by Coan as arriving at Hilo so as to cause retirement of the sea about 7 p. m. The surge returned in a few moments "breaking on the beach with a noise like thunder." Lowlands were submerged. Houses were swept away. People were left struggling in th water. The sea remained high for 15 minutes. Then a series of oscillations occurred, the water moving slowly out and in again. There was a meeting of the natives on the shore at the time, and the flood caused great consternation, the people shouting to find their lost relatives and rushing about in panic. An English whaler which was anchored in the bay lowered boats for relief. Canoes were all washed out to sea. The water ran past the ship with an eight-knot current, and soundings were reduced from five to three and a half fathoms, so that much of the bay was dry.

At Kahului in Maui the water retired widening the beach 120 feet so that the delighted natives ran out on the reefs that were left bare in order to pick up stranded fish. But they were terrified to see a wall of water returning



Lowered shore line with drowned pandanus trees where the coast subsided east of Kapoho in Puna April 23, 1924. The land back from the shore was cracked for a distance of four miles, and these events preceded by a fortnight the collapse of Halemaumau 30 miles to the west. This coast subsided in 1868 also, when a wave disaster was produced. Photo Emerson.

which engulfed them and the village. As they were good swimmers only two lives were lost. The back-and-forth disturbance of the water continued for more than 24 hours.

At Honolulu this 1837 tsunami lowered the water eight feet so as to leave the reef dry; returned slowly in 28 minutes; then fell six feet again; and the ebb and flow continued at intervals of about 28 minutes. The third of the flood-water spells reached about four inches above high water mark.

The next account is of a retirement of the waters at Honolulu May 17, 1841, at 5:20 p. m., when the ebb was sudden, leaving the reef bare, and the movement occurred twice in 40 minutes. This earthquake wave was especially sudden at Lahaina in its sucking down of the sea level, and it was reported as affecting the coast of Kamchatka also.

The year 1868 produced two disastrous tsunami on the island of Hawaii, the first accompanying the terrific local earthquake in Kau in April 2, the second from a submarine shock off Arica, Peru, August 13.

The local disaster of April 2, 1868, made a wave on the shore all the way from Kahuku to Kapoho, swept away the houses on the Puna shore, the Pahala shore, and the Honuapo shore, and with the earthquake the Puna coast subsided from four to seven feet. At Punaluu the stone church, the wooden houses, and all the coconut trees except two were washed down. Floating rubbish was driven inland "about a quarter of a mile," and large bowlders were washed in at Pohoiki. On the whole coast 108 houses were destroyed and 46 persons perished by the sea wave. At Hilo the sea receded horizontally 150 feet and when it returned rose about 10 feet above high-water mark.

The big Pacific wave of August 13, 1868, from near Peru, reached Hilo in about 14 hours, traveled about 350 miles per hour, and was reportedd to have been marked on a coconut tree somewhere near the present railway station as reaching 15 feet above ordinary low water and 5 feet above the ground. Hilo is 5,460 miles from Peru. At windward Maui the flood of this tsunami was reported 12 feet high. The damage was of the usual sort and must have been considerable in Waiakea and Kahului. The records of it are probably to be found in the newspapers of the time.

On August 27, 1872, just after a remarkable lava outbreak had begun in the summit crater of Mauna Loa which was destined to last some years, a small tsunami occurred at Hilo during calm weather, the water rising four feet, then six minutes later three feet, and diminishing for about 14 oscillations. The short period of this water wave, six minutes as contrasted with 20 to 30 minutes for the ones of distant origin, makes it likely to have been a local disturbance on the sea floor.

The earthquake wave of 1877 was the most disastrous on record for Hilo and closely resembled that of 1837. Like that one and the one of August 1868, it originated off the coast of South America between Chile and Peru in the evening of May 9, 1877, and reached Hilo at 4 a. m. May 10. At 5 a. m. it penetrated the shops on Front Street at a height reported by Luther Severance 12 feet 3 inches above ordinary low water. Every house within 100 yards of the water was swept away in Waiakea. Five lives were lost, seven persons were injured, 163 were left destitute, and 17 horses and mules were drowned. A vessel which had been anchored in four fathoms of water found itself on the ground. The rise and fall of the waters continued all day. At 7 a. m. one complete swing from low to high was measured 14 feet vertically. The sea swept completely over Coconut Island. Thirty-seven dwellings were destroyed and 17 badly wrecked. Lumber was washed away to the value of several thousand dollars, and the total damage was estimated at $13,000.

There have been several small local waves doing some damage in Hawaii, occasioned by submarine volcanic disturbances, of which the wave at Hoopuloa in 1919, at the time of the nearby Alika lava flow into the sea, is typical. There was a succession of short period shallow tidal waves ranging from 3 to 14 feet in height, with maximum nearest to the flow delta on the third day of the eruption. The Hoopuloa wharf was flooded.

On February 3, 1923, a destructive tidal wave at Kahului in Maui and at Hilo occurred about seven hours after a big earthquake under the Gulf of Alaska, 2,500 miles away. In Honolulu the waters receded revealing the reefs for 20 minutes and then there were in-and-out surges at intervals of 15 to 20 minutes. In Hilo sampans in the Wailoa River were smashed over the railroad bridge, the bridge was destroyed, a man was killed, and the railroad embankment between Hilo and Kuhio Wharf was washed down and houses and wharves were upset. The major wave was the third of the series and was said to pile up more than 20 feet in the funnel of the bay at Waiakea.

We have mentioned pronounced damage in 1837, twice in 1868, again in 1877, and 1923 in Hilo, say five times in the century or an average of once in 20 years, mostly waves from Alaska or South America. One great disaster in Puna and Kau was due to a local submarine disturbance. Nine measured large or small waves between 1918 and 1929 on the Hawaii coast have been discussed in publications of the Hawaiian Volcano Observatory, and only since 1927 have we operated the Hilo tide gauge. Probably waves occur to the number of more than one a year, disregarding the question of damage. There is no record yet of serious tidal wave damage in Honolulu, but waves from the west and northwest have recorded as strongly on the Honolulu tide gauge as on the Hilo gauge. T.A.J.

TILTING OF THE GROUND FOR JANUARY

The following figures show the net amount of tilt per week at the Observatory on the northeast rim of Kilauea crater, and its direction, computed from the daily seismograms, by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the direction given.

December 29-January 4	0.97 seconds	W
January 5-11	0.96 seconds	S
January 12-18	0.91 seconds	WNW
January 19-25	1.33 seconds	WSW
January 26-February 1	1.33 seconds	ENE

KILAUEA REPORT No. 995

WEEK ENDING FEBRUARY 15, 1931

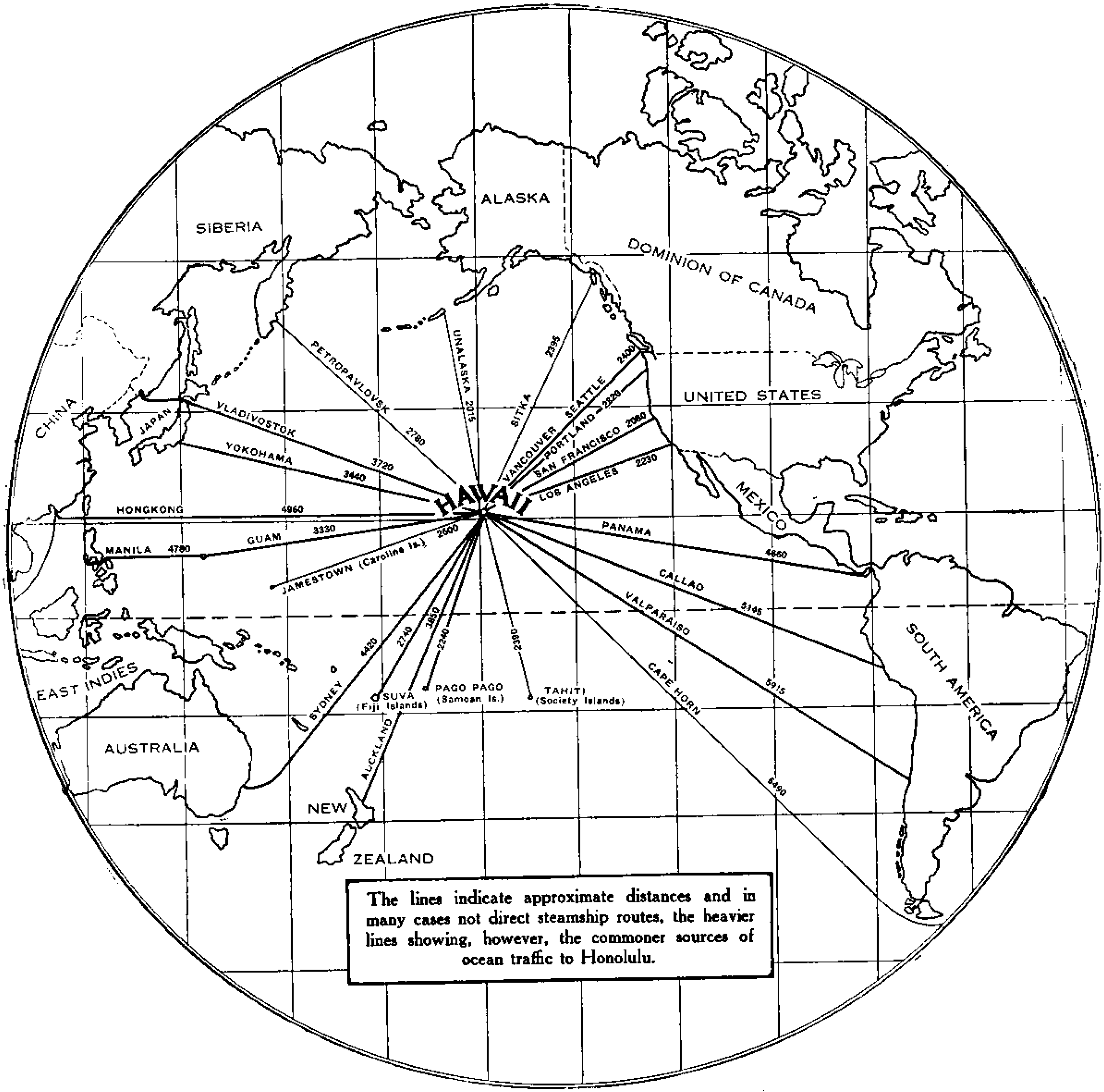
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar. Volcanologist in Charge

The island of Hawaii is at present very quiet and practically no changes have occurred during the week at Halemaumau pit of Kilauea Volcano. Measurement of cracks at the edge of the pit on February 10 revealed a very slight widening. There is but little steam on the south talus and a few rocks have slid down to the edge of the lava floor at the south.

Only two very feeble local earthquakes were registered at the Observatory, of which one at 4:51 a. m. February 11 indicated distance of origin 28 miles. In addition 12 tremors were recorded. Tilting of the ground was slight NNW, and microseismic motion was very slight.

Detail of lowered shore line of 1924 near east point of Hawaii showing new lagoon of salt water over 12 feet deep with submerged coconut palms. Photo Emerson.



Map of Pacific Ocean. Submarine earthquakes making destructive tidal waves in Hawaii originate generally in the northeastern semi-circle of the ocean from Kamchatka to South America.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

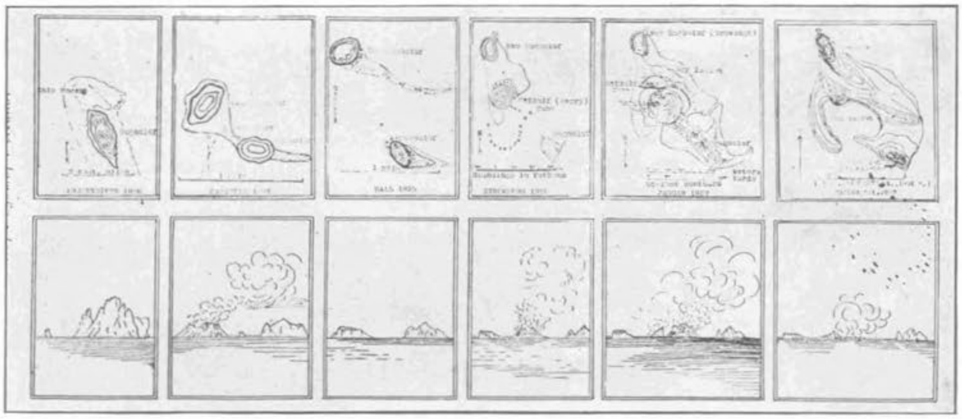
Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 322—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | February 26, 1931



Sketch maps and profiles of Bogoslof of dates from left to right as follows: (1) Krusenstern 1826, (2) Cantwell 1884, (3) Dall 1895, (4) Stromberg 1906, (5) Jaggar 1907, (6) Camden October 1907. These show the gradual growth of the island, and the lower cut in each case is the view from the south.

EVOLUTION OF BOGOSLOF VOLCANO

The scientific investigation of our vast American domain of active volcanoes in the Aleutian Islands and the Alaskan Peninsula is the largest task before the Section of Volcanology of the Geological Survey. Gradual advancement of this work is provided for by act of Congress, and during the coming summer Akutan Volcano, which has exhibited frequent activity, will be investigated. Akutan is next to the east of Unalaska (see map Page Four), and just to the northwest of Unlaska Bogoslof has been building up during the last 150 years by processes of squeezing up of lava domes similar to that of Tarumai Volcano (Volcano Letter No. 317).

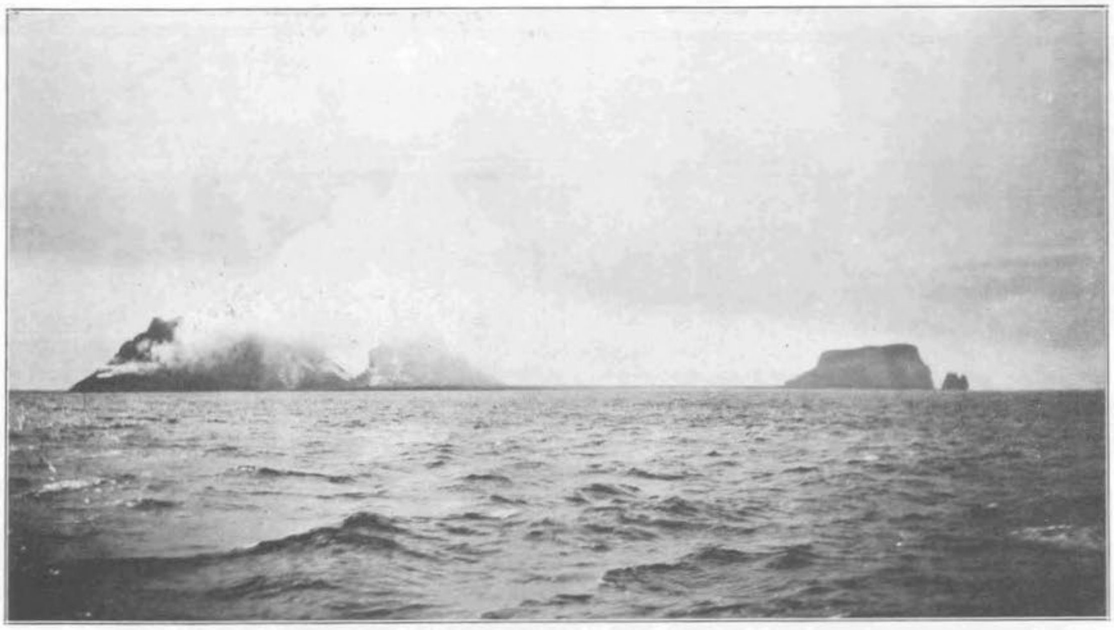
The gradual enlargement of Bogoslof island from 1826 to 1907 is shown in the succession of maps and sketches illustrated on Page One. Bogoslof is a big cone on the sea floor like Falcon Island and Niuafoou in Tonga, but only the tip of it is building above the waves. Under the ocean it is 6,000 feet high. The group of rocks that make the islet have been enlarging by alternations of rising lava and explosive steam jets, the former making domes, and the latter spreading gravel.

Ship Rock was first noticed by sailor men in 1768. Bogoslof proper or Castle Rock was thrown up in 1796. Grewingk or New Bogoslof rose about 1884 and the older Ship Rock was demolished, but Castle Rock still remained in 1891. In 1896 and 1899 there were two islands with water between. In May 1906 the "Albatross" reported a new volcano Metcalf Cone midway between Castle Rock and Grewingk, and attached by an isthmus to the latter. The cutter "Perry" in July 1906 reported 40 feet of water between the new dome and Castle Rock.

In July and August 1907 the writer visited the islands. A new cone McCulloch Peak had risen south of Metcalf Cone and adjacent to it. Metcalf had split in two showing an andesite horn rising through the split cone. This closely resembled the Pelee spine of Martinique. The rock was hornblende augite andesite with inclusions of sulphides and of diorite, some forms resembling pumice. There were also horn-like processes projecting from the summit of McCulloch dome, which was approximately 450 feet high above the sea. The channel between the islands was entirely filled so that Castle Rock, McCulloch, Metcalf, and Grewingk formed a single island a mile and a half long. McCulloch Peak was nearly surrounded by a steaming saltwater lagoon at about 90° F. and was itself steaming quietly. The following describes the adventures of the writer's party from the schooner "Lydia" of the Technology Expedition (Technology Review Vol. X, No. 1, 1908):

"Wednesday August 7, 1907. At 8 a. m. Bogoslof was in full view ahead, the weather fair, a steady southwest wind blowing. It was determined to land two dories and have the vessel stand off, while three or four hours if possible were spent in examination of the island. (The photograph on Page Two was made from the "Lydia" at this time looking west, and corresponds to the next to the last map of the series on Page One.)"

"The landing was made at 10:30 a. m. Hundreds of immense sea lions, bellowing with voices that well justify their name, swam within a stone's throw of the dories, when they would raise themselves high in the water, stare at the boat, and then plunge frantically beneath the waves. When we landed on the beach, most of the animals there had floundered into the water; but one immense bull re-



The northern hills and connecting sand bars of Bogoslof Island, looking west August 7, 1907, showing McCulloch dome on the left, Metcalf half-dome, and Grewingk. Castle Rock is out of the picture at the left. Photo Jaggar.

mained, apparently asleep. One of the party ran toward him with a camera, the monster awoke, and with awkward gait flopped down into the sea.

"The hours spent on Bogoslof were the most interesting of the whole expedition. The rocky cliffs are covered with millions of birds, their eggs and their chicks, chiefly murres and herring gulls. On startling them from the face of the cliff of Castle Rock, the swarm of winged creatures literally darkened the air. To members of the party climbing among the rocks the stench from offal and decayed eggs was intense. The island exhibited four rocky hills 350 to 500 feet high, Castle Rock peaked and prominent at the southeast, McCulloch dome circular and steaming actively in the middle, Metcalf crag half destroyed and adjacent to McCulloch on its north side, and Grewingk a flat table rock at the northwest end of the group. These were all connected by continuous gravel and sand strips where a year before there had been a broad channel and seven fathoms of water about the site of McCulloch dome."

"Around the base of McCulloch hill was a lagoon of hot salt water steaming quietly and yellow with iron stained mud. This hill was 450 feet high at the time of our visit, conical in outline by reason of the talus slopes, and showing great lumps or horns of what appeared to be ledge rock jutting out from the upper slopes, while the slide-rock slope of bowlders all around the base was straight in profile standing at 30 degrees. The entire mass was steaming from many fissures, and in places there were bright yellow sulphur coatings at the steam vents."

"Metcalf hill was a half-cone with its south side broken down where an explosion had destroyed it prior to the beginning of the welling up of the McCulloch lava. This rupture left Metcalf with a vertical precipice on the side opposite the remnant of its cone slope still steaming on the north side. Neither Grewingk at the north nor Castle Rock at the south was volcanically active at the time of this visit. The steep cliff of Metcalf revealed in cross section up its middle a great horn of congealed lava, which had risen into the midst of the cone with a smooth curved surface toward the west, and at the top a broken vertical surface toward the east. Seen from the north, this horn looked like a shark's fin or a parrot's beak; seen from the west like the horn of a rhinoceros."

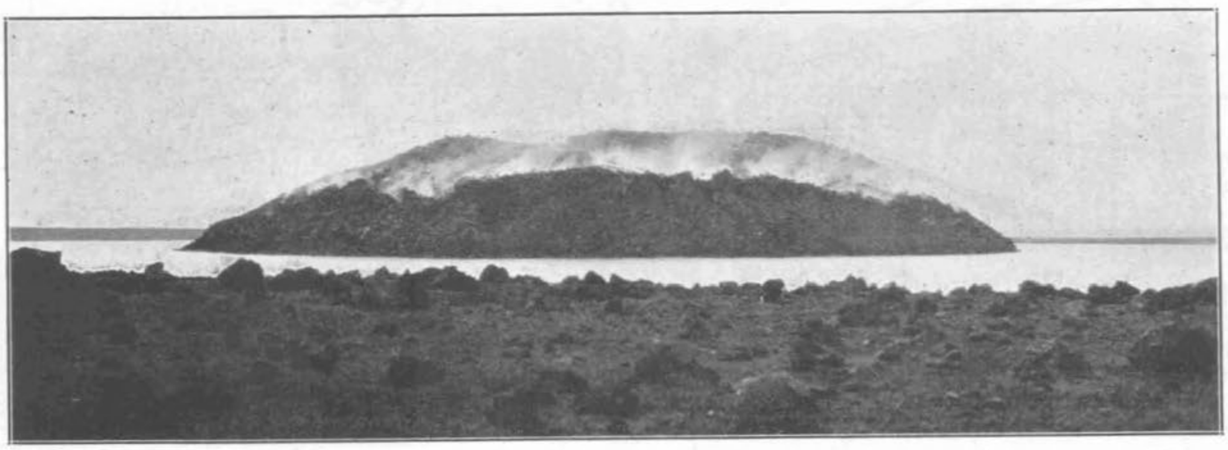
"McCulloch and Metcalf domes were both products of the slow pushing up from beneath the waves of a mass of refractory lava, semi-solid, crusting and breaking into blocks as it rose, with only the central portions retaining a semblance of fluidity. The horns were doubtless such central portions. The same mechanism produced the extraordinary spine which rose 1,000 feet above the dome of Mont Pelee in Martinique in 1902."

"Between 1891 and 1895 Grewingk had changed its form from a large irregular cone to a small flat-topped table. I believe this change was due (1) to its being leveled by the waves and covered with beach deposits, and (2) to its being subsequently uplifted. Beach bowlders and sands could now be seen in 1907 on its flat top and in section at the edge of the top of the cliffs. An extraordinary feature of the rocky wall of Castle Rock was a sea cave at the north end surmounting a rock bench or platform 25 feet above the ocean level. This notch and floor had evidently been made by the surf, but the present surf was beating the strand at a much lower level. On comparison with photographs of 1906, a year before, it was found that the uplift of 25 feet had taken place during the last year, for those photographs showed the same rock bench and cave at sea level. Evidently Castle Rock had been rising slowly during eight months, while the lava pressure under McCulloch hill was heaping up that dome over 400 feet, with a base measuring 2,000 feet across at the beach level. The effects of mass uplift were in evidence all over the island. While a half plastic lava was pushing up rapidly in the middle cone, the adjacent, older, hard rock summits of the submarine mountain were slowly heaved up."

"On September 1, 1907, after we had left the islands, a steam blast and an engulfment destroyed McCulloch hill, sand and dust fell 100 miles to the eastward, and a visit by the Coast Guard cutter in October 1907 revealed a watery lagoon at the south base of the Metcalf remnant, McCulloch dome was gone, and all of the rocks were shrouded in a heavy mantle of volcanic debris."

There was probably another explosion lowering the remains of Metcalf hill in 1908, leaving a bay surrounded by beaches between Castle Rock and Grewingk, and in September 1909 two small lava islands arose here, a new lagoon was formed shut off from the sea, and these in June 1910 had united into a single lava hill standing 178 feet above the sea. A true crater was opened by explosion in this hill September 18, 1910, which ceased fuming in 1914. This Tahoma hill, as it was called, had been eroded away in 1922 and a channel was again opened between Castle Rock and Grewingk so that a boat could sail through. Grewingk had diminished in size and Castle Rock was changed to two rocky horns with a big accumulation of sand and gravel piled round about which trailed off into a long sand spit at the north. In July 1926 an explosive eruption heralded new activity, another occurred in December, and then a new lava dome piled itself up in the middle region within a warm salt-water lagoon at 70° F. completely shut off from the ocean by a ring of sand and bombs, and gravel heaps connecting Castle Rock and Grewingk as before. Since that time the island has quieted down.

T.A.J.



New lava heap of Bogoslof Volcano about June 28, 1928, looking southwest showing warm salt lagoon and ring of explosion debris in about the same location as the active domes of 1907. Photo Wheeler.

KILAUEA REPORT No. 996

WEEK ENDING FEBRUARY 22, 1931

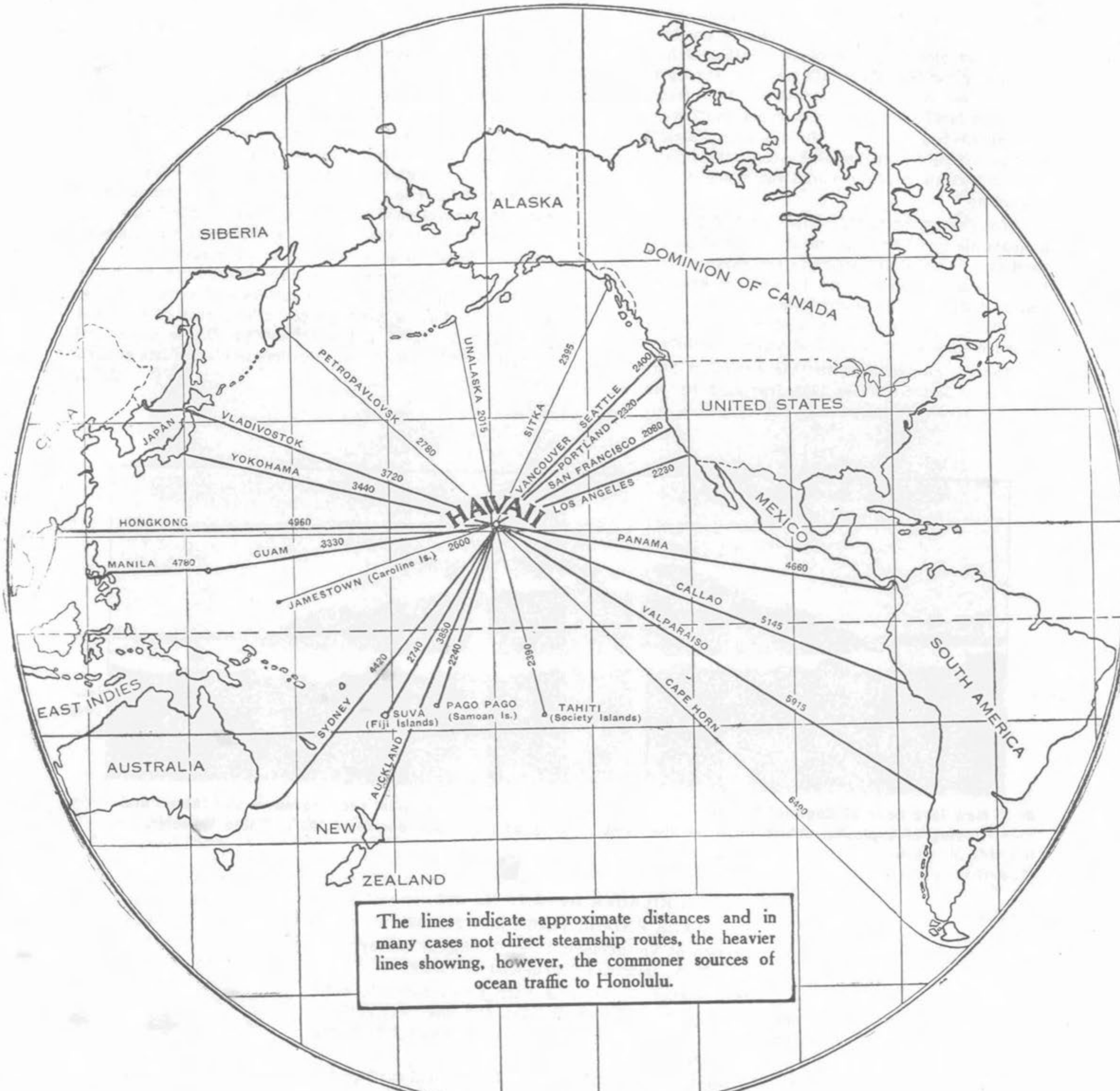
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Halemaumau pit remains very quiet, there is only slight steaming on the south talus, and dust was noticed from slides at the north wall of the pit about 3:10 p. m. February 19.

Eighteen tremors and one very feeble local earthquake were registered at the Observatory during the week, the earthquake at 12:56 a. m. February 20 indicating distance of origin nine miles. Another at 12:26 a. m. February 21 was only a tremor at Kilauea but was felt as a single bumping jolt at Kealakekua in Kona accompanied by a slight noise.

Tilting of the ground was moderate to the southwest at Kilauea, and microseismic motion was slight.



Map of the Pacific Ocean showing position of Unalaska southwest of Alaska in the Aleutian Islands. Bogoslof is 40 miles northwest of Unalaska.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

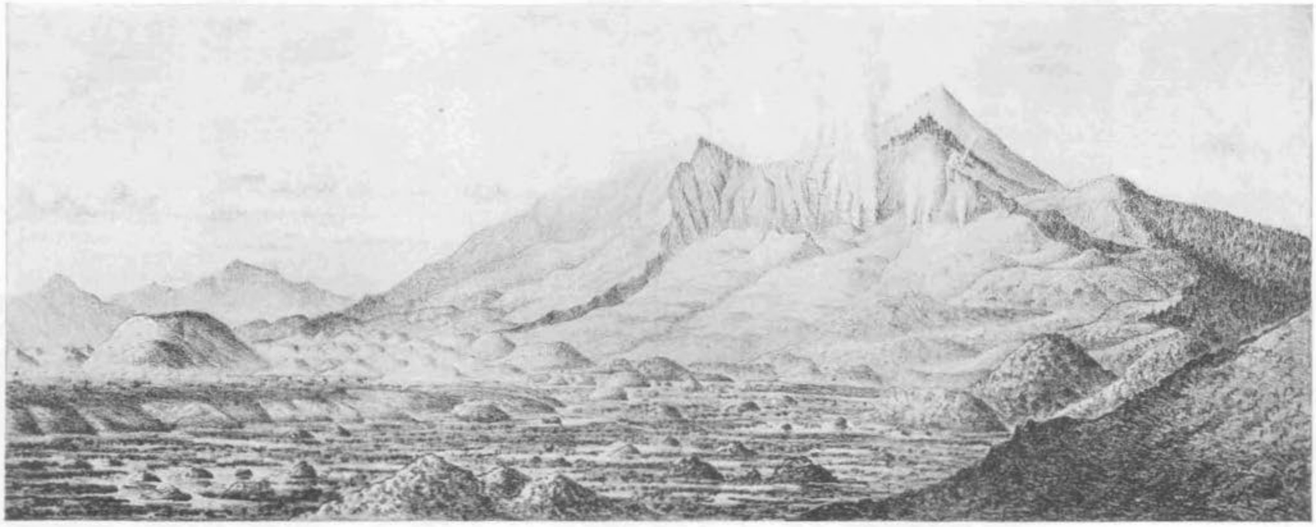
Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 323—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | March 5, 1931



Crater of Bandaisan after eruption of 1888 showing the steaming cleft in the mountainside, bare hillsides that were scored by the terrific avalanche, and mounds left by settlement of the debris. After Sekiya and Kikuchi.

JAPANESE VOLCANOES ARRANGED IN SERIES

In order to classify volcanoes intelligently it is necessary to know the deeper mechanism that gave birth to the crater or mound or mountain. In Volcano Letter No. 164 was reviewed the classification given by Sapper, (1) Hawaiian liquid lava flow, (2) liquid lava combined with steam jet as at Stromboli, (3) stiffer lava combined with steam and black dust as at Vulcano, (4) stiff lava plug combined with Vulcanian paroxysms of steam and dust as at Pelee in Martinique, and (5) steam explosion alone throwing up fragments of old rock as at Bandaisan in Japan. These are usually described as (1) Hawaiian, (2) Strombolian, (3) Vulcanian, (4) Pelean, and (5) Bandaian. Numerous unhappy Greek words have been invented by Schneider and others, which unfortunately some Japanese geologists are repeating, but clear descriptive language is best in the present stage of the science.

A recent essay by H. Tanakadate (Eruptive Types of Japanese Volcanoes in recent Years, Proc. Fourth Pac. Sci. Cong., Java, 1929, p. 621) is a sound attempt to arrange the eruptions of Japan in series. The author uses some technical terms which would much better be replaced by plain language. He distinguishes eleven types as follows:

Bandaisan	1.	Sudden explosion without lava.
Shiretoko	2.	Sulphur eruptions.
Kusatsu-shirane	3.	Crater lake eruptions.
Tokachidake	4.	Explosive avalanches with explosive lava.
Ususan	5.	Swelling mountain with explosive lava.
Tarumai	6.	Explosive jets and rising plug.
Asama	7.	Aa lava in crater with explosive jets.
Sakurajima	8.	Ruptured mountain flank with aa outflow.
Oshima	9.	Fluctuating crater lava and flows.
Minami-iwo-shima	10.	Submarine eruptions.
Hakone	11.	Subterranean lava movement making earthquakes.

(1) **Bandaisan** in interior central Japan had some solfataras on top of one of its peaks, elevation 1840 meters. July 15, 1888, subterranean roaring began at 7 a. m. and three-quarters of an hour later a gigantic steam blast rushed out at these solfataras and engulfed or threw out about half of this particular peak, avalanching 1700 million cubic meters of rock down the northern foot of the mountain, leaving a horseshoe crater 1 km. wide, 400 m. deep, and open to the north like a quarry with rushing steam in its bottom. The process dammed a river and made a lake. If there were fragments of new lava, they were in small amount.

(2) **Sulphur eruption.** In the eastern part of Hokkaido, the north island of Japan, Shiretoko-Iwo-san is a volcano of active solfataras where sulphur was mined. August 9, 1889, at 1 p. m. an explosion in a solfatara threw out sulphur both as blocks and liquid, forming a craterlet 40 m. long. The activity decreased at the end of two weeks, leaving a lake of boiling water, but sulphur production augmented. The next year on June 15, boiling water was thrown out. The accumulating and melting of sulphur coupled with geyser action influence such eruptions; the liquifaction temperature of sulphur is 114.5° C.

North side of Asama Volcano, central Japan, showing the great aa lava flow of 1783 and the fuming crater in the background. After Omori.

(3) **Crater lake eruptions.** Kusatsu-Shirane is a volcano 2,162 meters high in central Japan with three circular crater lakes and hot gases, amid sulphur mines. In July 1897 there were earth tremblings, a steam blast occurred in the middle of the largest lake and continued to mid-August. There were similar outbursts in 1900, 1902, and often between 1905 and 1925. Such eruptions in crater lakes are not rare in Japan. An explosive paroxysm of subterranean gas burst through Noboribetsu crater lake in southeast Hokkaido in the spring of 1927. The lake shows a temperature of 50° C. on the surface and 133° C. at the bottom. This place contains melted sulphur.

(4) **Explosive avalanches.** Tokachidake is a volcano in central Hokkaido 2,077 meters high with fumaroles so active that sulphur could be extracted from the fume by condensing it. Explosions began December 23, 1925, and culminated in two blasts May 24, 1926, upsetting the western half of a solfataric hill and causing it to avalanche down so as to leave a crater 130 by 300 meters and 50 meters deep. On May 25 a new sudden explosion threw up fresh lava and was accompanied by an earthquake, the scoriae falling on the avalanche debris. The activity waned except for renewed explosions September 8 and 10 ejecting high-temperature ash. Asosan in Kyushu and Kirishima are similar volcanoes beginning eruption by ejection of old rocks, ending with red-hot scoriae, this last phase continuing for a long time and declining gradually.

(5) **Swelling mountain.** Usu Volcano of elevation 725 meters in southern Hokkaido lies between the sea and a volcanic depression containing Lake Toya. After numerous earthquakes in 1910 it cracked along its flank for three kilometers, developed 45 explosive craterlets, and lifted a hill 700 meters long and 200 meters wide to a height of 100 meters (Volcano Letter No. 302). The lapilli thrown out were of new lava, and it is conceived that an intrusive mass of magma was pushing its way like a lens outward and upward, and by occasional recession permitting ground water to fill voids and turn to steam.

(6) **Rising plug.** The activity of Tarumai was described in Volcano Letter No. 317. This volcano also is in Hokkaido, is 1023 meters high, and after 15 years repose sent up a steam blast in 1909 with increasing violence for three months accompanied by the rise of 20,000 cubic meters of lava that formed a dome. This dome was quite like the andesite domes of Bogoslof, described in the last Volcano Letter (No. 322). The dome was 134 meters high, and several explosive outbursts have traversed it since April, 1917.

(7) **Lava in crater and gas blasts.** Asama Volcano in central Japan is the type, a big cone 2,542 meters high, much like Vesuvius, and in 1783 one of the greatest eruptions in the history of Japan spread volcanic detritus and ashes over a large area, followed by an aa lava flow. In recent years, between 1910 and 1915, and again 1919-23, the crater bottom welled up slowly by accumlation of new lava and there were repeated explosive eruptions proportional in frequency to the pulsations of rising of the lava. After big eruptions the bottom lava sank. There was a new eruption in September 1929.

(8) **Lava outflow from mountain flank.** Sakurajima is the type, described in Volcano Letter No. 308. This volcano is a peninsula in Kagoshima Bay at the south end of Japan and stands 1,060 meters high. It was shaken by earthquakes for two days in January 1914, then great cauliflower clouds arose, and two stiff, blocky lava flows of andesite poured from newly formed craterlets on both sides of the mountain. The volume of lava was estimated at 1.56 cu. km., the explosive materials 0.62 cu. km., and the area covered with lava 23.73 sq. km. The lava flowed for several months and the effusion ended gradually with weak explosions in the craterlets.

(9) **Crater lava and flows.** The volcano Miharayama,

755 meters high, constitutes the island of Oshima in Sagami Bay southwest of Yokohama. It had eruptions from 1912 to 1923 just before the Tokyo earthquake. In 1912 explosions of incandescent scoriae began in the central crater, in April it was filled with lava, in July its central part lowered 30 meters, in September pahoehoe lava poured up filling the crater by mid-October, fed by a cone of scoriae just as at Vesuvius at present. Then the lava field sank, on May 15, 1923 a Strombolian steam eruption occurred; thereafter the crater bottom rose and this was followed by a sinking and active border fissures in 1915. Lava eruptions were repeated in 1919, 1920, and 1923. In January of 1923 the lava field in the crater rose, with a cone 40 meters high standing upon it. Then there was a lowering, followed by the Tokyo earthquakes which had some of their epicenters close to Oshima. As shown by the changing pattern of the pit, the lava activity of Mihara is more like Kilauea than most Japanese volcanoes.

(10) **Submarine eruption.** In the ocean to the south of Oshima extends a line of volcanic islands. At Minami-Iwoshima a small island was built up after detonations and uprush of fume for 20 days in 1904. This was December 5, and in February 1905 the circumference was 5 km. and height 150 m. The cone was crowned with a crater of 120 m. diameter. It was eroded away soon after June 1905. In 1911 the water there was 400 m. deep, but on January 25 after two days of explosions a new cone arose, similar to the former one, and this had disappeared by June 1915. There were other eruptions along this line of the Ogasawara islands, making banks of pumice in 1906 and 1915.

(11) **Volcanic intrusion.** As a last stage in manifestation of magmatic energy, the Hakone Volcano, 1,439 meters high, near the beautiful lake of the Miyanoshita district so much visited by tourists, has been the scene of many earthquakes. Disastrous ones have occurred in the last few weeks. They were numerous in 1917, and also this district was terribly shaken by the great Tokyo earthquake of 1923. It lies on the Fuijyama volcanic zone. The earthquakes at Hualalai in Hawaii in 1929 marked another case of volcanic energy underground.

Professor Tanakadate shows analyses of lava from all these volcanoes, with silica increasing from No. 9 to No. 1, alumina decreasing, and decrease also in iron, magnesia, and lime. In other words the series is more basic the greater the fluidity of the lava. T.A.J.

KILAUEA REPORT No. 997

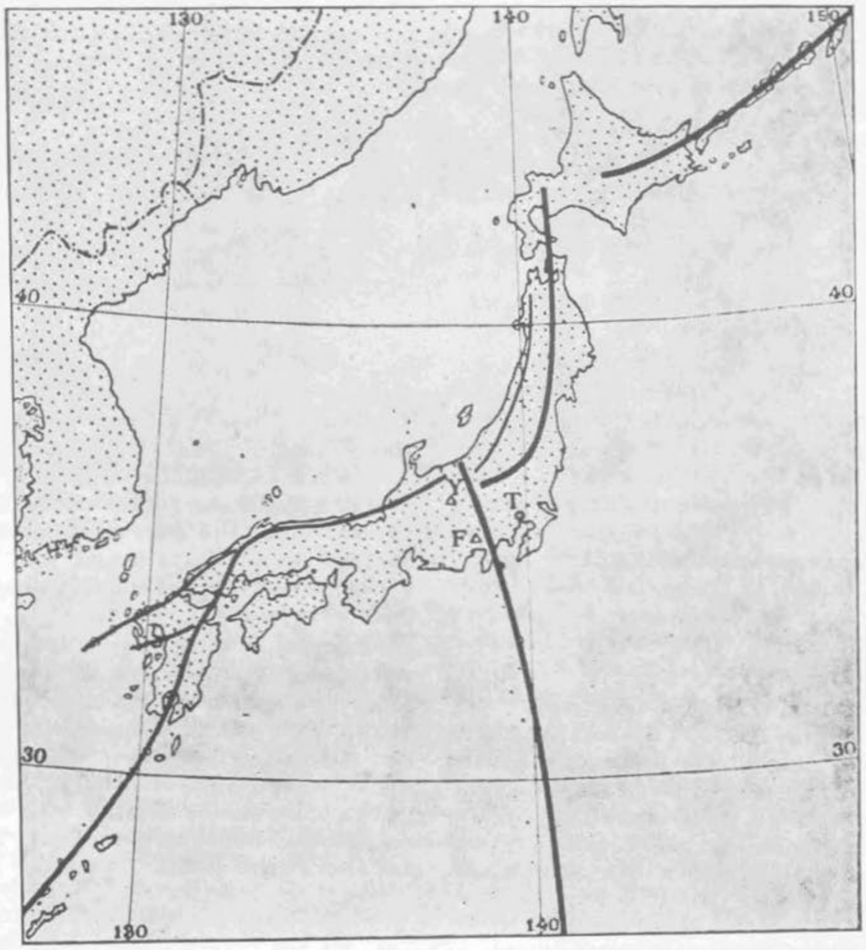
WEEK ENDING MARCH 1, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On February 23, 1931, no changes were observed at the pit Halemaumau of Kilauea Crater, the pit seismograph showed no tremors, and the tilting of the ground at the pit since the activity of November 1930 has been very gradually away from the center. It has never shown backward tilting toward the center such as would happen if the lava column subsided. On February 26 after heavy rain there was much steaming on the new crater floor near the cone of 1930 and some of the sulphur spots were somewhat washed away. Two spots on the northwestern part of the new floor appear to be fuming with blue sulphur smoke, the one in puffs and the other continuous, first observed on the afternoon of February 25.

Observatory seismographs have registered 25 tremors, one feeble local earthquake, and two very feeble ones, the distances shown being 9 and 11 miles from the station. Tilting of the ground was moderate to the south, a direction seasonally expectable at this time of the year. As a whole however this seasonal tilt has been delayed, as though upward pressure away from the volcano had been maintained here since December. Microseismic motion has been almost absent.

Three maps of the crater pit of Mihara Volcano in Sagami Bay near Tokyo. North is at the right. Right-hand sketch is the summer of 1907, in the middle is shown the condition of January 1, 1913, and on the left the block lava, terraces, spatter cones, ditches, pits, and fuming holes of 1916. After Tsuboi.



Map of volcanic rifts of Japan with Tokyo (T) and Fujiyama (F). The rift extending southeast underlies from north to south Asama, Hakone, Oshima, and Minami-Iwo-shima. The rift at the left underlies Sakurajima and Aso-san. The rift at the extreme northeast underlies Usu, Tarumai, Tokachi, and Shiretoko. Shirane and Bandaisan are over the rift north of Tokoyo. After Omori.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

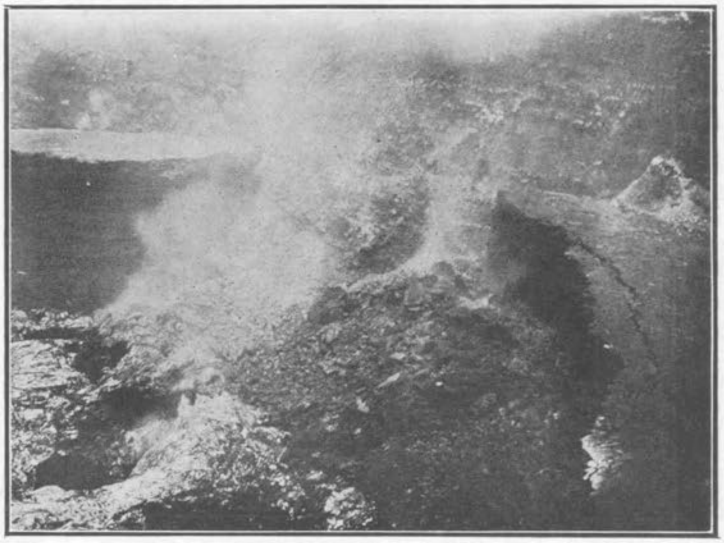
The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 324—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | March 12, 1931



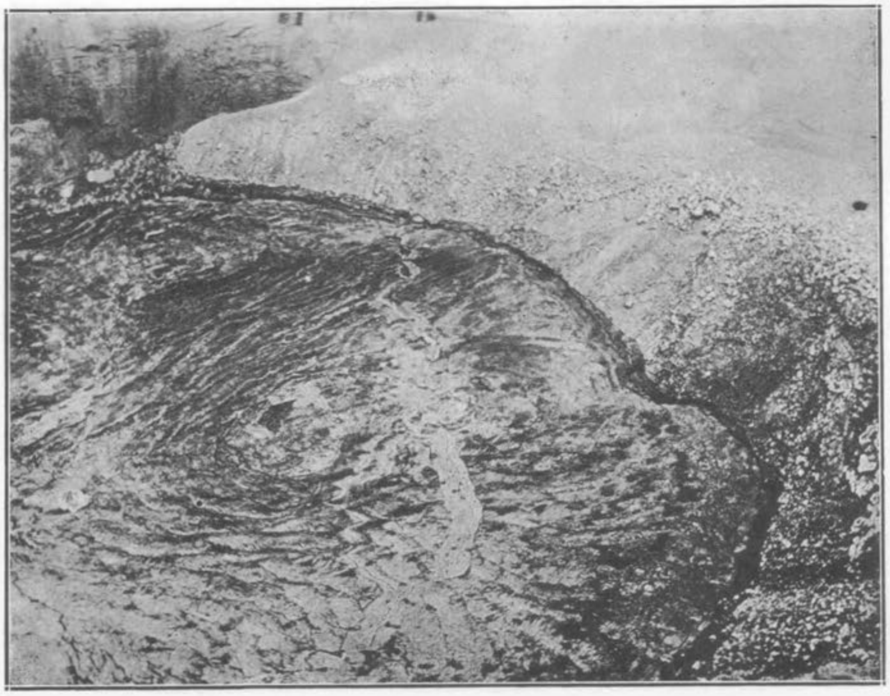
Looking down into the pit about noon on the day of the great subsidence of June 5, 1916. The east bench had collapsed, and a small island was shown to have a large extension of its mass under the lake which toppled over sideways as the lake sank. This is shown on the left. Bench cracking on the right.

WHEN THE PIT LAVA SINKS

In another number of the Volcano Letter (No. 291) the flooding action of boiling slag rising into Halemaumau pit was reviewed. Gas effervescence was shown to be the impelling agent. The question was asked, "Is the sinking of lava a reversal of the process that makes it rise?" The rising process is dependent on expansion and combustion of gases in the slag, a foaming up along with extra heating. It was shown that the foaming depends on release of pressure that otherwise confines gas in solution. Deep pressure is maintained by the weight of the accumulated mountains of lava, and these in turn are supported by blocks of the crust of the earth believed to rest on a substratum of basalt. Release of pressure is attained by periodic or occasional yielding of fault blocks of the mountain, or yielding of the crust blocks of the globe. The mountain is a strained heap of lava we call a volcano. The straining of the crust of the earth is complicated with the trigger-pulling forces of the tides, the atmosphere, and of the sun, moon, and earth.

When the lava subsides in Halemaumau pit, there are several explanations, and they may all apply at different times. If the slag loses its gas the remaining glass shrinks, and if the glass crystallizes underground, it shrinks still more. It changes from a foam to a rock. If a flank of the mountain opens a deep crevasse, or a fault block thousands of feet deep slips a little toward the sea, the lava which has been standing in the pit may drain away into an underground fissure. If a crust block of the earth hundreds of miles long and 30 miles deep moves ever so slightly by some tidal breathing of the globe, with its equatorial protuberance, its northing and southing of the sun, its fluctuations of the moon, its approach and recession to the sun in its orbit, and with the possible but unsolved mysterious relations of sunspot periods to magnetism and gravitation, it is likely that an increased pressure on the substratum would quickly show itself by a lessening of gas at the relatively tiny lava column represented by the pit.

The loss of gas and reestablishment of deep pressure to make the lava column recede should be gradual. The opening of the mountain to drain the lava into a crack, or through a fissure out to a submarine lava flow should be rapid. The diminution of gas, followed at other times by its increase, owing to astronomical controls, should be periodic and rythmical. The actual movements of the lava column when it subsides have suggested all three of these processes at different times; in 1912 there were striking quarter-yearly changes from high to low as though equinox and solstice were in control. Again and again a period of about three weeks has been observed from one sinking spell to the next. Earthquake frequency has shown a similar periodicity. From 1914 to 1917 during general rising of the lava there was a systematic series of risings and fallings with each complete wave about eight months long, each rising higher than the one before, and each sudden sinking lower than the one before. There were similar movements punctuated by sudden sinkings between 1917 and 1924. And in 1919 a critical investigation gave evidence of a daily tide in the lava.



New pool of lava in the bottom of Halemaumau November 30, 1919, after subsidence, looking southeast. The lake was rising very rapidly and the talus at the right turned out to be a ring crag of the bench magma which has subsided November 28, developing within two weeks into the ring island (Volcano Letter No. 282).

The sudden sinkings are accompanied by marked increase in numbers of local earthquakes. Four specially conspicuous ones were in 1916, 1919, 1922, and 1924. The first two were immediately after a lava flow from Mauna Loa, as though the sinking back of the lava in that volcano tended to drain Kilauea. The last two accompanied times when Kilauea itself tended to make lava flows, in 1922 a visible outpouring at the chain of craters, in 1924 a probable outpouring under the sea to the east. We may conclude that sudden subsidences justify the suspicion that the mountain mass has opened somewhere and created a true hydrostatic drainage of the lava. The seismical proof of this is illuminating. Earthquakes are few during the rising. They come in swarms during the sinking and in 1916 they showed Mauna Loa distances on the seismograms in May, and much shorter distances as though Kilauea Mountain were breaking on June 5.

On May 21 and thereafter, 1916, lava flows broke out on the southwest rift of Mauna Loa preceded by an explosion of gas and foamy lava high up the mountain May 19. The flows ceased about June 1. Kilauea lava had been rising vigorously for three months until May 25, when it was 265 feet below the rim of the pit. It then turned and lowered a little, and fluctuated until June 5. There was a ring-shaped lake with two islands within a black ledge of overflow. On June 5 the lake started to lower along with the islands, red-hot falls of bench matter from the black ledge crumbled and flowed into taluses around the receding pool of liquid, and finally terrific avalanches of old wall material made purple, white, brown, and black cauliflowers of dust that boiled up from the funnel below. The depression of the lake was 302 feet June 4, 340 feet 8:30 a. m., 380 feet 10:30 a. m., 540 feet 3 p. m., June 5, and 673 feet at noon June 6. There were occasional perceptible earthquakes, but a remarkable feature of the whole cataclysm was the rigidity of the upper walls.

In October 1919 Mauna Loa gave vent to the Alika flow southwest. Some time in November the flowing stopped. On November 28 a sudden, quiet drop of the Kilauea lava column took place amounting to at least 600 feet in a single morning. The subsidence was accompanied by almost continuous light local quaking of the ground, again with distances of origin shown on the seismograms much shorter than those which had indicated a distance of 35 miles or more for the earthquakes of Mauna Loa a month previously. It was as though the sinking back under Mauna Loa had brought the full force of the lava column to bear upon splitting open Kilauea, and then after filling the split by drainage, the lava column began to rise under Kilauea. The same thing had happened in 1916, for a very rapid Kilauea rise had followed the June subsidence. Now in December 1919 the rising in Halemaumau amounted to 30 feet a day after the drop of 600 feet mentioned above. This continued until in mid-December the rising wedge split the mountain clear to the surface, and the Kau Desert flow of Kilauea built up the slag heap Mauna Iki.

The 1922 subsidence in Halemaumau was so exactly parallel in its happenings to these two subsidences which had accompanied the termination of Mauna Loa eruptions, and the occasion of the subsidence was so clearly a Kilauea outflow accompanying a splitting open of the deep mountain mass, as to contstitute a proof that the connection between Mauna Loa and Kilauea need no longer be doubted. With each flow from Mauna Loa, the Halemaumau subsidence followed; with each flow from Kilauea, the Halemaumau subsidence preceded.

The liquid lava May 13, 1922, was less than 50 feet below the rim of Halemaumau. By May 21 the lake level had dropped 300 feet with a steady but majestic sinking carrying down peaked crags, lava lakes, and adjacent floors. Avalanches from crags and walls were numerous. Swarms of earthquakes were registered by the seismographs. On May 26 began spells of general caving in of the pit wall, sending up cauliflower clouds of brown and salmon color, and making a thunderous roar. This continued for two days, and the pit was greatly enlarged. A swaying earthquake about 8 p. m. May 28 heralded the appearance of bright glow over Makaopuhi Crater nine miles away in Puna. A crack in the side of this pit, on the Chain of Craters rift line leading from Kilauea, was vomiting up the lava stolen from Halemaumau by the splitting open of the mountain along the rift. Cascades poured from the top of the talus in Makaopuhi and made a pool in the bottom. This flowing dwindled, but a new eruption broke out in Napau Crater farther east and in the upland beyond for two days, showing that the rift was splitting open eastward.

This underground wound healed, the lava rose in Halemaumau, and again it lowered suddenly and split the eastern rift with outflow in the forest near Makaopuhi in August 1923. Then the rift healed again and by January 1924 an enormous lake of liquid lava filled Halemaumau pit, now 2,000 feet across, to within 121 feet of the rim. Here were pulsations year by year, of this wedging agent, the basalt of the crustal substratum, welling up into the pit, and then splitting open the eastern rift, after the work for the cycle was finished in building at the higher rifts of Kahuku on Mauna Loa, and of the Kau Desert on Kilauea. The final splitting open of the eastern rift was exhibited by cracks in the ground and swarms of earthquakes at Kapoho on the extreme eastern point of the island in April 1924, after the lava in Halemaumau had sunk more than 300 feet.

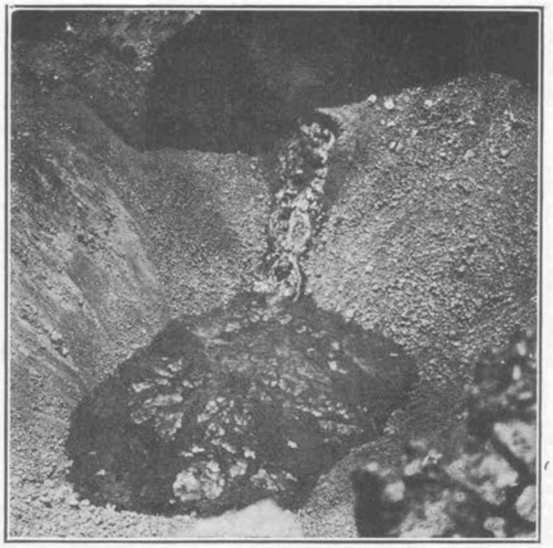
Then came the grand crash of lava subsidence and engulfment of the walls of Halemaumau in May of 1924, with every episode closely parallel to what had happened in 1922 and 1923 except that the outflowing lava on the rift did not appear above sea level. There could be no question but that it did flow out a few miles beyond the east point of the island under the deep cold water of the Pacific. Each incident of breakage of the island mass 1919, 1920, 1922, 1923, and April 1924 had been farther downhill, and eastward from Mauna Loa to the sea. The swarms of earthquakes and their distances on the seismograms plainly told the story of the splitting open of the eastern rift in the depths of the mountain mass. There was added the episode of steam explosion, (the great cataclysm of 1924), then the lava rose and appeared 1300 feet down Halemaumau in July 1924, and the system entered into repose.

T.A.J.

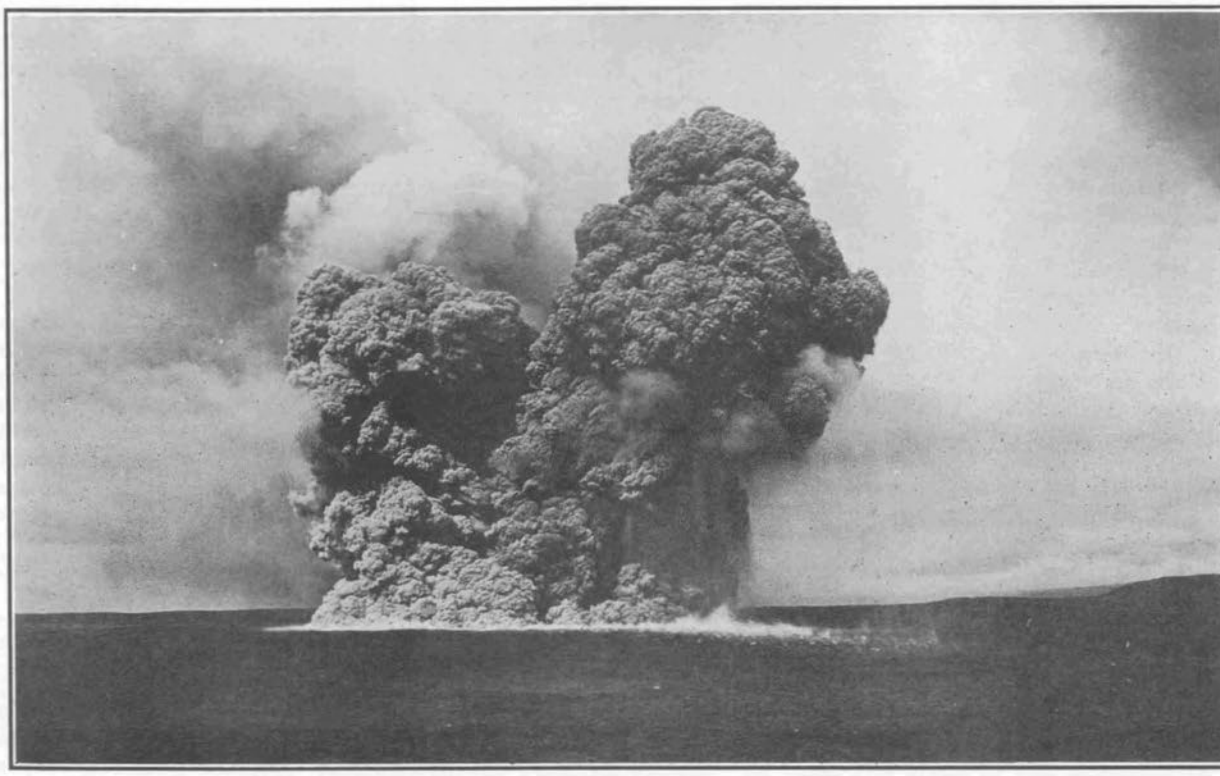
TILTING OF THE GROUND FOR FEBRUARY

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the direction given.

February 2-8	0.36 second	ESE
February 9-15	1.21 seconds	WNW
Feburary 16-22	1.31 seconds	SSW
February 23-March 1	1.74 seconds	SSW



The left-hand cut shows southwest wall of Halemaumau May 25, 1922, when the great subsidence had revealed a tunnel on the Kau Desert rift line through which the lava had flowed in 1920. The right-hand picture is the bottom of Halemaumau July 17, 1922, when the lava returned through a cup at the top of the talus slope pooling in the bottom. Photos Jaggar.



Halemaumau from Volcano House, 8:15 a. m. May 22, 1924, showing cauliflower cloud of one of the paroxysms of explosion and engulfment with bowlders bombarding the Kilauea floor. Photo Tai Sing Loo.

KILAUEA REPORT No. 998

WEEK ENDING MARCH 8, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Very slight fuming continues in the bottom of Halemaumau. New debris material was seen at the southeast edge of the floor on March 2, and on the 7th rocks were heard falling from the north rim. The pit is otherwise quiet.

A total of 19 seismic disturbances were recorded on the instruments of the Observatory during the week, as follows: 16 short tremors; 2 very feeble seisms, one at 9:04 a. m. March 7 originating 32 miles from the station; 1 slight shock at 6:53 a. m. March 8, 30 miles distant, felt in Hilo.

Tilt for the week accumulated slight NW. Microseismic motion was slight.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

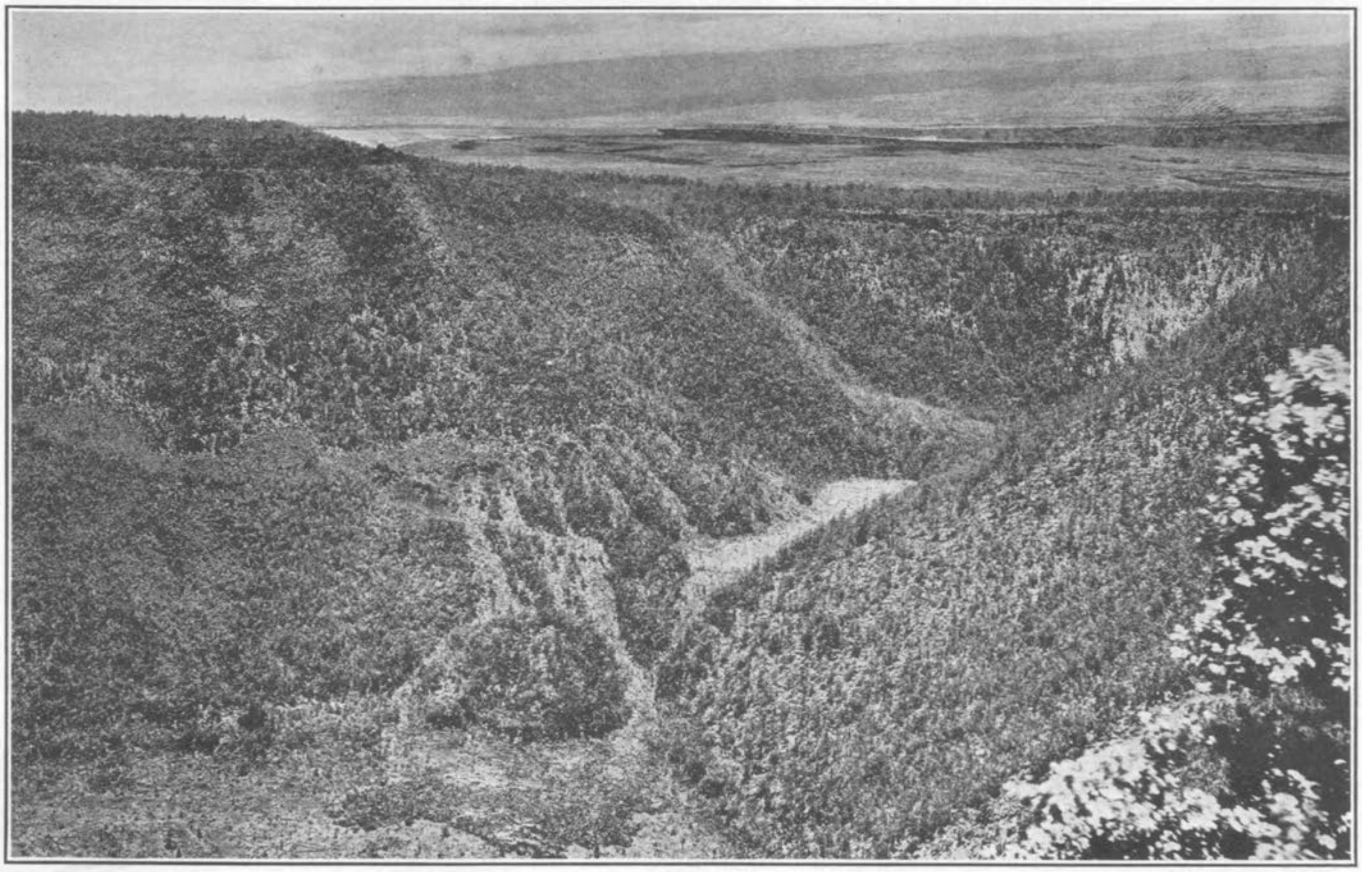
The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 325—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | March 19, 1931



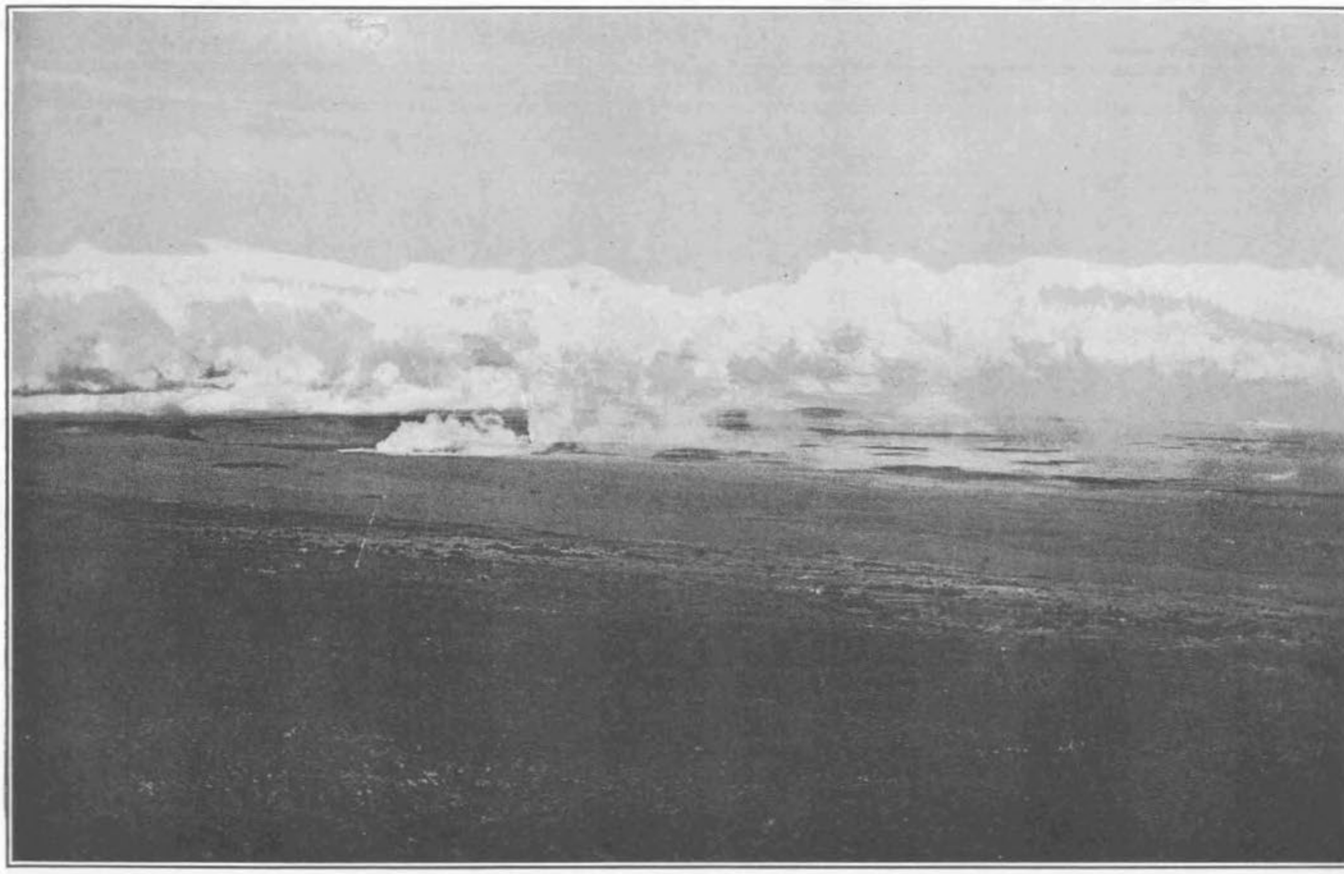
Looking across Kilauea Iki and Kilauea craters. The 1832 flow broke out on the ledge between the two. The 1868 flow made the frozen cascades shown. Photo Wilson.

THE HAWAIIAN VOLCANIC CYCLE

The summary of 20 years of Hawaiian eruptions in Volcano Letters Nos. 319 and 320, and the account last week (Volcano Letter No. 324) of the somewhat systematic repeated sinkings of the lava in Halemaumau pit from 1916 to 1924, naturally suggest to the reader the inquiry, "What can be made out of the sequence to suggest a definite cycle of accumulation and release of lava gas?"

William Lowthian Green (Vestiges of the Molten Globe, Honolulu, 1887), and more recently Wood (On Cyclical Variations in Eruption at Kilauea, Second Report of the Hawaiian Volcano Observatory, Cambridge, Mass., 1917), have commented on possible periodicities of 7 years, 9 years, 18.6 years, 65 years, and 130 years, and Wood has also suggested a semi-annual variation, or a possible variation during a term of about 14 months. Astronomical causes have been suggested. The possibility of a 9-year period, or roughly a decade, involving both Mauna Loa and Kilauea, became more and more plain after the Hawaiian Volcano Observatory was founded. The history of a century and a quarter from the end of the 18th century to 1925 strongly suggested a long term between explosive eruptions, here recorded about 1790 and in 1924, and a maximum volume of lava flowing (1855) in the middle of the term.

When we talk about cycles it is well to have a definite idea of what we mean. What was said in Volcano Letter No. 324 of the weight of the mountain bearing on one body of lava, of the weight of crust blocks of the earth bearing on a substratum of lava, and of the globe as a whole warping under the pull of the sun and moon, involves at least three possible units of volume to heave and sink, to be compressed and be released, and so to produce three different orders of magnitude of eruptive cycles at the same group of vents. It is thus entirely possible at the Hawaiian volcanic system, involving both Mauna Loa and Kilauea, to have a shorter cycle of puffs of the engine, so to speak, about 11 years long; and this superimposed upon a much longer cycle about 132 years long, at the end of which the engine opens its safety valve and produces a prolonged steam blast. Just this, to put the matter in round numbers, is the theory of cycles on which we are working at present, and if it is true, then the 12 episodes of 11 years each from 1792 to 1924 should approximately cover twelve similar eruptive periods of Mauna Loa and



Looking down on Kilauea, with Halemaumau smoking from 7000 feet elevation on Mauna Loa. Photo. Wood.

Kilauea combined. And if the 132-year cycle is itself made up of prolonged accumulation and release, then its first half for 66 years might well be expected to show increasing lava flow with perhaps some logical geographical sequence from Kilauea to Mauna Loa, and its last half should show decreasing lava flow with a progress to lower levels from the top of Mauna Loa downward past Kilauea to the east. It is also conceivable that the quarter period of 33 years may have some significance, for it happens that 1823, 1855, and 1894 produced extraordinary crises of eruption, the first and last on Kilauea, and the middle one on Mauna Loa.

Now let us examine the individual eleven-year cycles:

For the cycle 1781-1792 we know only that a lava flow in Puna east of Kilauea is reported for 1788, and that a major steam-blast eruption killing natives occurred at Kilauea about 1789-90, marking the end of one of our assumed supercycles approximately 132 years long. We thus begin a new supercycle.

The cycle 1792-1803 (end of each year named) involves report of a Puna lava flow 1793, and the very exceptional events which occurred on the west side of the island, lava flows from Hualalai Volcano in 1800 and 1801, the former at Huehue and the latter at Kaupulehu.

The cycle 1803-1814 we know nothing about, except that mariners reported fume continuing at Hualalai, and it is even said that fume was seen near Molokini west of Haleakala. Kilauea was presumably piling lava into its crater.

The cycle 1814-1825 was certainly a time of construction by lava up-building in Kilauea Crater, for the early missionaries after 1823 found a black ledge around the crater not covered with the debris of 1790. Therefore this was post-1790 lava. The year 1923 produced a tremendous breakdown in Kilauea, with the Keaiwa flow into the ocean below Pahala and low crater levels for two years thereafter.

The cycle 1825-1836 was a time of great activity and rising in Kilauea, a remarkable eruption on Byron's Ledge with lava flowing into Kilauea Iki and over the cliff into Kilauea Crater in 1832, a flow for three weeks on the top of Mauna Loa the same year, and a Halemaumau breakdown followed by recovery. Here is our first mention of Mauna Loa since 1790, and it will be seen that for 40 years the outpouring of lava had been from low levels in Kilauea and Hualalai.

The cycle 1836-1847 begins with Kilauea dull and unmentioned, then follows a rising to "terrific" effervescence there in 1840 and a breakdown with outflow far to the east in Puna, the lava reaching the sea at Nanawale. Kilauea pit recovered but slightly when Mauna Loa again took part, making a big northern flow piling a huge volume of lava in the saddle between Mauna Loa and Mauna Kea.

The cycle 1847-1858 involves the most tremendous flooding of lava which occurred in the nineteenth century. There were over 400 days of lava flow from Mauna Loa between 1851 and 1855. This was led up to by a dome forming over Halemaumau 1848, fluctuations of Kilauea activity until 1854, excessive flooding of Kilauea Crater in 1855, and lowering thereafter. Mauna Loa had outbreaks in 1849, 1851, 1852, and 1855, the last flowing for 13 months toward Hilo.

The cycle 1858-1869 is the beginning of the decline, showing 307 days of flowing lava, but is still characterized by enormous flooding from Mauna Loa. Kilauea was quiet, but Mauna Loa in 1859 made a big flow for seven months into the ocean in North Kona. Then Kilauea revived, the lava in Halemaumau rose and overflowed, the summit crater of Mauna Loa broke out for four months 1865-66, and in 1868 came a startling crisis with flows into Kilauea Iki, a world-shaking earthquake, a big breakdown of the

Kilauea floor, and outflows for the first time from the southwest flank of Mauna Loa, with a small outflow southwest from Kilauea. These events were accompanied by landslips, tidal waves, and shore lowering.

The cycle 1869-1880 was distinguished by great flooding of Mokuaweoweo, the summit crater of Mauna Loa, at the very top of the volcanic system. Kilauea recovered to low levels, then Mokuaweoweo was reported active in 1871, 1872, 1873, 1874, 1875, and 1876. Kilauea came to an overflowing with great activity in 1874, broke down and recovered in 1875, fluctuated and erupted at the small pit Keanakakoi in 1877. In that year Mauna Loa produced a submarine eruption in Kealakekua Bay on the west side of Hawaii. Then Kilauea built up crags and lakes and overflows with a collapse in 1879 followed by recovery.

The cycle 1880-1891 like the preceding produced more than 200 days of lava flowing, with Kilauea hard at work building up its floor until 1886, when it reached a crisis of breakdown. Mauna Loa in 1880-1881 produced the great flow that almost destroyed Hilo. Again in 1887 Mauna Loa had a short-lived but voluminous southern flow, Kilauea recovered and reached a breakdown in 1891.

The cycle 1891-1902 was distinguished by a great decline in numbers of flow days (only 37), yet there was activity in Mokuaweoweo in 1892 and 1896 and a northern flow from Mauna Loa in 1899. Kilauea increased its crateral activity to immense floods in 1894, when it broke down completely and remained dormant or very dull for 13 years. There is good reason to think that Kilauea had an outflow under the ocean.

The cycle 1902-1913 was marked by summit crater activity of Mauna Loa in 1903 and a flow to the southwest in 1907, only 28 flow days in all. Kilauea revived in 1905, reached very high effervescence in 1910 and 1912, and then lowered to a dormant year.

The last cycle 1913-1924 had somewhat higher flow duration, 71 days, and was the concluding cycle of the supercycle that led to the Kilauea explosive eruption of 1924. The lava pressure was marked by a steady climb of the lava in Kilauea fire pit from 1914 to 1919, and a pulsating subsidence with outflow from 1919 to 1924. Meanwhile Mauna Loa was active on the summit in 1914, and on the southwest flank with increasing floods in 1916 and 1919, but all small as compared with 1855. Kilauea exhibited increasing breakdowns until the grand crisis of 1924 when the east point of the island sank, Halemaumau exploded and probably there was submarine outflow. T.A.J.

KILAUEA REPORT No. 999

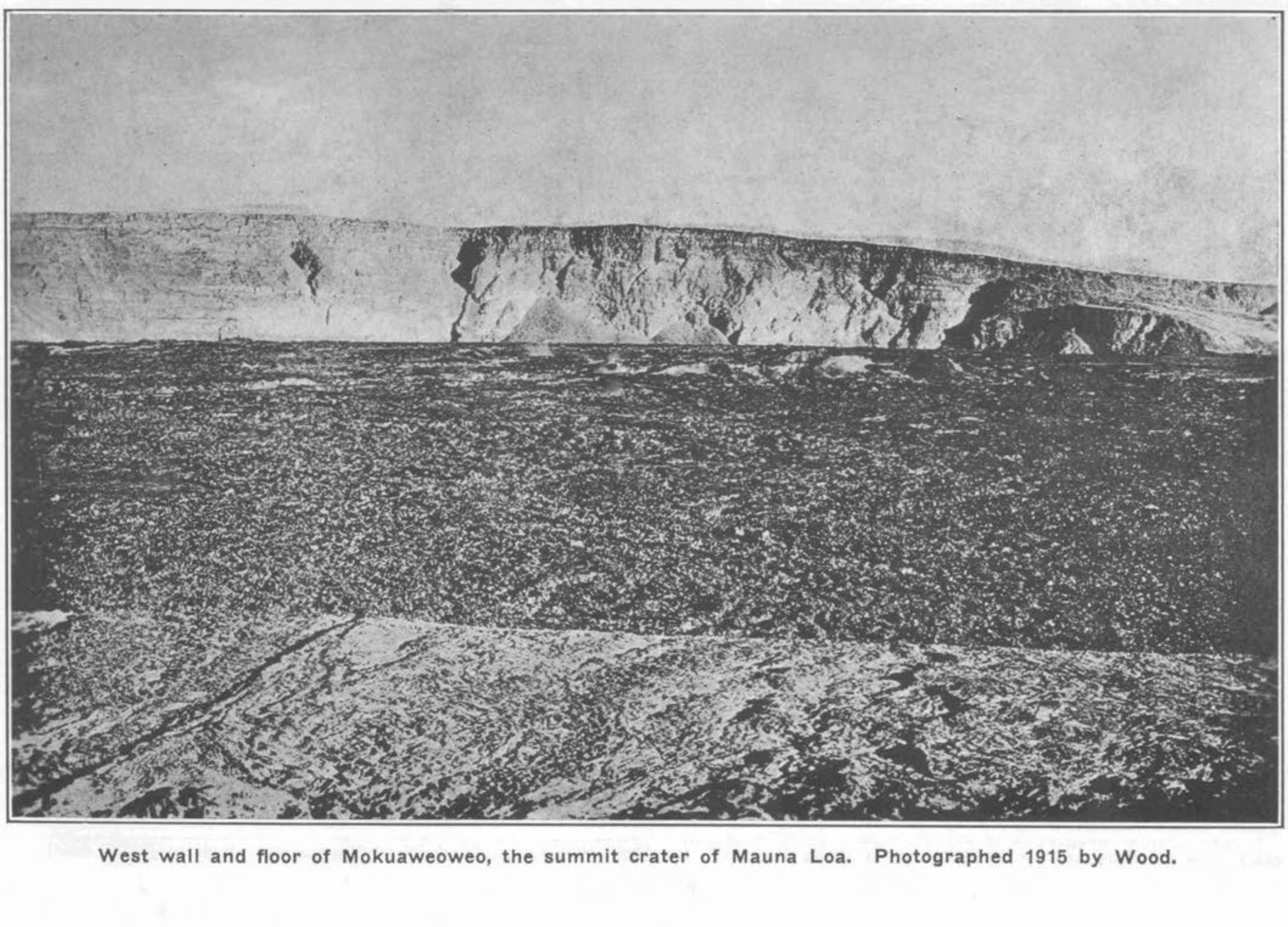
WEEK ENDING MARCH 15, 1931

Section of Volcanology, U. S. Geological Survey

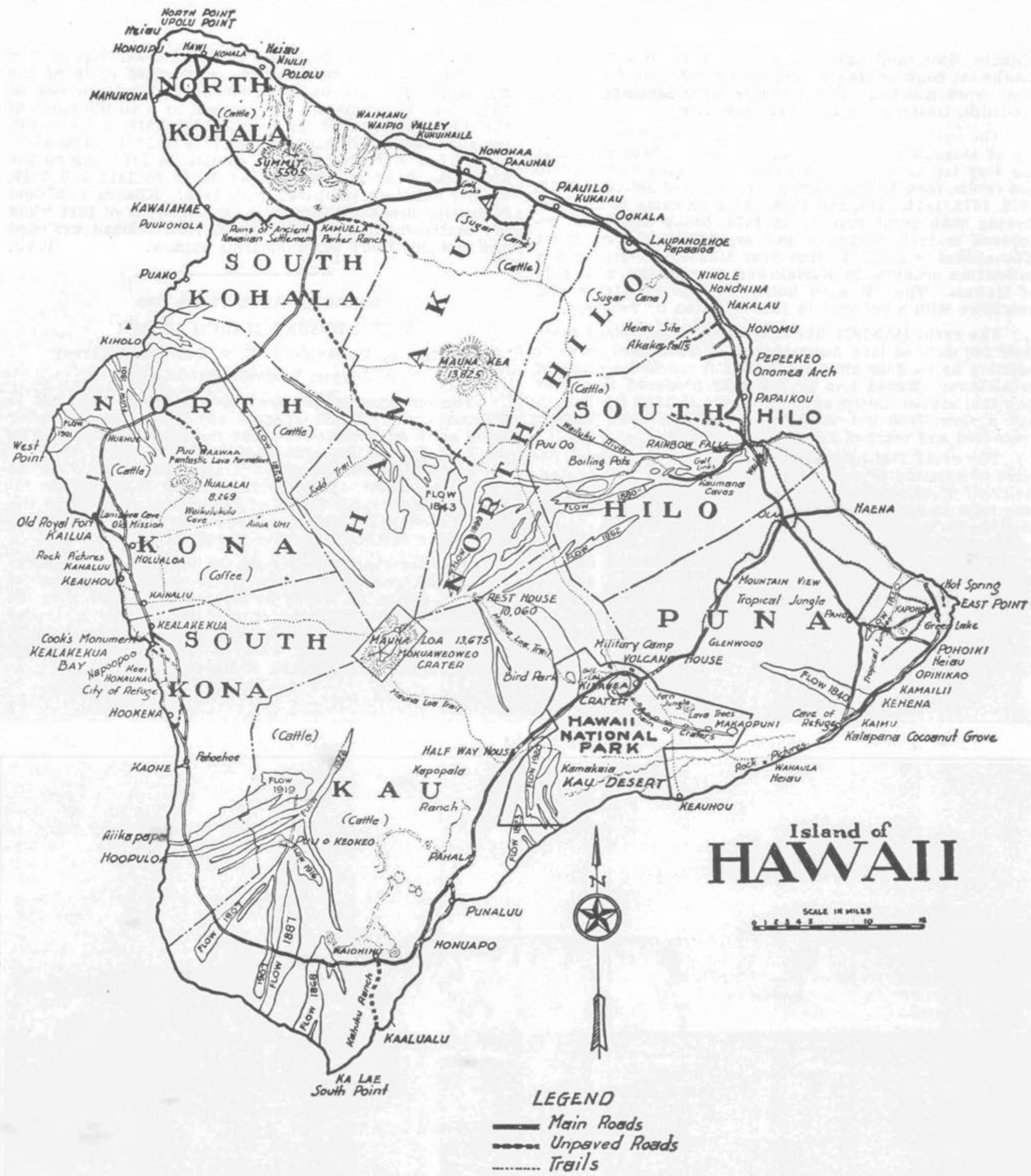
T. A. Jaggar, Volcanologist in Charge

The only noteworthy features of Halemaumau pit in Kilauea Crater which suggest any change are sulphur spots north and west of the cone that was left standing on the lava floor of 1930. These spots on March 12 were observed to be fuming steadily. A small slide was observed at the southwest. The seismograph at Halemaumau indicated rather rapid tilting of the ground away from the pit between February 28 and March 3, and a gradual accumulation of tilt away from the pit at other times.

The Observatory seismographs registered 34 tremors during the week and 3 very feeble local seisms, one of these at 4:43 a. m. March 14 being accompanied with tilt to the southeast. Tilting of the ground was otherwise moderate SSW, and microseismic motion was very slight. The fluctuation of tilting within a few days was strongly marked during the first half of March.



West wall and floor of Mokuaweoweo, the summit crater of Mauna Loa. Photographed 1915 by Wood.



THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

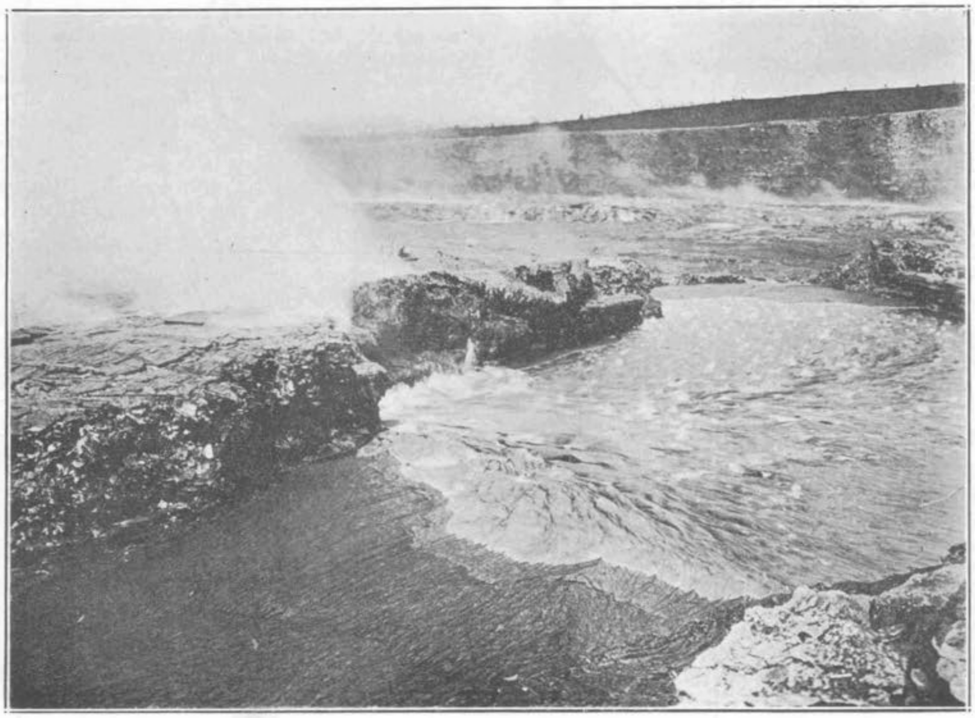
The Board of Directors includes Lorrin A. Thurston, President; Frank C. Atherton and Walter F. Dillingham, Vice-Presidents, L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 326—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | March 26, 1931



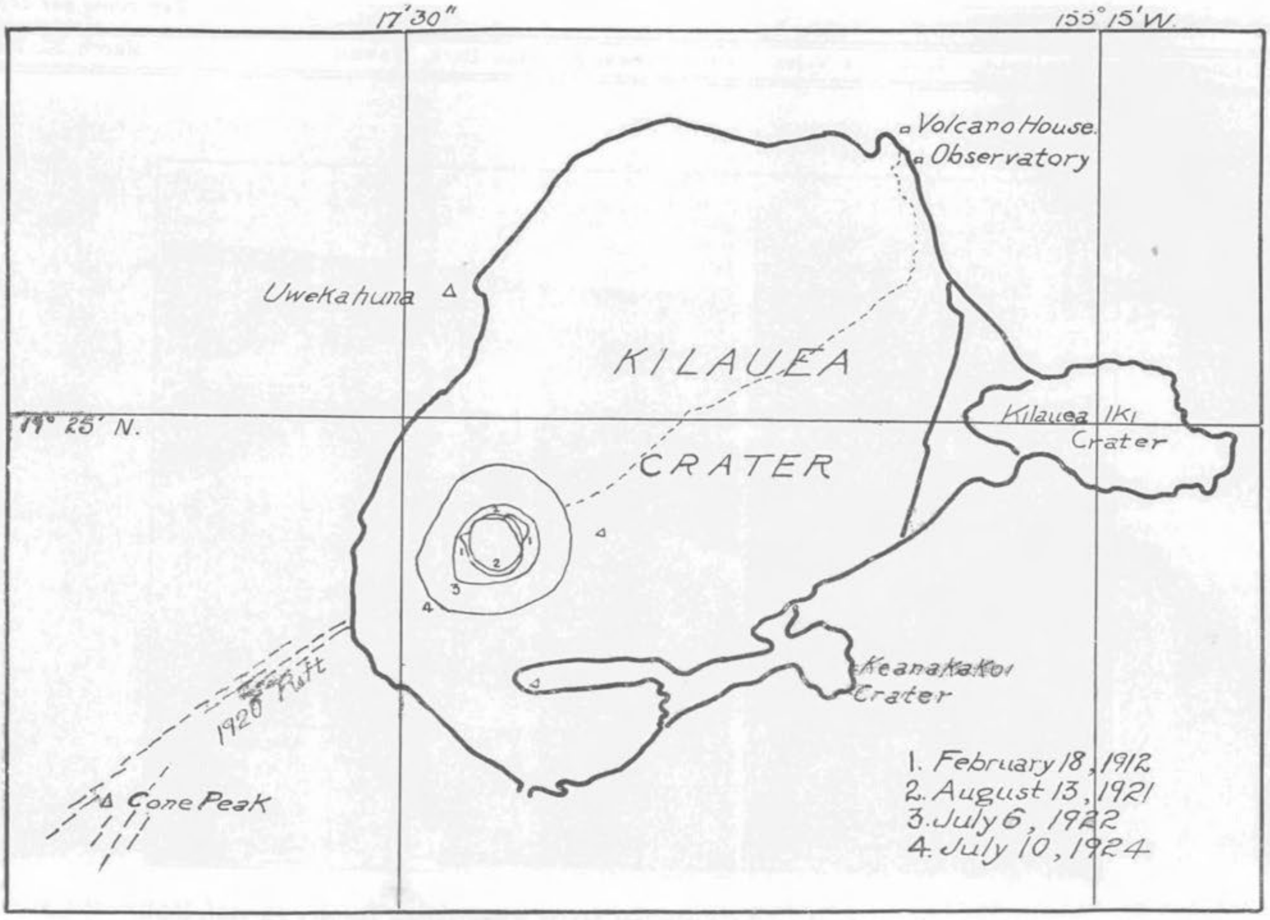
A high level in the cycle. Looking northwest across Halemaumau January 23, 1921, showing the rush of surface currents of bubbling lava into a grotto. Shows the fuming surface of the half solidified lava column, and in the background the Halemaumau wall and the Kilauea wall. Photo Jaggar.

VOLCANIC CYCLES AND SUNSPOTS

In the Volcano Letter Nos. 172 and 302, some notes are presented concerning a general similarity between curves of frequency of sunspots and of frequency of volcanic eruptions. Students of this subject who have taken the volcanic eruptions of the whole earth have published contradictory results, some finding more eruptions and some finding less eruptions for the time of sunspot maxima. Sapper found that gigantic volcanic explosions sometimes correspond with either high or low numbers of sunspots, but his curve shows a number of good correspondences between eruption frequency maxima and sunspot minima. For the period between 1790 and 1825, when sunspots were notably infrequent, volcanic eruptions were unusually inconspicuous.

Confusion in attempting to compare statistics is bound to result if such a word as "eruption" remains undefined. To take the great lava-flooding cycle of Kilauea 1913-1924 as an example, the peak of the lava pressure was 1919 when both Mauna Loa and Kilauea were vomiting floods of slag. This was also a time near sunspot maximum of frequency. To the layman, however, or to the ordinary geological traveler, the crisis of "eruption" was 1924 when Kilauea made tremendous steam explosions. And this was the time of sunspot minima. Which was the "eruption" of the decade for the statistician of the textbooks?

This leads us to examine critically the list of eleven-year cycles for Hawaii cited in last week's Volcano Letter, and to ask, "What are the distinguishing features of a cycle?" Probably Mercalli in his Italian book on "Active Volcanoes," and with his many years of experience as an observer of Vesuvius, hit the nail on the head when he said that the most distinctive feature of a volcanic cycle is the short repose period at its end. And this repose is often initiated by explosion, so as to be called "eruption" popularly. It is only on volcanoes such as Vesuvius and Kilauea, where the magma is visible most of the time, that these repose periods become striking. It is only when we can see the repose period in contrast to a high pressure period that has preceded, that we recognize its existence. If the high pressure has asserted itself by intrusion under a dormant volcano, seemingly always in repose except for a sudden explosion which goes unexplained, nobody will know about it. There may be a tide of flux and flow in the underground magma which has lifted the mountain and let it down again, but nobody has measured it. The sudden explosion may be the let down, as it certainly was at Kilauea in 1924. It is clear that even for the well recorded



Map showing successive outlines of Halemaumau pit in the southwest part of Kilauea Crater during a cycle. (1) Pit of 1912 with niches northeast and west. (2) Smaller pit of 1921 after nine years of building up. (3) Larger pit of 1922 after the first big collapse. (4) Very large pit of 1924 after steam-blast eruption and breakdown.

century of Hawaiian events, the only cycles that will bear intimate analysis are the recent ones where the descriptions are full.

The first reason for adopting eleven years is that this figure exactly fits the carefully observed cycle between two times of complete repose in 1913 and 1924 at Kilauea. The second reason for approving eleven years is by trial and error; if we apply nine, ten, twelve, or thirteen years as possible cycles for the events between 1790, the last great explosive eruption, and 1924, the newest one, none fits so well the division based on recorded repose periods as the number eleven. The third reason for approving eleven years as a cycle is that if we divide the 134 years from 1790 to 1924 into twelve cycles, we get 11.1 years as the average for each cycle, and each group of about three cycles leads to an unusually big crisis of lava breakdown or subsidence. And a reason for taking an interest in the sunspot analogy is that 11.1 years have been found by astronomers to stand for the average interval between sunspot maxima.

If we take the cycles at Kilauea and Mauna Loa immediately preceding the 1913-1924 period, we find 1902-1913 beginning and ending with complete repose, exhibiting Mauna Loa lava first in the summit crater and four years later pouring out of the south flank, and Kilauea lava rising to repeated maxima with effervescence and then sinking away. We find 1891-1902 beginning and ending with complete repose, exhibiting Mauna Loa lava twice in the summit crater and fianlly pouring out of the north flank, and Kilauea lava rising to a tremendous maximum so as to break the mountain and drain off. We find 1880-1891 following a repose in 1879 and leading to one at the end, exhibiting Mauna Loa lava twice in the summit crater and then pouring out of both the north and the south flanks in discharges six years apart; Kilauea builds up its floor with one of the greatest pressures of its history and then executes a series of breakdowns. These histories accord with the eleven-year cycle as a time of stress followed by a time of release, and with the conception that this cycle commonly involves both Mauna Loa and Kilauea as outlets for the same lava column. The details of sequence vary to such extent as the breakage of the island varies in yielding to the internal stress. The remarkable feature of these histories is that in spite of the incompleteness of the observations, there is such striking accord in showing two repose periods separated by an intervening high pressure period for both Mauna Loa and Kilauea.

Now when it comes to sunspots, let us keep in mind Mercalli's principle that the breakdown, whether it be explosive and conspicuous or not, begins a repose period, and the short repose or low period is the important punctuation mark in the cycle. The following two tables serve to compare low level quiet times in Hawaii with years of minimum numbers of sunspots:

Low Levels Hawaiian Lava	Sunspot Minima
1924 End of supercycle	1924
1913 Quiet year	1913
1902 Quiet year	1901
1891 Kilauea breakdown preceding great drainage of 1894	1889
1880 Follows Kilauea breakdown, starts Mauna Loa floods	1878
1869 Follows big breakdown both mountains	1867
1858 Quiet year following greatest lava floods of history	1856

1847 Quiet year	1843
1836 No mention in records, therefore quiet	1833
1825 Quiet year after great drainage of Kilauea 1823	1822
1814 Unknown	1810
1803 Quiet time following Hualalai outflows	1797
1792 Repose following supercycles crisis of 1790	Declining Sunspots

In these tables the Kilauea years are at arbitrary regular eleven-year intervals beginning at 1924 and going backward, and it will be seen that for this century the intervals between sunspot minima where notably longer than eleven years. In most cases if the actual years given in the sunspot column had been taken for the Hawaiian low levels, they would have been as near to the lava breakdowns as the years given in the Hawaiian column, but some of them would have preceded the breakdown instead of following it. If the observational data for Hawaii in the early years were as good as in the later ones, the bends of the Hawaiian curve might match many of the sunspotless years more perfectly. But the volcano record is very imperfect. What this shows is that the repose periods are remarkably systematic.

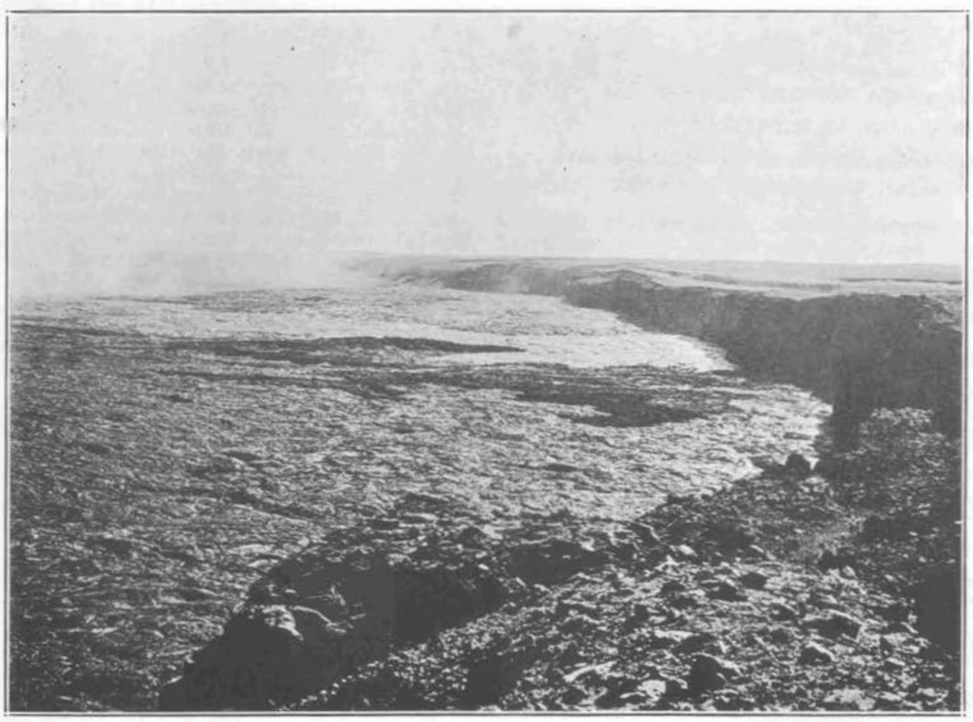
When it comes to the sunspot maxima, we find them in the midst of the Hawaiian periods of lava pressure, when within a cycle both Mauna Loa and Kilauea were flooding:

High Pressure Hawaiian Lava	Sunspot Maxima
1917-20 Kilauea and Mauna Loa flooding	1918
1903-07 Two flows Mauna Loa and Kilauea rising	1905
1892-99 Three flows Mauna Loa, Kilauea 1894 maximum	1893
1881-87 Kilauea and Mauna Loa big floods	1884
1869-77 Kilauea rising, continuous summit eruption Mauna Loa	1870
1859-68 Three flows Mauna Loa, Kilauea rising, overflowing	1859
1851-55 Mauna Loa maximum, Kilauea maximum	1848
1836-47 Kilauea flood 1840, Mauna Loa flood 1843	1837
1825-36 Kilauea and Mauna Loa floods 1832	1828
1814-25 Kilauea flood 1823, Mauna Loa unknown	1816
1803-14 Unkown, but Hualalai floods 1800-01	1804
1788-93 Probable Kilauea floods preceding 1790 explosions, and two flows reported in Puna	1787

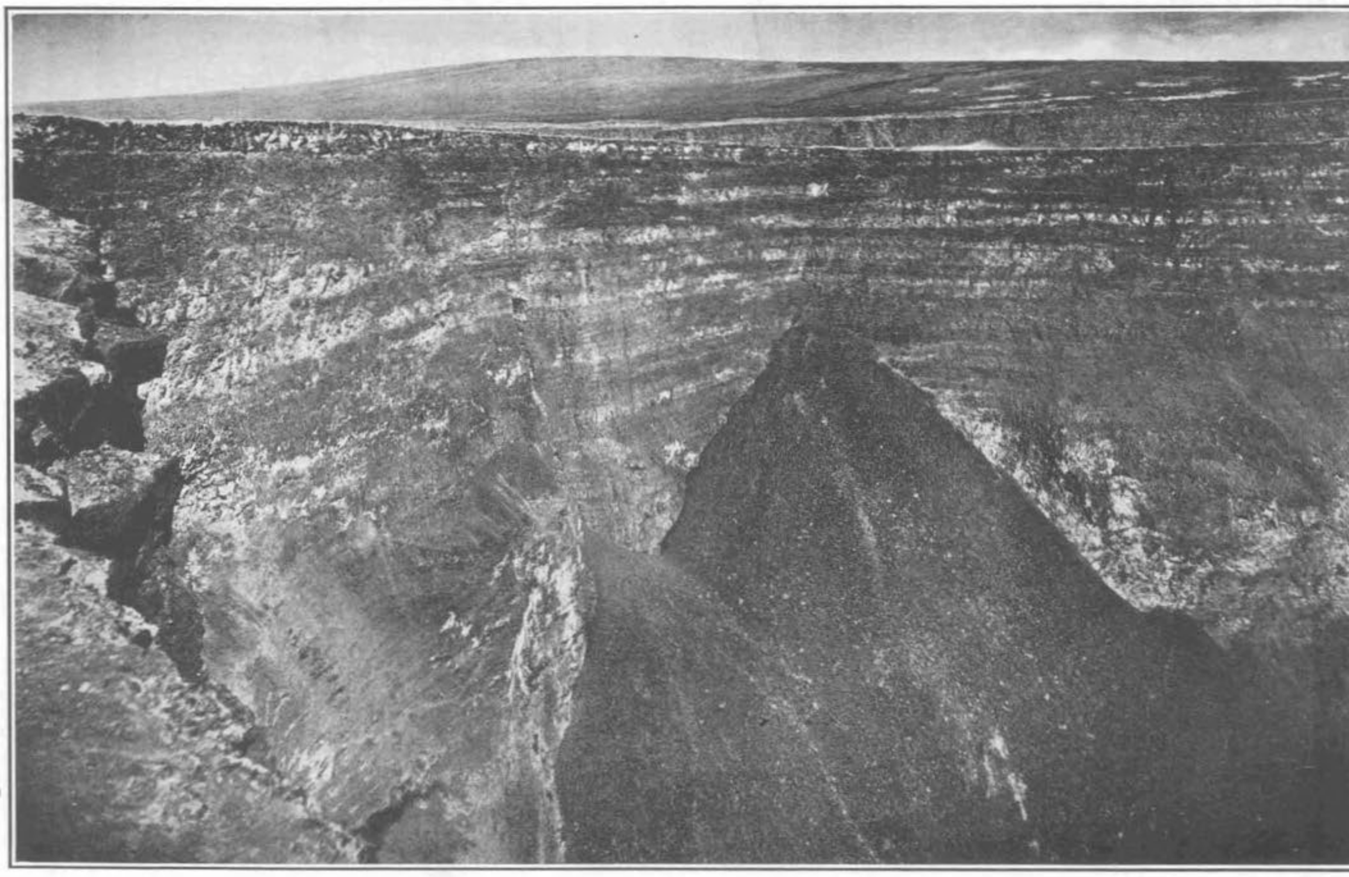
The sunspot maximum exhibited a very long interval between 1787 and 1804, and this was a turning point from high numbers to low numbers of sunspots for the maximum years. It was also the turning point at Kilauea for the supercycle that ended with the explosive eruption of 1790.

Referring to the low numbers of sunspots for some sunspot cycles and high numbers for others, the Humphreys curve (Sapper, Vulkankunde, page 272) shows low values 1790-1820, increasing values 1820-30, very high values 1830-80, declining vaules 1880-1920. The Hawaiian number of flow days roughly figured from existing descriptions was very few 1790-1820, about seven 1820-30, 132 1832-43, 411 1852-55, and then for six eruptive periods from 1859 to 1923 the figures 307, 207, 247, 37, 28, and 71. In other words the flooding of lava in Hawaii to the high maximum in the middle of the supercycle about the year 1855 corresponded to the higher maxima of sunspots in the nineteenth century.

If the reader asks why sunspots should have anything to do with volcanoes, the answer is that nobody knows. Times of maximum sunspots affect radio reception on the earth, magnetism on the earth, and auroras in the arctic regions. Sunspots are accompanied by gigantic eruptions of gas on the sun and colossal electrical phenomena in the solar system. If earth magnetism and electricity are in some way associated with gravity, volcanism may be affected. If heat by the earth's radio-activity affects volcanism, the sun may in turn affect the earth's radiations. Finally, if volcanic emanations on the earth are a last remnant of solar processes here, those processes by unknown means may be sympathetic with the sun. T.A.J.



Looking toward Kau Desert from high bluff west of Kilauea Crater January 3, 1921, when the white glistening flows from Halemaumau were filling the southwest corner of the crater. A maximum of flooding. Photo Jaggar.



Looking west across the vast void of Halemaumau in 1928, after the breakdown of 1924 was complete, showing the distant wall of Kilauea Crater beyond the Halemaumau wall, and still farther away the snake-like flow of 1881 on the smooth dome of Mauna Loa. Photo Wilson.

KILAUEA REPORT No. 1000

WEEK ENDING MARCH 22, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The pit Halemaumau Crater continues very quiet. A slide on the north wall was observed at 3:10 p. m. March 18. Fuming was observed at the two recently developed sulphurous spots on the north side of the 1930 floor the forenoon of March 19, and some rocks were heard falling on the north wall. The pit seismograph indicated two very small tremors about March 15.

The seismographs at the Kilauea Observatory registered a slight earthquake felt at Kilauea, at Hilo, and in Kona at 5:29 p. m. March 20, with indicated distance of origin 28 miles from the Observatory, and strong enough to dismantle the east-west stylus. Very feeble shocks were registered at 3:09 p. m. March 20 and 6:57 a. m. March 16, the last accompanied by tilt to the southeast. Twenty-two local tremors were registered. Weakly recorded distant earthquakes occurred at 10:47 p. m. March 17, at 9:56 a. m. March 18, this indicating a probable distance of origin of 800 miles; and at 8:08 p. m. March 18. Microseismic motion was slight with some increase March 19-20, and tilting of the ground was slight SW.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY

Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

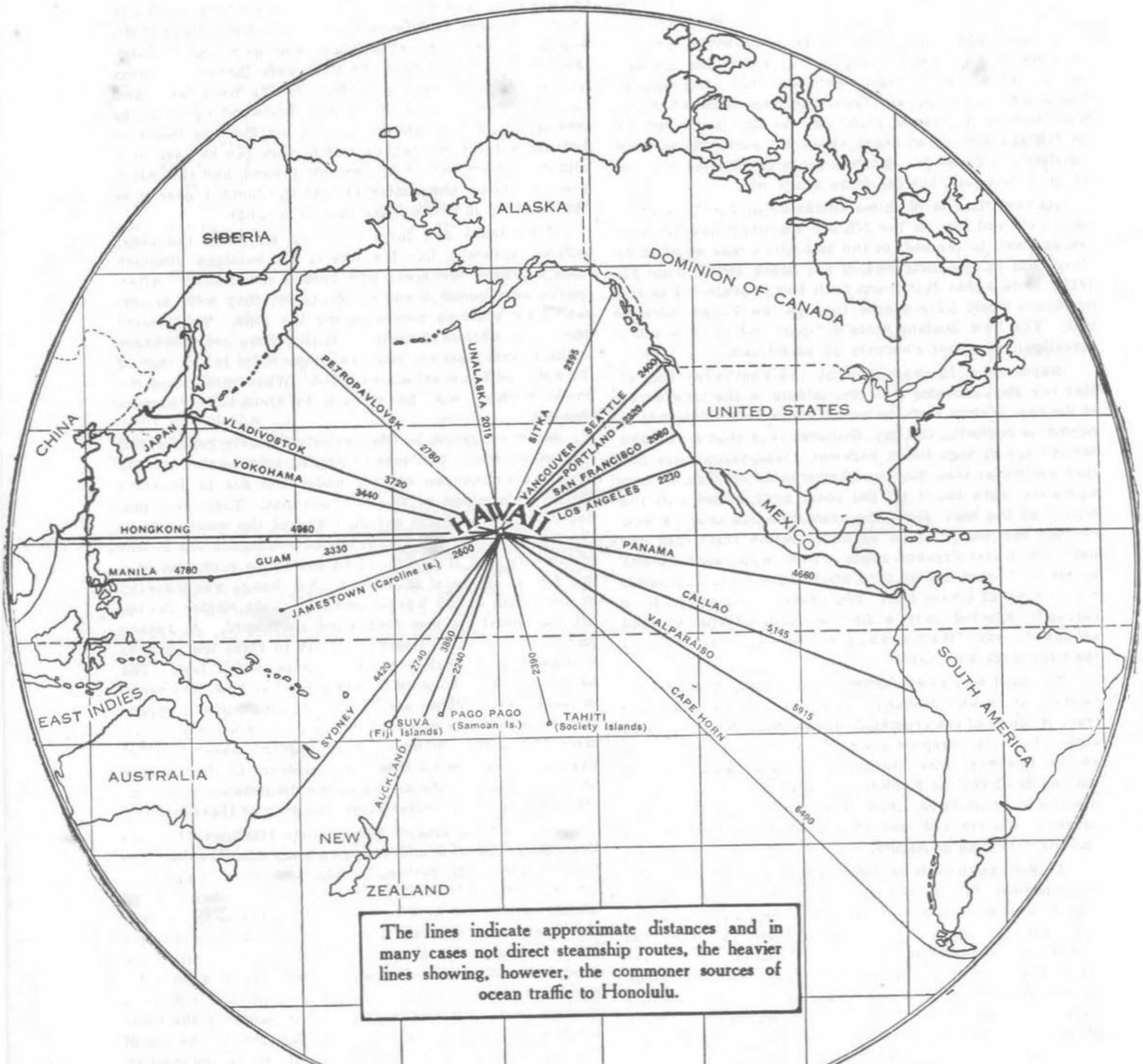
The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 327—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | April 2, 1931



Map of the Pacific Ocean showing New Zealand at the southwest. Hawke's Bay is at the southeastern end of the North Island. Napier is at the southwestern end of Hawke's Bay. This is the eastern border of a continental mass which falls off to deep water east of New Zealand.

GREAT NAPIER EARTHQUAKE NEW ZEALAND

On Frebruary 3, 1931, at 10:47 a. m. local time, a terrific earthquake occurred destroying the cities Napier and Hastings at the southwest end of Hawke's Bay, an indentation in the middle of the southeastern end of the North Island of New Zealand. This had been registered perfectly on the seismographs at the Hawaiian Volcano Observatory with indicated distance 8,040 km. SSW., which checks satisfactorily with the New Zealand location.

Seimographs at the Dominion Observatory in Wellington show that 588 shocks originating in the Hawke's Bay district occurred during February, the after-shocks diminishing more quickly than those recorded after the Murchison earthquake in 1929. For the first day following the initial mark of the heavy shock 151 earthquakes were registered in 24 hours. Most of the after-shocks were not felt in Wellington, but the large shock was.

Hawke's Bay is 60 miles southeast of the Taupo volcanic belt and lies on the NE-SW mountain axis of New Zealand well to the east of the belt which was stricken at Murchison in the north end of the South Island June 17, 1929. In fact that Murchison fault belt if projected to the northeast would have passed through the Taupo volcanic belt. The New Zealand Herald reports official and other investigations about February 21 as follows:

Napier and Hastings are at the southwest end of Hawke's Bay, Mohaka is in the middle of the long curve of the bay, Wairoa is at the north, Mahia is at the northern peninsula enclosing the bay, Gisborne is farther north, and Morere hot springs lie in between. Waipukurau lies farther southwest than Napier. Remarkable changes in configuration were found on the coast near Mohaka in the middle of the bay. Here the coast line has taken a new contour and owing to its uplift, residents state that one may now travel dryshod along a new, wide, sandy beach as far as Napier, a feat that would have been impossible before even at lowest tide. The upheavals, however, have seriously affected only a narrow strip of coastal land around the bay. Wairoa was much less seriously afflicted than Hastings and Napier.

The land was most shattered along cliffs and hills between Napier and Mohaka. Inland a short distance no trace is found of the crumbled hilltops with deeply fissured sides which are conspicucous at the shore. In some of the gorges, however, loose hillsides have fallen away, just as did the Bluff Hill at Napier. In these places the road is blocked or annihilated. Alluvial formations in rivers have subsided and cracked, and this is what happened to the embankment road at Napier.

At Mohaka there is evidence of a strong upthrust. The correspondent felt an earthquake while there, giving the sensation of somebody tapping upward beneath the earth's crust with a huge hammer, and workmen said that was how all the shakes had felt around Mohaka. There was direct evidence of an upward and downward movement. In the hills above the Maori village the floor of an entire valley has sunk at least 50 feet in a crumpled mass. Many of the ridges for miles around resembled newly made fillings, while the main road has disappeared entirely for about half a mile. The most remarkable evidence of the tremendous forces brought into play is seen near the mouth of the Mohaka River. Within a distance of about five miles three new peninsulas have been thrown out from the shore, and there has been a general rise in the level of the beach. Where the river enters the sea a bluff has been shaken down into a heap of dust and clay bowlders. A huge area of the sea is discolored with the discharge from the river which, after the middle of February, began to overflow a huge landslip dam which had blocked it for about 10 miles inland. Northward there juts out a promontory of what was formerly about 200 acres of pasture, and southward a bluff lies in ruins on one of the longest peninsulas formed by the upheaval. There are several of these upheavals along the coast. On the bluff in question about 160 acres of land were lost, and plants which originally grew just above the water level at the foot of the cliffs, were subsequently found growing near the top of the landslip. This indicates that the hills were thrown out from the base dropping down a block of the back land, and carrying beach shingle, sand, and driftwood up so as to overlap the sunken land behind. A big fish was found 50 feet above the water, shells and flotsam can be seen at a height of about 70 feet on the new ground, and this earth is so convulsed and contorted that the journey over it is like climbing in a miniature mountain range.

Homesteads and farm buildings all along the coast suffered severely, but the effects on buldings diminish rapidly toward the north and toward the interior After-shocks were common and residents say they were accompanied by booming noises among the hills. They sound like heavy objects dropping. While there are blockages in the rivers, most of them are open except in the case of the uplift of the coast above noted. When rain comes the whole country will be subject to tremendous surface changes.

An investigation by the Geological Survey reports that the main fracture lies east of Napier, passing through the principal earthquake centers under the sea in Hawke's Bay as determined by the seismographs. There is a prounounced uplift of the sea floor and of the coast west of the fracture line. "So many factors influence the height of the tide that it is difficult to determine a change of a few feet in the level of a coast. No change was detected at the mouth of the Ngaruroro River. At Napier the uplift was about six feet decreasing southward. At Petane just to the north of Napier it is six to eight feet, and at Whakaari still farther north, perhaps seven feet. The harbormaster at Wairora is sure there has been no change in level there. These scanty observations make it appear that the coast has arched gently on a northeast line, the crest of the arch being north of Napier. Assuming that the amount of coastal uplift is a measure of the violence of the earthquake, the center of the disturbance was some miles northeast of Napier below the floor of Hawkes Bay."

Napier suffered greater damage than Hastings, Hastings more than Waipawa, and Waipawa more than Wairoa. The report states that fissures in alluvium were remarkably abundant along rivers and in localities where there was no lateral support for filled-in material. In places the ground had stretched 12 feet in a few score yards, water and sewer pipes having been disrupted, and dwellings greatly damaged. The West Shore causeway built across a mud flat area had spread and the roadway split and collapsed through lack of lateral support. The banks of the chief tidal channel had closed in on a bridge, forcing the top of one set of piles from under the ends of the girders supporting a span of the bridge. At many points along the coast shingle beaches had slumped either toward the sea or backward toward the lagoon behind them, and the surfaces were ridged by a series of parallel steps and trenches.

The displacement of alluvium narrowed the river channels, and raised their beds, making it likely that their discharging capacity during floods will be seriously diminished. During the earthquakes large quantities of water, sand, and silt issued from fissures in the ground. The origin was a water-saturated sand layer below the surface. Land slides were not nearly so prominent as they were in the Murchison district in 1929, where the hills were steeper and the climate wetter. Their distribution showed that they depended largely on local conditions ranging in quality from vast landslips involving many millions of yards of rock to mere downward creep of the soil mantle on the hills. Pressure ridges appear to mark the surface trace of an important earth fracture through the Poukawa Valley extending northeast about six miles. The ground northwest of the fracture is fissured and swollen and that on the southeast side unaffected. It appears probable that the earth block on the northwest side moved. The movement was toward the east. Probably it follows a weak layer interbedded with the strong limestone bands. Probably also, movement occurred along several weak layers. This suggests that the movement was distributed over a zone several miles wide.

An investigation by a government vessel taking soundings for three days north from Napier indicated that the bed of the roadstead had risen in parts from six feet to seven feet, but in places the soundings gave the same depth of water as is shown on the charts. Nothing less than 33 feet of water was found from two miles off shore to half a mile from the breakwater at Napier, the sounding being on the line of beacons leading to the roadstead. The investigations show that the anchorage in the roadstead is just as safe for shipping as it was before the earthquake.

With reference to earthquake-proof construction, the following quotations from a sensible article by Archdeacon K. E. MacLean are pertinent quite as much to other places as to New Zealand. The Archdeacon asks whether sufferers by the earthquake need believe that the disaster was a divine punishment. He cites the case of a man who gets sunstroke by going out without his hat. We are sorry for him, but we say bluntly, "It was his own fault."

"To be quite honest is not our position much the same? We know what earthquakes are. We know a good deal about how and why they happen. We know there are faults in the earth's surface and that the countries near those faults are liable to earthquakes. We know—we always have known—that New Zealand is one of these countries, and that a bad earthquake might come at any time. Yet we came knowing this and lived here and shrugged our shoulders about earthquakes."

"Our fathers, who remembered the earthquake in Wellington in 1855, warned us against brick houses and high chimneys, but the years went by and more and more brick houses and tall chimneys were built, and the years went on and they stood. It was quite possible to build earthquake-proof houses in wood or brick, or concrete, but it was expensive, and we wanted money for other things. It was quite possible to build chimneys in ordinary houses which had not got a tight collar of wood around them at the flashing, but we did not bother."

"It was quite possible to follow sound principles of construction in building shops and offices, but no one cared and no one asked for it. So up went the flimsy, showy walls and the heavy copings. It is not the fault of anyone in particular. Architects, builders, and workmen just shared the common mind and built their own houses in just the same way that they built houses for other people. We are all in this together. It was public opinion that it did not matter."

"Two years ago the Murchison earthquake happened and we said, or nearly all of us said, 'Poor beggars! Come and live in Hawke's Bay and be safe.' And we went on living happily in the death trap we had built. Then, on February 3, the earth wriggled for a minute. The fault settled down a bit more. Who caused the death and suffering? Only if we face this honestly shall we live more wisely in the future."

This wise comment applies equally to all lands around and in the Pacific Ocean. T.A.J.

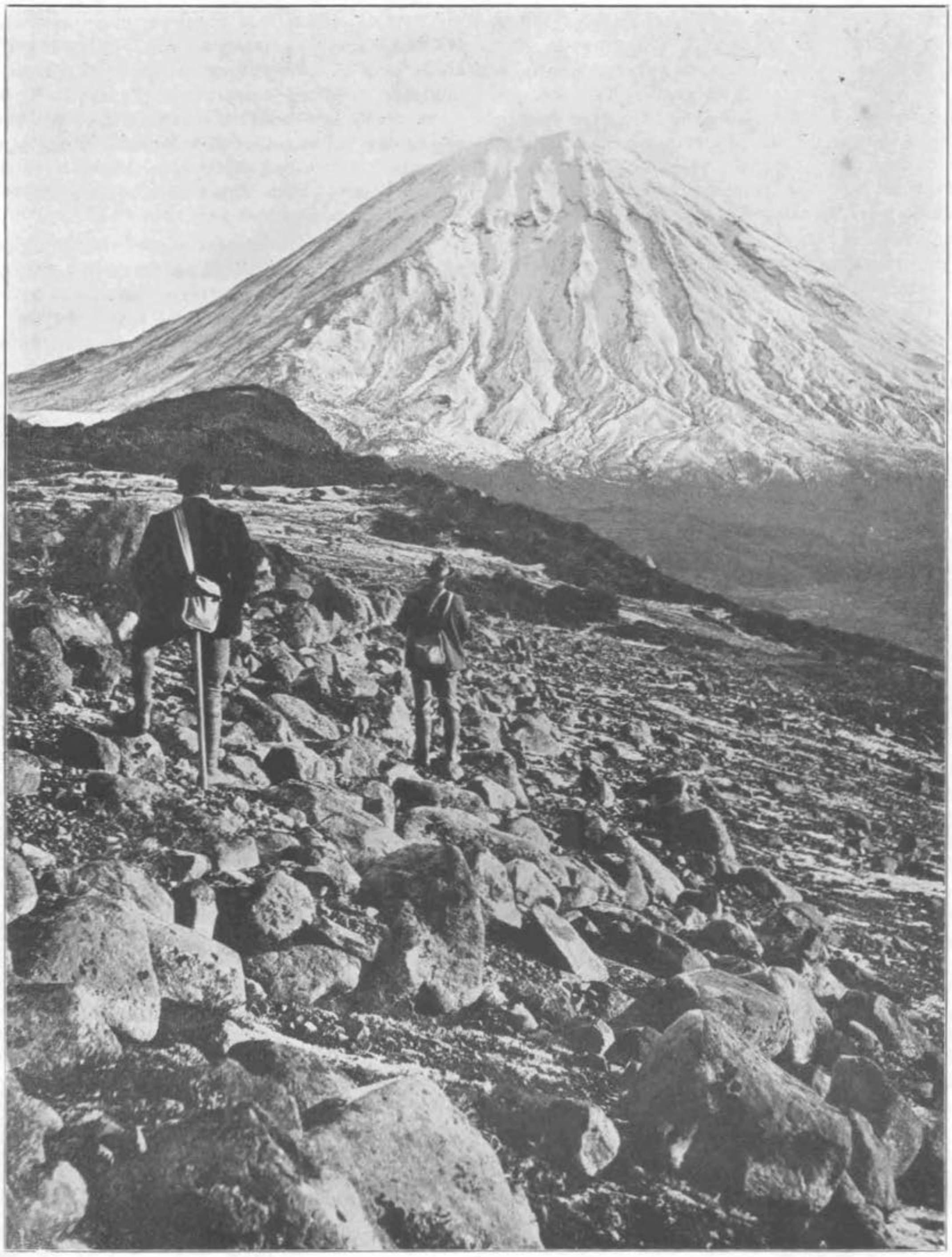
KILAUEA REPORT No. 1001

WEEK ENDING MARCH 29, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

No significant changes have happened at the Hawaiian volcanoes and the fire pit at Kilauea is quiet. Thirty tremors were registered on the seismographs of the Observatory at Kilauea and three very feeble local seisms, one of these at 7 p. m. March 25 indicating origin distance 28 miles, and one at 8:11 a. m. March 29 a distance of five miles. A tremor at 9:05 p. m. March 27 lasted eight minutes. A strong distant earthquake began at 2:21 a. m. March 28 local time (10 hours, 30 minutes slower than Greenwich) and indicated origin distance 8,830 km., apparently WSW. from station, which would locate it near the west end of New Guinea or the eastern part of the Dutch East Indies.

Tilting of the ground was moderate to the south, and microseismic motion was slight for the week.



Ngauruhoe Volcano in the Taupo belt of the central part of the North Island of New Zealand. This shows the volcano as seen in winter from the east, marking the line of active volcanoes which lie 60 miles northwest from Napier.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

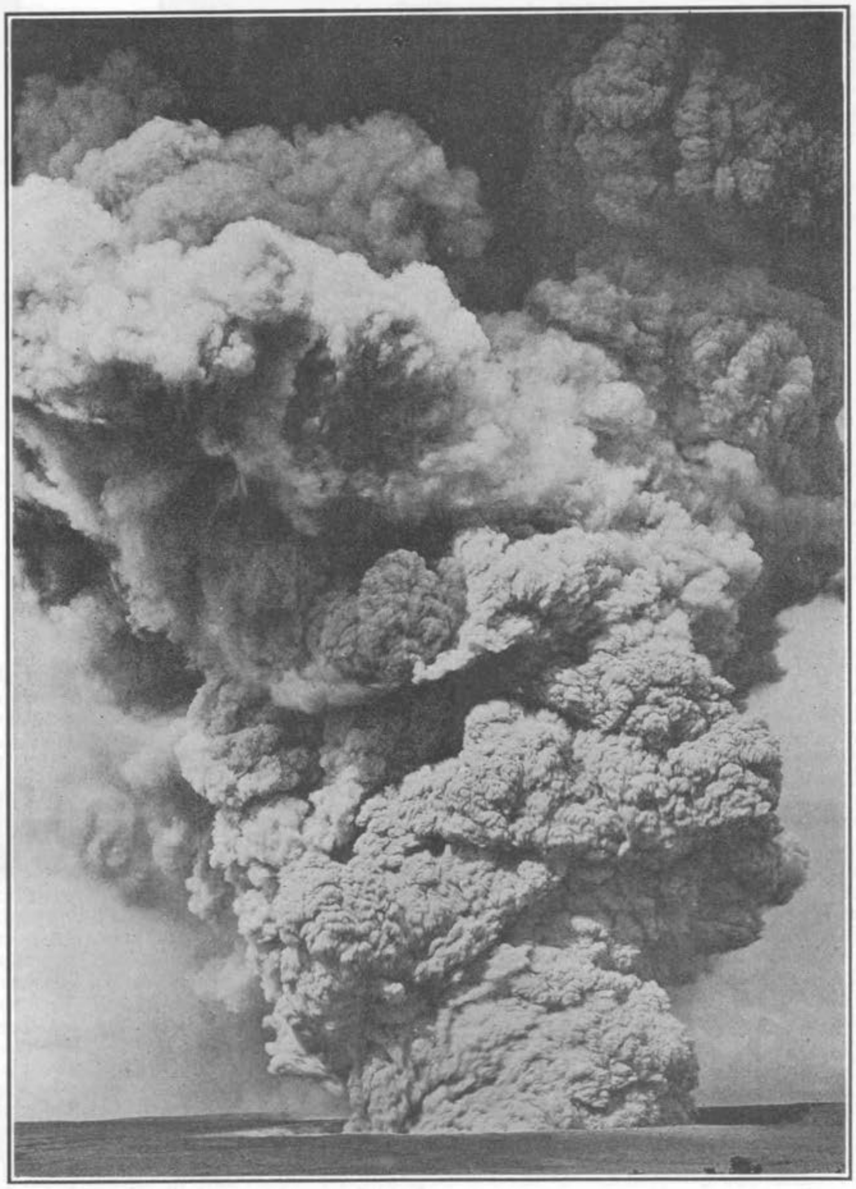
The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year **Ten cents per copy**

No. 328—Weekly Hawaiian Volcano Observatory, National Park, Hawaii April 9, 1931



Steam-blast eruption at Halemaumau pit about 8:30 a. m. May 22, 1924, showing tendency to spiral vortex and dark electrical cloud forming above. Photo Tai Sing Loo.

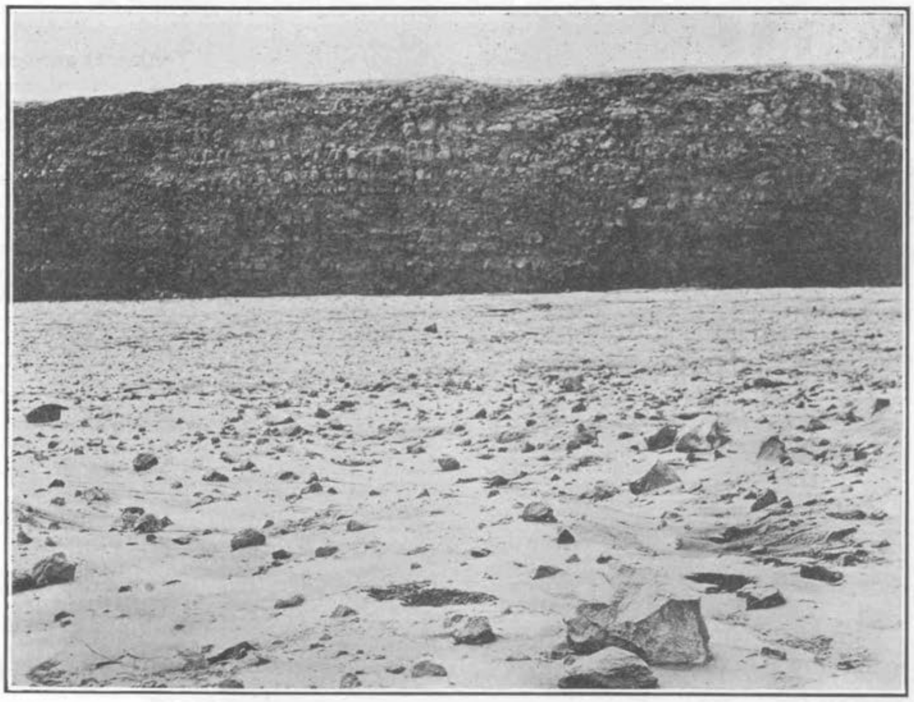
THE GREAT ERUPTION OF KILAUEA IN 1924

Much has been said in recent numbers of the Volcano Letter about the supercycle of 134 years which ended in the tremendous steam-blast eruption of Kilauea in the month of May 1924. The present covering of gravel and bowlders on the lava around the sides of Halemaumau was all thrown out during those three weeks in a series of violent upward jets of steam charged with rocks and sand, something which none of the present generation had ever seen in Hawaii. A much bigger ejection of this kind happened about 1790, and in 1823 there were steam jets that threw up gravel in the lava-flow crack east of Pahala. There are some fragmental stones evidently thrown out explosively around the crater Mokuaweoweo on top of Mauna Loa: no one knows their date.

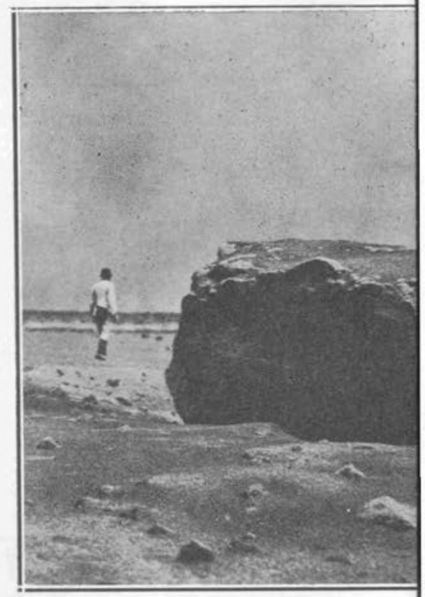
The sequence of events in 1924 was like what had happened in May 1922, when there had been:

(1) Sinking of the lava column.
(2) Great enlargement of Halemaumau pit with avalanches.
(3) Cracking open of the Puna rift to the east.
(4) Southerly tilt and many earthquakes at Kilauea.
(5) Cauliflower dust clouds rising.

What was different in 1924 was the subsidence farther away along the Puna rift (and no lava flow such as had broken out at Makaopuhi in 1922), this occurring in April of 1924 at the east point of the island with lowering of a big block of country, spreading open of cracks, and sinking of longshore vegetation below sea level. Then after the cauliflower clouds had been rising for several days from



Kilauea floor west from Halemaumau May 31, 1924. Shows bowlders and ash covering the lava surface. Photo Emerson.



Eight-ton bowlder thrown 3500 feet
May 18, 1924. Photo

huge avalanches tumbling into Halemaumau early in May, people began to notice a booming concussion in their ears, and stones began to be flung up and out, instead of merely falling down and in. The so-called eruption was therefore a gradual growth beginning the end of April with a collapsing bottom of the pit that was not at all unusual, producing ejection of rocks first on the night of May 10-11 that was very unusual indeed, and then exhibiting a series of violent steam blasts, at intervals of several hours, for 10 days following May 13. This crumbled away the edge of the pit so that the former rim migrated back on all sides for 700 feet, as the geyser-like steam blasts accompanied gigantic engulfment of the walls of the shaft. May 24th was the last peak of explosive intensity, and thereafter the new type of activity waned and ended about May 28, with avalanches and earthquakes all that remained, these dwindling during June.

The summary of the 1924 sequence was then as follows:

(1) Sinking of the lava column in March.

(2) Cracking open of the Puna rift far to the east April 22.

(3) Subsidence of a fault block at Kapoho in Puna.

(4) Southerly tilt and increasing earthquakes at Kilauea.

(5) Great enlargement of Halemaumau pit in May.

(6) Avalanches at Halemaumau making cauliflower clouds.

(7) Same cauliflower clouds containing steam blasts upward, May 11.

(8) Engulfment of pit walls in May.

(9) Steam-blast spasms two hours apart May 13, thereafter less often.

(10) Ejection of stones, maximum May 19.

(11) Duration explosive spasms, maximum seven. hours May 19.

(12) Electric storms maximum May 17-19.

(13) Felt earthquakes maximum May 22.

(14) Total earthquake frequency maximum May 24.

(15) Cessation of steam-blast phase May 28.

(16) Glowing intrusive body exposed in pit wall June 12.

(17) Adustment of pit walls June-July.

(18) Liquid lava in pit bottom July 19-31.

The diagram on Page Four shows how these various features waxed and waned between May 10 and May 27, the numbers of explosive spasms taking the lead at the beginning of the eruption and the numbers and intensity of earthquakes dominating the situation at the end of the eruption, when the other features were declining. The conspicuous mud rains accompanied electric storms of the period between May 15 and May 19. The caving-in of the rim of the pit began at the southwest where lay the Kau Desert rift of 1920, and where the enlargement had taken place in 1922. Then the breaking-in of the rim followed around the circle to the south, southeast, northeast, and north until the breakdown was balanced by collapse at the northwest. Then there was more collapsing all around the previous outline of the pit. The greatest engulfment was accomplished during the times of maximum steam blast, maximum duration of spasms, and maximum intensity of earthquakes. The greatest break-down of the walls observed took place May 21-22 when there were incessant avalanches. These were the two days following the explosive maxima.

To give the reader an idea of what happened we may quote from the journal of the Observatory a few items of May 17-18: "A station was occupied during the night May 16-17 on the gravel spit southwest of Keanakakoi. There were explosions at 1:20 and 1:27 a. m., a continuous roar from 2 a. m. on, an avalanche cloud at 2:28 a. m., increased roar 3:19 a. m., and at 3:20 a. m. the noise increased, an explosion occurred, a few red-hot rocks were thrown out southeast from the pit, and one minute later a few came out from the east side. At 3:32 a. m. the cloud had become enormous, the roar was continuous, pisolitic mud began to fall, and at 3:35 flashes were seen in the cloud over the pit. At 3:42 there was a roar lasting four seconds accompanied by a slight earthquake, and by now the cloud had spread out like a fan over almost the entire sky."

This sort of record was maintained for many days at the Observatory, and the seismographs showed tilts, prolonged tremblings, and numerous earthquakes, and required incessant attention restoring the pens to the drums. During the month ended May 31, 1924, 3,961 local earthquakes were registered, the maximum being 467 in 24 hours on May 24. Harmonic tremor appeared on the seismograms April 19, becoming moderate to strong after May 6, and decreasing May 16 so as to become very slight before the maximum of explosive activity was reached May 19. Probably the harmonic tremor was due to lava surging, which had receded to such great depths by May 17 that it

southeast from Halemaumau
Tai Sing Loo.

Rill-marked new ash May 29, 1924, south margin of Kilauea Crater. This ash lay over the country like drifted snow, and the rain gullies trench through to the old ash of 1790. Photo Emerson.

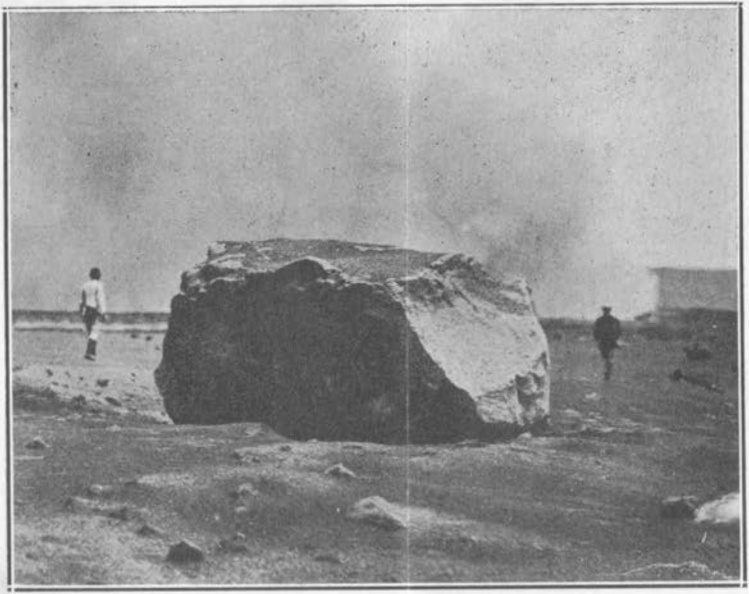
did not register. In 1924 the tilting of the ground at the Observatory in a south and southwesterly direction amounted to 88 seconds of arc between January and June, 58 seconds of this was during May, and the most rapid tilting took place just preceding, during, and immediately following the great engulfments and steam blasts. There was no good correlation between the number of earthquakes and the explosion days, true earthquakes increased on days when the steam blasts were inactive, but a peculiar shaking accompanied the explosions which gave long drawn out seismograms that built up gradually, without a preliminary tremor like a true earthquake, continuing for half a minute or so, with a period of 0.5 second, and then died away gradually.

Continuing the journal of May 17: "The pit was visited after 9 a. m. and found greatly enlarged so that rim had gone back 200 feet. Depth appeared over 1,000 feet, bottom was flat and covered with talus material, steam was rising without pressure and creeping across the floor irregularly in small continuous cottony clouds. The upper walls of the pit appeared to slope inward at 60°, approaching verticality farther down, so that the avalanches had a free fall to land with a tremendous crash at the bottom. Often the rocks fell with a pattering sound. The cracks across road 2,000 feet southeast of Halemaumau had widened and there were numerous other cracks between there and the pit. The Kilauea floor near the pit was now covered with bowlders in large numbers, locally extending a half mile from the pit and in places there was at least one fallen fragment for every square foot. Some bowlders weighed several thousand pounds."

"At noon came one of the impressive explosions, causing great consternation among visitors. At 12:02 p. m. came a roaring noise and a big dust cloud, accompanied by a moderate earthquake. At 12:32 p. m. there was a roar with sharp crashing noise lasting 50 seconds, and a very heavy black cauliflower cloud rose, much bigger than the one of the early morning hours. At 12:35 p. m. 15 explosive outbursts rose in the course of 11 minutes, accompanied by continuous roaring, and loud crashes of thunder made frequent lightning flashes very low over the Observatory. Showers of rocks were heard falling heavily. At 12:45 p. m. dust and sand fell for 25 minutes. A visit to the pit after this explosion showed newly fallen hot dust in a thick layer near the rim of the pit which had singed the grass farther away. The only gas noticed in the steam exhaled was a small amount of sulphur dioxide."

"May 18. At 11:07 a. m. began a great culminating explosion with tremendous dust cloud and ejected rocks. At 11:09 there was a second explosion plastering the area northeast of the pit with hot sand for several hundred yards. At 11:20 a. m. there was a steady loud roar and a fall of pisolitic mud at the Observatory. There was an Observatory party near the pit, and during the barrage of 11:09 a. m. Mr. Truman Taylor was fatally stricken down by bowlders and sand on the Kilauea floor about 1,800 feet southeast of Halemaumau. He was rescued, but died after being removed to a hospital. The observers were on the sand flat farther to the southeast and when sitting on the ground one could feel numerous quakes and a rumbling was heard. At the 11:09 explosion came a wave of increased air pressure that was painful to the ear drums. One of the rocks weighing over 300 pounds landed on the 1921 lava of the south embayment of Kilauea Crater, and another bowlder weighing eight tons fell at the landing field, made a deep impact cavity, and broke, the fragments bouncing and partially burying themselves on the side remote from the trajectory. An intense electrical storm followed."

T.A.J.



Eight-ton bowlder thrown 3500 feet southeast from Halemaumau May 18, 1924. Photo Tai Sing Loo.

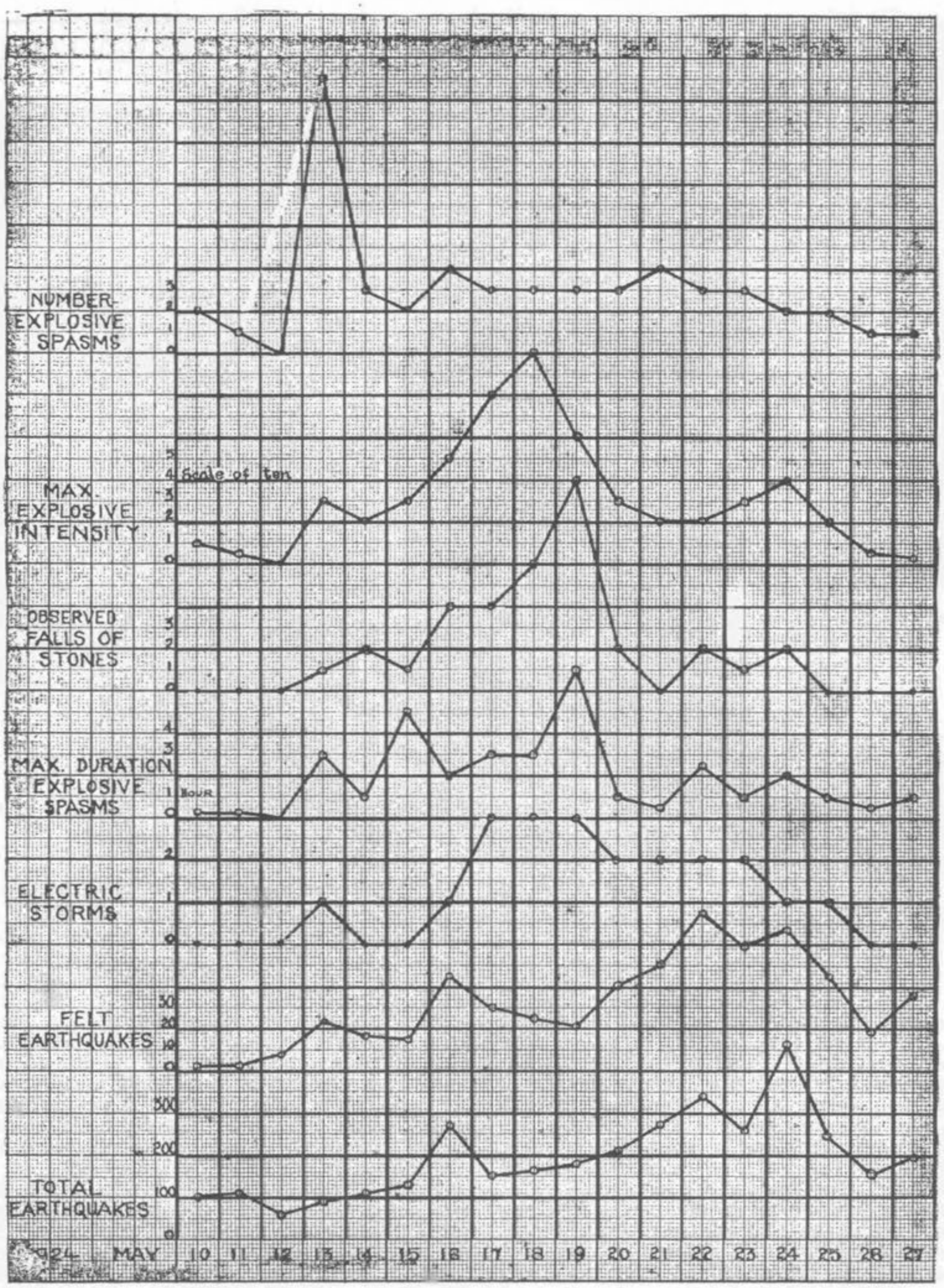


Diagram showing curves of measured activities taken from the tabular summary of the Kilauea steam-blast eruptions May 10-27, 1924.

KILAUEA REPORT No. 1002

WEEK ENDING APRIL 5, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Kilauea remains inactive and without noteworthy changes at the lava pit Halemaumau. There is still steady fume from vents near the north-central part of the pit floor. Steaming has lessened on the south talus.

A peculiar slow-period tremor recorded with more or less regularity on the pit seismograph 4 to 10 a. m. April 2 and again April 4. These were also noted on the instruments at Uwekahuna and the Observatory.

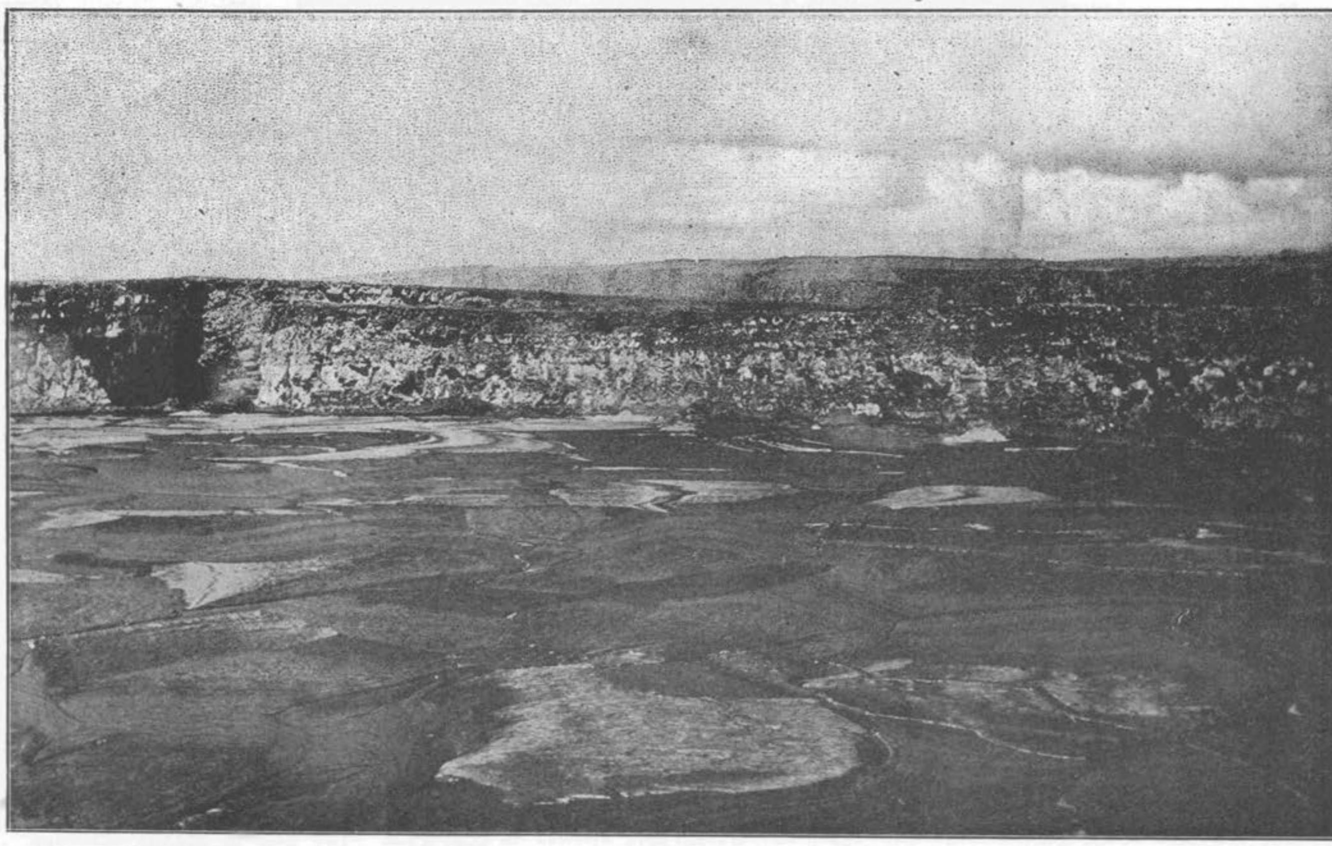
The seismographs at the Observatory recorded an increased number of disturbances during the week. There were 57 tremors, including 5 minutes of continuous tremor April 3 and 20 minutes of continuous tremor April 4; and there were 3 very feeble seisms, and 1 feeble shock occurring at 12:20 p. m. April 4. Phases of the last indicated 32 miles distance to origin. In addition on April 5 a very weak teleseism recorded at 8:30 p. m.

Tilt for the week was moderate to the south. Microseismic motion was moderate March 30 and 31 and at other times slight.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 329—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | April 16, 1931



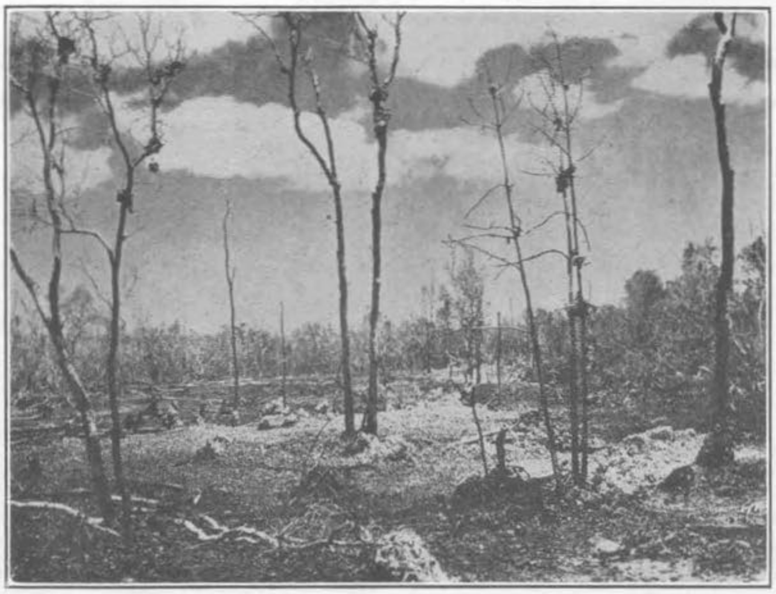
Halemaumau from the northeast rim, June 30, 1923, when the lava was liquid from cliff to cliff 129 feet below the edge. Photo Jaggar.

EVENTS PRECEDING THE GREAT ERUPTION 1924

As the steam-blast eruptions of Kilauea in May 1924 represented the end of the supercycle of 134 years and of the last of the 12 eleven-year cycles with its peculiar terminal characteristics, it is profitable to inquire what prophetic occurrences filled the years just preceding the eruption. For the similar eruption of 1790 we have only the hint in the tradition of the natives that there was a lava flow in Puna off to the east of Kilauea about 1788.

Until 1921 when in March there was a maximum of overflow from the actual lip of Halemaumau pit inside of Kilauea Crater, no very marked breakdown of the rim of Halemaumau had occurred, the pit outline enclosing the overflowing lava column was about as small as it had been in 1919, and the only outflow from the flank of Kilauea Mountain had been the Kau Desert activity of 1920. After the 1921 overflows the lava of Halemaumau subsided twice moderately with recovery of the lava following the sinking. Thus it may be said that until May 1922, or just two years before the great steam-blast eruptions, the only events that predicted those eruptions were (1) the supposition of a supercycle about 132 years long after 1790; (2) the general decline in volume of Hawaiian flows for the last half of the supercycle after 1855; (3) the down-hill progress of flank outflows from Mokuaweoweo 1914, to Puu o Keokeo 1916 and 1919, and then to Kau Desert 1919-20; this outflow from the flank of Kilauea was a suspicious new feature.

We read in the journal of the Observatory May 13, 1922, "This day was the end of the prolonged rise." The liquid lava had risen to a point 49 feet below the rim, fountaining and splashing activity varied, outer pools of lava between inner crags and the rim of Halemaumau often overflowed their banks, flames were abundant, and an oven cone on a crack outside of Halemaumau in the floor of Kilauea Crater showed glowing slag about 50 feet down. Then in the third week of May the rising which had started in November 1921 ceased, and by May 21 the lake level had dropped 300 feet steadily and majestically, the crag peaks between the pools maintaining their identity as they went down. Avalanches from crags and walls were numerous. There followed swarms of earthquakes, many of them perceptible over the island of Hawaii. The shelf of new lava caved away, making glowing avalanches. The crags and lava lakes were enveloped in debris slopes. Avalanches increased and sent up cauliflower clouds of dust. On May 26 this made a thunderous roar heard many miles away, the rim of the pit was generally carried away, and at the southwest the collapsed rift made a smoking



The Chain of Craters rift of August 25, 1923, with lava spatter in the trees and sulphur along the flow-crack in the forest. Locality west of Makaopuhi. Photo Emerson.

canyon extending Halemaumau 500 feet in that direction. The pit was enlarged from an oval of maximum diameter about 1,400 feet to an irregular cavity 2,030 feet long by 1,500 feet wide. By May 31 the top of the lava column had subsided at least 1,000 feet and the vacant cauldron was floored with debris 861 feet down. At 8 p. m. May 28 lava fountains broke out on the side of Makaopuhi Crater (end of Chain of Craters Road) along the rift east, and it was evident that the great eastern rift was receiving the underground drainage from Halemaumau and vomiting up a little of it in these local eruptions. This outflow was all at lower level than the Kau Desert outflows of 1920. In the map on Page Four Makaopuhi is near the letter "P" of Puna.

The lava column was executing pulsations of subsidence, but the mountain edifice had not yet yielded sufficiently to let the lava of Halemaumau escape under the ocean to the east. Superficially the lava crust solidified in Makaopuhi and Napau, in July and September of 1922 the liquid slag burst through the talus slopes of Halemaumau and started to fill the bottom of that pit, and pulsations of rising followed so that at the end of June 1923 a sea of lava with a narrow shelf around its border extended from cliff to cliff only 129 feet below the edge of Halemaumau. The sequence of events always suggests that the basaltic melt has an unconquerable gas potential actuating it, but the pressure of the big mountain slabs, now yielding a little to the gas expansion, and now again reasserting itself under gravitation, controls what the gas in solution can do. According as the edifice breaks down or splits apart in spasms through the ages, the so-called eruptions of lava break out or fill the pits as directed by the yielding of the mountain slabs. A glance at the map of Kilauea shows that it consists of a series of big slabs on the southeastern slope of Mauna Loa which have been slipping seaward for ages.

On August 24, 1923, the lava in Halemaumau was still high, only 220 feet down, but a subsidence had begun. Local earthquakes became numerous, by August 26 the bottom of the pit was full of enormous jagged and tilted blocks and hardly any fire was visible except where lava was streaming out of a crack at the southeast. By August 28 Halemaumau was floored with a tumbled mass of broken blocks 564 feet down, and a new crack in the Chain of Craters country was spouting lava and sending up white fumes full of poisonous sulphur vapors. This was in the forest west of Makaopuhi, and the photograph on Page Two shows the sulphurous stain along the flow-crack and the lava spatter in the trees. The belt of cracks extended north and south for a width of 500 feet and a length about 2,000 feet. Patches of sluggish pahoehoe developed at both ends of the crack belt, round holes were produced along the rift lined with new lava, small cones and innumerable tree molds were formed, and patches of sulphur appeared in certain places. In September the lava reasserted itself in the bottom of Halemaumau and began to rise. The oozing up of lava near Makaopuhi lasted only a few days, the visible steam there continued for months, and hot vapor along the crack developed blue-green algae, these hot places still persisting in 1931.

Again there was revival in Halemaumau, and again the great sea of lava was only 121 feet below the rim of the pit on January 27, 1924. This was followed by the same kind of lowering which had occurred in August of 1923, leaving in February and March a collapsed tumble of debris with a glowing hole about 400 feet down.

The event of April 21 at Kapoho near the east point of the island of Hawaii was unprecedented for the present generation of men. Prolonged, mild quaking began, there were several hundred shocks for three days, the ground cracked open in several directions, cracks from six inches to nine feet across yawned athwart the roads with a gradual process of opening, and the principal movement proved to consist in a lowering of the fault-block south of the Kula cliff shown in the photograph on Page Three. This was an old fault-scrap facing southward. The block which moved was about four miles long east and west, by a mile wide north and south, and it apparently hinged about the cracked zone on its south side near Kapoho village, and lowered the most along the Kula cliff on its north side, where the ground at the foot of the cliff gently dropped in the course of a few hours from 9 to 13 feet. This movement extended all the way to the sea at the east, with gaping cracks along the line of the cliff, and the lowering at sea level made new salt water lagoons and drowned the longshore vegetation. There was not a single big earthquake in the whole series of shocks. The fault block moved almost as though it were plastic. Houses and tanks which stood at a quarry against the fault cliff were lowered bodily and remained erect. Releveling of the ground showed a new profile 9 feet lower than before south of the quarry, and one foot lower than before at Kapoho station.

This April crisis at the east was the last premonitory happening before the Kilauea steam-blast eruption. It was led up to by earthquakes along the eastern rift which seemed to indicate that the lava was splitting its way in that direction. When the great crash came in Halemaumau in May, the supposition appeared to be justified that the lava escaped under the ocean to the east. The diagram at the top of Page Four exhibits one of the characteristic lava pulsations that led up to the great engulfment. T.A.J.

TILTING OF THE GROUND FOR MARCH

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the dirction given.

March 2-8	0.7 second	SSW
March 9-15	2.5 seconds	SW
March 16-22	1.0 second	S
March 23-29	1.9 seconds	SSW
March 30-April 5	1.1 seconds	E

KILAUEA REPORT No. 1003

WEEK ENDING APRIL 12, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

On April 7 at 3:30 p. m. no changes were observed at Halemaumau pit, no tremors were recorded on the pit seismograph, and there was a little steam on the south talus. On April 8 at 2:40 p. m. a small avalanche caused dust to rise from the pit. A little fume still rises from the sulphur spots, and the western of these is brighter yellow than the others. On April 11 at 10 a. m. the 1930 cone at the top of the new lava heap of last November had caved in a little at its upper edge. The pit seismograph indicated a sudden tilt away from the center between the 7th and 9th of April.

The Observatory seismographs indicated 17 tremors for the week ending at midnight April 17, two of these on April 10 being continuous for periods of 2.5 minutes and 7 minutes, respectively. Tilting of the ground was very slight NNE, and microseismic motion very slight.

Kula fault of April, 1924, near Kapoho, east point of Hawaii. The foreground dropped about 10 feet, the country was seamed with cracks, and scores of earthquakes occurred. Photo Emerson.

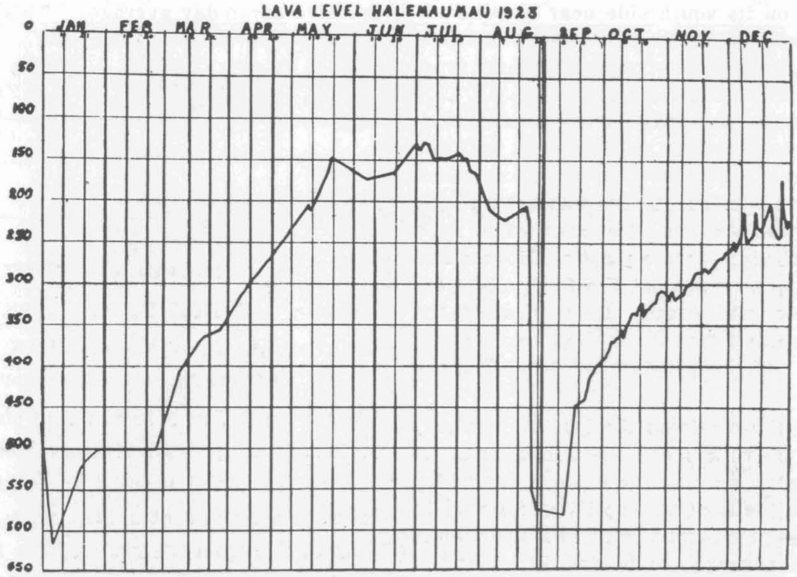
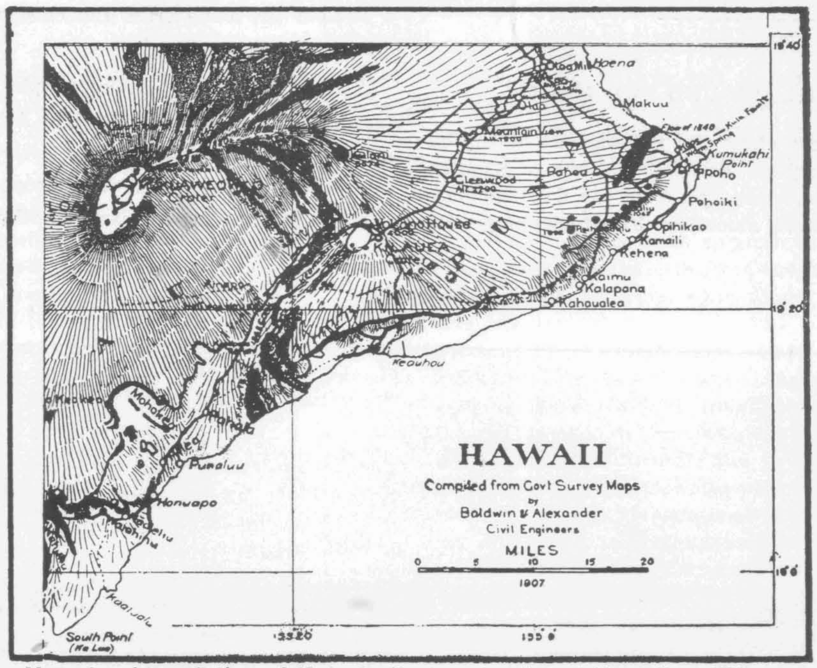


Diagram showing depression in feet of lava level below rim of Halemaumau during 1923. Shows sudden depression to 575 feet before the Chain of Craters outflow.



Map showing relation of Kula fault at east point of Hawaii to Kilauea and Mauna Loa. Here occurred the depression of April 1924.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

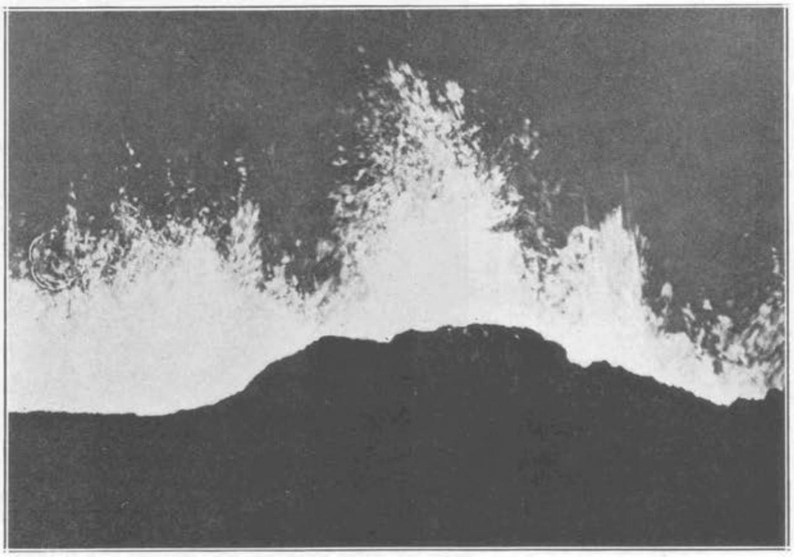
The Board of Directors includes Lorrin A. Thurston, President; Frank C. Atherton and Walter F. Dillingham, Vice-Presidents, L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 330—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | April 23, 1931

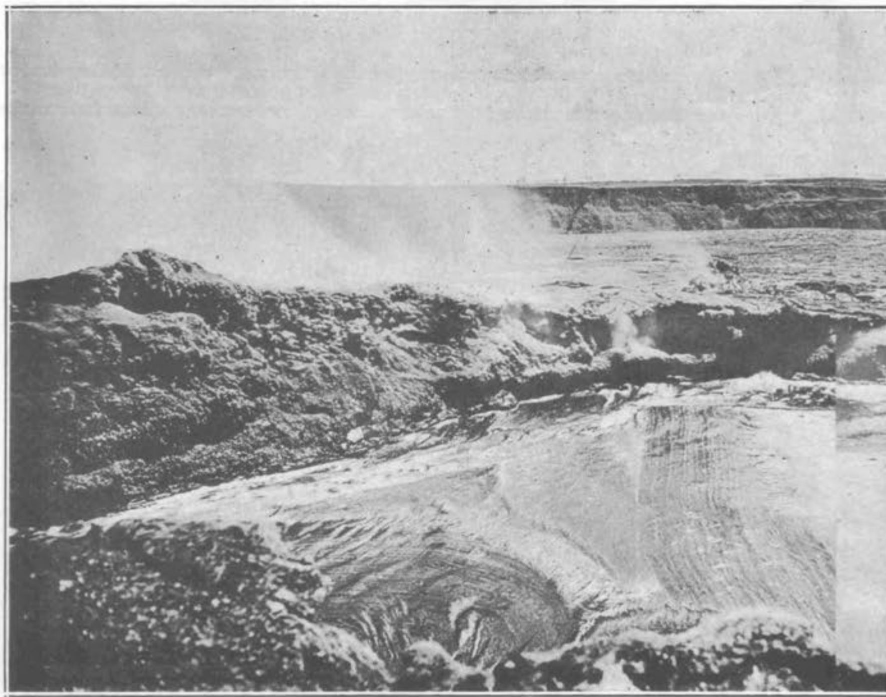


Source fountains of the main lake in the rift crack of the Alika flow, October 1, 1919, SW flank of Mauna Loa, 7000 feet elevation. Photographed by T. A. Jaggar 600 feet away, at night. "The great fountains 200-300 feet high were spouting continuously along the fissure for a thousand feet of length like a wall of red flames. In detail they were made of incandescent, light, crumbly material, yellow when it shot up, red when it came down. The noise was a roar like surf."

THE PEAK OF THE VOLCANIC CYCLE

In recent numbers of the Volcano Letter, beginning with No. 319, there have been reviewed the events of the last twenty years of Hawaiian eruptions, this review leading to a discussion of the eleven-year cycle from 1913 to 1924 as a type of twelve such cycles since 1790. Last week we discussed prophetic events which preceded the great steam-blast eruption of 1924, and in No. 328 that remarkable eruption was described. Pulsatory risings of about a year each followed by collapse and flank outflow were the features forecasting the grand crisis, and that crisis itself was an unusual collapse over lava that receded deeply. The immediate recovery of the lava and its appearance in the bottom of Halemaumau in high spouting fountains within two months after the time when the steam blasts ceased inaugurated a new cycle. We are living in the midst of that cycle, now characterized by small manifestations of spouting lava in 1924, 1926, 1927, 1928, 1929 (twice), and 1930. The 1926 happening began at the very top of Mauna Loa, so that the conclusion seems justified that the gas energy within the underground lava itself was not exhausted in 1924. Within two months hot and very vigorous lava was spouting in the Kilauea pit, and within two years it was bursting out through cracks 13,000 feet above the sea in Mauna Loa. What was exhausted, then, was the patience of the mountain in consenting to yield, now here, now there, more and more until 1919-21 when both Mauna Loa and Kilauea were inflated and let the lava squirt up through cracks. Then the great mountain blocks had been so uplifted and loosened that they even let the lava ooze out under the ocean somewhere east of Puna in 1924 about May and June, when the ground water flowed into the chamber under Halemaumau, and the steam puffed up like a freight engine. But the coldness of the Pacific conquered the submarine oozing slag, the frothing melt backed up into the Halemaumau conduit and reappeared in July 1924, the mountain blocks settled down hard owing to what had been withdrawn, and to their enormous weight, and the gas in the deeper magma was no longer able to lift them. The weight control of gravitation had again asserted itself.

This weight control of gravitation in a volcanic mountain, or better in a volcanic island consisting of several mountains, is like the spring control of a safety valve on an engine, opening only when the internal lava pressure has passed a certain minimum. The internal pressure under the volcanic island may be thought of as accumulating at a steady rate through the ages. The island safety valve has two or three openings, Mauna Loa, Kilauea, and Hualalai, with a heavy shell over cracked blocks determined in weight by the accumulation of the ages. This weight accumulation is operating against the pressure accumulation. Once in eleven years the underground lava gradually and irresistibly forces itself up into cracks under the several openings and extends out along the rift belts that break up the mountains into blocks. How this hot matter grades down into a pudding having horizontal extension we do not know. There may be subordinate puddings under each volcano dome led up to by old cracks extending down into bigger and deeper puddings representing



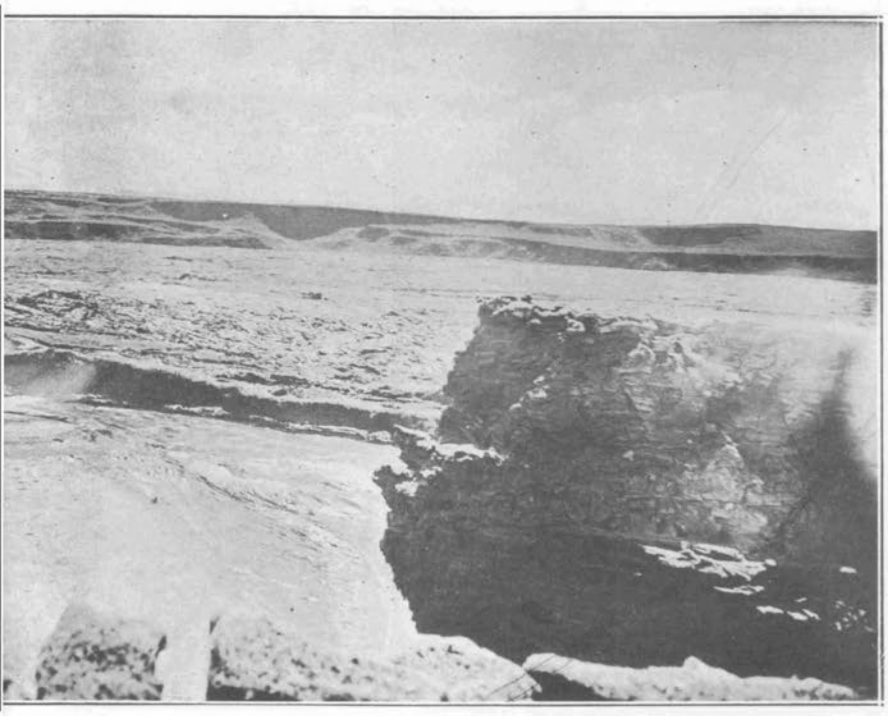
**May 10, 1919 looking NE. across main lava lake in Halemaumau from the top of t[h]
and indistinguishable. The photographer was thus standing on the top of the m[o]
right and left are live lava, wholly inside the pit. Central part of lava dom[e]**

ancestral domes. The height and size of the mountain puddings inside the island, and their supply of gas from the larger and deeper pudding, are what determines whether Mauna Loa or Kilauea shall erupt. If the weight control of Kilauea, the lower mountain, relative to its private pudding, is greater than that of Mauna Loa relative to its higher and larger internal pudding, it will be the higher mountain Mauna Loa which erupts. The yielding of each particular edifice relative to its internal lava expansion is what determines eruption. For the lava is not to be thought of as a rising liquid, but rather as a local expanding body of paste full of frothing gas.

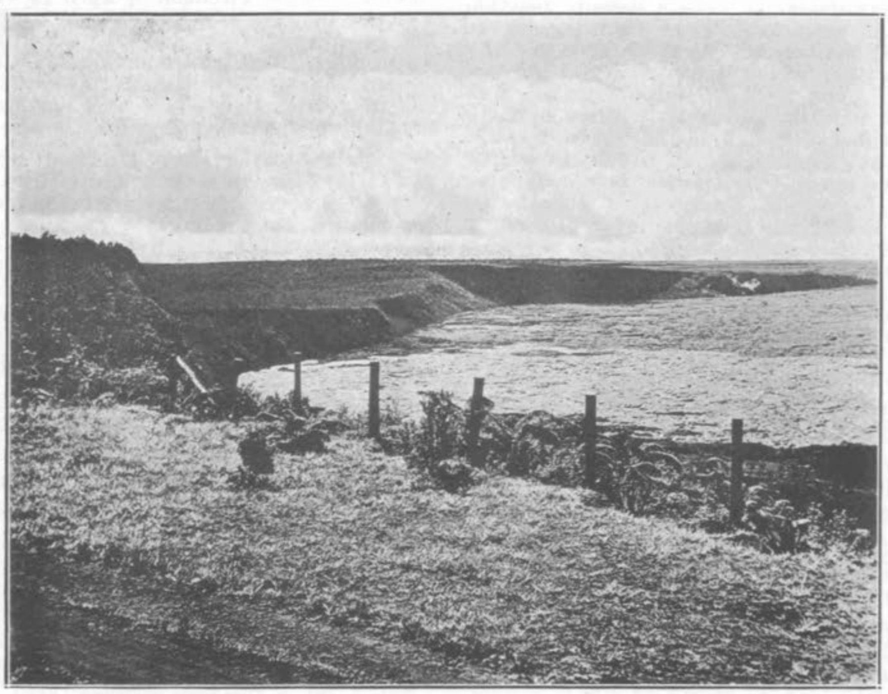
The yielding of the edifice needs clear definition. If a mountain block merely lifts on the flank of a pudding of underground slag, it does not weigh any less, and moreover solid basalt is heavier than pasty lava. Therefore what happens is an arching up or a tilting of blocks, and if new lava from below inserts itself into a mosaic of blocks up vertical cracks, it must spread the mountain apart horizontally. The eleven-year yielding is merely an average resultant of arching and tilting of blocks, swelling and penetrating of the lava, permission by the blocks to be pushed sidewise, slipping downward of those blocks which are on the slope toward the sea, breaking open of cracks at the surface to release pressure and start foaming in some parts of the lava, letting out of a large volume of paste, and re-assertion of weight to restrain the foaming by new flows on the upland or settling of crater fills. By "blocks" are here meant the big slices of mountain shell that lie between the important fault-rifts. These shells are miles wide and tens of miles long.

As there are big blocks of rock in this sense between the flow rifts of Kilauea and those of Mauna Loa which tip and squeeze the Kilauea pudding when Mauna Loa outflows come to an end, having lifted the shells and released the Halemaumau lava while the Mauna Loa flows were in action, it is easy to understand underground connection between the two volcanoes such as was described in the subsidences at Kilauea of 1914, 1916, and 1919 (Volcano Letter No. 324). Each of these sinkings came just at the end of a Mauna Loa flow period. Each Muna Loa flow period was accompanied by a gradual gushing of lava and rising in the Halemaumau pit of Kilauea.

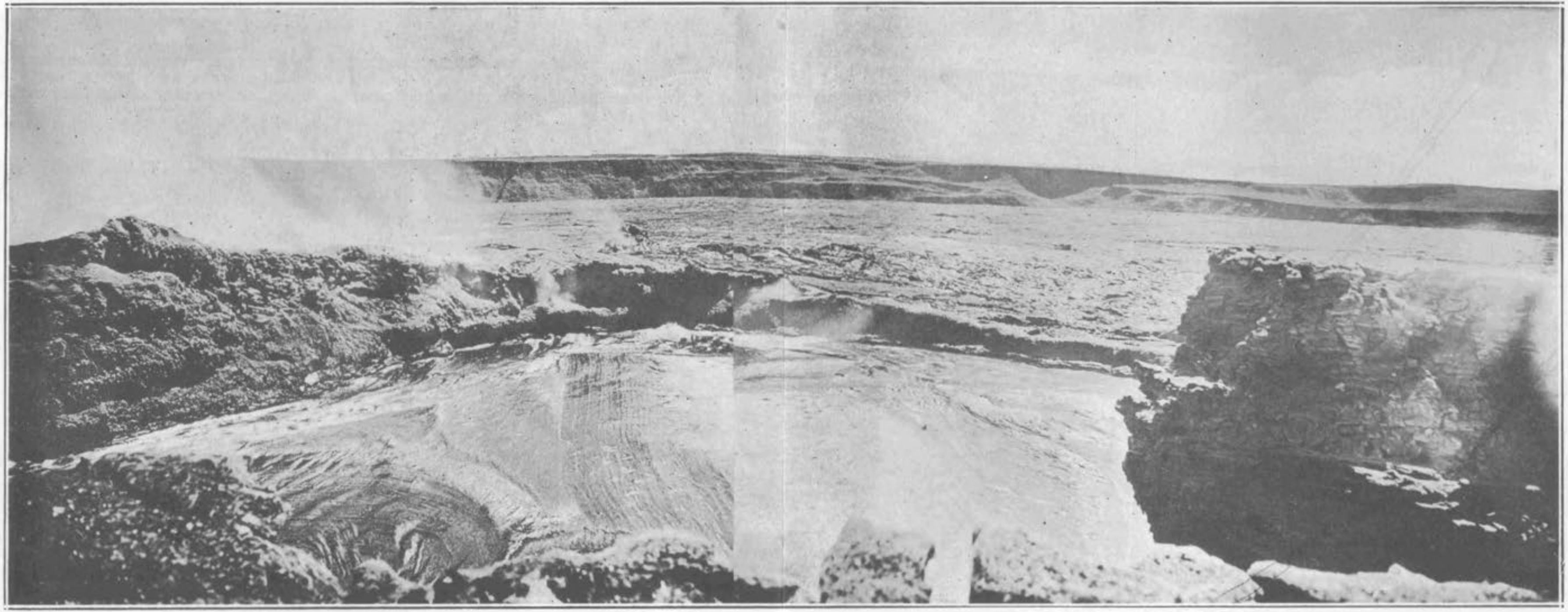
The peak of the volcanic cycle 1913-24, measured by internal pressure, was the intense gushing of lava over the Kilauea floor from Halemaumau pit, full to overflowing in October-November 1919. During this same time Mauna Loa was giving vent to the Alika flow. Throughout 1919 this flooding of the Kilauea Crater floor had been going on, with very slight ups and downs in the central pit, but from the very day when Mauna Loa broke out at the end of September, the Kilauea flooding increased. The process that led up to the nearly continuous overflowing of Halemaumau had been a very strong rising of lava in the pit at an increasingly rapid rate after the subsidence which had followed the 1916 outbreak of Mauna Loa. The year 1917 was intensely spectacular at Halemaumau, the observers could walk down on the lava floor surrounding the liquid lakes, and many experiments were made of taking temperature, collecting the gases, and sounding the slag pools with steel pipes. The year 1918 began a series of overflows of Halemaumau, first in one direction, then in another, from the lip of the pit, so that by 1919 the overflowing was virtually continuous. This all culminated in the Mauna Loa eruption of the autumn, which came to an end gradually, and at no very definite date, some time in November. It is impossible to name the day when such an eruption comes to an end, for the lava is flowing in tunnels beneath surface shells of hardened slag, the rift-source region is usually crusted over and may show glowing cracks for



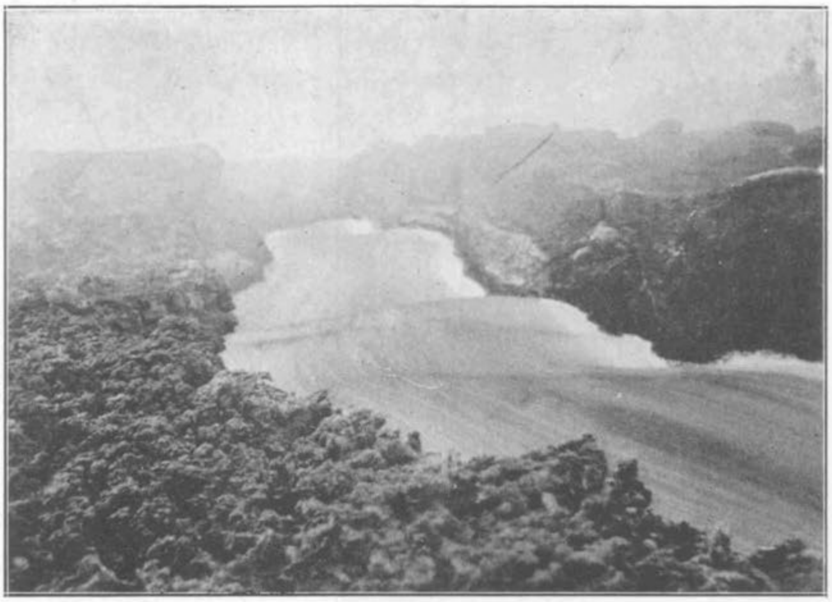
e dome of live lava, when the eastern edge of the pit was completely overflowed
ving lava column. Edge of pit underlies small cone in background. Benches
was at this time 87 feet above what had been hitherto the edge of the pit.



November 30, 1919 looking south from Observatory across Kilauea crater. The light colored nearer part of the crater floor is the fresh, then-glowing frontal portion of the live overflows from Halemaumau which had been pouring forth for seven months. The flows went west, north and bent east, filling the north corner of Kilauea crater 60 feet deep. Photos Jaggar.



May 10, 1919 looking NE. across main lava lake in Halemaumau from the top of the dome of live lava, when the eastern edge of the pit was completely overflowed and indistinguishable. The photographer was thus standing on the top of the moving lava column. Edge of pit underlies small cone in background. Benches right and left are live lava, wholly inside the pit. Central part of lava dome was at this time 87 feet above what had been hitherto the edge of the pit.



Middle stream of the Alika flow of 1919 early in October at road crossing in South Kona, showing the standing waves of rushing golden melt travelling eleven miles per hour. This stream was forty feet wide, within fields of consolidation of its own aa overflooding. These fields also moved, but very slowly. Mauna Loa flow, elevation 1570 feet above sealevel.

weeks, and there is no evidence left of any particularly sudden down-sinking at the source cone of the flow. Possibly some such reaction would be seen there if there were inhabitants.

At Kilauea, however, as has been often described in these pages, a remarkable, quiet, and sudden sinking 600 feet of the entire lava column in Halemaumau pit occurred November 28, 1919, as though it were a definite reaction from the Mauna Loa cessation. Then immediately the violently foaming Kilauea lava rose in the bottom of Halemaumau pit until in three weeks it was nearly at the top, then in three weeks more it had burst out in the Kau Desert southwest of Kilauea, and a long series of flank outflows of Kilauea began which lasted seven months. This, however, was not the end, for in 1920-21, December to March, there were again very intense overflowings of Halemaumau, after temporary reactions of subsidence. The March gushing of 1921 was accompanied by a flooding of the entire southern part of Kilauea Crater, so that one flow passed through a gap in the sand hills which bound the crater on that side. The fountaining was so violent that forty-pound blocks of crust were flung up into the whirlwinds over the fountains and dropped 300 feet away. Halemaumau was a surface saucer full of rushing, golden melt, building up a big spatter rampart at one side, with islands out in the middle. Then there came moderate subsidences, followed by the big ones of 1922 and 1924.

T.A.J.

KILAUEA REPORT No. 1004

WEEK ENDING APRIL 19, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

At Halemaumau pit in Kilauea Crater the only change observed on the forenoon of April 13 was that the sulphur spots on the new lava floor of 1930 seemed brighter yellow. The weather was dry and no steam was observed on the south talus. Dust from a slide rose at the pit at 3:30 p. m. April 13, and at 10:30 a. m. April 17 a fairly large avalanche fell from the middle of the wall above the northeast talus, sending up a thick cloud of dust.

A slight earthquake at 5:58 a. m. April 17 was strongly felt in the Volcano District and in Hilo, observed near the volcano as a slight preliminary bump followed in about two seconds by a stronger shaking occupying several seconds. This was sufficient to alarm a dog and in the region three miles toward Hilo from Kilauea the motion appeared to be northeastward. The Observatory seismograph indicated distance of origin 14 miles. Another feeble earthquake felt locally indicated distance of origin 23 miles, at 10:09 a. m. April 16. In all the Observatory instruments registered 26 local disturbances, of which six were very feeble seisms and 18 were tremors. A very feeble shock at 10:23 a. m. April 14 indicated origin distance 12 miles. Tilt for the week was slight WNW, and microseismic motion was slight.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 331—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | April 30, 1931

Northeastern corner of Halemaumau pit showing lava overflows, from northern and eastern sides of the lake, uniting to fill the wall-valley depression. Lava lake outside of picture at the left.

RISING OF PIT LAVA KILAUEA 1917

The first half of the cycle 1913-1924 was characterized by increasingly rapid rising. This showed itself by three, progressively more voluminous, lava ejections from Mauna Loa, and by a general rising of lava in Halemaumau pit, the inner well of Kilauea Crater. In order to understand the detail of the processes involved in the spectacular overflows of the inner lava lakes of Halemaumau pit, alternating with recessions of the lava from month to month, we here present a map and some photographs to exhibit the relation of the bench magma to the liquid lava. This is one of the hardest subjects for an outsider to understand.

The outline map of Halemaumau on Page Four has below it a true scale structure section showing what we saw and measured at the Observatory January 12, 1917, when with transit we went from one trig station to the next, as indicated by the little triangles around the rim of the pit. At the bottom of the structure section there is indicated a true scale extension downward of the pit profile as it was June 23, 1916, just after the liquid lava had come back vigorously, following the subsidence of June 5, which was described in Volcano Letter No. 324. The liquid lava at that time had filled a saucer in broken rocks, and then made its own spatter bench around the edges. The shape then of the liquid shown in black if we filled in the bottom would be that of the contents of a saucer, and as the lava was fed upward through small holes in the talus below, the only wells extending downward would be those holes, and everywhere else the liquid would be streaming over a hardened shell of its own glassy substance which had congealed against the cold broken rocks beneath it. The bench around the edges, then, was nothing more than the border expression of the hardened bottom lava.

What happened thereafter when the lava rose 500 feet filling the pit nearly to the top? The supply of liquid lava up the wells carries a certain amount of gas in vesicles which is reacting to keep it hot, but the air above, the sides of the pit, and its own congealed bottom lining are all tending to freeze the hot froth. The heat energy available can keep a saucerful liquid and streaming, the saucer in question being roughly of the size of the first pool. The rest that congeals under the pool is like the lava fields, that congeal on either side of a small medial stream, in a Mauna Loa flow. The congealing may be only partial so that this semicongealed substance is still mobile, and the upright wells are maintained through it. The rising then resolves itself into an uprush of the liquid froth through the wells, an overflow in pulsations of the liquid in the top saucer, and such additions of gas and heat to the under substance, as will cause it to swell or tumesce, under the hardened shells of overflow, that form the benches or platforms around the lava lake, or lakes.

If now we examine the map and section of January 1917, we see the main lava lake in black streaming from three coves at the west, and back of these, two source ponds, which are over wells. At the north, and at the south, there are overflow benches, the northern ones wide, and the southern ones narrow. There is a small wall pond at the south. There is a big crag-mass between the northwest pond and the lake which exhibited a tendency to rise gradually, as the tip of a northwestern sector of overflow shells. There is another such crag at the east, and a more complicated group of them making a peninsula, and southward tilted hills of uplifted overflow lava, at the southwest. At the southeast there is a line of big spatter grottoes along the edge of the lake, with inflowing liquid lava, as indicated by the white arrows. There is the same thing at the northeast. During subsidences these were revealed to be cascades into sinkhole wells, and the bottom of the lake of liquid was revealed to be a paste only 45 feet below the overflow bench.

This paste, under the shells of overflow, and under the crags created by the swelling up from day to day of the shells of overflow, is the substance spoken of as bench

Depressed northeastern floor of overflow in Halemaumau pit May 16, 1917, from north station, to be compared with elevated floor northwest shown on Page Three. These illustrate the balance whereby the weighted side of the floor goes down and the other side comes up creating a tabular crag of bench magma. The lava lake is in the fume at the right.

magma, and this semicongealed substance rises and falls from week to week as constituting the greater part of the lava column, apart from the mere wells, as shown in the section under the map. The depression of the lava at this time was 87 feet below the southeast trig station, and the bench marks (B.M.) east and north of the pit on the floor of Kilauea Crater stood at elevations 3,697 feet and 3,700 feet respectively above sea level.

The Journal of December 30, 1916, says: "The lava lake is a very different object from the elliptical pool of last June. It appears like a mighty river of fire amid hills and tilted crags, shaped in general like a "W." Roundish coves are bordered by high ramparts built up by overflow and by splashing fountains which have constructed huge domes, with glowing grottoes inside. Back of these ramparts, the overflow surface slopes back to the walls of the pit, so that the lake is really at the top of a low, flat, inner cone. Higher than these floors on three sides of the lake, but wholly within the pit, are craggy hills benched and fissured, which stand from 40 to 80 feet above the liquid lava."

"Other irregularities which add interest to the scene are high, flaming and puffing chimneys, outlying ponds of lava, and driblet cones built up over fissures in the floor. Following all the bends the lake is fully 1,800 feet long, with channels varying in width from 50 to 200 feet. The scene is magnificent from any side of the pit, and there is hardly any obstructing fume."

On April 6, 1917 we find the statement, "The rising of the crags is symmetrical about a central point in the pit, where the three arms of the lake lie at about 120° to each other. The sectors of bench, between these arms, are sinking around the circumference of the pit, and lifting their convergent points near the center. The marginal sinking is started by weight of the overflows, and increased by weight of debris fallen from the outer walls. As a result the south island peninsula, the crag-mass, and the east island are now all rising, and the floors are sinking. The inner bench confining the lake is therefore highest near the center of the pit. As usual the northwest and west ponds are the conduits of uprising liquid lava."

The beautiful symmetry of tumescence or swelling in the center, overflow of the lakes to weight down the wall valley around the edges, and up-tilting of the crag sectors to rise highest in the center, has appeared again and again, during the measurements conducted by the Observatory, so that the sectors of shell may be thought of as eternally overturning, away from the center of the pit. No solidified lava, except possibly light pumice, is capable of floating on liquid lava. The solidified crags, however, in some sense do float upon the bench magma paste beneath, or are of almost the same specific gravity, but this paste is not liquid lava. In addition to the circular symmetry, however, there would often develop a bilateral symmetry as shown on the map, whereby the three source wells are in the southwest half of the pit, and this southwest half was uplifted; whereas in general the northeast half was covered with overflows and tended to subside, except for the temporary east crag, which afterwards became overwhelmed and sank down.

The picture on Page One gives a clear idea of the northeast quadrant of the pit being filled by lava overflows from the lake in May 1917, the observation hut of the Observatory, and the old horse corral, showing in the background. This heavy flow is weighting down the wall valley, and tending to lift up the crag shown on the left-hand side of the photograph. If now we turn to the photographs on Pages Two and Three, we see a very striking illustration, on May 16, 1917, of a downweighted northeastern overflow bench (Page Two) which by a series of floods from the lake had subsided. This is looking from the north station straight southeast across the northeast overflow bench. The photograph on Page Three is looking from the same place straight southwest, across a new elevated northwest table crag, which for many days was in process of mass uplift. The following are Journal quotations from the history of this uplift.

"On May 12, 1917, the lakes had risen from 11 a. m. to 12:30 p. m., the main lake much faster than the southeast pool so that the northwest cove and the southwest shore were overflowing. The west cone was gushing incandescent lava and the crags had continued to rise. The tabular northwest crag was rising strongly while the north chasm was sinking. This was shown by a cracked ridge of fresh flow lava, lifted on the side of the crag, and though only two days old it showed a vertical displacement of about six feet from its original position. On May 25 the northwest table crag showed an extraordinary uplift of 15 feet since the previous day, carrying with it a bench of fresh flows around its base on the east and north. Instead of tilting, this tabular mass is rising bodily owing to inflow beneath it of pasty bench magma impelled by the weight of lava floods much larger than it in area in the lake basin itself and on the floors northeast and northwest. On May 28 a sudden readjustment of the bench magma was accompanied by a brilliant flare with opening of crevasses into which perhaps the lake magma flowed so as to lower it temporarily while the central crags were uplifted. The east crag rose bodily 10 feet, and the northwest tabular crag was now above the rim of the pit. The large cragmass rose so much with westward tilt that its northeast peak suddenly became its summit, whereas only that morning the middle peak had been the highest. The spatter markings along its base on the lake side were fully 40 feet high."

The northwest table here referred to, and shown on Page Three, occupied what in January was the north-northwest overflow bench, between lake and rim of pit (map Page Four). The photographs on Pages Two and Three were taken from the trig station, on north rim of pit, south of the letter "N". The balance between the rising crags and the weighted portions of the pit floor might be called "isostatic," but not because the crags are lighter. T.A.J.

KILAUEA REPORT No. 1005

WEEK ENDING APRIL 26, 1931

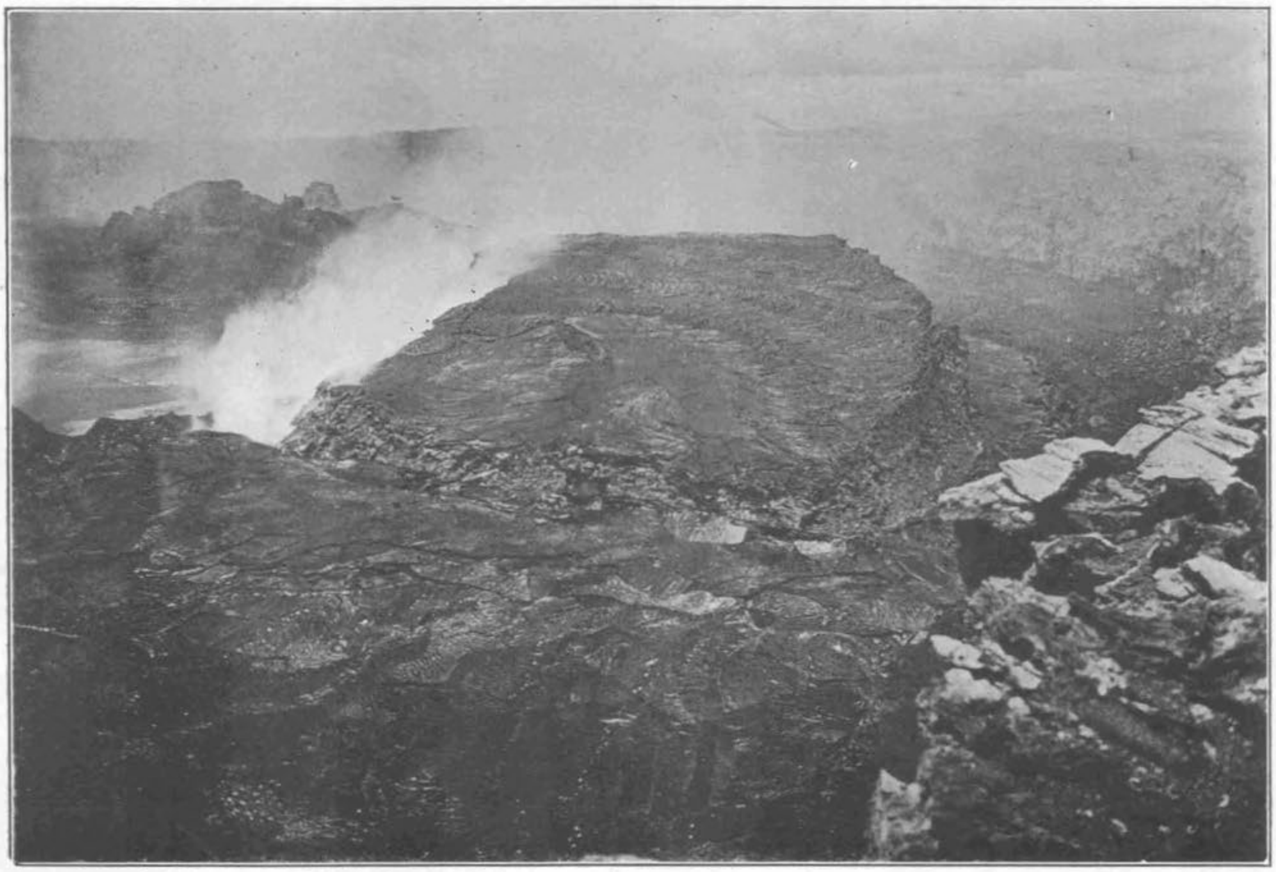
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Practically no changes have occurred at Halemaumau during the week ended at midnight April 26. Fume continues to escape steadily from the sulphur area north of the 1930 cone, which area is bright yellow. The instrument at the pit showed no volcanic tremors.

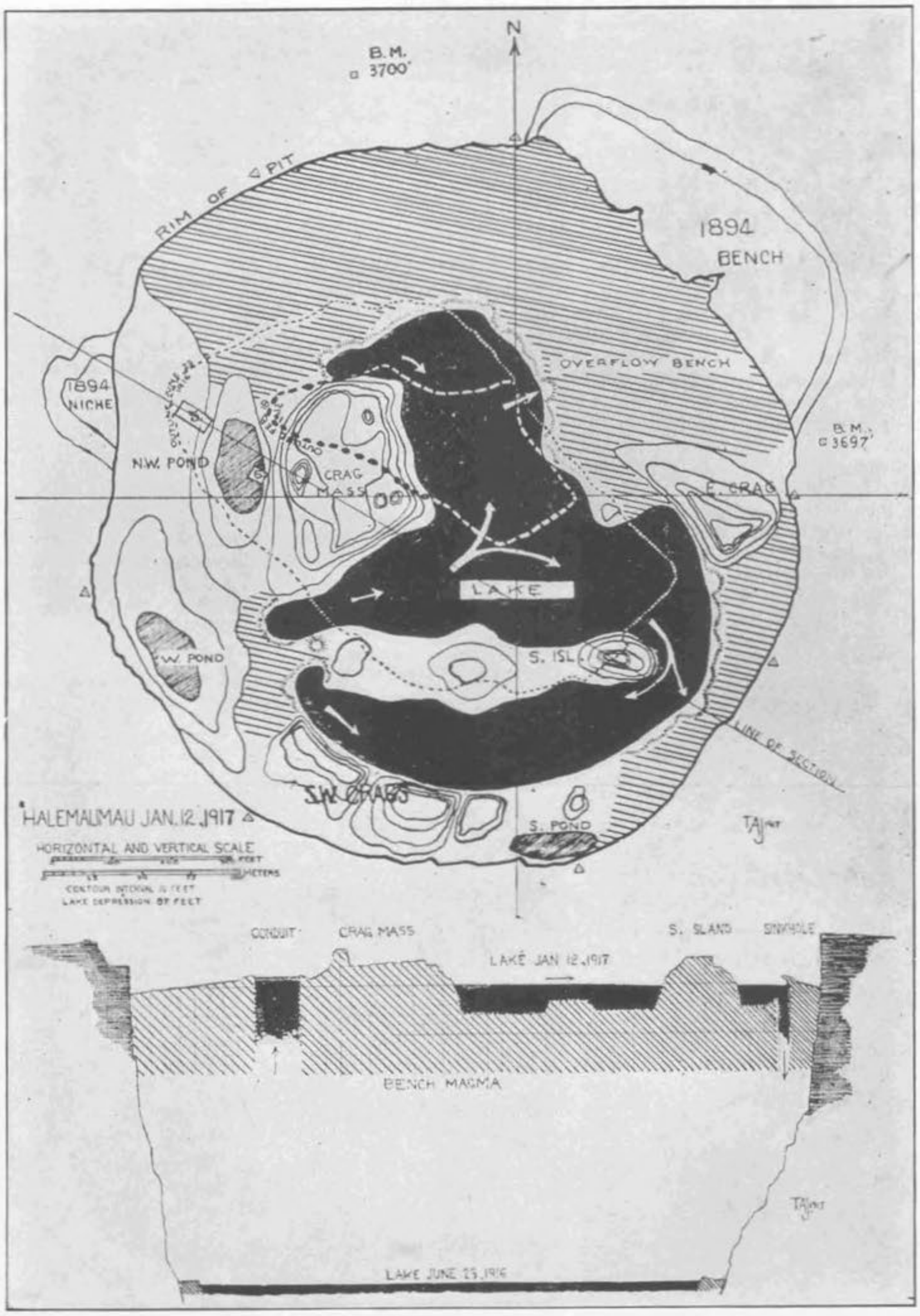
A total of 27 seismic disturbances were registered at the Observatory. Of this number were 23 brief tremors, three very feeble shocks, and one distant earthquake. The last recorded on April 24 for 10.5 minutes following 7:03 a. m. One of the very feeble shocks, at 11:25 p. m. April 25, indicated 25 miles distance to origin and was accompanied by tilt to the north; it was not reported felt.

Tilt was moderate WSW. Microseismic motion increased on April 21 from slight to moderate.



Elevated northwest table crag May 16, 1917, from north station, showing a block of bench magma in process of rising bodily by tumescence, or by the flowing in of paste beneath it, so that in two weeks its top was above the rim of the pit. This side of the floor rose, while the portion shown on Page Two was overflowed and subsided.

Photos Jaggar.



Plan and profile of Halemaumau pit January 12, 1917, when the great rise was in progress. Dotted outlines in map show progress of the rising and enlarging February 18, 1912, and June 23, 1916. Lower profile in section shows lake of June 23, 1916, in contrast to great development of bench magma, at higher level, six months later. Liquid lava black, source ponds shaded. Lake level 87 feet below southeast trig station. Crags with ten-foot contours.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of Volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

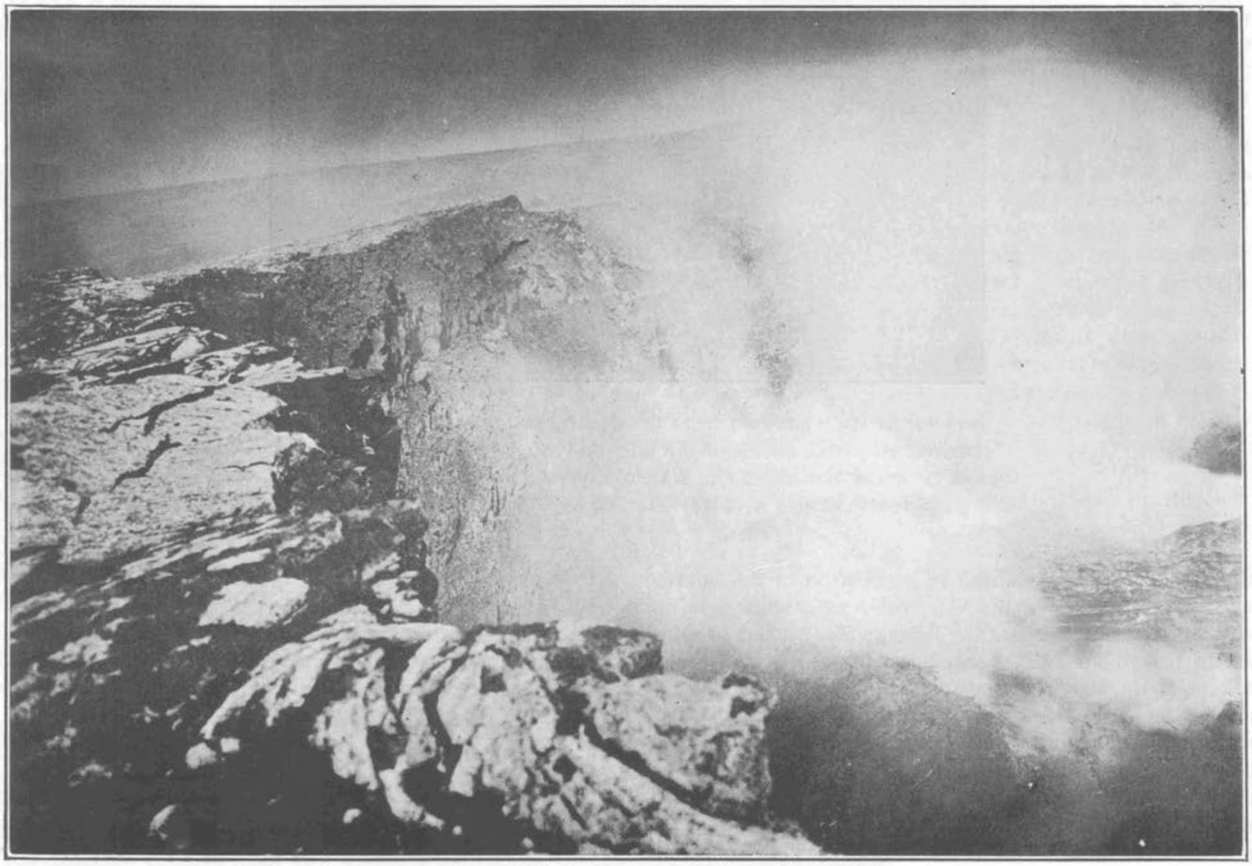
Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 332—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | May 7, 1931



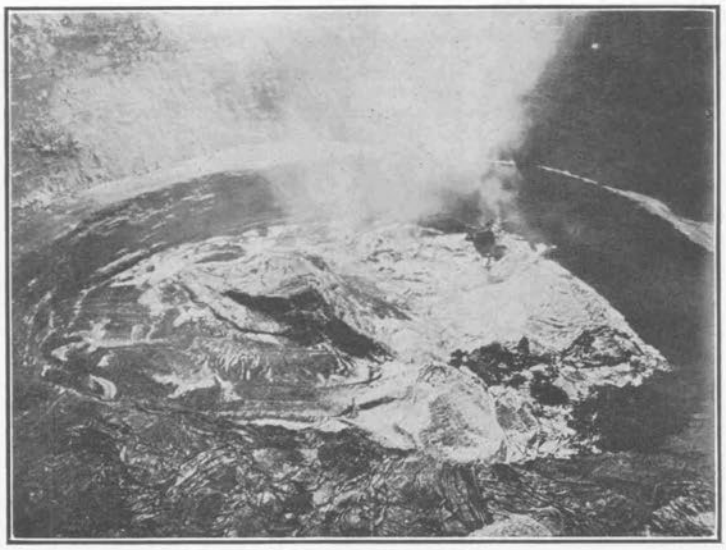
West rim of Halemaumau showing smoky conditions which were prevalent during the early years of the volcanic cycle 1913-1924. Taken from the south edge of the pit looking toward the region of the western source ponds, October 24, 1916.

BEGINNING OF THE VOLCANIC CYCLE

After reviewing twenty years of Hawaiian eruptions (Volcano Letters Nos. 319 and 320) and showing that the last cycle was 1913-24, we have recently described some details of this cycle, beginning at the end and going backwards. (Great Eruption 1924, No. 328, events preceding it, No. 329, Peak of Cycle, No. 330, rising of 1917, No. 331.) The beginning of the cycle was accompanied by two outbreaks of Mauna Loa in 1914 and 1916, and we have already described the remarkable subsidence of the latter year in Halemaumau (Volcano Letter No. 324). We have reason now in the cycle that began with influx of new lava in the bottom of Halemaumau July 1924, to make comparisons with the beginnings of the next preceding cycle. This might tell us something prophetic. But in doing so we must remember that 1913-24 ended with a gigantic collapse of about seven thousand million cubic feet of broken rock that fell down the Halemaumau shaft. This material is in the Halemaumau shaft now. No such fall of material occurred in 1913. At that time there was a solidified crust of live lava 600 feet down and the preceding cycle had been marked by slow risings with activity around the 300-foot level, and several sudden sinkings to depths not usually greater than 600 feet. Around the 300-foot depression level the lava column, therefore, of both bench lava and lake lava, was highly mobile, with an open shaft below into which it could sink. Now in 1931 the lava column 900 feet down is a pile of crusted layers, each not more than 60 feet thick, heaped up in five different years, and all comparatively stiff as a cake resting on top of the rock fill of 1924.

Such is the difference between the beginning of a new eleven-year cycle following the close of a supercycle, and the beginning of an eleven-year cycle which has many decades of mobility behind it. It is natural, therefore, that to some extent the years 1924-27 should be different in action from the years 1913-16. Both these periods, however, have been marked by gradual and somewhat intermittent rising of lava in the bottom of Halemaumau pit and by one or more outbreaks of frothy lava at the summit of Mauna Loa with eventual drainage in a Mauna Loa lava flow on the southwest flank of that mountain.

From May 1913 until just a year thereafter the lava lay 600 feet down in Halemaumau pit with great volumes of fume and steam making the bottom invisible. Slowly the lava rose in 1914, building spatter cones with glowing



Interior of Halemaumau from the southwest at 9 a. m. June 5, 1916, showing elliptical lake and the islands which on one occasion were seen to move horizontally. Depression of bench 253 feet, of lake 300 feet. Entire lava surface 780 by 675 feet in diameters.

trickles, the fume diminishing in proportion to the volume of lava fountaining. In the top crater of Mauna Loa big fountains burst out along a lengthwise north-and-south crack in November 1914, flooded the bottom of the crater and kept it up vigorously until the beginning of January 1915, the lava in Halemaumau meanwhile rising. There was no lateral outflow from Mauna Loa. When the summit activity of this big mountain ceased, Kilauea lava went down in Halemaumau 175 feet, but not very suddenly. This was the first of the occasions, that came under the observation of the Observatory, when in both rising and sinking, Kilauea showed sympathy with Mauna Loa.

The year 1915 produced a rising of lava in Halemaumau to a higher point than had been reached in 1914, and the peak of the rising in September was at the depression level 360 feet below rim of pit.

This September of 1915 produced a crisis of subsidence accompanied by many small earthquakes whereby the lava receded, the marginal bench cracked funnelwise and caved in, and the entire lava column lowered so as to leave a surging, liquid puddle in the bottom, destroying the integrity of the partially congealed saucer of bench magma. This saucer had consisted of four things: (1) The old slide-rock slopes of 1913, (2) the new liquid lava, (3) the overflow products of the lake, forming a bench, and (4) the partially congealed bottom material of the lake sometimes seen as shoals and islands. The measurements proved conclusively that these islands were part of the lake bottom and were not floating. The temperature of the liquid lava was proved quite incapable of melting the old slide-rock slopes of 1913. If we picture a cross-section of the top of the lava column at this time, we must imagine a stiff paste rising with the old talus breccia cemented in it, with a ring platform carried on its crest, the whole somewhat cylindrical in shape, and a shallow inside cup containing the lava lake fed by a well leading downward through the midst of the column of stiffer lava. Up the feeding well was coming the hot gas froth, which broke through the crust of the lake periodically about once a minute in what was known as "Old Faithful" fountain. This froth imported new fundamental magma from the depths, heated by gas reactions, and thereby this material was liquified and vesiculated to a fluid condition very different from the fundamental magma deep down under pressure, where it is presumably stiff, rigid, and heavy.

The September lowering was from depression 360 feet to depression 480 feet. The subsidence was like the one that had followed the Mauna Loa eruption in January of the preceding winter, but there was greater lowering in just such proportion as there had been greater clearing out of the throat below. The talus fragments had in a measure been appropriated as part of the bench magma column. This column had risen from a narrower throat below to a wider funnel above. Consequently with the uplift liquid lava occupies the ring channel and discharges through a border well into the upper saucer. By this process with every pronounced rising the throat is cleared bigger, and the pulsations of subsidence are permitted to go deeper. The lava entering loses its gas, becomes heavier and pours downward in some sinkhole wells, and the "Old Faithful" central well may reverse its flow and become a sinkhole at times.

The curve of rising and falling showed sudden drops in January of 1915, September 1915, and June 1916, each drop being bigger than the one preceding. As the first and the third of these followed the recession of lava into Mauna Loa after an outflow there, it appears altogether probable that the middle one of September stood for the same process. That is, lava rising into cracks under the center of the island, then escaping laterally by extending the cracks farther, thereby lowering its hydrostatic level, while Halemaumau as a gauge off to one side recorded the movement.

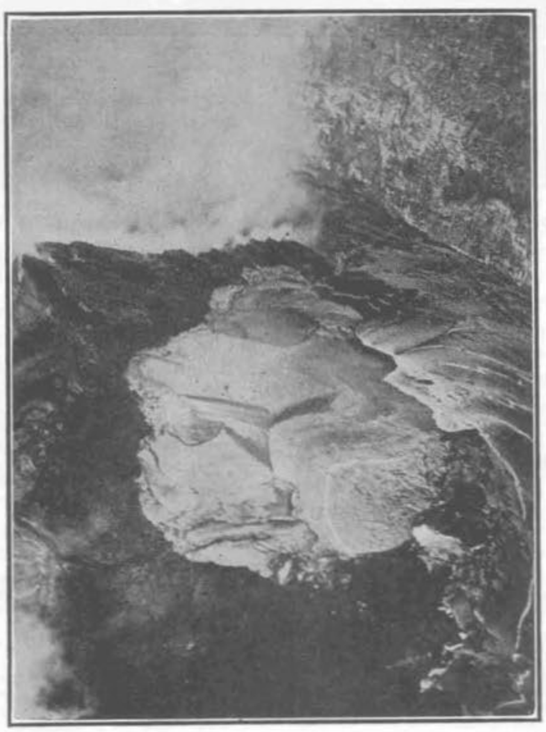
In early autumn of 1915 the circulation developed fiery cascades pouring into eastern coves and into a small outlying east pond connected by a tunnel with the main lake. At the west end was a source pond of rising lava, whence the lava streamed eastward to splashing border grottoes. Rising of liquid overflowed the floors around the lake after

October, and the floors as part of the fabric of the bench magma showed tendency to lift and tilt away from the lake while heavy floods weighted the margins of the floor so that the crags became escarpments with steep faces toward the center of the pit.

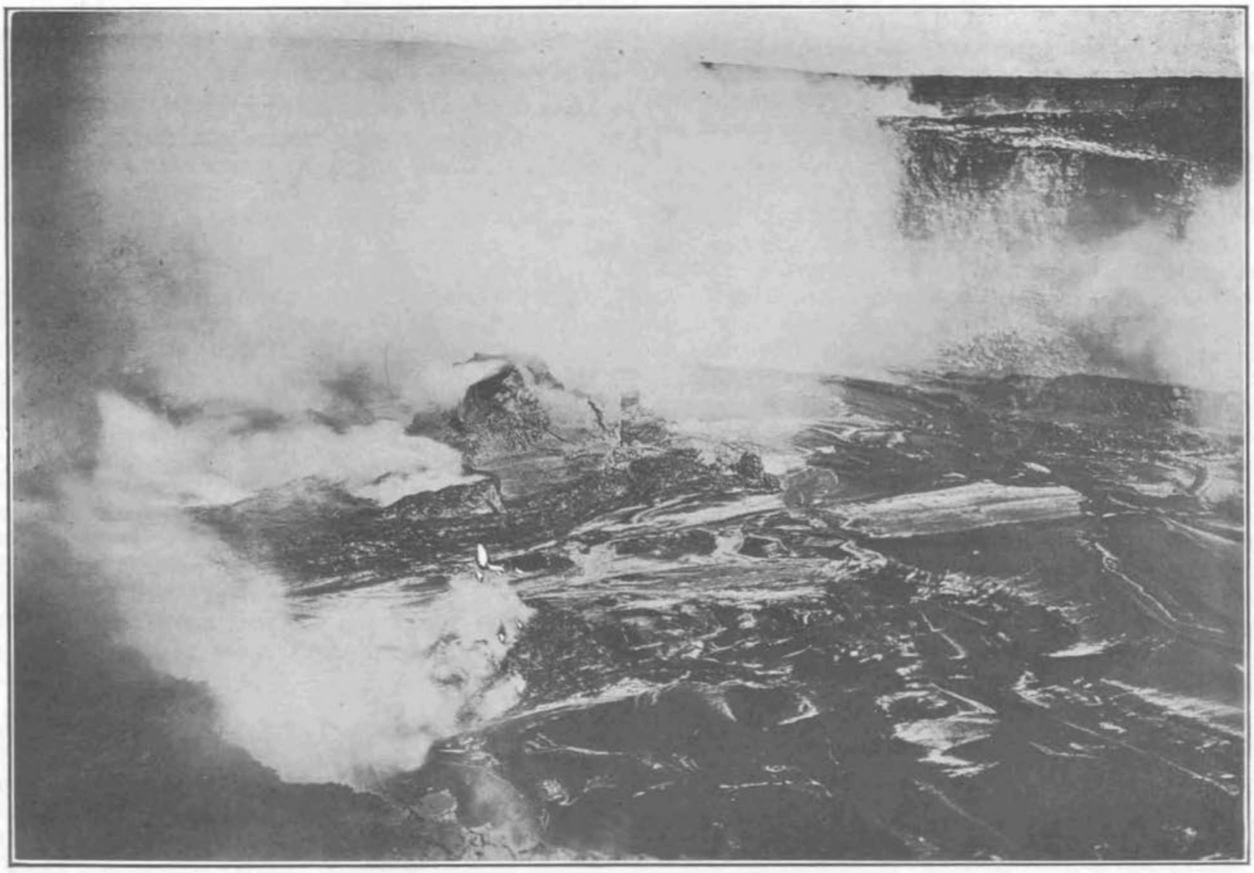
Watching the action of the upward pouring slag in Halemaumau pit in 1915-16 led to a fruitful conception to the effect that a lava lake in a pit is nothing more than what would be a flow if it were on a monutain side. In a pit, however, there comes about heat conservation and long preserved internal glow of the bench magma which is different from the overflow fields of the mountain flank. As the front can go nowhere, being confined in a pit, we get a side vent or well, several tunnels as crusts form, and an overturning circulation due to upflow of the light and gassy, downflow of the heavier gas-free fluid. The resemblance of the lake in 1915 to a lobate flow from west to east across the bottom of the pit was striking. The spring of 1916 developed tremendous overflows of the lake which poured between two broken halves of a crag seen gradually to split in two. The overflow on the bench duly became a pool with definite rounded shape in plan, until finally it appeared that the lake had changed its outline, and had developed a big extension. The temperature of the rising melt is not high enough to fuse the banks, but the gases and their reactions are what produce melting. When a mixture of gas and slag comes up rapidly, it enlarges the wells and lakes partly by gas-melting, partly by convectional erosion, and largely by determining the boundary change between two viscosities, that of the more liquid gas-charged lava, and that of the stiffer relatively gas-free paste.

From January to May 1916 the lava of Halemaumau rose rapidly so that the overflow of the floor, and the breakage of the bench magma column below developed in April a big S-shaped lake, then two crags became islands, and lastly the rising lake developed elliptical form around them. Finally the island crags exhibited horizontal movement, which is rare in Halemaumau. One of them migrated north bodily with rotation around its west point as a vertical axis. As the rate of rising was very rapid it seems probable that the island blocks of bench magma were undermined so as to execute a rotatory tilt, partially buoyed, and breaking away from a narrow stem. May 19 came the southwestern Mauna Loa eruption, and on June 5, after Mauna Loa ceased action, came the great subsidence in Halemaumau.

T.A.J.



The western source pond filling the wall valley under the northwestern cliff in Halemaumau August 23, 1916, after recovery from the great subsidence. This shows a typical source well and the process by which crags of bench magma were tilted up.



Halemaumau from the south-southwest when the lava bottom was 225 feet below rim, fume was diminishing, lava was flooding, and benches and crags were being elevated bodily around the lava lakes. Photos Jaggar.

KILAUEA REPORT No. 1006

WEEK ENDING MAY 3, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Conditions at Kilauea remain with little change. Fuming is steady at the yellow sulphur area north of the 1930 cone. A few falls of rock and dust from slides were noted at the north wall on April 27. On this date a southerly wind storm doing much damage in Kau District blew thick dust clouds from the desert over Kilauea Crater in the early forenoon.

Cracks paralleling the southeast rim of Halemaumau were measured on the 27th. Nearly all the marked points showed widening, the greatest being 1 7/16 inches at a place in the roped-off area near the tourist shelter.

A total of 39 seismic disturbances were recorded on the instruments at the Observatory, viz: 33 tremors, 4 very feeble seisms, and 2 feeble seisms, all local to the island of Hawaii. The greatest number of disturbances in one day was 11 on April 27. One very feeble shock at 12:18 p. m. April 28 was felt at the Observatory as a sudden jerk, the record indicating a close origin.

Tilt for the week was moderate SW. Microseismic motion was slight.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

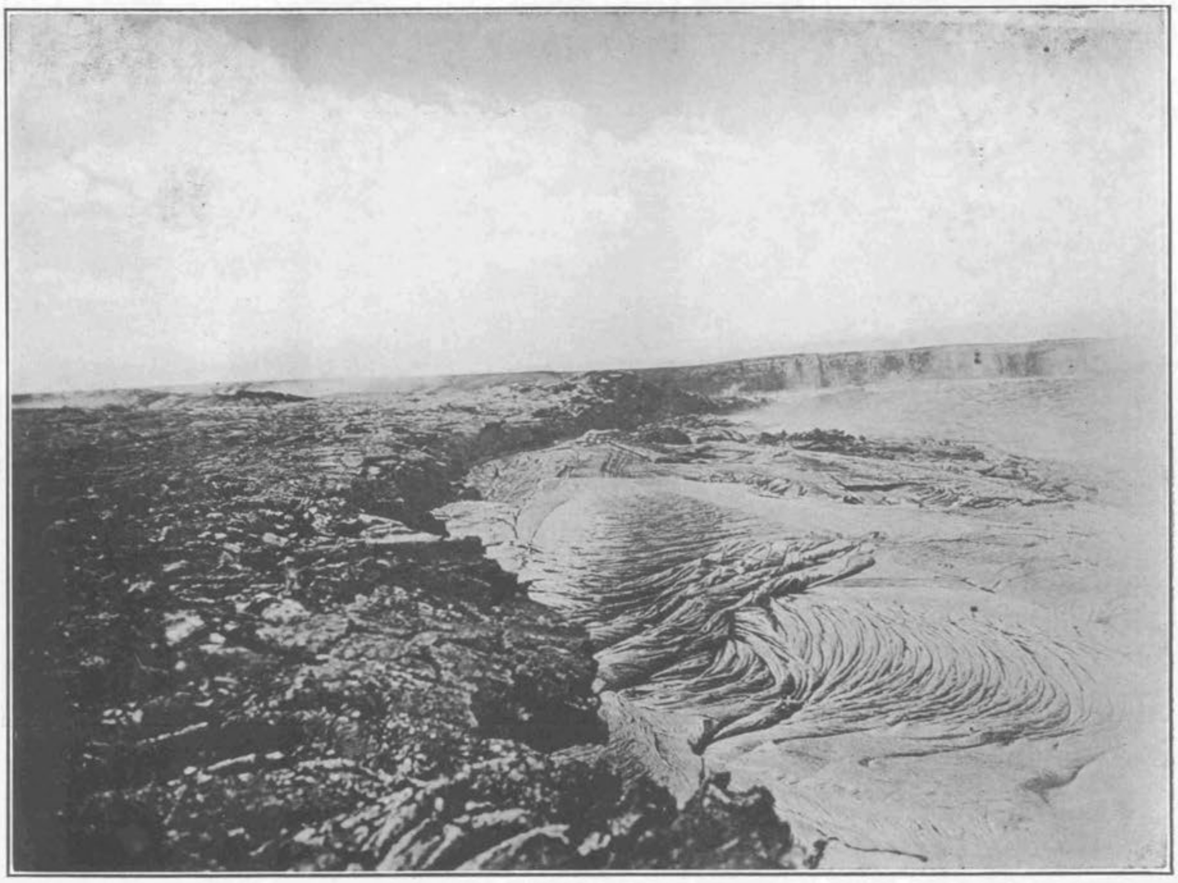
The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 333—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | May 14, 1931

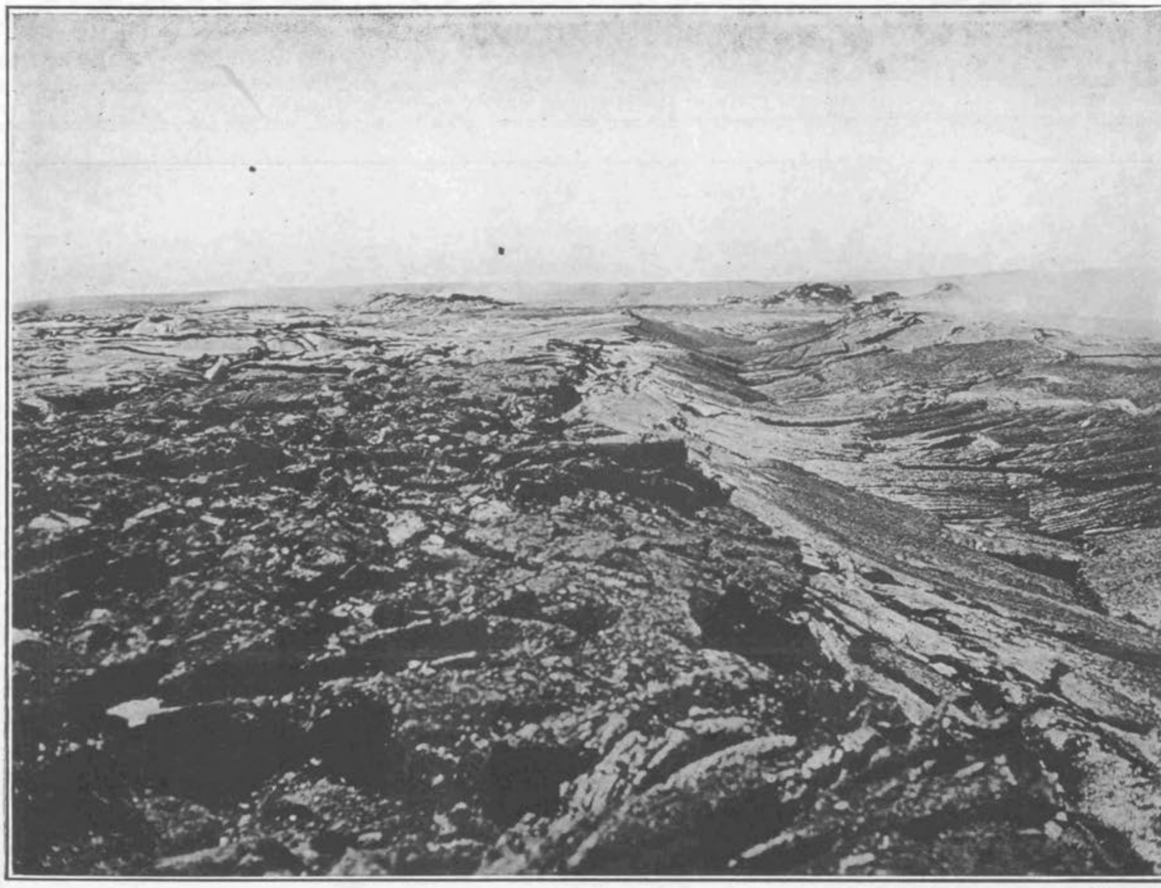


South rim of Halemaumau February 3, 1919, when it had begun to swell faintly, and on the right are seen live flows pouring along the wall crack from a small cone inside the pit. The live lava column of the pit is on the right. This margin of the pit was thrust up as the great pressure ridge February 25 and later.

HEAT AND UPLIFT AT KILAUEA 1919-21

In discussing the cycle of eleven years from 1913 to 1924, the story would be incomplete without a clear statement of the observed effects of increase of underground heat and the consequent uplift which was measured at the rim of the inner pit Halemaumau, and at the rim of the outer crater Kilauea. It is difficult for any one, who has not actually lived on the edge of such an active sink crater, to visualize as an actual fact the uplift of a mountain top by several feet in a few days. This is what truly happened at the edge of the pit Halemaumau when between February and May 1919, as shown in the sequence of pictures herewith, the liquid lava overflowed the rim of the pit, and a heaped tumescence from below swelled up the rim into a pressure ridge 15 to 20 feet high. And this was merely an index of what was happening on a larger scale to the whole inner floor of Kilauea Crater, and on a still larger scale to the whole top of the mountain outside of Kilauea Crater for a radius of 20 miles. (Tilt Records for Thirteen Years at the Hawaiian Volcano Observatory, by T. A. Jaggar and R. H. Finch, Bull. Seis. Soc. Amer. Mar. 1929.)

The swelling of volcanoes was reviewed in Volcano Letter No. 264, but it may be of interest here to summarize the facts about the top of Kilauea at the time of the peak of this active cycle. Leveling measurements of the summit in 1912, 1922, and 1926 showed that the top of the mountain rose two feet before 1922 and subsided from two to nine feet after 1922, the larger figure beiñg that of the inner crater floor. We have seen that seven thousand million cubic feet of rim rock fell into Halemaumau pit during the explosive eruption of 1924. Taking the leveling data and assuming symmetrical subsidence about Halemaumau as a center for the 1921-24 period, the volume of land withdrawn amounted to twenty thousand million cubic feet. This is nearly three times the amount engulfed in Halemaumau. The weight of such decrease of volume of the island above sea level would amount to one and one-quarter thousand million tons. Adding the volume of rock engulfed at the pit we would get a void space created inside the mountain when the lava withdrew of twenty-seven thousand million cubic feet. The down-warping was at a maximum about the crater and the form of the area lowered, with gradual decrease of lowering twenty miles out from the crater center, suggests a horizontal lens of lava evacuated under the shell of the mountain. The suggestion for



Same view as Page One five days later, February 8, 1919, showing the overflow which destroyed the trail, and the sagging crusts of new lava inside the pit on the right.

the whole period of rising and falling is that the dome of Kilauea behaved like a boil or pustule, filling and swelling during the first half of the cycle, and evacuating through an underground crack below sea level at the end.

Early in February 1919 the lava lakes of Halemaumau exhibited brimming and overflowing conditions, and a southern heap inside the pit overflowed the rim February 7 (see cut Page Two) so as to pour across country 400 feet damaging a trail at the road terminus. The liquid lava was rising and the bench magma was sinking. An earlier January overflow had abstracted weight from the top of the lava column and deep effervescence followed as in the overflow of a geyser pool. A northeastern slag heap next took its turn of building up 27 feet just inside the rim of Halemaumau and flows from it threatened the eastern stone tourist shelter. The last week of February produced mass swelling of the lava column, eruptions of standing fountains of melt, extended overflows on three sides, the lakes as well as the slag heaps contributed to the flows, and all the lakes stood as ring-shaped basins, six in number, above the rim level of the pit.

Mashing of the previous rim upward and outward next occurred at the southwest, south, and east, so as to make a pressure ridge from eight to fifteen feet high of what had been the rim before, illustrated by comparing the photograph of February 3 on Page One with that of May 6 on Page Three. The formation of this ridge, however, occurred within a few days at the end of February and the beginning of March. The ground begins to smoke and becomes stained around such a trig station as is shown as a white, circular concrete platform on Page Four. This same southeastern station and all the ground about it then rose and tilted back gradually but very rapidly in the course of a few days, so that it was sloping away from the center of the pit. The ridge formed was 20 feet wide in places, with an elephant's back curve on the side away from the pit. The three most used surveying stations were destroyed, and the net rise of the eastern side of the lava column inside of the pit at the same time was from 10 to 15 feet.

Moderate flowing during the first half of April 1919 gave place to mass swelling the third week of the month, ending in strong overflow that broke up the wall crack through the south pressure ridge, itself the edge of the pit, and this produced the longest and most liquid flow of 1919 to date. It covered the trail and reached the road terminus, and was the third flow of the year that had extended about a half mile from the Halemaumau center.

Within the year prior to February of 1919, Halemaumau had exhibited overflowing of its rim on eleven separate occasions and at nine different places Six of these extended more than 100 feet away from the pit, and of these the southeast flows of February-March 1918 had been the most extensive, reaching a half mile or more in length. Those of November 1918 came next in volume, and the flows of January-February 1919 tended to fill the gaps between the two earlier localities. August of 1918 had produced some driblet overflows at the north and southwest.

The appearance of Halemaumau in April 1919 was that of a smooth curved dome 1,200 feet across, rising from the base of what was left of the northwestern rim cliff of the pit. The swollen top of the lava column rose 50 feet above the general level of the former rim, and fell off abruptly as an escarpment 40 feet high on the southeast at the pressure ridge (see Page Three). Known landmarks on the pressure ridge measured in profile on a telescope scale from the Observatory two miles away, were seen to move horizontally easward within a few weeks. The old edge of the pit after being raised bodily was then mashed until it fell backward in a talus, and the upper part of the escarpment was now the cross-section of the inner live lava layers of the stiff lava column, where the pit floor had been lifted clear above what was left of the pit rim.

April 20, 1919, inaugurated a series of big flows from cracks in the Kilauea floor outside of Halemaumau at the north. These flows were destined to continue pouring across the northern part of the Kilauea floor throughout most of the year. They were called the Postal Rift flows because they originated at a hot crack where travelers formerly scorched postal cards. The swelling up of the rim of the pit was now extended around to the west and north, tilting the west station 4.5 degrees to the southwest, and the north bench mark 8.5 degrees to the north, so that it was lifted approximately eight feet in the course of a few days. This lifting up of old rim rock was accompanied by more or less heating and smoking of the cracks, and the outflow of liquid lava 800 feet back of the pit occurred without seismic disturbance, and was unquestionably connected through cracks with the same lava column that occupied Halemaumau. The Halemaumau lakes did not lower, but rose and increased their gas pressure while the tumescence of the inner bench magma lessened. The Postal Rift flow had advanced 1.4 miles across the Kilauea floor by April 25.

T.A.J.

KILAUEA REPORT No. 1007

WEEK ENDING MAY 10, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On May 6 in the forenoon at Halemaumau pit of Kilauea Volcano there was little fume that could be detected at the sulphur spots on the floor of the pit, and very little steam appeared at the south talus. The pit seismograph indicated a gradual tilt away from the pit until May 2 and thereafter motion in the opposite direction. On May 9 some newly fallen rocks were observed at the base of the north talus.

The Observatory seismographs registered 38 tremors

May 6, 1919, showing the same southern edge of Halemaumau as in the photographs on Pages One and Two, but now quite unrecognizable. Halemaumau had become a dome, the rim had become a pressure ridge, the former eastern stone shelter lay under the flows in the foreground, and the main lake was in a hollow at the top of the dome on the right. The trig station shown on Page Four was lifted up until it fell to pieces on the "elephant's back" shown here on the left.

Southeast trig station at rim of Halemaumau when the ground was beginning to be heated, fumed, and stained by tumescence, February 21, 1919. This within two weeks was lifted up and overturned backwards away from the pit on the pressure ridge shown at the left of cut on Page Three. Photo Jaggar.

during the week and a very feeble distant earthquake was recorded at 9:24 a. m. May 10. Tilting of the ground for the week was slight ENE, and microseismic motion was slight but increased somewhat May 4-5.

TILTING OF THE GROUND FOR APRIL

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the direction given.

April 6-12	0.3 seconds W.
April 13-19	1.3 seconds W.
April 20-26	2.5 seconds SW.
April 27-May 3	1.4 seconds SW.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

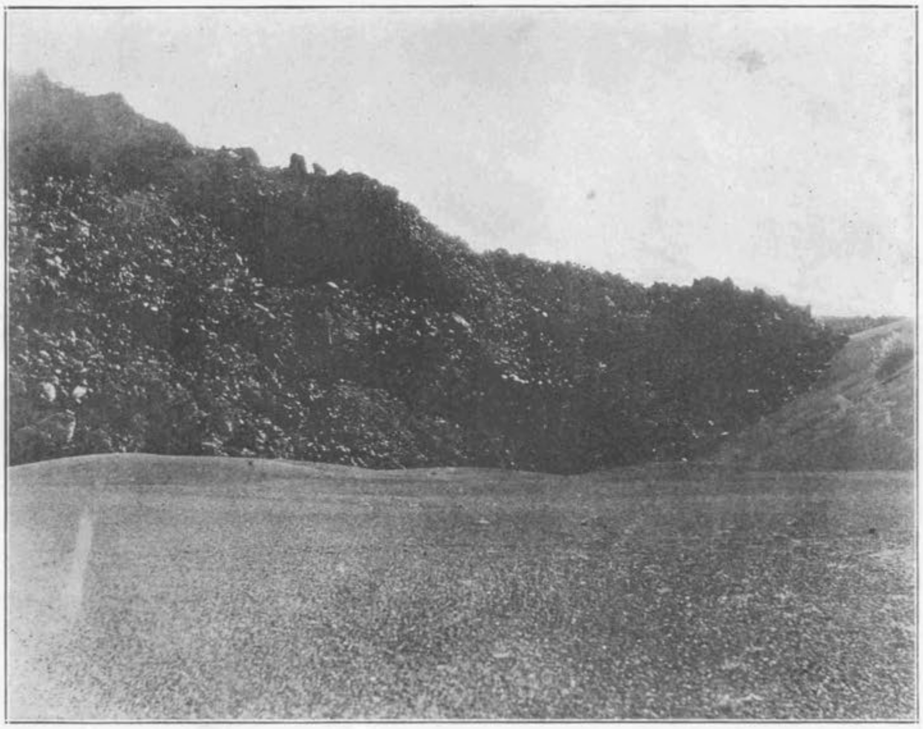
The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 334—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | May 21, 1931



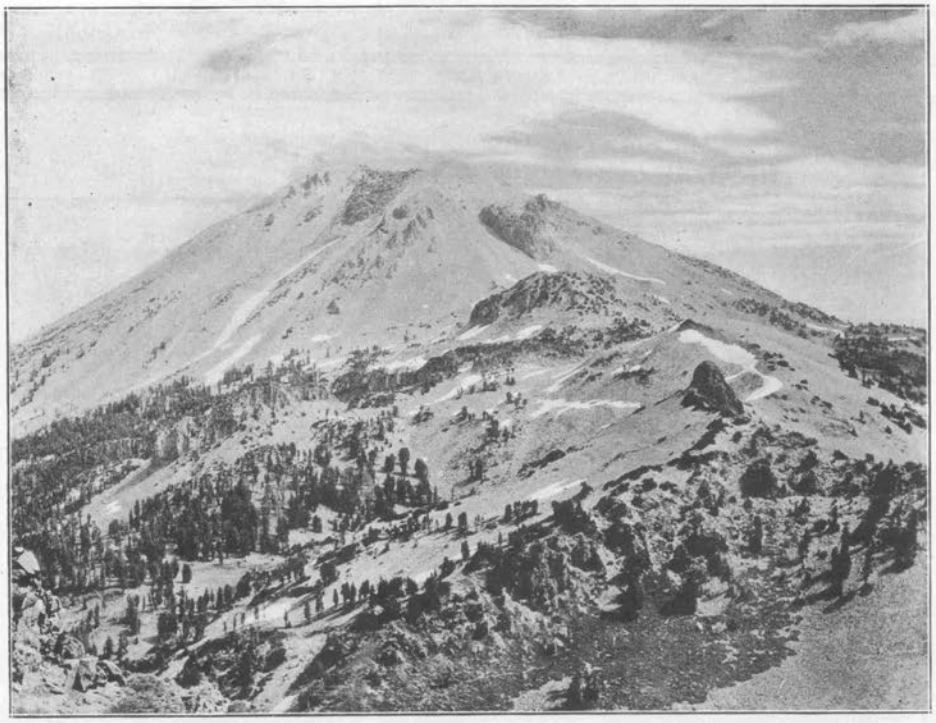
Edge of lava flow that poured out during the winter of 1850-51 at Cinder Cone, Lassen Volcanic National Park. Photo Finch.

THE YOUNGEST LAVA FLOW ON THE MAINLAND OF THE UNITED STATES

In the northwestern part of the United States there is a volcanic area covering about 25,000 square miles that extends from Lassen National Park, on the south, northeastward to Yellowstone National Park and northward to British Columbia. The eastern part of this volcanic area is the Columbia Plateau lava field, and the western part is the Cascade Range. In this range are Lassen Peak and other volcanoes that have been active in recent times. Mount Baker and Mount St. Helens were reported to have been smoking in 1843. Mount Rainier is said to have been feebly active in the nineteenth century, and steam still escapes from its summit crater. A volcanic eruption, possibly from Mount Shasta, was reported from a ship at sea in 1786. At the present time there are steam vents near the summit of Mount Shasta, 14,000 feet above sea level, so active that in a small area around them no snow can accumulate although a short distance away several glaciers have their sources.

In Arizona, New Mexico, and southern California there are very fresh-looking volcanic formations. The lava flow in the valley of the San Jose River in New Mexico is so fresh in appearance that it lends support to Indian traditions of a "river of fire" in this locality. Near Glass Mountain, in northern California, and at places in Oregon and Idaho, there are lava flows that appear to be less than 500 years old (Volcano Letter No. 292). At Cinder Cone, in Lassen National Park there are several recent lava flows, the latest of which (Page One) is believed to have poured out during the winter of 1850-51 (Volcano Letter No. 306).

It really was no surprise to those informed about the volcanic region of the northwestern United States when Lassen Peak became active in 1914. For a year the activity was largely confined to small explosions. Then during the night of May 19-20, 1915, Lassen produced the youngest lava flow on the mainland of the United States. The main crater was filled with new lava, and there were small overflows through low notches in the rim both to the east and to the west. The western branch of the flow is still in place, as shown on Page Two. Only remnants of the eastern branch of the flow remain, though there is good evidence pointing to the conclusion that it was the larger branch. Part of the eastern branch of the flow slid down the mountain shortly after it had been poured out, at the time of a mud flow during the same night. The photograph reproduced on Page Three, taken May 22, shows a remnant of the eastern flow, but most of this also slid down the steep mountain slope a few hours later. The most forcible explosion of the series took place during the after-



Lassen Peak from Mount Diller at the southwest August 27, 1927. The western branch of the youngest lava flow in the United States, produced in 1915, is the dark mass extending a short way down from the notch in the summit. Photo from Finch.

noon of May 22, 1915, after this photograph was made. Activity continued in varying degree until August 1917, but since then there have been no true volcanic eruptions of Lassen Peak.

Earthquakes that have their origin in the Lassen edifice are rather common as shown by the seismographs of the Lassen Volcano Observatory of the U. S. Geological Survey at Mineral, California. The fact that from 36 to 266 earthquakes are recorded each year at Mineral indicates that Lassen Peak is still somewhat uneasy.

Some references on Lassen Peak are as follows:

U. S. Geological Survey, Geologic Atlas, Lassen Peak folio (No. 15), by J. S. Diller, 1895.

The Volcanic activity and hot springs of Lassen Peak, by Arthur L. Day and E. T. Allen, Carnegie Institution of Washington, Publication 360, 1925.

Pictorial history of the Lassen Volcano, by B. F. Loomis, Anderson, California, Anderson Valley News Press, 1926.

The kingship of Mount Lassen, by Mrs. F. H. Colburn, San Francisco, Nemo Publishing Co.

The quartz basalt eruptions of Cinder Cone, by R. H. Finch and C. A. Anderson, Univ. Calif. Publ. Geol. Vol. 19, No. 10, 1930.

R.H.FINCH

HOT VOLCANISM OF NORTHWEST UNITED STATES AND CANADA

The article which precedes this is of great interest in presenting a newly discovered photograph (Page 3) by Mr. Loomis taken on May 22, 1915, at the same time as the one reproduced in Volcano Letters Nos. 266 and 304. The new one is different in showing the east side of the crater region of Lassen Volcano so clearly as to make it plain that the summit dark area is an unmistakable aa flow.

Lassen Volcano, therefore, produced in the end phases of its eruption May 19-20, 1915, stiff lava flows from its crater lips both east and west, and though the explosion of May 22 destroyed part of the eastern flow, fortunately Mr. Loomis was there in time to record its presence, and the remaining lava in the crater and on the west side was left in place to cool off where it may be seen today.

The history of the Cinder Cone and of Glass Mountain in that same volcanic district shows the area capable in recent times of pouring out extensive flows into the forest. It is still possible that within a few years activity may be renewed somewhere in northern California from the volcanic system represented by Lassen and Shasta, so as to pour out fresh lava flows. Mr. Finch shows how many places in the northwestern United States are active volcanoes with evidence of volcanic heat.

In addition to these places there may be mentioned the numerous hot springs of California thoroughly investigated by Waring (U. S. Geol. Surv., Water-Supply Paper No. 338, 1915), and some of these are boiling and accompanied by steam jets, as at Devil's Kitchen in Lassen Park shown on Page 4. Especially noteworthy is The Geysers canyon where steam is used for power north of San Francisco in the St. Helena range. Near Clear Lake there are old volcanoes, and there are boiling waters at Calistoga, and at the Little Geysers, and fumaroles at the sulphur bank, which is near to The Geysers. At The Geysers there is super-heated steam and volcanic gases, pointing to a magmatic origin (Steam Wells at The Geysers, California, by E. T. Allen and Athur L. Day, Publication 378 Carnegie Institution, 1927). This can only mean excessively hot gas-charged magma under the Coast Range close to San Francisco and not far from the center of the earthquake of 1906.

In addition to the abundant volcanoes of the Sierra Nevada and the Cascade Range from Lassen Peak to Mount Baker in Washington, Professor R. W. Brock (Proc. Third Pan-Pac. Sci. Cong. Tokyo 1926, Volcanoes of the Canadian Cordillers, p. 688) reports the discovery in 1909 of volcanic cones and lava flows 40 miles north of Vancouver, and also hot springs, marking an extension northward into Canada of the active volcanoes of the United States. The volcano Garibaldi is a cone rising 3,500 feet above the plateau to a total elevation of 8,700 feet, made up of cinders with some interbedded lava streams. In the Lillooet District there is andesitic pumice covering 1,500 square miles. On Naas River in British Columbia there is a lava flow consisting of olivine basalt, 20 miles long, and said by the Indians to be less than 200 years old. It dammed a river forming what is called Lava Lake, and there are explosion cones five in number, the description of which closely resembles that of Cinder Cone at Lassen. On the Unuk River there are other recent lava flows and vents so fresh that the volcanic ash can still be seen as black patches on the glaciers. Craters and flows on Ruby Creek in the extreme north of British Columbia, vast deposits of volcanic ash on the Yukon plateau, a volcanic cone north of the Pelly River, and some other places, lead Brock to the statement, "Complete exploration may show as much recent volcanic activity in western Canada as in most sections of the Pacific volcanic girdle."

T.A.J.

DEATH OF PRESIDENT THURSTON

The editor records with the utmost grief the death on May 11, 1931, of the Honorable Lorrin Andrews Thurston, President of the Association, in Honolulu.

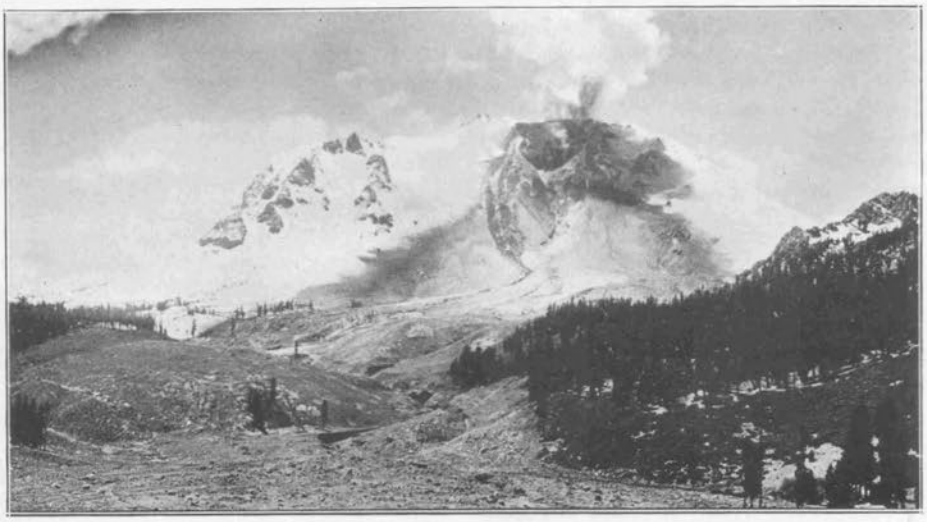
KILAUEA REPORT No. 1008

WEEK ENDING MAY 17, 1931

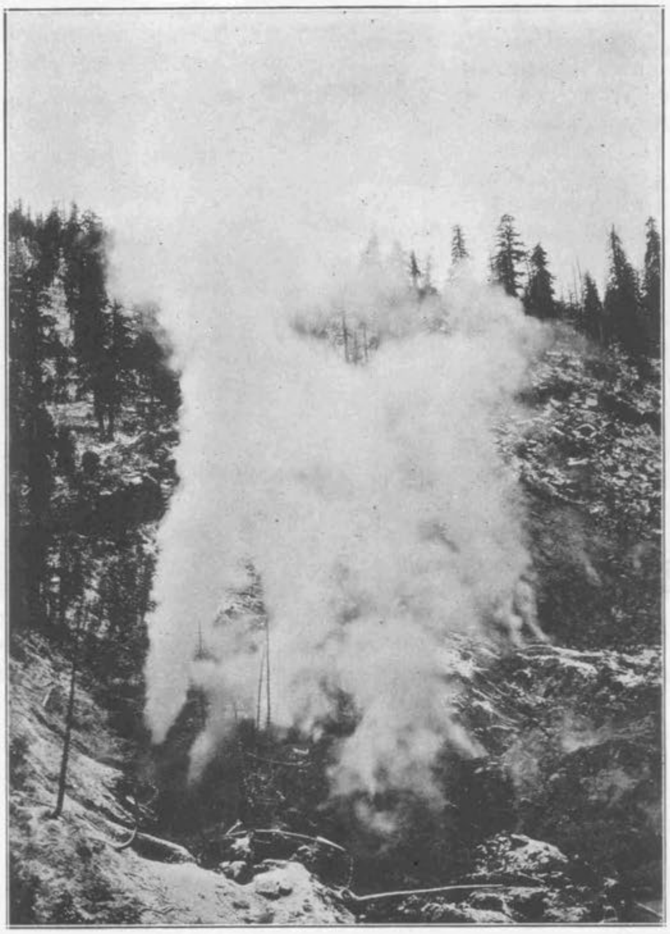
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Volcanic conditions are very quiet at the Hawaiian volcanoes and at Kilauea the only seismic movements of any consequence are very slight tremors. At Halemaumau pit on the inner floor of Kilauea Crater a visit at 10 a. m. May 14 showed everything quiet about the bottom lava of 1930, no steam was visible at any vents, and a little fume was infrequently detected at a yellow sulphur spot near the middle. One or two rocks were heard falling at the northeastern and northern walls of the pit. The same conditions were noted at 9:15 a. m. May 16, and a small slide occurred at the north wall at 9:25 a. m.

Twenty-eight tremors were registered on the Observatory seismograph during the week ending midnight May 17, and one very feeble local seism at 4:41 p. m. May 13. Tilting of the ground accumulated slightly SW, and microseismic motion was slight.



Lassen Peak from the northeast May 22, 1915. The dark area under the steam cloud is a part of the eastern branch of the lava flow that came out during the night of May 19-20, 1915. Photo B. F. Loomis.



Steam escaping with velocity in Devil's Kitchen, Lassen National Park, November 14, 1930. During the summer the seat of the principal vent was a boiling pool of water ten feet in diameter. The steam was above the boiling point for that elevation. A cold, disagreeable rain was always falling under the vapor cloud. Photo from Finch.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 335—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | May 28, 1931

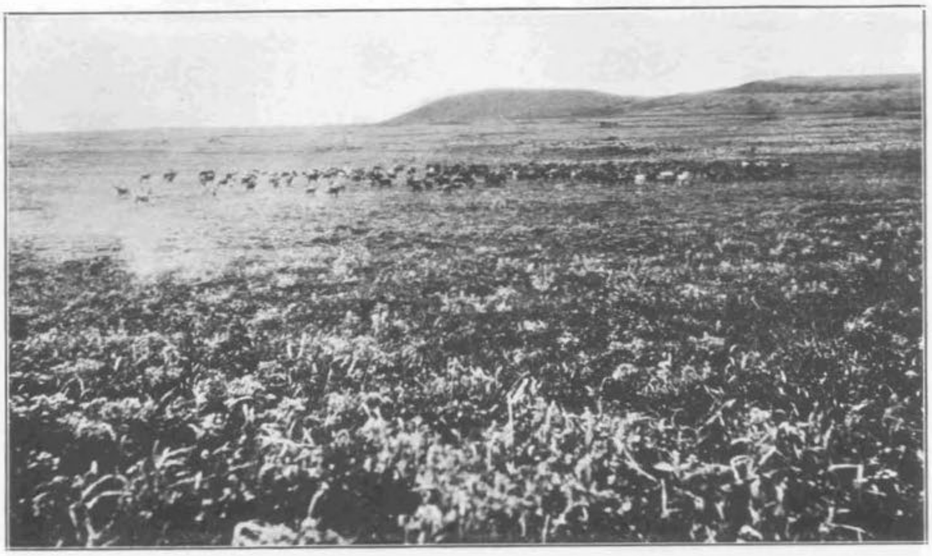
South end of St. Paul Island in the Pribilofs showing Gorbat rookery and Reef Point rookery with Otter Island in the extreme distance and St. Paul village beside the salt lagoon on the right. Photo Rauch.

ST. PAUL ISLAND IN THE PRIBILOF GROUP

During the writer's visit to the Aleutian Islands in 1917 he had the privilege of meeting Mr. William P. Rauch who kindly gave him specimens he had collected on St. Paul Island, the larger northwestern member of the seal islands, or the Pribilofs, where the fur seals are protected by the United States. St. Paul lies 200 miles north-northwest from Unalaska Island in the Bering Sea, and off the line of the Aleutian Islands. Mr. Rauch took photographs, some of which are reproduced herewith. The rocks of the Pribilof Islands have recently been described by Washington and Keyes (American Journal of Science, November, 1930). One of the pebbles collected by Mr. Rauch is described by these authors as hyalobasanite, a basaltic lava which would have contained much nephelite if the lava had been completely crystallized. This rock also contains olivine. Other specimens are ordinary fine-grained basalt.

Mr. Rauch writes: "I obtained a small piece of sedimentary rock containing shells, and have turned it over to Dr. P. S. Smith, Alaskan Branch, U. S. Geological Survey. This sedimentary rock was some ten to twelve feet above high tide, embedded in the perpendicular cliff just to the right of what is known as East Landing on St. Paul Island. I should judge that weathering and heavy seas had exposed it. The whole island gives one the impression of a sort of volcanic fairyland so many diminutive volcanic cones and craters, so small, and so different."

Black Bluff, a sea-dissected cone on the eastern coast, contains tuff with rounded, calcareous, or marly clay fragments with fossil shells of post-Pliocene age and of species now living including walrus bones. There is no glaciation. The island is volcanic and according to Stanley-Brown (Bul. Geol. Soc. Amer., Vol. 3, 1892, p. 496) was built up after the Tertiary with outpouring of lava from a central vent in a submarine eruption. "Its surface is diversified by at least a dozen cones and vents of unusual symmetry, surrounding in irregular fashion a true crater dome some 600 feet in height called 'Bogoslof' " (not to be confused with Bogoslof, the active volcano near Unalaska). Washington and Keyes say, "The island of St. Paul, the largest of the Pribilofs, has a greatest length of about 13 miles between its northeast and southwest points, and widths of from 6 to 8 miles. Its area is about 33 square miles. In its early stages it may have consisted of a group of 10 or 12 small islands, now joined together. The lava flows gradually built up the basement floor of the island, and these were vesicular basalt rich in olivine. There followed from the central vent great flows of basalt, with others from smaller cones, all together constituting an overlying sheet. It is more crystalline than the basement lava. The marked contact of the two sheets is near sea level. There are thin, unbroken lava domes" and small spatter heaps. No andesitic nor trachytic lavas are present and tuffs are rare. An analysis of the nephelite basanite by Washington and



Reindeer herd on St. Paul Island, looking southwest on the south side of the island in the region north of the salt lagoon. Photo Rauch.

Keyes shows a composition rich in iron, titanium, magnesia, lime, and the alkalies, with 44 per cent of silica.

St. George Island, about 40 miles southeast of St. Paul, reaches a height of a thousand feet, is bordered by bluffs, has a basement of dark basalt, and contains many breccias and tuffs as well as some non-basaltic lava. There is andesitic ash and possibly trachyte occurs.

As to activity in recent times, flames are said to have been seen to rise from the sea northeast of the Pribilof Islands, and a submarine eruption is recorded for 1815 northeast of St. George, where there are small circular shoals at depths of from three to eight fathoms. Out in the middle of Bering Sea Pinnacle Islet five miles south of St. Matthew Island, was cited by Elliott as having been in an almost constant state of activity since its discovery, and as being active at the time he was there in 1874. This author also thought Otter Island, a small rock southwest of St. Paul (faintly visible in the distance in the photograph reproduced on Page One), had been recently active. All of these facts are culled from Washington and Keyes.

Mr. Rauch made the accompanying sketch map on Page Four to express roughly the position of his photographs. The map should be turned so as to make the long right-hand point turned northeast, and not east. St. Paul village is thus at the south end of the island, Rush Hill 665 feet high is the highest point on the island at the west end, and the principal anchorage is in English Bay west of the village. The photograph on Page One shows Reef Point which projects south of the village, on the right are seen the village houses, and in front of them is the salt lagoon bordered by tundra flats. The entire island is grassy, without shrubs or trees, and the same is true of the Aleutian Islands. A considerable herd of reindeer is maintained on the island as shown on Page Two. There are two fur seal rookeries on the two points near the village, and on the lowland bars of the northeast point there is the largest seal rookery ground. Formerly a drum tractor was used for hauling the pelts across the island, now there is a wire cableway.

Looking into the interior of St. Paul Island from the village northward, one sees flat, grassy, rolling country with the salt lagoon in the foreground and four or five cones beyond, of which Bogoslof is the most dome-like. Standing on the top of Bogoslof and looking westward we see six or seven cones with marked tendency to horseshoe shape, the opening of the horseshoe generally facing toward the north as though the prevailing wind tended to build the higher heapings of the lava fountains toward the south. This is the scene photographed on Page Three. From this elevated point the expanse of flat tundra to the northeast covers about one-seventh of the island, all very slightly elevated above the sea. A large triangular lake of brackish water is inclosed by two bars which have shut off the lake by connecting an outlying islet with the main island at the northeast point. Such ponds are common partly as fresh water crater lakes and also as longshore lagoons as shown on the map by L. The letter V on the map indicates volcanic hills and craters. Looking southward from the summit of Bogoslof one sees a broad slope leading down to the southwestern embayments, all grassland over lava, with small lava pits in the foreground, the topography suggesting the pahoehoe of Hawaii. The lava conelets of the Pribilofs are much more Hawaiian in quality than the eastern islands of the Aleutians, but in some of the western Aleutian islands there are wide lava flats greatly resembling the photographs of St. Paul.

With reference to the opening northward of the horseshoe cones and the sweep from northeast to southwest of the barrier beaches that trail to the main island from the northeast point, it seems probable that the constructional action of the sea has been from northeast to southwest with the prevailing winds, thus smoothing the northern and southeastern shores, and leaving bays at the southwest. As there are three distinct embayments and two of them fairly deep on that side, it may well be that the volcanic tumescence which accompanied the outpouring of lavas had a tendency to uplift at the northeast and some drowning of topographic depressions at the southwest. The salt lagoon next north of the village, and the topography of the three bays adjacent to it, suggest drowned valleys among lava-flow ridges. T.A.J.

KILAUEA REPORT No. 1C09

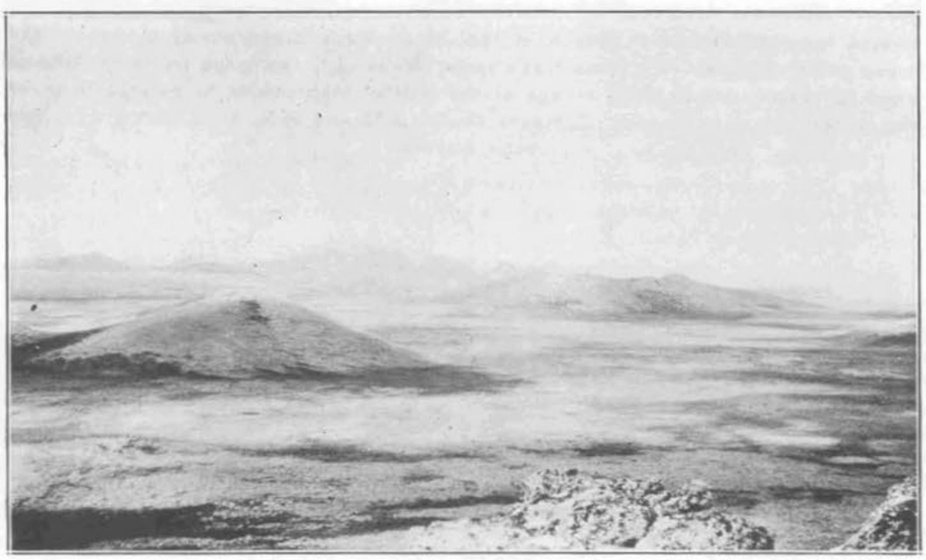
WEEK ENDING MAY 24, 1931

Section of Volcanology, U. S. Geological Survey

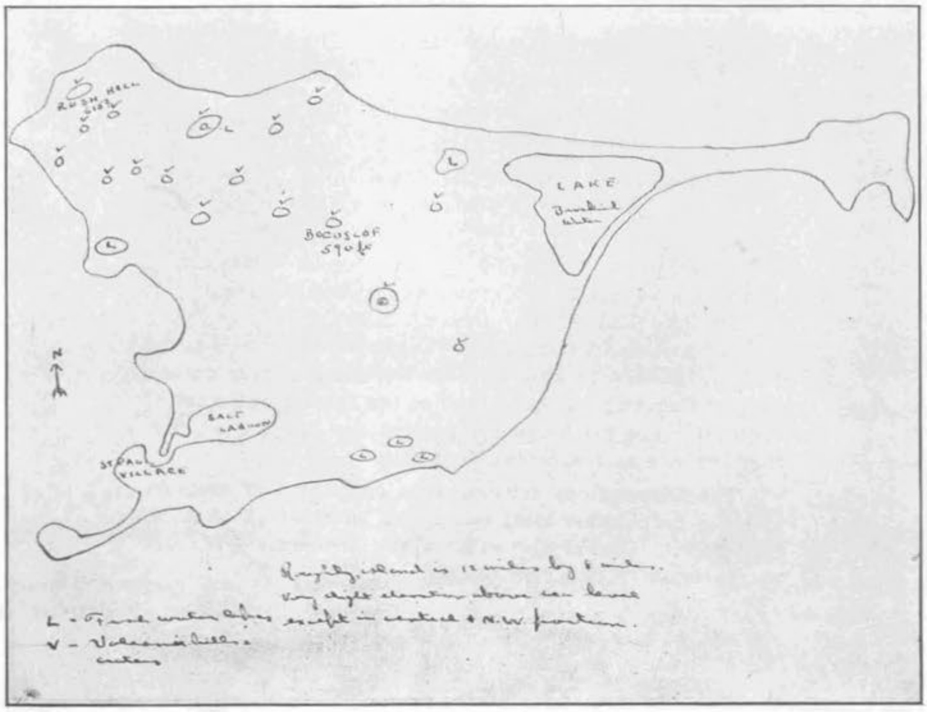
T. A. Jaggar, Volcanologist in Charge

At Halemaumau pit of Kilauea Crater a slide occurred on the northwest wall about 9 a. m. May 18 sending up a dust cloud. At 10:30 a. m. fume at the larger sulphur spot on the floor had slightly increased, but there was very little vapor rising from the wet area of the south talus. The avalanche was seen to have left a slight scar on the wall. Other sulphur spots besides the fuming one west of the center are bright yellow against the black floor, particularly one at the far western side.

The Observatory seismographs registered 25 tremors and one very feeble local seism, the latter at 12:18 p. m. May 23. Tilting of the ground was moderate SW, and microseismic motion very slight.



Photograph taken in July 1927 from the summit of Bogoslof hill in the middle of St. Paul Island looking westward toward Rush Hill in the extreme distance, that being the highest point of the island. At the right is shown a horseshoe cone resembling Diamond Head at Honolulu. Photo Rauch.



Sketch map by William P. Rauch in 1927 at St. Paul Island showing roughly the many volcanic cones (V), little fresh water lakes (L), the large northern lake of brackish water, and St. Paul village at the south. Map should be rotated to make the eastern point northeast. Compare charts 8802 and 8995, U. S. Coast and Geodetic Survey.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 336—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | June 4, 1931

Pumice Stone Mountain, west of Medicine Lake, California, seen from the south. The white pumice closely resembles snow. Photographed July 13, 1930.

LASSEN REPORT No. 29

SOME WORK OF THE LASSEN VOLCANO OBSERVATORY 1930

R. H. Finch, Associate Volcanologist.

Mount Harkness Seismographs

A two-component Hawaiian-type seismograph has been installed in the basement of the fire lookout observatory of the National Park Service on the summit of Mount Harkness, 12 miles east-southeast from Lassen Peak, California, elevation 8,039 feet. The instrument was started in operation on August 21, 1930, but owing to early snows Mr. H. C. Lind, the fire lookout and seismograph operator, was called away a little before the last of September and only a little over a month's record was obtained. The observatory building is located near the summit of a cinder cone that rests upon a lava base. Some earthquakes were recorded better on the Mount Harkness instruments than on the ones at Mineral.

Tilt

All instruments needed occasional attention to correct for tilting. The accumulation of tilt from the Mineral seismographs appears to be less during 1930 than in former years. Coincidental with a southwest tilt at Mineral there was a southeast tilt at Harkness. Of course, it is not yet know whether the Harkness tilt is local or not.

Earthquakes

The seismographs at Mineral recorded 74 earthquakes during the year. These disturbances by month were as follows:

January	5 shocks	July	7 shocks
February	7 "	August	5 "
March	5 "	September	4 "
April	4 "	October	4 "
May	5 "	November	14 "
June	0 "	December	14 "

The numbers recorded during the last four years are as follows:

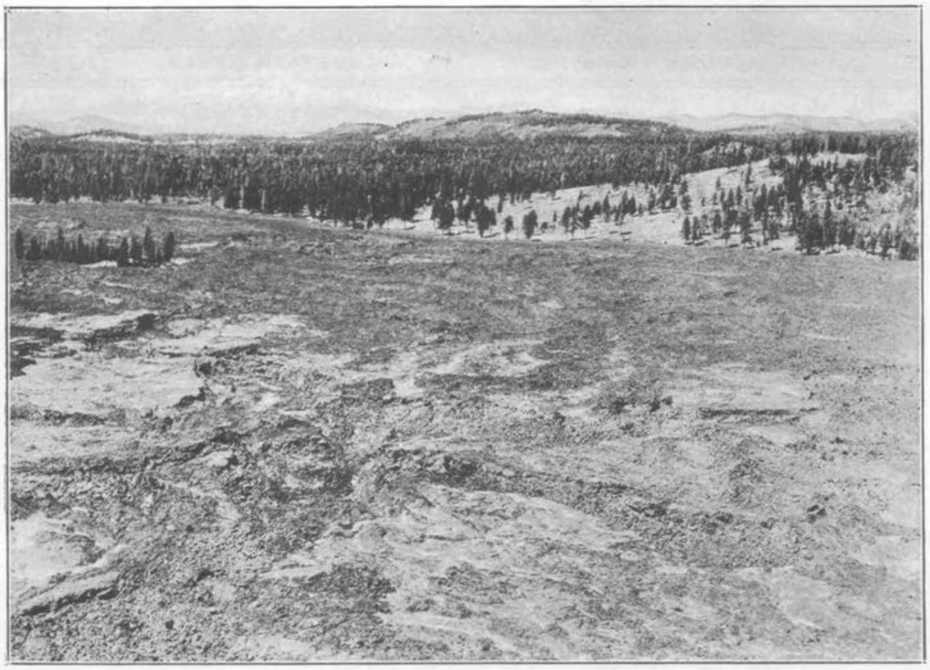
1927	266 shocks
1928	37 "
1929	96 "
1930	74 "

As in the preceding years, nearly all of the shakes had their origin in the Lassen massif.

Rainfall

The total precipitation for each of the last four years was as follows:

1927	43.32 inches
1928	42.10 "
1929	38.65 "
1930	38.94 "



View taken July 12, 1930, looking westerly across Burnt Lava Flow from edge of High Hole Crater.

Burnt Lava Flow

In July a topographic map of Burnt Lava flow, to the southwest of Glass Mountain and south of Medicine Lake, and 80 miles north-northwest from Lassen Peak, was made and specimens collected. Dr. C. A. Anderson, of the University of California, is to make a study of the specimens and a report of the flow will be prepared for publication.

Hot Springs Temperatures

Temperatures of springs at Morgan Springs on August 6, 1930, air temperature 88° F. follow:

Spring	Temperature	Remarks
No. 1	156°F	Algae and encrusted salts.
No. 2	125°	Very sluggish. Algae present.
No. 3 upper	196°	Less than normal flow. Some larvae present.
No. 3 lower	178°	
No. 4 east	195°	Flow very slight.
No. 4 west	164°	No. 4 area has been drained by ditching.
No. 4 clear pool	162°	
No. 9		No flow.
No. 17 steam at top	200.5°	
No. 17 hot water	201°	Volume as usual.
No. 20	200.5°	
No. 23 south	200°	
No. 23 north	196°	
Geyser	202°	Volume normal.

At Boiling Lake August 12, 1930, air temparature 82°:

Large mud pot northwest .... 196°
Boiler southwest edge of lake .... 195°
Boiling pool south edge of lake .... 194°
Dry steamer above south end of lake .... 201°
South end of lake .... 133°
North end of lake near outlet .... 121°

The water of boiling lake was about 12 inches below outlet. The lake level is the lowest it has been for several years according to Mr. Roy Sifford.

Temperatures at Devil's Kitchen August 12, 1930, were:

Mud pot northeast side .... 198°F
Mud pot north side .... 188°
Boiling pool north side, clear water 5 feet deep, small inflowing stream, no visible outlet .... 190°
Boiling pool north side, no visible inlet or outlet.......... 196°
Large boiling pool north side with pyrite scum .... 194°
Steamer northwest end (poor exposure) .... 198°
Big boiler southwest side .... 196°
Steamer southeast side .... 198°
Big boiler east end. Pool 10 feet in diameter. Main part of boiling jets goes to a height of 46 feet, small jets reach 10 feet .... 196°
Steamer below Big Boiler .... 198.5°

At Bumpass Hell, air temperature 71°, the following were obtained August 14, 1930:

High western pool .... 193°
Mud pot west of No. 1 .... 194°
No. 14, East pool .... 188°
No. 14, Middle pool .... 191°
No. 14, Big steamer .... 201°
No. 16 .... 193°
Steam vent Bumpass Creek below Bumpass Hell.......... 196°

Little Hot Springs Valley, August 14, 1930:

Clear pool east terrace .... 194°
Mud pot, east terrace .... 194°
Yellow pool .... 187°
Steam vent creek edge. Only fair exposure, steam emerging with considerable noise and pressure so that it was difficult to hold thermometer in vent even when tied rigidly to a stick .... 211°
Boiler surrounded by cold water in edge of stream.......... 188°

At Supan's, August 15, 1930, air temperature 82°:
Big steamer (sometime in July this vent became more active and scattered mud for a distance of 40 feet from its edges) .... 194°F
Big steamer on October 31, Spring overflowing.......... 192°

At Lassen Crater, August 20, 1930, air temperature 58°:
East vent near center of crater .... 132°
Middle vent under large rock .... 120°
Vent between two rocks north side of central area...... 162°
Steam vents above west edge of lake .... 146°

For earlier measurements of these temperatures at the various Lassen localities, see Volcano Letters Nos. 110, 162, 236, 238, and 279.

Land Slipping at Supan's

So many of the stakes were broken off that it was not possible to retape this area. Transit observations, however, failed to show any down-slipping. A new set of iron stakes was installed.

KILAUEA REPORT No. 1010

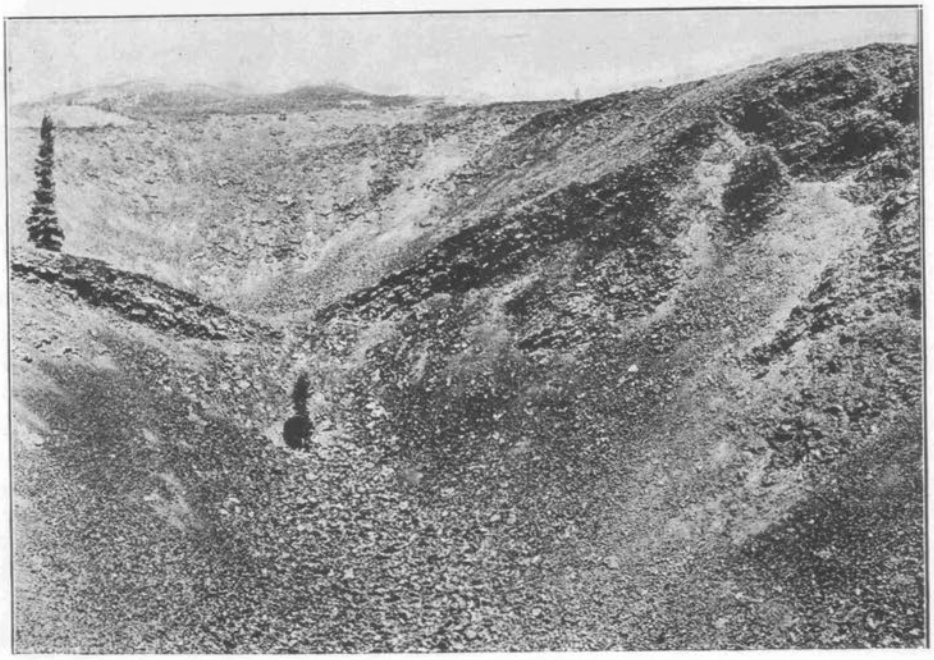
WEEK ENDING MAY 31, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

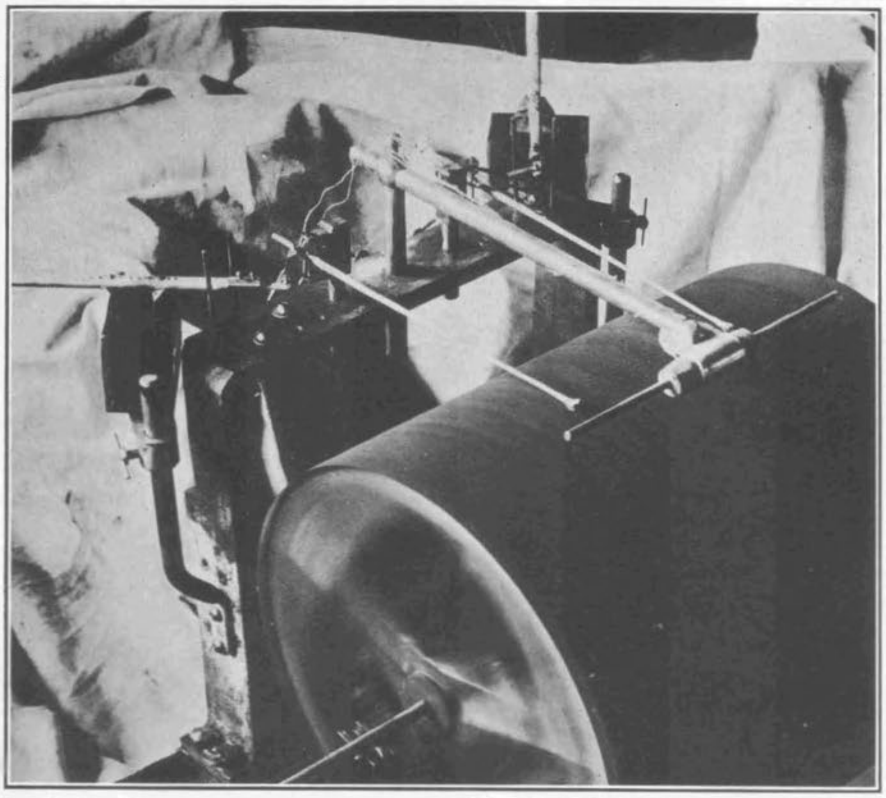
At the Kilauea fire pit on May 27, 11 to 11:15 a. m., steaming was slight at all the active vents, no steam showing on the south talus, a little on the west talus, and vigorous on the southeast rock bank. Fume was slight but steady at the west central sulphur area. A large scar from a slide showed on the north wall at the rim. At 1 p. m. a large dust cloud was seen rising north. On May 30 a very little steam showed on the south talus. Other conditions remained without changes.

The Observatory instruments registered 1 very feeble local seism and 33 volcanic tremors, including two and a half minutes of continuous tremor on May 25 and harmonic tremor from 4:06 to 4:24 p. m. May 29.

Tilting of the ground was moderate ESE. Microseismic motion was slight.



View showing the two parts of High Hole Crater in Burnt Lava Flow. Photographed July 12, 1930, by R. H. Finch.



Recording drum of Hawaiian Type Seismograph as installed at Mount Harkness. Drum covered with smoked "glassine" paper. Two pens write under the electromagnet, which lifts them every minute. They are connected with N-S and E-W arms. These are horizontal pendulums damped at the two small oil tanks. Drum moves along on its spindle.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

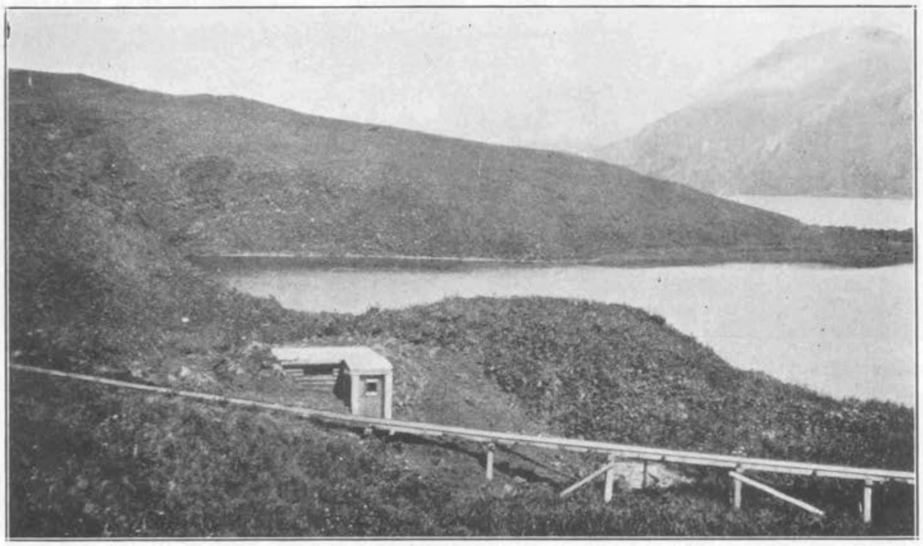
The Board of Directors includes Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year Ten cents per copy

No. 337—Weekly Hawaiian Volcano Observatory, National Park, Hawaii June 11, 1931



Dutch Harbor seismograph hut beside wharf tramway of Naval Radio Station as installed July 1929 by Austin E. Jones, so as to place instruments at some distance from the machinery. Looking east on Amaknak Island toward the entrance to Unalaska Harbor.

DIFFICULTIES OF ALASKAN EARTHQUAKE STUDY

The United States possesses one of the most important Volcano belts in the world in the Alaskan Peninsula and the Aleutian Islands. For a length of eighteen hundred miles from Attu at the west the ridge which separates Bering Sea from the Pacific Ocean extends in a pure curve northeast to Mount McKinley, rising higher and higher from islands at the west to the mightiest mountain in North America at the east. At the north is a shallow ocean, which is just as much a part of the combined Asia-America continent as is the Yukon Valley. It merely happens to be flooded with salt water in the present episode of geological time. At the south is the great Aleutian Deep reaching four thousand fathoms, a cleft or valley or sunken trough trending parallel with the Aleutian ridge, and in some way compensating the mysterious curved elevation. In like manner Japan is a curved ridge with the Tuscarora Deep east of it, with the outside of the curve toward the Pacific. Both places are famous earthquake belts with lines of volcanoes along the ridge. There are forty volcanoes reputed active in the Aleutian belt, many of them snowy peaks of greater and greater elevation as the line is followed northeastward to the upper part of the Alaskan Peninsula. The geology of the Peninsula and the islands shows folded sedimentary rocks of Mesozoic and Tertiary age, broken through by many igneous rocks, and overlaid by volcanic lavas and other accumulations along with glacial deposits.

The problem confronting the student of volcanology in such a place is to lay out a campaign for making use of the resident population to discover how many eruptions and how many earthquakes occur, where they occur in great number, what other movements like tilting of the ground are present, and in addition to explore individual volcanoes, promote mapping on land and sea, and gradually to acquire knowledge of places that may be used as strategic centers for continuous study of earth movements, hot springs, hot gases, and the action of lava underground.

The Section of Volcanology of the United States Geological Survey made a beginning in 1927 by establishing an Hawaiian-type seismograph in the Agricultural Experiment Station on Kodiak Island, shown on map of Alaska as the large island lying southeast of the upper part of the Alaskan Peninsula. In 1928 the volcanic area around Pavlof Volcano was mapped by the writer through an expedition conducted under the National Geographic Society. In 1929 another seismograph of the same type was established at the Naval Radio Station in Dutch Harbor on the island Unalaska (see Volcano Letter April 2, page one). Meanwhile an exploration had been made by way of reconnaissance all around the Peninsula and away out to Attu, in sequence upon a journey in a schooner through some of the eastern islands which had been made in 1907. All of this has shown us what the Aleutian lands are like, vast tundra flats with meandering streams on the north side of the Peninsula, rugged mountains and fjords crowned with

Seismograph hut at Dutch Harbor looking south, showing the harbor and mountains of Unalaska Island. Unalaska village just outside of picture on the right. Photo Jones.

volcanoes at the south, and these extending west through the grassy islands amid a climate of storms and fogs all the year around. There are a few villages of Aleut Indians and Eskimo, some canneries, huts occupied by winter trappers, and two or three sheep stations. Kodiak and Unalaska are the largest villages. In a few places there are resident white traders and officials throughout the year.

Until the present time, with between two and three years of record for the two seismographs at Kodiak and Dutch Harbor, there have been registered on the seismograms a few score local earthquakes and a very few distant ones. As a whole both places are disappointing in seismicity. Interruptions in operation due to storm and mechanical difficulties have been frequent. Storm microseisms are often so bad as to make seismic movements unrecognizable. Winter cold and wind and deep snow have produced rust and leakage and heaving at the unheated concrete huts, making endless trouble with the delicate clockworks, time pieces, electric contacts, wire connections and pivots which are essential parts of a complete two-component high-magnification seismograph. Neither Kodiak nor Dutch Harbor is actually at an active volcano, Kodiak being about 110 miles from Katmai and Dutch Harbor some twenty-five miles from Makushin.

The observers employed to tend the seismographs have all been devoted, conscientious women who were wives of officials or business men, and who do their utmost to keep the machines going even though the seismograph huts are buried under snow. The duties of these observers are fourfold: (1) to tend the seismographs, (2) to keep seismographs in repair, (3) to file and mail the seismograms, (4) to keep notes on volcanic happenings reported. It seems simple to anyone trained in physics to test the period, the damping ratio, the magnet adjustment, the tilt changes, the battery decline, and the time error of a pair of pendulums and an electrically connected eight-day regulator pendulum clock marking minutes and hours. It does not seem simple to untrained people buffeted by one of the most rigorous climates in the world, and with inspection by seismologists only at intervals of a year or more. All of this in a place without electric lights or watchmakers, where procuring supplies is difficult, where the building is unheated and the cold is intense, makes seismological registration a very different matter from Hawaii or California where supplies and assistance are abundant.

The following is from Mrs. M. V. Watkinson, the operator at the Kodiak station, who has to walk from her dwelling a mile or so up a hill to the seismograph chamber in an abandoned milk house of the Agricultural Experiment Station:

"February 21, 1930. We have had a great deal of trouble with the seismograph. The weather has been very severe, the natives say the worst for the last 40 years, so that all the water mains have been frozen. The storm has been almost continuous for twenty-eight days and has not broken yet. The time lift of the pens is not working right. The annunciator wire became saturated with moisture, in fact moisture was dropping down from walls and ceiling of room, and there were beads of water making a short between the wires. I changed the wires to waterproof covered ones, but this did not remedy the trouble. We found that the contact points of the clock were sticking, and fixed that. On February 4 and 5 the weather was so bad it was impossible to make my way up the hill. I started but had to turn back. Finally the seismograph went out of commission altogether owing to the heaving of the posts by frost. I have the machines running again, but not properly as the posts heaved diagonally. Yesterday I made the bumping test for period" (this is made by a light hanging weight giving a measured acceleration to the heavy mass).

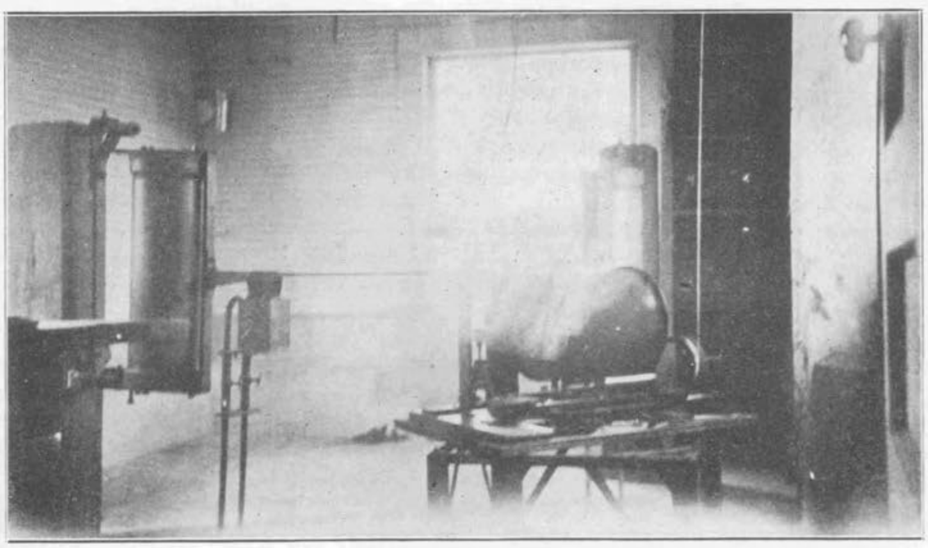
"March 22, 1920. The continual severe weather has driven a number of halibut boats into port for repairs. The weather has been so extremely cold, with regular blizzards of snow, that it has been impossible to stay in the chamber more than a couple of hours at a time in spite of the oil heater. The records I am now sending do not mean much beyond recording the process of trying to get the machine to run properly.' On another day came the news of an epidemic of influenza with the operator and her two sons ill. In January another violent storm was reported "raging so that it was impossible to face it up the hill." A note of December says "there is no record for the 15th as the new driving clock would not fit. We were so disappointed as there were earthquake shocks next day, and we had numerous inquiries from up and down the coast as to whether they were recorded here, and it kind of hurt to have to tell that our instrument was out of commission."

The following are human documents from the journal of Mrs. Esther Wendhab, wife of Naval radio operator at Dutch Harbor, who tends the seismographs:

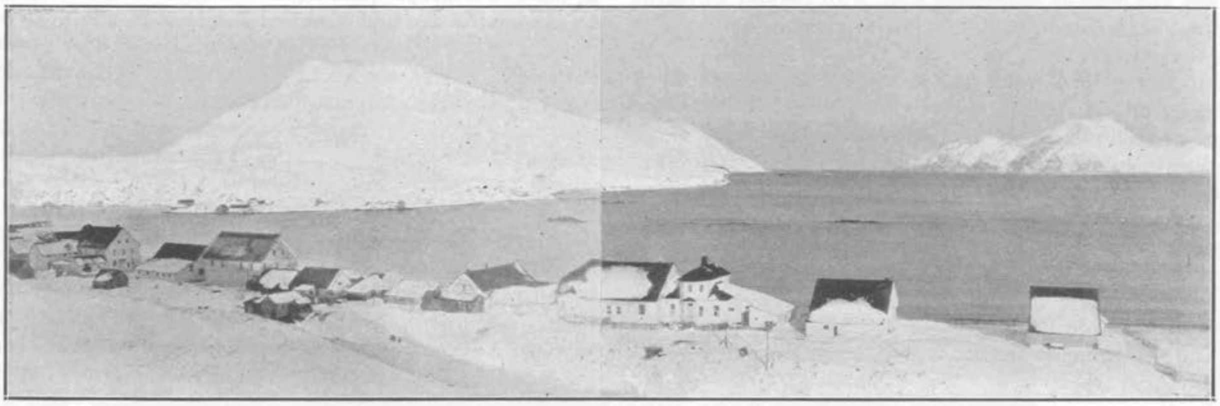
'March 18, 1931. Got 'stormed in' away from home and was unable to change the records. March 23: Was afraid to go out in the northwest wind on the icy trail. Captain Nelson of the Eunice reported a volcano smoking terribly with thick black fumes, where before he has only observed white steam, at Tulik on Umnak Island. He passed it March 21 and so unusual was its action he believes it is about to erupt. There was no record on the seismograph. March 29: Two earthquake shocks this morning, and the needle that has been causing trouble made the best record. April 2: The clock is going wrong again. The minute contact points are worn and get dirty very fast. I believe it will keep causing trouble, but I will do my best."

"February 18, 1931. Took mail to town and it stormed so badly I could not get home at all, so did not change record until following monrning. February 20: No trace of the seismograph building, had a hard time finding it, as all landmarks are under snow. Found it by the huge bank of snow that I've been piling up to get to the door recently. February 23: No chance of getting down to change record today. Terrible storm and blowing SE at seventy-five miles per hour. Will have to use the long stick again, to prod around to find the building, because even the snowbank will be gone now. February 26: The pen point came out again and stopped writing. Weather so bad nearly impossible to get down trail. Natives born and raised here (a year later than Mrs. Watkinson's report) call it the worst winter they ever witnessed, with the most snow, twenty feet deep in many places and getting worse. Have to find the building and dig it out every time now. March 2: Worked all day yesterday and fixed the arm. Put it on this morning after I finally got in. March 14: Had to fix the clock again as the points were dirty, but have it going. Weather still bad and sorry I have the work to do in such bad weather. They tell me this is the last month of that and then I believe it will be a pleasure again. It will be so much easier that it will make up for some times I've nearly frozen getting there, I'm sure. There is no news locally about any disturbances."

This sort of heroism in the cause of science deserves going on record, and was not contemplated when these stations were established in summertime. These documents show why the writer is so anxious to perfect a simple seismograph to register numbers and intensities of local shocks. Geographical distribution of shock-recorders is more important than attempts at precision where precision is impossible. Twenty shock-recorders placed with school teachers or trappers in different places in Alaska, some of these living very close to an active volcano, will tell more than precision instruments, until such time as a large observatory may be established there. T.A.J.



Early model Hawaiian-type, two-component, horizontal pendulum seismograph installed in dairy house Agricultural Experiment Station, Kodiak. In this model the damping vanes, in adjustable oil tank, are near the heavy masses, which are filled with sand and weigh approximately 160 pounds each. Magnifying levers write on smoked paper on the drum. Paper changed and shellacked daily. Time clock in same room, corrected by telephone from radio station. Photo Jones.



Unalaska in winter time. Seismograph station of U. S. Geological Survey is among the snowy hills on the left. Photo Yatchmeneff.

KILAUEA REPORT No. 1010

WEEK ENDING JUNE 7, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

On June 1 at Halemaumau pit of Kilauea Crater very faint fume could be seen at the sulphur spot on the floor, and vapor was thicker at the southeast rock wall at edge of floor than at the south talus. On June 3 the pit seismograph indicated quiet conditions and the rock wall steamed less. At 9:30 a. m. June 6 a slide occurred at the north wall.

Thirty tremors and one very feeble local seism were registered at the Observatory, the latter at 8:41 a. m. June 6, indicating distance of origin 25 miles. Tilting of the ground was slight WSW., and microseismic motion was slight.

TILTING OF THE GROUND FOR MAY

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the direction given.

May 4-10	0.9 second	E.
May 11-17	1.8 seconds	SW.
May 18-25	1 1 seconds	SSW.
May 26-June 1	7.7 seconds	SSW.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year — Ten cents per copy

No. 338—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — June 18, 1931

This map should be corrected by showing a broad strip of Hawaii National Park between Kilauea and Mokuaweoweo craters. The 1855 flow is between the flows of 1880-81 and 1899. About the Mauna Loa center there were flows at the beginning of the nineteenth century to NW, in the first half of the century to E, then a big series to N, and an increasing series from 1868 to 1926 to SW. The 1868 earthquake centered about Pahala, the 1929 about Hualalai. ("Flow 1901" at West Point is misprint for 1801.)

PREPAREDNESS AGAINST DISASTER

Address before Hilo Chamber of Commerce June 9, 1931, by T. A. Jaggar.

Recent Disasters

Recently there have been earthquake disasters in Japan, Mexico and New Zealand. The Napier earthquake in New Zealand has awakened the world again to the problems of fire following terrific earthquake at a place of population congestion, just as at San Fancisco in 1906, and at Tokyo in 1923.

Hilo, Hawaii

To the Associated Engineers of Hawaii January 16, 1918, I talked on the "index of danger from volcanoes," showing that the four classes of disaster to a volcanic land had happened in Hawaii. These are:

Class I, Explosion and volcanic blast
Example, Kilauea in 1924
Class II, Lava flow
Example, Hilo in 1881, Hoopuloa 1926
Class III, Earthquake
Example, Kau 1868, Puuwaawaa 1929
Class IV, Tidal wave, Example Puna shore 1868,
Hilo 1877, 1923

As each of these is represented by damage in this century, the topic is a live one. We have recently seen in addition terrific wind storms in Honolulu and rain floods damaging shops in Hilo. The wind combination along with lava flow or earthquake might be very serious for Hilo.

The 1918 lecture was published in Bulletin of Hawaiian Volcano Observatory January 1918, tidal wave damage in Hawaii was reviewed in Volcano Letter No. 321, and the cycles of Hawaiian volcanic happenings in Volcano Letter No. 325.

Napier Earthquake

The best way to envisage preparedness at Hilo is not to speak in hushed whispers because we are timid about frightening tourists away from our real estate. This is the attitude of some mainland cities. The insurance attitude is the correct one, expect fires, but put them out. If a terrific earthquake wrecks Hilo, let us in Hilo make a perfect demonstration of calm, unruffled preparedness, with the ready service of supplies that General Pershing had when he jumped in and helped at Chateau Thierry. There is no use in having hysterics about these things nor in publishing anything. The thing to do is to keep quiet and get action.

Now let us see what happened at Napier. Wherever you were, in your car, on the road, standing indoors, standing outdoors, suddenly there comes a tremendous crash like and explosion and down you go. Everything goes down, houses, bridges, gulches, cliffs, fires start, road fills crack open, automobiles fall into the cracks, wharfs are all down, some of the shipping is grounded, the breakwater has settled out of sight in places. In other words, the enemy has hit Hilo with a Big Bertha. The railway is out of commission, emergency telephones are called for as the wires are all down, the water mains have burst, the sewage is interrupted, the fire engines are pinned in their houses, the roads are interrupted by landslides. More than all, the people are struck dumb with shock, and until a warship arrives, to which this sort of thing is all in the days work, the population is dependent on whatever leaders happen to be soldiers.

Rescue parties are organized to dig out the wounded, portable cranes are in demand. Explosives must be used to demolish tottering masonry, which is likely to kill more people with the thousands of aftershocks that are coming along. Temporary wireless is one of the first requirements as the radio masts are down. Airplanes are summoned to rush anesthetics and medical supplies, for these things have given out. They have to be carried by air. A large number of tents are needed for temporary hospitals, and the roads interrupted by slides and cracks are not immediately available for carrying people to towns which suffered less. Sea transportation is organized as fast as possible by wireless, but that takes some time. The water supply being cut off, it is necessary to get in a chlorinating plant, organize a road survey immediately, and start work on pipes for an auxiliary water supply from a place where fresh water is available. The contents of the banks are laid wide open as well as many other valuable safes and cash drawers, and martial law is immediately organized by soldiers and constables who understand such things, a ring of pickets is run around the city, looters are shot on sight by marine guards. The jail prisoners are called out for digging, and do heroic work of rescue. Many motorists are caught in gorges and gulches and search parties have to be organized to seek them. The post office department is entirely disrupted and a quick reorganization is called for, as inquiries begin to pour in by mail as soon as any partial organization has been made; people inquire for the safety of their relatives. All lights go out at the very beginning and the organization of a temporary lighting plant and the cleaning up of wires is of first importance when the darkness of night settles over ruins, where work has to continue with the aid of flares, and where valuables have to be guarded.

Necessarily the Navy and shipping are of great use, and there were three ships which reached Napier. A small, compact, efficient, relief committee was found to be the first requirement at Napier and the organization of an information bureau to answer inquiries. Within a week when outsiders arrive to bring relief, there is need of quarters to correspond with the destroyed hotel, and there is need of increased wharf facility. Free meals have to be organized with the relief funds. Now there is need for a card record of hospital cases, of which there were 2,200 at Napier. The stoppage of the sewers and the bad water supply made it necessary to get together as many trucks as possible as soon as the road gangs had opened a way to get out of the district, and 5,000 people were evacuated from Napier and Hastings to a neighboring town which had not suffered, Palmerston. Palmerston organized itself to receive the transport of refugees. There was an acute clothing shortage, and notices had to be placed in newspapers of other towns instructing the public what to send, for they sent too many groceries and too little clothing. The loss at the central towns was of the order of $15,000,000. Fire insurance was simply not paid, for the situation was just the same as at San Francisco and Tokyo, and companies when they do write risks involving conflagration always reinsure with other companies. Only when earthquake is specified, and fire resulting from earthquake, and when these risks are paid for, can there be any expectation of restoration by insurance. **After the event** in all these cases, San Francisco, Tokyo, and Napier, insurance companies wrote earthquake risks. This is always done without any logic, on the part of the owners seeking insurance, who try to save the horses after the barn is burned down. Then after 45 or 50 years when there is real danger, everybody has forgotten it, insurance has been withdrawn, the building code has been relaxed, and it all happens over again. Such is human nature.

Organization for Preparedness

Every city should have a small committee of far-seeing men accustomed to administer discipline, representing commerce, public health, police and national guard, transport, and statistics. These people should have a clean-cut war problem with map of the city, just as war problems are worked out by General Staffs. The needs in time of disaster may be small or big, local or general, but the big possibilities should be looked at so that nobody will be surprised. The needs are:

(1) Organization of discipline and communication.
(2) Organization of rescue.
(3) Organization of relief.
(4) Organization of relief funds.
(5) Organization of camp for refugees.
(6) Organization of rebuilding.

(1) Discipline and Communication

This in Hilo would naturally fall to the Police service and the National Guard, and the communication side of it would call for the assistance and representation of the Naval and commercial wireless. Public Health agencies would be needed right away, and a representative of everybody possessing motor trucks.

(2) Rescue

This calls for large forces of laborers and truckmen, the National Guard to protect property, Boy and Girl Scouts to act as messengers, all the auxiliary police available, and all the resources of the Red Cross, including everybody who has had any nurse training.

(3) Relief

The prompt selection of camp grounds, creation of sanitation, and finding of auxiliary water, light if the main sources are destroyed, and assembling of food supplies have to be governed by circumstances. This sort of thing is best directed by some one familiar with organizing a camp on military lines and capable of enforcing martial law. There are needed food supplies, tents, surgical supplies, washing appliances, utensils, fuel, stoves, and competent cooks. Don't say 'get them at the hospital.'

The natural reaction of a committee is to say, "We have camp supplies in the armory, surgical things at the hospital, and trucks in the county stables.' Remember that for the extreme crisis contemplated, all three may be toppled over and burning, or under a lava flow, with 500 people dead, 1500 needing hospital treatment, and 5,000 homeless. The thing to face is the extreme possibility, the resources in water and supplies of Olaa and Hamakua, evacuation by sea to Maui or Kona, the place for a sanitary refugee concentration camp.

(4) Relief Funds

There have been cases of disaster where relief funds have been misapplied. One of the first things to happen when a catastrophe is announced is for subscriptions from elsewhere to pour in. The Red Cross is the proper center, with reputable financiers to act as custodians of money.

(5) Refugee Camp

Supposing Hilo partially destroyed under some great calamity, it is a matter of debate where to put a relief camp. The requirements are access to transportation, good water, supplies of food and clothing, policing, and communication by telephone and radio. If the wharves at Hilo were not destroyed or buried under lava, the place might be Waiakea or the airport. If a lava flow came through that side, the place would have to be in Hamakua.

(6) Reconstruction

The rebuilding after disaster has been a remarkable feature at San Francisco and Tokyo. The same is promised for Napier. As in the case of war, there are improvements in civilization, as well as evils, that result from a general clean-up.

One can imagine a new Hilo with a beautiful park all along the beach from the Wailuku River to the Wailoa, and with the railway moved back. One can imagine taking pride in a new city with no advertising signs visible from the harbor.

Actualities on the Island of Hawaii

Hilo is peculiar among cities in the world in that it is squarely in a volcanic belt, but happens to have been largely spared until now. So far as strong earthquake is concerned, this is equally true of Honolulu. Both of these places are liable to a terrific earthquake, when everybody will be surprised, and say, "This is the first we have ever had." Just that was said by the living generation at Charleston, Santa Barbara and San Francisco. The reason is that the earthquake interval overlaps several generations, and in Hawaii earthquakes in the 18th century before the coming of the whites made no impression on grass houses.

Hilo is definitely committed to future lava flows. The years 1801, 1843, and 1859 sent flows northwest, two of them building new land in the sea, from Hualalai and Mauna Loa. The years 1852, 1855, 1881 and 1899 sent flows towards Hilo, one reached Waiakea, and the one before it reached Kaumana (1855). The years 1868, 1887, 1907, 1919, 1919 and 1926 have sent flows at short intervals to the southwest from Mauna Loa, always different places, three of them reaching the shoreline, all destructive of ranches or roads or villages or all three. Earthquakes destructive and dangerous came in a swarm in October, 1929, shifting the area of underground activity of the enemy from Kahuku to Hualalai, and suggesting that the north side of Muna Loa as the center of it all will probably be the sector where he will concentrate his artillery for the next attack.

Apart from these dates history indicates that Mauna Loa will average activity about every four and a half years, so that we now are on the verge of a new outbreak. There are pros and cons that argue for a long interval in some parts of the century, but we know too little to apply them here. The fact is inevitable that Hilo will look up some evening and see what resembles a bright star on the northeast rift line of Mauna Loa, and a flow will start following the hollows among the flows of 1852, 1855, and 1881 in the direction of the valley of the Wailuku River. After it has been going a month we shall know whether it is likely to keep going for a year. It begins with rapid aa flows, the source cones make pahoehoe, the aa ceases, then the pahoehoe slowly tongues out from above past the earlier aa extremities, and pushing through tunnels to spreading leaf-like fronts, the pahoehoe may creep through the forest downward for many months. This would invade and dry up the Hilo water supply. The lava would be fed through a source tunnel up around the nine thousand foot level, forking out into many tubes down below. If a flow once got started between the 1855 and the 1881 flows, or on the north side of the 1855 flow, it would pour down the line of the waterfalls of the main valley of the Wailuku, as it has done in prehistoric times in the past, and as it did in 1881.

The waterfalls were made by many lava dams. The visible tributaries are mostly from the north, those from the south being buried under lava, and flowing underground. On this course the lava flow would pour straight through Piihonua, and the fate of Hilo would depend on how long the tunnel supply of pahoehoe kept on flooding at the source.

Just at this point could be applied the project to stop a lava flow advocated by the late honored L. A. Thurston. And only at this point. No aa flow in its early and rapid stages could be arrested. A pahoehoe flow in the later stages of an eruption, by reason of the tunnel mechanism, could be blown up at the source tunnel about the nine thousand foot level, or just below the source cone, so as to dam the lava stream with rock and force it to start fresh. The eruption would continue just as before, with the lava starting to flow anew out of the blocked channel over the surface of the country by a slightly changed course. If the previous pahoehoe flow took five months to get down near the Hilo level, the renewed flow 30 miles up the mountain would require as much or more, and the city would be given five months respite. The main source would go out of action in that time, and Hilo would be saved. There would be no necessity of employing the army or "T.N.T." Any contractor with a couple of men and some blasting powder, carried by pack mules from the ranch, and guided by the volcanologists, can do the job. If the 1881 or 1855 situation were exactly repeated, this diversion of the flow at the source could be done. It could not possibly have been done for Hoopuloa or Alika. The 1855 flow lasted 15 months, the 1859 ten months, and the 1881 nine months. Such durations are quite possible now, for the tunnel flows on the Kilauea floor in 1919 lasted seven months, and so did the Kau desert flow in 1920.

The Observatory asks from the Chamber of Commerce its complete cooperation, with as many members of the Chamber becoming members of the Hawaiian Volcano Research Association as possible, and taking a real interest. Meantime we are devoting all our energies to learning how to predict volcanic eruption.

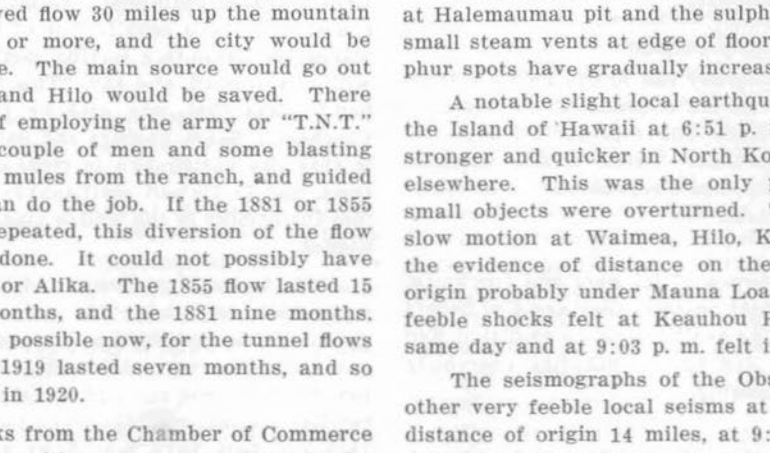
Contemplation of these possibilities is thoroughly sound economics for this community, and should make each firm ask, "Is our office earthquake-proof in its construction? Are our investments, our insurance, and our influence all they should be to prevent congestion, flood, or conflagration? Are we assisting those who are working on this problem? Or are we saying, "This is all nonsense. Life is too short. Such a thing couldn't happen to Hilo."

KILAUEA REPORT No. 1012
WEEK ENDING JUNE 14, 1931
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On June 8 at 9:40 a. m. seismic conditions were quiet at Halemaumau pit and the sulphur spots on the floor and small steam vents at edge of floor were as usual. The sulphur spots have gradually increased since December 1930.

A notable slight local earthquake was felt generally on the Island of Hawaii at 6:51 p. m. June 11, with motion stronger and quicker in North Kona near Honokahau than elsewhere. This was the only place where one or two small objects were overturned. The shock was felt as a slow motion at Waimea, Hilo, Kilauea, and in Kau, and the evidence of distance on the seismograms made the origin probably under Mauna Loa. There were other very feeble shocks felt at Keauhou Ranch at 4:29 p. m. the same day and at 9:03 p. m. felt in Hilo.

The seismographs of the Observatory registered four other very feeble local seisms at 9:08 p. m. June 12 with distance of origin 14 miles, at 9:22 a. m. June 8, at 3:06 p. m. June 13 and 6:11 June 14. In addition 28 tremors were registered during the week. The total of seismic disturbances for the week numbered 35. Tilting of the ground was slight WNW, and microseismic motion very small.



THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

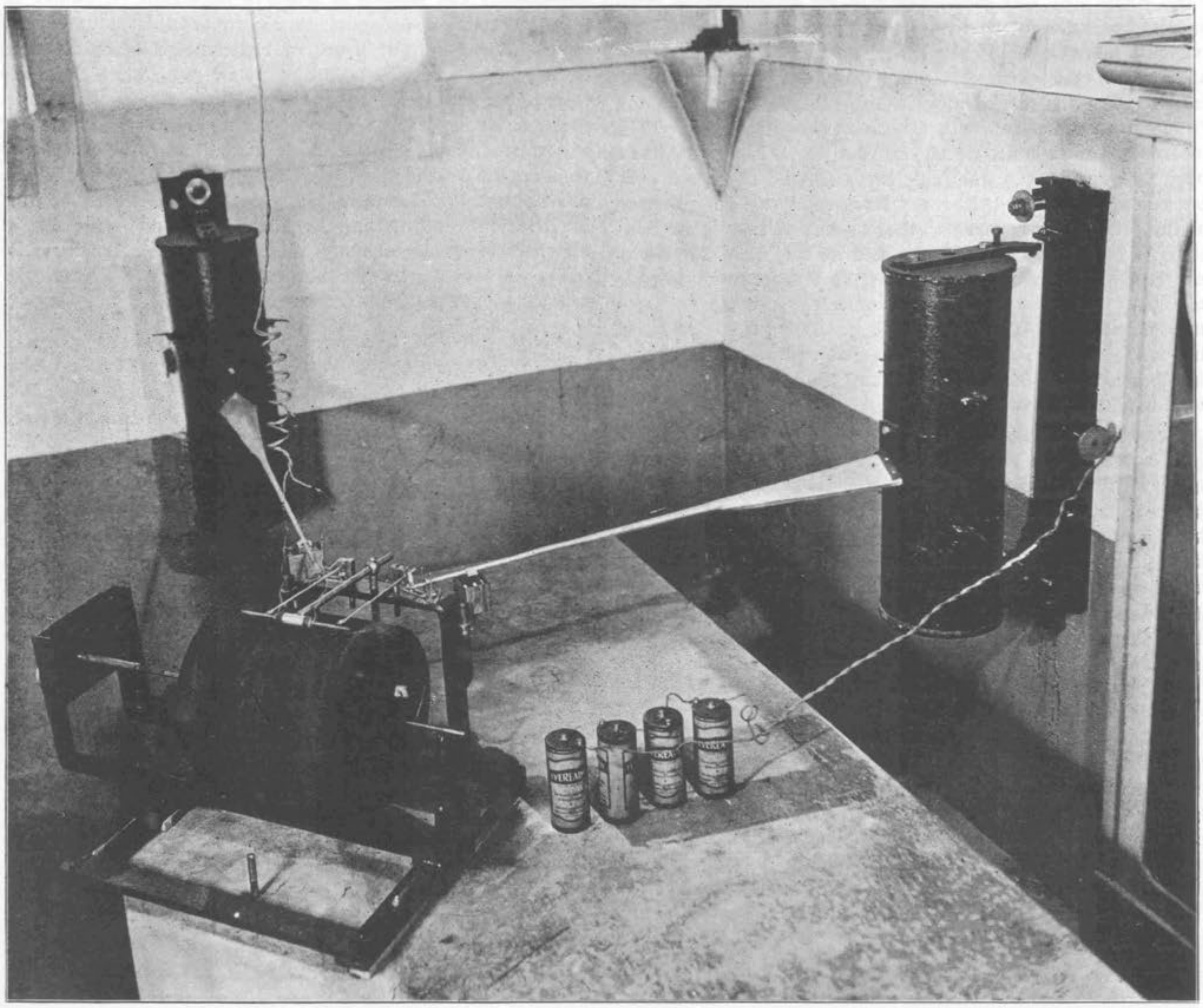
The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 339—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | June 25, 1931



Pair of Hawaiian Type horizontal pendulum seismographs, designed and built at the Hawaiian Volcano Observatory. Two heavy masses are hinged against plates on the wall east-west and north-south. Aluminum pens connected with booms from these masses write on a drum driven by clockwork and moving along on a screw. Paper is smoked and changed on the drum every day. The cross-bar electro magnet lifts the pens every minute and hour. The paper is shellacked and stored as the seismogram of the day. Photo Maehara.

EARTHQUAKE INSTRUMENTS HAWAIIAN VOLCANO OBSERVATORY

When the original building of the Hawaiian Volcano Observatory was constructed in February 1912, a preliminary equipment of instruments had been secured through the Massachusetts Institute of Technology, and by a special order placed in Japan. There were a pair of 100-kg. Bosch horizontal-pendulum seismographs made in Strasburg, an Omori portable two-component small seismograph for ordinary earthquakes, an Omori strong motion seismograph recording three components with an automatic starter, and a large one-component Omori horizontal pendulum of high magnification for distant earthquakes. A cellar 18 feet square and 9 feet deep was finished in concrete under the Observatory on the northeast edge of the greater Kilauea Crater. This was equipped with several concrete tables adapted to the instruments. During the first year of occupancy the instruments were set up and tested for the peculiarities of the Hawaiian ground, and the portable seismograph was used for a time in the hut built near the north rim of Halemaumau. Mr. H. O. Wood had charge of seismology from the summer of 1912 to 1917.

The tests at the fire pit showed that the insensitive Omori portable pendulum would yield nothing distinctive of that place. A high magnification instrument was needed. Mr. Perret in the summer of 1911 with a delicately poised seismoscope had shown the presence of tremors at the pit edge when lava was fountaining inside the cauldron, and special pulsations recording the heavier gushes of the periodic fountain then called "Old Faithful." In September 1928 a one-component horizontal pendulum was installed in a shallow depression dug in lava 450 feet southeast of Halemaumau, covered with a very small shelter hut. This instrument was built at the station, and had first been used in Kona on the west side of the Island of Hawaii. It hangs so as to record tilt away from or towards the center of the pit, its heavy mass weighs 30 kg., and its magnification is 70. It records on smoked paper, and the drum covered with paper is smoked at the Observatory, is protected by a special box, and is carried to the pit by automobile and changed every two days. This pit registration has made valuable records at times of outbreak, and shows tremors and tiltings different from those at the Observatory two miles away.

This sort of evolution, with gradual change of instruments suited to special needs, has gone on with all the instruments. Seismometry on an active volcano is quite different from that of a station which devotes most of its energies to distant earthquakes. Most of the seismometric stations of the world are of the latter type. In Japan for many years the meteorological stations and other establishments have maintained instruments for the study of local earthquakes, but the main purpose of these stations in Omori's time was to record "ordinary" earthquakes, meaning registration of frequency, time, and intensity of the shocks that would ordinarily be felt, so that some scientific data could be gathered on the subject. This led to the making of more sensitive instruments of higher magnification and to the attempt to make a "universal" seismograph, which would satisfactorily record both local and distant shocks. Most of the German instruments make this attempt, and most of the earthquake lists do not distinguish satisfactorily between distant and local shocks. The "local' shock is a phenomenon still dubious and obscure, for if it is intense enough and deep enough to register on distant instruments, it may be "felt" over a wide area, and on the other hand very intense disastrous earthquakes like the one at Managua recently may be very local in perceptibility, and fail of registration at the remote stations. An earthquake may be accompanied by a massive movement of the ground with actual faulting of the sod at the place of sensation. What is felt in this case is not an "elastic wave." Many felt earthquakes are entirely elastic waves, with no discovered faulting of the ground. The natural history of this subject needs much research.

From this the reader should understand that it is an actual fact that no one knows what an earthquake is. Waves of compression, transverse waves due to the rigidity modulus of the rock, surface waves involving an up-and-down movement, waves reflected at different surfaces of change of density within the crust of the earth, waves traveling at different speeds, the ground or hill or cliff or plain under foot oscillating with its own period as an independent pendulum, spells of tilting, places of local tilting, mass movements of sideways shifting, mass movements of sudden uplift or depression, mass movements of sudden tilting—all of these things are supposed to exist in the crust of the earth, and a one-component pendulum, meaning a pendulum capable of swinging in only one direction, does not tell much about them. What little is known indicates that a house totally distorts the motion of the ground. The one-component pendulum totally eliminates all but one set of motions of the ground, tends to swing on its own account, and tells nothing by itself as to whether the motion is massive or elastic, irregular or harmonic, until subjected to rigorous experimental criticism. The result of years of registration of many local earthquakes on the Island of Hawaii quite denies the notion of an epicenter. The epicenter is supposed to be a place right over the source of a shock. At the epicenter the shock should be felt most strongly. It is quite true that on the Island of Hawaii many shocks are felt which are not felt in Honolulu 200 miles away. There is thus localization. But within the island there are hundreds of shocks felt equally at many places, with the seismographic evidence pointing to epicenters where there is no more intensity of perception than anywhere else.

Now what is this seismographic evidence? This is clearly important, for if we may harness an island with instruments, and that island has many earthquakes of a small and harmless type, we may really study the nature history of the earthquake. From the beginning this was the aim of the Hawaiian Volcano Observatory. People think they can tell the direction of an earth shock which they feel. All they can tell is the way the maximum of a hundred motions affected the particular room or chair or bed where they were placed. The seismograph is a rocking chair specially placed in a chosen room in the rock of the earth itself where the vibration of the building will not create a separate pendulum. The writing of the seismograph on smoked paper, when a little earthquake occurs, begins with a preliminary tremor as the paper moves along under the pen, then a movement of greater amplitude follows, or the "long waves,' and this is the part which is felt. This tails off to nothing in the course of minutes. A sensitive person standing outdoors might feel very faintly the preliminary as a mere tremble because it is quick. The long wave he would feel as a thud. The tail portion is slow and not usually felt. The writing levers of a seismograph, after magnifying the motion 100 times, have hardly any energy, hence the tiny pen tip pivotted and touching lightly a smoked surface to avoid friction. Even the restraint of a spider's web on the pen may spoil the record. The preliminary quick tremor has been proved to be a combination of the compressional and rigidity waves which reaches the instrument more quickly, by faster travel, than the long waves. The long waves are a combination of mass movement and wave motion. The sharp change from the preliminary to the long waves makes it possible to measure in seconds the duration of the preliminary. The longer its duration the farther away the place of origin of the disturbance. Hence with several seismographs in different places we may triangulate on the origin location underground. If we can find the origin location underground we do not need to trouble about "epicenters."

As shown in the accompanying pictures, the seismograph chamber at the Observatory contains now horizontal pendulums built right here registering all components, the electrically connected clock registers time on the drums, and there are other stations with similar instruments in Hilo and Kona for triangulation. The horizontal pendulums also record tilting of the ground. T.A.J.

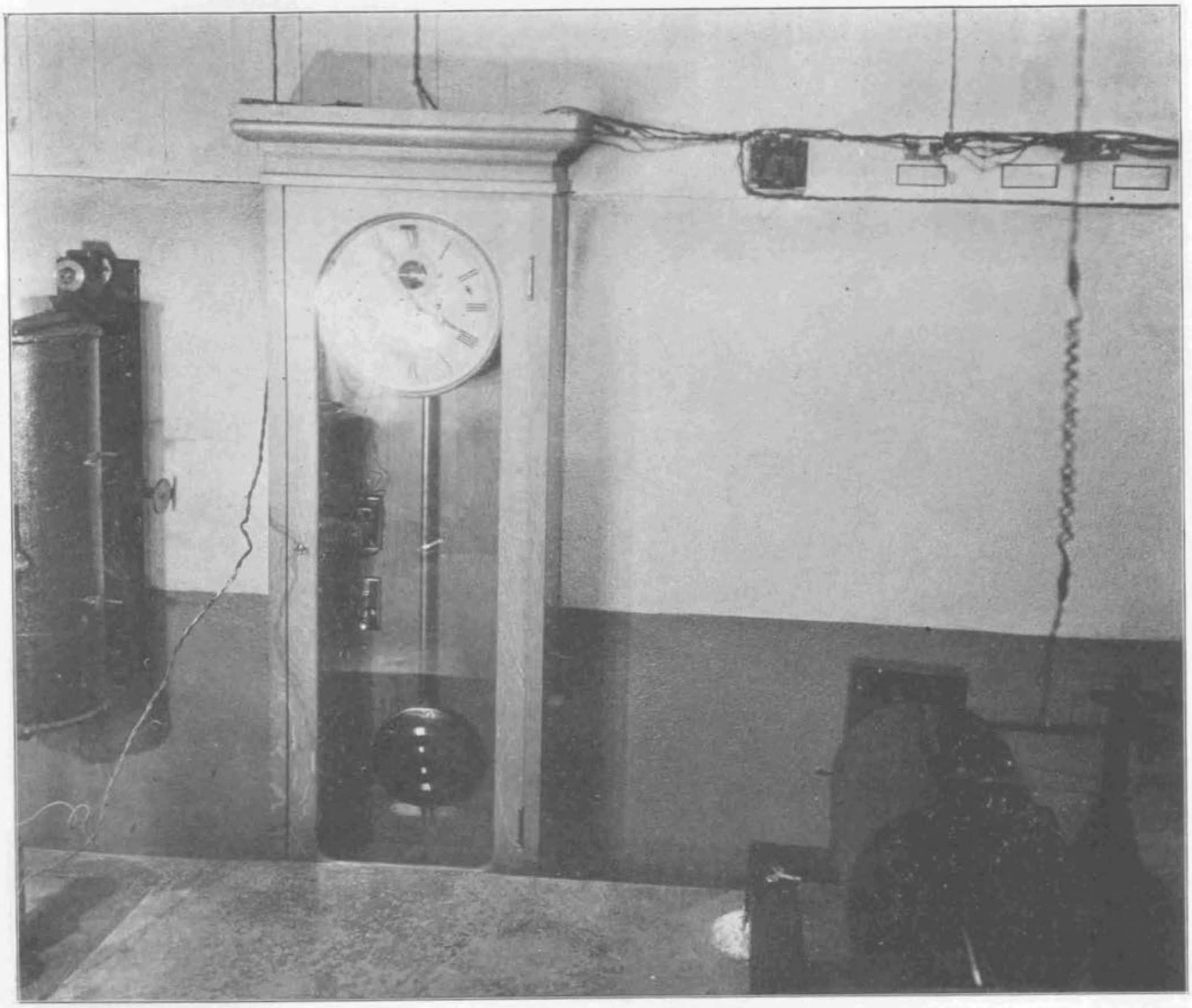
KILAUEA REPORT No. 1013

WEEK ENDING JUNE 21, 1931

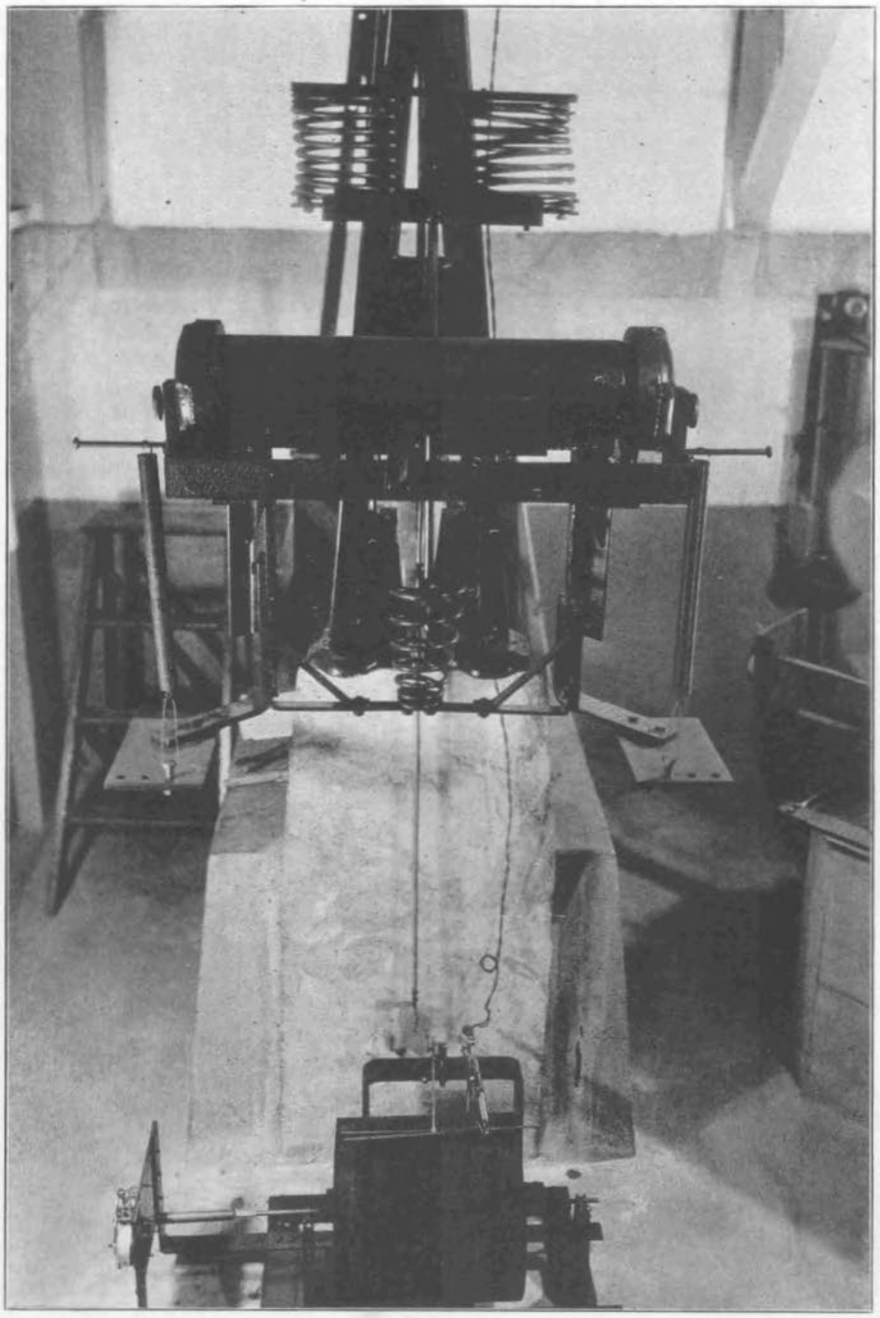
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On June 15 at 9:15 a m. a small slide occurred at the north wall of Halemaumau. Steam is emerging at the southeast rock bank. Fume is notably absent at present.

The Observatory seismographs registered 26 tremors, one very feeble local seism, and one feeble shock felt locally. The last was at 10:45 a. m. June 16, with indicated distance of origin 11 miles. Tilting of the ground was slight ENE, and microseismic motion was slight.



Howard electrically fitted regulator clock connected with all the self-recording instruments of the Observatory. The error of the clock is compared with wireless time every day. The wireless signal is impressed with telegraph key on all the seismograph drums. The clock is compared daily with a chronometer, and the temperature of the chamber is recorded.



Vertical component seismograph built at the Hawaiian Volcano Observatory. The heavy mass is here hung on spiral springs, with temperature compensation from small springs. The heavy mass is free swinging and registers the up-and-down motion of the rock under the concrete cellar. The up-and-down motion is smaller than the horizontal motion in earthquakes. Photo Maehara.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 340—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | July 2, 1931

Myrtledale Geyser near Calitoga, Napa County, California. Made artificially by casing a well 180 feet deep, where a stratum containing boiling water is reached. The spouting occurs once every 45 minutes, when the release of steam pressure is satisfied, and it takes another interval to bring the replacement underground water to the boiling point.

VOLCANIC WATERS OF NAPA COUNTY, CALIFORNIA

In the Coast Range north of San Francisco, on the border between Lake and Sonoma counties, stands the St. Helena range marking some recent volcanic activity where there are hot gases and steam and sulphur which have been pouring forth from Teritary time until the present. "The northern and western ranges in these counties are composed largely of altered sedimentary rocks that probably belong to the Franciscan (Jurassic or Lower Cretaceous) formation. Glaucophane schists and serpentine are associated with them. The age of other altered sedimentaries here" is unknown, some geologists thinking them Lower Cretaceous.

"In Napa County and the southern part of Lake County several peaks and ridges are formed of lava that is probably of Teritary age. This lava overlies the altered sediments, and tuffaceous phases of it form prominent cliffs at a number of localities. Numerous carbonated springs of slight flow issue in this region north of San Francisco Bay, both from the sedimentary rocks and from the lavas, and hot springs exist in several places. A few springs of noticeably sulphureted water have also been examined but are less numerous and less important than those of the carbonated type."

So wrote Waring (Springs of California, Water-supply Paper 338, U. S. Geological Survey) in 1908, pointing out that upright fault or fracture lines have close relation to the hot springs of California. "At Calistoga, near the head of Napa Valley" (three to four hours' journey north of San Francisco) "are several hot springs at which during the seventies there was a large resort. The hotel burned in the early eighties, however, and since that time the springs have not been of more than local importance. The name 'Calistoga' is said to be formed from the words California and Saratoga, but the springs are not at all like those of Saratoga Springs in New York. In 1910 the caretaker of the property had provided two bath-houses of two tubs each, half a dozen small cottages on the place were rented, and a few campers had pitched their tents nearby. Hand pumps supplied hot water directly to the tubs, and cool water was piped from a tank.

"Four main springs rise at the base of a knoll of buff-colored tuffaceous material at the northern border of the meadow land, and a few pools and seepages appear in the meadow itself. The observed temperatures of the principal springs ranged from 126° to 173° and their flows from about one-fourth gallon to five gallons a minute. The hottest spring, which yields about one gallon a minute, appears to be the most strongly mineralized, though its mineralization is only slightly perceptible to the taste. Algae probably give it the slight flavor that has caused it to be called a "chicken-soup" spring.

"At Calistoga Hotel, about 400 yards west from the springs, a dug well supplies warm water for tub baths and a swimming plunge. Warm water is also obtained in several other wells nearby, and there is one strongly flowing artesian well."

The following analysis of the swimming pool water, having a temperature of 122° Fahr., is characteristic, made by W. Anderson in 1888; constitutents are by weight in parts per million:

Sodium	212.0
Potassium	8.2
Calcium	12.0
Magnesium	5.7
Iron	6.0
Aluminum	2.4
Manganese	Trace
Sulphate	110.0
Chloride	255.0
Iodide	13.0
Carbonate	27.0
Silica	62.0
	713.3
Hydrogen sulphide	42.0

Concerning the geology of the hot springs Waring writes: "The position of the springs near the base of the knoll of volcanic tuff that rises in the valley land and the fact that a fault has been traced along this part of the valley furnish suggestive evidence that faulting has here provided escape for deep-seated water. The lava may also produce a high temperature gradient that aids in giving the abnormal temperatures to the water. The amount of heated water that rises is probably better indicated by the area of meadow-land that is formed than by the visible flow of hot water, for there is doubtless much seepage that is not observable."

This last conclusion has been borne out by discoveries since 1910 which prove the valley to be underlaid by **boiling** water instead of hot water (Waring maximum 173° F.). The writer visited Calistoga July 31, 1926, and learned that in 1915 borings 180 feet deep in the flat valley floor produced artificial geysers which spout up through the casings of wells 100 feet or more at intervals of 45 minutes to two hours. One of these, the Myrtledale Geyser, is shown on Page One. For a mile of length the east side of the valley is over an artesian basin of boiling water, whereas the springs are cold on the west. Mr. Finch determined the temperature of Plummer's Geyser March 22, 1927, to be 218° F., and Pacheteau's capped geyser 213.5° F. (Volcano Letter No. 236).

On the mountainside, five miles to the west of Calistoga, in Sonoma County, is the Petrified Forest where immense sequoias have been silicified in volcanic ash, mostly fallen in pairs, and with their butts toward Mount St. Helena. The suggestion is strong that St. Helena was the source of a volcanic blast that overturned them in prehistoric eruptions. The fossil tree shown on Page Three is 110 feet long with a diameter of 12 feet. There is a crater higher up the hillside.

Finch reports (Volcano Letter No. 236) that Mount Konocti, near Clear Lake north of this Napa country, is the most recently active volcano in this part of California. It is believed to have erupted somewhat over 1,000 years ago, or well within the historic period of Europe. The hills east of Sulphur Bank, itself east of Mount Konocti, contain a fairly well preserved crater, there is one on the south peak of the mountain, and between this country and Calistoga the lava flows capping the hills appear progressively older. Across the hills to the west at "The Geysers" in Sonoma County is superheated steam used for power (Volcano Letter No. 62, Allen and Day Publication 378 Carnegie Institution) believed to rise from hot underground magma.

It is worthy of note that the San Francisco earthquake of 1906, apart from the massive shift of terrain from Santa Cruz to Point Arena on the great fault, the greatest intensity was at Santa Rosa, with extensions of the belt northward toward Geyserville and southward to Petaluma. In the Napa valley and about Clear Lake there were other belts of apparent intensity VIII-IX R. F. This region of present-day volcanic heat of highest temperature for California, and of volcanoes active in the historic period, made localized centers of disturbance of enormous intensity. Therefore we should not treat too lightly the possible connection between underground magma and great earthquakes. (Map 23, Carnegie Institution, California Earthquake.)

T.A.J.

KILAUEA REPORT No. 1014

WEEK ENDING JUNE 28, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The week at Kilauea has been quiet and uneventful. On June 22 there was a little steam on the south talus of Halemaumau, but none elsewhere. On June 23 no steam was seen. Dust was dense near the north talus, probably due to air currents, there having been moderately strong trade winds, without rain, blowing and creating much dryness. On June 27 the pit remained unchanged. Sulphur areas appeared less conspicuous except a bright spot on the west side of the floor.

Twenty-two very feeble tremors were the only seismic disturbances recorded by the instruments at the Observatory. Tilt was slight NW. Microseismic motion was slight.

Silicified big tree at the petrified forest in ash beds five miles west of Calistoga, California. This tree, "The Queen," is 110 feet long and 12 feet thick... The replacement of the wood fibre by silica was accomplished by hot waters. These sequoia trees were overturned in pairs, their tops pointing away from St. Helena volcano. Probably an ancient steam blast eruption did the work.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

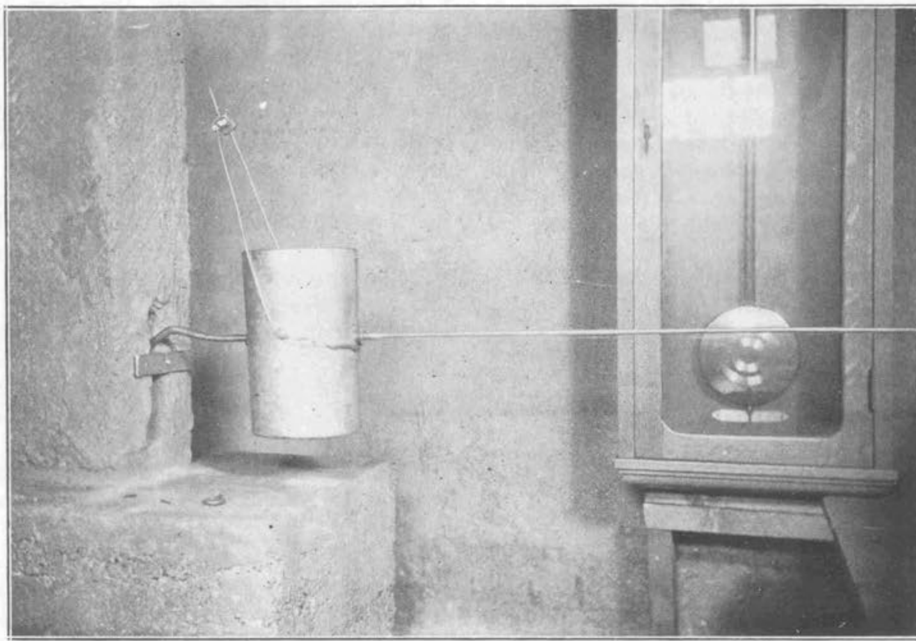
The Board of Directors includes Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 341—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | July 9, 1931



Experimental seismograph built of homemade materials at the Lassen Volcano Observatory by R. H. Finch, showing heavy mass, suspension and boom, the concrete pier and post, and the Howard clock.

MAKING A SIMPLE SEISMOGRAPH

The seismograph in most common use is a horizontal pendulum. The photograph shown on Page One is the hanging part of such a pendulum which anyone with a little ingenuity might make for himself. The machine shown in our illustrations is in fact one constructed by Mr. R. H. Finch in two months in the autumn of 1926 for preliminary tests of earth motion at the Lassen Volcano Observatory in California. This instrument was made entirely out of materials and labor available in any country town. There is here shown a clock on the wall which is a good timepiece made by the Howard Company in Boston, Mass. This is fitted with electrical contacts closing the circuit of a four-cell dry battery for about two seconds every minute and about six seconds every hour. It is a weight-driven pendulum regulator with eight-day movement. The electrical contacts on the minute and hour are for marking the time continuously on the smoked paper which covers the drum of the seismograph, so that any hour or minute may be identified on the paper for discovering the time when an earthquake has marked the paper.

On the left is shown a concrete post in a basement room with an upright hollow or groove cast at the bottom where the post rises from a concrete table or pier. It is better to have the cylinder as shown hanging from an isolated post than to hang it from the wall. We have tried both plans for different instruments at the Hawaiian Volcano Observatory. As the hanging cylinder is very sensitive to the slightest tilt given to its supports, walls are not desirable. The upper part of the concrete wall of a cellar on the outside of the building is heated by the sun for some parts of each day. The heating expands the wall and it cools at night, thereby contracting. The seismograph is so sensitive, magnifying earth motion some two hundred times in case of a horizontal displacement, that the distortion of the wall under expansion and contraction will cause the writing pen to swing sidewise an inch or more in the course of a day. This causes the lines to interfere and interlace with each other. A certain amount of normal tilting of the ground is to be expected in the course of each day anywhere, and it is likely to be exceptionally big at an active volcano. Therefore we do not want any tilting due to solar heating of the house. What tilting we get, measured by the swinging apart or the close approach of the lines, should be indicative of what the actual ground is doing under the whole country, and therefore is measurable for the particular two directions in which a single horizontal pendulum swings.

The dimensions of the cellar shown in the picture are ten by ten feet, and the general plan of the instruments followed the lines of the Omori seismograph. The concrete post, ten by ten inches square, stands 27 inches high above the pier which is 18 inches high above the floor and two feet square. The cylinder consists of a cast-iron container holding nine circular lead discs, which make the whole weigh 225 pounds. The lead discs are each bored and threaded in the center to take a large screw-eye, so that the container can be handled by one man by lifting the discs out or putting them in separately.

An iron rod, bigger near the post, and smaller at its outer end, passes horizontally through the middle of the heavy mass or cylinder. This protrudes 52 inches from the center of the cylinder. The big end of the rod is bent and lies in the niche at the base of the post, supported by a short hinge of spring-steel wire. This wire hinge is terminated by metal balls in two slots cut with a hack-saw. One of these slots is in the flat iron strap shown pinned across the niche, the other in the bent end of the rod. The heavy cylinder is supported by a stirrup hanging from a piano wire which is made fast to a simple adjustable bolt in two angle irons pinned to the top of the concrete post. For these attachments to the post it is convenient to use expansion bolts, which are readily put in holes drilled in the concrete. The adjustments of the upper attachment of the piano wire permit of winding it up to lift the mass, and of moving it right and left to bring the outer end of the rod or boom to a medial position.

From all this there results a mass hung like a door with a boom protruding out from it, designed to record those oscillations or tilts of the earth at right angles to the plane of the suspension. The boom is braced by fine steel wires extending from its outer end to the cylinder. If the boom points to the east, the inertia of the mass registers the north-south earthquakes. Another similar pendulum is hung north-south to record the east-west earthquakes. Or better, for the same earthquake, two such pendulums register the north-south and the east-west components of the motion. Under each pendulum the system is damped, or prevented from free swaying on its own account, by sheet-aluminum vanes attached to the boom, protruding downward into a metal tank of automobile oil, so that with swinging of the pendulum, the vanes move edgeways in the oil. The little oil tanks, four or five inches square, not shown in the illustration, are supported by a removable stand in front of the pier.

The registering mechanism is shown in the figure on Page Three. The recording drum is built on a steel spindle threaded with ¼-inch worm at the end away from the drive-clock. This moves the drum lengthways in a sleeve at the driving end. The drive-clock is a Seth Thomas two-barrel power movement with rotation of spindle once in 30 minutes. The inner sleeve of the drum is set by a screw on the clockwork spindle. The worm end of the drum spindle rests on knife-edge wheels. Glassine paper is wrapped around the drum, pasted at the ends, smoked over a kerosene lamp, and the drum is set in place with the set-screw locking it to the clock. The writing lever-pen from the pendulum has a hinged stainless steel tip which rests on the smoke surface. The lever pens are made of aluminum. They are pivotted about a vertical axis near the end of the booms. The pen tips and the levers have pivots made of standard clock and watch balance staffs. Motion is transmitted from the boom to the lever by light metal T-bars, with the ends of the cross-bar in the boom and the lever respectively. The drum ends are made of ply-wood and the surface of pasteboard. The pen tips are magnetized, lifted to make a gap in the written line on the smoked paper every minute by an electro-magnet connected with the time-piece on the wall. The drum surface moves 30 mm. to the minute. The static magnification of the boom is five and of the writing lever forty, making the total 200. A marker pen attached to the plate supporting the drum and lever system, is made to write a line for a few minutes once a day on the side of the smoked paper, to be used as a datum line for measurement of wandering of the pendulums under tilting of the ground.

The free period of the pendulums is adjusted to seven seconds by moving the upper support of the piano wire in and out from the posts. The pen tips are laid back with a horseshoe magnet when the drum is changed. The change of paper is made once a day and the seismogram removed is passed through a bath of very dilute shellac and denatured alcohol, which fixes the smoke image of the line written by the pens. In the second photograph there is shown the second boom vanishing into the foreground, connected with the second pen by its T-bar impinging on an angle piece in the lever at right angles to the lever. In this way both pens, north-south and east-west, write during the day bands of lines side by side on the same paper. The paper is 12½ by 38 inches. Each line is interrupted by its minute and hour marks, the operator indicates the time of the starting mark by scratching it in the smoke, and simple counting of the succeeding hour marks on the smoke is all that is needed for timing an earthquake autograph that may appear. The light pasting of the ends of the paper on the drum is easily separated by a slender paper-cutter. The seismogram is dated and marked with its location before shellacking.

It will readily be seen from this account that any amateur with mechanical aptitude can build for himself a senstitive seismograph, and he can learn all about the technique of the science if he will consult the back files of the Bulletin of the Seismological Society of America, the headquarters of which are at Stanford University, California. T.A.J.

KILAUEA REPORT No. 1015

WEEK ENDING JULY 5, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Conditions remain unchanged at Halemaumau pit. The cauldron is quiet and dry. Strong northeast trade winds continue.

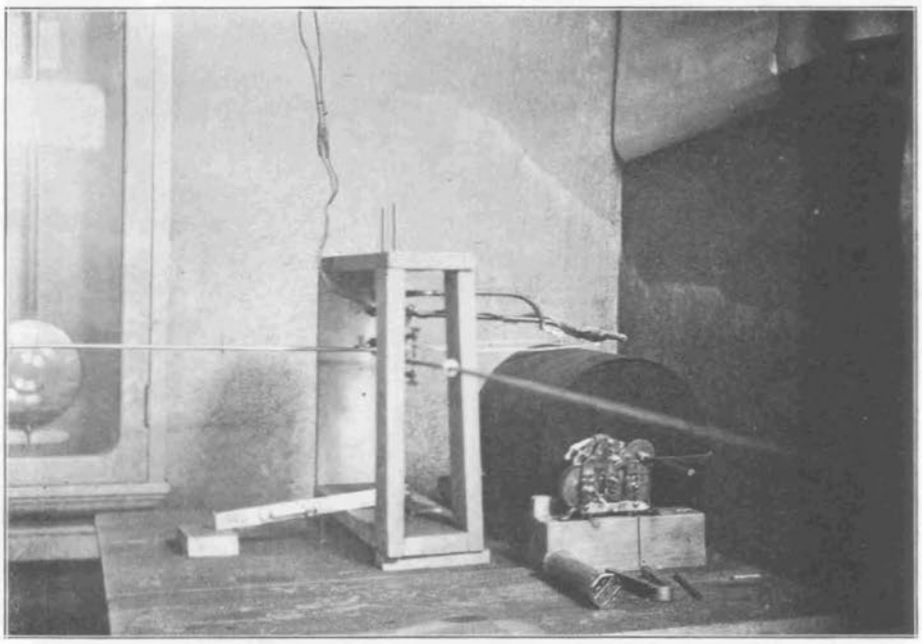
Seismic disturbances recorded during the week included 34 tremors and two very feeble local seisms. One of the latter at 12:08 a. m. July 4 indicated origin distance 23 miles from the Observatory.

Tilt for the week was slight NNW. Microseismic motion was slight.

TILTING OF THE GROUND FOR JUNE

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping progressive seven-day averages. This is the departure of the plumbline in the direction given.

June 1-7	0.1 second	W.
June 8-14	1.4 seconds	NE.
June 15-21	0.3 second	ENE.
June 22-28	1.4 seconds	NNW.



Recording end of homemade seismograph, showing booms of both north-south and east-west pendulums, pivot connections with writing levers, straight wound electric magnet for marking time, and the driving clock and drum, the latter with smoked paper.

Interior of seismograph cellar at St. Mary's School, Hilo, Hawaii, showing two-component seismograph hung on wall of chamber, with recording drum in middle of room.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

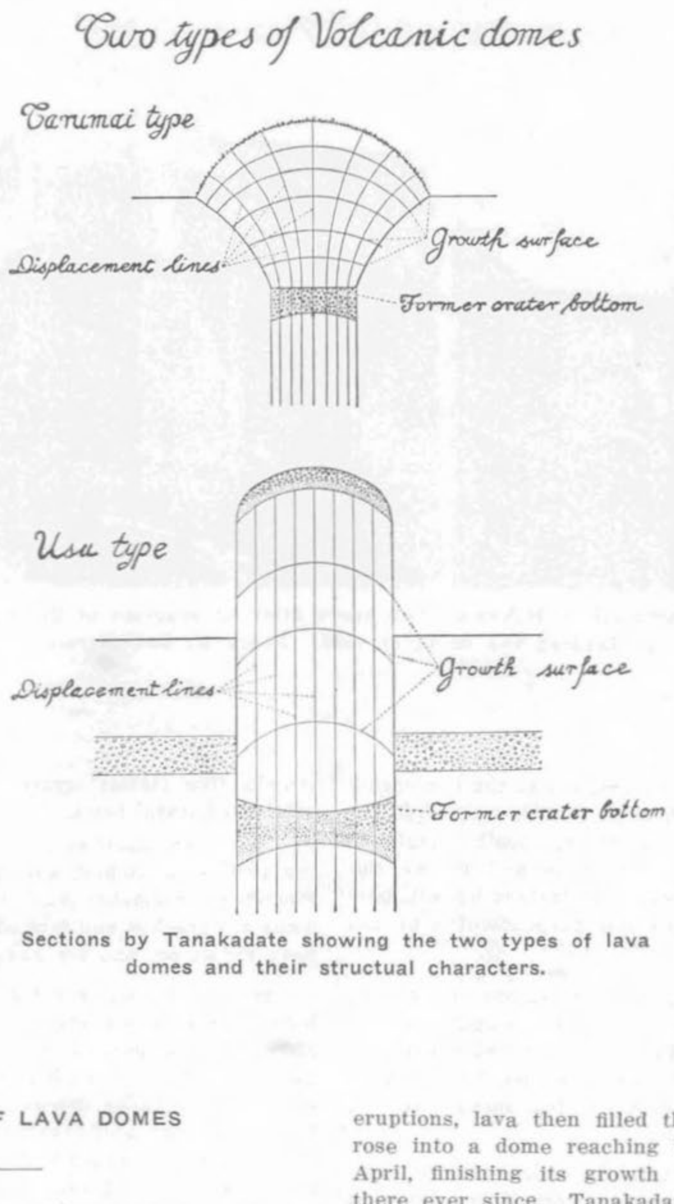
The Board of Directors includes Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 342—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | July 16, 1931



Sections by Tanakadate showing the two types of lava domes and their structual characters.

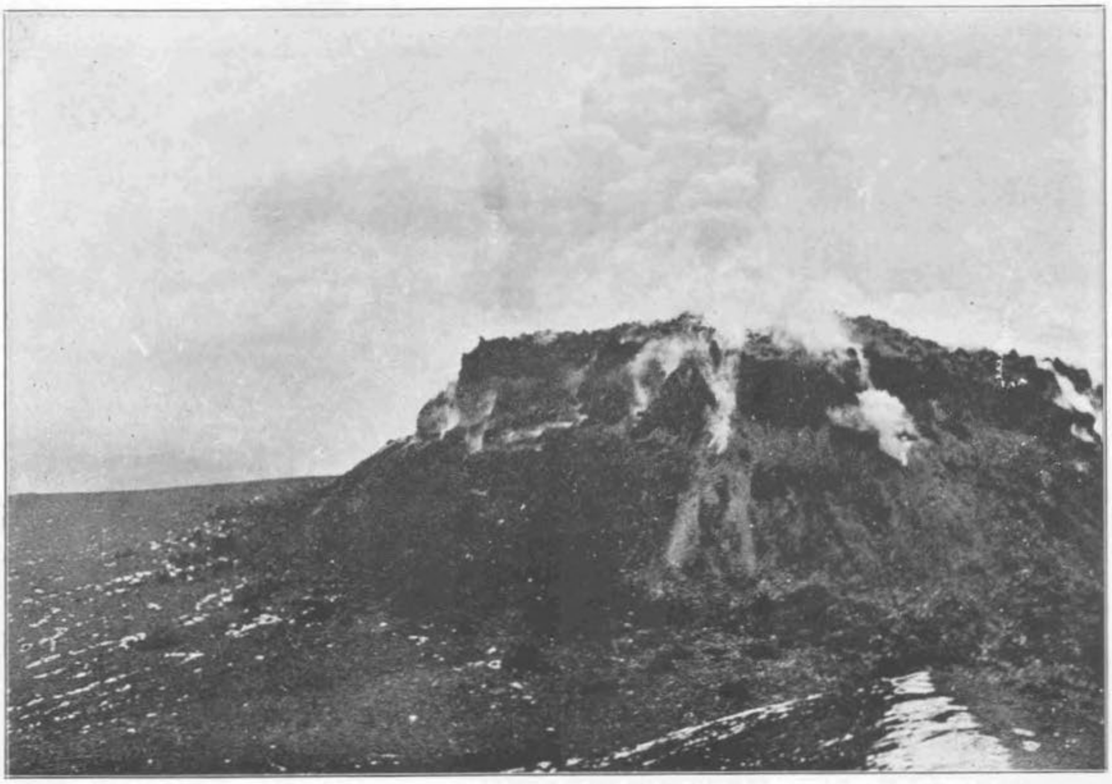
TWO KINDS OF LAVA DOMES

A clear analysis of the materials and the rising of stiff lava into two kinds of lava domes in Japan has been made by Tanakadate. (H. Tanakadate, Imperial University, Sandai, Japan. Proc. Fourth Pacific Science Congress Java 1929, pp. 695-703.)

The first is the Tarumai type, based on the Volcano Tarumaisan in the north island of Japan, which pushed up its crater floor into a dome in 1909. Before the eruption the crater was a funnel 600 meters across, gently sloping inward above and precipitous within. The funnel was 65 meters deep with a bottom 60 meters across, exhibiting active solfataras there and in the wall.

March 30 to April 12, 1909, there were big steam-blast eruptions, lava then filled the funnel, then the pudding rose into a dome reaching its maximum at the end of April, finishing its growth in mid-May, and remaining there ever since. Tanakadate expresses the mechanism by the upper diagram on Page One. By expressing the original crater bottom as a horizontal line in section, lava covered with gravel, the successive stages are shown by the **growth surface** lines, when the gravel must have been scattered on the increased area of the top of the dome. Such loose materials were found sparsely scattered on the slaggy surface of the dome when it was explored after it had cooled off between 1909 and 1917. Explosive eruptions in the latter year through fissures in the dome flung out fragmental materials on to the dome. At present detritus and lava blocks caught in the lava are found on the dome.

The **displacement lines**, radiating from the former



Lava dome of Tarumaisan in Hokkaido, two hours after an eruption of October 30, 1926, which fissured the dome of 1909. Photo K. Shibahara.

bottom of the crater upward, correspond to the successive positions in lateral displacement of equally spaced points on the crater floor at the beginning. Each imaginary vertical filament of lava in section rises and widens, the more in the center, the less where restrained by wall friction. The displacement lines are perpendicular to the growth surfaces.

The lava developed prismatic structure, mostly at right angles to the growth surface, with columns parallel to the displacement lines. In crater pits and fissures of the dome can be seen the chasms bounded by columnar joints, caused by contraction when the surface cooled, making upright parting planes.

In the large caldera of Usudake Volcano, near Tarumaisan but farther south (see map Page Four), is found the second type of lifted plug or dome, illustrated by the lower diagram on Page One. There are two domes on Usu (see map Page Three), and three crater lakes. Taking the bigger one called O-usu, it is 725 meters above sea, 350 meters high about its base, and is smoothly round like a cathedral. The top of it is not a round shell of rock, but is composed of gravel, sand, and clay 3 to 6 meters thick. The gravel contains fragments of quartzose rocks, crystalline schist, and several old volcanics; there are andesites with pyrite and hematite. The pebbles are reddened with oxidation, as though through the heating effect of the dome lava, and are sometimes bowlders a foot in diameter. They are smooth and scratched with parallel streaks like glacial erratics. The sands and clays are baked to natural brick.

The dome itself of rock is exposed on one side with the surface scratched, and a structure of parallel shells. Elsewhere fragments mask the rock. The sectors of the dome are cracked and faulted so that one sector may have been thrust up, another has lowered.

If the dome was regular on its rising, the volcano may have formed its caldera of subsidence in the course of a river, which deposited ordinary gravel, sand, and clay in the crater lake. The highly viscous lava rose and congealed under these deposits. The lava continued rising, lifting the plug, and heaving up the overlay of sediments. This made a structure with vertical side walls and dome-shaped top. The friction on the confining wall produced the streaks and striations. Just the same thing was shown by the Pelee spine. The lava and sediments agglutinated and formed a hard crust. The lava core pushing into the gravel layers produced the striations in the pebbles.

The parallel-shelled structure gives evidence that at first the growth surface was horizontal, later the viscous sides lagged and the center rose most, arching the top. Sinking of parts of the magma below, and renewed pressure, bring about the splitting into separate sectors or columns with differential lift at the top.

In the case of the Tarumai dome of the first type, the recession of magma caused a flattening of the top of the dome. (See Page Two).

The O-usu dome is much more siliceous than the Tarumai dome. The O-usu rock is a dacite with 68 percent of silica, that of Tarumai on augite andesite with 61 percent. The O-usu rock is fine grained, light gray, with few and small porphyritic crystals and a trachytic groundmass. The Tarumai rock is coarsely porphyritic with large anorthite feldspar prisms, and smaller augites. The lava shows fluidal streaks of red and gray.

The old outside lava wall of the caldera of Uusu is basic, and so was the new lava of the lower slopes of Usu, thrown up as bombs in the uplifting eruption of the outer flank in 1910. Both of these have only 51 percent of silica (see Volcano Letter No. 302).

Other volcanoes which have produced the low-dome type of eruption are Bogoslof, Katmai, and Galunggung. The spine or plug has been upraised in Pelee, Lamongan, and in the inner fin of McCulloch dome at Bogosloff in 1907. T.A.J.

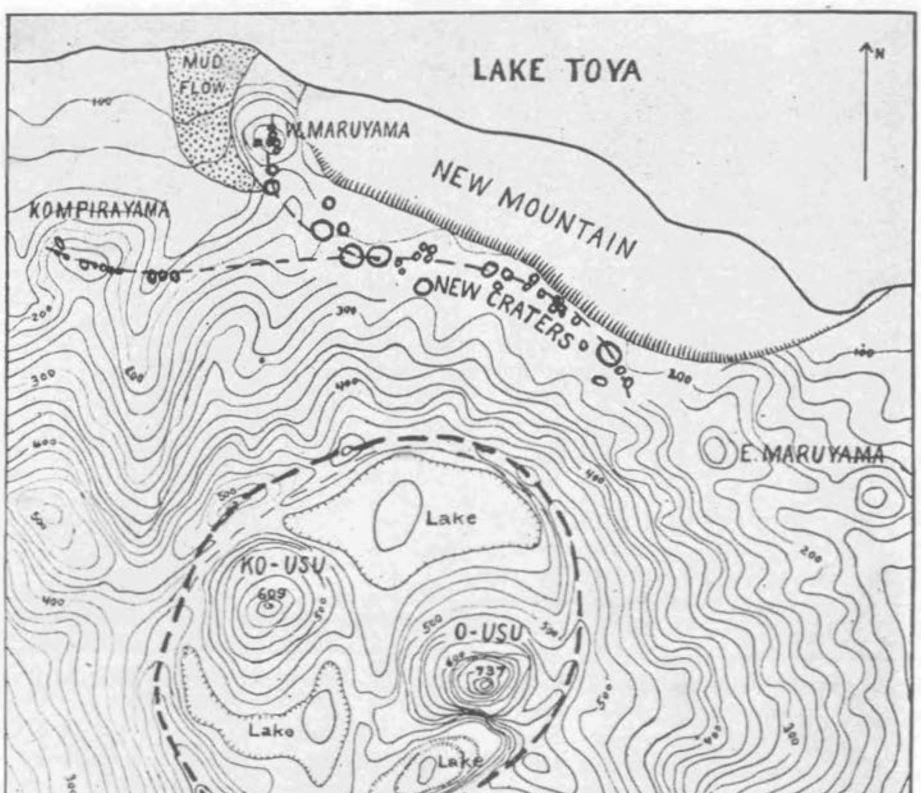
KILAUEA REPORT No. 1016

WEEK ENDING JULY 12, 1931

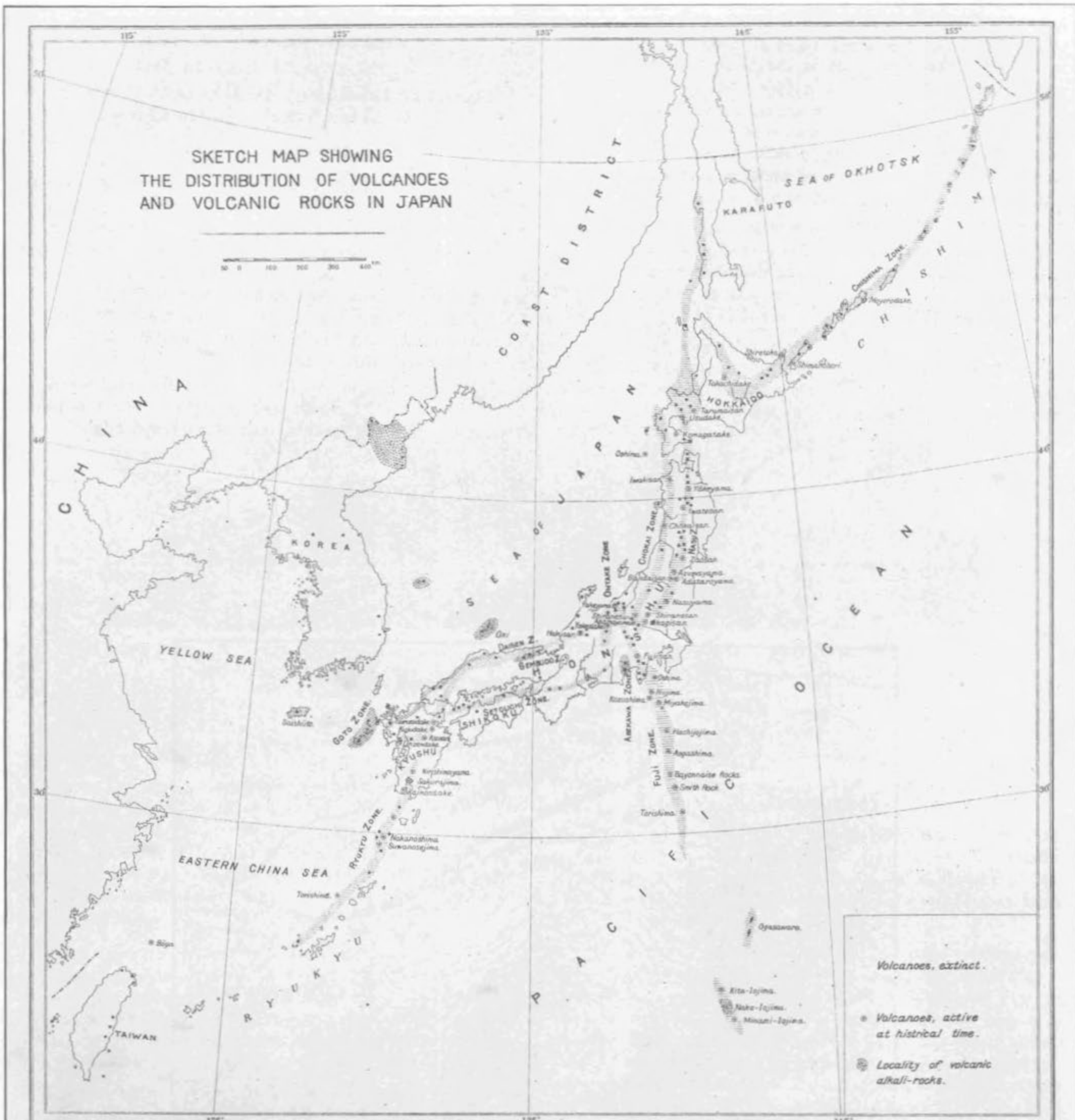
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Halemaumau has shown a few changes of interest. Blue fume has reappeared on the bottom in two new places, directly north of the 1930 cone in a sulphur area, the edge of which has caved in, and at the bright sulphur spot on the far northwest side. Dust from an avalanche was seen rising from the northeast rim of the pit at 4:30 p. m. July 10 in a compact cloud which gradually thinned. The seismograph on the crater floor recorded a few slow motion tremors without tilt.

The instruments at the Observatory registered 18 tremors and 5 very feeble local seisms during the week. Tilt was slight W. Microseismic motion was slight.



Map showing old caldera ring and domes of Usu, the active craters of 1910, and the uplifted "New Mountain" of 1910. After Daly.



Map of volcano belts in Japan by S. Kozu, showing extinct, active, and alkaline lavas.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 343—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | July 23, 1931

Haleakala seen across Hawaii Channel from the summit of Hualalai. Photo Emerson.

HAWAIIAN VOLCANO LANDSCAPES

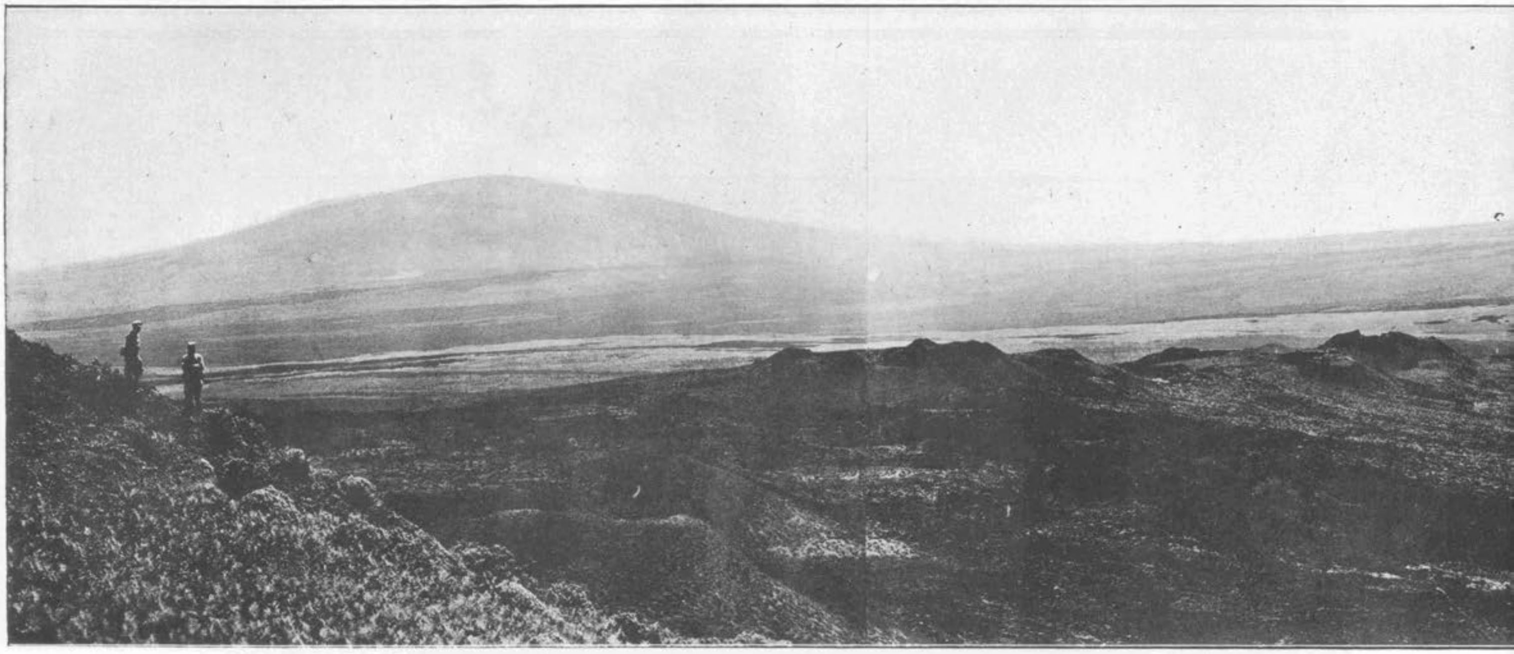
Professor Norman E. A. Hinds has produced an interesting paper on "The Relative Ages of the Hawaiian Landscapes" (Univ. of Cal. Publ. Bull. Dept. Geol. Vol. 20, No. 6, pp. 143-260, pls. 15-42, 13 text-figures; Berkeley 1931). He reviews the evidence for the supposition that Kauai is the oldest of the windward group of Hawaiian Islands, and points out that the extra heavy rainfall there, to speed up erosion, has not been sufficiently allowed for. Kauai may be younger than Oahu. He also accents downfaulting of island blocks along shore-lines which has robbed some islands of their mass. The text by Wentworth on quantitative estimates of marine and fluvial erosion in Hawaii (Jour. Geol. Vol. 35, 117-133, 1927) and Wentworth's Bishop Museum papers come in for criticism, and it is refreshing to note that both Hinds and Wentworth attempt to evaluate erosion on the basis of rainfall and drainage, and even to make some estimates of rate of removal of soil in carving landscapes. This is the beginning of a science of erosion.

Hinds writes: "According to Wentworth, the depths of material removed from the various mountains by streams stand in the following order: (1) East Oahu; (2) Kauai; (3) East Molokai; (4) West Maui; (5) Mauna Kea; (6) West Oahu; (7) East Maui; (8) Lanai; (9) Niihau; (10) Kahoolawe; (11) Kohala; (12) the rest of Hawaii. The estimates for East and West Oahu and Kauai apparently neglect extensive loss of bulk by downfaulting, hence the amounts of removal by rivers in these three cases are excessive. On East Molokai, Kohala, and Niihau, streams have eroded a residual of once larger domes since about half of these mountains has been carried below sea level by downfaulting. It is not improbable that faulting may have been partly responsible for the development of some of the great canyons on Kohala, East Molokai, Kauai, and Oahu."

Hinds uses the term "engulfment" for downfaulting, but this word "engulfment" is a volcanologic term for downbreak in volcanic craters or underground conduits, and is hardly identical with graben downfaulting.

"For Lanai, Wentworth has calculated the average rate of removal as one foot in 5,000 years, and from this he has estimated the approximate age of the landscape of that dome to be 125,000 years. Using the **same** rate of removal, he obtains figures of 225,000 years for Kohala and 2,090,000 years for Kauai." Hinds objects to applying a dry island rate to a wet island.

"According to wentworth, the relative amounts of



Panorama of Mauna Kea and Mauna Loa from a summit cone on Hualalai. The near foreground of Hualalai shows a slope of 35°.
foreground cones extend the Hualalai rift toward Mauna Loa. The left of this picture

material removed by wave action from the various islands stand in the following order: (1) Hawaii; (2) Kauai; (3) Molokai; (4) Niihau; (5) Maui and Kahoolawe; (6) Oahu; (7) Lanai." Hinds objects that the several domes on Hawaii are of different ages, and have been cliffed by the sea in different amounts. And that the formation of cliffs by faults has not been recognized. "The determination of relative amounts lost by downfaulting and by later marine erosion probably is impossible, though approximate values may later be obtained."

The point of this discussion is that the Hawaiian Islands form an excellent field for measures of erosion in time, if some one will only go at it experimentally by the observatory method.

Hinds arrives at the following conclusions:

The order of extinction of the younger Hawaiian mountains apparently has been: (a) Haleakala, (b) Mauna Kea, (c) Hualalai. Mauna Loa and Kilauea are still in process of construction, hence their landscapes will undergo certain changes before their major activity ends." (With Haleakala known to have made lava flow about the middle of the eighteenth century, and Hualalai in 1800-1801, one wonders why these two should be considered extinct.)

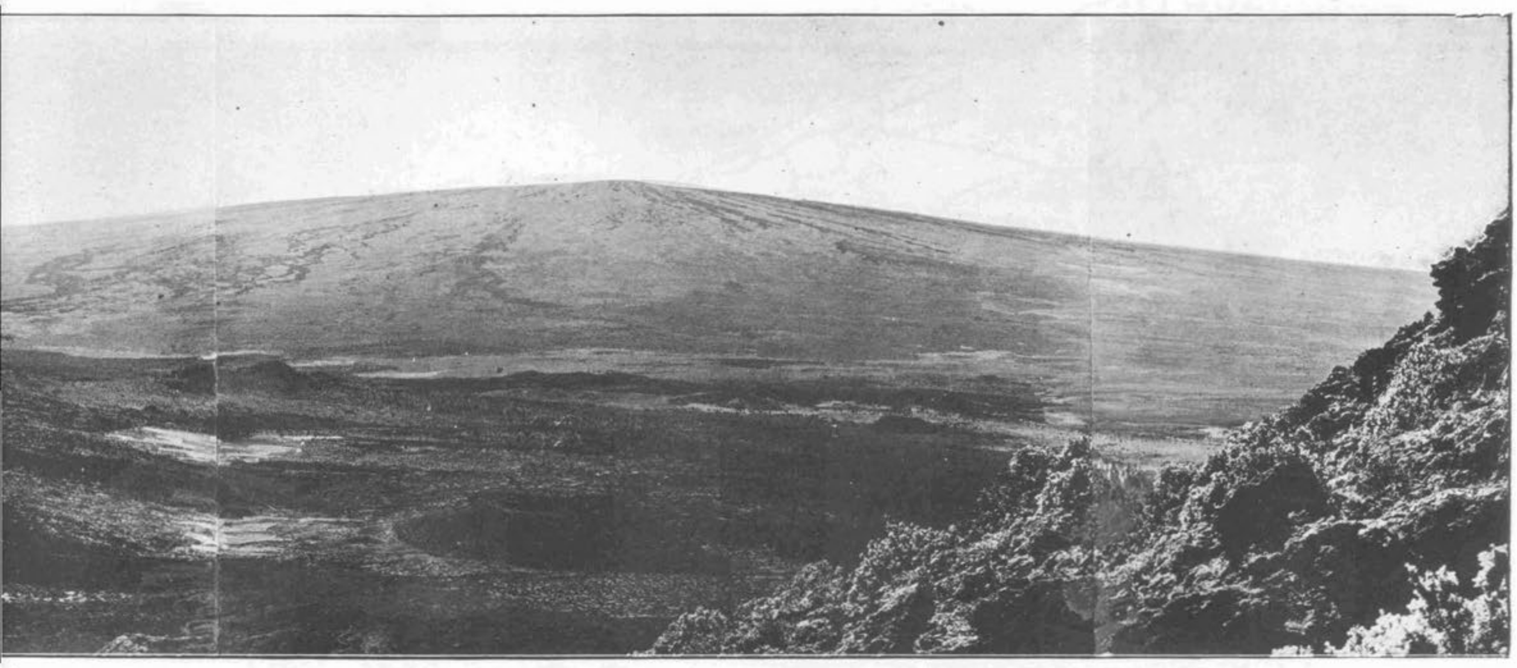
"The constructional surfaces of the old, high domes have been largely destroyed either by erosion alone or by erosion and downfaulting. On all the mountains either major or minor features of the relief have been formed by faulting, and in the ultimate destruction of the domes, faulting is one of the chief agents.

"West Oahu, West Molokai, and West Maui each became extinct before the eastern member of these doublet islands. The landscape of Kohala is the oldest on Hawaii."

Probably both of the Oahu domes are older than Kauai since the close of the last principal volcanism. The more rapid rate of fluvial erosion on Kauai, owing to the climate, does not establish the greater age of the landscape. The relatives ages of the landscapes of the high old domes appears to be: (1) West Oahu, (2) East Oahu, (3) Kauai, (4) East Molokai. West Maui and Kohala are younger, but their sequences is yet to be determined."

"Neglecting buried landscapes, the oldest landscape in the windward Hawaiian Islands is that of the Penguin Bank The final products of the destruction of lava domes are the volcanic stacks like Nihoa, roof islands, calcareous sand islands, and submarine banks without islands which make up the leeward group."

Hinds disagrees with Wentworth in the latter's belief that the Hawaiian Islands emerged in the late Tertiary. "The destruction of the leeward islands suggests that volcanism ceased there well back in the Tertiary, hence the mountains must have risen above the ocean long before, perhaps even in Mesozoic time. Buried erosion surfaces in the windward volcanoes prove that interruptions in the volcanic cycle took place and that there was deep erosion before the renewal of eruptions. The erosion of the present landscapes of the older domes probably began in late Tertiary or early Pleistocene times. The time required for the cutting of the great cliffs of Kauai very likely took at least two million years." T.A.J.



auna Kea has slopes of 12° to 40°, and Mauna Loa on the right 3° to 8°. The long 1859 flow sweeps to the left from Mauna Loa. The Mauna Kea) is incorrectly named "Hualalai" in pl. 16 of Hinds. Photo Emerson.

KILAUEA REPORT No. 1017

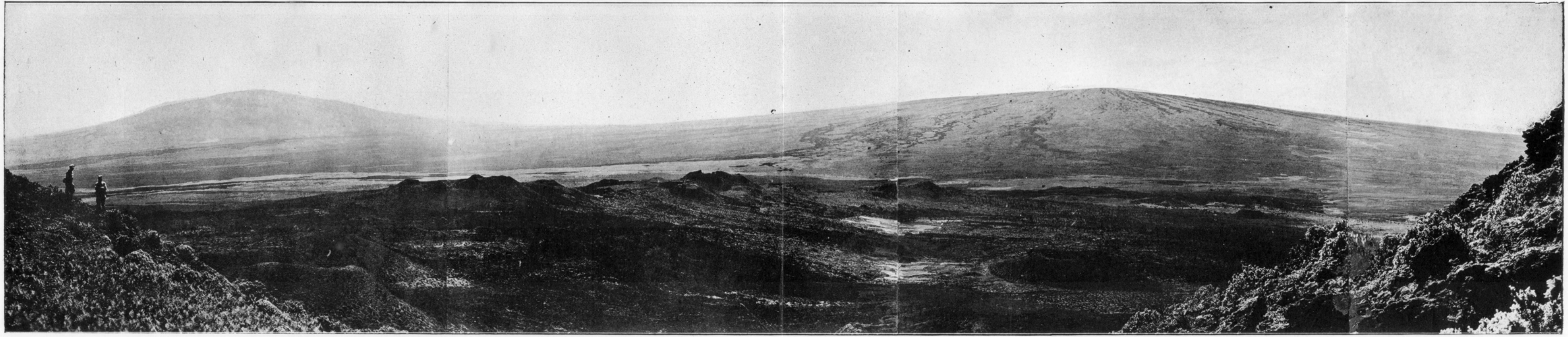
WEEK ENDING JULY 19, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Kilauea Volcano remains dormant. A few rocks were heard falling north at 11 a. m. July 16. On July 17 dust clouds from avalanches were seen at 5:30 and 9:40 a. m., and a scar showed on the northwest wall of Halemaumau. No fume or steam was reported visible during the week.

The instruments recorded 18 tremors and 3 very feeble local seisms. The average tilt movement for the week was slight northwest. Microseismic motion was slight.



Panorama of Mauna Kea and Mauna Loa from a summit cone on Hualalai. The near foreground of Hualalai shows a slope of 35°. Mauna Kea has slopes of 12° to 40°, and Mauna Loa on the right 3° to 8°. The long 1859 flow sweeps to the left from Mauna Loa. The foreground cones extend the Hualalai rift toward Mauna Loa. The left of this picture (Mauna Kea) is incorrectly named "Hualalai" in pl. 16 of Hinds. Photo Emerson.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year — Ten cents per copy

No. 344—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — July 30, 1931

THE LANDSCAPE OF MAUNA LOA

Hinds speaks of Mauna Loa and Kilauea (Hawaiian Landscapes, Bull. Geol. Univ. of Cal. Vol. 20, No. 6, 1931) as being still under construction, with shallow weathering, and stream gulches only where eruptions have not recently taken place. "On certain parts of the rainy, windward side of the mountains, where flows have not been erupted for long periods of time, the lavas are decomposed enough to allow the growth of a heavy jungle forest in the soil cover. The more recent lavas are virtually untouched by ground water or atmospheirc solutions, and even in the rainest sections, have little or no vegetation on them."

This last statement is not correct for the 1881 flow at Hilo, where the rainfall is 200 inches, and good sized trees and bushes cover the flow.

"Where the climate is dry, weathering is much slower and there is little soil on any of the flows." This is particularly true of the Kau Desert on the southwest side of Kilauea, of Kahuku on the southwest side of Mauna Loa, and of the northwest flows of Hualalai. These places have rainfalls of 30 to 70 inches.

"Only a few permanent streams are present, and these have not cut deep valleys. Most of the constructional surface is unbroken. The eruption of new lava apparently is sufficiently frequent to cover most of the exposed surface before any considerable amount of weathering or erosion can take place.

"Short stretches of the coast are cliffed to heights of 50 or 60 feet, since flows apparently do not reach sea level often enough to prevent some inroads by wave abrasion. The occasional flows which pour into the ocean repair in part destruction thus caused. Low fault scarps are present, especially on the southeastern flanks of the domes, and part of the cliffed southeastern coast (of Hawaii Island) has been developed by faulting.

"Parasitic cinder cones in considerable numbers dot the flanks of the dome; part of these show rude linear arrangement as though erupted at various points along radial fissures.

"At the summits of both Mauna Loa and Kilauea are volcanic sinks, in which the principal eruptive center is located." Mokuaweoweo the Mauna Loa crater being 3½ by 1¾ miles in dimensions and 800 feet deep; Kilauea Crater 2 by 1¾ miles and 500 feet deep.

"The sinks are depressions resulting from the collapse of the crust in the vicinity of the principal eruptive center as liquid material has been emitted from below the surface. Small step-faulted blocks are present locally about the walls of the sinks." Near the middle is the conduit pit through which the lava rises and falls, in the case of Kilauea. Mokuaweoweo has cones and pits in the middle.

"As long as activity prevails at the central vents or eruptions take place from lateral fissures, the surface may be periodically renewed and the pre-existing topography blotted out. The final constructional outlines therefore are not complete.

"Kilauea is a small mountain far down on the southeast side of Mauna Loa at an elevation of about 4,000 feet. The relative ages of the two domes has been disputed. Jaggar formerly held that Kilauea is the older of the two, and that Mauna Loa has grown up in a great vale between Kilauea and Mauna Kea. Daly believes that Kilauea is fed by a laccolithic offshoot from the larger volcano, and now is independent of the main reservoir because of the sealing of the connecting channel. **It is now generally accepted that Kilauea is the younger mountain."**

"Field evidence supporting this view has been presented by Stone, who has recently described the general features and the geology of the volcano. Stone notes that Kilauea is an independent dome on the flank of Mauna Loa, but because of the very gentle slope of both Mauna Loa and Kilauea its domelike character is not apparent in some parts of the area. Important data are given by Stone proving the superposition of the Kilauea volcanics on older lavas from Mauna Loa and the association of the Kilauean series with faults which developed in the side of the greater mountain."

With reference to the general acceptance of the youth of Kilauea, the reviewer does not know what this statement is based on. Mr. Stearns in his "Geology of Kau" (Water-supply Paper U. S. Geological Survey) leaves the question open. In Kapapala and along the valley between Kilauea and Mauna Loa it is Mauna Loa flows which are overlapping the Kilauea slopes. The great sink of Kilauea is an old-age feature of a major dome. It was not the vale between Kilauea and Mauna Loa, but rather between Kilauea and Hualalai, that appears to have lain under the modern slagheap of Mauna Loa. Mauna Kea was the ancestral dome at the northeast which blocked any growth of Mauna Loa in that direction. Hence the pronounced development of a long lobe of Mauna Loa into the sea at the southwest. Both Kilauea and Mauna Loa have parallel lava rifts, starting at their craters, and trending respectively southwest and northeast.

The history, however, was not so simple. Both Kilauea and Mauna Loa appear to be over an older topography. Kilauea sink is in line with two other sunken amphitheatres southwest of it, Wood Valley and Mohokea, back of Kapapala and Hilea. These three sinks appear to lie along a common rift in the ancient land which the new dome volcanoes are burying. The live Mauna Loa of the present day has three centers of lava heaping, northeast, on top, and southwest. The accompanying panoramas show something of this vast bulky mass. T.A.J.

KILAUEA REPORT No. 1018

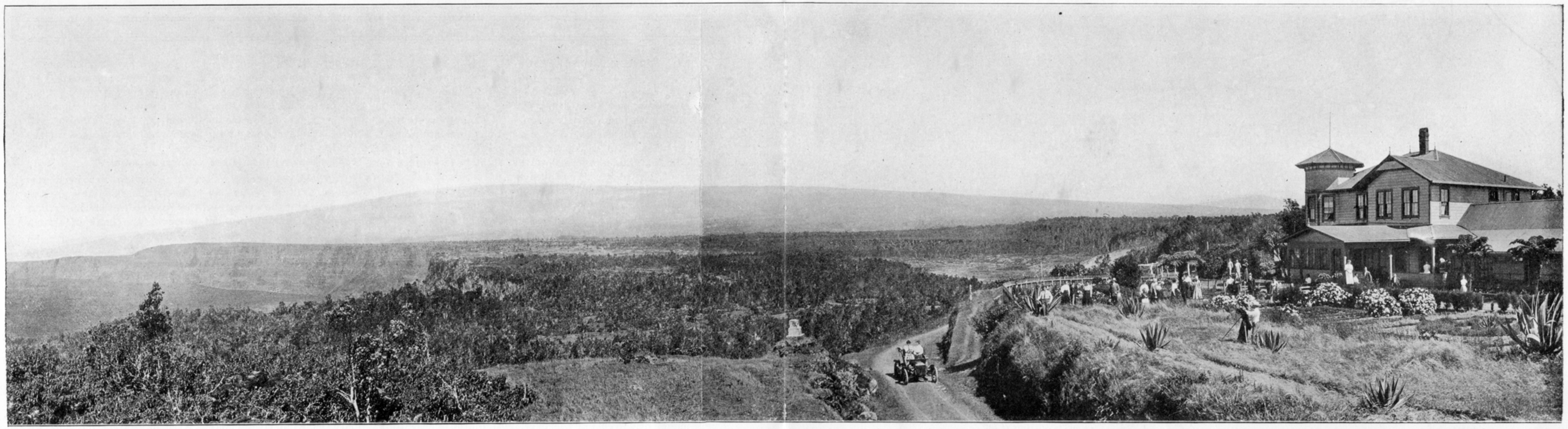
WEEK ENDING JULY 26, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

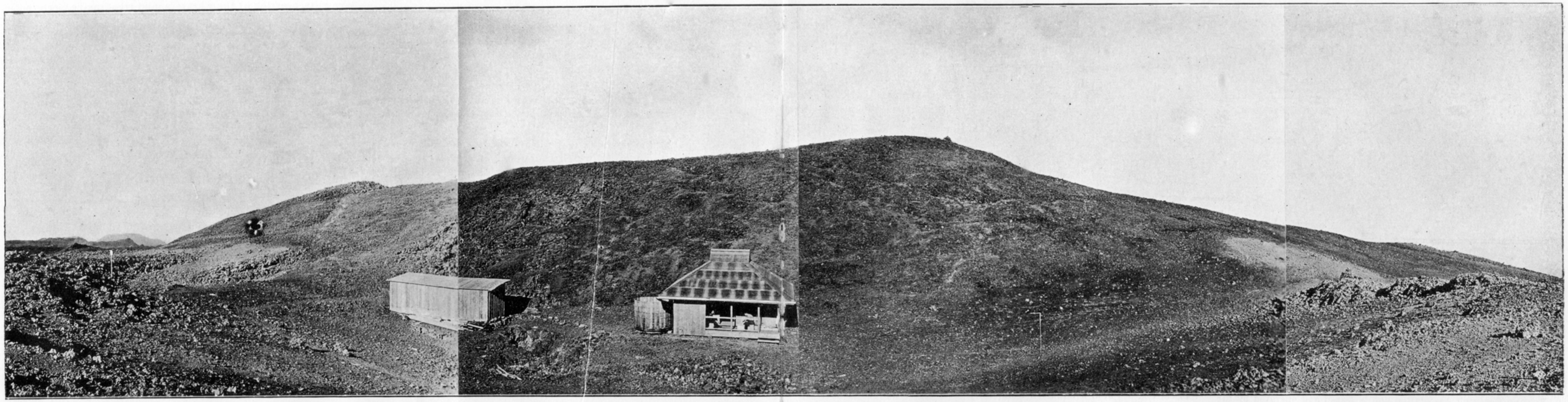
On Monday, July 20, the interior of Halemaumau was partly obscured from view by fog and light rain. Some steam was seen at the southeast rock slope. Heavy rains Tuesday caused great steam clouds to rise from the pit. All vents within the pit were steaming actively on July 22. Fuming was also strong at two places north of the 1930 cone. The pit seismograph showed heavy tilt due to the weight of rain water in the vicinity.

The seismographs at the Observatory registered three spells of strong continuous tremor on July 23: 6:43 to 7:05 a. m., 7:49 to 8:02 a. m., and 5:31 to 5:45 p. m. In addition there were 16 tremors and 2 seisms.

Average tilt for the week was slight NE. Microseismic motion was strongish on July 21 due to windstorm, and thereafter slight.



Panorama of Kilauea Crater, Mauna Loa, Mauna Kea, and Volcano House, looking west. Shows the three lobes of Mauna Loa and the valley between Mauna Loa and the foreground ridge of Kilauea. Mauna Loa slope 6° on left, 4° on right. Photo Gartley about 1912.



Puu Ulaula, or Red Hill, looking north, showing the rest house on the northeast rift of Mauna Loa. A characteristic old clinker-lava cone at elevation 10,060 feet. Center of the northern lobe of Mauna Loa. Photo Wood in 1916. Slope 20° on left, 10° to 19° on right.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

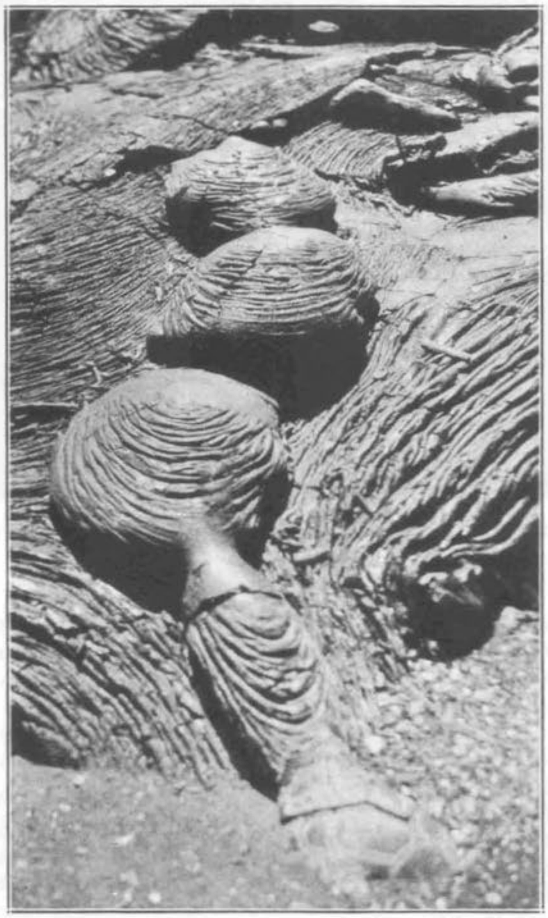
The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year — Ten cents per copy

No. 345—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — August 6, 1931



Toes of pahoehoe lava on north floor of Kilauea in 1919 lava. Photo Maehara.

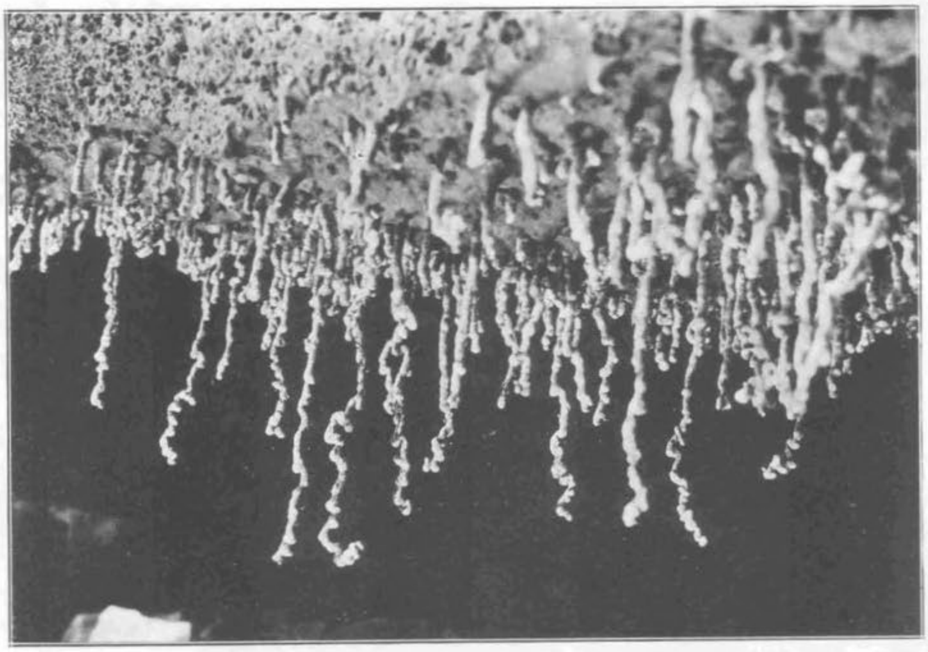
LAVA STALACTITES, STALAGMITES, TOES, and "SQUEEZE-UPS"

In Volcano Letter No. 300 Professor Colton described "squeeze-ups" in lava fissures whereby basaltic magma plastic like stiff clay has been forced up a crack several feet into the air, with sides of the solidified paste grooved like slickensides as it scraped past the roughnesses of the walls of the fractured rock. As something of this kind occurs in Hawaii on both big and small scales, and in addition we have stalactites and stalagmites of entirely different origin which have been erroneously attributed to water, it would seem of interest to review the subject.

The supreme "squeeze-up" of history is the Pelee spine in Martinique. All lava dome eruptions are similar in origin and one may quite justifiably inquire whether "squeeze-ins" as well as "squeeze-ups" do not constitute many of the intrusions of geology. The hydrostatic pressure of granitic intrusions at Schneeberg in Germany is such that it split folia in slate, penetrated between the thin paper-like layers of the slate, and recrystallized the clay to hornstone. The Pelee spine was a central pencil of paste in a cumulo-dome, scored vertically on the outside as it scraped the walls of its container and rose 1,000 feet into the air. Then its top curled over and spalled off. It was never sucked back, but flaked away to a stump. Its composition was a hypersthene andesite, and so it was more viscous and refractory than basalt.

In the history of "bench magma" inside Halemaumau pit there have been many occasions when the crags of semi-solidified basaltic paste at 900° C., forming the walls of the container of the lava lakes—not the walls of the pit —have risen as separate pencils of paste within other material of greater hardness. When they did this they showed scraped surfaces. When the entire lava column of this bench material has lowered rapidly, it has fractured into terraces on the insloping funnel wall of old rock, and the terrace faces show scraping made by the sinking block of the next terrace below.

In the filling of basins with pahoehoe lava by overflow



Worm stalactites from glaze of roof of cavern, Kilauea floor. Photo Maehara.

in the larger craters, there are built "schollen-domes" or hillocks of swelling crust. What was a puddled flat, with ropy lava shell, begins in the course of hours to swell up. A laccolith of basalt paste is rising inside, because of some equation between resistance to further spreading and resistance to upward lift. If upward lift is the easier for the onflow of the feeding stream which is pouring through a tunnel to feed the flat, there will be no further escape of "toes" pushing out from under the skirt of crust. When the swollen dome, 50 to 100 feet across, lifts a shell 3 feet thick, there finally arises a star-shaped opening between sectors in the top of the dome. The dome gets to be 10 or 15 feet high. Then the paste "squeezes up" through the opening on top. It either trickles down and skins over, or it sputters up and builds a spatter cone. If it has partially crystallized inside the heap it may rise as an "aa" or clinker lava pudding and so produce a stiff plug or spine or "squeeze-up," to use Colton's expression.

The picture on Page One shows four toes with festooned skins of pahoehoe lava which has welled up from a crack in the floor of Kilauea Crater in 1919. Each toe is derived by squeezing out from under the skirt of the toe next preceding. The festoons are convex downstream. The farther toe welled up a crack, the next two were progressively formed by swelling and rupturing fronts, and the long one in the foreground is double and exhausted the lava available. While incandescent and in action these toes or "pushes" as Brigham called them resemble a bag of red jelly. They are a foot or two in diameter.

Stalactites and stalagmites in grottoes and caverns tell quite a different story. Here again there are some which are products of splash phenomena, and are nothing more than lava drip where a stream has vacated its banks and left pointed glassy shreds hanging from shelves. Not so with such vermiform or rod-like stalactites and driblet spires as are shown on Pages Two and Three. These photographs were taken by flashlight in a cavern on the Kilauea Crater floor. Such caverns were in 1919 red hot and full of flowing lava. They were formed by streams which crusted over and then kept on flowing under a bridge of crust. These same streams in tunnels of their own congealment are what lead at the front of a flow to the escape of toes such as are depicted on Page One.

But there comes a time in every flow where the supply of lava diminshes. In such case the amount flowing from the source does not equal the capacity of the tunnel. Accordingly the river of melt bubbling along inside the tube lowers so that the upper half of the pipe is full of gas or air, the walls are of bright yellow incandescence, and the gases escaping from the lava are continually burning to maintain a very high temperature on the ceiling of the cavern. With this temperature above 1,200° C., air being sucked in below as the hotter gas escapes through cracks and windows in the roof, there is set up a blast furnace condition often maintained for weeks or months on the inner rock lining of the cupolas in the ceiling and of the side walls of the tunnel. This flow of gas quietly burning with great volumes of excess oxygen dragged up the tunnel from inumerable holes, cracks, and pores, melts the tunnel walls to a glaze of quite different crystallinity from normal lava.

In 1919 it was repeatedly possible to go to the "windows" of collapse in the roof of the "Postal Rift Tube," where from Halemaumau a torrent of lava was flowing through a tunnel, and to look inside and see an orange-hot cavity with a golden river sweeping by underneath, little bubbles continually breaking the surface of the glowing stream, and adding gas to the evenly brilliant walls. On these walls hung motionless stalactites, some like currants, some like grapes, some like walking sticks, and some like worms. These are what are shown in the photographs. They are the material of the gas-melted glaze. They form very slowly. When incandescent they may be rocked back and forth like macaroni before it has dried.

If the heat has fallen below their formation temperature, a touch will break them off. They do not trickle. They form by accretion.

If we take one of the worm stalactites and examine it with a lens, its outer skin has very delicate tracery of ripples in a silvery coating of magnetic oxide of iron. If we break a worm stalactite it has vesicles inside lined with crystals of feldspar and augite. If we make a thin section of a solid part it is crystalline, but different in texture from crystalline basalt. If we break a rod stalactite it may be hollow like a pipe-stem. The stalagmites underneath must be made by drip in some early high-temperature stage of the stalactite formation above them. I have never seen worm stalactites so hot that they were visibly dripping. In any case the drip is melted rock, and has nothing to do with water. These stalactites are sometimes two feet long.

There are two kinds of extrusion within caverns which are direct squeezings of molten slag. One is a "miniature volcano" of the cavern floor. Types of these are seen in the innermost recesses of Thurston's tube at Hawaii Natoinal Park. It is cone or pie-shaped with slopes like a miniature Vesuvius. Another is the "barnacle stalactite" squeezed through pores or cracks in the cavern walls while all are incandescent. These things are all products of pressure adjustment between cracking shell of cavern and molten matter in the flow beyond the shell. The barnacle stalactite has striations on the sides and may even be a thin papery layer which has oozed through a small crack and stands out from the wall. Lastly, there are glaze stalactites which take massive forms like udders and teats. T.A.J.

KILAUEA REPORT No. 1019

WEEK ENDING AUGUST 2, 1931

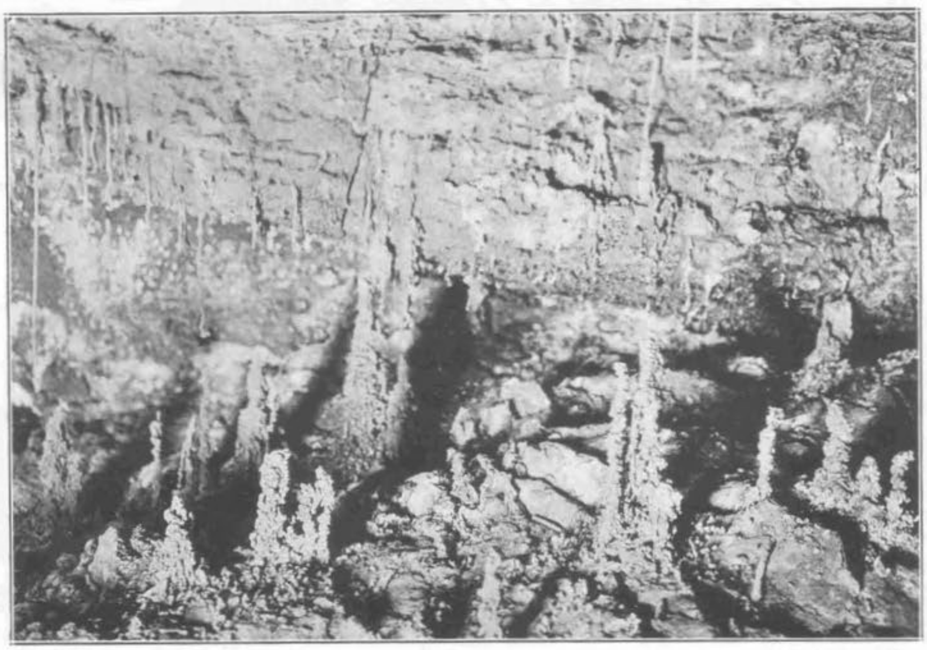
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

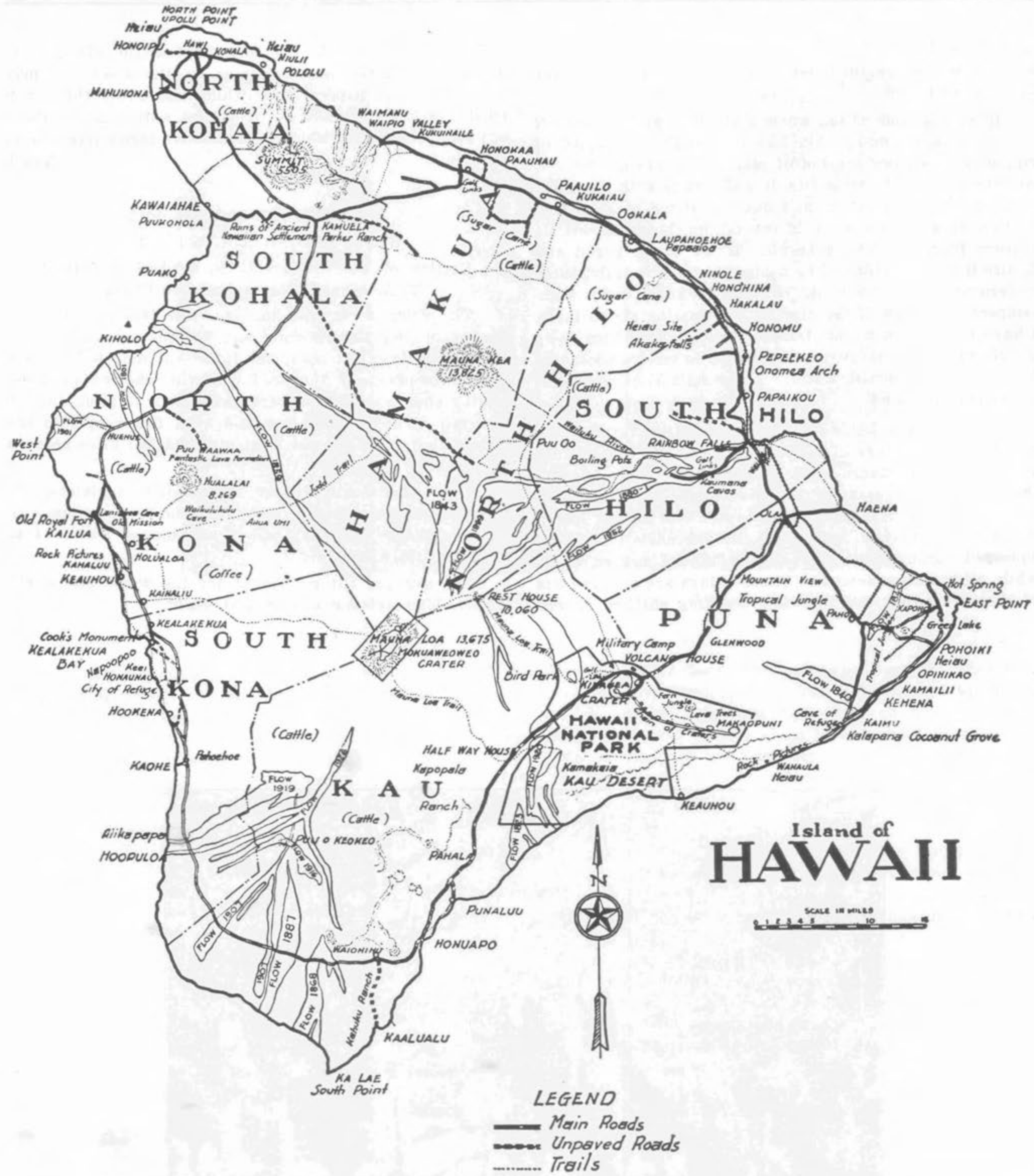
The volcano remains inactive. On July 27 some sulphur spots on the Halemaumau bottom seemed a little brighter yellow. No steam or fume was detected. Crack measurements near the southeast rim showed no noteworthy changes. A local earthquake at 2:43 p. m. July 30 was felt at the Observatory and by a few people in the near vicinity. It has not been reported felt elsewhere on the island.

The instruments at the Observatory registered 15 tremors, one very feeble seism, and one feeble seism. In addition there was one spell of continuous tremor 4:43 a. m. to 5:09 a. m. July 30.

The avarage tilt movement for the week was slight NNW. Microseismic motion was slight.



Worm and rod stalactites, and stalagmite spires below, inner recesses of cavern, Kilauea floor. Photo Maehara.



THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members two dollars per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

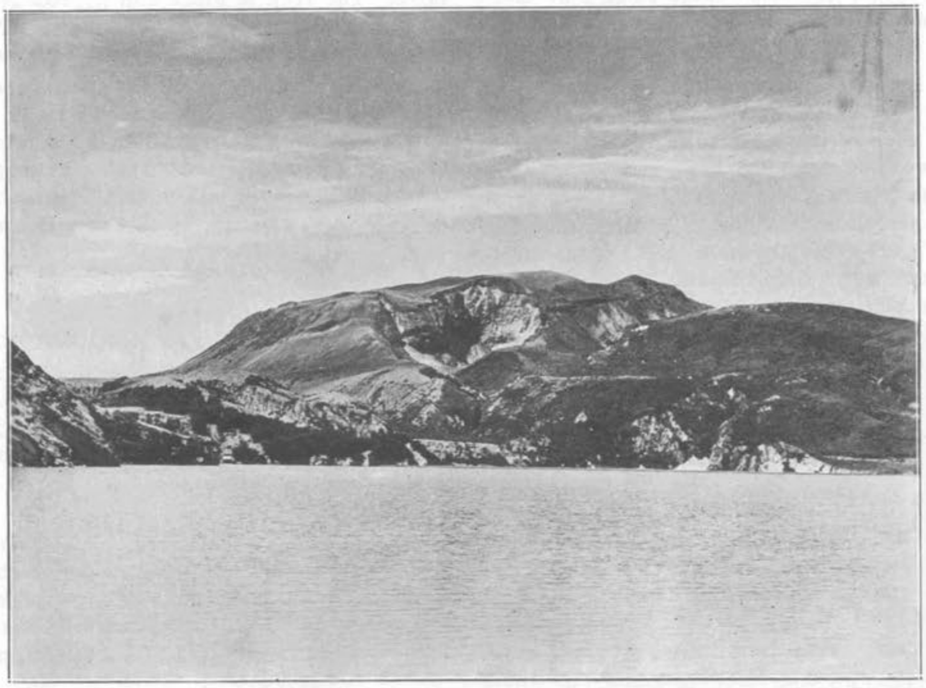
The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 346—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | August 13, 1931



Tarawera Volcano and the Tarawera chasm of 1886, showing the refilled Rotomahana Crater in the foreground. Country covered with ash. Photographed in 1925 by Baker.

ERUPTION OF TARAWERA

In June of 1886 a steam-blast eruption took place from the old volcanic mountain Tarawera and the geyser basin Rotomahana. This event in the thermal springs district of the North Island of New Zealand is worthy of review. The volcano region lies 60 miles to the west of Napier, which was stricken by earthquake February 3, 1931 (Volcano Letter No. 327).

Tarawera lies in the Taupo volcanic zone trending N. 38° E. from Ruapehu to White Island. This zone is famous for many hot springs, geysers, mud volcanoes, and solfataras. Masses of heated magma must exist at no great distance below the surface. Ruapehu, Ngauruhoe. and Tongariro, in the southern part of the zone, are definitely active volcanoes 5,500 to 8,900 feet high. Lake Taupo is in a subsided area north of these volcanoes and covers 242 square miles. About midway between Lake Taupo and the Bay of Plenty is Tarawera Lake, northeast from Lake Taupo. Tarawera Mountain is next to the lake, a flat-topped mass of porous rhyolite lava of light gray color, standing 3,606 feet above sea level, and 1,040 feet above the lake. It was not known to be an active volcano, but studies of its structure show that it is a true cone, with beds dipping outwards, lava streams on its lower slopes, and a plug of what was viscid lava from a former eruption in a NE-SW fissure on its top. There is something of concentric structure in this lava cap.

The warm lake Rotomahana lay two miles southwest of Tarawera, bordered by hot springs and jets of steam. The siliceous sinter of the White and Pink Terraces was on ground which sloped down to the shores of this lake. Water which overflowed the terraces boiled as geyser in the basins above. Rotomahana with its terraced sculpturing, azure warm waters, flocks of dainty terns, and greenery amid steam jets was one of the fairylands of the globe.

At the top of the White Terrace was a snow-white geyser bowl 90 feet broad full of clear blue water boiling up violently in gushes 15 feet high. The basin became dry when south wind blew, but filled again when the wind changed. When the basin was almost full on these occasions, columns of boiling water 20 feet in diameter were hurled 60 feet into the air. In November 1885 there were unusual eruptions of this geyser sending a column of water up 150 feet and of steam 1,020 feet, unheard of in the experience of the resident Maoris. This was the prelude to the great eruption eight months later. The acid waters of the crater basin on White Island Volcano in the Bay of Plenty disappeared in the middle of 1885, leaving the bed dry. In April of 1886 Ruapehu sent up unusual steam jets, At the beginning of June, 1886, a creek went dry on Lake Tarawera, then with a rushing sound the lake water came running up, overflowing the creek bed, and thereafter retiring twice after the fashion of unusual flood waves. No earthquake was noticed, but some fault block movement in Tarawera Mountain may have caused the retirement of the waters.

The district is thinly populated. Natives on Lake Tarawera did not survive to relate what happened. The nearest observers were at the Wairoa, eight miles west of Tarawera. The previous year had been very dry. After a fine evening June 9, 1886, earthquakes occurred at 12:30 a. m. June 10 and increased in violence for an hour. The northern part of Tarawera Mountain split open and a column of black ash-laden steam arose. This spread to other parts of the plateau summit of the mountain. At 2:10 a. m. there was a violent earthquake, followed by a loud and prolonged roar. A black cloud ascended and spread outwards. Red-hot fragments were seen darting from the cloud. Lightning began to appear, there was rumbling, a red glow lit the scene and as fresh outbursts occurred the clouds were lit up with stronger glow. Fire-balls fell about the summit.

The fissure probably split its way southwest through Lake Rotomahana soon after 3 a. m., for about that time earthquakes were especially severe, the heaviest one happening at 3:20 a. m. Engulfment on a big scale probably occurred at this time. This continued southwest from Rotomahana to other craters. By 3:30 a. m. the whole line was in violent eruption for a distance of nine miles from beyond Tarawera on the northeast to Lake Okaro on the southwest. Glow was seen only at the Tarawera end. The clouds spread out, stones and sand began to fall at Wairoa about 3 a. m, then at Rotorua about 4 a. m., and a fierce southwest gale at this time drove the ash-laden cloud away from Rotorua in the direction of the Bay of Plenty. It dropped its ash over all the country between Rotorua and the sea. The chief violence of the eruption was over before 6 a. m. At Rotorua darkness lasted until after 9 a. m. At Wairoa ash fell until 9 a. m., and about Lake Tarawera many people were killed. In the direction to which the ash cloud was blown, at Opotiki, 47 miles away, it was pitch dark until 10:20 a m., when the fall of dust became lighter, and daylight gradually appeared. Detonations were heard even as far away as Hokianga (253 miles) and Auckland (133 miles).

Along the line of the great fissure a series of steam-blast craters was formed. The greatest was the Rotomahana Lake crater, with a hot lake left at the south and another at the north. A great chasm was left in the southern face of Tarawera Mountain, shown in the photograph on Page One, with the Rotomahana lake refilled. There were lines of pits at the north and at the south. The Pink and White Terraces were blown out, with fragments left in the debris. Bold Pinnacle Rocks of rhyolite stand near where the White Terrace geyser was. The southern portion of Rotomahana Crater is bounded by high cliffs of horizontal strata. Tarawera chasm in the hillside is a gash a mile and a quarter long. The bottom is marked by crater-like hollows. The largest hollow has a thousand-foot wall at its back Large trees were blown off the mountain and their stubs were found near Rotomahana. Molten augite andesite was believed to rise in the fissure during the glowing stages of the eruption, and was ejected explosively as scoriae, sand, and dust. There were also bombs one to eight inches in diameter, with cracked surfaces. The rock is black and approaches basalt, with sp. gr. 2.93. Olivine occurs sparingly. The only ryholite ejected was fragmental from old country rock.

At the south end of the Rotomahana Crater there developed in later years the famous destructive mud geyser Waimangu, irregular in its outbursts and at times behaving like a steam-blast volcanic eruption. On several occasions it caused loss of life. (From A. P. W Thomas, Eruption of Tarawera. N. Z. Gov't Report, 1888.) T.A.J.

TILTING OF THE GROUND FOR JULY

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily sesimograms by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in the direction given.

June 29-July 5	0.9 second W.
July 6-12	0.4 second NW.
July 13-19	0.7 second NNE.
July 20-26	0.4 second NNE.
July 27-August 2	0.8 second WNW.

KILAUEA REPORT No. 1020

WEEK ENDING AUGUST 9, 1931

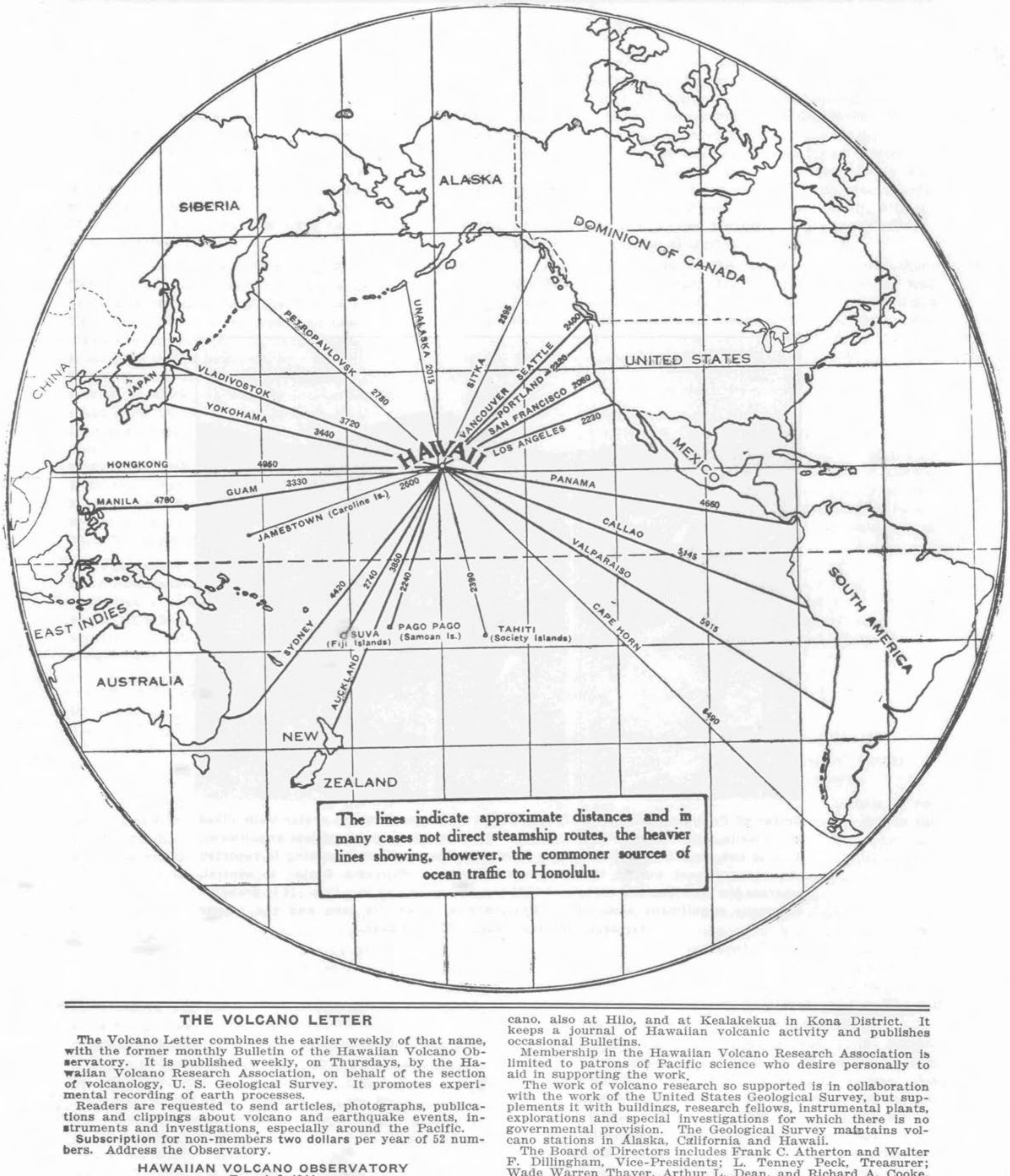
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The week at Kilauea passed without changes in volcanic conditions. On August 3 no fume was visible on the Halemaumau bottom. Steam showed at the southeast rock slope but not at the south talus. A strip of sulphur at the lower edge of the south talus appears to be spreading in the direction of the 1931 cone. Rim cracks were measured and showed no changes. On August 4 fume reappeared at the sulphur spot north of the 1931 cone. The pit seismograph had registered two small tremors with slight tilt toward the pit. On August 8 steam and fume were absent from the interior of the pit. A few rocks were heard falling on the north talus at 9:30 a. m. The pit seismograph recorded a few slow-period tremors.

There was a very considerable increase in the number of seismic disturbances recorded by the instruments at the Observatory, including 39 tremors and 6 seisms. One of the latter at 1:43 a. m. August 3 showed distance to origin 23 miles; another at 4:22 p. m. on the 8th showed distance 14 miles and was felt locally. In addition there was a teleseism at 3:54 p. m. August 6 feebly recorded.

The average of accumulated tilt was slight NE. Microseismic motion was slight.

Crater of Fujiyama, August 1917, showing a typical engulfment crater with dikes in its walls, with a section of a lava fill, and inner debris slopes of last engulfment. This is not especially different from Tarawera Chasm, though nothing is reported about engulfment during the Tarawera eruption. Fujiyama Crater is central, whereas the New Zealand craters of 1886 are numerous and in a line. It is probable enormous engulfment occurred at Rotomahana, when the lake and the geyser terraces fell into a void. Photo Baker.



THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

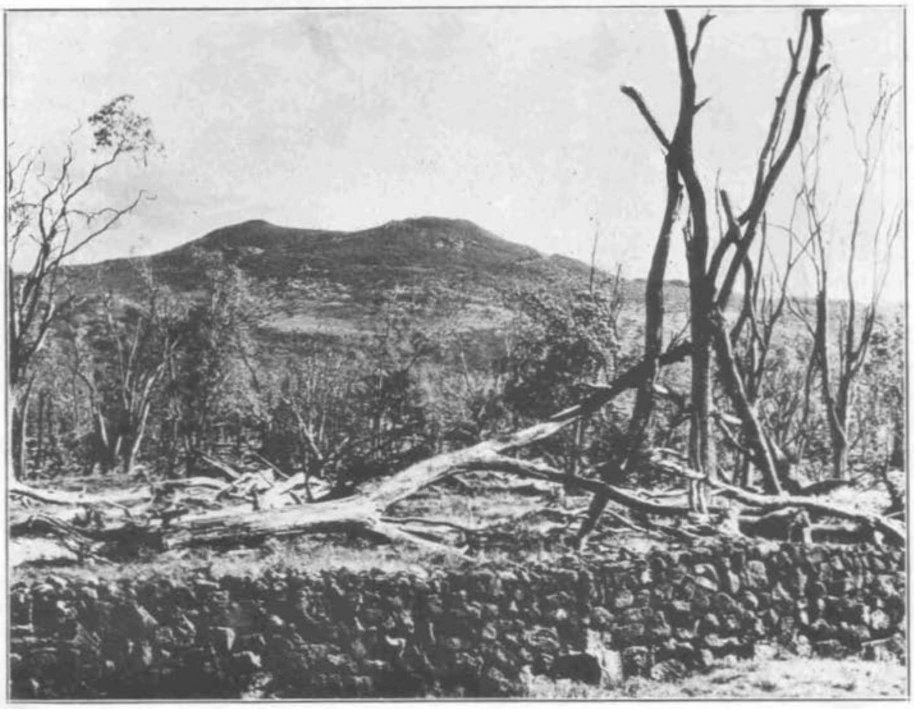
The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 347—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | August 20, 1931



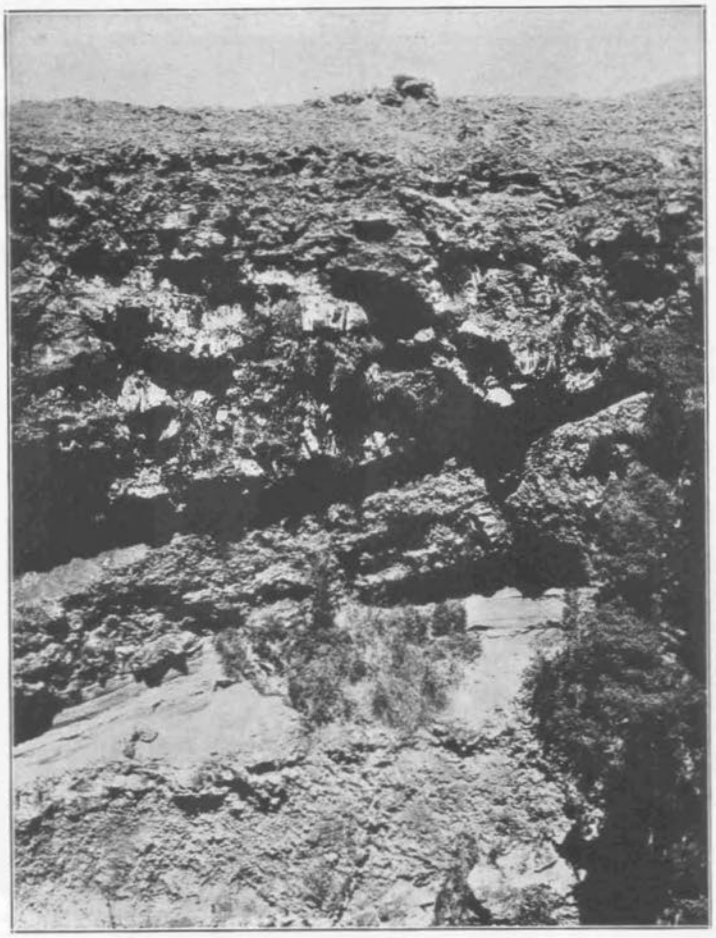
Hualalai as seen from the southeast. The two prominent points are large cones of cinder and slag. The largest summit pit crater is not visible but is located just over the skyline formed by the saddle between the two cones. Photo O. H. Emerson.

HUALALAI

Hualalai Volcano lies entirely within the bounds of the North Kona District of the Island of Hawaii. It has the shape of an elongated dome with the longer dimension of the dome lying almost on a line drawn due northwest from the summit crater of Mauna Loa. The belt road around Hawaii follows the slopes of Hualalai for a distance of more than 30 miles between Kealakekua and Waimea, half encircling the volcano. The broad fan-shaped plain which culminates in Keahole Point, the westermost point of the Island of Hawaii, is formed of pahoehoe flows from this volcano.

The summit peak of Hualalai has an elevation of 8,251 feet above sea level, more than twice the elevation of Kilauea Crater, but lacking more than 5,000 feet of attaining the extreme altitudes of Mauna Kea and Mauna Loa. Because of its moderate height, the mountain is covered with vegetation almost to its very summit. There is a remarkable contrast in type of vegetation on the two opposite slopes of the mountain due to different conditions of rainfall. The northeast slopes, the trade wind side, are reached by trade winds only after they have crossed the broad plains of Waimea and have lost most of their moisture. As a consequence, the entire northern slope of Hualalai has a relatively small rainfall, probably nowhere exceeding 40 or 50 inches of rain a year. The vegetation of this slope accordingly is made up of the kinds of plants which exist on a small amount of moisture, but it is sufficiently luxuriant to provide pasture for cattle so that most of the northern slopes are utilized as range land by the Huehue and Puuwaawaa ranches.

Conditions on the southwest or leeward slopes are very different. The area is sheltered from the trade winds by the mass of the mountain, so that a true land and sea breeze is characteristic. During the night, the slopes of the mountain cool off more rapidly than does the ocean which causes a breeze to blow from the colder mountain slope toward the warmer ocean. Then as the sun warms the mountain slope more rapidly during the morning hours than it does the surface of the ocean, the wind reverses and blows



A small pit crater near the summit of the mountain. In the wall is exposed an old lava flow (at bottom of picture) covered with several feet of bedded cinders from a nearby cone, and over all two or three flows of recent lava which have been poured out since the cinder cone activity. Photo O. H. Emerson.

from the sea onto the land. This day breeze is laden with moisture from the ocean, and as it cools on its way up the mountain side, it drops its excess moisture in almost the same general area every day. As a consequence of this combination of conditions, the rainfall gradually increases from sea level up the slope of the mountain till it reaches a maximum (over 100 inches a year) at an elevation between 2,500 and 3,000 feet, then decreases gradually from this rain belt to the top of the mountain. Thus the vegetation of the southern slope of Hualalai changes with this distribution of rainfall from the semiarid plants at sea level, through fern jungles in the rain belt, then back to the forests and grasses of the dry lands on the higher slopes. The belt road passes through a region of moderately heavy rain and the lands accessible from the road are used for coffee and other planted crops. The lower and upper dryer slopes are used almost entirely as grazing lands by the ranches of the area, but the narrow belt of highest rainfall is too wet and swampy for human use, so in the main is left as native fern jungle.

Hualalai is by far the most "climbable" of all the volcanoes of Hawaii. The ascent to its summit and side trips over its slopes are pleasure jaunts compared to the gruelling climbs to the summits of Mauna Loa or Mauna Kea or to the arduous wanderings through the jungles on Kilauea. It also is an extremely interesting volcano from the standpoint of the geologist or volcanologist.

The first mystery of Hualalai is the question of its relation to Puu Anahula and Puuwaawaa. These two areas are located on the northeast slopes of the mountain and are kipukas, or islands, left in the younger floods of lava from the top of the volcano. From their position so near to Hualalai, they would seem to be a part of that volcano, yet the lava of which they are formed is very different from all the other lavas of Hualalai, but very similar to some of the lavas of the Kohala volcanoes. So far the question has not been answered whether Puu Anahula and Puuwaawaa belong to a very old stage of the activity of Hualalai or whether they really are parts of the Kohala mountains.

Leaving this question open, it is known that the volcano as we see it began its activity by pouring floods of aa and pahoehoe lava out of a number of vents arranged along a fissure line or zone of cracks which is almost straight in a northwest-southeast direction. As more and more of these flows were poured out they built an elongated dome. Activity was more pronounced at one particular part of the fissure line so that the dome of flows was built up to a greater elevation at this spot. There may possibly have been a summit crater similar to Mokuaweoweo on the top of this Hualalai dome. Certainly the structure of the Hualalai dome, elongated along a line of cracks, is very similar to the structure of Mauna Loa as it exists today.

Gradually the eruptions from the Hualalai dome began to change from quiet outpourings of lava flows to eruptions which were more violently explosive and which broke up the molten lava into small particles of cinder and ash. These cinder eruptions broke out in many places along the main rift line and built up huge conical piles of cinders and ash, as well as poured out smaller flows of aa lava. Many of these cinder piles can be seen on the lower slopes of the mountain below the Huehue Ranch, and the two most prominent ones form the two highest points of the mountain.

After these explosive eruptions, for some reason the activity changed back again to the more quite type, and the later flows have been poured out with less explosive activity at the source vent. Accompanying this change in type of activity, the main activity seems to have shifted from the center of the volcano out along the rift line in both directions from the center. There has been a moderate amount of the later activity at the top of the dome, enough to pour out a few small flows and to build several large pit craters at the top, but by far most of the later flows have been poured out from points on the rift line down both slopes from the center. Most of the pit craters and slag cones which show up so well along the rift line on the relief map which was made by Dr. Pope have been formed during these later eruptions.

This type of activity has continued into historic time. There have been apparently several flows from Hualalai since the occupation of the island by the Hawaiians according to accounts given by natives to Ellis in 1823. He says: ". . . . the traditional accounts given by the natives of the eruptions, which, from craters on its (Hualalai) summit, had in different ages deluged the low land along the coast; . . . ." (Ellis, p. 53). The only activity which has occurred since the arrival on the island of English settlers took place in 1800-01. On Dr. Pope's relief map two recent flows are shown on the north slope of the mountain. The western and shorter one of these is marked as the flow of 1801, and the other as the flows of Kaupulehu. There has been a considerable discussion as to whether or not both of these flows are of the same date, i.e. 1801. In a personal communication Dr. Pope states that he is convinced that the Kaupulehu flow belongs to the 1801 eruption.

Ellis' description of a visit to the source crater of the 1801 activity certainly seems to indicate that the Kaupulehu flow is the one in question. Parts of his description follow:

"Having traveled about 12 miles in a northeasterly direction, they arrived at the last house on the western side of the mountain." (Probably Huehue Ranch) ". . . . Leaving the path, the party began to ascend in a southeast direction and traveled about six miles."

At this spot the party spent the night. The location of their camp probably was on the northwest ridge of Hualalai, a few miles above the present belt road.

"Having united in their morning sacrifice of thanksgiving to God, and taken a light breakfast, they resumed their laborious journey. The road, lying through thick underwood and fern, was wet and fatiguing for about two miles, when they arrived at an ancient stream of lava, about twenty rods wide, running in a direction nearly west. Ascending the hardened surface of this stream of lava, over deep chasms, or large volcanic stones imbedded in it, for a distance of three or four miles, they reached the top of one of the ridges on the western side of the mountain.

"Between nine and ten in the forenoon they arrived at a large extinguished crater, about a mile in circumference, and apparently 400 feet deep, probably the same that was visited by some of Vancouver's people in 1792. The sides sloped regularly, and at the bottom was a small mound, with an aperture in its centre. By the side of this large crater, divided from it by a narrow ridge of volcanic rocks, was another fifty-six feet in circumference, from which volumes of sulphureous smoke and vapour continually ascended. No bottom could be seen; and on throwing stones into it, they were heard to strike against its sides for eight seconds, but not to reach the bottom. There were two other apertures near this, nine feet in diameter, and apparently about 200 feet deep.

"As the party walked along the giddy verge of the large crater, they could distinguish the course of two principal streams, that had issued from it in the great eruption, about the year 1800. One had taken a direction nearly northeast; the other had flowed to the northwest, in broad irresistible torrents, for a distance of twelve or fifteen miles to the sea, where driving back the waters, it had extended the boundaries of the island. They attempted to descend this crater, but the steepness of its sides prevented their examining it so fully as they desired."

H.A.P.

KILAUEA REPORT No. 1021

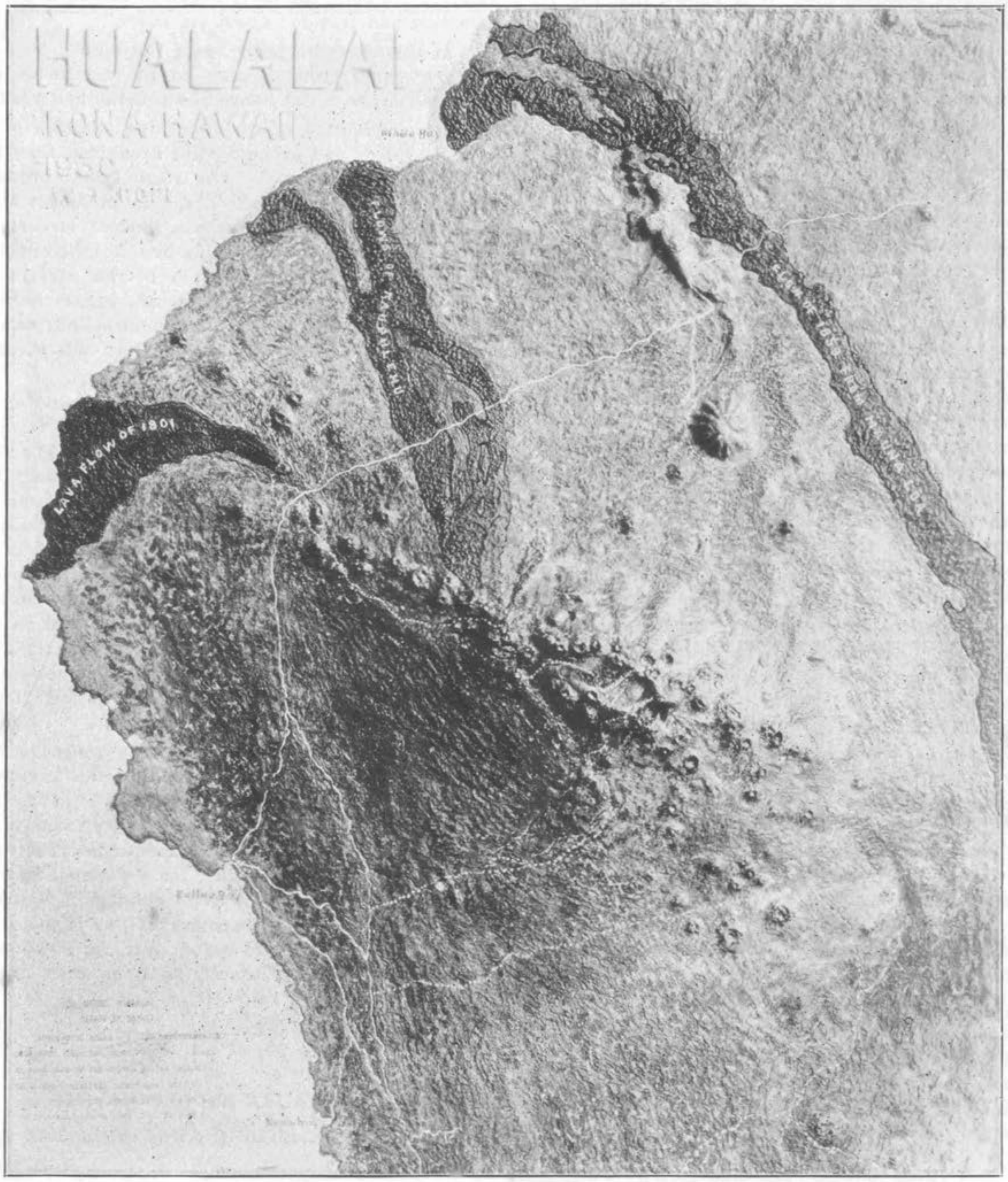
WEEK ENDING AUGUST 16, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

There is nothing new to report. Steam and fume were detected occasionally at vents within Halemaumau, usually very thin as dry weather has prevailed. On August 13 about 9 a. m. there was a large avalanche from the middle of the northwest wall, causing much dust. Another avalanche dust cloud was observed from Uwekahuna about 9:20 a. m. August 15.

The seismographs at the Observatory recorded 23 volcanic tremors, six very feeble local seisms and one teleseism. Three seisms gave indicated distances as follows: August 12 6:11 a. m., 4 miles; August 13 6:20 a. m., 11 miles, and 7:03 a. m., 5 miles. None was reported felt. The teleseism registered at 11:04 a. m. August 10 without distance phases.

Tilt for the week was slight NNE. Microseismic motion was slight.



Model of Hualalai, 1930, by Willis T. Pope. Shows recent flows and the northwest-southeast summit rift well marked by cinder cones and pit craters. Distance from Kailua Bay to Keauhou Bay (southwest corner) is about six miles

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subscription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year — Ten cents per copy

No. 348—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — August 27. 1031

A typical pahoehoe surface on a lava flow. The skin of vesicular glass which forms rapidly is often wrinkled and contorted into curious shapes. Flow from southwest flank of Kilauea December 1919. Photo Finch.

VOLCANIC PRODUCTS

The statement is often made that the islands of the Hawaiian group have been formed by volcanic action. In other words, the islands are built of materials which have been thrown out from a number of separate volcanoes. It may be of interest to consider in some detail what these volcanic products are of which the Hawaiian Islands are made.

Geologists who have studied the question are rather well agreed that the basin of the Pacific Ocean is made up largely of a kind of rock known as basalt. One of the facts on which this statement is based is that most of the material thrown out of the numerous volcanoes in the Pacific Ocean basin is basalt of nearly uniform composition. This is certainly true in the Hawaiian Islands. All of the volcanoes in the Hawaiian group have drawn the materials for their eruptions from a common, deep-lying supply of basalt. Geologists do not agree as to the exact physical condition in which the basalt exists under the ocean. However, for the study of volcanic products it is unnecessary to determine this original condition. We are interested in the basalt only after it begins to be erupted from one of the volcanoes.

Under appropriate conditions of heat and pressure, part of the deep supply of basalt under a volcano becomes liquid, and then is capable of being erupted from the volcanic vent at the surface of the earth. When it is in this liquid condition it is called "magma." Magma may be defined simply as liquid rock. In more detail it may be defined as a solution of a number of chemical elements in different chemical combinations just as sea water is a solution of many chemical elements, the most important of which are sodium chloride (common salt) and pure water. Chemists express the amounts of the different elements in a rock in terms of their weight when combined with oxygen. A typical basaltic magma would be made up of the following principle elements in the given proportions:

Oxide of silicon	50%
Oxide of aluminum	14%
Oxide of iron	10%
Oxide of magnesium	8%
Oxide of calcium	10%
Oxide of sodium	3%
Oxide of potassium	1%
Other substances	4%

In addition to the main elements, the magma contains very small amounts of many substances such as water, manganese, titanium, phosphorus, sulphur, nickel, chromium, copper, chlorine, carbon, and molybdenum. Thus we see that a magma is a very complex liquid made up of a large number of elements in solution.

The magma can exist as a liquid only at very high temperatures. Dr. Jaggar made a number of measurements of the temperatures in different parts of the magma lake ranging from about 750 degrees Centigrade to 1,500 degrees Centigrade. Iron in a blast furnace would be white hot at the higher of these temperatures.

When the magma begins to rise in the throat of the volcano, some of its elements begin to combine to form gas such as water vapor, sulphur dioxide, and carbon

The lava flow from Mauna Loa in 1926 as it crossed the road like a moving cinder pile. The clinkery, broken surface of the aa flow is radically different from the smooth, glassy surface of the pahoehoe flow, yet the lava forming the two different flows may be of exactly the same composition. Photo Boles.

dioxide. The gas comes out of the magma solution, begins to expand and form bubbles, and cause the whole mass of the magma to swell and froth like soda water in a bottle after the cap is removed. The expanding gas makes pressure within the liquid magma which helps force it to the opening in the crater of the volcano and makes the magma erupt. If the gas pressure is relatively low and the opening to the volcanic vent is fairly open, the escaping gas makes fountains of liquid lava at the vent such as are seen in Halemaumau or at the heads of the Mauna Loa flows. However, if the gas pressure is great and the escape of gas is partly obstructed, the lava may be thrown out of the vent with great violence. These stronger gas explosions break the lava up into drops and fragments of different sizes so that, instead of a lava flow, an eruption of volcanic ash and cinders will result. Such activity has formed the large cinder cones on Mauna Kea and such craters as Diamond Head on Oahu.

Going back to the magma, as the gas begins to bubble out and the lava rises in the volcano, its temperature is lowered by radiation of heat to the rocks forming the throat of the volcano and to the open air. As the temperature drops, some of the constituents of the magma combine and crystallize from the solutions as minerals which can become solids at high temperatures. Olivine (Hawaiian diamond) is one of these minerals which begins to form crystals while most of the magma is still liquid. Some of the liquid lava dipped from Halemaumau had large crystals of olivine floating in it. Since the olivine crystals begin to grow before the lava is erupted, many of them attain a large size and are conspicuous in some flows as large greenish crystals known as phenocrysts Olivine is made up of magnesium, iron, and silica and is called a magnesium-iron silicate.

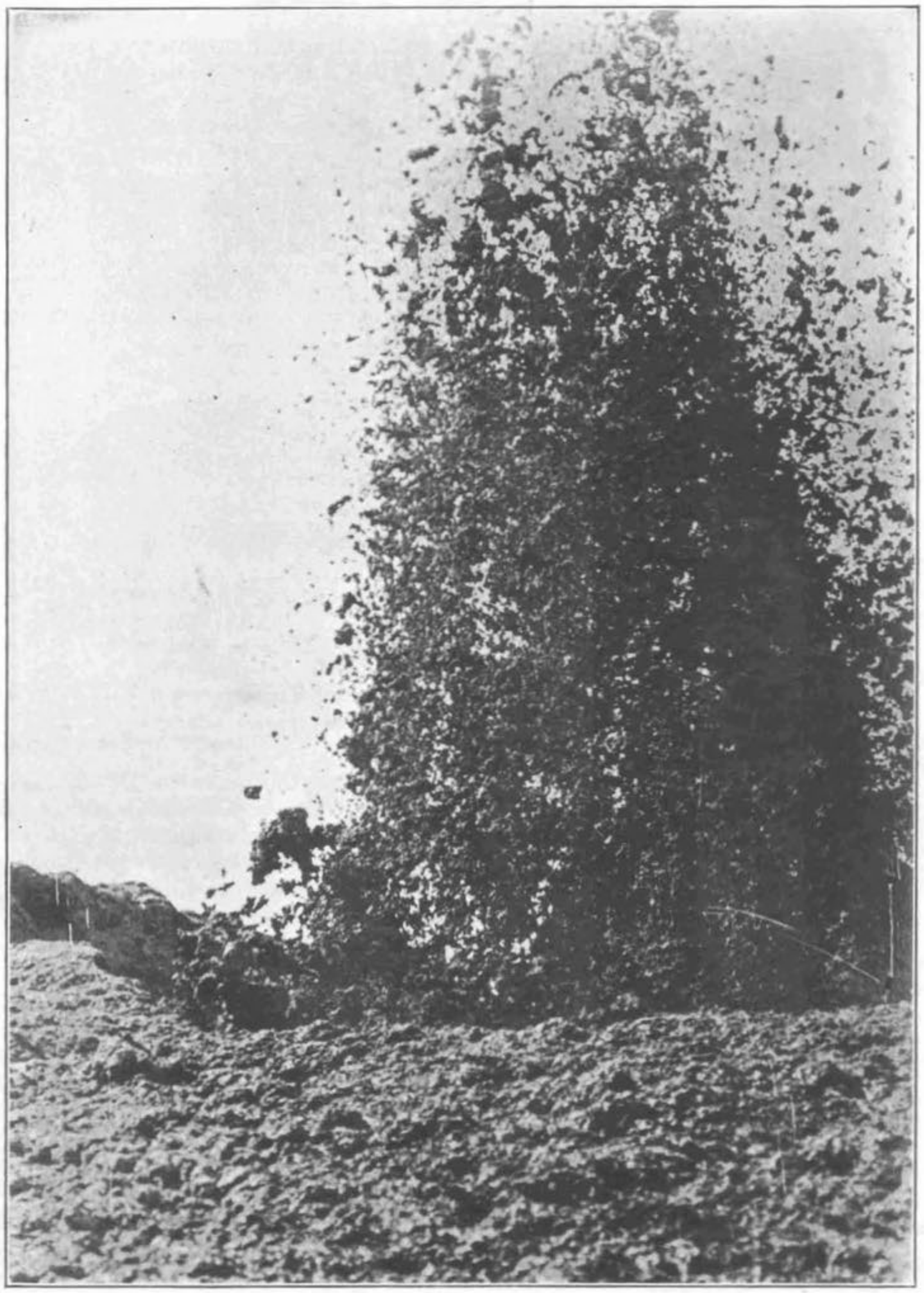
Other minerals begin to precipitate from the magma when the temperature drops still lower. The two other important minerals which form from basaltic magma are pyroxene and calcium feldspar. Proxene is made up of calcium, magnesium, iron, and silica. Calcium feldspar is made of calcium, aluminum, silica, some sodium, and a little potassium. Proxene and calcium feldspar are the most abundant minerals in basalt, olivine is third in abundance, and the only other common mineral of much importance is magnetic iron ore which is present up to 5 or 6 per cent in some basalts. Though olivine is the most common phenocryst in the Hawaiian basalts, occasionally pyroxene and calcium feldspar are found as black and white phenocrysts, respectively.

If magma cools fairly slowly, there will be time enough for all of its constitutents to combine in crystals of the above mentioned minerals. However, if the liquid magma is cooled very rapidly it may freeze to a solid form without giving the elements time to form crystals. This rapidly frozen magma is a volcanic glass which is called basaltic obsidian.

If the magma is thrown out in explosive eruptions, such as have occurred on Mauna Kea, the small drops of magma which are suddenly blown out into the air cool very rapidly and form small particles of basaltic obsidian. Many of these particles are full of gas bubbles and so form a sort of glass sponge which is called pumice. The larger fragments or blebs of magma may be big enough to cool more slowly and so have time to crystallize to some extent. Many of them are full of bubble holes also and so form slag-like pieces which are called cinders. An explosive eruption thus produces fine grains of glassy ash or pumice and coarser fragments of partly crystalline cinders.

A small part of the magma which comes out in a quiet eruption is blown into the air by the fountains at the source vent. This part freezes rapidly and forms a little pumice and Pele's hair which is basaltic glass drawn out into fine threads. However, most of the magma from quiet eruptions pours out as lava flows. These are of two types, aa and pahoehoe, which are distinguished by the character of the surface of the lava flow and not by any difference of composition of the lava.

If the magma which flows out is so hot that it contains very few crystals, the surface of the flow rapidly freezes and forms a thin skin of basaltic glass on top of the flow. This skin acts as an insulator and permits the rest of the lava in the flow to retain its heat and so to cool slowly enough for complete crystallization. A flow



Fountaining lava at the source of the 1919 flow from Mauna Loa. The force of the rising gas throws the lava into the air and blows it full of bubble holes. Pumice and Pele's hair are formed by this sort of fountain. If the explosive force becomes much greater, all of the rising lava may be blown into the air to form cinder and ash cones. Photo Jaggar.

which has formed such a glassy skin on its surface is called a pahoehoe flow.

In contrast, if the magma has been cooled enough before exposure to the air so that it is full of tiny crystals, as soon as it is exposed to the air all of the magma crystallizes rapidly. Thus, instead of forming a glassy skin on its surface, the flow forms a top layer of crystalline clinkers. This clinkery surface also is an insulator so that the inner part of the flow loses its heat slowly and has time to crystallize completely. A lava flow with a clinkery surface is called an aa flow.

Aa and pahoehoe flows make up most of the rock of the Hawaiian Islands. Cinders and ash are present in appreciable quantity on the islands of Maui and Hawaii, and are fairly conspicuous as building material in the make up of Oahu. For example, Punch Bowl and Diamond Head on Oahu are craters made up largely of ash and cinders.

H.A.P.

KILAUEA REPORT No. 1022

WEEK ENDING AUGUST 23, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

There are no visible changes in volcanic conditions at Kilauea. Halemaumau remains quiet and with the usual vapor activity. The records of the seismograph nearby indicate quiet conditions.

There were 21 short tremors registered by the instruments at the Observatory, one two-minute tremor, and one eight-minute tremor; and three very feeble local seisms. One of the seisms, occurring August 21 at 12:09 a. m., and having close epicentral distance, was felt locally; another at 11:05 p. m. August 22 showed distance to origin 32 miles.

The average tilt for the week was very slight NE, with a decided trend to N toward the end of this period. Microseismic motion was slight.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 349—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | September 3, 1931

Marked crack where it emerges at southeast rim of Halemaumau, showing method of measurement with wooden calipers at painted spots.

VERTICAL AND HORIZONTAL GROUND MOVEMENT

"Tilting of the ground as recorded by the slow and persistent wandering of the recording pens of the seismograph has been found through past years at the Observatory to be well worth observation. Such tilting away from the pit of Halemaumau has in general been correlated with rising of the lava column, while tilting towards the pit has usually come with retirement of the lava or at times of general collapse. The tilt at the Observatory appears to have a normal annual range of about 10 seconds of arc towards the pit (southwest) during the first half of the year, and a recovery during the second half. This normal movement and some other shorter period variations may not be strictly due to volcanic causes. General temperature changes either of the instrument room, of the ground upon which the Observatory stands, or of the face of the cliff near the Observatory may produce tilting effect and so account in part for this annual change, though experiments show that it certainly is not a purely local movement. Volcanic conditions are known to produce tilt also, and these volcanic tilt effects are superimposed upon the tilts produced by other causes." (R. M. Wilson in "Review of Local Seismic Features for the Year," Monthly Bulletin of the Hawaiian Volcano Observatory, Vol. XV. No. 12, December 1927.)

Quantitative measurements of the uplift and depression of the Kilauea dome have been made on several occasions in the past by means of precise spirit levels and horizontal movement detected by a careful retriangulation of a network of stations about the pit also connected by precise levels. The first spirit levels were run in 1912 by the U. S. Geological Survey and subsequent runnings of this line by the same organization in 1920 and the U. S. Coast and Geodetic Survey in 1927 have shown the value of spirit levels as a means of detecting even small amounts of vertical displacement. The methods used are fully described in Monthly Bulletin of the Observatory Vol. XV, No. 6, 1927.

The net of triangulation stations about Kilauea was first established in 1920 and the connecting levels run during the same period. Final adjustments of both surveys by the method of least squares was made by the computing section of the Geological Survey in Washington, D. C.

In 1927 and 1928 Mr. R. M. Wilson, engineer and mathematician of the Observatory at that time, who was also the author of the 1920 surveys, made an identical resurvey of this net. The results correlated satisfactorily with the general breakdown and depression of the Kilauea dome during the seven-year period which they covered. Horizontal movement was shown to be a general pull-in of all points towards Halemaumau as a center.

Similar repetitions of surveys have also been extensively made by the Japanese government in their quake-stricken provinces and the U. S. Coast and Geodetic Survey has retriangulated the area along the San Andreas rift in California. ("Earth Movements in California," by William Bowie, U. S. Coast and Geodetic Survey Special Publication No. 106.) The results of these measurements as of those in Hawaii show clearly and accurately the amount of displacement of the earth's crust which took place during the period of the cataclysm. Now as has been said some of these displacements were very small and required the most accurate of modern engineering methods to detect, also the surveys were made after the greatest movement had occurred. The question arises since such small movements have been measured after a quake has occurred, would it not be possible to apply these same methods to the prediction of quakes, or as more closely concerns us in Hawaii, the rise of the Kilauea or Mauna Loa lava columns?

The measurements in California and Japan have been concerned partly with quakes of tectonic origin, and as such quakes are caused by continued long strain and warping of the earth's crust over a number of years until it has reached the breaking point, it would seem that here a periodic survey of known active fault areas would be of value. This in Japan is called "chronic tilting" by Imamura. (Topographical changes accompanying earthquakes or volcanic eruptions, by A. Imamura, Publ. E. I. C. No. 25, Tokyo, 1930.)

Here in Hawaii any such measurements would have to be correlated with data from the seismograph or tilt-meter and continued through two or more active phases, since the actual tilt of the ground from day to day is small and not perceptible except by magnification. However, cumulative tilt is undoubtedly a measurable quantity and since accumulated tilt away from the pit has been shown generally to precede an active period, it is possible that measurements of the relative change in elevation of established bench marks together with the measurement of the horizontal angular change between such points would give a more firm basis for prediction.

With this end in view, and for general engineering use, four new stations marked with standard U. S. B. M. tablets have been established about the rim of Halemaumau. One is a few feet from the seismograph cellar at the pit and the other three form a rough square spanning the crater. Triangulation of these points has been made for any immediate emergency. Later they will be connected by precise levels to the 1927 circuit and a more accurate triangulation made with perhaps an especially measured base.

Horizontal angles are observed by a repetition with a Berger transit graduated to 20 seconds. Each angle is observed 12 times, six times in a clockwise direction, three settings made with telescope direct, and three reversed, both verniers being read. The angle is then measured in a similar manner but in a counter-clockwise direction, the mean of the 12 readings giving the correct angular value free from instrumental errors. Horizon closures are made in the same way. Particular care must be given to the centering of the instrument over the station and of the signals over their respective marks.

The larger net of Kilauea stations will also be reoccupied and identical angles measured as the loss of any lines from the previously adjusted figure would necessitate an almost complete new adjustment and much of the value of the work lost from its intended purpose, a comparative study with the two older surveys, together with the accumulated data for the same period from the seismographs.

A similar resurvey with the spirit level would give a means for study of any relative changes of elevation among the several stations in the net.

The measurement of rim cracks about Halemaumau has in the past proved of interest, as well as of value to the public in marking off weak or dangerous sections about the pit. The measurements, however, have not been very refined, instrumental errors amounting to as much as two or three millimeters due partially to uncertainty of exact points of measurement as well as the inaccessibility of some of the points. These measurements are to be resumed with new points added from time to time and the methods of measuring revised. Tumescence of the Kilauea dome as the result of rising lava has its effect on the more deep-seated fractures; a lift of this lava column before eruptions in 1927 and 1929 caused a widening of the superficial rim cracks with sections breaking off and avalanching into the pit.

Kilauea, due to its accessibility, is ideally situated for observation and measurement of tilt. Mauna Loa, on the contrary, presents a problem. Previously established triangulation points of suitable accuracy are scarce, and the precise spirit levels to the summit run by the U. S. Coast and Geodetic Survey in 1926 provide the only accurate datum bench marks on the entire mountain.

Mauna Loa above timber line alone comprises an area of over 500 square miles and is really accessible only by means of three trails; one on the Kona or west side and two on the southeast side. Water is obtainable only at the summit from melted ice or snow in the cracks and from scattered water holes along the forest edge.

Most of the historic activity, however, with a few exceptions has occurred along the two rift zones or ridges and at the summit crater, and all of the flows since 1881 have commenced within a relatively small area along the southwest rift a few miles above Puu o Keokeo, though generally preceded by an eruptive period of several hours at the summit.

The establishment of a net of triangulation about the whole mountain similar to the Kilauea net would be of immense value for future study, but the expense of surveying such a net would be more or less prohibitive. Astronomic azimuth observations would have to be made, a base line measured, the present transit replaced by a repeating or direction theodolite, and the net carefully connected to the recent inter-island triangulation by the Coast Survey. However, small independent nets spanning the most active parts of the rift zones as well as the summit crater would not be prohibitive in cost, and like the small Kilauea net would be readily subject to periodic remeasurement and hence comparative study. Extension to these nets of the existing levels could be made and vertical displacement measured from time to time.

Mauna Loa as a whole presents a problem of absorbing interest as yet practically untouched. Some sort of auto road to the summit and one from the Kona side to the southwest rift would go a great way towards overcoming the obstacles encountered by any one attempting observations on the mountain. The roads would also open an entire new field to the tourist. Seismograph and tiltmeter stations would be established at critical points and proper attention given them.

With its present inaccessibility Mauna Loa can be perhaps best studied through the means of small triangulation nets connected by levels and the construction of tiltmeter stations with a tiltmeter devised which would record its readings at the distant Observatory and require but infrequent field inspection. Dr. Jaggar is at present working on plans for such an instrument.

The Puna District and Hualalai have been scenes of recent severe shocks and also present fields for the study of tilt problems.

The above notes represent an outline of some of the work the Observatory has done in the past and what the writer hopes to take up in the future in the investigation of the horizontal and vertical movements or tilt of the ground about the several active volcanic regions in Hawaii.

E.G.W.

KILAUEA REPORT No. 1023

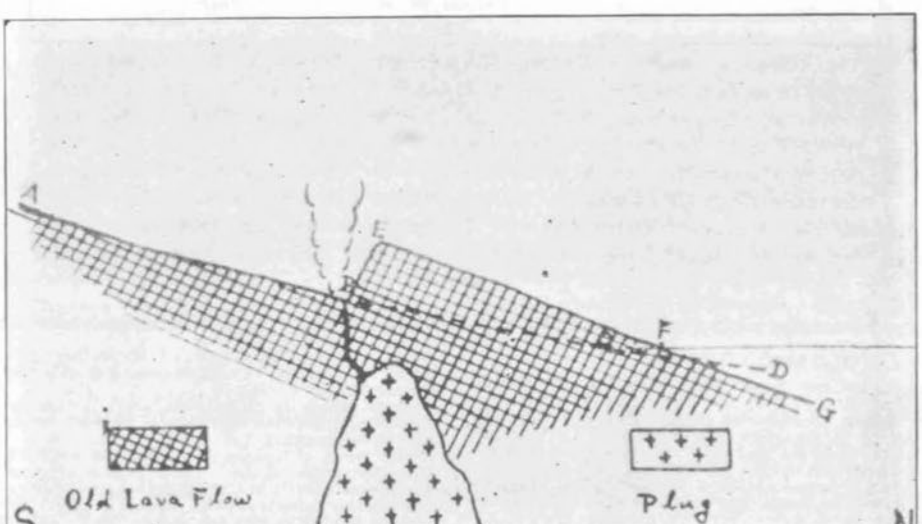
WEED ENDING AUGUST 30, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

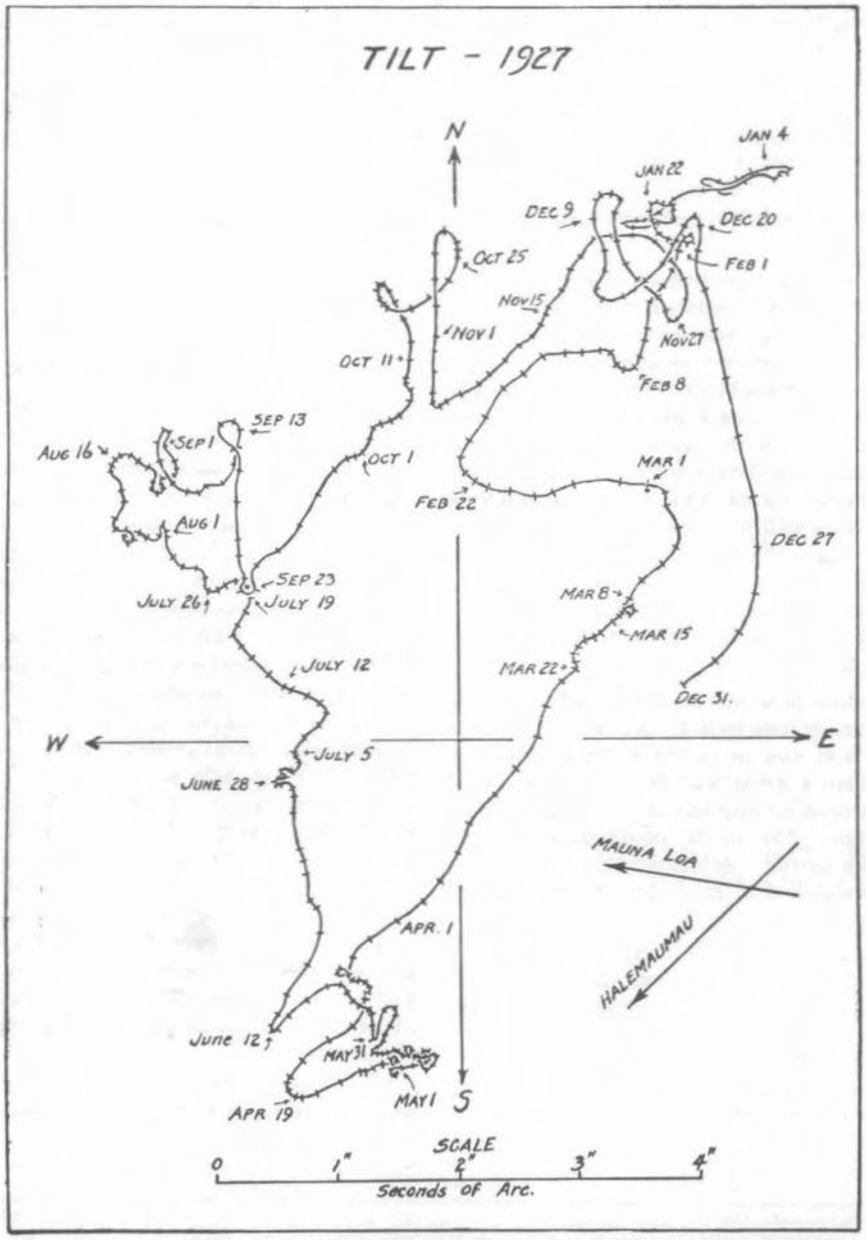
At Halemaumau pit slight fume was observed rising from a sulphur spot on the north side of the 1930 cone on the afternoon of August 23. Steam was notably absent August 24. A slide from the wall occurred about 9:40 a. m. August 26, and fume was observed on the floor. About 7 a. m. August 30, soon after the moderate earthquake recorded below, an avalanche at the pit on the northeast side sent up a thick cloud of dust.

The seismographs at the Observatory registered 19 tremors and 4 local seisms. Of these one at 2 a. m. August 25 was very slightly perceptible and indicated distance of origin 14 miles. A stronger earthquake was felt generally on the island at 7:53 a. m. August 30, dismantling instruments in Kona, Hilo, and at Kilauea, indicating distance of origin 15 miles from Kilauea and 35 miles from Hilo. It was felt as a slight and prolonged tremor near Kilauea, and more strongly in Hilo, Olaa, and Kona. The facts suggest an origin under the northern part of Mauna Loa, and this is confirmed by the vertical component seismograph which indicates an origin northwest of the Kilauea Observatory.

The average tilt for the week was moderate to the N, and microseismic motion was slight.



Profile of north slope of Usu Volcano in Japan where during a single eruption the block shown was lifted 500 feet and the whole mountain was affected by elevation and tilting. After Ouinoue.



Tilt diagram, Hawaiian Volcano Observatory, for 1927. On the scale in seconds shown, the line beginning January 1 in the northeast corner indicates daily amounts and directions of changes of a plumb line for the year, with tilting to the southwest in spring and to the northeast in autumn. The data are caculated from seismograph records. The bend northwest July 8 corresponds to an outbreak of Halemaumau the previous day. Arrows indicate directions of Mauna Loa and Kilauea from the Observatory. Comparing January 1 and December 31, net change for the year was four seconds south.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 350—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | September 10, 1931

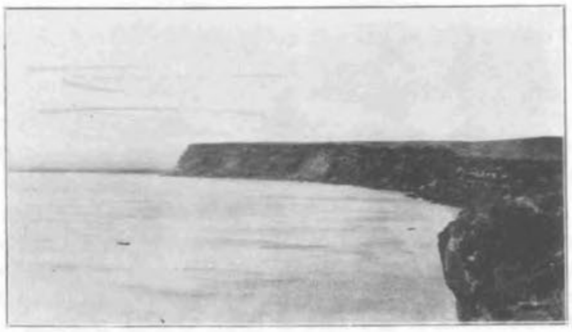


Figure 1. Looking north along the west-facing fault cliff, north of Ka Lae, Hawaii. In the main cliff may be seen the edges of many lava flows. The top of the lava cliff is backed by a gently-sloping terrace, back of which is a low cliff cut in loess. Back of the loess cliff is gently rolling loess grassland. In the distance, at the left, is down-faulted western block. Photo H. S. Palmer.

LOESS AT KA LAE, HAWAII

Ka Lae, the southermost point of the Island of Hawaii, may be reached by leaving the main highway about four miles west of Waiohinu, and driving southward about twelve miles over secondary roads. One first goes through the Kamaoa homesteads and then across open, strongly wind-swept grasslands to the Lighthouse Reservation at the extreme tip of the island. Ka Lae is bounded on the west by a west-facing fault cliff which, though low at the south end, increases in height inland to 500 feet or more (figure 1). The fault cliff extends inland at least ten miles from Ka Lae and is said by fishermen to extend also some distance southward under the sea. The block west of the fault has sunk and has thus formed a depression into and along which lava flows have poured on several occasions within historic times. The block east of the cliff, in contrast, has been freer of lava flows in recent times because of its greater elevation. Its coastline runs northeastward from Ka Lae and has been built out into the sea by prehistoric lava flows.

The block east of the fault cliff is entirely covered by variable thicknesses of a fine grained, yellow-brown material. In some places this has been drifted into sand dune ridges which parallel the direction of the prevailing trade wind (see figure 2). Along the top of the big fault cliff this upper fine grained deposit has been cut back slightly from the edge. This forms a small secondary cliff in which different layers of the upper material are exposed.

At many places there are small lenses of coaly or carbonaceous material at horizons in the little cliff which are below the present surface. Each coaly lens represents an accumulation of vegetable matter in a chance depression in what formerly was the land surface, but which has since been buried by new layers of silt. For the most part, nothing can be made out as to the nature of the plants that supplied the vegetable matter, but one block was found bearing the clear impression of a dicotyledonous leaf. The presence of the leaf print, as well as the presence of the coaly lenses, proves that the fine-grained material has been carried in in some way, and that it is not a residual soil formed by the weathering of the lava in place. Moreover, the fine-grained material rests on rather fresh lava rock and does not show the transition from surface soil to fresh rock, through various degrees of weathering, that residual soils show. Since wind is the only transporting agent that can be conceived of as having operated here, the material is properly classified as loess, a term that was originally applied in Germany to fine-grained wind deposited sediments.

For some miles east of the Lighthouse Reservation at Ka Lae, the actual shore line is of lava rock, largely pahoehoe lava. It is exposed as a rather uneven rock terrace, in places submerged and in places making a clifflet two or three feet high along the water's edge. The terrace rises inland to heights of four to six feet above sea level, and is from ten to a hundred feet wide. Back of the lava terrace is a single or compound loess cliff. In the few places where it is a single cliff it is in general about six feet high. Where it is a double cliff, the lower cliff is about four feet high and exposes a red-brown loess. The upper cliff is four to eight feet back of the top of the lower cliff and is about two feet high. It is composed of yellow-brown loess. In places there are low dune ridges of sand a short way back of the top of the upper cliff and resting on the finer-grained, yellow-brown loess (see figure 3).

The upper cliff is protected at its upper part by a good turf, the roots of which effectively bind the top few inches of loess and greatly retard its erosion. The lower part of the loess is not thus bound and therefore is readily cut away by windblown sand. Thus the turf layer is slowly undermined and is forced to collapse by the removal of its support.

In many places the red-brown loess cliff is double instead of single. The top of the lower red-brown cliff seems to be due to the slightly greater resistance to erosion offered by the remains of an old turf layer (see figure 3).

The ability of the lower or red-brown loess to resist erosion presented a different problem, for it lacks the protective network of roots, except at the one horizon mentioned in the preceding paragraph. Samples were taken near the top and near the base of the yellow-brown layer, and near the top, near the middle, and near the base of the red-brown layer. The samples were numbered from 1 to 5, in the order just named. Fair-sized portions of each were weighed and then dried to constant weight at 108° C., to determine the amount of moisture they contained. Smaller portions of each were then weighed out and leached with a fairly large volume of distilled water to extract the soluble salts. The extract was then analyzed

Figure 2. Low, grass-bound sand dunes, between and around which the road wanders, about five miles north of Ka Lae. Photo H. S. Palmer.

for chlorine, and the equivalent salt content of the original sample calculated. The results of these determinations are given in the following table.

Moisture and Salt Contents of Loess Samples from Ka Lae

Sample number	Position of sample	Per cent water lost at 108° C.	Per cent salt (NaCl) in sample
1	Top of yellow-brown loess	4.64	0.79
2	Base of yellow-brown loess	13.72	1.26
3	Top of red-brown loess	24.40	5.31
4	Middle of red-brown loess	22.36	5.46
5	Base of red-brown loess	21.62	2.16

It is clear that the red-brown loess is much moister than the yellow-brown loess. Except for its basal portion, it is also saltier than the yellow brown. The conclusion seems inevitable that salt water is carried up by capillary action into the red-brown zone. The upper limit of capillary rise appears to be the top of the red-brown loess. There appears to have been some reaction of the salt which has oxidized the iron of the loess so that the red-brown color has developed. The nature of the reaction is not known, but is presumably like the proverbially bad rusting of iron by salt spray. The new iron compounds thus formed seem to cement the red-brown loess a little and thus to give it some resistance to erosion.

Reference to the table will show one inconsistency in the preceding discussion, for the base of the red-brown loess is less than half as salty, though almost as moist, as the middle and top parts. One might expect the base to be the saltiest and moistest as it is nearest to the source of supply of salt water. A reasonable explanation of the greater saltiness above is that, as capillary action raises water and its dissolved salt, subsoil evaporation removes the water and leaves the salt behind. Thus there is a progressive accumulation of salt to such depth as evaporation can reach. In the lowest layer exaporation is virtually inoperative and no such concentration of salt has taken place.

The slightly greater moisture content of the middle and top as compared with the base of the red-brown loess is perhaps due to some retention of water by the hygroscopic action of the salts.

The accumulation of the loess has taken place in part since the occupation of the Hawaiian Islands by human beings. At one place, a hundred feet or so east of the Lighthouse Reservation, there is exposed in the loess cliff a pavement of wave-rounded bowlders. That they got here through the activity of human beings is shown (1) by their rather regular arrangement, (2) by the fact that the pavement consists of only one layer of bowlders, and (3) by the fitting of coral fragments into the chinks between the lava bowlders. All of these features are characteristic of the platforms made by the Hawaiians so often along the shores for use in ceremonies in connection with fishing operations. Waves would not select bowlders of such uniformity of size; they would not select coral for chinking; and they would not make a uniform layer only one bowlder deep. Clearly the platform is man-made, yet it is overlain by loess, so part at least of the loess has been made since the platform was made and therefore since human occupation of Hawaii.

The horizon of the bowlder pavement or platform is traceable as a somewhat pebbly and shelly layer for about a hundred feet. The pebbles and shells may well have been scattered by the persons who made and used the platform. If so, it is a sort of fossil kitchen midden.

It happens that the bowlder pavement lies between the yellow-brown and the red-brown horizons of loess. This may be purely accidental, but it may be that the coarse layer breaks up the capillary channels so that the reddening and cementing actions are stopped at their level.

The fact that the loess cliff is within ten to a hundred feet of the water's edge suggests that it is a wave-cut cliff. However, on July 12, 1930, there was a place at which some initials had been cut in the red-brown loess cliff. The date was illegible as it had been cut away by a little vertical groove due to run-off from above. At other places the cliff was similarly grooved. It appears, then, that waves are doing less at such places than is run-off. One might expect the energy of storm waves to be dissipated largely in crossing the lava rock terrace. In ordinary weather waves do not come near the cliff, even at high tide. Where the lava bench is narrowest (see figure 3) the loess is being cut back by storm waves, it would seem, and makes a single cliff in both the red-brown and yellow-brown loess layers.

Outcrops of the loess on top of lava rock are continuous along almost all of the shoreline from Ka Lae northeastward to Kaalualu. Puu o Mahana, three miles northeast of Ka Lae, is a tuff cone, the seaward part of which has been cut away by waves. Loess makes a rather deep mantle on its lower windward slopes, but seems not to have lodged readily on its upper windward slopes nor on its leeward slopes. Whether any loess underlies the tuff is not known.

About a mile and a half northeast of Ka Lae there is a young flow of aa lava, which divided a mile or so inland and reached the shore as two flows, leaving a kipuka in between. Underneath the southwestern of the two arms there is some loess, the precise relationships of which were not ascertained. This loess is believed also to underlie the northeastern arm of the aa flow. Much fuller observations were made on a similar occurrence of loess beneath another young lava flow about half a mile southeast of Kaalualu.

On the west side of Paiahaa Bay, the small bay just west of Kaalualu Bay, the shore line is cut for some distance in a pahoehoe flow which has the usual somewhat irregular upper surface. On this pahoehoe flow lies a bed of loess with a smooth wind-made upper surface. Since the lower surface of the loess follows the irregularities of the upper surface of the pahoehoe flow, the thick-

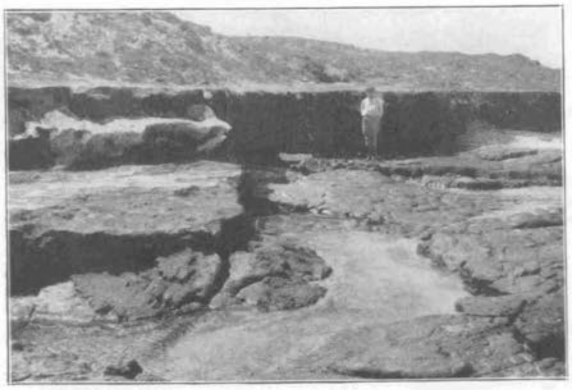


Figure 3

The ridge forming the sky-line is a sand dune ridge, resting on the yellow-brown loess, which extends down to the level of the man's belt. The separation of the loess horizons is lost in the shadow behind the man. At the left of the picture the uppermost clifflet is in yellow-brown loess, below which are two clifflets in red-brown loess. The lowest clifflet is in front of a broad bench and leads down to the terrace cut on pahoehoe lava. Quiet pools of sea water occupy depressions in the pahoehoe terrace. At the right, coral fragments and shells have been piled against the loess cliff. Photo H. A. Powers.

ness of the loess varies from eight to ten feet. The loess bed and the underlying pahoehoe curve downward in both directions till they are hidden beneath a heap of boulders at the foot of the cliff. This loess is older than most of the loess along the Ka Lae-Kaalualu shoreline. At a typical point its red-brown, lowest zone is about two feet thick and reaches an elevation of about seven feet above sea level. It is overlain by about six feet of loess which shades upward from darker to lighter yellow-brown. The topmost six-inch layer of the loess is very dark gray, in fact nearly black, in color because the vegetable matter that it once contained has been charred or carbonized by the heat of the pahoehoe lava that flooded over it.

Immediately overlying the loess is a pahoehoe flow about three feet thick; on this there is an aa flow, also abou three feet thick; and at the surface there is about two feet of loess which is continuous with the layer of loess that is so extensive. Perhaps the two lava flows are of approximately the same age as the artificial bowlder pavement at Ka Lae for the thicknesses of both the overlying and the underlying loess deposits are about the same at both places.

The lower loess deposit is much weaker than the overlying pahoehoe flow and has therefore been cut back farther so that for a distance of about a hundred feet the pahoehoe overhangs as a ledge with an average width of two and half or three feet. Thus between 250 and 300 square feet are exposed, which give some clues as to the nature of the older loess at the time that the pahoehoe lava flooded over it. A rather cursory examination revealed over 30 molds of trunks and limbs of trees. Half a dozen of the molds are vertical and represent growths which the pahoehoe surrounded but did not destroy. The largest of these erect molds has an elliptical cross-section which is 10 by 12 inches at a level 12 inches above the former ground level. The tree that made the mold had a gently fluted trunk. The other erect molds are from one to four inches in diameter. The erect molds extend through the three feet of pahoehoe but are capped by the overlying aa. They imply, without doubt, the existence of half a dozen trees or saplings in the 250 or 300 square feet.

Prostrate molds greatly outnumber the erect molds, and represent either dead wood that was lying on the ground or stems and trunks that were knocked over by the advancing lava. They range in diameter from one to three inches. One prostrate mold is two inches in diameter and five and a half feet long. Since some of the prostrate molds may well be the relics of trees that were alive until they were pushed over by the advancing lava it seems probable that the 250 or 300 square feet bore more than the half dozen that are definitely implied by the erect molds. There must, therefore, have been a fairly thick cover of trees at this place. This conclusion is supported by the presence of much charred vegetable matter in the black loess immediately underlying, far more than could be produced by the charring of the turf that now grows in this region.

We can reconstruct the following events in the history of this small area southwest of Kaalualu. Soon after the eruption of the lower pahoehoe flow volcanic activity ceased temporarily and was succeeded by wind work which brought in 8 to 10 feet of loess. The loess formed a fertile soil in which a fair growth of trees took root. The climate must have been somewhat moister than it now is to permit the growth of good-sized trees. Short-lived volcanic activity followed, and made two thin lava flows, the first of pahoehoe and the second of aa. Since then there has been no volcanic activity at this particular place, and winds have brought in two feet more of loess which supports a fair growth of turf-making grass. At present, wind is adding slowly to the upper surface of the loess, and is also, with the help of waves, exposing the edges of the various rock layers as a low cliff.

I am indebted to Dr. Howard A Powers, of the Hawaiian Volcano Observatory, for much help in the field study on which this paper is based. It is in fact a question where he or I should have written it.

Harold S Palmer.

KILAUEA REPORT No. 1024

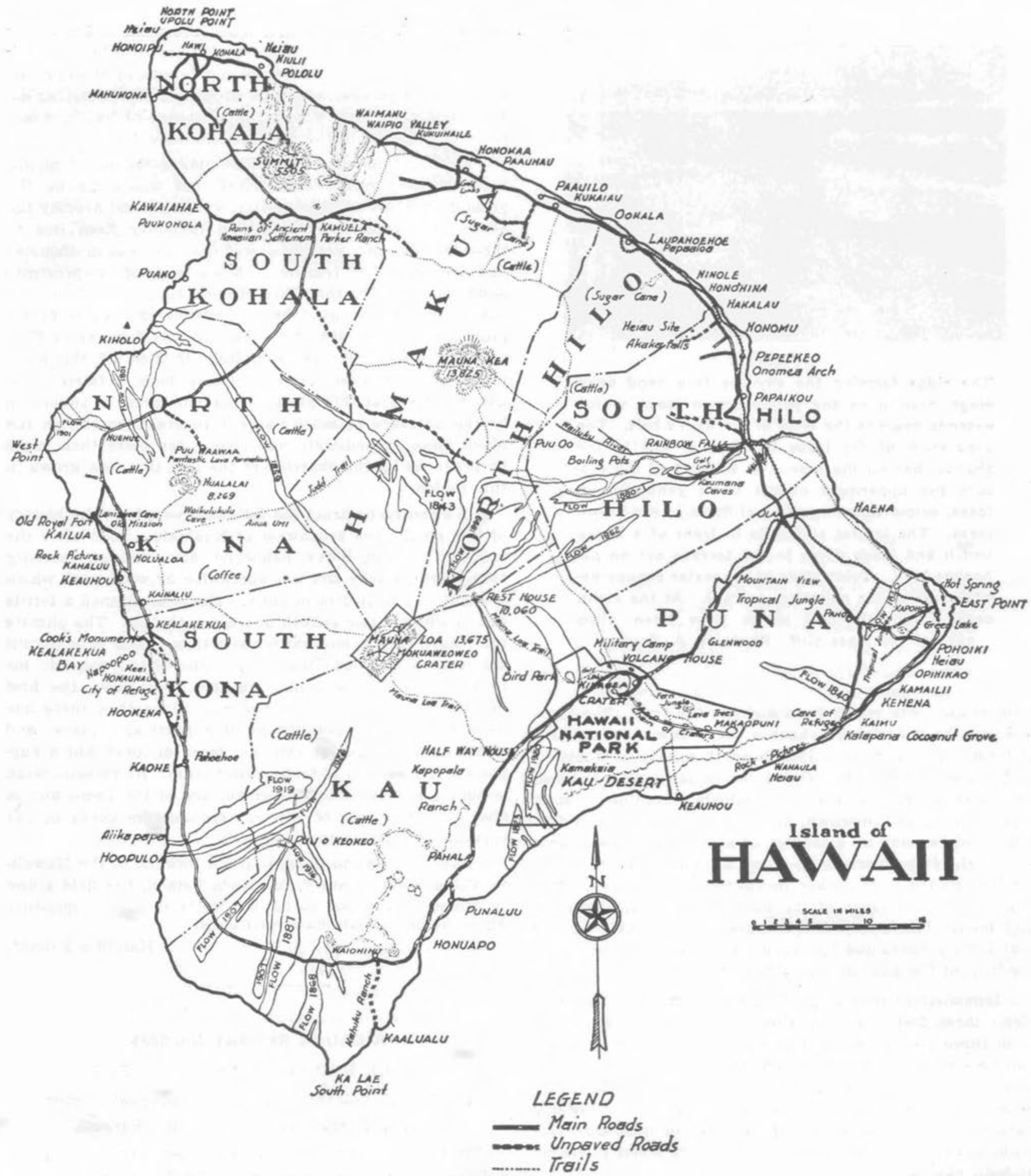
WEEK ENDING SEPTEMBER 6, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Halemaumau pit continues to remain quiet with about a dozen stained spots on the floor of 1930, one of these yellow with sulphur showing very slight bluish fume. Older spots are whitish and dead ones are brown. After rain vapor mixes with the fume and very light vapor appears at the south talus. Measurement of rim cracks August 31 showed no widening.

Three tremors at the pit seismograph about September 5 indicated slight tilt away from the pit. The Observatory seismographs on the northeast rim of Kilauea Crater registered 37 tremors, of which one was accompanied with east tilt and another lasted two minutes. Five very feeble local seisms were registered, of which three indicated origin only four miles away. Average tilting of the ground was slight SW, and microseismic motion was slight.



THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 351—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | September 17, 1931

Newly acquired Engineering Building of the Hawaiian Volcano Observatory, standing back in the forest east of the Volcano House garage. Photo Maehara.

VOLCANOLOGIC OPERATIONS OF THE U. S. GEOLOGICAL SURVEY AND THE HAWAIIAN VOLCANO RESEARCH ASSOCIATION, 1930-1931

The Geological Survey covers stations at Hawaii, Lassen, Kodiak, and Dutch Harbor; the Research Association supplements the work at Kilauea with stations at Kona and Hilo. The eruption at Kilauea November 19 to December 7, 1930 added 70 feet of lava to the bottom of Halemaumau. Such eruptions have averaged one a year at Kilauea for six years. The flow from Mauna Loa in 1926 and the earthquake spasm of Hualalai in 1929 add to the evidence that the Hawaiian volcanic system is fully alive. Mauna Loa in the twentieth century has had an outbreak once in four years, so that there is reason to be prepared for live lava in Hawaii within the next year.

Lassen station reports declining tilt and earthquakes. In the Aleutian belt Pavlof, Aniakchak, and Tulik have been reported active. The circum-Pacific region has produced disastrous earthquake at Napier, Oaxaca, Managua, and in the Izu Peninsula near Yokohama, and volcanic disturbances in northwestern Argentina, not far from the south Chile volcanoes investigated by the Research Association through Dr. John B. Stone. All the disasters mentioned are close to active volcanoes.

Growth of the Section of Volcanology leads to division in subsections as follows, with T. A. Jaggar directing the work, the Kilauea laboratories of the Hawaiian Volcano Research Association serving as headquarters, and a somewhat increased staff appearing in 1931-32:

Volcanology of Hawaii

T. A. Jaggar, Volcanologist in Charge
- Observation of volcanoes
- Designing and building instruments
- Preparation of publications
- Administration

Seismology of Hawaii

E. G. Wingate, Associate Topographic Engineer, in Charge
- Correlation of leveling and tilt
- Drafting and research in maps of crater
- Recording Hilo tide data
- Special investigations of Mauna Loa
- Special topographic mapping wherever required

Seismologic routine

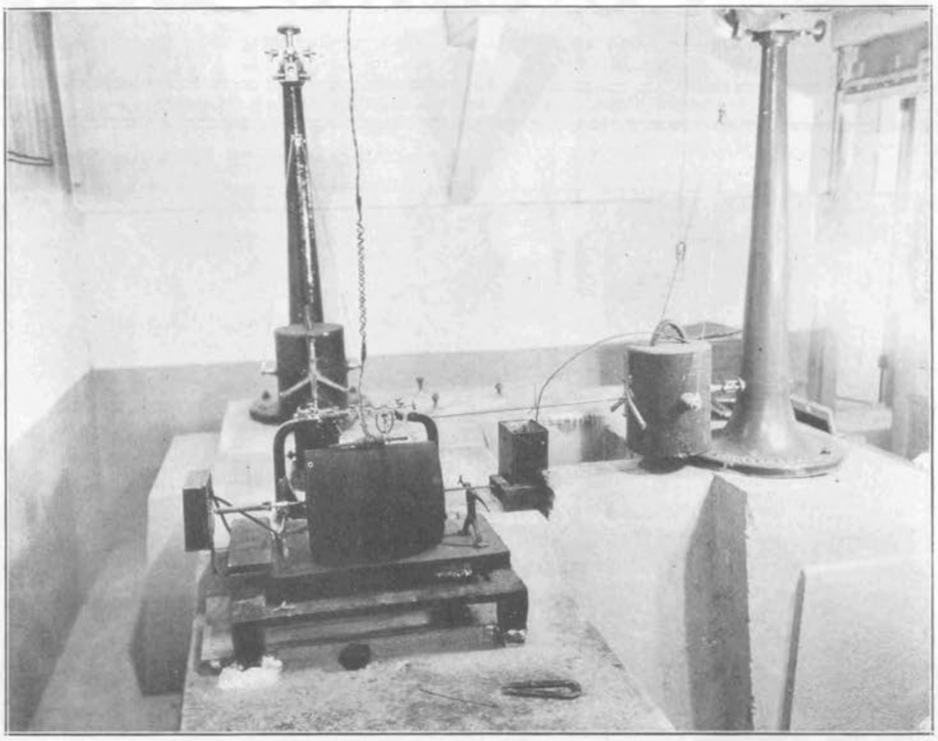
A. E. Jones, Assistant Seismologist, in Charge
- Operation of seismographs
- Measurement of seismograms
- Preparation of earthquake bulletins

Volcanologic Surveys of Hawaii

H. A. Powers, Assistant Geologist in Charge
- Field mapping of lava and ash formations
- Petrologic study of specimens and analyses

Volcanology of Northwestern United States and Alaska

R. H. Finch, Associate Volcanologist in Charge
- Operation of Lassen Volcano Observatory
- Operation of Alaska stations
- Investigation of northwestern volcanoes
- Installation of new seismometric stations



Bosch-Omori seismograph rebuilt at the Hawaiian Volcano Observatory with high-speed drum, damping tanks, both arms writing on a single smoked paper, and pen tips lifted by an electromagnet for marking minutes. This instrument has been most satisfactory for many years for registering tilt and local earthquakes in the cellar at Kilauea, and the records of this machine are the basis for new studies, of tilt, and depth and distances of earthquake origins. Photo Maehara

The Volcanologist has given a course in Volcanology at the summer sessions of the University of Hawaii for three years past, many of the students being teachers in schools in Hawaii. These persons will be useful volunteer seismologic observers. The Volcanologist represented the Geological Survey on the Naval Eclipse Expedition and studied the volcano Niuafoou in the autumn of 1930, leaving a shock-recorder there and supplying another to the Dominion Astronomer of New Zealand, Dr. C. E. Adams.

Messrs. Wingate and Jones joined the staff in July and September 1931. Dr. Powers has studied the shore line changes with Dr. Palmer, has mapped soils and loose deposits all over the island Hawaii, but especially in Kona in collaboration with Mr. J. C. Ripperton of the U. S. Agricultural Experiment Station, and has mapped in detail the lava flows and volcanic ash of the west slopes of Hualalai and Mauna Loa. As a petrologist he is studying these materials microscopically. This work of a geologist has in view extending our knowledge of the structure of Hawaii. (See Geology and Water Resources of Kau District, by Stearns, Clark and Meinzer, Water-supply Paper 616, 1930, U. S. G. S., and also Products and Structure of Kilauea, by J. B. Stone, Bishop Museum Bull. 33, 1926, Honolulu.)

The remaining members of the staff of the Hawaiian station are: R. B. Hodges, clerk and disbursing agent; Tai On Au, mechanic; H. Yasunaka, janitor; and M. F. Lacerdo, tide gauge operator at Hilo. R. V. Woods and J. B. Albert operate the seismographs at Kealakekua and Hilo.

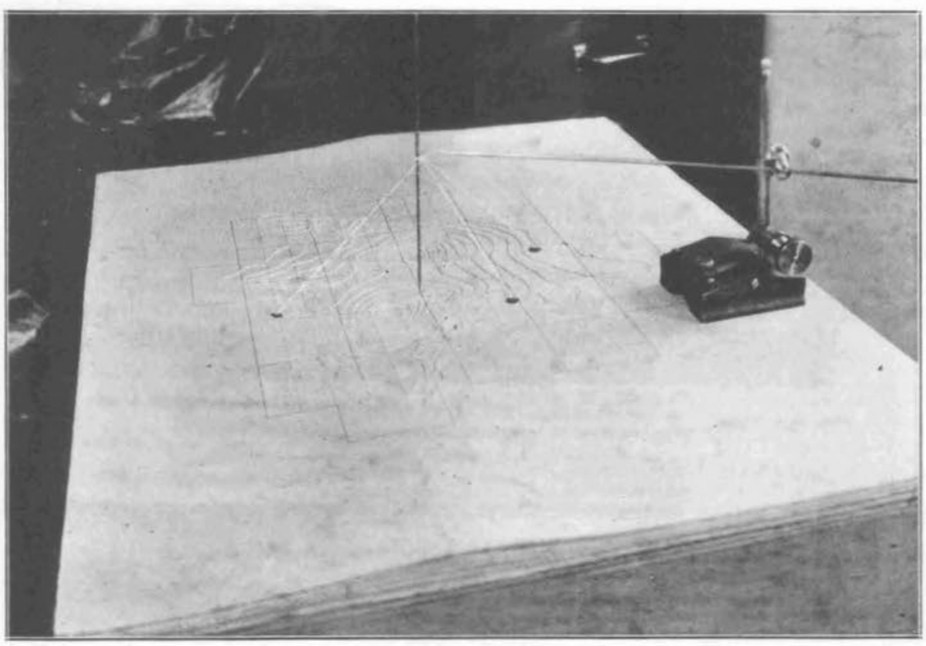
Associate Volcanologist Finch operates three seismograph stations near Lassen and with assistants studies the hot vents and the geology of old lava flows in northern California. The instrument at Mineral is operated throughout the year; those at Viola and Mount Harkness are discontinued in winter. Mr. Finch has spent the summer of 1931 inspecting the Aleutian seismograph stations, and making an exploration of Akutan Volcano and its hot crater. He left Kodiak for Seattle on September 6.

The study of local tilting of the ground in Hawaii, as correlated with faults, with earthquakes, and with volcanic centers of tumescence, has justified more men and instruments. One of the interesting developments has been the registration of "tilt earthquakes." These are seismograms of local earthquakes showing at several different instruments, not all at the same place, that the ground has tilted and offset the pens in the same direction, at the moment when the local shock occurred. In other words the creaking action of the motion of the fault block has been accompanied by a slight tipping. The direction of this tipping is a discovery of prime importance, and the coordination of many such tippings at the same place, occurring simultaneously with earthquakes, indicates the manner of action of the net tilt for a given period. It is obvious that to discover the geographic boundary of such tilting, distributed instruments are necessary, and these instruments should be simplified as much as possible so as to show graphically without computation the direction of the tilt, as well as its angular amount.

With this in view, an observation made several years ago with a small plumb line to which a vertical lever was attached was utilized in the spring of 1931 as basis for construction of a new tiltometer. The instrument was at first placed in a shallow well in concrete in the seismograph cellar of the Observatory, the device consisting of a heavy mass hung vertically on piano wires, with a magnifying boom rising vertically from the center of the mass so suspended and counterpoised that the faintest deviation of the mass as a plumb bob would be highly magnified at a pointer moving in a horizontal plane at the upper end of the sytem. This pointer is free to move in all directions in accordance with the absolute direction of tilt which disturbs the heavy mass as a plumb bob, and the linear amount of its motion radially from its adjusted center is a measure of the angle of tilt.

Another line of experimental investigation which was set in motion in January 1931 promises much for the location of earthquake centers. The determination of depth of origin for local earthquakes on the Island of Hawaii has puzzled us for many years. Mathematical methods of determining depth of origin for more distant or stronger earthquakes are in vogue in California and Japan, dependent on exact time-keeping. Omori used a simple method of determining distance by the preliminary tremor at several stations, and figuring the depth of centrum by the overlap of these distances beyond their point of intersection on a map. In other words, if the distances indicated are greater than their meeting point in plan, the origin is not in the horizontal plane, but is below the horizontal plane by the amount in which the distances are excessive. The determination of the meeting point of these lines underground, and the depth of that point below the local topography, is somewhat troublesome where a large number of earthquakes have to be investigated. The method, however. is good when the formulae for determining distance by the preliminary tremor have been checked for a given terrain.

In order to determine the depth of origin graphically by this method in Hawaii, a model was built showing the island as a hollow shell, as though the topography were seen from below. (See cut Page Three.) On this shell the several seismograph stations are accurately located and threads are carried through holes at these stations to weights hanging below. These several threads are drawn together at one point on an adjustable carrier which may be moved around until the lengths of the threads correspond to the centrum distances for a given earthquake indicated by the several seismographs. The threads are marked in miles to the scale of the model. A rod similarly marked may thus be placed against the meeting points of the threads, and this indicates vertically the depth of a given earthquake center. and the position of the epicenter, after the straight threads have been adjusted for any given earthquake. Thus the shell model (upside down) graphically exhibits the hollow space inside the island on a table, and the threads may be quickly adjusted to exhibit the point in space corresponding to the earthquake center, and their angles of emergence at the model should correspond to the angle of emergence of the earthquake wave. Tests with this model will show at once whether the several computed distances meet at a point or not, and so serve to check the theory of distance as applied to the preliminary tremor. Also the azimuth of the graphically determined center from each station may be checked against the theoretical azimuth determined



The inverse contour model of Hawaii, perforated to receive weighted threads at the spots marking seismograph stations The scriber shown has the three threads drawn together. By moving this junction point around until the three distances on the threads, on the scale of the model. correspond with the three distances to origin indicated by three seimograms for the same earthquake, the location of the centrum is determined graphically as though the observer were under the island. A brass scale rod as shown then determines the epicenter and the depth. The horizontal and vertical scales are identical in the model. Photo Maehara.

seismometrically. The preliminary trials of this graphic method for the same earthquake as registered in Kona, at Kilauea, and at Hilo have yielded promising results.

The third activity in our shops by way of seismometric experimentation has been the renewal of construction of shock-recorders as reported in 1929 in connection with the campaign of the Scientific American for enlisting amateurs in seismology, and in connection with assisting New Zealand in her earthquake difficulties. This last cooperation was given added zest by the terrible disaster at Napier in February 1931. after which the minister for scientific research, Dr. Marsden, of the New Zealand government, telegraphed to me asking for shock-recorders of my design. Through the Hawaiian Volcano Research Association, which furnished the materials, I at once set about new tests of an improved shock-recorder which registered several local earthquakes in our basement. The Research Association will supply the New Zealand government with eight of these instruments, and incidentally the Hawaiian Volcano Observatory will profit by this investigation, which is along the lines of what I did with similar instruments at Niuafoou in the South Seas on the Eclipse Expedition of 1930. Both in Alaska and in Hawaii it is becoming inceasingly evident that we need distribution of simple instruments, and in Hawaii there is a new demand through the school teachers who are distributed here, who have taken my course in Volcanology during three summers at the University of Hawaii.

The Research Association has added to the buildings of the Volcano Observatory the house shown on Page One, to be used for offices of the engineer and geologist. With this there is water supply and a garage. In addition a garage and carpenter shop have been rebuilt near the main observatory building.

A publication of interest to students of volcanology is Bulletin No. 77 of the National Research Council, "Physics of the Earth: I, Volcanology," Washington, 1931, by Day, Sapper, Friedlaender, and Jaggar. Dr. Day writes the Introduction; Dr. Sapper, "Volcanoes, their activity and their causes," covering the geographical aspects of the science particularly; Dr. Friedlaender, "The Present Condition and the future of Volcanology," reviews methods and theories; and Dr. Jaggar, "The mechanism of volcanoes," discusses experimental work, gas mechanism, and the relation of earthquakes to volcanic magma. There are long lists of references. T.A.J.

KILAUEA REPORT No. 1025

WEEK ENDING SEPTEMBER 13, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The bottom of Halemaumau pit shows nothing remarkable. Fume continues to emerge at a spot west of the 1930 lava pool. Vapor rises at the north end of the south talus and at the south wall above the floor. Dust rose from the pit at 9:20 a. m. September 7. The bottom fume smelled of sulphur at the southeast rim September 8. On this day new points were located at the rim cracks and an improved caliper was applied to these cracks. This work is in charge of E. G. Wingate, who has recently located datum stations near the pit for triangulation and leveling.

At the Observatory instruments 54 tremors were registered, but some of these may be occasioned by blasting by the road workers. One distant earthquake weakly recorded began at 10:18 a. m. September 9. One feeble local seism occurred at 5:19 p. m. September 12, was felt locally, and came from an origin close at hand. A very feeble shock was felt at 10:29 a. m. September 12. Four other very feeble seisms were registered, several showing easterly tilt, and two indicating origins very near. On September 7 nine tremors at the Halemaumau seismograph occurred in close succession, all indicating inward tilt toward the pit.

Tilt for the week at the Observatory was slight E, and microseismic motion was slight.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year — Ten cents per copy

No. 352—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — September 24, 1931

A camp in the Aleutian lands showing country quite simi'ar to Akutan. (Captain Harbor, Natl. Geog. Exped. 1928)

ALEUTIAN EXPLORATION 1931

The increase in work permitted to the Section of Volcanology of the U. S. Geological Survey by Act of Congress in 1931, as shown in the organization outlined in Volcano Letter No. 351, is based in part on recognition of the importance of the Alaskan Peninsula and the Aleutian Islands. These are essentially a long interrupted line of volcanoes, many of them active, adjacent to the great Aleutian Deep where many major earthquakes occur. This is an extension of the series of Japanese and Kamchatkan volcanic arcs, and offers a most fruitful field of study, in which at present it is possible to do only the barest preliminary work, but this work should be done as a foundation for more systematic and detailed investigations in the future.

The Lassen Observatory will expand its work in the volcano areas of California and Oregon, and during each summer, field work is provided for, on one of the volcanoes of Alaska, combined with inspection of seismograph stations at Kodiak and Dutch Harbor. The volcano on Akutan Island was selected for exploration this year and Mr. R. H. Finch did the work, taking with him as guide and packer John Gardner of False Pass.

Akutan is the volcano, like Stromboli, which is often seen smoking by mariners, on the left of Unimak Pass as the ships for Nome pass through to Bering Sea. It is not far from the middle of the Aleutian arc, counting Iliamna as the easternmost volcano far up the Peninsula. The peaks of Akutan are 3170 and 4100 feet high. The island is 17 nautical miles long, and it lies next NE of Unalaska Island. As a volcano it is relatively accessible as compared with great snowy peaks like Shishaldin, it is close by Dutch Harbor, it possesses a village, a harbor and a whaling station, and close at hand is the hot sulphurous deposit of Akun Island. It is just north of the 54th parallel and in longitude 166° west.

Mr. Finch took the steamer "Catherine D.," thanks to the courtesy of the Pacific American Fisheries of Bellingham, leaving that port July 1, 1931. Arrived at King Cove, the seat of one of their salmon canneries, near the west end of Alaskan Peninsula, he embarked on the mail steamer "Starr" July 16, Gardner joined him at False Pass, and the two disembarked at Akutan July 17. Two ascents were made to the summit crater, and on the second the party was caught in a fog cloud, which is a serious matter in these mountains.

The ascent of July 24 proved very interesting and Mr.

Finch secured some good photographs. The crater is some two miles in diameter with a cone about 600 feet high near the center. "The cone is quite uniformly hot, though but little steam is escaping. The heat appears as a dry heat. The outer crater contains a lake in the southwest side. On one side of the lake there is ice, with small icebergs breaking off occasionally, while the temperature of the water on the other side averages 119° F., with small localities showing even higher temperatures, and there is boiling action."

"One vent in the central cone is still open. Rumbling was heard on August 11. Very recent lava flows occur in the crater."

Finch reports that he secured the services of Alec McGlassan, a resident of Auktan, to act as additional packer for a trip around the island on foot during the first week in August. Many photographs were obtained and most of the island was sketched topographically. A Jaggar shock-recorder was operated for ten days on Akutan, but on July 26 no earthquakes had been recorded so far.

Finch sailed on the "Starr" for Unalaska August 10th, inspected and overhauled the needs of the seismograph at Dutch Harbor, operated at the Naval Radio Station, then returned to Akutan on the "Victoria" August 16th. This gave him two days more to finish operations on Akutan, which island he left for the trip back to Kodiak on the "Starr" August 18th. He remained at Kodiak overhauling the seismograph there, in charge of Mrs. M. V. Watkinson, until September 5, when he sailed for Seattle on the Admiral Line steamer. His full report on the mapping of Akutan and the seismological work, with photographic illustrations, will be awaited with interest. T.A.J.

IMPROVED JAGGAR SHOCK-RECORDER

The photograph on Page Four shows a new form of the shock-recorder described first in the Scientific American, November, 1929. The original machine was set up horizontally, as though left side of picture were the bottom, a 10-pound lead cylinder being cast about two flat blades clamped in a vertical plane. This made a sensitive small horizontal pendulum hung like a door, with the blades as hinge, and a boom extending out from the weight has a brass pen pivotted at its outer end resting on a smoked cardboard disc. A common clock movement rotates the disc and moves itself along slowly so that a day's registration is like a gramophone record. The disc is changed every day, and fixed with shellac. The disc itself is a timepiece for subdivision into minutes.

This machine was of great service counting the hundreds of earthquakes that occurred near Hualalai in 1929. It was tested in the South Seas in 1930 and some models like it have been made in New Zealand. In Niuafoou I set up two complete weighted arms and clockworks at right angles to each other on the concrete floor of a warehouse. As each box was three feet long, this took much space. The object was to record separately east-west and north-south earthquake motion. There was also recorded the motion of rats, kittens, chickens, cockroaches and spiders, and these were not planned for. The apparatus must therefore be housed in a tight case, and tending such an extensive machine each day on the floor is laborious. Horizontal surfaces of the smoked cards are hard to examine and are tempting to insects.

An improvement in the machine, with the principle of action but slightly changed, is shown in the cuts. The cylindrical mass has its two flat hinge blades clamped horizontally below, the boom protrudes upward, and the recording disc is in a vertical plane like an ordinary clock. The pivotted pen on the top of the boom is arcuate and long, and may be tipped over against the smoked card at about 45 degrees to the disc surface. The blades are stiff enough to give the system a free period of nearly one second with only about one eighth inch of spring blades exposed between the lead cylinder and the clamps. At this period the inverted pendulum is stable and upright. If the exposed part of blades is shortened the period becomes shorter. This inverted pendulum system oscillates only in the azimuth at right angles to the hinge line, which was also true when the system was swung as a horizontal pendulum.

The advantages of the new system are that the clock can now roll along on pulleys on a rubber-shod track in the plane of the clock-work wheels. These pulleys are attached to the spring barrels and given a diameter appropriate to the travel-speed desired. The center sleeve of the disc plate slides on the minute-hand spindle, so that the card makes one revolution per hour. The whole apparatus is enclosed in an upright clock-case with glass front (not shown) and screwed against the wall. The boom is of balsa wood. The clock may be slid sideways on its tracks so as to move the disc under or away from the pen. When disc is removed the clock is wound, a new disc is smoked and screwed by a central button to the plate, and is slid back to the starting position under the pen. With a steel point the date and the time of starting and stopping are marked on the smoke. The card is smoked by twirling it over a smoking kerosene lamp until it is an even brown. The rear suspension of the clock is a free pulley on a second track. The pen and the top of the boom may be seen at the right in the cut on Page Three. A final advantage of this machine is that in the corner of a room two complete shock-recorders may be set up at right angles on the two walls, with their two dials side by side. Obviously the handling of the discs is easy, and almost no floor-space is required.

Several earthquakes have been registered and the seismograms are good. It is necessary to choose a very quiet cellar wall, as the instrument is extremely sensitive to the opening and closing of doors. T.A.J.

KILAUEA REPORT No. 1026

WEEK ENDING SEPTEMBER 20, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

There are no essential changes in the bottom of Halemaumau pit. There is a little fume on the floor and vapor at the edges of the floor, and these increase in visibility after rain. Measurement of the rim cracks shows little change.

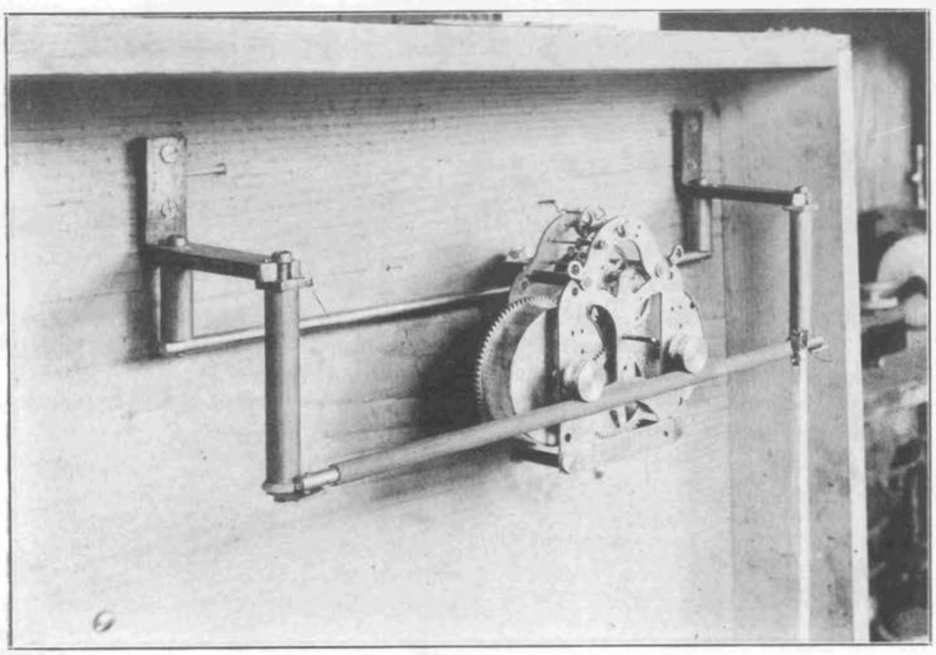
The seismographs at the Observatory registered 43 counted tremors, of which three were continuous, and one of these spells lasted from 6:33 to 7:50 p. m. September 20. There were many smaller tremors September 18.

Two feeble earthquakes were felt at Kilauea at 4:23 a m. September 18 and 6:14 a. m. September 19. These indicated origin distances of six and four miles from the Observatory. The first was accompanied by tilt away from the pit at Halemaumau. Neither was observed in Kona, and the indications suggested Kilauea origins. There was one very feeble quake September 14. Tilt for the week was slight NE, and microseismic motion was slight.

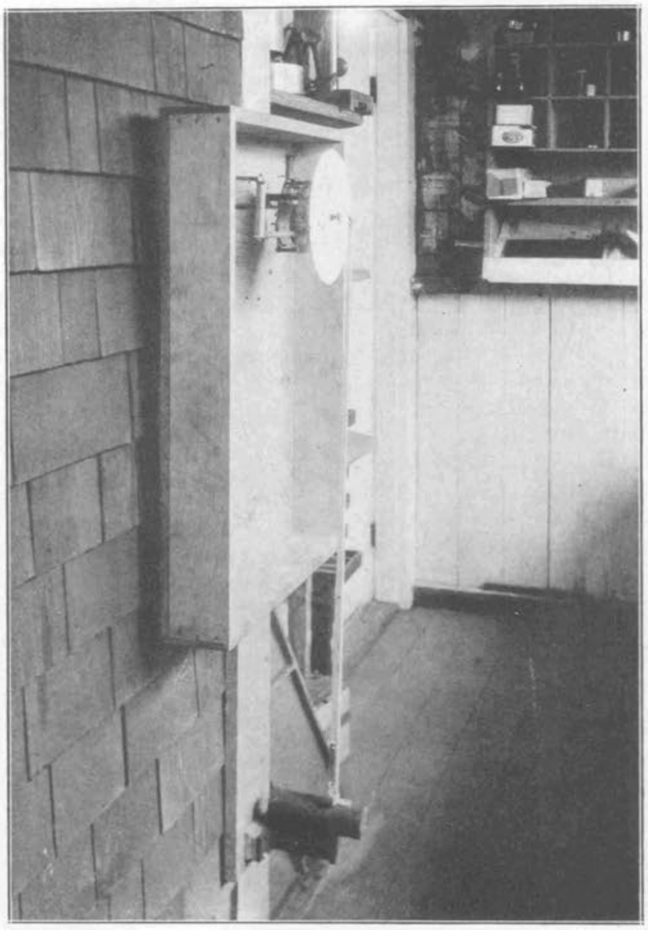
TILTING OF THE GROUND FOR AUGUST

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

August 3 - 9	1.3 seconds NE
August 10-16	0.4 second W
August 17-23	1.4 seconds NNE
August 24-30	1.0 second WSW



Seth Thomas clock on tracks with Jaggar shock-recorder boom and pen on right. A card disc is affixed to the central spindle, and the pen falls over on its smoked surface recording time and size of earthquakes. Photo Maehara.



New model Jaggar shock-recorder without case. Cylindrical weight below attached by flat springs to angle-iron clamps on wall. Boom and pen rise from weight, to write on revolving disc above. Clock and disc move along slowly so as to write circle in circle like a gramophone. An earth shock writes a zig-zag, and the clock disc times the occurrence.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | **Ten cents per copy**

No. 353—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | October 1, 1931

Gorely Volcano seen smoking during its eruption January 1, 1931. View from Petropavlovsk, 67 km. from the volcano. The summit of Gorely is behind the range, and the conspicuous cone is Vilutchinsky, which is nearer. Photo I. Larin.

KAMCHATKA VOLCANOES IN 1931

Professor P. T. Novograblenof, Director of the Kamchatka Museum at Petropavlovsk, under date June 24, 1931, has kindly sent us the accompanying photographs and a description of volcanic activities in Kamchatka during the winter and spring. This material is of great value as hitherto the world of science has heard but rarely from this great volcanic region. In Volcano Letter No. 314 it was noted that the Academy of Sciences of U. S. S. R. is doing volcanological work in Kamchatka. Also the eruption of Gorely Volcano was mentioned, lasting from September 1929 to March 1930 and covering much of southern Kamchatka with ash. Also there was activity of Kluchevskaya and Shiveluch in 1929 and 1930. An excellent account of travels in Kamchatka, 1920-22, with two valuable maps and numerous photographic illustrations has been published in German by Sten Bergman entitled, "Volcanoes, Bears, and Nomads" (Strecker and Schroeder, Stuttgart, 1926).

The active volcanoes of Kamchatka extend NNE-SSW along the eastern side of the peninsula, and near the middle of the belt is Kluchevskaya in the midst of a mighty group of volcanoes rising to a height of 4,861 meters. About 60 km. to the south lies Tolbachinsky Volcano. Petropavlovsk, the capital, with a population of something over a thousand people, is on the north side of a bay in the southeastern part of the country, and across the bay from it to the southwest the southern end of Kamchatka is occupied by a belt of great volcanoes, and this is prolonged farther south in the arc of the Kurile Islands. Several of these big cones are in full view from Petropavlovsk, the most conspicuous being the pure cone of Vilutchinsky Volcano shown in the photographs. The white steam from Mutnovsky shown in the photograph on Page Three is about 66 km. from Petropavlovsk, where the picture was taken.

The following is an account by Bergman of his visit to Mutnovsky Volcano:

"On this day we reached an elevation of a thousand meters on the volcano which is here surrounded by a lava plateau which extends as a shoulder around the greater part of the volcanic mass. Here we were at the upper limit of vegetation, where the last scrubby alder thickets gave out. The crater of Mutnovsky lay on the other side of the cone, and we had now to follow this shoulder around the mountain until we were immediately under the crater.

"Toward evening a mischance that we had most feared occurred: the weather which during the day had been misty, closed in dense and it began to rain. Impenetrable clouds veiled the entire mountain. We were in a waste of lava, where there was not a stick of wood, and where it would not do to be overtaken by night. So we climbed down through rain and fog to the upper limit of the bushes and found after a long search a small thicket where we succeeded in pitching our tent, and after much labor ignited a fire. Since, however, our silk portable tent was not adapted for plateau rains, particularly where there was no opportunity to draw the surfaces tight, we were soon as wet as though we had been immersed in a lake with our clothes on. In order to give the drops of rain as little chance to accumulate as possible, we sat huddled together surrounded by our sleeping bags and rain coats throughout the entire night, and had abundant time to repent us of our sins. I thought of my warm bed at home in Sweden, and during the long hours of this sleepless night had opportunity to appreciate how little we realize our blessings.

"Not until morning did the rain cease, but the fog still hung over the mountain, though not so low as on the preceding day. We saw nothing of the volcano, but the plateau shoulder of lava was free from cloud. We were about an hour getting a fire to going so that with its help and numerous cups of tea we acquired some warmth inside and out. We were not afraid of catching cold for we had long since proved that we were quite immune to such disease in that fine air free from bacteria. If it were not so it seems probable we would never have gone home to Sweden.

"After ridding ourselves of our wet clothes and donning from the packsacks some relatively dry ones, we were ready for the march. The weather cleared and a fresh breeze sprang up so that after some hours our outer clothing became perfectly dry.

"We had not proceeded far before the first bear appeared and I attempted to photograph him. He headed straight for us. Taking advantage of the unevennesses of the ground and crouching down, I succeeded in getting within 20 meters of him and made an exposure with my camera in one hand and the rifle in the other. As soon as I snapped the shutter the bear saw me and made off. Above the bushes the snow-buntings appeared, fluttering about and showing up sharply and beautifully in contrast to the black lava. We gave the day to studies of birds and enlarged our acquaintance wth them as compared with another volcano previously visited. The birds of the two volcanoes were strikingly alike.

"Just as on the previous evening we pitched our tent in the uppermost alder bushes, but we had made good headway toward the crater after this day of trudging across the treacherous lava waste. On the following mornng it was still cloudy, but the volcano was clear. We could have no question about the position of the crater, whence rose a frightful column of smoke. We headed for the crater at once, which was about 500 meters above our camp ground and 3 to 4 km. away. The sun came out during our climb and showed us a completely new and magnificent landscape, which had been hidden from us during the days of fog and rain.

"The nearer we came to the crater the more noticeable was the smell of sulphur, so that finally breathing was difficult, and made us all cough, including our little dog Kuma. In places fume came out of cracks in the ground which was so porous that it seemed as though we might break through and burrough underground like a sand crab. The extraordinary colors of the ground varied from sulphur yellow to deep red. At last we stood on the rim of the gigantic crater, the smoke of which we had so often seen from the window of our house in Petropavlovsk. The crater is not quite at the summit of the volcano, so that we could climb still farther and from above look down obliquely at the colossal spectacle; a frightful cauldron of boiling vapor. From this lava pinnacle we were able to see still more: adjacent to the smoking crater there was a still larger abyss where far below we saw a glacier and a small waterfall. These were several hundred meters down, and the cliff above them was almost vertical. Then the fog closed in on us and it was with great difficulty that we made our way back to the vegetation line."

Mr. Eric Hulten, botanist of the expedition, on another trip after waiting for many days for clouds and rain to cease, succeeding in reaching the crater with his party and in getting a better view of Mutnovsky and its outlook. The smoking crater lies on the west rim of a large cauldron, and the party followed a small ridge on which stands a number of knobs. From the highest of these the clouds were seen rolling in from the sea, and the volcanoes were beginning to don their cloud caps.

"It was a wild and wonderful panorama. Not less then 14 big volcanoes were in sight, from Schupanowa, ten miles north from Petropavlovsk, down to Kambolnaja, the southernmost volcano of Kamchatka. For a time the smoke of the crater blew directly over us, and a fine dust rain fell consisting of milky drops, which made small white spots on our clothing, presumably sulphur.

"As the wind veered and the smoke went in another direction we obtained a view that I shall never forget. It was as though we were permitted a glimpse of the workshop of the gods, where gigantic forces are at work such as began millions and millions of years ago when the first strokes of creation fashioned the earth. White jets of steam shot whistling and blustering out from holes in the cliff, hot water ran down from the walls and melted its way through a glacier whose sharp-edged broken green and crevassed blocks of ice were heaped together in a jumble at the mouth of a huge canyon that led away from this Hell cauldron. In the midst of the ice two mighty steam jets arose, and through the crooked tunnels that had been melted out of the ice one could see the bedrock of the mountain. Higher up the cauldron wall where its edge stood several hundred meters above the glacier the younger crater belched its smoke upward, as though a thousand locomotives were clustered together opening their safety valves—and yet we knew that this was but a weak imitation of what Mutnovsky once was.

"And how describe the cliffs themselves? They had not the common gray color of a mountain, but were painted over in fantastic shades. We sat on a minor cliff of bright colors which gave place below to a terra cotta precipice, and showed on the right a row of sharp pointed gray-blue pyramids which stood on an underpinning of white spotted with baked dark carmine and indigo blue points. Beyond the wall of the kettle was bright blue with big yellow areas of pure sulphur, which were bordered with green and orange rings. All of this, along with the gray-white rifted snow covering of the glacier, on which diamond shaped small black pyramids were strewn, and also the sharp green-blue ice pinnacles, left us with a memory never to be forgotten. Bornachoff, one of our companions, who had never known fear, became suddenly very anxious and careful, and it was with difficulty that I persuaded him to follow us down the yellow-white cliffs of the gorge. Possibly there awakened in him a trace of the terror his ancesters felt for the 'smoking mountains' that one dared not approach too near, lest the 'Gamuli,' the mountain spirits, might be cooking their whales, which nighttimes they go down and fetch up out of the sea, one on each finger, and flying bear them home.

"The stream pouring out below was buried under snow and ice blocks, and we reached the tunnels and got under the upright walls which lead down into the crater, out of the rifts of which small and furious jets of steam escape. There rose a thin knife-edged slice of rock out of the ice, from the walls and base of which hundreds of steam jets shot up. Warm water ran down carrying red-brown mud, and a grayish-yellow brook broke its way through the ice, the melted green walls of which could be seen transparent behind the vapor. The jets of steam so hissed and roared that it was necessary to shout in order to be heard. In such an environment one may believe anything, and none of us would have been astonished to look up and see an ancient mountain spirit of the Kamchadals sitting astride one of these cliffs holding out a whale on a spit wherewith to cook it in a steam jet.

"This devil's canyon under the glacier was near the summit. The veil of smoke hid whatever the crater might conceal in its depths, but there was no lava lake nor incandescence, but rather numerous holes some hundreds of decimeters across as sources of jets of steam."

1931 ACTIVITES

During the winter three big volcanoes, Tolbachinsky, Kluchevskaya, and Gorely, were in activity, all situated on the eastern shore of the peninsula.

Tolbachinsky, elevation 3730 m., had a magmatic explosion March 4, 1931. Its cone and the vicinity were covered with ash. In the village Tolbachik, 41 km. from the volcano, the ash was a few milimeters thick.

Kluchevskaya, elevation 4861 m., had a severe eruption on March 25, 26, and 27, 1931. All day March 25 this beautiful volcano was quiet, but after sunset in the village Kluchi, 32 km. from the crater, was heard a crash, and then a column of fire appeared upon the summit. The rumbling increased in successive periods of noise, and during the night the volcano thundered and several loud explosions were heard. In Kluchi next morning ash fell and the air darkened. The volcanic ash and sand were falling during three days. All traveling by dog sledge became impossible. The strip of country covered with ash on top of the snow was 240 km. long and 50 km. wide; the average depth of the ash was 1 cm.; therefore during this short eruption Kluchevskaya threw out approximately 120 million cubic meters of ash on the northern side only.

Professor Novograblenof describes the ash as consisting of freshly broken pieces of different sizes, a small portion of them appearing rounded as though melted. There are pieces of lava glass and pumice and fragments of the minerals pyroxene, magnetite, plagioclase, and colored undetermined substances.

Gorely Volcano, elevation 1831 m., has continued in activity since 1929. In the summer of 1930 it was more or less quiet, but in the autumn its eruptions were renewed. For example, on September 30, 1930, it threw out clouds of vapor and ash in large quantity. The dark blue masses of ash fell in South Kamchatka over a vast area. January 1, 1931, the column of gases and ash over the summit of Gorely was more than 5,000 meters high. The eruption lasted until January 17, when the column was 6,000 meters high. The volcano smoked like a battleship (cut Page One). The smoke extended toward the northeast for a distance of more than 90 km. (cut Page Three). There was some reflection of fire seen on the summit. When the atmospheric pressure was very low the activity increased.

Mr. V. S. Kulakof, geologist of the Kamchtka volcanological expedition under Professor A. N. Zavaritsky, visited Gorely in May. He states that on the summit there are five and possibly six craters. Only one of these, 250 m. in diameter, is in activity, and no lava flows poured from this last eruption. Bombs, lapilli, sand and ash fell. Ash was falling mixed with snow. One hundred meters from the edge of an eruptive crater a thermometer thrust into ash showed -2° C. Under the ash there were layers of snow. The bottom of the crater could not be seen owing to the clouds of fume rising from the chasm. We are greatly indebted to Professor Novograblenof for this information. T.A.J.

KILAUEA REPORT No. 1027

WEEK ENDING SEPTEMBER 27, 1931

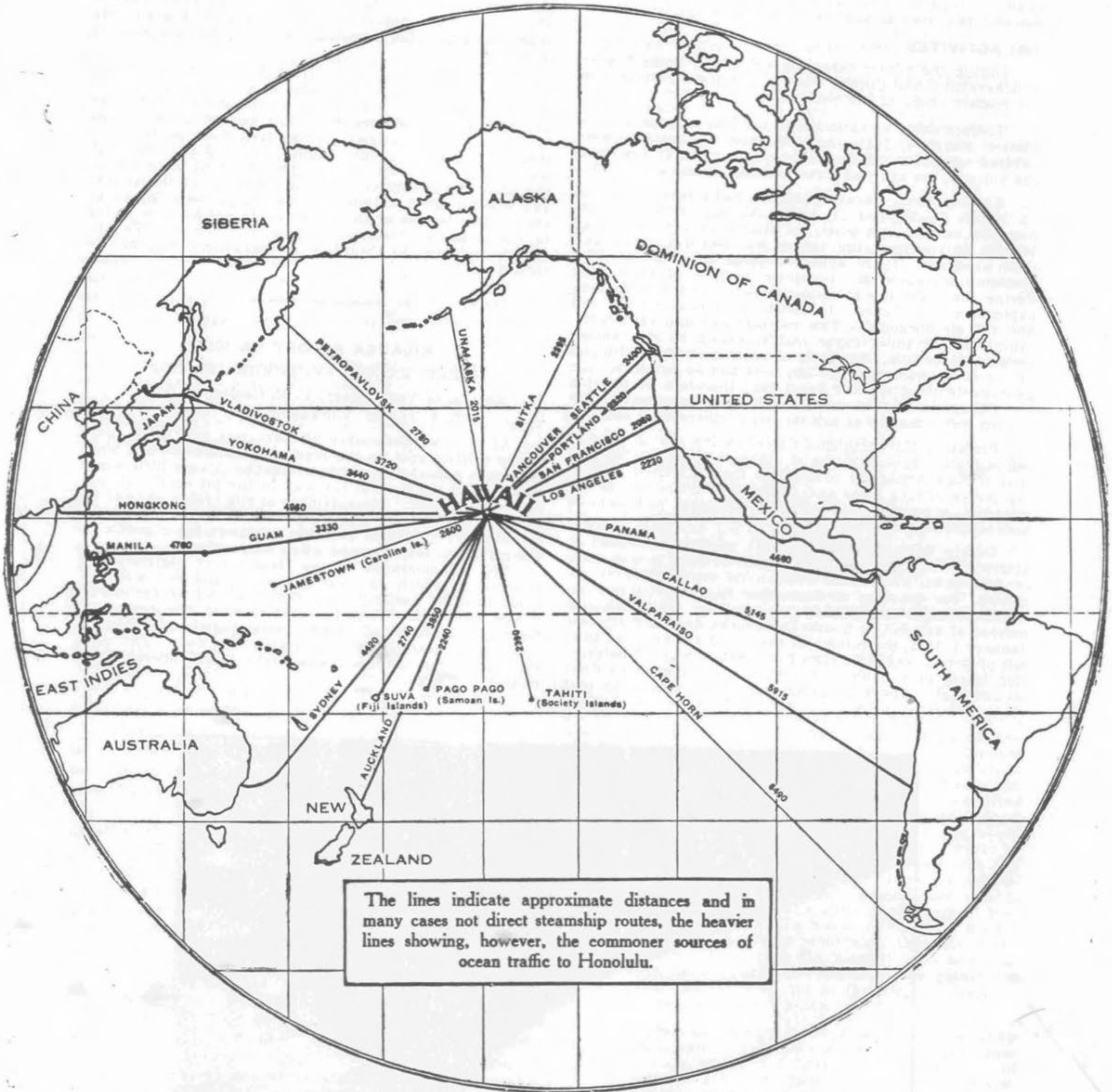
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

At 10 a. m. September 21 there was very little fume at the sulphur spot on the floor of Halemaumau and what there was appeared to emerge in puffs. A very little vapor came out of the rock of the wall of the pit southeast just above the bottom. Measurement of rim cracks showed no widening. There have been no other changes during the week. Surveys are in progress to determine a profile of the pit which may be used when lava returns.

The seismographs at the Observatory registered 26 tremors, of which one was prolonged, and two were accompanied by easterly tilt. One doubtful distant earthquake was weakly recorded at 3:15 a. m. September 21. Four very feeble local seisms were registered, showing tendency to easterly tilt and origins very near. Tilting of the ground for the week was slight E and microseismic motion was slight.

Heavy column of smoke from Gorely Volcano as seen from Petropavlovsk 67 km. away, January 17, 1931. The white steam on the left is from Mutnovsky Volcano in the background, the sharp cone in the middle is Vilutchinsky, and Gorely is on the right. Photo I. Larin.



Map of the Pacific showing position of Kamchatkan Peninsula.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

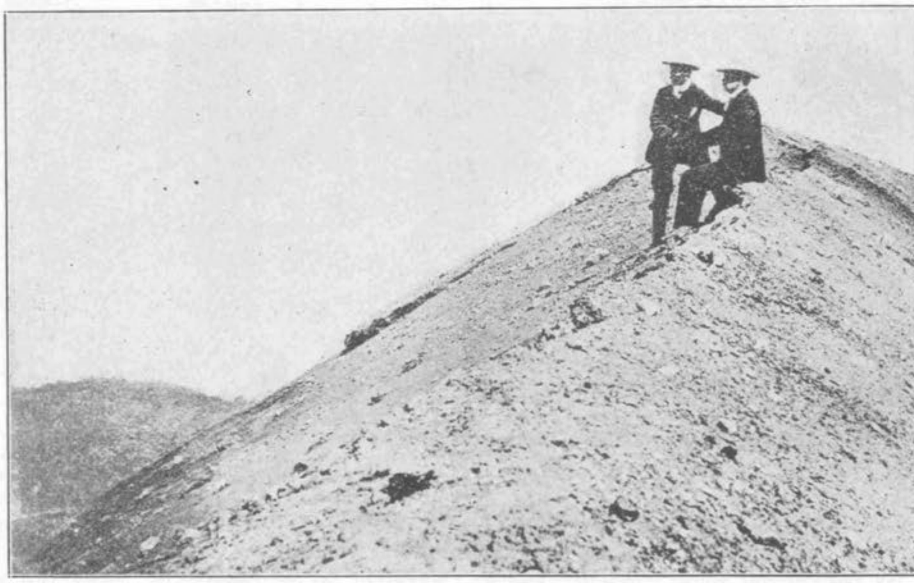
Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

The Volcano Letter

Two dollars per year | **Ten cents per copy**

No. 354—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | October 8, 1931



Steep summit between the craters of Turrialba Volcano, Costa Rica.

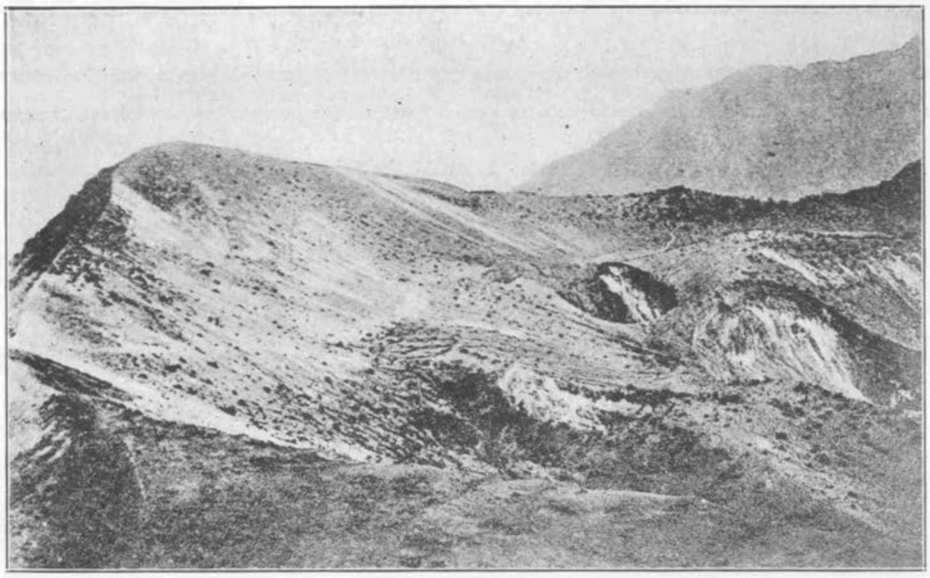
ACTIVE VOLCANOES OF COSTA RICA

Pittier describes the mountains of Costa Rica as divided into a southeastern system of old eruptive rocks without volcanoes, and one peak reaching an elevation of 12,467 feet; and a northwestern system with active craters. This chain of volcanoes begins with the conical peak of Turrialba, rising in an uninterrupted slope from the Santa Clara plains to a height of 10,965 feet. Going west from Turrialba we pass Irazu, Barba and Poas volcanoes, and from there northwestward the range diminishes in height past the less conspicuous volcanoes Tenorio, Miravalles, La Vieja, and Orosi, when we reach the Nicaraguan boundary (Costa Rica, Vulcan's smithy, by H. Pittier, Nat. Geog. Mag. June 1910).

Dr. Jaggar visited Costa Rica in the early summer of 1910 in order to study the effects of the terrible earthquake of May 4, 1910, at Cartago. He visited the craters of Irazu and Poas. President Jimenez kindly furnished the following account of a visit to the crater of Turrialba in 1864. The account states that at that time Poas, Barba, and Irazu were "not altogether dead," but Turrialba was in complete activity, and had been so for many years, sending out thick and high columns of smoke mixed with plenty of sulphur so as to destroy the vegetation on the slope of the mountain. Large deposits of sulphur of great purity were said to exist on the northeast side.

The biggest craters, more than 300 feet deep, showed black and yellow walls leading into the depths where more than a hundred mouths five to six feet in diameter, fringed with yellow layers of sulphur were hissing and sending up vapor with a noise like steam boilers. The roar of the steam was terrifying especially on the east and west corners of the crater where two larger vents sent up excessive vapor with a rush. All of the vents together made a large column of fume at the lip of the crater over 90 yards in circumference, and this made a high column above the mountain in calm weather as seen from the town of Heredia. The vapor was said to increase in winter time after heavy rain. There is an eastern extinct crater adjacent to the active one, and yet a third to the northeast where water collects in winter time. Between the three craters are three sharp ridges meeting in peaks of which th northern and eastern are the steeper. (See cut Page One). The circumference of the crater region is about 1,800 yards. Its shape is somewhat elliptical and irregular. Its inside walls are nearly vertical, covered in places with yellow layers of sulphur, and on account of the noxious fumes and the loose ground the descent is dangerous, and to return might perhaps be impossible. The outer wall of the crater to the west is peculiarly dangerous to walk upon; wherever one digs with a stick a small smoking chimney is created with deposits of sulphur and other salts, and in a short time the heat rising from the hole so made is excessive. The ground on the plateau about the summit is covered with lava fragments, sand, clinker, sulphur, and various salts, and there is little vegetation except to the south where the ground is not reached by fume. Here there are dwarf scrub and creeping plants. The walls show layers of rock of many different colors exhibiting the structure of the mountain, and there is sign of lava flows toward the north, where also the greatest devastation has been brought by fallen materials.

Pittier (1910) describes Turrialba as having a beautiful crater, forming a narrow elongated basin, in constant activity through the ejection of sulphurous vapors mixed with sand seen escaping noisily during recent years from the broad vent at its westernmost extremity. The only known violent eruption of Turrialba occurred in 1869 when



Crater of Irazu Volcano, showing part of cup and inner pits.

it threw out much explosive material and fine sand carried by the trade winds far to the west.

Irazu is about 360 feet higher than Turrialba, and a portion of its open crater, containing several interior pits, is shown on Page Two. The following is from my journal of 1910, when we started for the summit from a beautiful dairy ranch in the forest high on the mountain flank:

On June 3 we were up before the dawn, our hostess served coffee, and accompanied by a guide we mounted our beasts and entered a steep winding woodland path. Mr. Alfaro pointed out a rather large quick-flying bird which gave a plaintive whistling call: it was that rara avis the Quetzal which in Guatemala is regraded as the national bird. We passed from the tree line to a zone of shrubs and here the glorious summit view burst upon us, the Caribbean Sea far to the east and a dark Pacific loom under the clouds to the west. We were standing on one of the dividing peaks of the Central American watershed and viewing both oceans at once! Below us stretched the fair and fertile plains of Paraiso, Cartago, and San José, too far away to show any sign of the recent tragedy. Beyond to the south were the calm, dark mountains, as still, silent, and emblematic of **terra firma** as though earthquakes had never been. More tumultuous were the moving clouds, especially over the Pacific where they caught the high roseate lights and dark shadows of the dawn. Looking eastward towards Limon the rising sun made a trail of tropical glory along dim misty waters and pale pearl-gray clouds below, the foothills piercing the clouds like islets in a billowy sea.

As geologist I noted the much greater fall of the eastern streams, such as the Raventazon, as contrasted with the extended gently falling drainage of the broad valley to the west occupied by San Jose, San Domingo, Heredia, and Alajuela and other towns. The Raventazon shows a gorge just east of Paraiso and it is clear that if any massive uplift of this country is going on which causes the drainage to cut deeper, the maximum uplift is on the eastern side of the country. If the movement is a tilt, then it is a tilt **up** on the east, down to the west. This agrees with the appearance of elevated coral shelves and forelands in British Honduras and at Limon in Costa Rica, in that such raised oceanic formations give evidence of elevation on the east cost. And the west coast shows drowned valleys.

As one looks down from the summit of Irazu on Cartago and Paraiso, these towns appear to lie on an intramontane plain, and all about them are the evenly rectangular tilled fields of a fertile agricultural land. They are really on the pediment of the volcano, where the outwash from the gulches has built fan-cones of soil and bowlders onto the floor of a broad valley which originally drained **westward**; ie., towards San Jose and the Pacific. The evidence of this change of drainage is shown by a barbed stream beyond (S. E. of) Paraiso, in a deep gorge which now joins the Raventazon at an acute angle headwards, whereas its original junction with a normal west-flowing drainage was at an acute angle mouthwards. In other words, the Raventazon and its tributaries has robbed the waters of formerly west-flowing rivers and thereby has forced the continental divide to shift from a former position east of Paraiso to a present position west of Cartago. Cartago is thus practically on the continental divide, in territory where the divide is, so to speak, disputed by a conquering eastern drainage, which is cutting deep canyons, and a conquered western drainage which has lost volume and is losing rapidly its basin lands. This physiographic change may have significance as one of the many causes which serve as trigger to the earth stresses which make the earthquakes.

Continuing our climb, now in the bushy zone of the high summit, we came to bare patches of soft black cinder with new fractures in the earth. These fractures were marked by rows of caving holes—in one place two feet wide and another six feet wide and the rows trending WNW. Such cracks are not unusual in the crater region of a volcano and these in Irazu are not necessarily the product of the recent earthquake disturbance. The WNW trend is about parallel to the main fissure system which must underlie the chain of volcanoes of which Irazu is a part.

The summit of Irazu was soon reached. This is on the south side of the crater and is merely the highest point of its rim. The crater north of us, as we stood on the peak in an uncomfortably stiff breeze, appeared to be an irregular drainless depression over a mile wide with two broad shelves of lava within it, one over the other like steps, on the side toward us, and a quantity of irregular deep pits in the opposite or northern side of the hollow. The effect is as though the whole cauldron had once been filled with lava to the level of the highest step; the lava seems thereafter to have hardened and tumbled in on the north and amid the tumbled blocks new explosion craters were formed at different times, making the several roundish or elliptical pits. The lower step would by this explanation be a piece of the frozen lava lake which had slipped down toward the convulsed northern half of the bowl. On the east there is the largest of the pits, which reaches almost the dignity of a subordinate crater. The northern rim is very low, and the northern side of the mountain is profoundly eroded in deep, steep furrows by the headwater branches of a muddy river, known as the Rio Sucio, by reason of its turbid waters This river is undoubtedly the main drain of the crater by underground channels. The crater had some shrubby and herbaceous vegetation. There is nothing immediately suggestive of recent activity or earthquake slides. The ground on the crater rim is covered with angular fragments of andesite and blackish gravel. The walls of the steps and of some of the pits show bedded sections of lava, hard rock, while the "treads" of the step-like terraces have "playas," dried mud ponds, on their surfaces. There are seven or eight pits, mostly choked at the bottom visibly by slide-rock, but one or two extend below into black holes which continue indefinitely. There is a shallow pond of milky water in one of the pits.

To the east rises Turrialba, a beautiful flat-topped cone, said by those who live on its flanks to be the theater of hollow murmurings from the bowels of the earth. These "retombos," or terrestrial grumblings, we heard described by all our friends resident in the vicinity of San Jose, and the residents had become so sensitive to these noises that they heard them constantly even during the time of our stay. We never succeeded in hearing them, or if we heard them, in distinguishing them from thunder, which we heard nearly every afternoon. We were also unfortunate in being unable to perceive any of the aftershocks of the earthquake, though they were felt by others and instrumentally recorded at the observatory.

At the headwaters of the Rio Sucio on the north side of Irazu there are bare brown landslide surfaces occasioned by the tropical rains and the steep slopes. The river has cut a canyon with vertical walls a short distance below the summit cone. A tributary waterfall cascades over the eastern cliff of this gorge. Just below the north rim of the outside surface of the mountain, and on the flanks of one of the gulleys that lead into the Sucio, there is a patch of bare sulphur-covered rock extending 200 yards down the mointainside. Mr. Alfaro informed us that the solfataric activity which generated this patch began about 1888 and that the sulphur, which may be removed in fairly thick cakes, is deposited from gases which emerge from pores of the rock. We saw no hot water or visible vapor, but recent photographs and records by other observers indicate that solfataric steam is ejected from time to time.

Some days later we took horses from the village of San Pedro for the ascent of Poas Volcano. Through country lanes we climbed, with the volcano ahead appearing as a mass of densely wooded hillocks. We entered the jungle by way of a narrow path over muddy hillslopes and muddier tangles of enormous roots. We frequently had to dismount and whip up the animals ahead of us. This jungle was remarkably different from the open groves of Irazu. There are here great trees with hanging vines, aerial parasitic flowers, some orchids, immense horn flowers and ferns, and all kinds of dense, shrubby undergrowth. We came upon a jaguar trap, and the guide told us that two of these cats had been caught in it. It consisted of a rectangular pen made by driving heavy sticks into the ground and roofing them with logs. A freshly killed fowl was placed as bait inside the pen, and provision was made for a heavy shutter to fall and close the opening when the bait was touched. Twice during the ascent we came to open meadows surrounded by elevated land which are possibly old craters. We passed wild cattle. Finally we dismounted and entered

Lake of steaming water, usually in effervescence, in crater of Poas Volcano. Photo Jaggar 1910.

upon the last stage of the journey on foot. The jungle thinned somewhat to a scrubby growth probably determined by occasional ashfall from the volcano. Poas is much lower than Irazu, its elevation approximately 8,000 feet. Bushes became open with a gravely soil between them, and then we came out on the edge of the greater crater at first obscured by clouds. We could smell sulphurous acid.

After a visit to a higher cold lagoon which fills a subsidiary crater, we returned to the edge of the greater crater and found it free from cloud. It proved to be a big cauldron filled with whitish water in constant ebullition, and bordered by bare, low banks of clay and bowlders radially trenched by hundreds of rain rills. The upper lip appeared to be half a mile in diameter; the depth from the rim to the water surface was perhaps 800 feet, and the distance across the pool 1,500 feet. On the north side of the crater a hill appeared. somewhat higher than the one we were on (see cut Page Three). Toward the west from the water-filled basin there is an irregular tract of "bad lands" drained westward by a gulch which shows a bedded section of agglomerates and tuffs towards its head. This gulch does not drain the boiling pool at the present level of the water, though it would do so if that level were raised a very few feet. There was evidently much relatively new sand and dust and gravel from the eruption of January 25, 1910.

The water in the muddy pool was bubbling up chiefly at one spot near the eastern side of the pool. It rose in a small dome of ebullition from time to time. There were sheets and tails of vapor rising from all over the surface of the water and the color was a pearly gray. The water appeared to be hot but not boiling hot, and the ebullition appeared to be the escape of vapors from a vent below. The eruptions of Poas are described by Pittier as geyser eruptions, and the column of steam and water, when a big jet occurs, is said to reach heights of thousands of feet, and to constitute the greatest geyser in the world. It is doubtful whether such eruptions may be described as a true geyser, for this volcano throws out bombs, ash, and mud, and the gases which rush upward through the water are highly sulphurous, and probably are not steam in the sense of being occasioned by the boiling of this same water column. It appears to be merely a case of a volcanic eruption making its way through a crater lake. In the bigger eruptions the lake is probably discharged completely. Such was the eruption of January 25, 1910, when stones fell on the edge of the crater, and the finer dust fell at San Jose, 20 miles to the southeast. Pittier states that the water of the crater lake "tastes like strong vinegar."

There was good evidence of the recent eruption on the rim of the crater. Lumps of gray ash, clotted by rains into the appearance of portland cement, were to be seen under the bushes where they had gathered in the branches and fallen off to the ground beneath. There were pumiceous bombs, large blocks of rock, which had fallen from great heights into the soft earth of the hillside. They had punched holes in the ground and buried themselves. We dug up several of these, in size from a few inches to two feet in diameter; one was found buried 38 inches below the surface of the ground. There were many stones coated with sulphur.

Pittier describes the eruption in question as follows: "At 5 p. m. January 25 a smoke-like column rose from Poas to prodigious height, estimated at no less than 13,000 feet. After reaching its higher point, the column spread into a mushroom-shaped grayish cloud, which, carried by the trade winds, soon covered like an immense screen the whole valley of San José."

"An hour after the first indication of eruption a rain of ash began to fall, increasing in coarseness as well as in quantity as the eruption proceeded.

"Near the crater volcanic mud was mixed with stones and the latter broke thick limbs and roots of trees and penetrated deep into the ground. When visited after the eruption, the boiling of the crater lake had ceased.

"This eruption was followed on April 13 by a serious earthquake over all the central plateau of Costa Rica, just after midnight. Everyone ran into the streets. There were numerous shocks the next day, and several public buldings were badly wrecked. Ground was rent and fissured in the neighborhood of Cartago. On May 4, at 6:50 p. m., came the terriffic jolt from the east which wrecked the city of Cartago, just at the foot of Irazu Volcano. This was one of the most intense earthquakes of modern times." (See Jaggar and Spofford, Costa Rica earthquakes, Jour. Assoc. Eng. Socs. 46, No. 2, (Feb. 1911). T.A.J.

KILAUEA REPORT No. 1028

WEEK ENDING OCTOBER 4, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Fume was fairly strong at the floor vents of Halemaumau early in the week, appearing irregularly in puffs, probably due to the strong NE wind. Heavy rain increased steam activity in the pit. Accumulation of water in a pool near the Halemaumau seismograph caused deceptive tilt of that instrument away from the pit.

On October 1 fume was plentiful at the SE sulphur spot. Two small slides from the north wall were observed at 7:35 and 7:40 a. m. There was the usual increase of steam after rain on this day and the next. A small slide also occurred on October 2 at 7:30 a. m. A faint smell of sulphur was noticed on the west side of the pit.

The instruments at the Observatory recorded a total of 19 very feeble tremors, one showing easterly tilt; 3 very feeble local seisms, one at 8:40 a. m. October 3 showing distance 4 miles and another showng easterly tilt; and a distant earthquake at 8:45 a. m. October 3 (uncorrected H. S. T.). The record of this shock is much larger than the Napier disaster of February 2, though the distance, 3750 miles, is not so great. Phases were as follows:

eP 8:53:42 a. m.
eS 9:01:17 a. m.

The average of accumulated tilting of the ground at the Observatory was slight ENE. Microseismic motion was slight

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 355—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | October 15, 1931

Lake Amatitlan and Agua Volcano in Guatemala.

VOLCANO ACTIVITY OF CENTRAL AMERICA

In some early numbers of the Volcano Letter the question was reviewed as to what constitutes comparative volcanic activity for different districts. Different methods suggested have been Von Wolff's "Index of decadence," where an index number is applied to the percentage of extinct volcanoes for the total number of new districts; the total number of historical "outbreaks;" the number of volcanoes active for the aggregate length of the volcanic zone; volume of output of lava; and lastly volume of output of explosive materials. It was found that the volume of output makes the most consistent table for a list of regions, but that the output of lava is at the opposite end of the list from the output of explosive material. Thus Iceland leads all other districts in output of lava and the Dutch East Indies lead the world very greatly in output of fragmental deposits for the period of human history. The oceans and subarctic regions are the great lava producers, the continental borders and the equatorial belt produce much explosion.

Reading by explosive output alone, we get the following series by Sapper's revised tables (Zeitschr. Vulk. XI, Heft 3, 1928):

		Cu. Km. Fragmental
1.	Java belt	185.0
2.	Central America	58.0
3.	Alaska-Aleutian	30.0
4.	Iceland	10.0
5.	South America	9.5
6.	Japan	8.2
7.	Philippines-Molucca	6.5
8.	Kamchatka-Kurile	6.0
9.	New Zealand-Tonga	4.1
10.	North America-Antilles	3.5
11.	Mediterranean	3.5
12.	Melanesia	3.1
13.	Atlantic Ocean	2.2
14.	Indian Ocean-Africa	2.0
15.	Central Pacific	1..5

Contrast with this the following list in the order of lava output:

		Cu. Km. Lava
1.	Iceland	15.5
2.	Central Pacific	11.0
3.	Indian Ocean-Africa	8.0
4.	Atlantic Ocean	5.5
5.	Mediterranean	5.1
6.	Kamchatka-Kurile	5.0
7.	Japan	3.5
8.	Alaska-Aleutian	2.0
9.	New Zealand-Tonga	2.0
10.	North Amerca-Antilles	1.5
11.	South America	1.2
12.	Philippines-Molucca	1.2
13.	Central America	0.6
14	Java Belt	0.5
15.	Melanesia	0.1

If we compare these two columns it is evident that for the geologist to whom explosive violence is characteristic of terrestrial activity, the Dutch East Indies stands at the top. And to him for whom magmatic outflow is all important, Iceland and Hawaii are the leaders, though Hawaii comes at the bottom of the list based on explosiveness. Japan occupies nearly the same position (Nos. 6 and 7) in the two lists, and the districts occupying the same position in both lists are New Zealand-Tonga and North America. It is clear that explosive violence and lava outflow are opposed, and that if either of these qualities is to be used as a measure of volcanic activity, the other should be in the nature of a measure of decadence.

If we grant that engulfment and the admission of ground water is what leads to explosion, and that on the other hand the rise of primitive magma and exclusion of ground water is what leads to lava flow, then it would appear that only the latter magmatic happening can be construed as a measure of pure volcanicity. Any magmatic vent in the earth-crust may enter into an explosive phase through the recession of the magma, this has happened in Iceland and Hawaii, and the fragmental output thus produced is merely a rearrangement of broken rocks.

On the other hand, it is quite possible that some volcanic regions are charaterized by intrusive magma in just as great volume as anything poured out in Iceland or Hawaii. These places would make steaming solfataras and boiling waters, would deposit much sulphur and other salts along cracks, and if the intrusive magma receded, would generate explosive eruptions, followed by an exhibit of little or no lava at the surface. The little lava exhibited might be a stiff plug or dome of highly siliceous magma at the crater. It happens that just such andesite or dacite domes are well known at many explosive volcanoes. This proves that these volcanoes are truly magmatic, but that they do not make lava flows.

Decadence of volcanism, then, as interpreted by explosion, may mean merely a transition from basaltic flow lava to andesitic intrusion lava. In this connection Central America is very interesting. Sapper lists 26 active volcanoes between Costa Rica and the Mexican border, averaging one every 50 kilometers when this line of activity is treated as a single belt. Central America ranks thirteenth in lava output among volcanic regions, but is second only to the Dutch East Indies in explosive output.

In a recent article on the most active "volcanic regions," Dr. Sapper has compared the strongly active districts of the world by density of clustering of volcanoes, by frequency, and by output, and makes the following remarks on the resulting tables:

"Iceland in the period since 1500 A. D. has exceeded all other places in output of lava, in that it has poured out a third of the world's lava output, or about 16 cubic kilometers out of a total of 50 cubic kilometers. Hawaii comes next to Iceland in lava output.

"In the production of broken material the Dutch East Indies have produced more than half of the 325 cubic kilometers ejected on earth since 1500 A. D., with Central America coming next and the Aleutian-Alaska system third." (These figures differ from the tables in Volcano Letter No. 12, owing to the inclusion of a large volume for Katmai in 1912. This illustrates how quickly proportions may change through a single volcanic event.) If one considers the great length of the Java-Sumatra and the Aleutian belts, respectively, as compared with the shorter Central American belt, and thus includes density of clustering as a measure of activity, it is found that the output of Central America per hundred kilometers of length is 4.6 cubic kilometers of explosive material, whereas that of the Dutch East Indies is only 3.7. This would make the Central American region the most productive of explosive material per unit of area, with the Dutch East Indies second and the Alaska-Aleutian belt third. It further appears that when these belts are examined in detail, the two ends are less productive than the middle. It is remarkable that the three most important regions on earth for throwing up explosive material, and so giving evidence of cycles of intrusive activity at the present time, all lie in inter-continental districts—Java between Asia and Australia, the Aleutian Islands between North America and Asia, and Central America between North and South America. The Central American belt is strikingly different in its volcanic activity from the much weaker volcanism of the mainland of North and South America. By this demontration, Sapper makes the Central American region one of the most important on earth.

In the map on Page Four there are shown many volcanoes between Turrialba in Costa Rica and Tacana near the Mexican border of Guatemala The last Volcano Letter discussed the moderate activities of the Costa Rican group. In Salvador and Guatemala there are volcanoes producing lava flows, and others producing extrusive lava domes. In Nicaragua there are volcanoes of first magnitude and very frequent activity represented by Masaya, whereas Momotombo and Coseguina are both distinguished for some of the greatest eruptions of history. It is worthy of note that two of these are on opposite sides of Managua, where the recent earthquake occurred, and that the proposed route of the Nicaragua Canal is in the midst of an earthquake and volcano belt.

In Volcano Letters Nos. 87 and 262 some description has been given of Santa Maria Volcano in Guatemala near the city of Quetzaltenango. This is the most interesting active vent of the Central American group at the present time, and will be treated in the next number. The illustration on Page One shows Agua Volcano, one of the beautiful cones near the capital, Guatemala City. There are three in this group, Agua, Fuego, and Acatenango. Here again it should be noted that some of the terrific earthquakes of history occurred right at the foot of all these volcanoes, and both of the cities named were recently wrecked, Quetzaltenango in 1902, and Guatemala City in 1917. Here and at Managua it is legitimate to inquire whether intrusive magma does not strain the earth-crust to make great earthquakes. There is no reason whatever for expecting simultaneous "activity" at the nearby volcanoes if an intrusive mass, by spreading laterally far underground, suddenly breaks or splits the earth shell subterraneously.

Acatenango, elevation 3960 meters, is a double cone close to Fuego, and at the end of the nineteenth century it exhibited slight fumarole activity in its southern summit crater. At 8 p. m. December 18, 1924, an explosive eruption broke out and lasted 20 minutes. A crack opened about 300 meters north of this summit, in the saddle between it and the northern peak called Tres Marias. (See cut Page Three.) The crack was right on the line connecting the two cones. Fiery glow was seen and products of the eruption were water, sulphur vapor, and fine gray ash. There were 15 cups along a rift 75 meters in length; bright yellow sulphur deposits were formed along the crack. There were light falls of ash in three towns. An ascent of the volcano by residents January 5, 1925, discovered the straight line of vents steaming like an engine ending at the south with a new large crater 60 meters in diameter and 80 meters deep. The steam rushed out violently so as to eject small stones. The west slope was covered with ash, and one's feet sank in it 20 centimeters at each step. The individual fumaroles were 2 to 4 meters across and up to a meter and a half deep. The ash was dark and muddy and there were sulphur stains. The big new crater sent up dark, yellow, sulphur vapor, whereas at the north end of the row of small cups pure steam was rising. At the southern summit crater there was no participation in the eruption, but a little white vapor rose at the west edge.

The second outbreak occurred February 10, 1925, at a large crater in the middle of the north slope of the southern peak. This also lasted 20 minutes, with wind in different direction from the first one. There was hissing from the new fumaroles, but the explosion was not so strong as before. On February 22 there was decrease of activity, and a new ash field made a conspicuous white object for 200 meters on the east slope of the summit. A new pit had been formed 50 by 40 meters in size, on the rim of which lay many stones in the midst of the ash, of 50 centimeters diameter. There was further activity at 4 a. m. March 4 and again at 2 p. m., so that a new ashfall occurred, and when the peak was visited March 13 some of the fumaroles had increased their activity. There was wet ash around all the openings, some blocks of rock a meter in diameter were found during the ascent, and trees were broken down. A compass needle showed no disturbance on Acatenango, whereas Fuego at its summit produced great irregularities in magnetic declination. At this time Fuego also was showing increased fumarole activity.

On May 7 a strong outbreak of ash again occurred at Acatenango, and it was found that trees 30 centimeters in diameter were broken off one meter above the ground, only the eastern of the saddle fumaroles were active weakly, while the western ones had caved in to form a large hole where gas was escaping. A small channel had formed connecting different openings. From the mid-slope crater on the north side of the southern peak steam arose feebly, but from the summit rose big steam jets mixed with ash, and a part of the crest had fallen in. All these facts suggested a gradual increase of activity from the beginning of the year 1925.

A later note (Zeitschr. Vulk., Vol. XI, Heft 3, p. 188) states that Acatenango in 1926 after September was in continuous light activity from the same vents, and March 30, 1927 a great rumbling occurred heard in the neighboring towns. Some fine gray ash fell March 31 and April 1 while thick steam clouds rose from the peak. Then the activity died away and nothing more was heard from this peak. Steam was occasionally seen. On the other hand Fuego in August 1927 had increased its activity, 25 irregular fumaroles were in action on the southern peak and about 10 on the east side. There was much sulphur at the peak of Fuego. Out of the crater steam puffs shot up every 10 minutes, and during two hours there were six slides heard in the crater, which is from 300 to 400 meters deep. The east-west diameter is 150 meters and the south-north 75 meters. The northeast rim consists of ash and is higher than the southwest margin, which shows bedrock.

T.A.J.

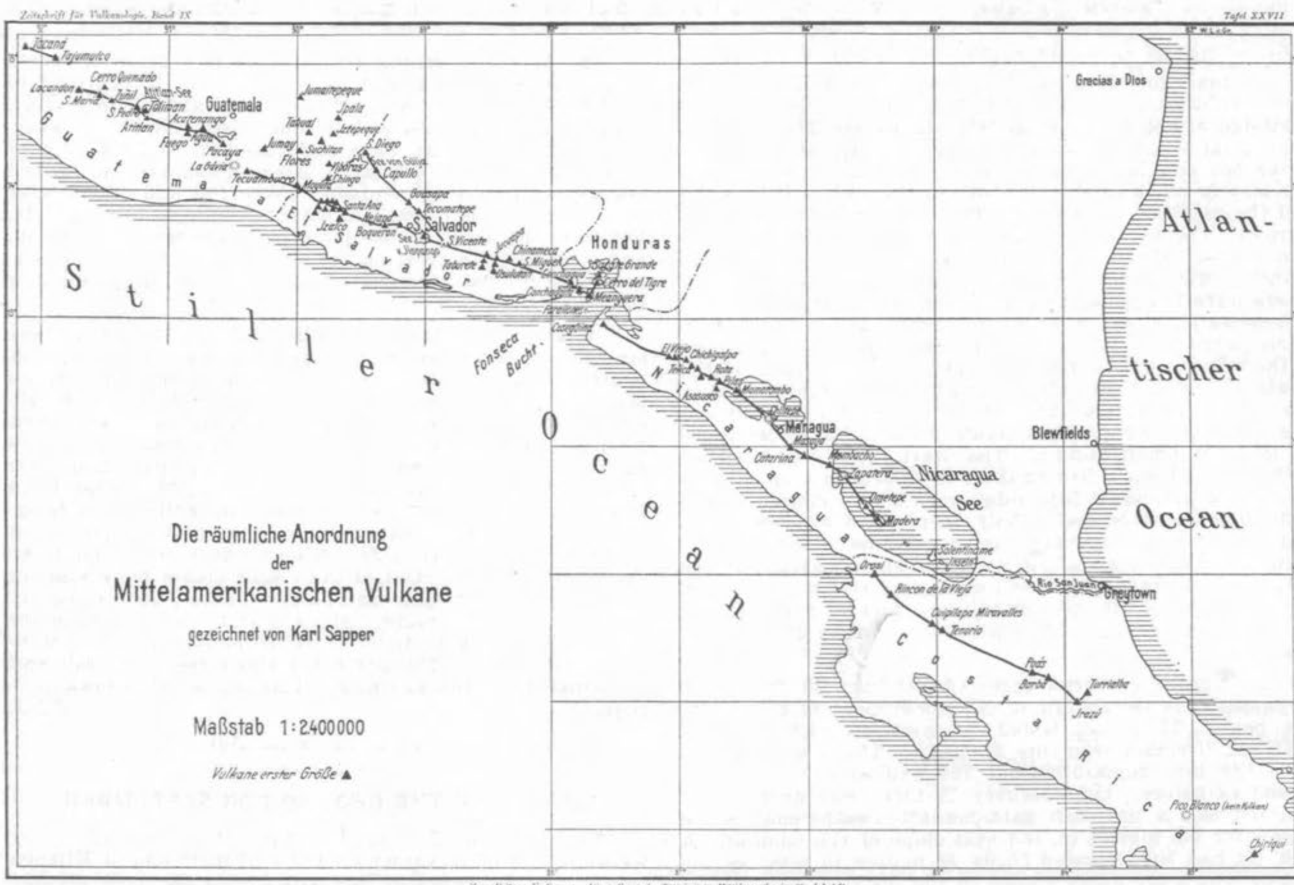
TILTING OF THE GROUND FOR SEPTEMBER

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

August 31-September 6....	1.1 seconds SW
September 7-13	1.7 seconds NE
September 14-20	0.5 second E
September 21-27	1.4 seconds ENE

E.G.W.

Looking south from Tres Marias at the main peak of Acatenango in 1925. After Sapper.



Map of Central America, showing the belts of active volcanoes, from Costa Rica on the east through Nicaragua, Hondura, Salvador, and Guatemala. After Sapper.

KILAUEA REPORT No. 1029

WEEK ENDING OCTOBER 11, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

At Halemaumau blue fume in the bottom was thin throughout the week. Steam activity also decreased very noticeably. The east rim cracks were measured on October 5 but no changes were found. On the 6th the seismograph at the pit indicated very quiet conditions. On the 8th a few quick-period tremors were recorded. On the 9th a distant earthquake was recorded at 2 p. m.

The seismograps at the Observatory recorded during the week 28 tremors, of which only one gave indication of distance—10 miles. Of a total of eight very feeble local seisms, one showed distance 4 miles, one 6 miles, three 9 miles, one 28 miles, and two 42 miles from the Observatory. One in the third group was felt at Uwekahuna at 3:41 p. m. October 6. There were no stronger shocks.

One teleseism, distance 3500 miles and lasting 1 hour 45 minutes on the record, was registered at about 2 p. m. October 9, the origin not even approximately known as yet. The teleseism of October 3 reported last week was tentatively located by the Honolulu station of the U. S. Coast and Geodetic Survey at 14° S lat., 160° E long., in the Coral Sea near Rennel Island at SE end of the Solomons.

Average tilting of the ground for the week was slight NNW. Microseismic motion was moderately strong.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

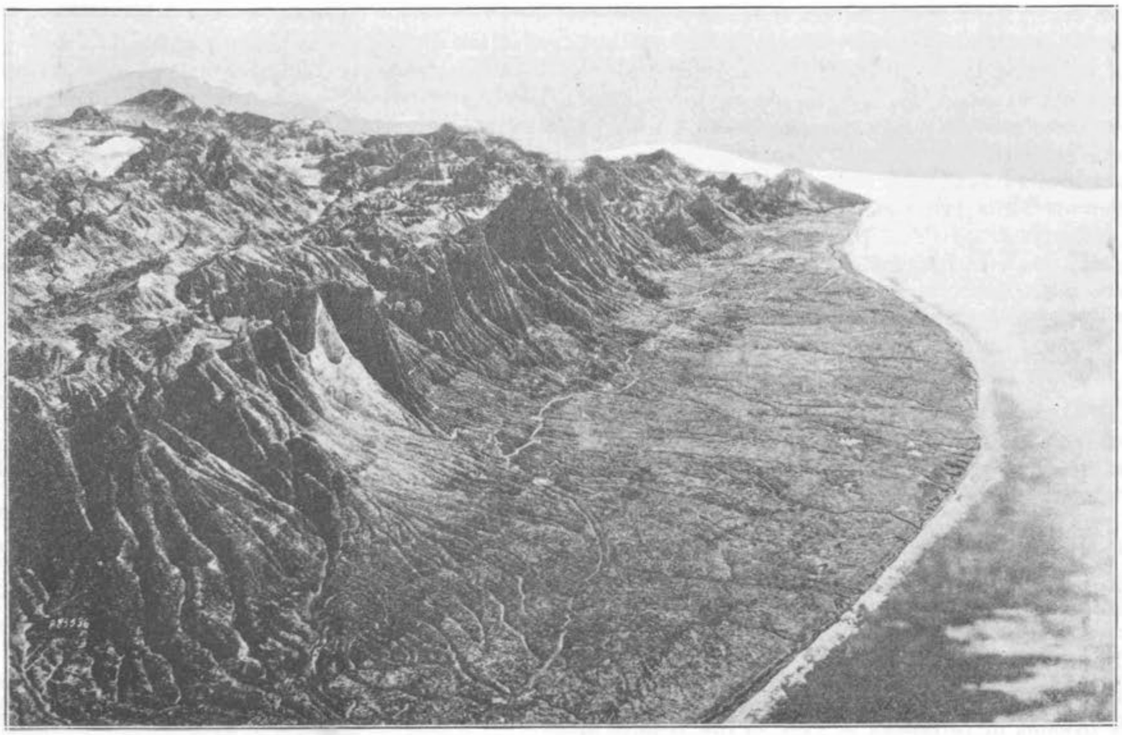
The Board of Directors includes Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year **Ten cents per copy**

No. 356—Weekly Hawaiian Volcano Observatory, National Park, Hawaii October 22, 1931



Photograph of a large model of Guatemala, looking southeast along the Pacific coastal plain, which has been uplifted at the base of the line of active volcanoes. Great vertical exaggeration. Santa Maria Volcano with hole in its side from the eruption of 1902. At the left the mountainous plateau of Guatemala. a region of fertility, and one of the coffee belts of the world. Adjacent to this volcanic rift have occurred some of the biggest earthquakes of history.

ERUPTION OF SANTA MARIA NOVEMBER 1929

Santa Maria Volcano in western Guatemala has become a key vent of great importance in connection with the seismic and volcanic activity surrounding the Caribbean Sea. (See Volcano Letters 87 and 262). Heilprin states (The Eruption of Pelée, Lippincott, Philadelphia, 1908) that there was no recorded eruption prior to 1902, and in this apparently Sapper concurs. The 1902 outburst in October split open a great hole in the southwest flank of the mountain (see cut Page One) at about 6,500 feet elevation. the chasm being about the same size as the present Halemaumau, 3,300 feet across. and 800 feet below the rim stood a geyser-like lake of boiling water spouting and making sulphurous fumes until after 1906. Then the volcano became quiet until 1922 when at the end of June new explosive eruptions began and a dome of hornblende-hypersthene andesite lava rose through a fissure in the bottom of the crater and in August of that year had grown until it stood 300 feet above the downhill rim of the cauldron. Thereafter the dome kept growing until in 1925 there was a big castellated heap 1,600 feet high and 4,000 feet across. The growth was replaced by solfataric activity which continued until May 14, 1928, along with the slow development of a second swollen dome on the north and northwest sides of the former dome (Termer, Zeitschr. Vulk. XII Heft 2/3, p.231). About the site of this new plug eruption a short-lived explosive eruption occurred May 14, 1928, throwing ash over the country to the depth of a few millimeters.

Heilprin (l.c. page 71) believed the events of 1902 indicated that in a region like the Caribbean, volcanic and seismic phenomena over distances as great as 2,000 miles are related, that the deep-seated strain of magma might make great earthquakes such as geologists call "tectonic," that the slipping, upheaval and torsion of surface formations in the rock of the earth's crust might be resultants of the jarrings already given to the deeper earth-crust by magma, that the seismo-volcanic condition of the crust is proved to be connected with electro-magnetic phenomena as shown by the magnetic storms all over the earth accompanying the Pelée eruption, and that there is marked synchronism or close following of major disturbances. as has been proved at different periods for eruptions and great earthquakes far removed from each other. The striking illustration of these facts was a destructive earthquake at Quetzaltenango in Guatemala April 17, 1902, synchronous with the first outbreak of Pelée in Martinique at the other end of the Caribbean Sea 2,100 miles away. Two hundred miles south of Quetzaltenango, Izalco Volcano broke out in Salvador and was in full eruption May 10, two days after Pelée had destroyed St. Pierre. Sourière in St. Vincent had broken out more than 100 miles south of Pelée the day before the St. Pierre catastrophe. Both Soufrière and Pelée continued their eruptions in concert into the autumn of 1902, and during this time Masaya Volcano in Nicaragua started eruptions which continued for two years. And finally Santa Maria in Guatemala developed its unprecedented eruption October 24-November 15 and devastated the coffee lands. If there were any doubt about the sub-crustal sympathy of the magma in these leaps from the volcanic fissure of Guatemala to the great rift of the Caribbee Islands and back, it should be dispelled by the fact that in September 1929 Pelée broke into explosive eruption again just after Santa Maria in 1928 had renewed explosive activity which came to a crisis in November of 1929. It is of interest in comparing Soufrière of St. Vincent with Santa Maria, to note that both these volcanoes in 1902 were left with boiling crater lakes. Now Santa Maria has exterminated this lake and replaced it with a lava dome: will Soufrière eventually do the same?

The photograph on Page Three has much in common with the scenes pictured on the northeast slope of Lassen Peak after its eruption of 1915, and this photograph represents part of a stream bed in the forest below the crater of Santa Maria as it appeared after the new catastrophe of 1929 which destroyed human life and wrecked plantations with an incandescent down-rushing cloud of ash, and torrential floods which transported gigantic bowlders. In both Lassen and Santa Maria volcanoes, as well as at Pelée in 1902, the source of the down-blast was a crater partially filled with a stiff plug of lava.

In the evening of November 2, 1929, in the vicinity of Santa Maria, there had been no forewarning of the coming danger. It was sultry and there was a dry lightning storm, but there had been such electrical phenomena in that vicinity of the lava dome frequently. At Las Animas, close to the volcano on the downhill side, about 9:30 p. m. November 2, persons sleeping on the plantation were suddenly awakened and saw a glowing rain and a flood rushing from the heights of the volcano. Alarming underground noises followed each other in quick succession, then glowing sand and ash fell on the roofs. Those who were so fortunate started to flee finding it difficult to breath the hot air. The bell was rung to awaken the laborers and all hastened toward the Rio Concepcion, where the river bed was found full of boiling mud erroneously called "lava" by the peasants. This was beginning to overflow the adjacent land. They made for another branch of the stream and found it equally in flood so that they were penned on a peninsula between the two torrents and the volcano. They spent the night in the plantation house; when there was a pause in the rumblings shrieks of the sufferers and calls for help could be heard. When they attempted to go to the rescue they found that the cries came from natives who were already engulfed in boiling mud. Nothing could be done. Early the following morning when daylight enabled them to see the devastated land, they improvised a bridge of logs across the stream and about 25 persons were rescued. The wounded were taken to a house on the main road where a relief commission soon began the work of rescue. Bodies were seen protruding from the hardened mud and some persons were trapped in the wreckage of houses. The residence house of one plantation was found totally destroyed and in many places it was necessary to lay down boards in order to cross the excessively hot mud and ash. The manager of this second plantation reported hearing a terrible thundering, and on looking up toward the crater he saw red-hot masses weighing tons being hurled into the air and breaking to pieces when they struck the earth so that glowing fragments and sparks bounced away. Then came subterranean rumblings and fiery streams seemed to pour down from the crater in winding avalanches of incandescence. The illumination was like daytime. Ash and sand fell in a dense rain, the temperature rose, and flight became imperative. Here also the bell was rung for the laborers and at the bank of the Rio Tambor, which had a channel 100 meters deep and 80 meters wide, the river was found in flood and so incandescent with the dry accumulations on its upper surface that they lighted the bank. This is a very remarkable statement, but quite believable, and accounts for phenomena observed in many of the explosive eruptions of Java and elsewhere, when stream floods have been confused with lava flows. It is easy to believe that light pumiceous ash will make a dry bed on top of a mud stream, capable of holding incandescent fragments so as to remain luminous while it flows. Throughout this eruption of Santa Maria the natives thought the contents of the river beds were lavas.

The River Tambor had almost reached the top of the bridge, the under irons were bent, but as yet they had not given way. A smaller stream, the San Jeronimo, was visited and was found to be flowing backwards owing to the fact that this stream pours into the larger river Concepcion, which by reason of its greater height and viscosity due to ash sent a backwater flood up the smaller stream. This was an added danger to the plantation as soon as the backflood poured into the lands and about the buildings.

There was no time to be lost. The laborers were panic stricken and demoralized. Twenty-six of them escaped over the bridge. The man describing the event said his chauffeur wished to go back to the garage to get the automobile and he had to use force to prevent his doing so and snatch the key out of his hand. While he was trying to persuade him to come across the bridge there was a sudden rush of the fiery mud across the slope at the bridge head; this liquid, by its great weight and stickiness, grasped the man's legs and dragged him downstream into the hot torrent. There was only a single heartrending cry and he was gone. Half of the laborers had delayed and were still in the plantation, and now streams of overflow could be seen making their way through the hamlet. The man remaining on the bridge called to them as loudly as possible, but his voice was drowned in the thunder of the cataclysm. He saw his residence collapse, and his automobile torn out and tossed like a toy on the surface of the stiff flood. More thon 25 of those who had remained in the grounds perished. The narrator saw there was nothing for him to do but to save himself, and he ran across the bridge just in time to see it carried away, leaving the plantation cut off. Then the ruins of his house disappeared.

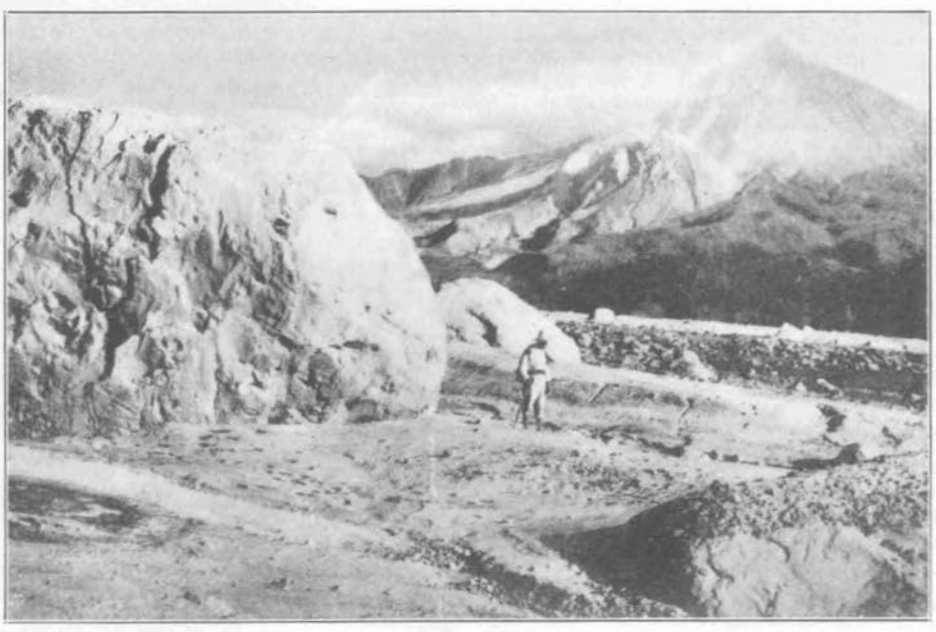
Dr. Sapper concludes that this was a true fiery downblast of the Pelée type such as destroyed St. Pierre. If this eruption is compared with the first outbreak of Santa Maria October 24, 1902, there are marked differences. The 1902 explosion was enormously bigger in output of material, and while the loss of life was not greatly different, the destruction of property was much less in 1929. The area covered in 1929 was comparatively small, whereas hundreds of square kilometers were buried in 1902. The thickness of ash in 1929 was from 2 to 10 centimeters as against 10 to 20 meters in many places in 1902. Whereas in the earlier eruption earthquakes were numerous and big, in 1929 they were few and unimportant. The noise in 1902 was heard several hundred kilometers away, whereas in this recent eruption it was confined to the immediate neighborhood.

On the other hand, the devastation in the immediate path of the fiery blast was terrific in 1929, though probably not so great as that which destroyed St. Pierre in Martinique. There was the same deep booming noise, the electrical phenomena in the sky, the hurling out of glowing masses, the carrying of big bowlders on the flood paste of the streams. A notable difference lay in the fact that the Martinique eruption was by daylight at 8 a m., whereas the 1929 eruption at Santa Maria was at night so that light phenomena were conspicuous. The lava dome of Santa Maria glowed with reddish incandescence and glowing masses rolled into the gulches. The force of the blast was much greater at Mount Pelée accompanied with hurricane violence so as to carry big stones like cannon balls. In the Guatemala outbreak the glowing sand and ash masses flowed downwards simply by gravity. There were heat phenomena in both blasts, but the Pelée blast did damage to much greater heights, for there were hills in the path of the hot blast of Santa Maria where vegetation and houses stood uninjured above the level of the destructive cloud. There were at least two distinct blasts in the 1929 eruption. The contents of the ash cloud consisted of hot stones, sand, and dust which retained their heat a long while, and the same was true in 1902 at Soufrière and Pelée. The killing of people in Martinique was due to hot steam mixed with ash, and no case was identified of true asphyxiation. In Guatemala there were more cases apparently due to unbreathable gas, a fact confirmed by many accounts indicating that the people died without any outcry. The breathing of intensely hot air might produce this effect, particularly if it were charged with dust, and the reviewer would point out that incandescent substances driven through vegetation would very quickly generate enough carbon monoxide for instantaneous poisoning. There were cases in both eruptions where the bodies were burned beneath relatively uninjured clothing, owing to death by scalding rather than incineration.

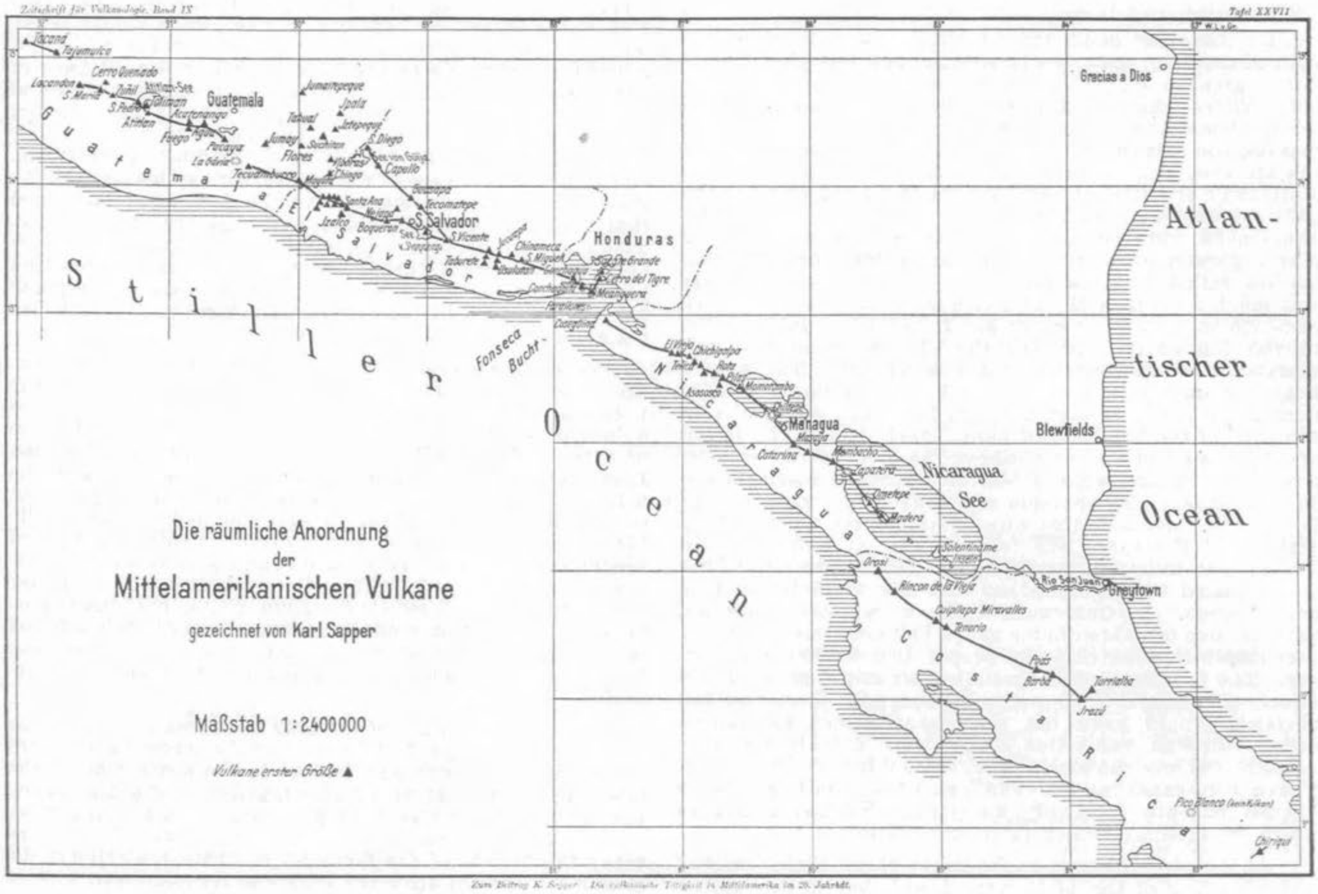
At the place nearest to the Santa Maria crater roaring and whistling of the blast were heard, but in distinction from the Martinique happening an inrushing reverse wind was conspicuous, blowing toward the crater, trees showed scour on the side way from the crater, and in some cases were scorched on the side remote from the volcano. This recalls the indraft at Vesuvius in 1906, when stones broke windows on the sides remote from the volcano. A peculiarity of the Guatemala happening was the wetness of the climate and the occurrence of the eruption at the end of the rainy season. Thus it came about that glowing stones and sand clogged the streams and caused their waters to boil, greatly increasing the volume of the liquid, and in places the valleys were filled with solids so that the flood swept through the intervening lands. It happened that the downblast coincided with the drainage system. There is no reason to suppose that the gigantic bowlders (photograph Page Three) were thrown to the position where they now lie any more than in the case of the flooding of Hat Creek in the Lassen cataclysm of 1915. These big stones were carried with the mud jumble.

Very little pumice fell at the beginning of the eruption. There was much reddish ash. An analysis showed the presence of sodium chloride with three per cent of lime sulphate and traces of silica. Petrographic investigation of a rock sample from the lava dome gulch at elevation 1,800 meters above sea level determined the magma to be a hypersthene-hornblende andesite containing 55 per cent of plagioclase, hypersthene in well bounded crystals, hornblende deeply corroded and showing dense borders of magnetite granules. Three ash somples of various coarseness were examined, with splinter outlines of irregular shape generally showing colorless glass, but sometimes none, and otherwise containing fragments of feldspar, red brown hornblende, and rare rhombric pyroxene. Otherwise there was some augite and a moderate amount of magnetite.

The place of origin of the 1929 blast was the lava dome of 1922. This dome had begun to glow some days before the outbreak. A rift was formed in the south side of the dome where earlier small glowing discharges had taken place. The place was thus prepared for a glowing avalanche along a gash into the valley below. Somewhere along the middle of the dome an elongate crateriform depression was seen after the eruption, its alignment almost due south. (See cut Page Three.) Here after the main eruption a steep-sided bulbous lava mass welled up, the



Looking north after the eruption of November 2, 1929, showing the lava dome in the midst of the crater in the side of Santa Maria Volcano, and in the foreground the flood waste occasioned by the eruption. The ash torrents mingled with flood waters carried the huge bowlders shown. The downblast originated in a rift in the lava dome. There is new lava in the rift. Photo from Sapper and Termer.



Volcanic map of Central America showing the position of Santa Maria Volcano at the west end of Guatemala. From Sapper, Zeitschr. Vulk. IX.

avalanches from the slopes of which produced almost no dust, in contrast to the outer avalanches of the older dome which stirred up great quantities of the dust from the recent eruption. (Zeitschr. Vulk. XIII Heft 2, August 1930. K. Sapper and F. Termer, Outbreak of Santa Maria 2-4 November, 1929. In German.) T.A.J.

KILAUEA REPORT No. 1030

WEEK ENDING OCTOBER 18, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

There is nothing new to report at Halemaumau. During observations throughout the week very little fume and steam were noted, except a slight increase October 12 after heavy rain. On this day at 4 p m. an avalanche north was seen making very little dust because of the wet walls. A few rocks were heard falling at 9:15 a. m. October 16.

The instruments at the Observatory recorded 40 tremors and two very feeble local seisms. There were only two tremors of any length, one lasting five minutes and the other a minute and a half. The latter, judging by the period of its wave, may have been part of an earthquake with a focus near the Island of Hawaii. A seism at 12:32 p. m. October 14 showed distance to origin 6 miles; one at about 5 p. m. October 13 was obscured by the hour mark, but appeared to be less than 30 miles from the Observatory. Spasmodic tremor occurred for more than nine hours October 16 and about six hours October 17. There were no felt shocks.

Tilt was moderate NNE. Microseismic motion was moderate.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year Ten cents per copy

No. 357—Weekly Hawaiian Volcano Observatory, National Park, Hawaii October 29, 1931

Ropy festoons of pahoehoe basaltic lava, on the Mauna Iki trail southwest of Kilauea Crater. Shows the wrinkling mechanism by which lava flows in the direction of the arching, with twisting of the wrinkles where the middle belt flows the faster. Photo 1931 by Lewis M. Werth.

THE VISCOSITY OF LAVA

By Jean Kinsley

Little experimenting has been done dealing with the viscosity of lava. Viscosity has been defined as the resistance to flow. Where lava is the chief product of a volcano, the shape of the dome may depend on the viscosity of the lava, as well as on its copiousness in different stages of the upbuilding of the dome. The rate of flowing will depend on viscosity, and on change of viscosity as the lava cools. Highly basic lava is more liquid and less viscous that the less fusible acid lava, rich in silica, such as rhyolite or trachyte. Some basic lavas like basalt are fluid enough to run down a one per cent slope, and form flat domes with slopes of from four to ten degrees. Mauna Loa is an example of such a dome, immense in size, yet flat in profile. The andesitic lavas of Japan and Central America are much more viscous, forming cones with slopes of from 25 to 35 degrees, though this production of slope is often complicated with fragmental materials. What effect viscosity actually has, has been little experimented with.

Dr. George F. Becker (Some inquiries into rock differentiation, American Journal of Science, January 1897, page 29) discusses viscosity in connection with theories of diffusivity. Becker estimates the rate of flow of the Kilauea lava stream of 1840 at 22 feet a minute down a two per cent slope. The flow was fed from fissures for a considerable part of its length, thus maintaining a fairly constant temperature. Water according to Becker would flow 24 times as fast. Since lava is 2.5 times as dense as water, it would then be 24 times 2.5, or 60 times as viscous as water.

Becker refutes the possible assertion that lava underground is more fluid before it erupts. Viscosity increases with pressure, and underground magma is under great pressure and close to the melting point. It can not be superheated, according to Becker, or it would melt the surrounding rock and be reduced in temperature. Therefore he concludes that, owing to the pressure, viscosity must be greater before eruption than afterwards. To this statement may be added the heating effects occasioned by gases released from solution, which would diminish viscosity when eruption begins.

Dr. H. S. Palmer (The viscosity of lava, Bulletin Hawaiian Volcano Observatory, January 1927, Vol. XV, No. 1) assumes that Becker based his measurements upon progress of the first front of the flow of 1840, which would be slower than the streaming after a channel has been established. Hence Becker's estimate of the viscosity is too high. That is, he makes the lava too stiff.

No general law connecting temperature with viscosity has been found, though there are several interpolation formulae permitting computation of the variation of viscosity with temperature for any given liquid. In case of water, the decrease of viscosity per degree of rising temperature is greater at the lower temperatures. Becker says that fluid lava need not necessarily be superheated above its melting point, and this agrees with observed facts of measurement in the Kilauea lava lakes which indicates that they are undercooled. Viscosity varies with the molecular weight, and the heavier basic lavas, other things being equal with reference to relation of temperature to fusing point, should be more viscous by reason of their density. But chemical composition and crystallinity play important parts, and the quantity of gas bubbles may act as ball bearings in increasing mobility.

Dr. T. A. Jaggar estimated the Alika flow of 1919 on Mauna Loa in its established channel near the source to be moving 15 miles an hour. Four miles west of the source it was moving three miles an hour. The source lava was pahoehoe, the other aa. The lava feeding the fields moved through the stream forks in the channel about 200 feet an hour, but the field itself moved about two feet an hour. Dr. Palmer thinks that Dr. Jaggar observed a surface thread of lava in the middle of the channel, which would have a velocity 5 to 15 per cent greater than the mean velocity of the inner lava river for its full width. (See photograph of lava festoons Page One.)

The rate of flow of the Alika stream Palmer assumes to have been steady with a force 1.4 times greater driving the lava stream to overcome its viscosity, than would drive a comparable water stream, since the specific gravity of the gas-charged live lava is 1.4. He writes: "If streams of two fluids were alike in all respects except specific gravity, the driving forces would be in the same ratio as the specific gravity. And if the velocities were the same, the viscosities would be proportional to the specific gravities; that is, to the driving forces. Since the velocity of a stream is inversely proportional to the viscosity, we may write the equation

$$\text{Viscosity} = \text{a constant} \times \frac{\text{specific gravity}}{\text{velocity}} \text{''}$$

From this formula he concludes that the viscosity of the Alika flow was about 15 times greater than that of water. He conceded the possibility of error in comparing the Alika flow with a similar stream of water, from uncontrolled conditions of the channel and grade.

Jaggar in 1921 (for Alika flow details see Bulletin Hawaiian Volcano Observatory, October 1919, pp. 127, 133-4, 156; also February 1921. pp. 28-9) made an experiment at Halemaumau comparing the viscosity of live lava in a rift cone, and in the lava lake. He attempted to avoid stream errors by measuring the rate of entry of live lava through an aperture in a vessel immersed in it. The apparatus was a metal cylinder 27 inches long of 3 inches inside diameter, on which was a cap with an opening 1.5 inches in diameter. This on the end of a long pipe was immersed about a meter in the molten liquid in the cone and left there for 4 minutes. On withdrawal, the cylinder was found to be about one-third full of pahoehoe lava.

The same experiment was tried in the bubbling lake, with the result that the cylinder was incompletely filled, but in larger volume than before. The current in the molten slag carried the cylinder irrestibly sidewise so as to prevent it from remaining vertical. Large gas vesicles were found in the glassy lava inside the vessel, showing that gas vesiculation had played a part in permitting the lava to enter. A defect in these experiments was the cooling effect of the iron on thrusting it into the lava without preheating to the lava temperature.

In the first experiment, 1180 cubic centimeters of lava weighing 1656 grams had entered the cylinder, filling it 33 per cent. In the second lake experiment, 2500 cubic centimeters entered with a weight of 3500 grams, filling it 83 per cent. The viscosity was thus greater in the spatter cone lava. The density of ordinary Hawaiian lava is from 2.7 to 3.0, but the vesicular lava of the experiment had specific gravity of only 1.4, owing to the large proportion of gas. The radius of the orifice was 2.9 centimeters, and the time of flow 240 seconds. The temperature of the lava in the first experiment was 1100 degrees C., in the second experiment 1200 degrees C., as might be expected from the lower viscosity of the highly effervescent lake lava.

TWO SURFACE FORMATIONS NEAR MAUNA IKI

The photograph on Page One is relevant to what was said above about viscosity of basaltic lava. The ordinary small pahoehoe lava flow has the form of a leaf, with the feeding stream considered as the stem. This stem or feeding thread of molten slag skins over on its upper surface and quickly divides itself into at least three belts of motion, consisting of two drawn-out curtains at the sides, and a belt of festoons in the middle arching downstream. These festoons are at first merely wrinkles, then they cluster together and pile up into folds, then the different speed of flowing of the faster central belt and the two lateral belts tends to twist the contact wrinkles into ropes. Finally the whole structure forms a crust and the incandescent stream inside flows under the bridge of festoons. This stream later escapes at the lower skirts of the flow and leaves the arch of festoons a hollow shell which is apt to cave in and reveal a cavern. The presence of arched festoons is a sure sign of the original direction of flow with the crest of the arches pointing downstream. It often happens that the hardened shells exhibiting such festoons become swollen up in the later history of a flow puddle so that the surface slopes backward in the opposite direction from the slope that made the festoons.

The photograph on Page Three exhibits the detail of a footprint made by a barefooted Hawaiian in the ash mud of 1790 east of Mauna Iki. This is one of the hundreds of footprints which mark the old trail of that time, the material being a pisolitic ash with some small angular pebbles. The pisolites or mud raindrops of the period are the small, round, whitish objects seen at the left of the picture. The footprint shows the five toes and the spread-out effect as the foot squashed down in the mud of that period, which has since hardened like cement so as to preserve the footprints from erosion throughout nearly a century and a half.

T.A.J.

NOTES FROM THE ALEUTIAN ISLANDS

The seismograph observer, Mrs. Wendhab, reports from Dutch Harbor that the trader Mr. Schroder, who owns the store at Chichagof Harbor in Attu, came back from one of his voyages at the end of August and reported that on May 30, 1931, about 12 midnight (following), a very severe earthquake was felt at Attu. He had himself experienced the California earthquake of 1906 and he thought that this one was very nearly as severe. Everything on the shelves was dislodged, dishes were broken, and there was general havoc. Aftershocks continued every few days accompanied by a distinct roaring noise which preceded the shock and grew in volume as though something was coming closer with great rapidity. Then would come the shake, the roaring accompanying it, followed by a passing on of the movement and a dwindling of both tremor and sound.

Our seismograph records at Kilauea did not show any registration of a large distant earthquake at that time.

Mr. R. H. Finch reports that Aniakchak Volcano on the Alaskan Peninsula was exploding in May 1931 and scattered ashes over a hundred miles from the center. The material that fell at a great distance was very fine and looked like flour under a pocket lens. Some account of this Aniakchak eruption has recently been reported by the explorer Father Hubbard. Katmai Volcano was observed to be smoking early in July. Pavlof was smoking nearly all summer and according to the Reverend D. Hotovitsky of Belkofsky this volcano was in active eruption about May 20, 1931, making a noticeable ashfall, and at times glow was discernible at the crater. Two other volcanoes on the Peninsula were reported fuming.

Gareloi Volcano, a peak 5,334 feet high far to the west in the Aleutian Islands, was very active during the spring and summer of 1930. The appearance of half of the island was said to be changed by lava flows from fissures, and a hut was destroyed belonging to fox farmers. R.H.F.

KILAUEA REPORT No. 1031

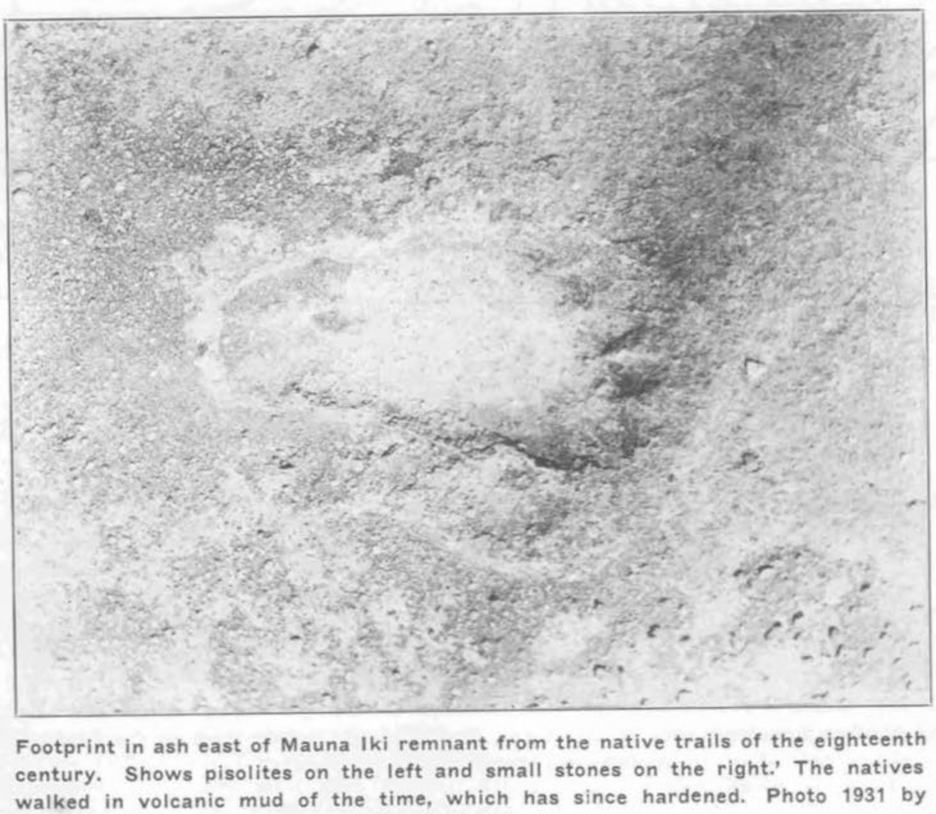
WEEK ENDING OCTOBER 25, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

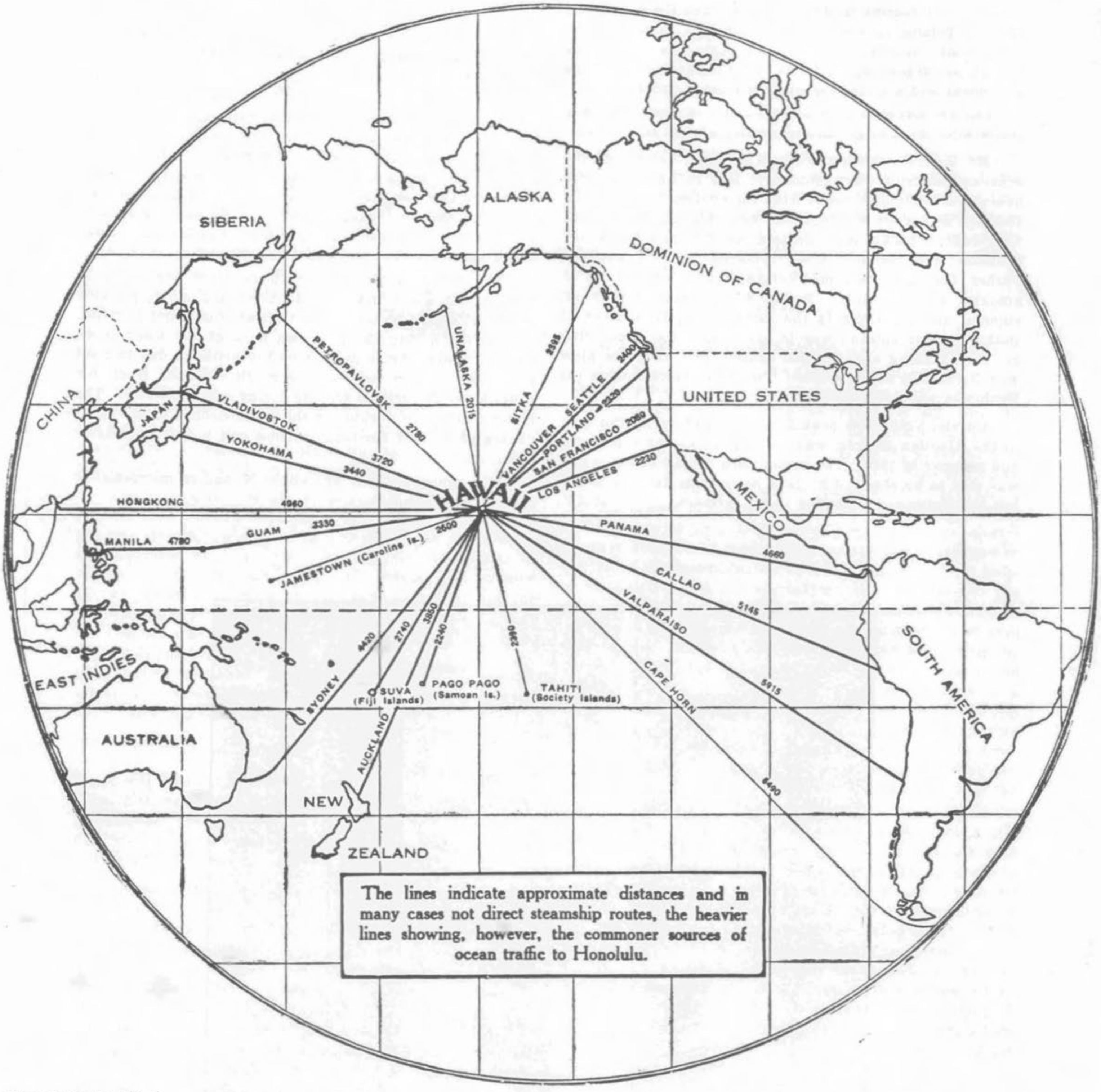
The fume area on the Halemaumau bottom appeared inactive on October 19, and only thin fume and steam were noticeable on the 20th. After light rain on the 21st there was some increase of fume. On the 22d both fume and steam were entirely absent. The seismograph at Halemaumau showed quiet conditions and practically no tilting. There are two new large bowlders on the pit floor between the south and southeast taluses. On October 24 at 8:30 a. m. there was a large avalanche north causing much dust. Crack measurements on October 20 showed no changes.

The seismographs at the Observatory registered 11 tremors, three of which were doubtful, and one very feeble shock, with good phases, from a distance of about 37 miles. In addition during the first two days of the week there were 46 spasmodic tremors, possibly artificial due to road machinery. There has been so much vibration from this cause as to obscure the records during daylight hours. The heavy machinery working in the neighborhood of 100 yards causes periods of one-tenth second and a half millimeter amplitude.

The average of tilt was slight N, and of microseismic motion moderate.



Footprint in ash east of Mauna Iki remnant from the native trails of the eighteenth century. Shows pisolites on the left and small stones on the right.' The natives walked in volcanic mud of the time, which has since hardened. Photo 1931 by Lewis M. Werth.



Map of the Pacific Ocean. Attu Island is the westernmost of the Islands extending towards Kamchatka from Unalaska, and Aniakchak in on the outer part of the Alaskan Peninsula east of Unalaska. Pavlof is still farther west on the Peninsula, and Gareloi is an island midway between Unalaska and Attu.

THE VOLCANO LETTER

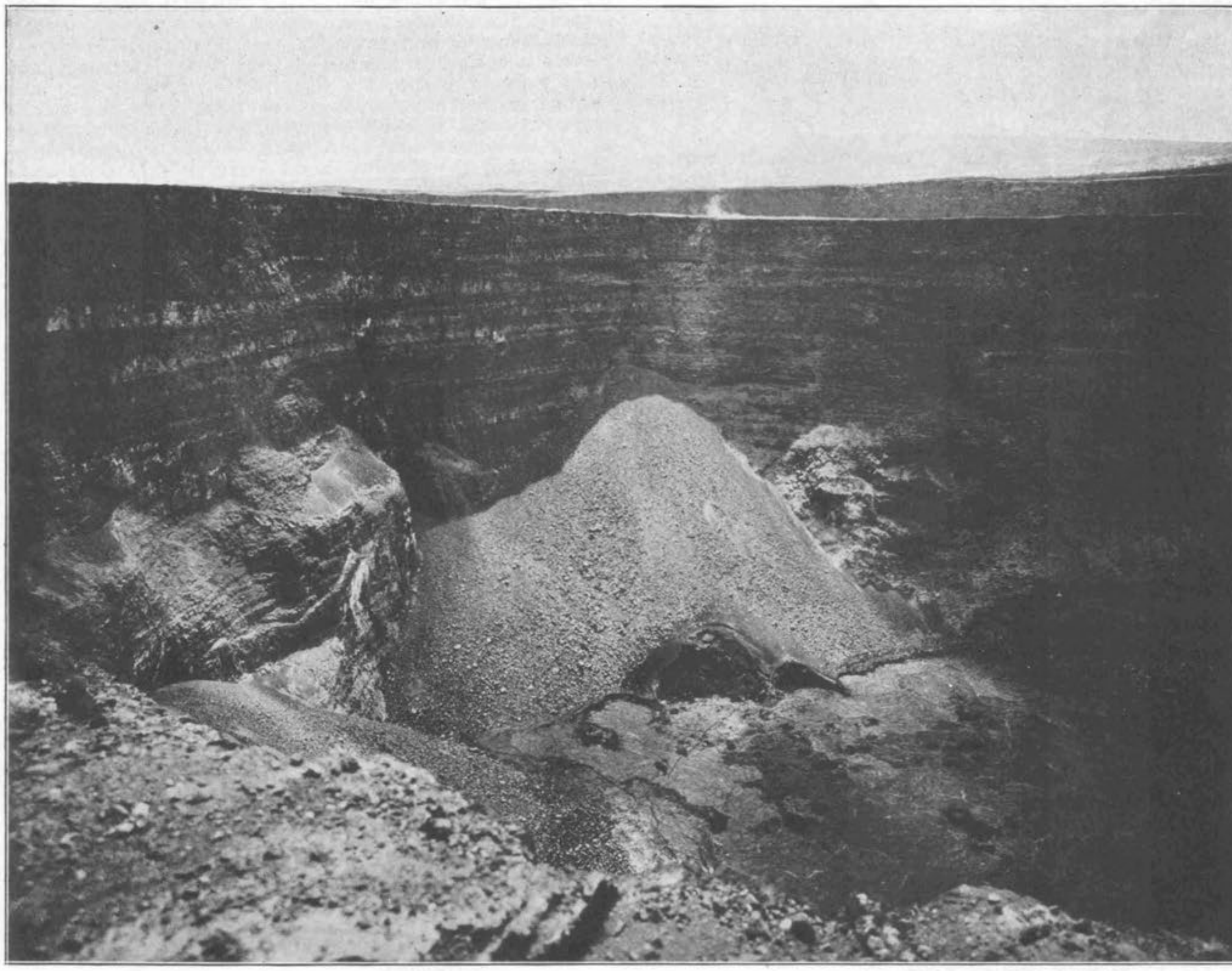
The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.
Subcription for non-members two dollars per year of 52 numbers. Address the Observatory.

The Volcano Letter

Two dollars per year | **Ten cents per copy**

No. 358—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | November 5, 1931



Lava floor of 1929 showing the large half-dome against the west talus left by the fountaining grotto of about July 25, 1929. This half-dome still protrudes at the edge of the floor left by the activity of November-December 1930. Photo Baker.

REVIEW OF HAWAIIAN EARTHQUAKES 1929-1930

The Volcano Letter has recently reviewed the cycles of volcanic activity at Kilauea, showing a tendency to eleven-year periods, and indicating that the present cycle began with the return of lava to Halemaumau pit in July 1924. From time to time we have reviewed the earthquake frequency, showing that recently the Kilauea station registers about 1,000 disturbances per year due to local cause. The following was the record of 1929:

By weeks ending on the dates listed, the following were the frequencies of local earthquakes for 1929:

Date	Number for Week	Notes
Jan. 2, 1929	2 very feeble	
Jan. 9	8 very feeble	Some continuous tremor.
Jan. 16	8 very feeble	
Jan. 23	1 feeble 21 very feeble	Several continuous tremors.
Jan. 30	10 very feeble	Less continuous tremor.
Feb. 6	1 moderate 9 very feeble	Felt Feb. 5 Hilo and Kohala.
Feb. 13	7 very feeble	Some spasmodic tremor.
Feb. 20	17 very feeble	Continuous harmonic tremor Feb. 20 with outbreak of lava.
Feb. 27	3 slight 5 very feeble	Tremor ended when lava stopped Feb. 21.
Mar. 6	1 slight 1 feeble 4 very feeble	
Mar. 13	4 very feeble	
Mar. 20	17 very feeble	Five prolonged tremor spasms.
Mar. 27	20 very feeble	Seven tremor spasms.
Apr. 3	16 very feeble	Irregular very feeble tremor.
Apr. 10	5 very feeble	Tremor ceased after April 6.
Apr. 17	9 very feeble	
Apr. 24	8 very feeble	
May 1	8 very feeble	Some very faint tremor.
May 8	4 very feeble	

Date	Number for Week	Notes
May 15	1 feeble 6 very feeble	
May 22	3 very feeble	
May 29	7 very feeble	
June 5	8 very feeble	
June 12	16 very feeble	
June 19	2 moderate Several very feeble	One prolonged tremor.
June 26	1 moderate 7 very feeble	One tremor spasm.
July 3	8 very feeble	
July 10	1 feeble 28 very feeble	
July 17	2 feeble 16 very feeble	One tremor spasm.
July 24	19 very feeble	Numerous tremor spasms July 21 and harmonic tremor accompaning lava flow began to be steady the morning of July 25.
July 31	17 very feeble	Harmonic tremor ended July 28 when fountain went out of action.
Aug. 7	2 feeble 27 very feeble	One period of spasmodic tremor.
Aug. 14	28 very feeble	Some continuous tremor.
Aug. 21	1 feeble 19 very feeble	
Aug. 28	1 slight 16 very feeble	
Sept. 4	15 very feeble	
Sept. 11	4 very feeble	
Sept. 18	1 feeble 8 very feeble	
Sept. 25	221 earthquakes and tremors	Violent earthquake disturbances near Hualalai. Some long tremors at seismograph.
Oct. 2	244 earthquakes and tremors	Many more felt in North Kona.
Oct 9	129 earthquakes and tremors	The two strongest shocks were September 25 and October 5.
Oct. 16	97 earthquakes and tremors	North Kona crisis declining.
Oct. 23	3 feeble 9 very feeble	41 prolonged tremors. Total 53 seismic disturbances as compared with 97 for the previous week. The orgin continued to be near Hualalai.
Oct. 30	1 feeble 39 very feeble 56 tremors	Hualalai origins continue active.
Nov. 6	1 feeble 21 very feeble 35 tremors	Hualalai origins continue active.
Nov. 13	2 feeble 28 very feeble 32 tremors	Hualalai origins continue active.
Nov. 20	16 very feeble 12 tremors	Hualalai crisis dwindling.
Nov. 27	2 feeble 12 very feble 18 tremors	Hualalai crisis dwindling.
Dec. 4	2 feeble 13 very feeble 10 tremors	North Kona still feeling shocks.
Dec. 11	8 very feeble 9 tremors	Five indicated North Kona origin.
Dec. 18	9 very feeble 4 tremors	Five indicated North Kona origin.
Dec. 25	3 very feeble 10 tremors	Felt in North Kona.
Jan. 1, 1930	1 feeble 8 very feeble	Five indicated North Kona origin.

The year 1929 as recorded seismically above for Kilauea, was notable volcanically for actual inflow of lava at Halemaumau pit February 20-21 and July 25-28, and for such subterranean disturbance at Hualalai Volcano that intense shaking affected the North Kona District and much of the Island of Hawaii from September 19 to the end of the year. These three events are clearly reflected in the harmonic tremor produced by the Halemaumau eruptions at the Kilauea Observatory, and in the great excess of earthquakes and tremors of all classes which accompanied the Hualalai disturbance beginning with the week which ended September 25. Seismically the frequency and intensity of the Hualalai spasm were both at a maximum during the first fortnight and declined rather evenly thereafter. No lava outflow was determined as occurring under the sea or anywhere during the Hualalai crisis. If we compare the seismic record shown above with the earthquake freqency and intensity that accompanied the explosive eruption of Kilauea in May 1924 (diagram Page Four Volcano Letter No. 328), it is apparent that the seismic maximum at Kilauea was toward the end of the eruptive period, and both frequency and intensity increased as this maximum was approached. There is good reason to think that the Kilauea steam blasts of 1924 were occasioned by an outflow under the sea. Therefore it seems improbable that any submarine outflow occurred at Hualalai in 1929, for the seismic behavior was exactly the opposite of that of Kilauea. It seems more likely that lava flowed in under Hualalai with an upward pressure, splitting open deep rifts, and preparing for eventual outflow somewhere to the north of the Mauna Loa center.

After this gradual dwindling of the Hualalai earthquakes at the end of 1929, it will be of interest to examine the frequencies of local earthquakes at the Kilauea Observatory for 1930, by weeks ending on the dates listed:

Date	Number for Week	Notes
Jan. 5, 1930	8 very feeble	Five indicated North Kona origins.
Jan. 12	7 very feeble 12 tremors	One indicated North Kona origin.
Jan. 19	5 very feeble 5 tremors	One indicated North Kona origin.
Jan. 26	3 very feeble 6 tremors	One indicated North Kona origin.
Feb. 2	1 slight 6 very feeble 7 tremors	North Kona origin. Three indicated North Kona origins.
Feb. 9	4 feeble 2 very feeble 8 tremors	Three probably North Kona origin.
Feb. 16	7 very feeble 16 tremors	One indicating North Kona origin.
Feb. 23	1 slight 9 very feeble 13 tremors	
Mar. 2	3 very feeble 8 tremors	Two indicating North Kona origin.
Mar. 9	1 feeble 7 very feeble 5 tremors	Three indicating North Kona distances.
Mar. 16	1 feeble 5 very feeble 9 tremors	
Mar. 23	5 very feeble 2 tremors	
Mar. 30	4 very feeble 9 tremors	
Apri. 6	5 very feeble 12 tremors	
Apr. 13	1 very feeble 12 tremors	
Apr. 20	3 very feeble 6 tremors	
Apr. 27	3 very feeble 4 tremors	
May 4	5 very feeble 6 tremors	
May 11	3 very feeble 11 tremors	
May 18	8 very feeble 11 tremors	
May 25	1 moderate 2 feeble 3 very feeble 5 tremors	Probably in Puna. Probable origin North Kona.
June 1	1 very feeble 9 tremors	

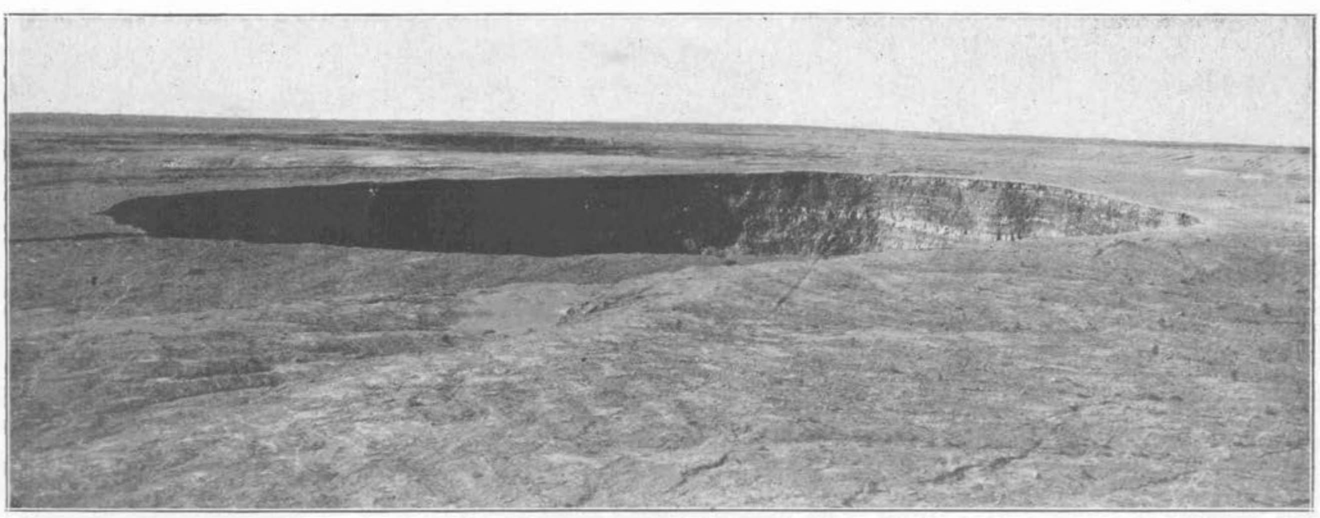
Date	Number for Week	Notes
June 8	3 feeble 1 very feeble 6 tremors	One probably Hualalai.
June 15	1 slight 3 very feeble 4 tremors	
June 22	6 very feeble 7 tremors	
June 29	1 very feeble 5 tremors	
July 6	3 tremors	
July 13	4 very feeble 4 tremors	
July 20	6 very feeble 6 tremors	
July 27	1 moderate 5 very feeble 4 tremors	Strong in North Kona.
Aug. 3	3 very feeble 10 tremors	
Aug. 10	2 feeble 3 very feeble 5 tremors	Several tremors notably at Halemaumau.
Aug. 17	3 very feeble	Several tremors.
Aug. 24	1 feeble 3 very feeble 25 tremors	
Aug. 31	5 very feeble 31 tremors	
Sept. 7	6 very feeble 26 tremors	
Sept. 14	1 very feeble 46 tremors	
Sept. 21	5 very feeble 49 tremors	
Sept. 28	1 moderate 2 feeble 7 very feeble 23 tremors	
Oct. 5	1 feeble 3 very feeble 25 tremors	
Oct. 12	3 very feeble 17 tremors	
Oct. 19	1 moderate 2 very feeble 17 tremors	
Oct. 26	1 moderate 1 very feeble 57 tremors	
Nov. 2	1 slight 3 very feeble 42 tremors	
Nov. 9	1 feeble 44 tremors	
Nov. 16	10 very feeble 48 tremors	
Nov. 23	1 feeble 8 very feeble 24 tremors	Harmonic continuous tremor accompanied lava outbreak at Halemaumau November 19.
Nov. 30	None	Harmonic volcanic tremor continuous along with lava inflow at Halemaumau.
Dec. 7	2 very feeble 4 tremor spasms	Harmonic tremor and lava action ceased December 7.
Dec. 14	3 very feeble 33 tremors	
Dec. 21	1 feeble 3 very feeble 36 tremors	
Dec. 28	1 feeble 42 tremors	

The year 1930 as here recorded seismically for Kilauea was notable as retaining traces of the Hualalai seismic spasm in North Kona until March, and thereafter the seismicity may be considered normal as compared with past years. Volcanically there was registered continuous tremor accompanying lava outbreak in Halemaumau from November 19 to December 7 with one week in the middle of this activity showing no local earthquakes at all. It may be said that, except for phenomena of volcanic tremor and tilt, the three lava inflow eruptions of Halemaumau in 1929-30 were notably quiet seismically. and this characteristic was observed in 1927 and at other times. Rising below a sealed vent may make strong preliminary shocks some time before the eruption, but through an open vent like Halemaumau the movement of lava does not make earthquakes.

The totals for the two years were 1,516 local disturbances at the Hawaiian Volcano Observatory for Kilauea seismographs in 1929, and 1070 disturbances for 1930 To show the difference in a distance of 50 miles for a localized seismic spasm, compare the 1929 figure for Kilauea with the 6,211 shocks that were registered in the vicinity of Hualalai between September 21 and October 16, 1929. The Kilauea total for the same period was about 691 shocks, many of them felt.

The totals of seismic disturbances at Kilauea per year since the explosive eruption of 1924 have been:

1925	922
1926	1778
1927	1149
1928	1034
1929	1516
1930	1070



The vast lava pit of Halemaumau taken from the high western bluff of Kilauea Crater. This is the pit the bottom of which has been gradually filling since the tremendous engulfment of 1924. Photo Baker.

The high total of 1926 was due to the Mauna Loa eruption in April, just as that of 1929 was due to the seismic spasm on Hualalai. It is of interest to note that for the 20 days of this Mouna Loa eruption the maximum of both frequency and intensity of earthquakes was reached during the first week in the registration at Kilauea, and in this it was similar to the happenings on Hualalai, and in like manner was contrasted with the seismic record of the Kilauea subsidence and steamblast eruption of 1924. This is further evidence favoring the supposition that the Hualalai disturbance marked an upward lava pressure which suddenly disrupted the mountain by intrusion of lava which has not yet been evacuated.

It will be seen that the average of the last six years at Kilauea is 1278 local disturbances per year, including tremor spasms, whereas the record from 1914 to 1925. inclusive, (Volcano Letter No. 54) showed an average per year of 1022 local earthquakes, wherein all the tremor spasms were not counted, and wherein also the very exceptional total for the year 1924 of 5877 shocks was included In general the figures for the eight years of continuous lava activity in Halemaumau pit between 1914 and 1923. inclusive, omitting 1916 and 1919 when Mauna Loa introduced complications, averaged 410 local shocks per year, which is less than the average at the present time. The figures are not strictly comparable as the listing of tremor spasms greatly increases the totals at present. Nevertheless it appears certain that free lava flow in the pit causes a decrease in numbers of earthquakes. T.A.J.

KILAUEA REPORT No. 1032

WEEK ENDING NOVEMBER 1, 1931

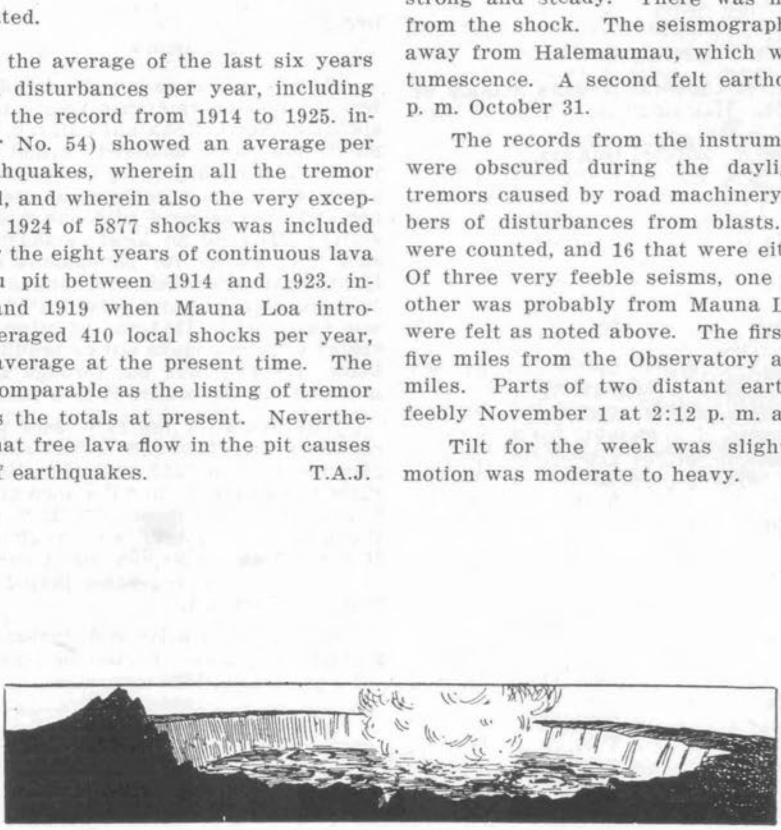
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Crack measurements on October 26 found no changes. Two new measuring points were marked on the northeast side of Halemaumau, where freshly broken ground was discovered on October 24. By October 31 one of these points had moved open nearly one-half inch. Fume and steam were absent. On the 27th both fume and steam were fairly thick after rain. Conditions at Halemaumau were quiet seismically. The pit was visited on the 29th after a felt earthquake at 5:45 a. m., and fume appeared strong and steady. There was no apparent avalanching from the shock. The seismograph at the pit showed tilt away from Halemaumau, which would appear to indicate tumescence. A second felt earthquake occurred at 11:34 p. m. October 31.

The records from the instruments at the Observatory were obscured during the daylight hours by artificial tremors caused by road machinery. There were also numbers of disturbances from blasts. Forty known tremors were counted, and 16 that were either artificial or natural. Of three very feeble seisms, one was very local and another was probably from Mauna Loa. Two feeble shocks were felt as noted above. The first showed distance about five miles from the Observatory and the second about 10 miles. Parts of two distant earthquakes were recorded feebly November 1 at 2:12 p. m. and 11:45 p. m.

Tilt for the week was slight WNW. Microseismic motion was moderate to heavy.



THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

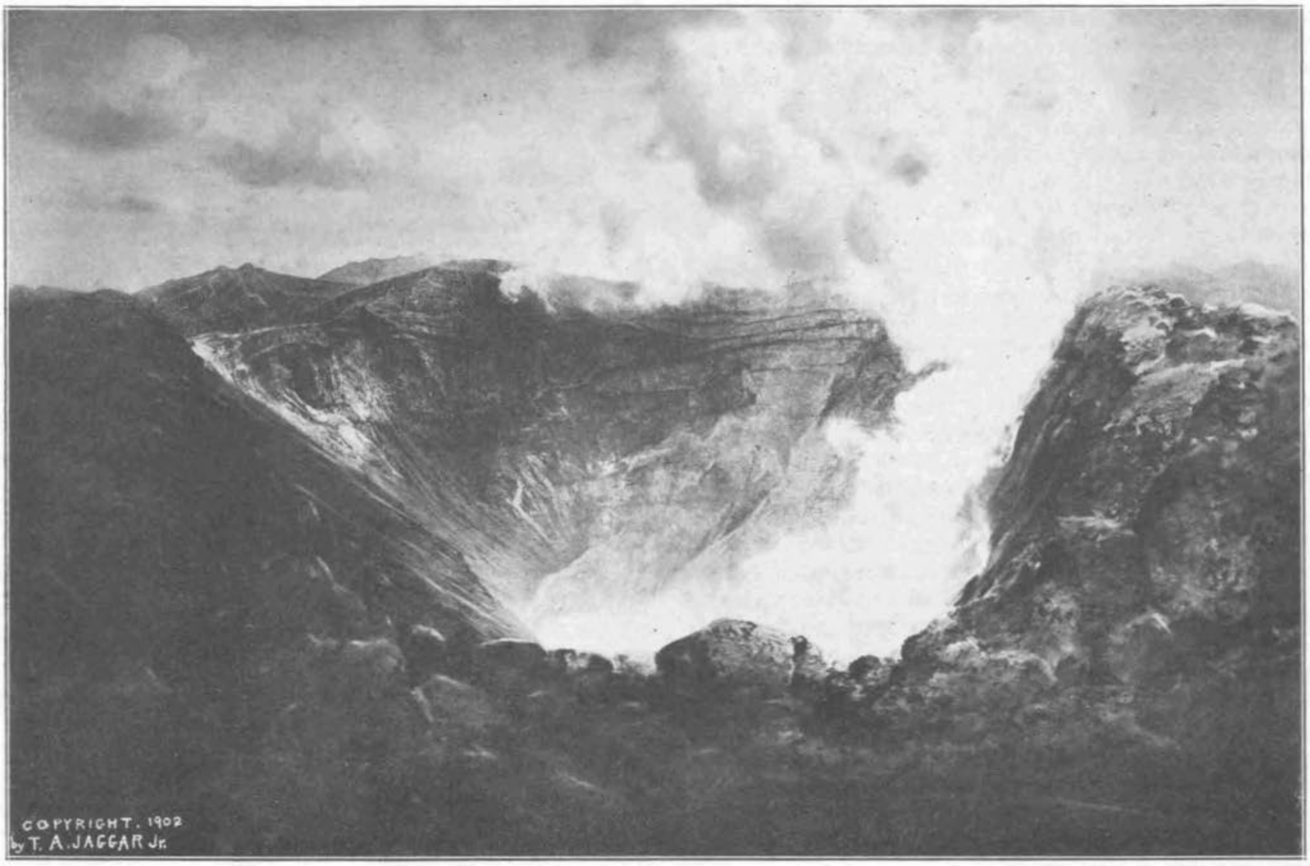
The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 359—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | November 12, 1931



Interior of Soufrière crater, St. Vincent, from southwest rim May 31, 1902, showing boiling pools in the bottom after the great eruption of May 7, 1902, and before the later eruptions, which tended partially to fill the inner bowl with ash surrounding a circular lake at higher level. This filling followed a series of geyser-like gushes in March 1903. Photo Jaggar.

THE CRATER OF SOUFRIERE VOLCANO

A remarkable feature of the volcanic eruptions in the Caribbee Islands made famous by the destruction of St. Pierre by the volcano Pelée in Martinique in 1902, was the fact that a great steam-blast eruption at St. Vincent, 100 miles south of Martinique, occurred at 1:30 p. m. May 7, 1902, and the next morning, about 8 o'clock, occurred the cataclysm at Mont Pelée. There was clearly sympathy along the subterranean rift above which the line of islands has been built. The writer visited both volcanoes in May 1902, and was with the first party that made the ascent of Soufrière Volcano on May 31. He made a sketch map of the crater and a photographic panorama reproduced herewith. We shall here examine the evolution of this crater, which contained a lake before the eruption of May 7, showed boiling water in the bottom immediately afterwards, and refilled to about the former lake level during the following year.

It may be well at the outset to describe the crater as it appeared during our visit of May 31. We ascended the mountain following the spurs which had been swept bare on the southwest side. The mountain is a rugged cone deeply trenched by radial gorges and charted as being 4048 feet high. The old slopes had been steepened by rapid wash and landslides, the luxuriant vegetation was swept away, the slopes were furrowed with feathery patterns of rill drainage cut in the muddy ash covering, and each spur was like a very steep roof with a smooth pathway along the divide and erosion corrugations at the sides. Here and there huge stumps remnant from the former jungle lay prone or jutted upward with limbs charred and sharpened to dagger points by the volcanic sand-blast. At 1610 feet elevation the smooth spurs changed to a steep tumble of mud clots, sometimes knee deep and sticky, with blocks of rock two feet or more in diameter scattered about by the eruption.

After nearly three hours of climbing we came to the crest and looked down into an enormous cauldron, almost circular, showing on the opposite side a wall striped with horizontal bands of columnar intrusive lava, and the peak of the mountain beyond rising high into steam clouds. On the right was a black precipice falling away 2,000 feet almost sheer, and on its face there purled upward from the bottom a long, noise-less column of steam which broke away in billows. Down at the bottom was a pale green muddy pool sending up a hundred tails of steam and boiling vigorously. On the opposite shore of the pool springs from the wall trickled across a flat making red and sulphurous stains, and uniting into a brook which had built a small delta. The middle bands in the wall were of gray lava, one of these showing a funnel-shaped section as though the slag had filled an upright fissure that spread out above into a drooping mushroom. Farther down there were reddish brown tuffs made of fragments A large dike filled a fissure from bottom to top of the wall on the left, and at the top the northern crater edge was seen to be backed by a higher ridge. Between the two occurs the crater of 1812 which is a subsidiary cup or flat that was filled with debris by the eruption of 1902. These features may be seen in the photograph on Page One. The bottom of the crater was 2550 feet below the highest distant summit, and 1660 feet below the rim. The upper diameter is 4870 feet, and the western rim where the photograph was taken stood 2735 feet above sea level. The old chart indicated 2013 feet for this elevation. The figures here given were obtained by rough angular measurements from the ends of a base line paced off on the edge of the crater. The eastern rim of the bowl stood over 2000 feet above the boiling pool. This pool was about 1200 feet across from east to west and was incessantly changing. It is probable that the oval of the crater had a greater dimension of more than a mile diameter north and south. The north-northwest corner had been blown away or had collapsed so as to notch the rim outward. The column of steam rose from a point south 18 degrees east from the center of the cauldron and was about 50 feet wide. The base of the steam column marked that part of the lake which was in most violent ebullition, sputtering fiercely and occasionally sending up spurts of black mud and rock fragments a few feet above the bottom of the crater. Jets of steam were seen to come directly from rock fissures on the southern side. The level of the lake was about 1100 feet above the ocean and some 800 feet lower than the lake surface that existed in this crater before the eruption. The pool of boiling water appeared shallow, for the slopes of slide rock shelved off into it at low angles and mud islets rose in the middle.

The crater lake of the Soufrière, before the eruption. was described as a pearly green sheet of water, set in sloping verdant crater walls, smelling of sulphuretted hydrogen, and the water was cold. A native trail crossed the mountain and people had bathed in the lake. The level of the lake surface was 1,930 feet, so that the southern wall over the water had been 1100 feet high, and the northern about 1700 feet. There was no known outlet. Soudings of 43 fathoms near the shore and about 88 fathoms near the center indicated that the bottom of the depression had its deepest part to the north of the center and the bottom must have been over 1600 feet below the southern lip of the crater. In other words, the rock bottom left by earlier eruptions was not very different from what the 1902 eruption produced. The former crater was described as nearly circular, with its northern lip 3623 feet above sea level and about 600 feet higher than the southern lip. The edge of the crater had been an irregular knife edge with inward and outward slopes both of from 30 to 40 degrees, and the crater depression was due to engulfment and erosion. It had not been difficult, with the aid of bushes and small trees, for passers-by to descend to the edge of the lake.

The eruptions of May 1902 disrupted the bottom of this cauldron and somewhat enlarged it, but the small crater under the crescent ridge on the north took no part in them. The phenomena were quite like those of Mont Pelée, gigantic cauliflower clouds, a downblast at the southwest, heavy accumulations of broken rock, sand, and dust 50 to 80 feet deep in the gulches, and this material so hot that the subsequent revival of spring waters made explosions in the valleys where the streams made contact with the banks of hot gravel. These banks were crusted over by a shell of rain mud which tended to retain the heat. Down some of the gulches there were doubtless combinations of flood and blast, similar to those described at Santa Maria in 1929 (Volcano Letter No. 356). Glow appears to have been seen above the crater in certain eruptions, and we may conclude that glowing magma lay under the crater lake, but it never reached the stage of lifting a crater plug as on Mont Pelée.

Just after a notably disastrous explosion of Pelée August 30, 1902, Soufreière followed with a damaging eruption that took no lives. This occurred on September 3 in a series of pulsations with detonations. They reached their climax in 20 hours, sending up a black cloud alive with electric displays and accompanied by some earthquakes. Mud flowed down one of the valleys and there was a heavy fall of ash to leeward. An inspection of the crater September 22 showed newly ejected blocks down to 400 feet below the summit, the great pit was 150 feet deeper than it had been, the lip had been lowered on the west, and banks of ash were piled against the northern and eastern walls. Steam rose from a fissure at the south. At the bottom was a small lake of stone-colored liquid in ebullition and sending up steam clouds.

An intense eruption occurred October 14, 1902, with preliminary clouds of dust-laden steam and the rumbling of avalanches at 8 p. m. followed by violent detonations at midnight. By 12:30 a. m. "a ball of fire" was followed by an incandescent hurricane, or cloud, or blast, down the Larikai valley west-northwest from the crater. At Chateau Belair southwest of the volcano stones began to fall about 2 a. m. October 15 and continued for two hours along with strong electrical displays and the rumbling of thunder. Mud fell at 2 a. m., the detonations died away at 5 a. m., there were several earthquake shocks, and volumes of dust-laden vapor rose from the crater for two days. Dust was carried to Barbados, and coarse debris fell to windward.

An ascent of Soufrière October 28, 1902, was made, and volumes of steam were found rising from the crater. Numerous cones of ashes were being thrown up to a height of 40 feet over a fissure close to the southern wall, and the lake was boiling near the center.

A phenomenon of interest November 26, 1902, was a mud flow down the Rabaka River which leads from under the crescent summit of the mountain to the southeast, as an extension of the Larikai valley on the opposite side of the volcano. This river had been completely blocked by ash avalanches during five months of heavy rainfall. Probably a lake formed in the higher reaches of the river. When the dam broke, two raging steaming torrents descended the valley, destroying the remains of a sugar mill, and blocking up the old stream bed near the sea, so that the river now runs in a new channel to the north of the old one.

An examination of the crater by Sapper February 6, 1903, showed that landslides had deepened the gap at the north, that the diameter of the crater was 1320 meters, that the longer diameter was WNW-ESE, and that the lake had dimensions 540 by 340 meters and its height above sea level was 585 meters or 1919 feet, agreeing with the old chart. In other words, the water had come back to the old level. The lake water was boiling in the center and at the southeast corner.

There was not much saddle left between the northern craterlet and the big pit, this region was deeply covered with ejecta, the smaller crater contained a shallow lake 230 feet in diameter, and fumaroles were found in the main crater rim in two places. It is an interesting and unexplained condition that in both Pelée and Soufrière there are main craters forming profound pits well below the summit on one flank of the mountain, just as at Santa Maria in Guatemala, and minor flat cups containing ephemeral shallow ponds close to the summit. Apparently the great active craters are on a radial fracture line and the little summit cups are adjacent to an old outlying lip of some former engulfment, as at Monte Somma on Vesuvius.

Lacroix and Hovey visited Soufrière crater March 3, 1903, hot mud ejections upward through the crater lake were happening from time to time, and these as photographed by Lacroix strongly recall the mud geyser explosions of the Waimangu crater in New Zealand. A sudden descent of a torrent of mud was seen in one of the western valleys. The condition of the slopes was unstable and a cloudburst could easily produce phenomena of this kind. Avalanches were falling at the crater, there was an increase in quantities of small stones and large ejected blocks of old rock on the slopes outside the crater, and the water of the lake was quiet and yellow with mud between spells of ebullition. When agitated it became more gray in color. The geyser-like gush which was photographed arose from the center of the lake as a mass of inky mud entangling blocks of rock. One photograph shows it as seen from the south-southeast rim in process of rising, like sheaves of rockets, with upward jetting shreds in the profile and rounded undersurfaces to each sheaf. At this stage it was a thousand meters high above the lake. A photograph made 20 seconds later shows the nodes expanded into steam clouds and the beginning of showers of backfall. The mass of mud, which rose noisily, fell heavily back with a roar, followed from below by a fresh column of vapor. A heavy shower of mud fell at the rim of the crater. These explosions were seen 50 miles away, and were precursors of the last considerable eruption. Hovey, who had seen the crater in 1902, comments on the rapidity of erosion since the first eruption, estimates that 25 million tons had been carried out to sea by the one valley Wallibu at the southwest, and notes many andesite bombs up to three feet in diameter among the ejecta.

On March 21, 1903, Soufrière crater emitted much steam, on March 22 at 7:25 a. m. an explosive black cloud appeared, of cauliflower shape, rising to a tremendous height and then passing away in all directions. Detonations ceased about 10 a m., but there were later noises from the crater and there were several earthquakes during the morning. Dust-laden vapor continued to rise for nine days. A few inches of dust had fallen at the west coast, and 20 feet of new gravel in one of the ravines, with a hot bomb, weighing 75 pounds, on top of an ash layer. Some illumination at the crater was seen on the evening of March 30.

A visitor at the beginning of April 1903 described the inside of Soufrière crater as changed in appearance with the bottom filled up with chocolate-colored ash to about the old water level. In the center of this new deposit was a narrow funnel, which gradually widened in later months. The southern lip of the crater had been built up with new ash, much of the northeastern wall had caved in, and fissures in the new bottom deposit were steaming.

In the spring of 1907 Tempest Anderson revisited

Soufrière Volcano looking northeast, showing the mouth of Wallibu River in foreground and the ruins of the sugar mill, after the eruption of May 7, 1902. The steep sea cliffs were produced by submarine landslip, and Richmond village was buried under 45 feet of hot gravel. This hot gravel shows white under a coating of wet sand, and up the river the stream water produced incessant explosions in contact with it. Photo Taylor May 31, 1902.

Profile section and map of Soufrière crater made by a sketch survey May 31, 1902, by T. A. Jaggar. Vertical and horizontal scales the same, 0.64 mile to the inch. Bottom of crater 2550 feet below summit, 1660 feet below rim. Diameter crater lip 4870 feet. Coast benches east 60 and 200 feet above sea level. Depth of ocean in profile 125 fathoms east, 530 fathoms west. Profile on line north 66 degrees east.

Soufrière (Report on Soufrière, Part I, 1903, Part II, 1908, Phil. Trans. Roy. Soc. Lon., Vols. 200 and 204), and from his review much of the above is taken. He obtained a new and excellent picture of the inner ash terrace of the crater bottom and the enlarged funnel, containing the lake, restored as a circular pool. The topography was as represented on the older chart. The walls are nearly vertical, consisting of alternate layers of tuff and compact rock dipping outwards from the crater. The rock layers are either lava flows or intrusive sheets, and two dikes were seen cutting them. One layer is several hundred feet thick and columnar. The broad bench around the lake, formed by the ejecta of March 1903, is widest on the north and east, and has a talus forming on it by falls from the cliffs above. The lake is something over half a mile in diameter, of uniform light green color, at about the level indicated in the old charts, which is presumably the groundwater level of the mountain. A very little vapor was seen in 1907 from two spots near the foot of the crater walls south and east. There appeared to be more stones on the ground northeast of the crater than elsewhere, and the deposit of new ash a few feet thick on the southern lip was deeply trenched by rain rills and sloped inward evenly at 30 degrees. The upper section of the northern walls shows continuous tuff beds, while the lenses of andesite below interlock, like a pile of flat fish. (See cut Page One.)

T.A.J.

TILTING OF THE GROUND FOR OCTOBER

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater, and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

September 28-October 4	0.4 second N
October 5-11	0.1 second W
October 12-18	1.9 seconds NNE
October 19-25	0.5 second N
October 26-November 1	0.3 second SSW

E.G.W.

KILAUEA REPORT No. 1033

WEEK ENDING NOVEMBER 8, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Conditions at Kilauea are quiet. Crack point No. 25 on the northeast rim of Halemaumau continues to move open steadily at the rate of about one-half inch per week. Dust from an avalanche was observed from the Observatory at 1:50 p. m. November 3. Fume and steam were absent from Halemaumau except on November 4. On this day in thick fog and mist fume showed steadily at the central sulphur spot, and steam occurred on both the south talus and southeast rock slope.

Road work near the Obseravtory has lessened so that there are fewer artificial disturbances on the records. There were 59 tremors, a few probably of artificial origin. There were no other earthquakes of any class.

Tilt for the week was moderate NE. Microseismic motion was moderate at the beginning of the week, increased to strong on the 3rd, and decreased the following day to moderate for the remainder of the week.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

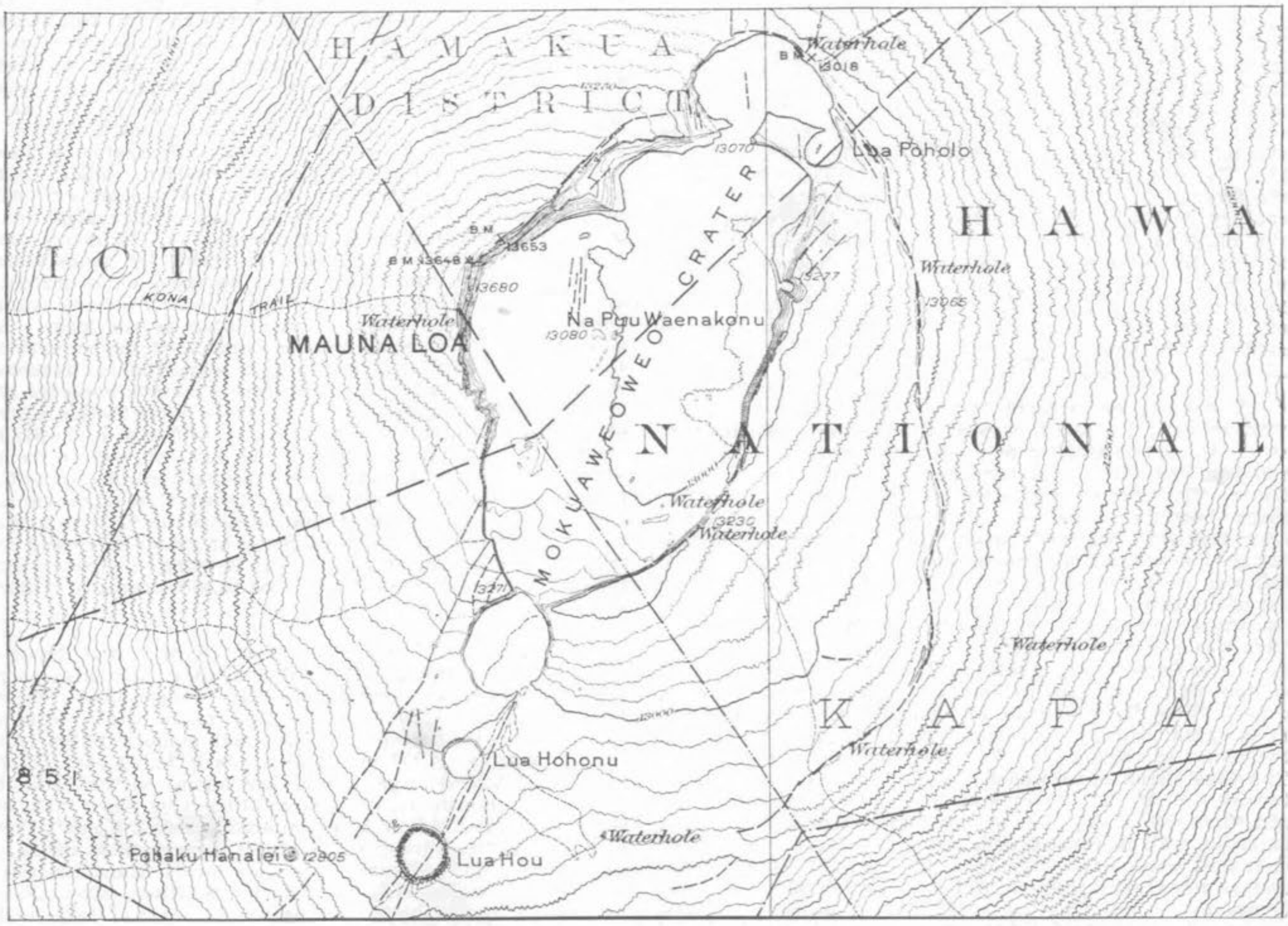
The Board of Directors includes Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | **Ten cents per copy**

No. 360—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | November 19, 1031



Map of Mokuaweoweo in 1926, topography by E. G. Wingate, scale 1 inch to the mile, contour interval 50 feet outside of the crater, contours largely omitted on the inside. Shows the arrangement by which the crater is a group of coalescing pits in a straight line.

THE CRATER OF MAUNA LOA

The summit crater of Mauna Loa is a sink-like depression or caldera at the meeting point of two fissure belts, the one trending approximately S. 30° W. from the south end of the crater, the other N. 65° E. from the north end of the crater. The crater itself extends these fractures into its western walls, but if the walls were considered extensions of the rifts they would each have to be bent westward, for the west wall of the crater in plan makes an angle of 120° 1.5 kilometers to the northwest of the center of the caldera. The meeting point of the two larger rift systems on the mountain is really at the north embayment of the crater, making an angle as indicated by the above trends of about 145°. The southern rift therefore really extends the whole length of the crater in the direction following the line of pits N. 28° E., thus departing from the northern rift belt 37°. As shown by the modern map on Page One (U. S. G. S. Mokuaweoweo quadrangle) the crater Mokuaweoweo, as the summit crater of Mauna Loa is called by the Hawaiians, really consists of five depressions, of which the second from the north is the large caldera: and this in turn is made up of three parts described as the north and south lunate platforms, and the central more or less circular sink with a group of cones in the middle. It is debatable whether the two lunate platforms were ever themselves separate circular pits in the history of the collapse and merging of the row of pits which has created the crater. It seems likely that they were, for stages of growth of such merging are represented by the order, south pit, north embayment, north lunate, and south lunate, progressively more and more obliterated as distinct circles.

It will be remembered that the Kilauea Crater is at a rather sharp angle between the eastern row of pits and the southwest rift. In like manner on the map of Hawaii the Mauna Loa crater is at a very open angle off to the west of Kilauea, between its northeast and southwest rifts. Both are sinks or subsidence cauldron at the apex of southeastern sectors of the respective domes. The resemblance of both in detail to the craters on the moon, when due allowance is made for scale and gravity differences, will be discussed in another place. In both Mauna Loa and Kilauea the cauldrons lie immediately under the summit points, which in each case stand at an angle of the western wall. The generation of the largest summit pit, therefore, by pulsations of rising and sinking lava, and the overflow of that lava, is directly related to the highest heaping of the lava pile.

In Volcano Letter 325 and 326 the cycle of 132 years in Hawaii after 1792 suggested a building up of increasing lava outflows to 1858, a decline thereafter to 1924, and throughout the cycle a tendency to big collapses occasionally which may have been produced by submarine outflow. It is of interest to examine the old maps of Mokuaweoweo, the greater center of all this activity, to discover when its floor built up, and when it subsided.

Such imperfect maps as exist have been collated by the writer in four drawings on Pages Three and Four, reduced to a common scale, and drawn with contours of 20 meters interval. The four mappings were by Wilkes in 1841, Lydgate in 1874, J. M. Alexander in 1885, and B. Friedlaender in 1896. To these some details have been added from sketches by other observers. On Page One is reproduced the map abridged from Wingate on the engraved sheet of the U. S. Geological Survey to show without the original details the outline of 1926. In the Wilkes map of 1841 the original summit elevation has been retained on the ground that total subsidence was probable in the half century following, and in any case Wilkes reported a summit point farther north than Alexander, at the main bend of the west wall where there was subsequent caving in. The other maps on Pages Three and Four are drawn to conform to the Alexander summit level. Lydgate's map of 1874 appears disproportionately large, and the size and depth of the south pit is dubious for both Lydgate and Alexander, but it may have been deeper than it is now.

The north embayment in 1841 contained a pit at its western end; in 1874 it was as a whole an elongate pit; after 1885 it contained a pit at its eastern end. The main cauldron contained changing small pits and cones and lava lakes. The conspicuous changes in the crater which the maps show are a breaking back of the western walls to the main fractures originally indicated by Wilkes, and a pronounced deepening by subsidence between 1841 and 1874, followed by filling of the bottom thereafter, and overflowing of the two lunate platforms by this central filling. That the walls cave in was reported by Stearns in August 1924. This was just after the great collapse at Kilauea (U. S. G. S. Water-Supply Paper 616): "During the week at the summit avalanching of rocks from the walls was common, especially on the east side, and made climbing in and out of the great caldera dangerous. At 12:10 a. m. August 23 two smart earthquake shocks were felt in quick succession. The first shock had intensity 4 R. F. and the second intensity 8 R. F. The camp was 40 feet from the rim S. E., and when the earthquakes occurred tons of rock avalanched from the wall in front of the camp, sending up a cloud of dust that was clearly visible in the starlight. Other avalanches were heard thundering to the bottom of the caldera, especially a short distance northeast of the camp. In the morning the pass to the floor, a quarter mile northeast of the camp, was no longer recognizable. A thin section of the rim had fallen down and left a vertical cliff, and a new crack several hundred feet long and over a foot wide had opened a few yards from the brink. Avalanching was frequent all that day, especially at east pit."

Wilkes made the crater a line of four pits and two big platforms, and the circularity of the main cauldron was never afterwards so marked, and it was then the deepest part of the crater. The floor of the cauldron was made of flat sheets of pahoehoe, with ridges 3 to 15 meters high, many fissures trending NNE., and some deep chasms. Wilkes shows a crescent escarpment concentric with the main cauldron in the surface rock of the country separating the south lunate platform from the south pit. This does not appear today, and is of interest in connection with the southeastern plateau shown on the modern map (Page One), bounded by curved fractures on the east and south, which suggests an old greater crater that has been filled up on that side. If these fractures extended around to the southwest, they have been obliterated by later floods of lava, and the crack shown by Wilkes was one of them. In the south pit Wilkes counted 70 horizontal layers, a cascade of frozen lava extended from the lunate platform of the big crater into the south pit, and a great steam crack extended down the mountain southward, and others trended northeast. The only activity was vaporing, especially on the west side of the floor of the main cauldron, and Wilkes mapped 14 cinder cones, one of the inner ones being 61 meters high. Wilkes indicated the cracking, the lava sputter that built cones, the concentric subsidence that built pits, and the sinking fault blocks that connected the pits. He showed that the in-breaking area was a wide isosceles triangle with hinge line at the southeast and apex at the northwest.

Lydgate's survey 33 years after Wilkes, followed five outflows and also the great crisis of 1868 when Mauna Loa had started anew, after an unknown interval, to discharge lava from its low southern slopes. The western wall of the cauldron is a third higher, and the eastern wall twice as high as in 1841. Severance in 1870 had reported the eastern wall still higher (366 meters). Lydgate reported a maximum depth of 320 meters. The southern pit was larger and deeper than that reported by Wilkes. The northern embayment had become a long elliptical pit with two cones on its floor, and Lydgate's report indicated two cones in the main cauldron also. The lunate platforms had sunk deeper and changed proportions. A new southwest extension of the main crater floor contained the active lava pool of June 1874, 153 meters in diameter, and the scene of lava fountains for years after 1872. The floor was rising owing to repeated overflows, and the crisis of 1868 appears to have been a turning point from crateral subsidence to upbuilding of the floor. A subsidence of 27 meters for the summit of the mountain (based on Alexander 1885) is quite conceivable, if there was a sinking of approximately nine square kilometers of crater flooring to a depth of 100 meters between the times of Wilkes and Lydgate. There was 25 years of outflow from 1843 to 1868, implying withdrawal of matter from within the mountain. At least 165 kilometers of lava flow, measured longitudinally as radial ribbons of varying width, was discharged down the mountain slope. Subsiding crest of the dome may follow subsidence of crater floor due to relief by outflow in excess of that balance of pressure of rising lava, which by sill intrusion might keep the crater stationary.

The question of actual height of Mauna Loa is important, for this summit over live lava certainly fluctuates over pressing intrusive magmas which recurrently exude through fissures. Menzies in 1794 made the elevation 13,564 feet (4134 meters); Wilkes 1841 made it 13,750 feet (4194) meters); Alexander 1885 made it 13,675 feet (4168 meters), "obtained with a spherical signal on the summit accurately determined by triangulation from more than 20 stations on Mauna Kea, Hualalai, and in South Kona." The U. S. Geological Survey (U. S. Coast Survey data) made it 13,680 feet (4170 meters) by precise levels from Hilo tide guage in 1926, showing stationary conditions after 1885. Apparently the summit rose between 1794 and 1841, and sank between 1841 and 1885. There may have been some vast outflows of Mauna Loa in the last half of the eighteenth century preceding the great Kilauea eruption of 1790, which accounted for the low level of the summit measured by Menzies.

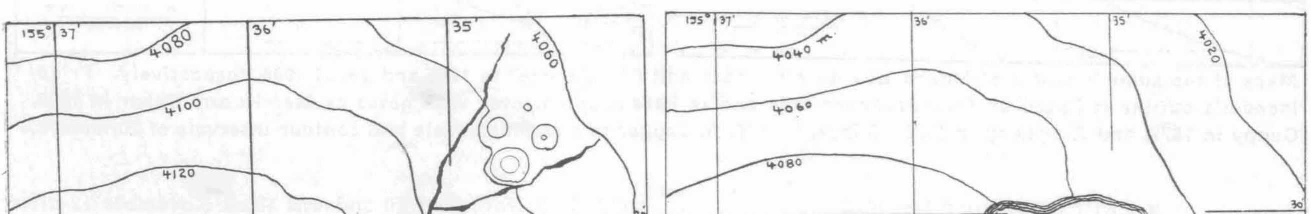
In July 1880 Brigham reported at Mokuaweoweo fresh lava spread over the central floor, obliteration of the inner walls of the lunate platform, talus suggesting recent earthquake, and a lava flow away from the crater on the southwest rim which came from fissures near the brow of the cliff. The flooding of the summit crater with lava from 1872 to 1876 was accompanied by repeated lakings, crater flows, and fountains, and no recorded outflows, except that in 1877 there was a submarine lava flow at Kealakekua Bay. The lava flow of 1881 produced 68 linear kilometers of streaming, starting in November of 1880 after summit effusions in the spring of that year, and taking its origin on the northeast rift 10 km. ENE. from the north embayment of Mokuaweoweo and 3350 meters above sea level. There is a large pit crater where this flow emerged, and the lava divided into two streams, one flowing towards Kilauea, the other towards Mauna Kea, and this latter again divided and its longer arm reached Hilo after nine months of activity.

Alexander in 1885, eleven years after Lydgate, mapped great changes of building up. The south pit was smaller, filled by lateral inflow from wall fissures and from the gateway. The south lunate platform had less relief and was smaller. A fresh lava flow had poured across the platform into the south pit and lava cataracts from cliff-edge fissures had flowed onto the platform. The main floor had been built up to new high levels from a vent in the southwest corner. This vent migrated northward 600 meters after 1874; the lava filled 100 meters of depth on the north and east, 80 meters on the west, and 40 meters on the south. The floor apparently sloped away to the northeast from a lava lake at the south just as at Kilauea. The walls had changed, but the northwest angle at the high summit remained the controlling feature of the crater. Alexander saw vaporing from hundreds of cracks in the floor, from the cone at the southwest corner, and from the wall fractures at the heads of the lava cataracts. The floor cracks were streaked with sulphur, the cone was of hot friable lava and pumice 43 meters high, north of it was a solidified lava pool surrounded by a rim six meters high, and the lava of the greater crater floor was pahoehoe. The north lunate platform was overflowed, the promotories had crumbled back. the northern embayment had changed to become a second and higher platform, the western cone was replaced by a lava flow, and the eastern one by a circular pit 183 meters deep and 305 meters across, with a central cone on its floor emitting vapor.

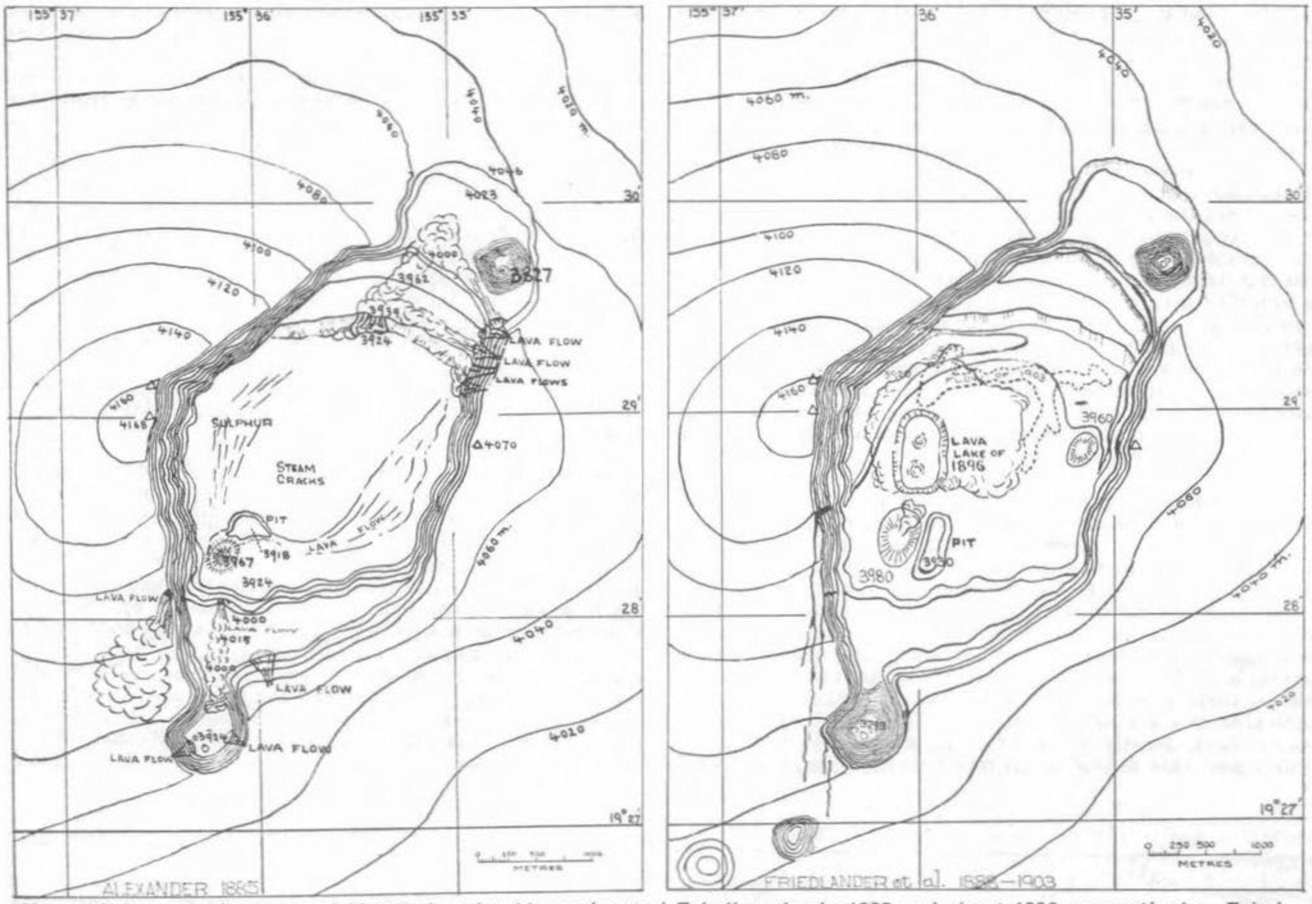
Wood in 1915 (Am. Jour. Sci. May 1916) describes the changes since 1885 as a building up of the floor, submergence under lava of the lunate platforms, and as products of the floor eruption of 1903 a central cone and lava flow, with a NNE rift east of it representing the fresh cones of 1914. The lava flows of 1914 on the floor had covered large portions of the two platforms and the central cauldron. Wood mentions blade lava of extraordinary quality unlike anything in Kilauea, the blades characterizing the texture of the surface of both pahoehoe and aa. Stearns in 1924 indicates the geology of the crater as distributing fresh recent lava, mostly since 1832, all along the line of the crater pits, this widening out into fans of flows at the NNE and SSW slopes of the mountain. He mapped fissures, spatter cones, cinder cones, pit craters, faults. water and ice holes, trails, and fumaroles. The principal scene of eruptions in Mokuaweoweo is a fissure zone about one and one-half miles long extending northeastward from the southwest side of the main crater, and along this zone lie chains of cones. The 1914 cone stands in the southwest part of the floor 100 feet high, is still steaming, and southwest of it is a small crater which contained the lava lake of 1903. Hot yellow pumice lies northwest of it in a field from which dense, blue, sulphur fumes ascend. North of this is a depression 15 or 20 feet deep covered with pahoehoe having islands of aa. Heat radiates from cracks in the floor and rim of this craterlet. Northeast of it is a line of driblet and pumice cones 10 to 75 feet high. The large cone of 1903 near the center of the greater crater, has the remains of another lava lake near it with a hot solfatara west of this lake which is depositing crystalline sulphur. This large 1903 cone lies west of the fissure of 1914.

The fissure zone passes across the south platform up to the rim of the caldera and may be seen in the crater wall. On the rim 200 feet above the platform is a small driblet cone and the lava actually shows as a dike in the cliff below. Southwest from the crater rim is a line of driblet cones which poured out lava that cascaded over the vertical wall of the caldera and spread out on the floor, showing that lava was being extruded on the floor and on the cliff above at two levels different by 300 feet. According to the map by Stearns, which is based on Wingate's topographic map, the country rock east and west of the crater is older basalt showing explosion debris in two marked accumulations northwest and southeast of the central cauldron.

T.A.J.



Maps of the summit crater of Mauna Loa by Wilkes and Lydgate in 1841 and 1874, respectively. Adapted by T. A. Jaggar to a common scale and contour intervals of 20 meters. Lydgate's map supplemented by notes of Hall in 1873 and Brigham's discussion of 1880. Lydgate's summit elevation adopted from Alexander in 1875.



Maps of the summit crater of Mauna Loa by Alexander and Friedlaender in 1885 and about 1896, respectively. Friedlaender's outline is based on the Alexander map and is here supplemented with notes by Merritt and Baker in 1888, Guppy in 1879, and Ridgeway in 1903. Adapted by T. A. Jaggar to a common scale and contour intervals of 20 meters.

KILAUEA REPORT No. 1034

WEEK ENDING NOVEMBER 15, 1931

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The only noteworthy changes, at Halemaumau are a steady tilt away from the pit, as indicated by the Halemaumau seismograph, and continuous widening at crack point No. 21. Measurements indicate that this point has moved one and one-half inches from October 26 to November 12.

Fume and steam were thin on November 9. Fume increased on November 10 and was thick November 12 after rain.

Because of wet weather road work slackened, and consequently there were fewer artificial disturbances on the records of the Observatory. Of 81 tremors registered, one gave distance 4 miles, 4 gave 15 miles, one gave 18 miles, and one gave 42 miles. Eight tremors were probably of artificial origin. Of six very feeble local seisms, one with indefinite phases showed distance 18 to 28 miles from the Observatory; the others had obscure phases.

Tilt for the week averaged light ESE. Microseismic motion was moderately strong at the beginning of the week, decreased to light on the 14th, and was light to moderate on the 15th.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 361—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | November 26, 1931

Kapele lagoon at east end of Kula fault where a block of land subsided April 21-23, 1924, at the east point of the island of Hawaii. Along with earthquakes and cracking open of the country, this shore line subsided 10 to 12 feet so that these coconut palms, on the date of this photograph, June 9, 1924, and ever since, were submerged with their butts under 8 feet of water. Photo Finch.

PUNA SHORELINE SUBSIDENCE

The Puna District of Hawaii in the vicinity of Kapoho, the east point of the island, was the scene of destructive seismic activity in the spring of 1924. This activity was recorded in Bull. Hawaiian Volcano Observatory April 1924 and in Bull. Seis. Soc. Amer. Dec. 1924. Photographs of the region affected are reproduced in these articles and in the Bulletin of the Observatory for January 1926.

On April 21, 1924, there began a prolonged mild quaking in the Kapoho district, approximately 88 felt earthquakes were counted, and on April 22 and 23 extensive cracks began to open near Kapoho. About 20 pronounced chasms were mapped by an Observatory party. Leveling surveys were run along the railroad by Superintendent Boles of Hawaii National Park, and these indicated a new profile 9 feet lower than before, south of the quarry at Kula, and one foot lower than before at Kapoho station. The block of country between the Kapoho hills and the Kula fault where the greatest downthrow occurred sank in varying amounts from one foot to over 11 feet. At the ocean end of the Kula fault a new lagoon running 200 feet inland was formed, and coconut trees were found standing in 8 feet of water (see cut Page One).

The earthquakes were quite localized and were not felt in Kalapana, about 12 miles to the southwest, nor were any changes in elevation or cracking of the ground noticed in the country south of Kapoho.

Reports, however, have come from time to time during the last few years to members of the Observatory staff of a gradual subsidence of the Puna coast as far south of Kapoho as Kaimu and Kalapana. After a recent conversation with Mr. Henry Lyman of Kapoho, a trip was made through the Puna District for the purpose of verifying, if possible, these reports and gathering further evidence, as well as for locating likely points for future observation and measurement.

The trip was made November 12, 1931, and residents were interviewed at Kapaahu, Kalapana, Kaimu, Opihikao, Pohoiki, and Pahoa; Mr. Richard Lyman of the last place gave information concerning Kapoho and the general conditions of the district. The following was the evidence from different places:

Kapaahu, Kalapana, Kaimu;

Four families were interviewed. None had noticed any change in shore elevation. The washing of waves over the black sand beach and piling back of the sand was thought to be the result of changing currents and unusually high waves. A mark was placed at Punaluu Pond in Kapaahu, and this will be observed from time to time.

Opihikao;

Only one family found at home and these proved to be newcomers.

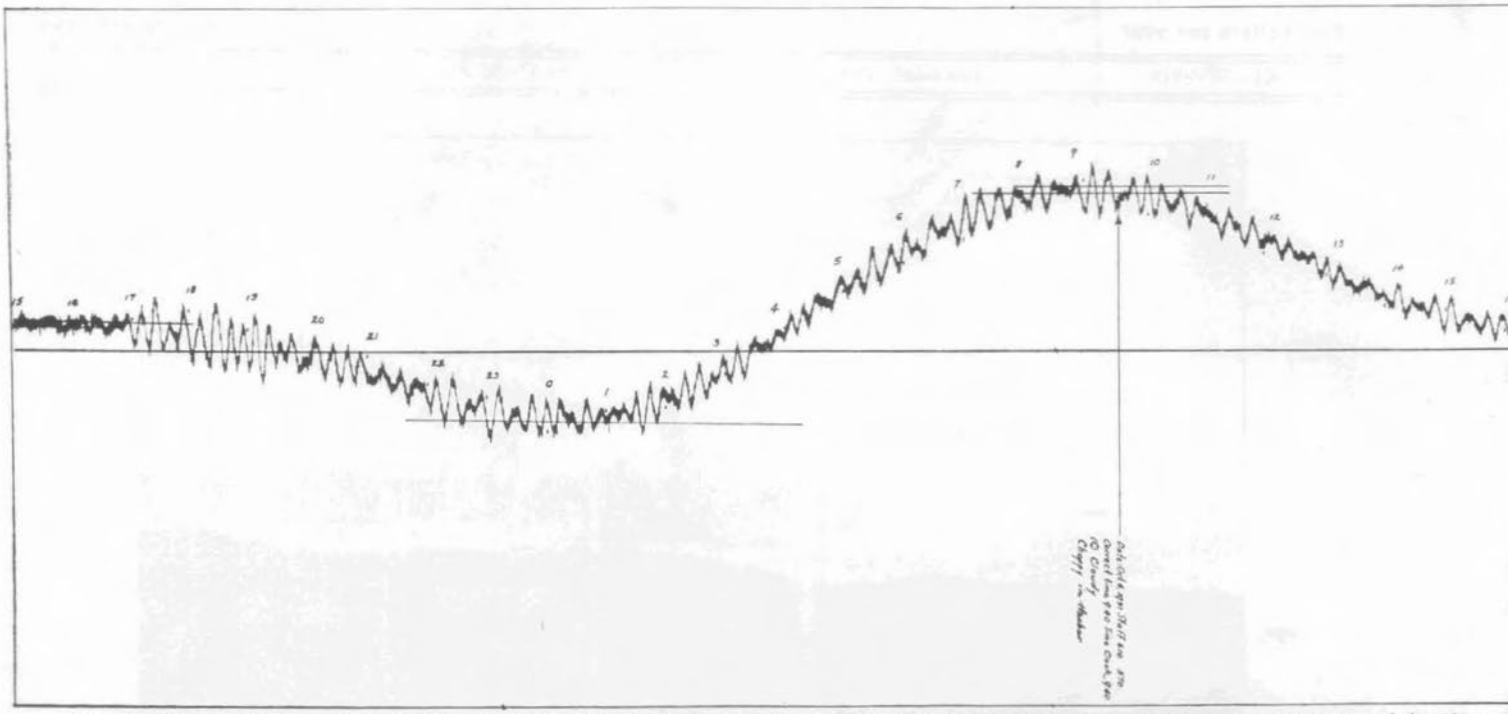
Pohoiki;

One family named Mioi was interviewed. They state as common knowledge in that district that the land has lowered, but are certain that the drop took place during the Kapoho earthquakes of April 1924. They do not connect this tradition with the shore line.

Kapoho;

Mr. Richard Lyman thinks that the sinking occurred entirely at the time of the destructive earthquakes of 1924.

Kapoho crater was visited and it was found that the



Record of tide gauge at Hilo, Hawaii, evening of October 3, 1931 (Hawaiian date), showing trace of seismic sea wave originating n wave something over 8 hours. The range of the wave movement shown at the beginn

middle one of the three pit craters which formerly had a moderate sized pond with water lilies, had gone practically dry. This is due probably to an unusually dry year. Puu Kukii, which in 1922 was covered with growing cane, is now overgrown with guava except where the 1924 disturbance left a bright red scarp. The Kula fault and Koae were also visited, but showed nothing new.

The investigation indicates that probably shore subsidence has extended from Kula as far south as Pohoiki and perhaps Kaimu, and that this subsidence occurred all at once in 1924 and is not a continued slow movement. The down-faulting corresponds on a smaller scale with that of 1868 in this same district (see Memoirs Bernice Pauahi Bishop Museum Volume 2 No. 4 1909). E.G.W.

Erratum

In Volcano Letter No. 359, Page Four, map of Soufrière Crater, the scale is 0.64 inch to the mile, and contour interval 100 feet. In Volcano Letter No. 360, Page Four, line 8, read "crack point No. 25."

EARTHQUAKE AND SEA WAVE OF OCTOBER 3, 1931

On the morning of October 3 the seismographs of the Hawaiian Volcano Observatory showed the record of a big earthquake somewhere, and indicated that possibly a seismic sea wave might arrive at the shores of Hawaii. On October 22 the London Times reported that a severe earthquake occurred on October 4 (the equivalent of October 3 in Hawaii on the western side of the date line) in the central and eastern areas of the British Solomon Islands. The damage was not serious in the central part of the group, but in the island of San Christoval the earthquake was followed by a seismic sea wave which destroyed 18 native villages with a loss of life estimated at 50. The center of the disturbance was believed to have been in the vicinity of Rennell Island, one of the southernmost of the group.

"The British Solomon Islands protectorate consists of the southern islands of the Solomon group, lying to the southeast of New Guinea. The native population is estimated at 150,000, and Europeans and Asiatics between 400 and 500. The principal articles of trade are copra, green snail, and trochus shell, ivory nuts, pearl shell, and tortoise shell.

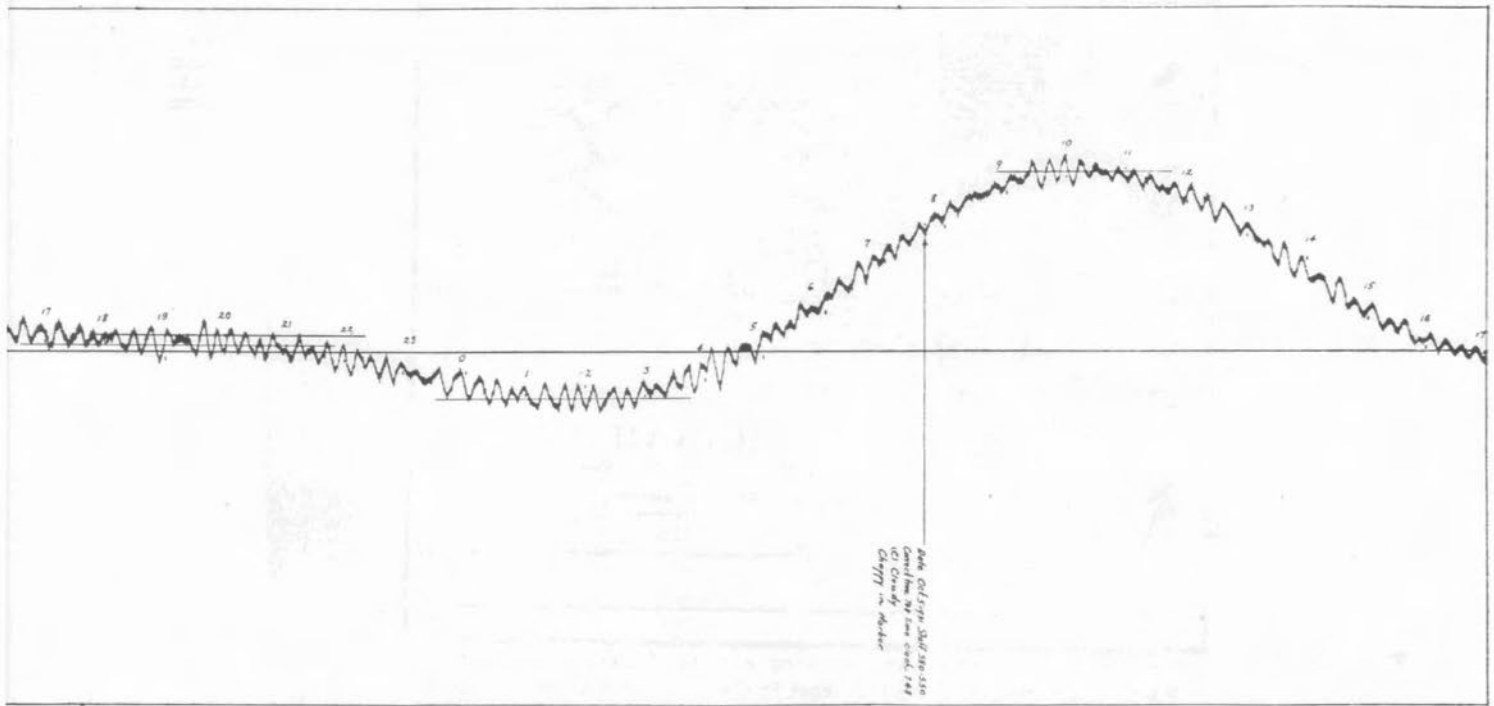
"The earthquake was recorded by instruments in England, Italy, Australia, and New Zealand," and all around the Pacific. It was a world-shaking earthquake of great energy.

The primary or P wave of the earthquake arrived at the Hawaiian Volcano Observatory at 8:52:06 a. m. Hawaiian standard time. The secondary or S wave arrived at 8:59:35 a. m. The interval was 7 minutes 29 seconds which by the tables indicated 3680 miles as the distance to the origin. The indicated time of occurrence was 9 minutes 27 seconds prior to the arrival of the first preliminary wave, which would make the big earthquake at the source region 8:42:39 a. m. by Hawaiian time.

For some little time we expected a sea wave, but nothing arrived sufficient to excite notice without the aid of the tide gauge. As the velocity of such an ocean wave has been found to be about 450 statute miles an hour, it should arrive about 5 p. m. of the same day. It should take a little over 8 hours to travel to the Hilo tide gauge.

By an inspection of the records the direction of the earthquake origin was found by the direction of the first disturbance of the pendulums to be approximately northeast or southwest 3680 miles from the island of Hawaii. To the northeast the origin would be in the center of North America and accordingly there would not be a water wave. To the southwest the origin would be off New Zealand or New Caledonia and there should be a sea wave. As there were a number of shielding island chains in that direction, and from what we know by previous experience here, it was decided that a wave would likely be damped out by their shielding action, and in any case not be dangerous. Accordingly no warning was sent out.

Later findings verified these rough estimates. The Coast and Geodetic Survey announced the first tentative location of the earthquake center as latitude 14°south and longitude 160°east, and the time of occurrence as 8:42:48 a. m. H. S. T. The Jesuit Seismological Association gave a second tentative epicenter as latitude 10° south, longitude



ar the Solomon Islands in a large submarine earthquake. The earth wave took about 9 minutes to reach Hawaii, and the water ng of the disturbance is about 6 inches on the tide staff at Pier One, Kuhio Wharf.

161.4° east, and the time of occurrence as 8:43.10 a. m. H. S T.

These placed the epicenter in or near Solomon Islands. The report above quoted verifies this and announces a big tidal wave.

The tide gauge in Hilo bay on the east side of the island of Hawaii shows that the waves began to arrive within 3 minutes after 5 p. m. October 3 H. S. T. The water in the bay rose and fell every 15 minutes for the next 48 hours. The rise and fall averaged about half a foot total range and the motion was so slow as not to be noticed by the casual observer. The record, however, is plainly shown on the marigram (see cut Pages Two-Three), and the very long duration of it is unusual. There was first a lowering of one-quarter of a foot followed by a rise of three-eighths of a foot, with somewhat irregular seiches thereafter for two days.

These waves are so flat that they can not be seen on the open ocean. Since they travel at the rate of 450 statute miles an hour, and 15 minutes apart, they will measure 112 miles from crest to crest, and being less than half a foot high on the open ocean they are not perceptible.

Such seaquake waves in the water, or tsunamis as they are technically called, have been known to continue even for two or three days with slowly diminishing amplitude (Dutton, Earthquakes, page 280). In R. M. Wilson's account (Bull. H. V. O. XVI June 1928) of a tidal wave arriving at Hawaii from the coast of Mexico, the maximum risings exceeded a foot, and there were several recurrences of the smaller waves at intervals, the whole lasting for 24 hours.

In this sea wave of October 4, 1931, the oscillations lasted for 48 hours. There are several ways to account for this long endurance of water disturbance, for some sea waves last only a few hours. There may be reflections or echoes from the coasts near the origin of the earthquake, which would have the effect of adding to the number of wave trains. In this case the waves, large at the source, may have broken up into numerous small ones by the groups of islands and shallows that they pass through. Again, a large body of water, such as is inclosed in any bay or small sea, if once set in motion is very slow to stop and would vibrate in its natural period for a long time after being disturbed. It is difficult to say in what proportions these possible causes affect the lengthening of the record. (See Bull. H. V. O. March 1928, Monthly Weather Review March 1924, and Volcano Letter No. 274 March 27, 1930.)

A.E.J.

KILAUEA REPORT No. 1035

WEEK ENDING NOVEMBER 22, 1931

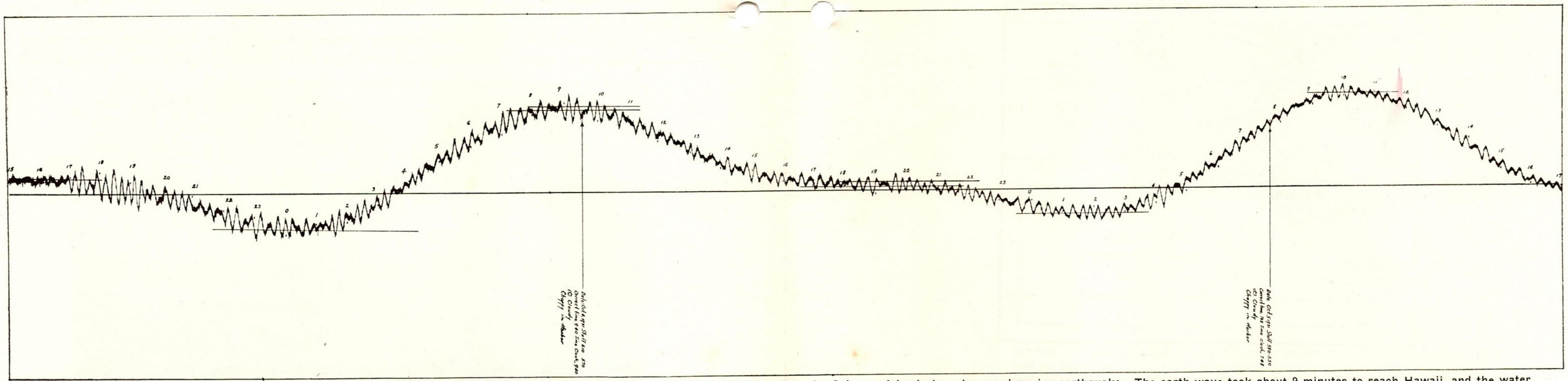
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

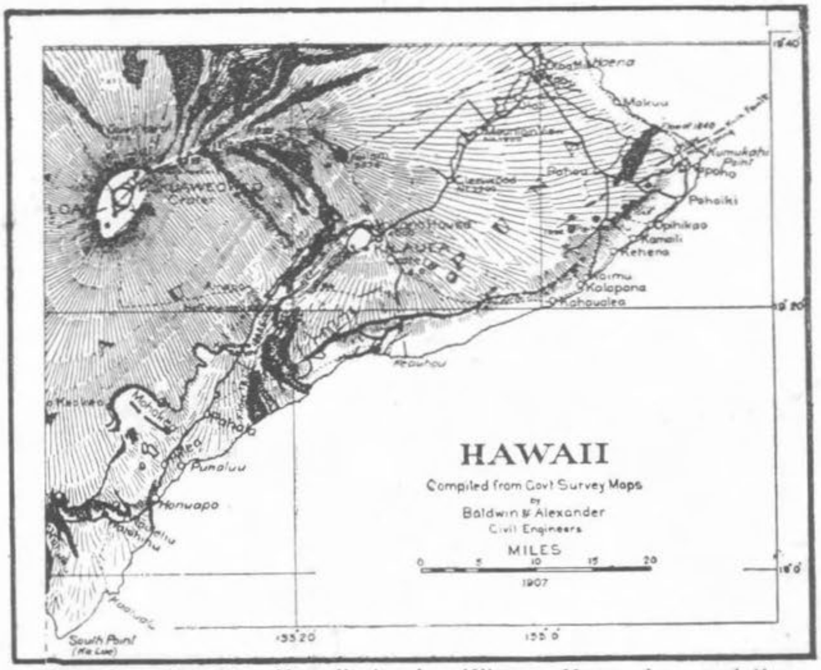
Kilauea continues inactive. Halemaumau pit shows no significant changes, the fume and steam on the floor varying in visibility according to the temperature and the amount of recent rainfall. A few rocks were observed falling from the northeast wall on the forenoon of November 18. Crack point No. 25 shows a widening of the rim fissure here ⅝ inch between November 12 and November 20, 1931. On November 20 new fallen fine debris was seen on one of the northern taluses. The crack above mentioned is where the rim is breaking down at the northeast by adjustment of the pit circle where a year ago there was heavy avalanching and excessive cracking back of a very precipitous part of the wall.

Artificial disturbances were fewer on the records of the Observatory. Fifty-one tremors were recorded, four of which indicated approximate distances of from 40 to 60 miles. On the 19th occurred part of a teleseism without definite phases. A feeble seism at 6:46 p. m. November 22 was felt locally. Its epicenter was 5 miles from the Observatory. At 5:10 p. m. a very feeble seism was registered with a distance of about 12 miles.

Tilt for the week was slight NE. Microseismic motion was moderate, becoming strong at the end of the week. The tilt or ground movement indicates a quiet condition. What slight tilt has occurred can be attributed to seasonal effects. The number of recorded shocks is less than occurred during the preceeding week. The shocks appear to have originated at greater distances than those of last week.



Record of tide gauge at Hilo, Hawaii, evening of October 3, 1931 (Hawaiian date), showing trace of seismic sea wave originating near the Solomon Islands in a large submarine earthquake. The earth wave took about 9 minutes to reach Hawaii, and the water wave something over 8 hours. The range of the wave movement shown at the beginn ing of the disturbance is about 6 inches on the tide staff at Pier One, Kuhio Wharf.



Map of southeastern Hawaii showing Kilauea, Mauna Loa, and the Puna fault cliffs extending northeast to the Kula fault, where the land on the south side subsided in April 1924. The photograph on Page One is looking seaward on the south side of the Kula fault cliff where it enters the ocean.

Black sands of Kaimu beach in November, 1931, showing invasion of the coconut grove and roadway by the sea. The road is being moved back. Photo Powers.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 362—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | December 3, 1931

New steam vent discovered on south slope of Diamond Peak in southwestern part of Lassen Volcanic National Park. The locality is solfataric but was not known to be steaming prior to the autumn of 1931. Photo taken October 14, 1931, by R. H. Finch, Lassen Volcano Observatory.

CHEMICAL ANALYSES OF KILAUEA LAVAS

One phase of the study of volcanoes which attracts no public attention, but nevertheless is of utmost scientific importance, is the study of the changes which take place in the composition of the lava during the life cycle of a volcano. Geologists may express the composition of a rock either in terms of the kind and amounts of the different minerals which make up the rock, or in terms of the kind and amounts of the different chemical elements contained in the rock. Of course the mineral composition and the chemical composition depend on each other so that a statement of either kind of analysis gives a picture of the composition of the rock. Since an analysis of the chemical composition can be made more accurately and can be expressed in more definite quantitive terms, more attention is paid to determining the chemical composition of different lavas of the important volcanoes which are studied.

Scientists have been studying the chemistry of the lavas of Hawaiian volcanoes for many years. Geologic literature contains first rate analyses of over a hundred different specimens of lava from the several volcanoes of the islands. Part of the work of the Geological Survey is to carry on with this collection of quantitative data. During the past two years, chemical analyses have been made of six different lavas from Kilauea and two from Mauna Loa. These new analyses are given in Table I at the end of this article.

It is obvious that these eight different lavas show very little difference in their chemical composition. Furthermore, the same lavas are decidedly similar in their mineral composition. They all belong to a class of rocks known as basalt. The Hawaiian lavas contain porphyritic crystals of olivine in a groundmass of about equal parts of plagioclase and pyroxene, with glass only in the quickly cooled surface phases (see Volcano Letter No. 348). Not only do the different basalts from Hawaii show a similarity in composition, but they also are remarkably like basalts from other volcanoes in the Pacific islands and basalts from the huge volcanic fields of India, Iceland, and other islands of the north Atlantic, Patagonia, and the Columbia River plateau of North America. This similarity in composition of basalts the world over, together with some other technical reasons, has led many geologists to believe that the whole surface of the earth is underlain by a layer of eruptible basalt of fairly uniform composition. This parent basalt is considered to be the original material of all volcanoes, and the many other kinds of lava with different compositions have all been derived from this basalt by some process of differentiation. The average of 16 analyses of Kilauea basalts, and the average of several other types of this parent basalt, are given in Table II.

The different lavas from Kilauea do not show any great variation from this average basaltic composition. That would mean that no great amount of differentiation has taken place in the lavas during the life of the volcano. This should logically be the case when we consider that Kilauea is a relatively young volcano and probably has lived only part of its normal life cycle. The same is true of Mauna Loa, and the lavas from the present active Mauna Loa do not show very much variation in their composition. It is in the older volcanoes of Hawaii which have completed their life cycle that we would expect to find the greatest change in composition of the lavas, and such is the case. The lava of Puuwaawaa is almost true pumice and obsidian with a chemical composition of trachyte (62 per cent silica, 12 per cent alkalies soda and potash). Also many flows on Kohala and Mauna Kea approach trachyte in their chemical composition.

One of the many problems confronting us is to determine, if possible, how and why this change in composition takes place. The most alluring reason for desiring a solution to this problem is that gold and many other precious metals are associated not with basaltic rocks but with rocks, like the above, which approach a granite in chemical composition. It thus is essential to understand the origin of these ore-bearing rocks in order to learn more of the origin of the valuable ores themselves.

TABLE I

Lavas, Hawaii

1. Olaa. Mauna Loa aa flow, road cut on government road at south boundary of Waiakea Forest Reserve. Analyst J. J. Tahey.
2. Reservoir. Mauna Loa pahoehoe flow, from reservoir at Piihonua. Analyst J. J. Tahey.
3. Quarry. Kilauea pahoehoe flow, National Park quarry, on Hilo road one mile from Observatory. Analyst J. J. Tahey.
4. 1917 Halemaumau. Splash from lava lake. Analyst J. J. Tahey.
5. 1919 Halemaumau. Splash from lava lake during eruption of Alika flow from Mauna Loa. Analyst J. J. Tahey.
6. 1919 Halemaumau. Pahoehoe flow NE edge of floor of Kilauea Crater. Analyist, J. J. Tahey.
7. 1921 Halemaumau. Pahoehoe flow S edge of floor of Kilauea Crater. Analyst L. T. Richardson.
8. 1929 Halemaumau. Scoria from lava fountain. July 1929. Analyst R. E. Stevens.

	1	2	3	4	5	6	7	8
SiO_2	50.41	52.14	51.35	50.14	50.37	50.52	50.85	51.00
Al_2O_3	12.37	13.60	13.36	13.93	14.20	13.85	15.30	13.03
Fe_2O_3	1.94	2.31	1.32	0.57	1.28	0.98	0.28	1.83
FeO	9.56	8.80	9.85	10.07	10.10	9.77	10.42	10.02
MgO	7.68	7.26	7.62	8.25	7.75	7.07	7.80	6.76
CaO	12.56	10.14	10.74	11.17	11.24	11.33	11.45	12.40
Na_2O	1.68	2.02	1.93	1.29	2.20	1.51	.70	2.02
K_2O	0.40	0.48	0.50	0.41	0.56	0.47	.58	0.73
$H_2O+110°$ C.	0.22	0.16	0.29	0.03	0.06	0.04	.18	0.35
$H_2O-110°$ C.	None	0.06	none	none	none	none	trace	none
TiO_2	2.26	2.20	2.50	3.20	2.33	3.63	1.55	2.33
P_2O_5	0.57	0.29	0.28	0.23	0.02	0.22	.22	0.14
Cr_2O_3	0.05	0.02	0.03	0.07	0.05	0.06	.05	0.008*
NiO	0.004	0.005	0.025	0.002	0.008	less than 0.001	.002	trace
MnO	0.06	0.07	0.07	0.06	0.14	0.14	.10	0.18
	99.76	99.55	99.86	99.42	100.31	99.59	99.48	100.80

*Quantity of sample insufficient.

TABLE II

	K	D	O	T
SiO_2	49.9	50.6	50.0	47.5
Al_2O_3	12.7	13.6	13.7	13.9
Fe_2O_3	1.45	3.2	2.4	3.6
FeO	10.0	9.9	11.6	9.4
MgO	9.9	5.5	4.7	6.8
CaO	10.5	9.5	8.2	9.8
Na_2O	2.0	2.6	2.9	2.9
K_2O	.45	.7	1.3	1.0
TiO_2	2.7	1.9	2.8	2.7
P_2O_5	.25	.4	.8	.4
MnO	.12	.16	.24	.22

K. Average of 19 analyses Kilauea lavas. 13 from H. S. Washington, Petrology of Hawaiian Lavas. (Amer. Jour. Sci.)

D. Average of 11 analyses Deccan (Western India) lava. H. S. Washington, Deccan Traps and other Plateau Basalts. (Geol. Soc. Amer.)

O. Average of 6 analyses Oregon basalts, H. S. Washington, Deccan Traps, etc. (Geol. Soc. Amer.)

T. Average of 33 Thulean (Iceland-Britain-Greenland) basalts. H. S. Washington, Deccan Traps, etc. (Geol. Soc. Amer.)

H.A.P.

LASSEN REPORT No. 30

NEW DIAMOND PEAK STEAM VENT

R. H. Finch, Asociate Volcanologist

A new steam vent was discovered in the Lassen Volcanic National Park during the early autumn of 1931. It is located just below Diamond Peak on the ridge between East and West Sulphur Creeks. This is in the southwestern part of the park near the new road which crosses the mountain mass. The vent was discovered by National Park workmen, and is shown in the photograph on Page One, taken October 14, 1931. As the steam appeared in a clump of trees, the workmen thought at first that they had discovered a forest fire. Adjacent to the new vent, especially on the slope just below, are old solfataric areas. It appears, however, that there has been no activity in this locality for a great many years. Steam escapes from a small vent in the center of an area over which sulphates, chiefly alum, are being deposited. The temperature of the steam is 198 degrees Fahr. The photograph was taken with a view to making later pictures that will show changes in chemical erosion, etc.

The map shown on Page Four is a reduced copy of the topographic map of Lassen Volcanic National Park surveyed by E. P. Davis and R. G. Stevenson of the U. S. Geological Survey in 1925-26. The new road between Upper Meadow and Helen Lake has been completed since the map was made. Mineral, headquarters of the Lassen National Forest, where the volcano observatory is located, is three miles outside of this map to the southwest. Lassen Volcano is in the middle of the west part of the park, the Loomis Museum (where seismograph No. 2 is located) is at Reflection Lake inside the park northwest, and Mount Harkness (where seismograph No. 3 is in the forest ranger station) is just inside the park at the southeast. Cinder Cone and its lava flows lie between Snag Lake and Butte Lake in the northeast corner of the park. The principal hot and boiling spring areas, and the solfataric deposits, and steam jets which accompany them, are in the southwestern part of the park amid the mountains of the northwestern end of the Sierra Nevada above which Lassen Peak stands as an imposing volcanic cone 10,453 feet high.

R.H.F.

KILAUEA REPORT No. 1036

WEEK ENDING NOVEMBER 29, 1931

Section of Volcanology, U. S. Geological Survey

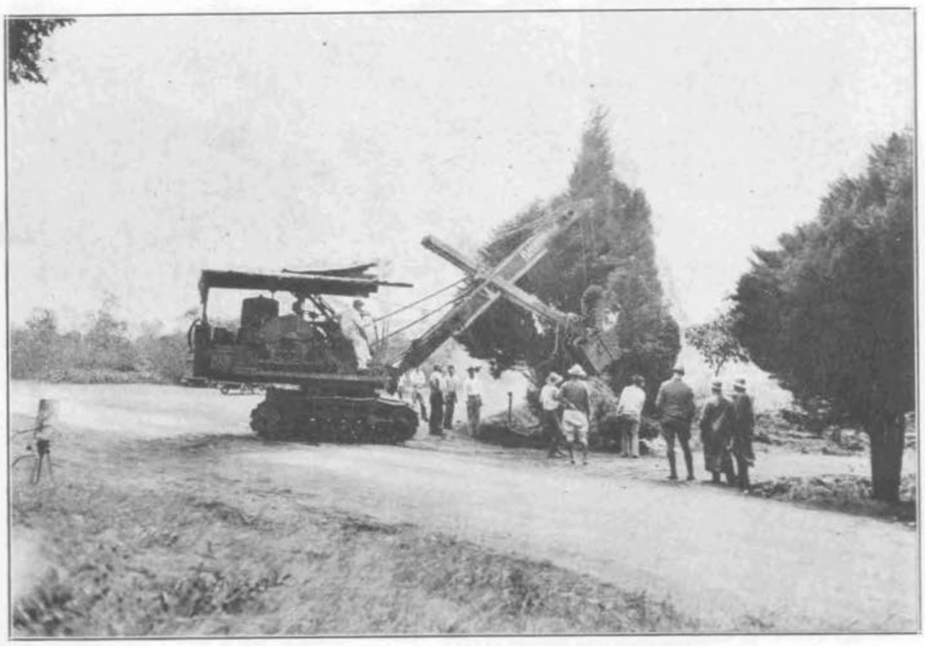
T. A. Jaggar, Volcanologist in Charge

No significant changes in the bottom of Halemaumau pit have occurred. The crack at the northeast edge, No. 25, opened three-quarters of an inch November 20-30. Measurements show a lowering of the rim block adjacent to the crack about one foot between October 26 and November 23. At 10:35 a. m. November 24 an avalanche producing much dust occurred at the northeast wall of the pit under this crack.

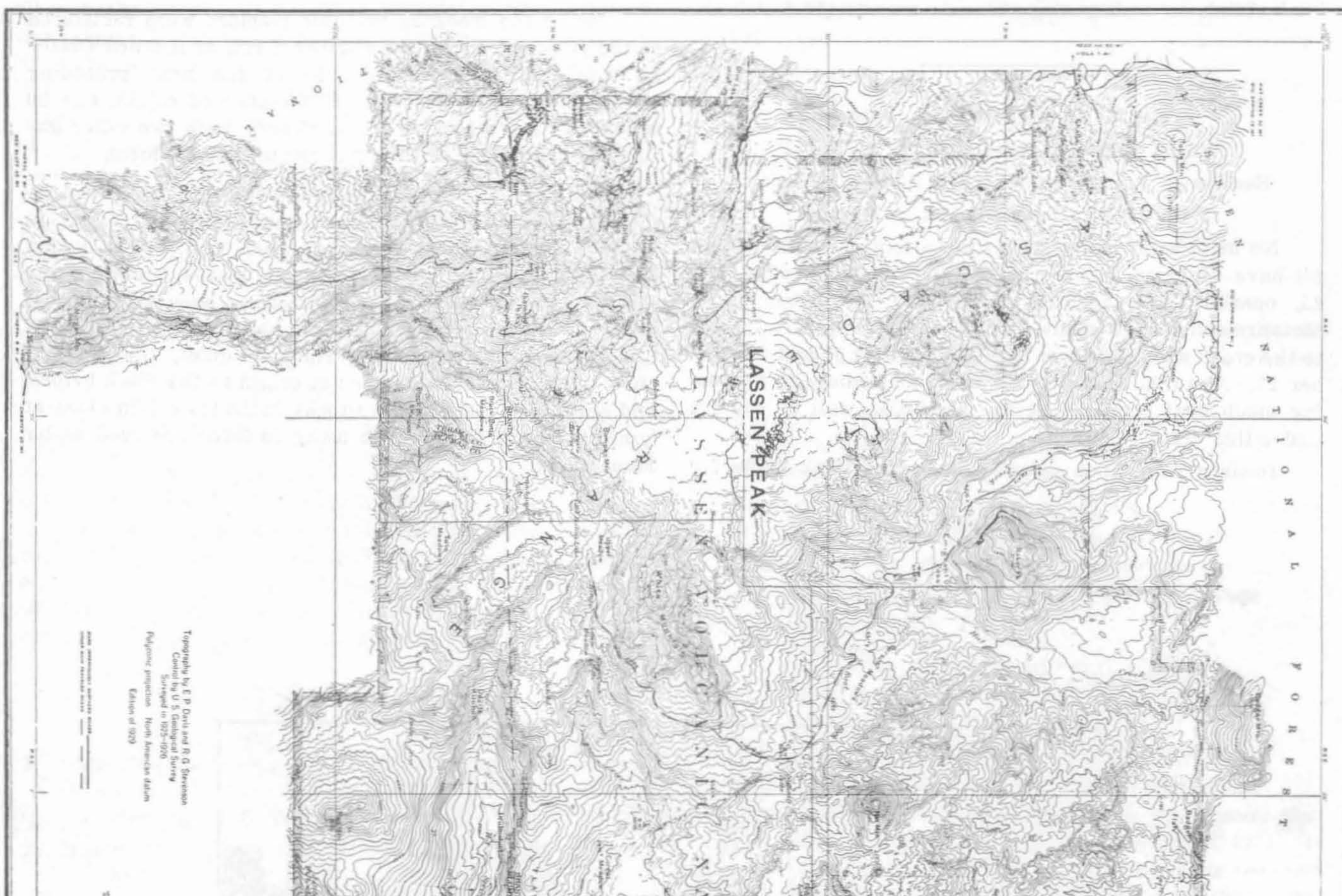
Designs have been drawn and preparations made for rebuilding the seismograph hut at Halemaumau with the cooperation of the National Park Service.

During the week 22 volcanic tremors were registered at the Observatory on the northeast rim of Kilauea Crater as compared to more than 50 of the next preceding weeks. Four gave evidence of distance of origin, one 20 miles, and the others 40 miles. There were two other disturbances possibly of artificial origin, but doubtful.

Two very feeble local seisms were registered, one indicating origin distance about 1 mile, the other about 20 miles. Microseismic motion has been very heavy during the week, probably owing to ocean waves pounding the steep shores of the island, as there has been some strong wind. Tilting of the ground has been very slight NNW. General conditions indicate volcanic quiet, the tremors show about the same distance of origin as the week before, and one of the very feeble shocks indicates origin close at hand, the other far enough away to have occurred under Mauna Loa.



Contractor moving cypress and Japanese cedar trees back from the road front, for purposes of new road construction, Hawaiian Volcano Observatory. Large pits were dug to receive the trees, black fertilizer and loam mixtures were prepared in the pits, and the power shovel with caterpillar treads lifted each trunk with its ball of soil and deposited it at its destination. Photo Jaggar.

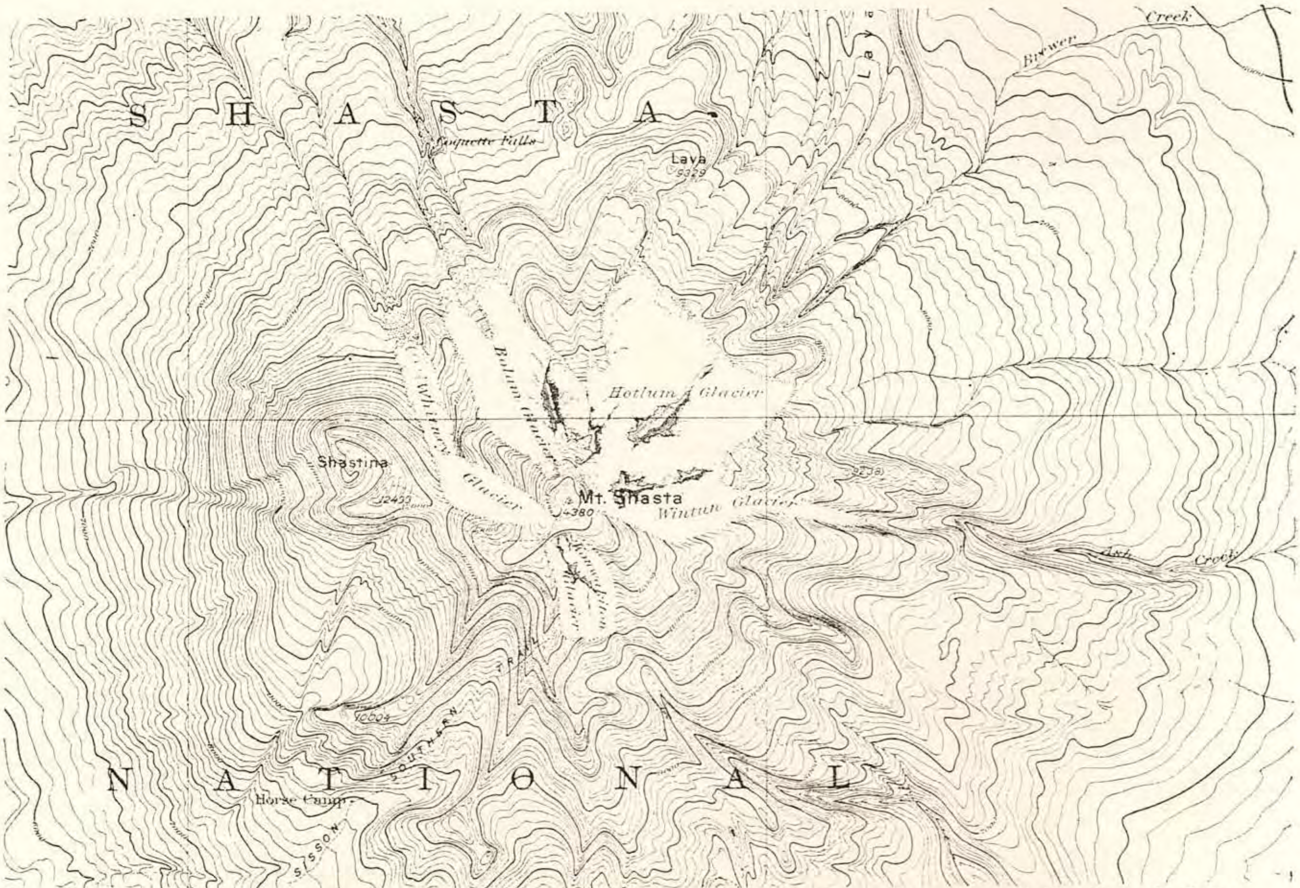


Map of Lassen Volcanic National Park, U. S. Geological Survey 1925-26. Seismographs of the Section of Volcanology are maintained northwest. southwest, and southeast of Lassen Peak, as described in the text.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 363—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | December 10, 1931



Map of the cone of Mount Shasta in California, an isolated volcano in the southern part of the Cascade Range, with hot springs and steaming vents, and well marked old lava flows about the flanks. Like most of these cones, remnant glaciers surround the summit, which stands 14,380 feet above sea level.

THE ACTIVE AND RECENTLY EXTINCT VOLCANOES OF NORTH AMERICA

Review by G. L. Chang

The most prominent fact brought out by a study of the geographical distribution of volcanoes is that, with but few exceptions, they are mostly situated on the borders of continents or on the ocean's floor.

The volcanoes of North America form a part of a great system of volcanic vents which may be said to surround the Pacific Ocean. This chain of fire beginning in Terra del Fuego extends along the west border of South America, where its course is marked in the Andes by some of the loftiest igneous mountains in the world; it is narrow and well defined on the west border of Central America and far into Mexico, where still steaming craters, some of which are among the highest summits on the continent of North America, define its position. The volcanic belt broadens in the northern part of Mexico and the United States, but is marked by few active craters. Again contracting and approaching close to the ocean's shore, and in several instances marked by island volcanoes, the igneous belt follows the coast of British Columbia and Alaska, and extends westward throughout the length of the Aleutian Islands. Still active craters in Alaska show the positions of earth fractures which unite the volcanic belt of the new world with the still more energetic volcanoes of Kamchatka, Korea, Japan, Formosa, the Philippine Islands, New Guinea, New Caledonia, New Hebrides, and New Zealand. The length of this vast system of active volcanoes, from the southern end of South America about the Northern Pacific to New Zealand, is about 30,000 miles. Within the embrace of the great curve, and rising from the deeply submerged floor of the Pacific, are many volcanic islands and still active craters.

A branch of the western arm of the volcanic system just referred to embraces Java and Sumatra. A corresponding offshoot of the eastern arm is marked by the volcanoes of the West Indies.

It is a matter of observation that the loftiest mountains of a continent face the largest ocean washing its shores. In a similar way it may be remembered from a study of the distribution of volcanoes that the largest volcanic belt in the world embraces the largest ocean. Whether this association indicates an essential or genetic connection between the height of mountains, the prevalence of volcanoes, and the extent of water bodies, remains to be shown.

The volcanic areas of North America form a part of the great Pacific belt, but include an exceptional portion of it, since from central Mexico to southeastern Alaska there are chiefly dormant vents. In this interval of some 4,000 miles, however, there are many recently extinct craters, as well as hot springs and geysers. It is in this break in the chain of steaming craters that the breadth of the volcanic belt is greatest. This coincidence is significant of some subterranean change.

An examination of the map of North America, in which the positions of most of the active and recently extinct volcanoes are indicated, will show that active volcanoes are confined to the western portion of the continent, and for the most part to the immediate border of the Pacific. No volcanoes sufficiently recent to be recognized by their topographic forms occur east of the sharply defined eastern border of the Cordilleran mountain series. The central and eastern portions of the United States, the central, eastern, and northern portions of Canada, and much of Alaska excepting its immediate southern border, are without evidence of recent volcanic activity. No active or recently extinct volcanoes have been discovered in the Greenland region. Iceland, as is well known, is an active volcanic center.

The most recent volcanic rocks in all of the vast region just referred to—east and north of the Cordilleran series and embracing five-sixths of North America—are, so far as known, confined to the Atlantic border and occur in the Newark system. They were poured out in part as molten lavas during the mesozoic era, or the middle age of the earth's geological history. Erosion has been so great since the volcanoes from which they came were in activity that scarcely a vestige of the cinder cones or of the mountains they formed now remains. The preservation of such records as still exist is due to the facts that volcanic rocks were buried beneath sedimentary deposits and, for a very long period, so depressed that they were below the ocean's level, and thus escaped removal by erosive agencies.

Still more remote in the earth's history, volcanic eruptions on a grand scale occurred in what is now the Appalachian region and in the Lake Superior basin These ancient volcanoes illustrate the fact that even in the remote past volcanoes were situated on continental borders. When the vents from which the rocks were derived were in activity, the continent had increased but little from its original Archaean nucleus. and the sea occupied the whole of what is now the Mississippi Valley and the northward extension of the same interior basin to the Arctic regions.

The volcanic mountains of the west are nearly all of post-Tertiary age. Some of the lava flows of Idaho, Washington, and California were poured out during the Tertiary and were buried beneath the sediments of great lakes, the date of which is recorded by the fossils they contain.

A portion of the Pacific volcanic belt is only a score of miles wide in Central America, but broadens in the central part of Mexico somewhat abruptly to about 800 miles, and touches both the Gulf and Pacific coasts. A gradual increase in breadth occurs north of Mexico, and in the latitude of San Francisco and Denver it attains its maximum width about 1,000 miles. When followed northward, it again contracts, and in Alaska is as narrow and sharply definied as in Central America. The narrow tapering southern extremity of this volcanic belt curves eastward; its similar northern extremity, which also contracts in breadth towards its extremity, curves westward.

It is in the narrow, curved extremities of this volcanic belt that volcanic eruptions have occurred most recently, and here most of the still active volcanoes of North America are situated. In the broader and less curved central portion chiefly dormant volcanoes occur. (Russell, Volcanoes of North America.)

THE VOLCANOES OF THE CASCADE MOUNTAINS

Review by C. B. Crawford

The Cascade Mountains extend from northern California across Oregon and Washington. Lassen Peak is situated at the extreme southern end of the range; the northern extremity extends past Mount Baker into British Columbia. This range, 500 miles long and 50 miles wide, runs parallel with the Pacific Coast about 120 to 200 miles inland, and its peaks rise 5,000 to 14,000 feet above sea level. The eastern border shows monoclinal structure due to the tilting of fault blocks. Russell suggests that the lava composing the Cascade Mountains, more especially in Washington, is an extension of Columbia lava, which was poured out in successive sheets and afterwards broken, and the blocks thus formed tilted at various angles. However, they are not wholly composed of lava; there are Tertiary rocks of unknown age beneath the lava which have been raised and tilted by the same disturbances. Much of the northern portion of the range is free from lava, the rocks being largely granite and schist, showing that the range as a whole is not of volcanic origin.

The great volcanic peaks hereinafter discussed are of a later date than the uplifting of the main Cascade Range, and owe their origin to the escape of molten material through fractures which were formed at the time of the disturbances. The conclusion that these peaks are of volcanic origin rests in some instances on their general appearance and their occurrence in a volcanic region. None of them is an example of very fresh volcanic activity with the exception of Lassen Peak. Most of these peaks have craters at their summits or on their flanks. They are for the most part the result of Tertiary eruptions and have been modified by erosion, have developed glaciers, and dominate the neighboring mountains.

Mount Shasta is probably typical of the peaks of the Cascade Range. It is a volcanic mountain which has suffered from erosion caused by streams and glaciers. It is 14,380 feet above sea level and its summit is 4,000 feet above the timber line. Small glaciers are still present on its sides. On the west end, 2,000 feet from the summit, is a cone with a crater in its top known as Shastina. On the lower slopes are similar craters, some built of cinders. some of lava. The mountain itself is composed of lava flows with a minor quantity of scoria. On the flanks of Shasta are well defined lava streams which still retain their original rough surface. The longest and most copious of the more recent streams that flowed from Mount Shasta started at an elevation of 5,500 feet. This stream divided into two branches, one of which was 12 miles long. The other entered the canyon of the Sacramento River and reached a distance 50 miles from its source before it cooled. This stream is of ancient date as is shown by the erosion the river has been able to perform in making a new gorge 100 feet deep through the flow. These lava streams, however, show no evidence of having been glaciated, and are considered as being of more recent date than the time when the glaciers starting from the summit reached the plain below; they are subsequent to the glacial epoch. Besides the two principal vents, there are numerous subsidiary ones. There is no history of eruption within memory of man.

Lassen Peak, the most recently active volcano in continental United States, is 10,453 feet above sea level at its summit and marks the terminus of the Cascades. The Lassen Peak district is crossed from northwest to southeast by a belt of volcanic cones about 50 miles long and 25 miles wide. The Cinder Cone is closely connected with Mount Lassen and shows at least two periods of eruption separated by a time sufficiently long to allow 10 feet of infusorial earth to accumulate on the ancient bottom of Lake Bidwell. The first period was one of explosive eruptions which formed the Cinder Cone and ash field; the second of quiet effusion of a large mass of lava. The whole aspect of the Cinder Cone is new, but the evidence demonstrates that the earliest eruption occurred before the beginning of the 19th century. Its age is shown by the relation of the old and new forest trees to the volcanic sand of the first eruption. The living trees grew on the top of the sand but the dead ones were standing at the time of the eruption and grew from the soil beneath the sand. This evidence was thought by Russell to show that the first eruption occurred some 200 years ago and the second more than 75 years ago. The most recent activity occurred 1914-1917 at Lassen Peak in the form of an explosive eruption. Ash was thrown out and large steam clouds were observed. The crater floor was upheaved, rough lava overtopped the rim, and an explosion hole 1,000 feet in diameter was formed. These eruptions were accompanied by blasts from the crater which leveled trees in their path.

The history of Mount Pitt in southern Oregon is similar to that of Shasta. It forms a beautifully regular volcanic cone which shows the remnant of a crater at the summit.

Mount Hood, 11,225 feet above sea level at its summit, is in northwest Oregon. Its summit retains only a portion of the crater walls. In 1888 it was reported that there were still fumaroles on the northeast slope and steaming rifts on the side near what is known as Crater Rock. Sulphurous fumes were very strong. A peculiar phenomenon was noticed in the occurrence of a fumarole in the deeply snow-filled crater. Mount Hood was reported in eruption in 1859 and 1865 (Jillson, Geog. Review, June 1917). A resident reports there was fume from Mount Hood the whole summer about 1886.

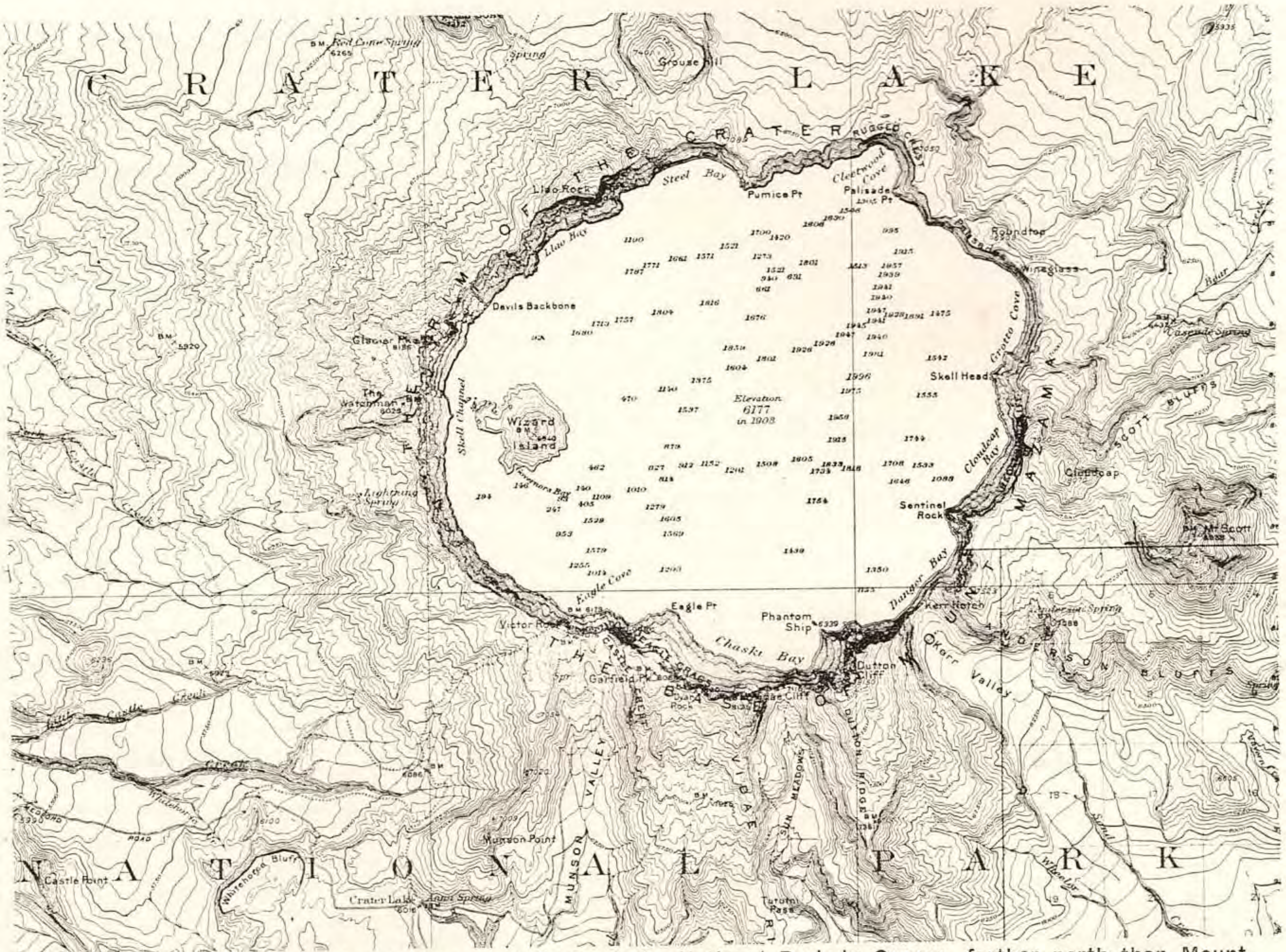
Mount Adams, 30 miles north of the Columbia, is deeply truncated at the summit and its slopes are scarred. It is very broad—possibly due to the great size of the original crater, or possibly to the blowing away of the top. Authentic history is unavailable, as it has not been much studied. It has radiating glaciers.

Mount St. Helens (9,671 ft. high) is of regular conical form, which suggests that it may be younger than Mount Adams. Reports of frontiersmen say that it was in activity in 1841-42. There is apparent from a distance the track of a lava flow which cut its way through the forest for miles. There is also discernible a lava flow northward for about 20 miles through the timber. This flow left many interesting tree molds in its path. When the last flow took place the lava appears to have passed over wet places or areas where the steam generated escaped at the surface leaving what are termed "blow-holes."

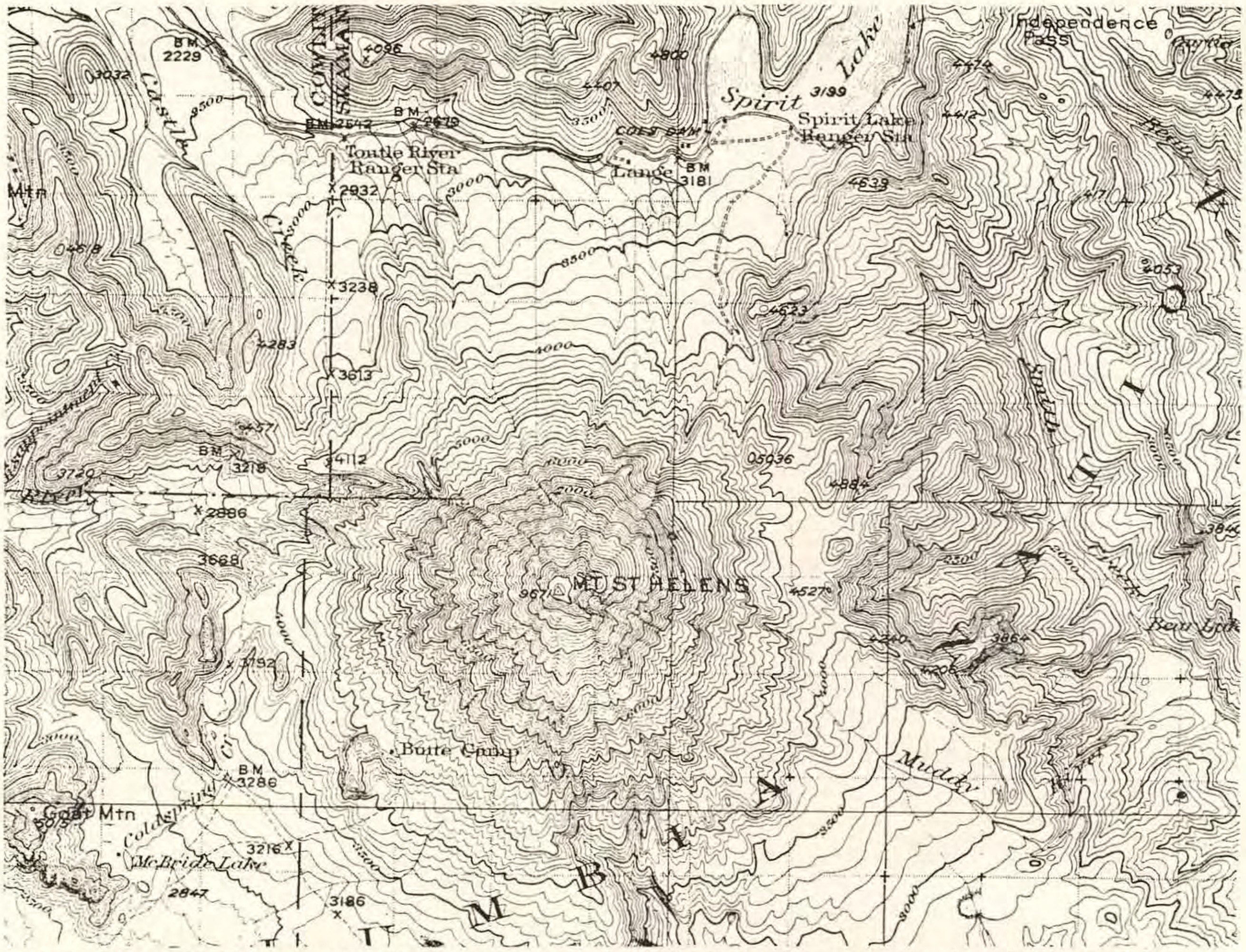
Mount Rainier has a bowl-shaped crater almost circular in form and now filled with snow. Adjoining it are the remains of an earlier crater in the interior of which the more recent one has built itself. There are exposed areas of black lava free from snow which show evidence of internal heat at no great depth below the surface. Countless small jets of steam and gas are present around the interior rim of the crater. No recent eruptions are recorded.

Mount Baker is the most northerly of the volcanic mountains of the Cascade Range south of the Canada line. (See Volcano Letter No. 334 for British Columbia volcanoes.) Little can be said of the history of Mount Baker. The summit is broken, whether due to erosion or volcanic explosions can not be said. Indians state that an eruption occurred about 1843 sympathetic with that of Mount St. Helens, and covered the whole country with ashes, and that the waters of the Skagit River became hot enough to cause the death of all the fish.

Thus the history of the great peaks of the Cascade Range proves to be that of active volcanoes, but now of very slight heat. The history is fragmentary and incomplete. (Largely after Russell.)



Map of the Crater Lake in Mount Mazama at Crater Lake National Park in Oregon, farther north than Mount Shasta. The west rim of this engulfment crater stands 8,156 feet above sea level, and the lake 6,177 feet. The greatest depth of water is 1,996 feet.



Map of Mount St. Helens in Washington State at the Columbia National Forest north of Lewis River. This is a volcano with a record of activity in historic time, elevation 9,671 feet, with radial glaciers, and radial lava flows which have dammed the drainage. Maps U. S. Geological Survey.

KILAUEA REPORT No. 1037

WEEK ENDING DECEMBER 6, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The bottom of Halemaumau remains unchanged, with one fuming sulphur spot and steam on the talus almost absent. Widening continues at a single northeast rim crack where the edge is evidently breaking down. Dust from an avalanche rose at the north rim at 9:08 a. m. December 6.

At the Observatory 24 volcanic tremors occurred, 4 of which indicated origin distances respectively of 2, 4, 46, and 53 miles. Three very feeble local seisms indicated distances of 9 miles for two of them, and 23 miles for the other. Microseismic motion in the middle of the week increased from strong to very strong, and tilting of the ground was moderate ESE.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members two dollars per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

The Board of Directors includes Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 364—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | December 17, 1931

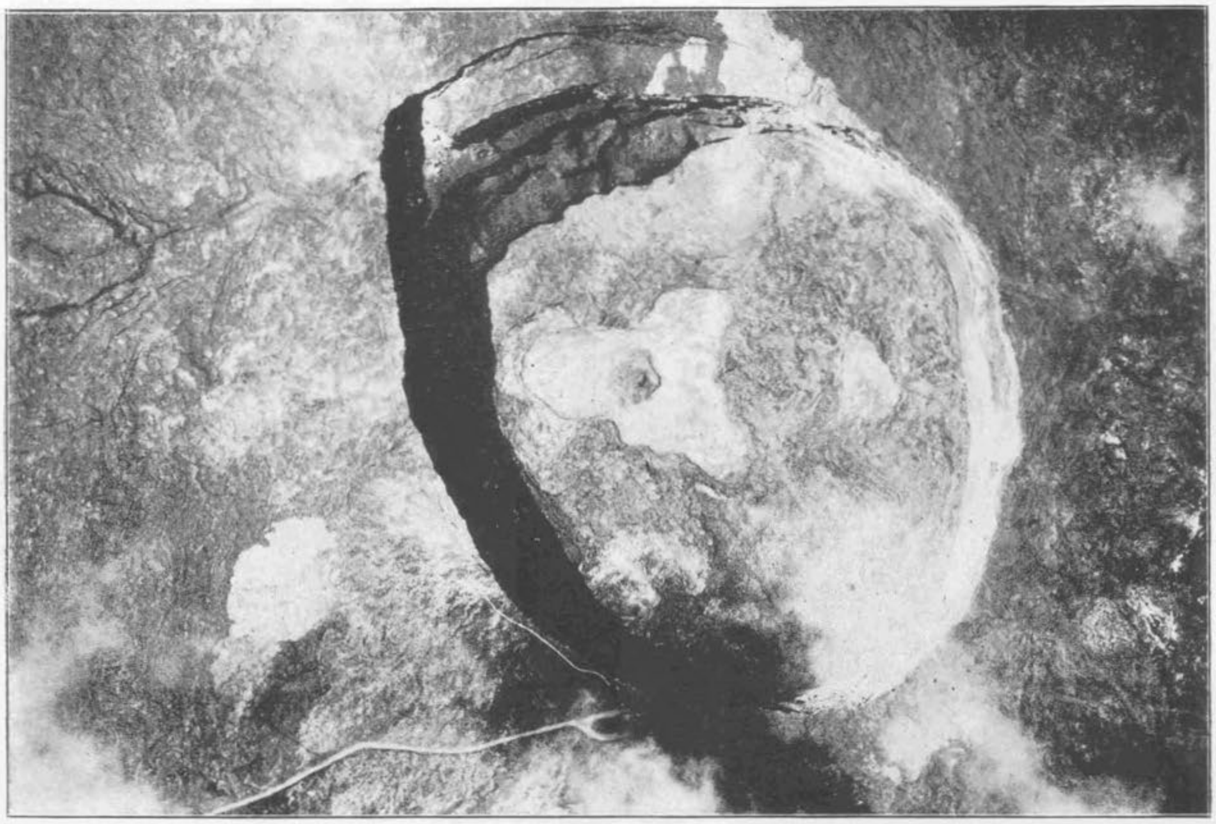
Kilauea Crater 1913 looking north. Showing detail of Halemaumau pit when 1,300 feet in diameter. The outer crack of the Postal Card Rift was the trace of the rim of 1894. There was a subsided shelf at the northeast, and huts were maintained at the north rim by the Hawaiian Volcano Research Association. Photo of Curtis model at Harvard University.

THE CRATER OF KILAUEA

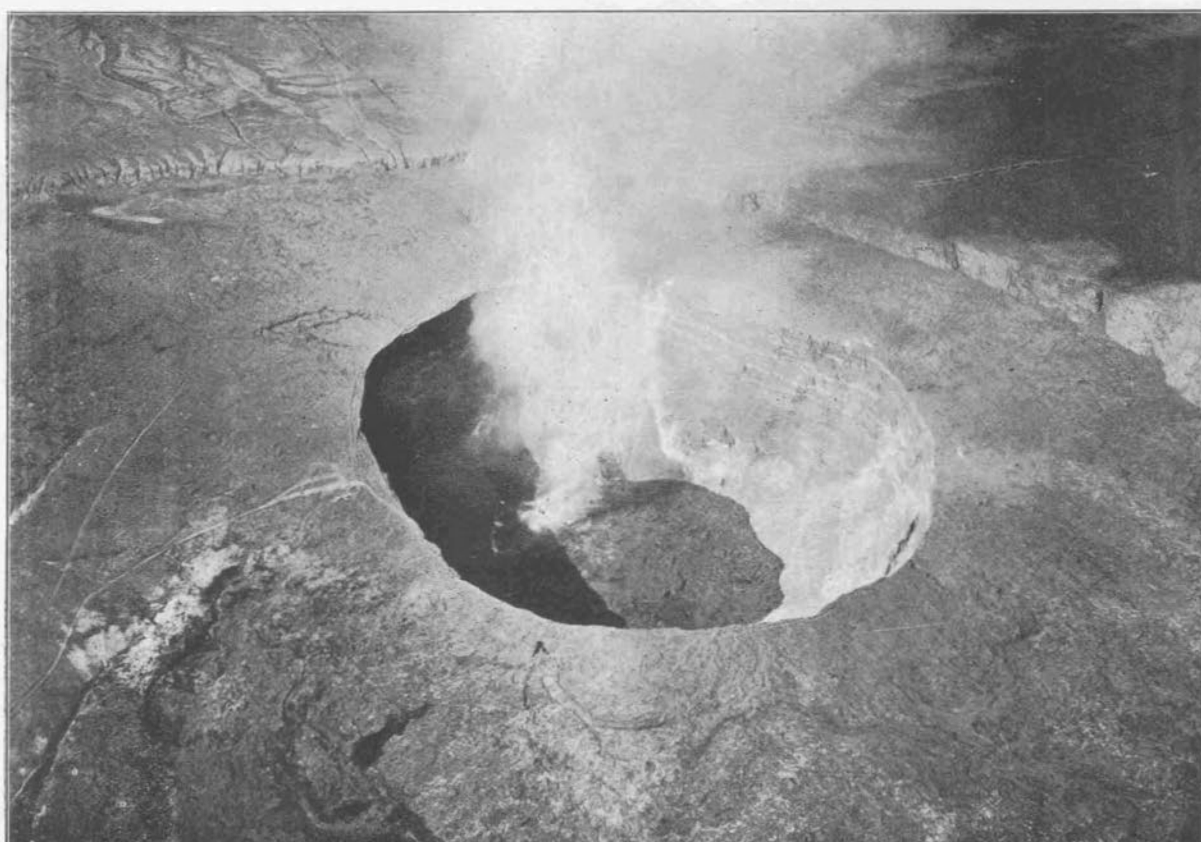
The illustrations of this number are arranged to show the evolution of Kilauea Crater from 1913 to the present time. The cycle 1913-1924 (see Volcano Letters 319, 320, 325, and 326) filled the inner pit, overflowed its rim to build up the floor of the outer crater, and then withdrew the lava, and the inner pit was enlarged by collapse. This 11-year cycle marked for the island of Hawaii the end of a volcanic supercycle of about 132 years, which reached its peak of lava flowing in 1858, and thereafter declined in pulsations of less outflow for both Mauna Loa and Kilauea

Referring to the recently published pictorial review of the evolution of the summit crater of Mauna Loa (Volcano Letter No. 360), it was shown that Mokuaweoweo is the product of merging pits at the angle where two rift lines meet. In like manner the accompanying map indicates that Kilauea Crater has been enlarging by the merging of pits at the angle where two rift lines meet. The rift lines are the southwest Kau Desert cracks that produced the Mauna Iki flows of 1920 far down the mountain flank, and the Chain of Craters fissure that produced flank activities in 1922, 1923, and 1924. The Kilauea angle is almost a right angle shown at the north corner of Kilauea Crater and at the fault cliffs farther north back from the crater's rim. In both Kilauea and Mauna Loa we have to deal with a sector of the mountain flank that has collapsed about its tip at the mountain summit.

The inner pit Halemaumau is the vent that happens to be open near the tip of the sector for the present epoch of activity. Within the last century both Keanakakoi and Kilauea Iki have taken part in this emission and withdrawal of lavas that we call "activity." There were great collapses of Halemaumau in 1840, 1868, and 1886, and in the early part of the 19th century the greater crater of Kilauea was all a large pit with its bottom more than a thousand feet below where it is now. As shown in the contour map, Halemaumau at the peak of the recent cycle was



Airplane photograph of Halemaumau pit November 9, 1923, taken vertically with the sun at the east. The earlier pit had been overflowed in 1919, its rim built up, and then had collapsed to a longer diameter of about 2,000 feet. This diameter is approximately coincident with the Kau Desert rift line trending southwest. Photo 11th Photo Section from elevation 4,000 feet. U. S. Army.



Present pit of Halemaumau 3,500 feet in longer diameter, photographed from the air, looking west, November 25, 1930, during the new activity of that period tending to fill the bottom of the pit. The road terminus is entirely new and 700 feet back of the former one. Compare oval cracked area outside of pit to the south with the same in cut above. Southwestern rim of Kilauea Crater and Kau Desert cracks are shown. Photo Air Corps, U. S. Army, 11th Photo Section.

at the top of a new heap built up since 1886, which had overflowed extensively in 1894, 1919, and 1921. The cut on Page One shows the large outer circle of cracks which had been the pit rim in the early nineties, but was built up by the action of a smaller inner pit in 1894, until the inner heap had overflowed the outer rim, and all that remained of this earlier wall was a scar. The tendency of a building period to make the pit smaller is what may be expected through the congealing of lava on the older walls of collapse. The same thing happened between 1913 and 1919, the rim shown in the first cut became more perfectly circular and smaller, as shown on the map on Page Four, and the lip of the cauldron was built up about 30 feet, so that the pit was replaced by a heap, with lava lakes on top.

It will be observed in Cut 1 that two crescent niches in the rim of Halemaumau northeast and west were filled up and disappeared during the overflows of 1918-21 (compare map Page Four). In the same way there had been extensive niches and outlying small pits extending the Halemaumau of the decades next preceding 1894. These niches are the sites of subordinate pits that are formed by the rise and fall of lava up and down cracks extending from, and close to, a larger pit. The development of an outlying vent which is at first a crack leads to a concentric structure about a vertical shaft, owing to the tendency of lava to freeze in the narrower portions of the crack, and to enlarge the vent circularly in the wider portions. The remarkably perfect circularity of the structure reaches its best development in an active lava slag-pool within a surrounding bench of its own semi-cooled substance, where by pulsations up and down, the central shaft is finally shaped like a paste-tube, and the convectional circulation builds the marginal rampart equally at all points about a center.

We now come to the phenomena of subsidence illustrated by the two airplane photographs on Page Two. It will be remembered that the culmination of constructional overflow was in 1919, and that from 1920 on, the bottom of Halemaumau subsided strongly, while the lava which it had contained flowed out repeatedly from the flank of Kilauea Mountain. Again and again the lava in the pit frothed up to the rim or nearly so, one such rise making the spasmodic and tumultuous overflow of 1921. The overflow or outflow was each time followed by bigger and bigger collapse at the pit. This collapse was dominantly guided by the deep rift in the mountain to the southwest, so that the resultant enlargement of Halemaumau was to an oval in plan extending the pit in that direction. This is illustrated by the first of the two photographs, taken November 9, 1923, and showing the results of the tremendous subsidence accompanied by avalanches which in May 13-27, 1922, enlarged the pit from a maximum diameter of 1,400 feet to 2,000 feet. The floor of Kilauea just outside of Halemaumau to the southwest had been heating, fuming, building cones, and flowing from cracks for four years. It was undermined by tunnels along the line of the Kau Desert rift, and the largest portion of these tunnels, close to the pit, caved in and engulfed a crescent of rim rock, as shown in the picture.

An object of great interest in this picture is the three-armed lake of lava, which was building up the inner floor in the autumn of 1923. An island stands at the meeting point of the three arms. This clover-leaf arrangement of the inner lakes had happened repeatedly during many years prior to this time. It appears to mark a tendency of the inner heap to fracture by tumescence into three sectors, and there is some reason to suspect that the larger domes of Kilauea and Mauna Loa have tendency to a similar breakage. Thus about the Mauna Loa center there are cracks to the northeast, the southwest, and towards Hualalai; about the Kilauea center there are cracks to the southwest, to the east, and towards Kulani north, (a cone in the forest between Kilauea and the northeast rift of Mauna Loa).

The second airplane photograph of Halemaumau, taken November 25, 1930, again during a period of activity of the bottom, exhibits the enormous pit left by the explosive engulfment of 1924. This is also an oval, its greatest length determined underground by the Kau Desert cracks, which appear in the background. It has now become 3,500 feet long, and a very striking feature of this picture is the tendency to concentric rim cracking, shown especially at the left by faint lines of black close to the rim of the pit, these cracks showing clearly the effort of nature to make a perfect circular funnel. This is the more remarkable as the rock which is so breaking is more than 700 feet back from the edge shown in the upper photograph. This enlargement will be realized if the reader will compare the irregular elliptical broken area of the outside lava surface at the south, which in the picture of 1923 lies away from the rim, and in that of 1930 is on the rim. The road terminus of 1930 is entirely different and far to the left of the road loop shown in the 1923 picture. This older loop would now lie far inside the pit, if it were redrawn on the photograph of 1930. The tendency to circularity by collapse, like the tendency to circularity by upbuilding, must be occasioned by a highly centralized shaft.

This picture of 1930 shows the inner dome of the Kilauea floor surrounding Halemaumau pit, and this dome expresses not only the overflows of the peak of the cycle, but also the tendency to swelling which had been characteristic of that time. This tendency to swelling is also a characteristic of the larger volcanic edifice, and its measurement with tilt instruments is one of the most fundamental scientific procedures for interpreting what is going on inside a volcanic mountain.

The history of pulsations of rising and falling lava, as creating a constructional smaller pit of effusion, and then a destructional larger funnel of subsidence, and this within a short cycle of 11 years, is indicative of the larger process that has made the greater craters through larger ages of activity. The crescent niches at the border of Halemaumau, in the pit of 1913 and the pit of 1923, are closely imitated in the lunate platforms of the Mauna Loa crater, and the two similar ones at the northeast (Sulphur Banks flat) and southwest ends of Kilauea Crater. To such extent as the Mauna Loa niches represent outlying lava pits, they are like Keanakakoi and Kilauea Iki outside of Kilauea at the east. There is a tendency for the walls of the Halemaumau funnel to assume at times a rounded pentagonal outline in plan; the same thing is true of the general plan of Kilauea Crater, and of the inner cauldron of Mokuaweoweo. All of these features are also characteristic of many of the craters on the moon, so that to a volcanologist there is no appeal in the impact theory of lunar craters. T.A.J.

TILTING OF THE GROUND FOR NOVEMBER

The following figures show the net amount of tilt by weeks at the Observatory on the northeast rim of Kilauea Crater and its direction, computed from the daily seismograms by platting a curve smoothed by overlapping seven-day averages. This is the departure of the plumbline in seconds of arc, in the direction given.

November 2-8	2.3 seconds	NE
November 9-15	0.7 second	ESE
November 16-22	1.2 seconds	ENE
November 23-29	1.0 second	SE

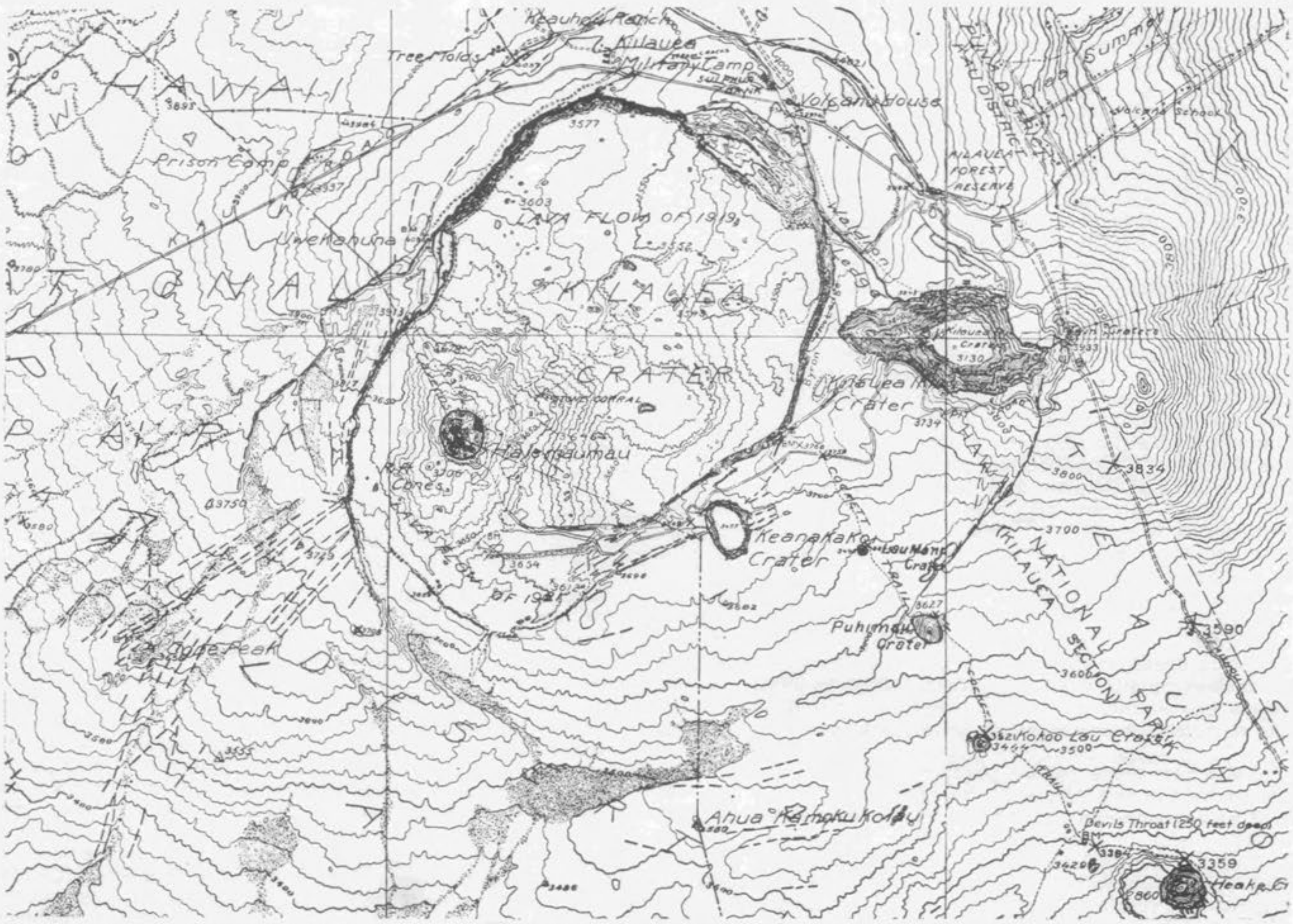
E.G.W.

KILAUEA REPORT No. 1038

WEEK ENDING DECEMBER 13, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On December 7 at 9:50 a. m. there were the usual steaming cracks about Halemaumau pit and on the Kilauea floor which are always seen during damp and cool weather. The fume at the principal sulphur patch on the bottom of the pit appeared denser and rising in puffs. The crack No. 25 at the northeast rim of the pit, which has recently widened, with subsidence of the block on the inner side of it, showed further widening as did other cracks. A small slide fell here at 10:06 a. m. At 3:30 p. m. this rim block fell completely and made an avalanche. A block of the rim fell in from 100 to 150 feet long and from 1 to 20 feet wide. New cracks appeared in the ash for 250 feet



Map of Kilauea Crater, U. S. Geological Survey, showing Halemaumau August 13, 1921, prior to the first collapse and enlargement shown in Cut 2, but after the overflows which had obliterated the conditions of Cut 1. The lava flow of 1919 had filled north corner of Kilauea Crater about 60 feet, and the lava flow of 1921 had filled the south corner and slightly overflowed through a gap as shown by dotted line. From the Postal Card Rift (Cut 1) had arisen flows to the north which created the Postal Caverns. The hot cracks had originally been used by tourists for browning postal cards.

to the north but not to the south. Several small slides were observed after 4 p. m. at the northeast wall, and fresh bowlders lay on the northeast talus. The perceptible earthquake of 10:20 a. m. December 8 dislodged three slides, respectively SW, SE, and NE of the pit, the last the largest. The quake was perceptible at the SE pit rim as a NW-SE swaying. On December 10 in calm weather the fume from the sulphur spot on the bottom of the pit rose in sufficient volume to be seen from a distance rising above rim of pit. This had diminished December 12. After the slides of December -8 the crack widening ceased and some cracks showed a slight closing.

The seismographs at the Observatory recorded 57 disturbances, including twice as many tremors and three times as many small earthquakes as occurred in previous weeks. There were 46 volcanic tremors, 9 very feeble shocks one of which was felt, 1 feeble shock at 12:30 p. m. December 13, and 1 moderate earthquake 10:22 a. m. December 8 that dismantled instruments. This indicated origin 14 miles from the Observatory and persons near Mauna Iki in the Kau Desert reported noise seemingly from Mauna Loa progressing underfoot, and rocks were heard falling down cracks. The tremors indicated origin distances of 6, 9, and 14 miles. the other earthquakes distances of from 9 to 23 miles. Microseismic motion for the week was moderate, and tilting of the ground was light NE.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 365—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | December 24, 1931

Mokuaweoweo Crater December 1, 1931, looking southwest from the rim salient between it and the northesat embayment. The smooth lava in the left foreground is the floor of the crater, described in the text, which broke out years ago simultaneously with one on the rim behind the camera. Photo Doerr.

SUMMIT OF MAUNA LOA 1931

Through the courtesy and cooperation of Superintendent Leavitt and Chief Ranger Christ of the Hawaii National Park, two members of the Volcano Observatory staff were enabled to make the ascent and spend two nights at the summit of Mauna Loa observing volcanic conditions and making preliminary geologic investigations. As no Observatory party has been to the summit crater since R. M. Wilson's trip in 1927, and as the close of one of Mauna Loa's four and one-half year cycles has passed (the last activity being in the spring of 1926), and renewed activity may be expected at any time, it was deemed advisable to make an inspection at the present time before the winter snows set in.

The party which left the Park headquarters at 6:10 a. m., November 30, 1931, was composed of Naturalist Doerr of the National Park, in charge, Powers and Wingate of the Observatory staff, and Rangers Brumaghim and Lee of the National Park. The party went by automobile as far as the Ohaikea tanks, where Levi, packer and guide, had the riding horses and pack animals ready for the trip. Chief Ranger Christ was on hand to superintend the start.

The path from Ohaikea leads across country for about a half mile where it joins the new Park trail, from Brown's ranch and the Bird Park, to the summit. The new trail as far as the Rest House at Puu Ulaula is an excellent one, crossing two tongues of the Keaumoku flow and continuing upward through lovely, grassy glades and groves of koa, mamane, and ohia. Ohelo, aalii, and pukeawe are shrubs which are found in abundance. The stone wall marking the upper boundary of the Kapapala grazing lands was passed at 9 a. m., and from that point the vegetation quickly thins out. At the Rest House, elevation 10,000 feet, which was reached at noon, only a little scattered grass and some stunted ohelo and pukeawe are to be found.

Rangers Brumaghim and Lee left the party at this point to make camp at the Rest House for several days while marking the upper part of the trail. The rest of the party, after a short rest for lunch, continued on to the summit which was reached at 5 p. m. Camp was made in the "Hotel de Jaggar," a partly collapsed lava tube on the northeast rim of Mokuaweoweo. The guide returned to the Rest House with the animals which he reached about 8:30 p. m., after a trying trip in the dark.

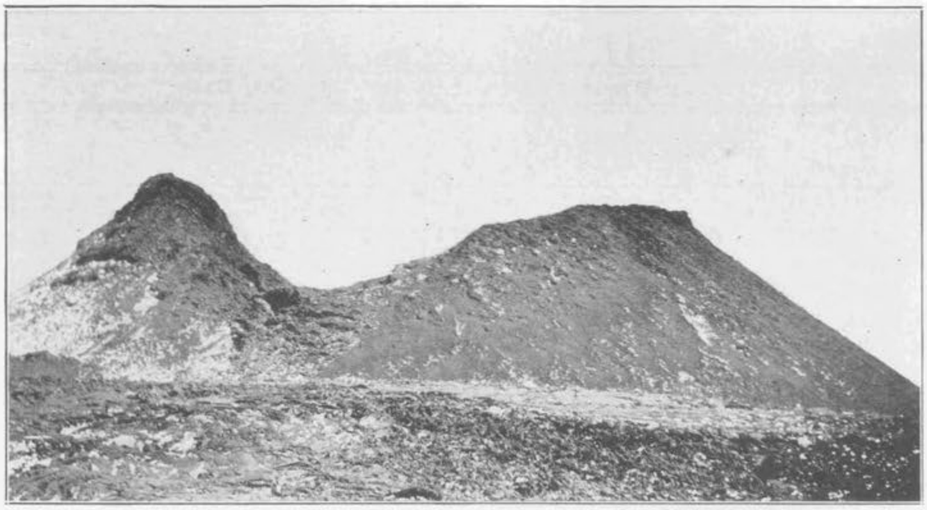
The "Hotel de Jaggar," which has been used for a camp by parties staying overnight at the crater, and by Wingate's topographic party in 1925, was found in rather shabby condition. No attempt at policing the camp apparently had been made for some time.

Due to lack of precipitation on the mountain in the last few years, cracks which held a quantity of ice in 1925 were nearly dried up and such moisture as remained was frozen solid to the bottom. An ample supply, however, was chipped out with a small pick and melted over the fire, for water for the party.

The topographic party in 1926 and 1925 used two small, one piece, kerosene stoves for cooking at the summit camp. On the present trip, charcoal was carried up for fuel and readily proved its superiority, being much easier to pack, and making a more even fire for cooking, as well as being cleaner and less offensive.

December 1 was given to an exploration of the east side of the north embayment, and along the east rim of Mokuaweoweo as far as Wilkes camp ruins, from which point the return to camp was made by following the outlying fault cracks which parallel the east rim of the crater. The party had intended to continue to the south end of the crater, and the head of the upper 1926 flow, but the sky, though clear until noon, had become overcast and threatening, and by 2:30 p. m. snow was falling. During the rest of the afternoon and the evening of December 1 about three-fourths of an inch of snow fell.

The observations made, from a volcanic standpoint, show some changes since 1926, but nothing significant was



Hanalei Peak December 1, 1931, one of the huge cones of frothy lava and slag built up along the northeast rift by the fountains at the source of one of the recent "rift flows." Photo Doerr.

noted. The principal change appeared to be the shifting of the main fuming area from the central part of the crater, in the vicinity of and to the west of the cones of 1903, to the area of the main cone of 1914 in the southwest part of the crater. This cone was steaming strongly and considerable fume was visible at the sunken area west and south of it, and along a few cracks to the east. On the northwest part of the sunken area west of the cone, new patches of sulphur have appeared which are brilliant yellow in color. Steam appeared over this entire area.

Some steam and a little fume were visible in the central part of the crater, which Mr. Doerr said was less than on his visit of November 10 of this year.

Steam along the northeast rift appeared in about the same places and amount as in 1926. Three spots on the floor of the northeast embayment were seen steaming in cloudy weather, and steam appears at one point on the south lunate platform.

As a base for reports by future visitors, a map was prepared showing the locations of the above points with the approximate strength of steam and fume recorded, based on the assumption that very voluminous fume might become visible from the Volcano House, 22 miles away, on a clear day. It is hoped that by this means some check may be kept on visitors' data at the summit crater.

A number of striking geological formations were hurriedly examined. The trail approaches the northeast end of the crater for the last quarter mile over a very shelly pahoehoe flow, which is mantled with khaki-colored pumice and lava froth. The pumice was formed by lava fountains in the northeast rift from which the lava was extruded. This surface flow was formed before the northeast embayment of the crater had reached its present size and shape. It is plainly seen that the walls of the crater are being extended by cracking and slumping of the lava at the edge, and the blocks of wall, which have dropped down most recently, are made up of the same pumice-covered pahoehoe which forms the rim. The floor of the northeast embayment is covered with younger lava which laps up on, and partly buries, some of the huge blocks which have fallen in from the wall. The southwest wall of the northeast embayment slopes rather gradually in its upper part, then is cut off sharply by a cliff down to the lava floor. A small gush of lava has broken out through the loose blocks of the sloping part of the wall and flowed down into the crater. However, this flow is cut off sharply at the cliff. Apparently this small side flow poured out at a time when the crater was filled with lava to the level of the top of the present cliff. Since then, the whole floor of the embayment has sunk many feet, leaving the small feeding flow suspended far above the present floor.

In the southeast side of the northeast embayment is a pit almost circular in shape, much like Halemaumau only a great deal smaller and a little over a hundred feet deep. This pit does not appear on a map of the crater made in 1872, but is shown on one drawn in 1885 (see discussion by T. A. Jaggar in Volcano Letter No. 360). On the east wall of this pit are several patches of cascade lava, remnants of a large lava fall which spilled over the east rim into the pit. This pahoehoe flow came from several large cracks in the outer rim of the main crater about a half mile to the south, and at 200 feet higher elevation. The lava poured out from the cracks, flowed north down the steep slope till it reached the northeast wall of the northeast embayment. Here it piled up high on the wall, then spilled over westward into the small pit. As the lava flowed into the pit, the level of the pond receded about 20 feet, leaving a "high lava mark" of crust and splash along the northeast bank. Part of this same flow tumbled westward over a 200-foot cliff into the main crater. At the same time that the flow was pouring out of cracks on the top of the rim, another flow with its fountains was pouring out from cracks in the sloping floor of the main crater 200 feet below and almost beneath the fountains of the rim flow. The lavas from the two vents, one 200 feet above the other, flowed together on the floor of the main crater. This same strange phenomenon took place in the 1851 eruption from the southwest side of the main crater, only here the difference in elevation, between the floor fountains and the rim fountains was over 300 feet.

While at the summit all of the party suffered from severe headaches and to a slight extent nausea, possibly in part due to charcoal fume.

The lowest temperature recorded on the trip was 22° F at 6 a. m. on December 2.

Very few goats were seen either on the ascent or descent. The descent was made without event, though rain fell over most of the region below the Kapapala stone wall. Park headquarters was reached at 6:30 p. m. December 2.

E.G.W. and H.A.P.

KILAUEA REPORT No. 1039

WEEK ENDING DECEMBER 20, 1931

Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

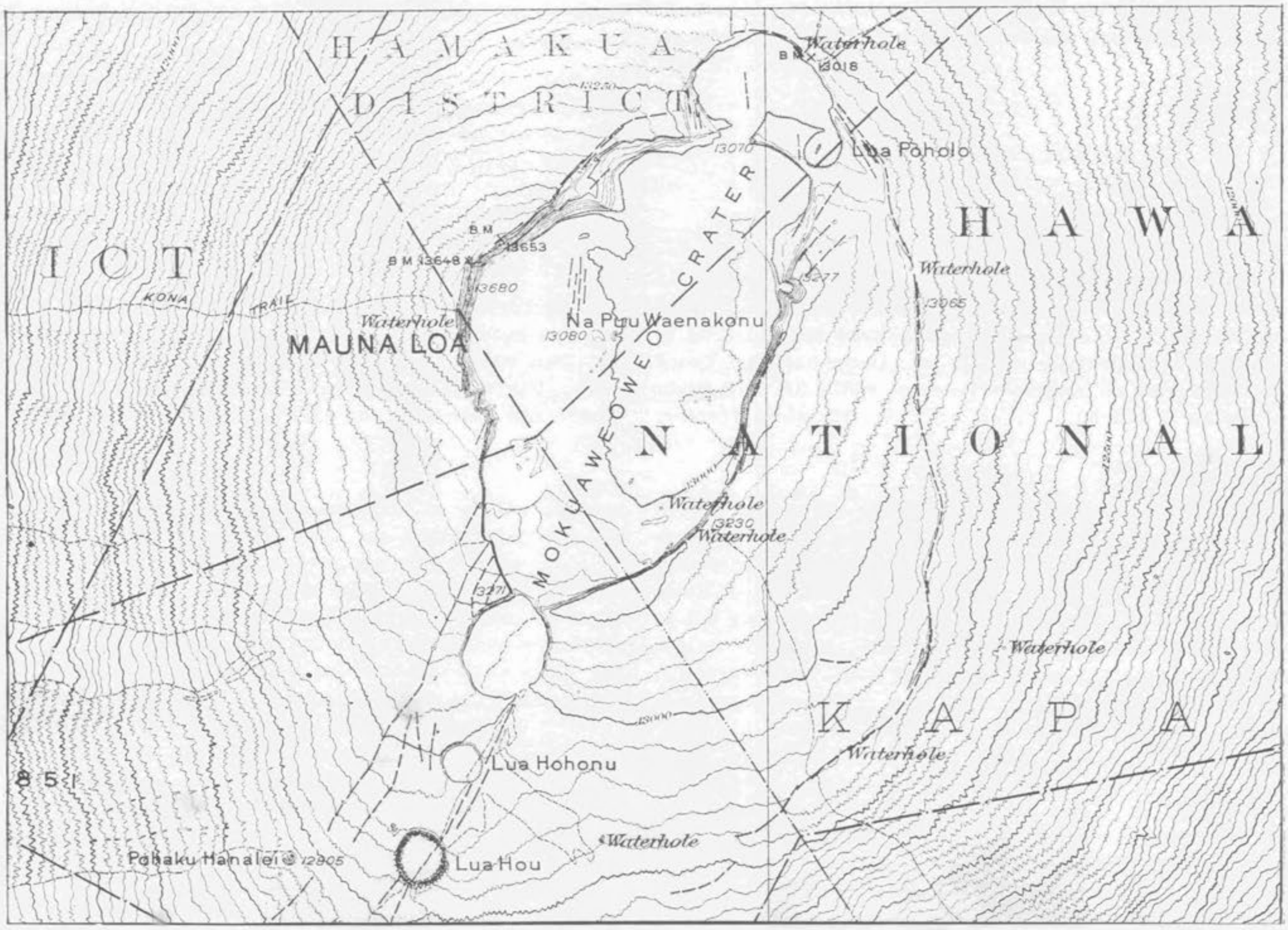
Halemaumau pit remains stationary and inactive and the increased seismic activity of the previous week proved temporary. At the pit a few rocks were heard falling at the northwest wall at 9:55 a. m. December 14. Crack measurements showed a decrease of width SE, and slight widening E and NE. Crack mark No. 25, which recently showed excessive widening, is now stationary. A noisy avalanche was heard at 4:10 a. m. December 16, and subsequent inspection of Halemaumau showed fresh debris on NE talus. There were other fresh scars on the walls NW, S, and SE. Crack measurements showed no change in the rim.

During this week the Park force has excavated a new seismograph cellar near Halemaumau and construction is in progress.

Thirty-four seismic disturbances were registered at the Observatory, of which 28 were tremors, and 6 were very feeble earthquakes, of which four indicated origin distances of 4. 9, 14, and 18 miles. The last at 10 minutes past midnight the morning of December 16 was felt at Kapapala Ranch. Its duration was approximately 15 seconds and its estimated origin distance agrees with the ranch distance within a mile.

Microseismic motion was heavy December 14-16, moderate to heavy December 17-19, and very heavy December 20. This was probably due to heavy seas on the Hamakua cliffs. Tilting of the ground was moderate ENE, with increase and change to the east beginning December 16.

Hotel de Jaggar, the collapsed lava tube which is used as a camp by parties staying at the summit. The "bedroom" extends back about 20 feet behind the men in the "kitchen." Photo Doerr, Dec. 1, 1931.



Map of Mokuaweoweo, the summit crater of Mauna Loa, by E. G. Wingate, surveyed in 1925-26, U. S. Geological Survey.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year **Ten cents per copy**

No. 366—Weekly Hawaiian Volcano Observatory, National Park, Hawaii December 31, 1931

The outporing of lava November 19, 1930, which prepared the floor for the eruption of December 23, 1931. The bright fountain at the left built a big cone, and the high half-dome against the talus at the back was the grotto of 1929. The new crack of 1931 extends straight across the middle of the floor between these two, and the new fill covers all of what is here shown by about 100 feet.

JOURNAL OF HALEMAUMAU ERUPTION DECEMBER 23 27, 1931

There is much about this eruption identical in character with those of 1927. 1929, and 1930, each of which tended to add 50 to 60 feet to the bottom of the pit after the lava had shrunk and solidified. and each tended to break out along a crack either diagonally across the former floor or tangentially along the former edge of the floor. The duration of these eruptions varied from a day to three weeks; it is quite in order for such an eruption to develop increased violence of fountaining even when it is dwindling, as the spurting fountains are indicative of clogging vents.

There has been a series of events pointing to the coming of this eruption. The interval average for seismic and volcanic crises in Hawaii during the last 20 years has been one year, and the average of outbreaks of Halemaumau since 1924 has been one a year. The last outbreak ended December 7, 1930. so that now an eruption was expectable. The tilt instrument near the southeast edge of Halemaumau has shown 50 seconds of tipping of the ground away from the center of the pit since the last eruption, suggesting upward pressure. The tilt instrument at the Observatory on the northeast rim of Kilauea Crater has shown tilt away from the crater center of 5.4 seconds to the northeast between November 30 and December 20, 1931, suggesting upward pressure in the mountain. Finally came the rim block avalanche on the northeast edge of Halemaumau December 7 and the excessive number of seismic disturbances for the week ending December 13, 1931, followed on December 23 by the smart local earthquake in the forenoon that left 15 scars of avalanches on the big west bluff of Kilauea Crater, and left the walls of Halemaumau pit continually sliding for hours. This was undoubtedly the actual rending asunder of the inner heap which constitutes the floor of Kilauea Crater.

December 23.

When the dust cleared after the earthquake of 10:38 a. m., Wingate saw that avalanches had fallen around the northern walls of the pit, scattering debris and dust on the 1930 floor. There were scars on the walls and in some places rim rock had fallen, while 15 whitish scars on the great west wall of the big crater marked places where avalanches had fallen. Before the earthquake the rim cracks measured had shown no opening and the sulphur patches on the 1930 floor shown no fume, this being attributed to dispersal by strong northeast wind. After the earthquake there was no visible increase in fume. Sixteen crack points on the edge of Halemaumau were measured and showed increases in width up to more than an inch in places. A large block on the east rim had moved as a whole, and fresh cracks in the dirt appeared along the north, east, and south rims. Small slides were continuous for hours. After 2:15 p. m. six large slides were counted in 20 minutes. About 2:40, when he was working at surveying stations back of the rim, Wingate heard a low, rumbling noise not like an avalanche. He ran to the edge, where heavy fume clouds had already reached the rim level and were spreading about the interior of the pit. The whole floor was rapidly cracking open along a straight line athwart the middle of the bottom beginning at the southwest under the rift tunnels. Lava fountains there started up and spread to the northeast along the crack. Voluminous fume followed immediately after the first cracking, and the molten lava appeared following the fume. The whole time consumed for the break was probably less than half a minute. It was just at this time, 2:36 to 2:39 p. m., that the seismographs at the Observatory showed sudden development of continuous harmonic tremor from slight to strong.

Wingate reported visibility bad, but the botttom crust appeared rather to be pulled apart than to be heaved up and broken. There was undoubtedly tumescence. He was in imminent danger of asphyxiation, but went to the Park phone and could get no answer. He returned to the rim for a few seconds and saw spatter from the fountains blown high over the rim wall. Some of this from later fountains has been collected, light brown basaltic pumice like the "thread-lace scoria" of the Kilauea Iki region, and like the first ejecta of the Mauna Loa cones. Hasty count showed him 17 large fountains with the two strongest at the northeast end of the crack across the bottom of the pit. Then he ran for his car, badly gassed, and succeeded in escaping to the Keanakakoi sandspit where the air was clear. The sun was obscured for a time, appearing as though viewed through smoked glasses, bluish over the pit against a dark background, and reddish brown in transmitted light where it blew away and was seen against the sky. This was the first time that a scientific observer here watched details of first outbreak inside the pit, and it will be remembered that it was Mr. Wingate's party, engaged in topographic surveys, that was camped nearest to the place of summit outbreak on Mauna Loa in 1926.

The outbreak at the Observatory was observed by the change from rising dust to rising fume, and by the sudden development of harmonic tremor at the instruments. Also there was sudden change at the time of the earthquake in tilting of the ground from northeast to south.

At 4 p. m. the volume of fume rising was greater than in any recent eruption since 1924, and the eddying tornado effects due to convection from the large number of fountains, including the four enormous dome fountains at the north end of the bottom crack, coupled with the high wind from northeast, submerged the road terminals under clouds of sulphur dioxide. The fume and grit were bad on the roadway from Uwekahuna to leeward of the pit. From the north lip of the pit about 30 fountains were counted making a great roar, in a nearly straight line, after darkness began to fall between 5 and 6 p. m., but the seeing was poor. There was already a great lake with bright lines between the skins, spreading out over the whole of the inner mound of 1930 lava. At 4 the glowing froth had been seen flowing away from the fountain line, at 5:30 it was already a flat lake covering the irregularities of the 1930 floor. Therefore the volume of inflow in the first three hours was enormous. The poisonous blue fume tended occasionally to spread in a low layer to the eastward, so that it was necessary to make a wide detour. A fortunate photograph at 7:30 p. m. by Higashida showed four large fountains at the corners of a square under the northeast sill, with a small fountain in the middle, and a grotto fountain against the bank, while the line of smaller fountains extended southwestward across the middle of the lake in the line of the two eastward big gushers of the square. The crack proved to be very slightly offset to the west from the rift tunnels in the southwest Halemaumau wall. The inward convectional draft was from the north and west, and the brown clouds boiled up and rolled off over the desert to the southwest and southeast. Spurts from the big fountains were probably several hundred feet high, but they could not be measured. Pellets of pumice and Pele's hair fell to leeward. The line of smaller fountains were partly merged, and partly isolated, and there were some outlying fountains, with concentric patterns of bright lines clear to the edges of the big lake. where there were outward-pushing toes and some minor grotto fountaining. The illumination at night was so brilliant that every detail of the ground could be seen by pedestrians.

December 24

At 2 a. m. the amplitude of the continuous tremor diminished to about half, and at 5 a. m. increased slightly, and thereafter continued. This was the index of the cessation of the big northeastern fountains. At 3 a. m. Powers reported the fountaining almost stopped except for a few bubbling spots along the rift line. The bright-line pattern of the lake surface extended to the edge of the new fill. The liquid lava had reached the rock cliff, covering the low talus NNW. Both 1929 and 1930 spatter cones appeared to be covered.

At 10 a. m. the botttom appeared to be a continuous leaf-shaped lake with nearly flat floor, the line of fountains making a short belt of big domes southwest of the center. This was extended by small bubble fountains in both directions, ending at the southwest in a small grottto fountain at the bank which was increasing in size. There were traces of crust islands at the southeast about where the 1930 cone had been. The shore line of the lake had made a nearly continuous rampart of congelation and piled crusts, interrupted at one place between the northwest and west taluses where the liquid lava appeared to be nearly against the rock wall. There was a cross line of small fountains, nearly straight and at right angles to the main fountaining line between the central group and the southwest grotto. There was another straight line of fountains parallel with the central line across the northwest part of the lake. The crust nortwestward from the central fountains showed a pattern like a flow or belt of streaming. Small islets were forming in front of the southwest grotto, and the central fountains showed signs of migrating southwestward during the day. There were concentric skins of pahoehoe pattern. The northwest edge showed some cliffs in the rampart facing inward. The southeast edge showed toes of flowing through the rampart. The brightness at night was moderate.

December 25

At noon the nature of the activity was in general as before, but the gas pressure at the fountains was increasing and there was apparent a change in the cross line of small fountains to become the arc of a circle concentric with the lake instead of a straight rectilinear belt. The southwest border fountain was building a higher grotto against the talus, bright lines were radial from this grotto, and there was a clifflet or infacing scarp along the northeast rampart. Rapid moving puffs of blue fume rose up the west wall from the fountains. The liquid lava about the central fountain belt made slow waves outward. The fountaining waxed and waned, some individual spurts going up 200 feet during a time of high pressure, and the noise was like surf on rocks. There was a fine-meshed pattern about the central fountains bounded by a U-shaped curve of contact to the southwest with a broad horseshoe of coarse-meshed bright lines extending from the southwest grotto as a center away to the east and west so as to envelop the central more liquid pool. It was evident that the northeastern region was cracking and solidifying so that the rampart belt was widening inward, and measurements later proved that the southwest was becoming a center of elevation with individual pools about the several fountains. and these tended to stream and make overflows northeastward, over something that was solidifying below. The lake was definitely against the WNW wall of the pit, without any rampart.

December 26

At 9 a. m. a new fountain had developed to the northeast of the elongated central belt, and the southwest grotto was now dominant with a large crescent niche behind it built against the talus. The lake edge was here irregular. At noon it was apparent that the northeastern fountain was sending streams radially outward to the northeast and that the central fountains occupied the most liquid portion of the floor with a fine greenish pattern to the skins. This area was a thick crescent with two horns northward. The big strong fountains of the southwest grotto had built up a high canopy of spatter on the bank, a crescent wall with overhang which broke down from time to time and immediately built up again. A coarse bright-line pattern extended out to the north and east from this grotto with a surface in daylight like black satin. The central fountains were smaller and more separated. There were fresh overflows between the rampart and the talus at the east.

December 27

Measurements by the Observatory engineer on this day showed that lava covered the top of the 1930 cone to a depth of 50 feet, and the depths of the new covering on the irregular relief of the 1930 mound were as follows:

West Bay, 85 feet
North Bay, 96 feet
Northeast Bay, 98 feet
Southwest Bay, 115 feet

As there are shallower places over the big 1930 cone, the average depth of the new fill was about 90 feet, its size 2600 feet long northeast-southwest and 1950 feet wide, covering an area of about 80 acres. Its volume is estimated at 260 million cubic feet, which would amount to some 20 million tons. If this had been distributed over the interval from the beginning it would mean about 45,000 cubic feet per minute from all the vents. The height of lava lake above sea level at southwest grotto was 2773 feet, making the depth of the pit from the southeast rim 971 feet.

At 10 a. m. December 27 fountaining was more violent and the lava from the central group of fountains had encroached on the southwestern crusted belt and on the northeast fountain pool. The later was fountaining steadily but with decreased strength.

At 3 p. m. the northeast margin of the floor for perhaps one-eighth of the area had become bench lava. Marginal overflowing was active SE and N. The southwest horseshoe lake was feeding flows at the edges, and the middle lake was spilling over a bench magma slope at the northeast. At 5:30 p. m. the northeast fountain was making only a sluggish gushing, but the southwest grotto had become a very powerful continuous fountain with a high grotto behind it, and this was beginning to develop the true Mauna Loa type of spraying jet. Detonations now accompanied some of the viscous bursts of the central area.

At 11 p. m. the southwest fountain was sometimes 400 feet high, overflow continued southeast, the lake was shrinking, and gas bubbles burst with loud reports. T.A.J.

KILAUEA REPORT No. 1040

WEEK ENDING DECEMBER 27, 1931

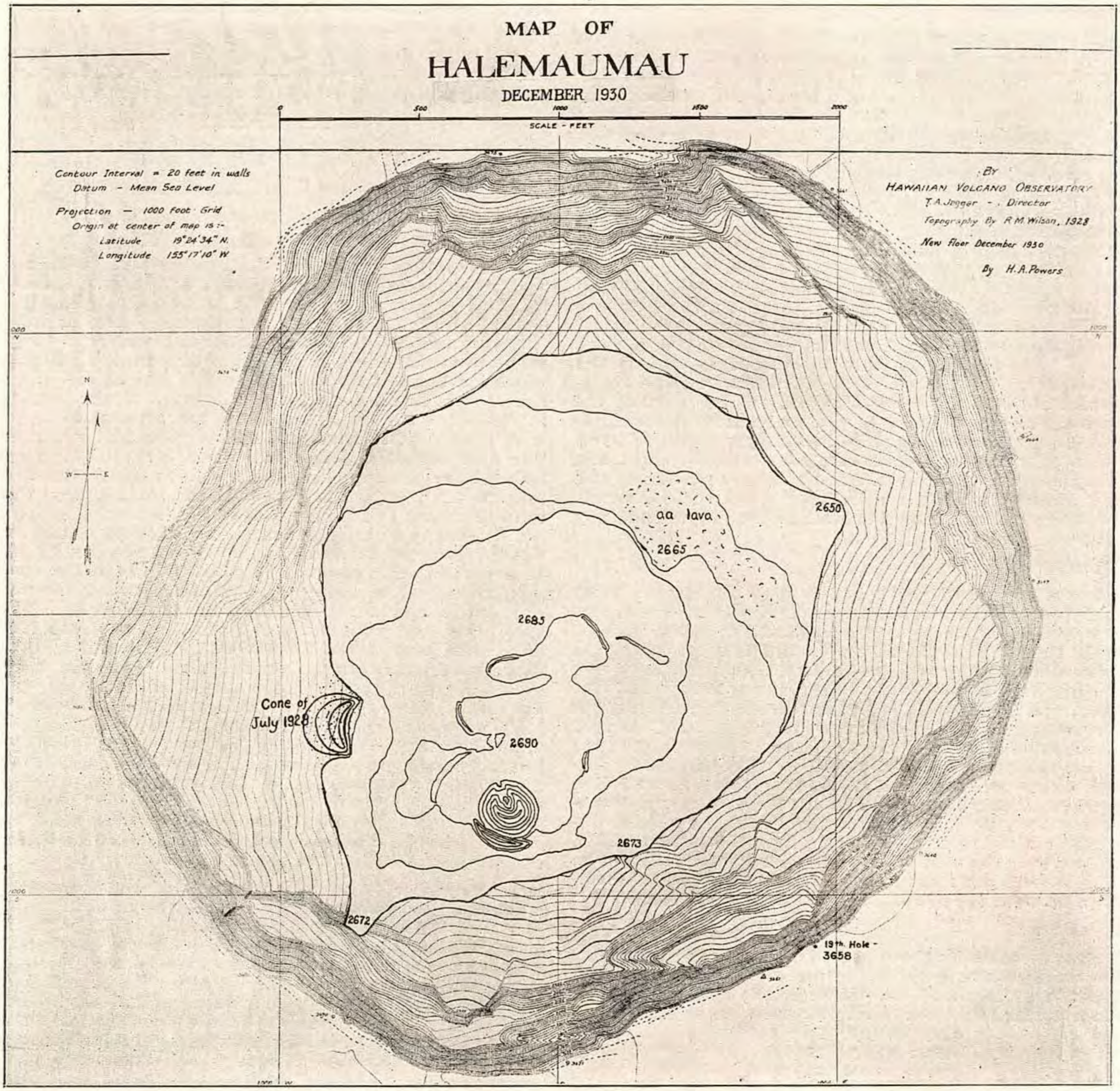
Section of Volcanology, U S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The past week has produced a new outbreak of lava in the bottom of Halemaumau pit about 2:36 p. m. December 23. This was preceded at 10:38 a. m. by a strongish earthquake highly localized and not generally felt at other points on the island. Mr. E. G. Wingate was close to the pit when the outbreak occurred, and heard a low rumbling which led him to look over the edge, where he saw heavy fume clouds filling the interior, and lava fountains starting at the foot of the southwest talus. The floor cracked open from southwest to northeast in less than half a minute. The floor broken appeared to be pulled apart with some tumescence. Spatter from the fountains was blown high over the rim wall, and 17 large fountains were counted with the two largest at the northeast end of the crack. Then a gale of dust, sand, and fume overran the tourist station and it was necessary to retreat to avoid asphyxiation by sulphur dioxide. The sun was obscured by a brownish cloud seen to be blue in reflected light. Lava during the next 11 hours foamed into the pit in enormous volume estimated 6500 cubic feet per second, and the density of the fume cloud was very great for Kilauea. The two or three enormous fountains at the northeast end of the line inside the pit ceased action about 2 a. m. December 24, the fume diminished, and normal conditions were restored whereby the southeast road terminal became accessible. The fountaining continued in a belt of big central gushers and a grotto fountain at the talus at the southwest end of the line. Before the cessation of the big fountains, the brilliancy of the pit at night exceeded anything seen thereafter, and about 30 fountaining points were counted along the straight line of vents that crossed the middle of the bottom of the pit in the direction of the Kau Desert rift.

On December 24 there was a line of small fountains straight across the south end of the lake at right angles to the main rift, and another line parallel to the main rift across the northwest part of the lake. Islets of crust appeared about where the 1930 cone had been. On December 25 a more liquid pool was defined about the central fountain, there had now developed a rampart all about the lake, and the southwest fountain was building a grotto. There were brilliant radial and concentric patterns about the main fountains, and the gas pressure was increasing so as to fling up individual spurts 200 feet into the air. December 27 there were three principal fountaining areas with streaming northeastward in concentric horseshoes. The gas pressure was still stronger and tending to concentrate southwest in spraying jets sometimes 300 feet high, building a huge spatter niche, while the central fountains made detonating puffs of blue fume. Measurements showed the average fill to be 90 feet deep above the 1930 floor and about 260 million cubic feet of new lava had poured in.

Prior to the eruption there were 11 tremors and 7 very feeble earthquakes recorded. Four indicated origin distance four miles. The earthquake of 10:38 a. m. December 23 was strong enough to overturn some objects, especially on Uwekahuna Bluff, and would rank as grade IV R. F. Two very feeble shocks occurred after the eruption. Traces of continuous volcanic tremor appeared after the 10:38 a. m. earthquake, became quite continuous at 2:36 p. m. December 23, reached a maximum at 2:39 p. m., and continued so until 2 a. m. December 24, when the big fountains stopped, and the continuous tremor diminished in amplitude. December 24 at 5 a. m. this tremor increased slightly and has continued ever since. Microseismic motion has been moderate to heavy, and tilt changed suddenly at the time of the strongish earthquake from moderate ENE to strong S. The pit seismograph has for months been indicating tilt away from the center.



Map of the lava floor of December 1930 with 10-foot contours for the bottom area, showing the big 1930 cone and solidified lake at the south, from which the rest of the bottom sloped away as a mound. The cone of July 1929 is shown at the left. All of this is now buried by the new eruption, and the grotto center of 1931 is just south of the 1929 cone.

THE VOLCANO LETTER

The Volcano Letter combines the earlier weekly of that name, with the former monthly Bulletin of the Hawaiian Volcano Observatory. It is published weekly, on Thursdays, by the Hawaiian Volcano Research Association, on behalf of the section of volcanology, U. S. Geological Survey. It promotes experimental recording of earth processes.

Readers are requested to send articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations, especially around the Pacific.

Subcription for non-members **two dollars** per year of 52 numbers. Address the Observatory.

HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

This laboratory at Kilauea Volcano belongs to the Hawaiian Volcano Research Association and is leased and operated by the United States Geological Survey.

It maintains seismographs at three places near Kilauea Volcano, also at Hilo, and at Kealakekua in Kona District. It keeps a journal of Hawaiian volcanic activity and publishes occasional Bulletins.

Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains volcano stations in Alaska, California and Hawaii.

Persons desiring application blanks for membership ($5.00 or more) should address the Secretary, Hawaiian Volcano Research Association, 320 James Campbell Building, Honolulu, T. H.