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

Please send publications and news notes about volcanic matters
Address: HAWAIIAN VOLCANO OBSERVATORY, HAWAII NATIONAL PARK, T. H.

THE VOLCANO LETTER

A Weekly news leaflet of the Hawaiian Volcano Research Association

Sent free to libraries and to members. Dues of Association $5 per annum. Members receive in addition the illustrated Monthly Bulletin of the Hawaiian Volcano Observatory. Anyone may join the Association and thereby support Pacific volcano research. The Society has also patrons—individuals, firms and institutions.

No. 262 RELEASED WITHOUT COPYRIGHT RESTRICTION January 2, 1930

KILAUEA REPORT No. 936

WEEK ENDING JANUARY 1, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

There has been no visible change in volcanic conditions at Kilauea during the past week. Halemaumau pit remains quiet. No new scars are to be seen on the walls and no new slides have been reported.

On December 30 an observer noted that a section of the center of the July grotto had fallen. Steam was noticeably absent at the vents within the pit on this day and on January 1, although rainy weather has been prevalent during the week.

Nine seismic disturbances were recorded by the seismographs. Of these five shocks, of very feeble intensity, gave an average distance to origin of 44 miles. One feeble earthquake, at 11:52 p. m. December 29, indicated an origin 9 miles from the observatory.

Microseimic motion was slight. Tilt accumulated moderately strong ENE.

ACTIVITY OF PELEE, MARTINIQUE

Little has been heard from Martinique since the terrible destruction of St. Pierre in 1902 by volcanic blast from Pelée. This volcano is in the middle of the Caribbee Islands, which extend in a curve from Porto Rico to Trinidad.

September 16, 1929, ash eruptions began again from the crater of Mount Pelée. At 8:45 p. m. September 26 an earthquake lasted a minute and a half at Fort de France. October 14 Pelée burst into eruption more strongly than in September. This calmed down on the 18th, but October 19 the director of the volcano observatory reported for the early morning of that day an outbreak stronger than the two preceding. Gas and ashes were thrown up, and the flashes of light lasted for 10 minutes. Intermittent rumblings and bursts of white steam accompanied the eruption, the dust column rose nearly 4,000 feet, and cinders were showered over the country. The activity occurred at the head of the valley of the Riviere Blanche, just as in 1902, beside the ruins of the famous lava spine which rose in that year.

The complete evacuation of Prêcheur, Saint-Pierre, and Morne-Rouge has been ordered by the authorities. It appears that Saint-Pierre had risen from its ashes by 1923, and possessed 1,000 inhabitants, more than 100 houses, a club, shops, a restaurant, a market, and a custom house. There is a daily steamer from Fort de France, and the town has running water, a sewage system, and is presided over by a mayor. The 1929 activity appeared to have been kindled at about the September equinox, just as was the seismic shaking in Hawaii, but like the latter, it dwindled. New activity is reported in December. (Seismological Despatches, Georgetown University; London Times, Oct. 21; New York Times, Sept. 21 and Oct. 20, Nov. 4.)

T. A. J.

REVIVAL OF SANTA-MARIA, GUATEMALA

It will be remembered that the Pelée eruptions of May, 1902, were followed in October of that year by disastrous ash falls and floods from Santa-Maria volcano in Guatemala. In like manner the Pelée outbreak in September, 1929, is followed by a disastrous explosive eruption at Santa-Maria. This volcano is 12,361 feet high.

The volcano dominates the coffee lands of western Guatemala. Between 1922 and 1925 (Volcano Letter No. 87, Aug. 26, 1926) new stiff lava rose in the vast crater which the 1902 eruption had left in the flank of the mountain. The new plug replaced the crater with a lava hill 1,600 feet high and 4,000 feet across. Its top was a cluster of smoking turrets.

We now have despatches of November 5 and 8 which are difficult to interpret because of the newspaper habit of calling everything "lava" that pours from a volcano (Chicago Tribune, Paris, Nov. 5, and New York Times, Nov. 8). The "lava" is presumably glowing ash and mud floods.

On November 4, 1929, after three days of increasing rumblings, hot ash was vomited up about the new plug, probably cauliflower clouds of ash and steam shot thousands of feet into the air, incandescent blasts of falling material were impelled downward, and torrents of rainfall mixed with the hot ash to swell all the streams. Probably there was engulfment of the lava plug and widening of the crater. Heavy showers of ash were still falling November 7. There were destroyed villages, coffee plantations, and farms. El Palmar suffered the most, 21 bodies being recovered there. El Palmar is six miles south of the crater.

In the zone between Mazatenango, 15 miles to the south, and the crater cavity half-way up the mountain, the country is completely covered with ashes, and the air smells of sulphur. The buildings of El Palmar and the farmhouses thereabout still stand. On November 7 there were people still to be seen in the streets. Forty-five deaths are reported as the total, and loss of farm property in the coffee district to the value of one million dollars. Eight coffee plantations were destroyed, and the losses of life appear to be due to suffocation with hot ash, to burns, and to bombardment from falling stones, just as in 1902. Some bodies were found of persons who had climbed trees. The green foliage was burned to a dirty brown.

T. A. J.

The Volcano Letter

Hawaiian Volcano Observatory, National Park, Hawaii

TITLE PAGE AND INDEX FOR 1930

(Nos. 263-313)

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.

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The Volcano Letter

No. 263—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | January 9, 1930

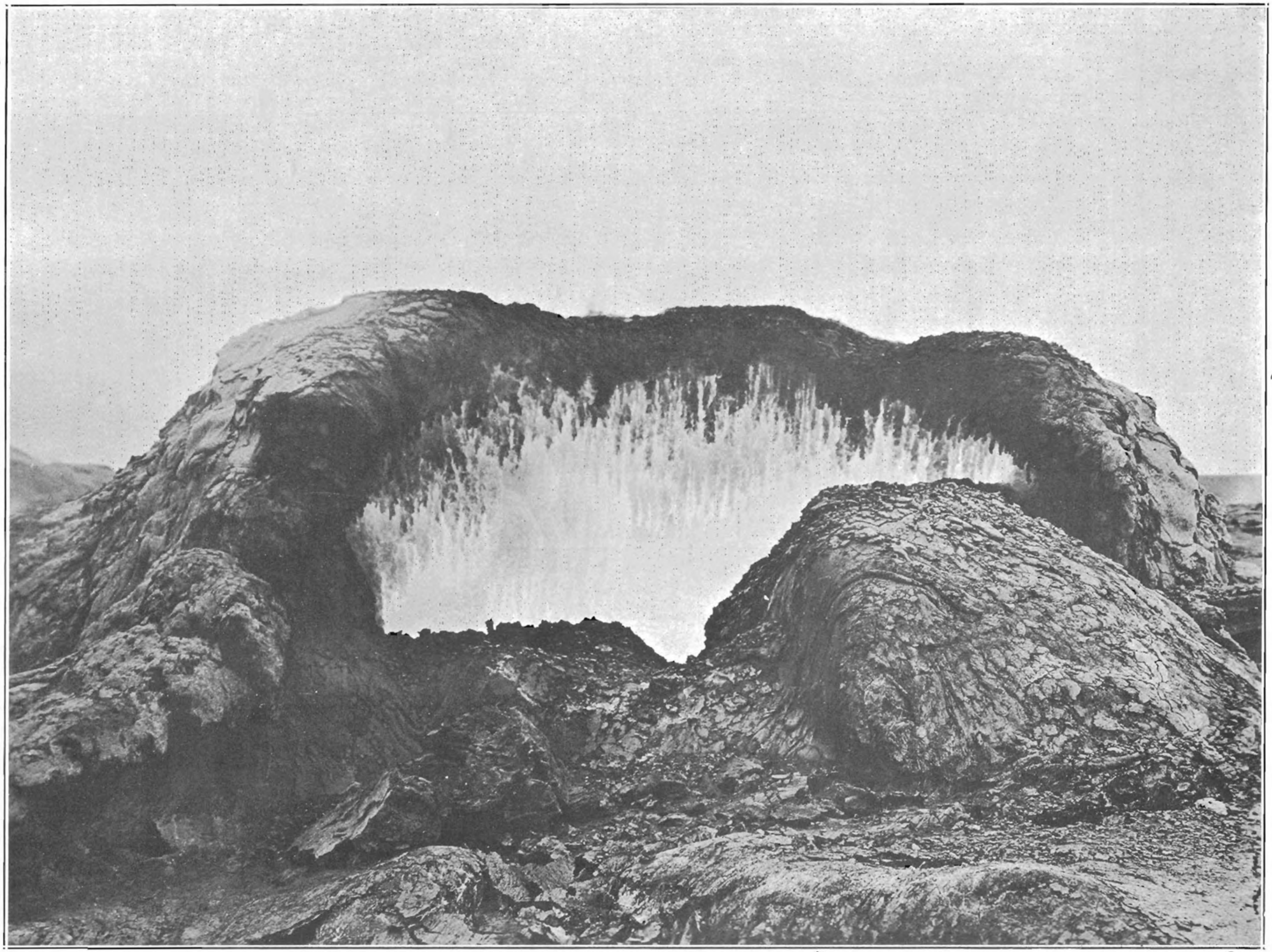
Looking into red hot tunnel hung with stalactites at orifice of eastern breathing cone, February 13, 1919, 11 a. m. This is inside Halemaumau pit on the inner floor when the lava lakes were level with rim of pit. The glowing tunnel connects through to the largest lake, and lava was splashing inside the tunnel. —Photo Jaggar.

BREATHING CONES

The extraordinary lava activity of the year 1919 at Halemaumau, the fire pit of Kilauea, marked the peak of the eleven-year cycle. To a tourist who sees the vast cauldron of today, a thousand feet deep and three thousand feet across, it is hard to realize that glowing molten slag was overflowing the edge of the pit a decade ago. The pit had its definite margin of cold rock, but within that margin and overlapping it there were lava lakes, pots, driblet spires, flow heaps, tunnels, stalactite grottoes, smoke holes, and breathing cones.

The East Cone of the spring of 1919 was a low hillock built up around a lava pot on the inner floor of Halemaumau. Visitors habitually walked over this floor, which extended from the lakes inside the pit area to merge with the overflows outside. This pot was supplied with glowing, gassy melt through a tunnel leading from the main lake. With the rise and fall of the liquid lava a cone was built around the pot, and the interior ceiling of the tunnel became hung with huge gas-glazed stalactites three or four feet long.

One could stand on the rim of this conelet, and gaze into the open pot where lava of bright yellow glow was splashing 15 feet below. Under the lip of the orifice the interior chamber was bright orange with incandescence, hung with the delicately sculptured fiery stalactites



Rift Oven of the Red Solfatara. This photograph was taken by evening light April 4, 1921, with panchromatic plate and deep red filter. The glowing oven, 9 feet high and 20 feet across, stood over the rift about 500 feet outside Halemaumau and remained like this throughout the spring. Photo Jaggar shaped like long bunches of grapes. By night a banner was visible of blue-green flame fluttering above the orifice sending off pale blue transparent fumes acrid with sulphur.

As a whole during this period the lakes were rising, the inner floor was being overflowed in spasms, and the heaps, cones, and spiracles were building up. The East Cone hissed and breathed and roared at different times. Sometimes it would vomit up its molten stuff like an artesian well, and give vent to a glowing flow. At such times the pot and tunnel were obliterated, only to reappear with the stalactites reforming when the outflow ceased.

The grape-like droplets, and the gray, yellow, red, or brown glazes on the surface of these stalactites are not the result of direct spatter. There are other stalactites in curtains and frozen drip points which are formed by direct splash. The grape bunches, however, and the long worm-like stalactites are formed by the remelting of the roof of the cavern by slow action of the intensely hot burning gases. This burning is converted into a blow-torch effect when air has access to the tunnel so as to convert the combustible gases from the boiling lava into oxidation flames. When air reaches the volcanic gas pipe suddenly, the change in the iron oxides of the glaze may be equally sudden, and a whole cavern may be caused to glow by the access of air alone.

The illustration on the first page shows the East Cone here described at a time when the liquid lava was about 15 feet down. The second illustration shows a similar cone that developed over a crack about 500 feet away from Halemaumau in the direction of the desert to the southwest in the spring of 1921. This cone it was that displayed several times an extraordinary revival of glowing through access of air below while its walls were still hot.

This second cone was called the Rift Oven of the Red Solfatara. It was over the great deep crack that leads from Halemaumau radially down the mountain to the southwest. The two long, black gashes standing vertical in the present wall of Halemaumau as seen by tourists to the left of the visitors' station are where this rift emerges into the pit. It can be readily understood that if lava now rose into those tunnels by the filling up of the pit, and a vertical shaft outside of the pit led from the uppermost tunnel to a cone on the surface, that the gases from the boiling lava in the shaft would heat the cone. This was exactly the situation of 1921. The cone breathed and puffed, lava was visible far down the shaft, pale flame played around the orifice, and sulphurous gas was given off.

There was direct connection between the lava in this well and the lava lakes in the pit, but often the lava in the well by reason of gas frothing would stand much higher than the same liquid in the open pit. The gases kept the well at bright orange glow and maintained the stalactites, even when the heat from the open lakes and the glow above the pit decreased strongly. With the liquid lava 200 feet down the well in April, 1921, the glow was maintained up to the top, in a shaft 10 to 15 feet in diameter, by the action of burning gases. Finally there came a time, however, when the interior of the oven became dark red and even black and the stalactites were seen to be a silvery gray with the black oxide of iron. The hot gases continued to rise.

Now came the extraordinary and dramatic demonstration of what air could do in heating up a volcanic furnace. All this time the lava lakes in Halemaumau had been above the level of the wall tunnel. In July the lava lakes lowered below the tunnel so that a black cavern or arcade could be seen, just as at present, leading into the wall at the southwest. Immediately an air blast, smelling strongly of sulphuric acid came rushing with a roar up the outside well, where quiet gas had been rising before. The shaft, oven, stalactites, and the entire lining of an adjoining tunnel all began to glow again, the tunnel walls becoming red hot away out to its remoter entrance 150 feet away from the rift. Incandescent sparks were visible after nightfall in the blast. Then the furnace cooled off again and within four days the wells and the tunnel were dark, but the steel-gray glaze of magnetic needles of iron oxide, the common lining of such caves, had changed to brick red

T. A. J.

KILAUEA REPORT No. 937

WEEK ENDING JANUARY 5, 1930

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

The current report on volcanic conditions in Hawaii overlaps the preceding one by two days, as it introduces a new series of weekly reports ending at midnight Sundays. This is for convenience in the new series of the Volcano Letter, beginning 1930, prepared at the station on Mondays instead of Wednesdays.

For the week ending January 5, 1930, there is little change in Halemaumau pit. On December 30 part of the July fountain heap had slightly fallen in the middle. There is remarkably little steam emerging from the floor and talus slopes, in spite of recent rains. This is in contrast to the rim cracks outside of the pit, which on January 1 at 2 p. m. sent up much vapor. Much fine material was observed lying thickly on the talus at the north. January 3 much steam arose from the pit, in general blending with the clouds above, and from the cracks of the Kilauea floor. At 9:30 a. m. January 4 there was more vapor at the Halemaumau vents, particularly on the south wall.

Eight very feeble local earthquakes were recorded by the Observatory seismagraphs, and five of these indicated average distance of 44 miles, corresponding as heretofore since September to the distance of Hualalai from the station. One very feeble shock indicated distance of origin 19 miles.

Microseismic motion for the week was slight, and tilt accumulated strongly to the southwest. This tilt is characteristic of the seasonal curves for January.

HAWAIIAN VOLCANOES IN 1929

The end of 1929 finds the Hawaiian volcanoes quiet, but the year has produced three notable activities, two of them volcanic eruptions and one a seismic spasm of extraordinary quality. The first was the influx of new lava in the bottom of Halemaumau in February, following upon similar fillings of the bottom in July 1924 and 1927, and in January 1928. The second 1929 event was a similar influx in July and each of these eruptions of lava leaves a new floor higher than before so that the pit has decreased some 300 feet in depth since June of 1924.

A curve platted to follow the progress of these fillings of Halemaumau in relation to the lapse of time indicates decrease of interval between eruptions, so that the expectation was recorded that lava activity might return in the autumn of 1929 unless the magma were to rise in one of the other volcanoes. There are three of these which are potentially active, Mauna Loa, Hualalai, and Haleakala.

The seismic spasm which began in September and has continued, dwindling, ever since, appeared to confirm this expectation. The evidence of locality points to Hualalai. The shaking was violent in North Kona, reached its maximum October 5, and now has become very slight, but still shows signs of life. The indication is that the underground lava column at the Mauna Loa center, which for many years has vented itself to the southwest, is now pressing up along rifts extending toward the northwest and may eventually find release there.

Meanwhile nothing new has happened in the craters of Kilauea and Mauna Loa. The July lava in Halemaumau pit at Kilauea Volcano solidified with some shrinkage, leaving the scar of its big southwestern fountains in a built-up heap surrounded by pumice and shaped like an armchair, and leaving what was the lake area a lumpy floor surrounded by a rampart. The only changes have been falls of rock from the walls of the pit slightly overlapping the new lava floor with their debris.

Seismic phenomena local to Kilauea have not been remarkable during the last part of the year, and there is nothing in tilt, tremor, or earthquakes indicative of a change of magmatic action under Kilauea Volcano. The avalanching at Halemaumau in December has been remarkably slight.

T. A. J.

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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.

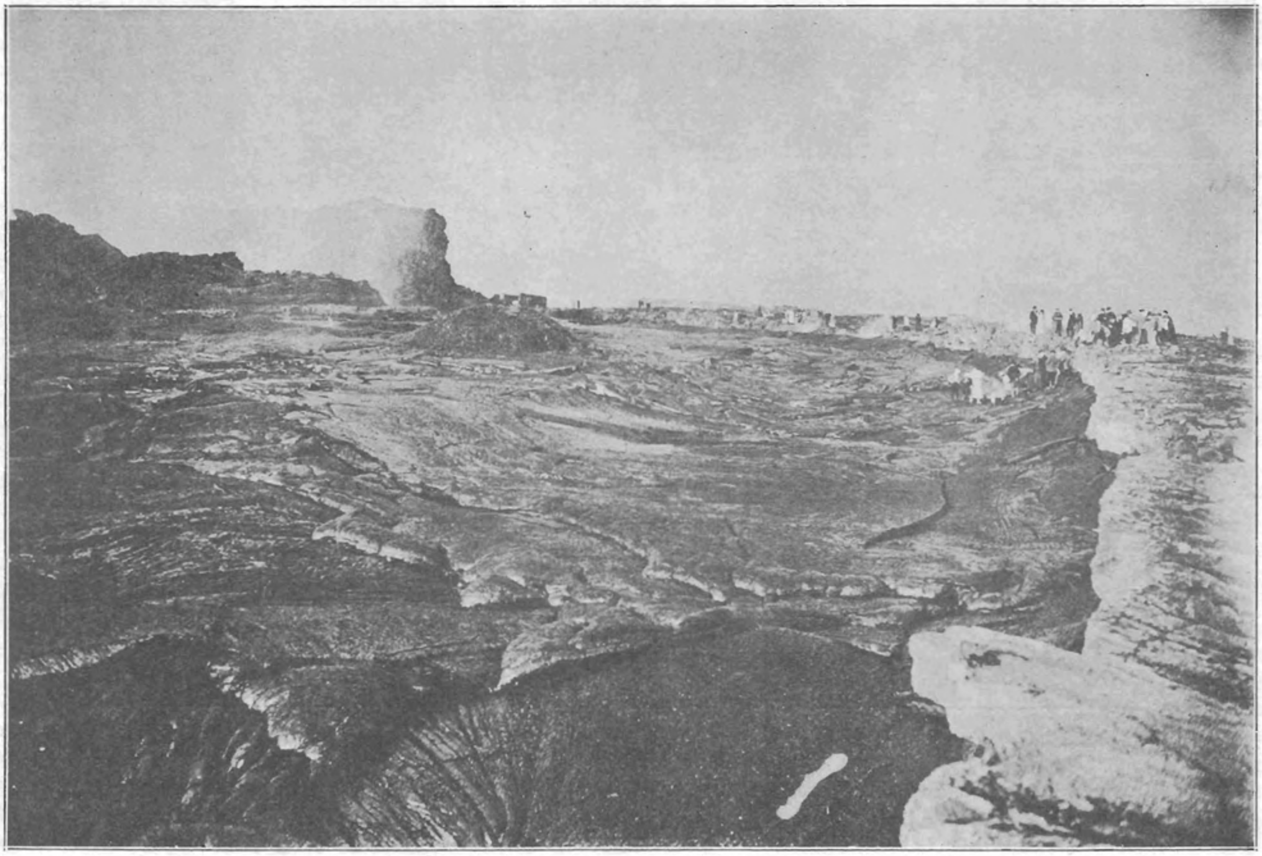
Membership in the Hawaiian Volcano Research Association is limited to patrons of Pacific science who desire personally to aid in supporting the work.

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

No. 264—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | January 16, 1930



The southeastern rim of Halemaumau on February 22, 1918, the day before the pit overflowed the road terminus. The light ground at the right is the rim, the dark foreground is the overflow lava of the fountaining lakes, which are among the crags at the left. The rim rock shows no swelling.

THE SWELLING OF VOLCANOES

The edge of Kilauea Crater is a live place, no matter what the eruptions are doing. The ground under the Observatory and the hotel is always tipping away from the center of the crater, or else tipping back again. The ground at the edge of the firepit, always visited by the tourists, tips back and forth still more strongly than the rim of the greater crater. The ground between Volcano House and Hilo actually rose by amounts measurable in feet between 1912 and 1922 and sank by similar amounts at the time of the great engulfment eruption of 1924. This engulfment enlarged Halemaumau pit, by caving-in of the rim, some 700 feet outward on all sides. There is thus a cycle of swelling and shrinking in a volcano, and this note is to call attention to the gradations of swelling which have been studied by the Observatory.

Measured Tipping of the Ground.

Tipping of the ground is one of the subjects studied with pendulums at the Hawaiian Volcano Observatory. This means that the flat floor of the seismograph cellar tips a little each day back and forth. Accumulated tilting in a week becomes a real change in the plumb line. At the edge of a sink crater in the top of a lava dome over red-hot lava a little way down—such is the situation of the Observatory—it may be readily understood that when molten lava pours forth from the pit inside of the crater, an increased heat and pressure inside the mountain is developed. The effect of this should be a small swelling up of the mountain, measurable as tilt away from the center. Just such tilt was measured on the seismographs during the years leading to the great overflows which built up the Kilauea floor between 1918 and 1921. And the reverse of this, a strong, sudden and large inward tip toward the center happened in 1924 when the lava sank away. This was accompanied by collapse of the pit and the famous steam-blast eruption.

Visible Swelling at the Pit.

But this swelling of the volcano at the edge of the pit itself was so tremendous that it actually became visible. We are now speaking of Halemaumau, the inner pit of the Kilauea sink, more than two miles from the Observatory, and itself the crater of the domed-up inner floor of the large sink. The first illustration shows the southeastern rim of Halemaumau on February 22, 1918. The crowd of people is clustered on the rim, and a few of them have stepped down and are walking on the shells of new hardened lava which by rising has just reached the rim level.

At this time, December 28, 1920, great outflows poured from Halemaumau through the breathing rift cones just outside. This picture shows the Red Solfatara, with bright orange and yellow sulphur and selenium, in foreground, and flows around the cones.

It is as though the present floor which tourists see one thousand feet down were up to the level of the rim station.

This picture was taken the day before the inner lava overflowed the rim. The black crags on the left are adjacent to the lava lake, and represent blocks of the overflow benches of the lake which had been uplifted. There is a rectangular stone shelter on the rim of the pit in the background, and this was the principal tourist station of that time. The lake of slag was boiling and fountaining as a large puddle of molten stuff, generally in clover-leaf shape, off to the left of the picture, with risings and fallings from hour to hour which made the black fill in the foreground.

At this time the light-colored rim of the pit on the right was rising. The rise only showed as a faint tip away from the center. Then came the overflow which sent a torrent of candy-like lava a half mile away over the automobile road, and the inner floor of the pit swelled up into more crags. Within six days the old rock of the southwest rim of the pit had been pushed up nine feet in a ridge showing the profile of a half arch on the outer side, while the wall inside remained upright. This old, hard rock moved like broken wax. A year later came another spasm of swelling extending the pressure ridge for several hundred feet around to the tourist station. A six-foot leveled platform of concrete used as a surveying station was tipped back 45 degrees until it fell to pieces. By August of 1919 a similar leveled concrete platform 100 yards back from the rim of the pit on the north side was tilted away from the center 10 degrees or more. Meantime there had been numerous overflows and gushings of lava up cracks back from the rim of the pit. It was clear that in fissures of unknown form the underpinning of the floor of the greater crater was surcharged with lava that caused it to swell.

This whole period of 1919-20 was a time of repeated risings and outflows about Kilauea Crater as a center. The pressure ridge around the south rim of Halemaumau became a great feature 15 or 20 feet high, and persisted until a deep collapse occurred in April, 1921. Our second picture shows the same rift cone that contained the glowing stalactites in the second illustration of Volcano Letter No. 263, but at this earlier time the cone vent was vomiting out lava flows and burying brilliant colored deposits of alum, epsom salts, selenium and sulphur. This cone was over the deep crack leading from Halemaumau to the southwest, and about 500 feet from the edge of the firepit.

The illustration on the last page is a photograph of the first concrete monument above referred to. It shows the round surveying station on the old rim of the pit actually heaved up into the air and tipped back, so that all the ridge which extends across the picture had been the flat edge of the pit only two weeks before. The observer is looking toward the pit.

A Pendulum Set up at Halemaumau.

All this evidence of visible swelling when the lava was high made it interesting to place at the rim of the pit a machine to microscope such movements. A seismograph pendulum was set up in a stone hut a few hundred feet back from the tourist station at the southeast rim of the present big cauldron. A horizontal pendulum is somewhat like a barnyard gate. The boy sitting on the gate corresponds to the lead weight. If the gate post is tipped away from the pasture, and the gate is unlatched, the boy swings out toward the road. Just so it is with the pendulum at the crater, with a hinge at one side, attached to a concrete post, and the gate-like pendulum hung parallel to the edge of the pit. If lava comes into the bottom of the big pit so as to swell up the whole dome floor of the larger Kilauea Crater, the pendulum should swing away from the center of the pit. If the bottom of the pit collapses, the pendulum should swing toward it.

The pendulum at Halemaumau writes all day long on a sheet of paper which is pulled under its pen by a clockwork. If the pendulum swings away from the pit the written line shows it, and the amount of the swing may be measured for any hour of the day, and for any day of the year, by the position of the line on the paper. To revert to the boy on the gate, if an automobile were dragging a sheet of white canvas along the road, and the boy on the open gate dug his muddy heel into the canvas, the mark would show how much the gate was open. So it is with a seismogram.

The outbreak of lava far down in Halemaumau February 20, 1929, wrote a complete autograph on this instrument, 1,100 feet above it and at least half a mile from the center of fountaining. First there were little earthquakes written on the instrument and then a tipping of the ground away from the pit. The moment the lava fountaining began, the seismograph pen started writing a strong back-and-forth line like a tremulous invalid, and the tipping stopped. This tremor continued and became excessively strong toward the end of the two days' activity, and then the tipping began to go in the opposite direction, namely, toward the pit. This tipping and tremor continued up to the moment when the fountaining stopped, when the line became smooth and straight. These sheets of paper taking the pulse of an active crater for the three days, February 19, 20 and 21, 1929, are epoch-making in the history of science. They prove that a microscopic record of a lava outbreak may tell the story with perfect fidelity.

Swelling and Shrinking on a Large Scale.

We have seen that the visible gushing lava swells and shrinks its containing vessel, that the mountain top swelled and contracted during the cycle of activity from 1913 to 1924, and that these things were measured by instruments designed to show the trembling and tipping of the ground, and measured also by the careful methods of the surveyor. These last made use of the telescope, the level bubble, and the exact determination of mean sea level at Hilo with the aid of the tide gauge.

When the traveler gazes at the pure curve of the dome of Mauna Loa, he may well make inquiry, "How much of that is swelling?" This leads to the question, "How large a part do swelling and shrinking play in the mechanism of building active volcanoes?" And going still farther to such a region as eastern Japan or western California, where volcanic heat is still rampant and where great earthquakes occur, he may well ask, "Does not this mechanism of volcano swelling, deep under the earth's crust, play an important part in the uplift of the shore lines in both these uplifed lands?"

In Hawaii itself the question of large scale uplift and breakdown of the islands is of intense interest both geographically and with respect to the passage of time. The geographic evidence is the astonishingly regular gradation of height or uplift of the islands as we go from east to west; Hawaii is the highest and contains the active volcanoes; Midway Island, far away at the west, is a tiny coral reef. In between there are intermediate islands containing old volcanic rock. The time evidence shows that Kilauea at the east, among the active volcanoes, almost continuously ejects liquid lava, but is breaking down along its shore line. Mauna Loa, next to the west, is less continuously active, and Hualalai, farther west, has still greater intervals. Haleakala, the last of the four volcanoes with an active record, was probably last flowing very long ago, about 1750, and its crater is a more broken structure. In time and space the Hawaiian Islands are swelling and swollen at the east, and shrinking or shrunken at the west. T. A. J.

KILAUEA REPORT NO. 938

WEEK ENDING JANUARY 12, 1930

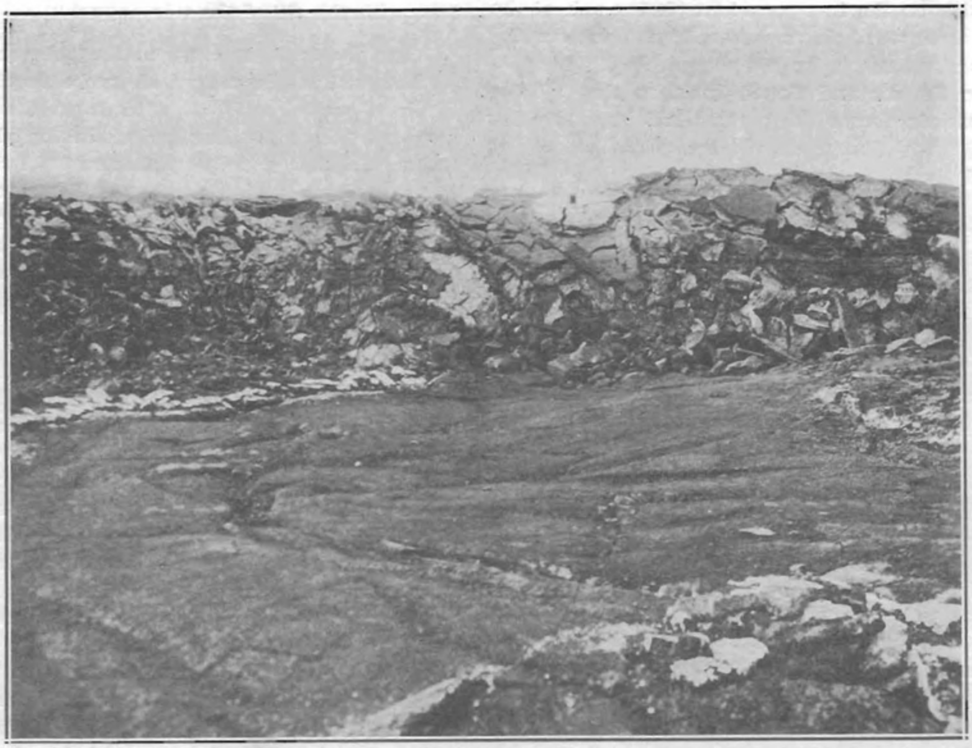
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The Hawaiian volcanoes remained quiet, fresh snow was observed on Mauna Kea and Mauna Loa when the mountains cleared January 8, and on Hualalai an odor of spicy sulphur was noticed by the foresters near the western summit January 7. A similar odor had been perceived there by the forest ranger December 31.

At Halemaumau dust from a slide at the north side of the pit was observed during the forenoon January 8, and the wall there was afterwards seen to be grooved from the loss of fresh debris, which lay on the talus below.

The seismographs at Kilauea Observatory registered 19 local disturbances for the week, of which 12 were tremors, lasting each from 15 to 45 seconds, and seven were very feeble earthquakes. One such earthquake indicated origin distance 52 miles, time 6:08 p. m., January 8. This probably centered in North Kona. Microseismic motion for the week was slight, and tilt was slight to the southeast.



The rim of Halemaumau, looking straight toward the pit. This photograph, March 6, 1919, shows southeast surveying station tipped up away from the pit on a pressure ridge 15 feet high. The swelling had begun suddenly February 25. Photos Jaggar.

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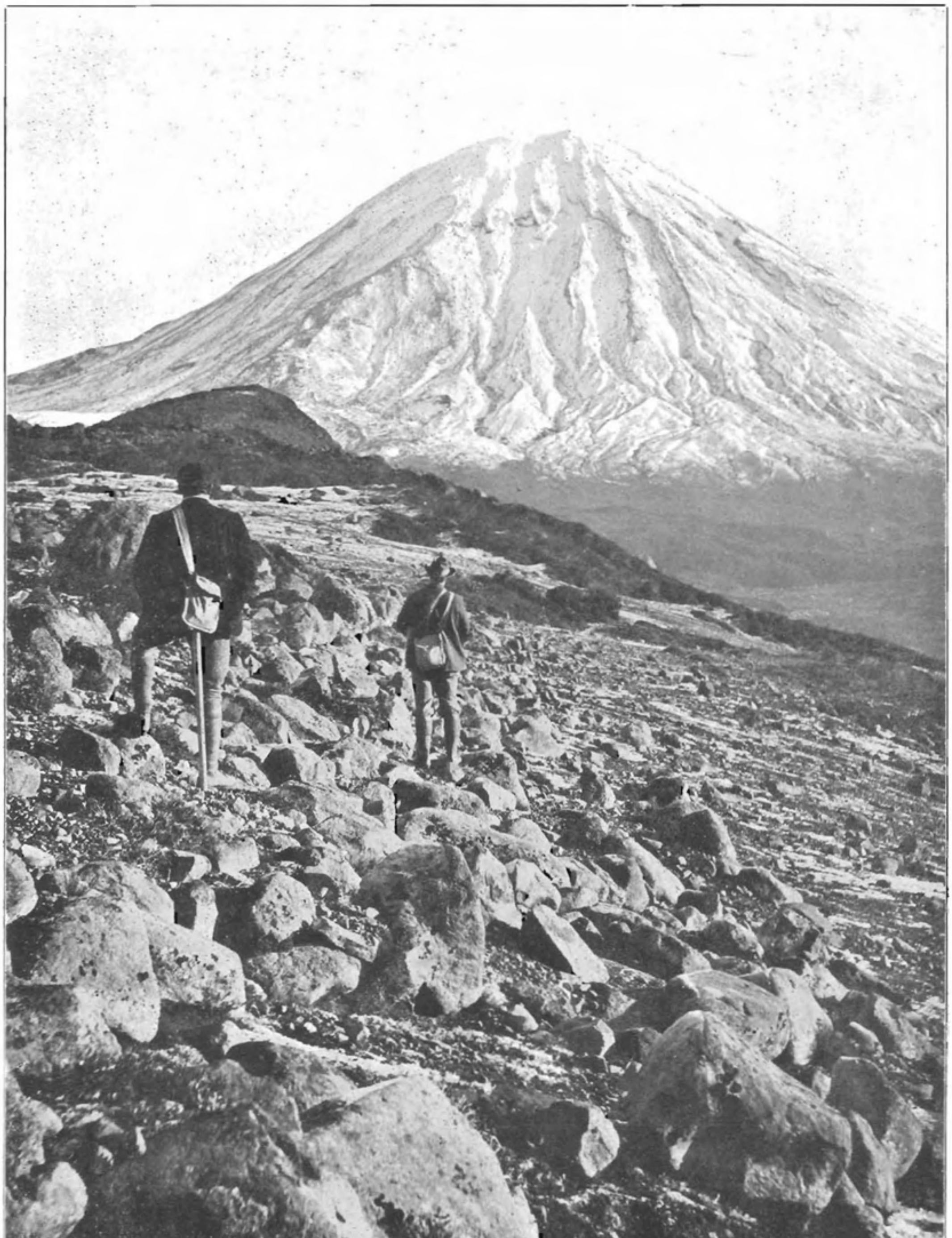
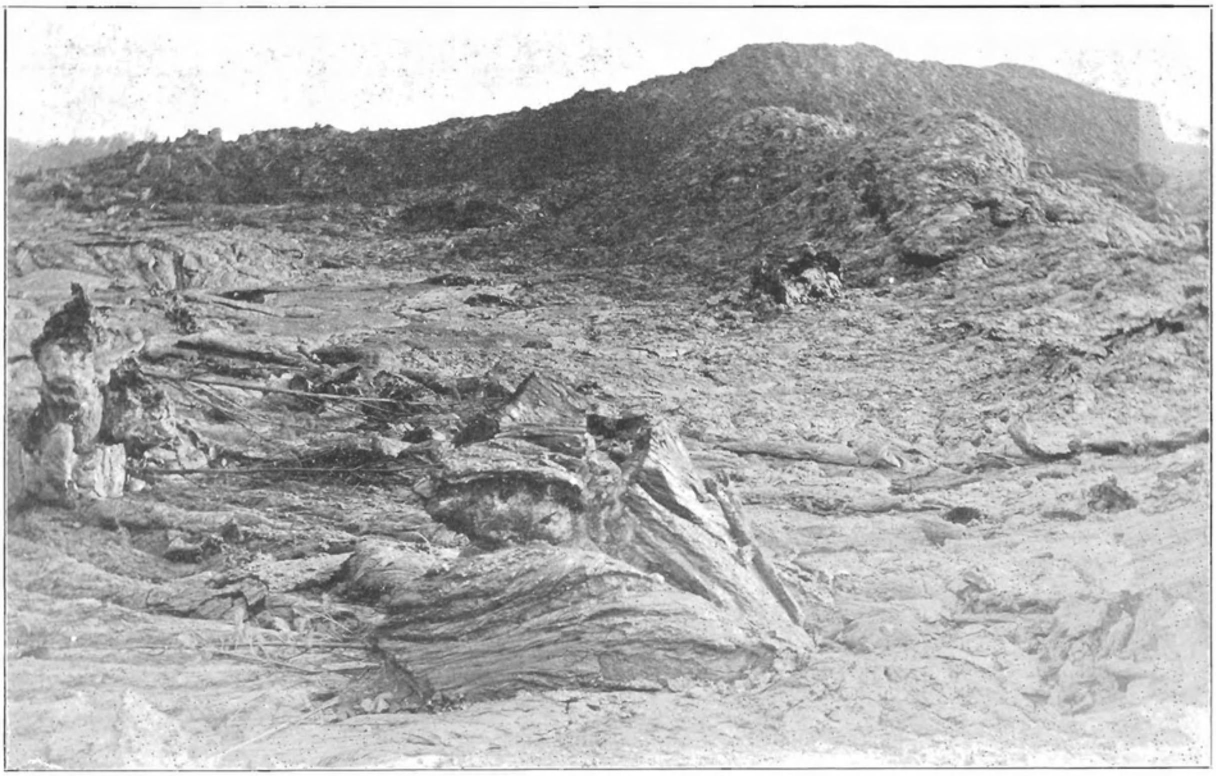
The Volcano Letter

No. 265—Weekly Hawaiian Volcano Observatory, National Park, Hawaii January 23, 1930



Ngauruhoe Volcano. New Zealand National Park, as seen in winter from the Eastern side. This is the most active of the splendid volcanic cones of New Zealand, and was throwing out rocks and had glowing lava within its crater in March, 1928. —Photo Malcolm Ross.



Fresh Pahoehoe Lava on Niuafou, 1913. There has been much controversy about whether historic lava flows have occurred in the Tonga Islands. This photograph, with fresh source cones and ropy basalt of 1912, when there was an eruption near Futu, settles the question in the affirmative. Photo from Captain Crawford, Canadian Australasian Steamship Company.

VOLCANOES OF NEW ZEALAND-TONGA BELT

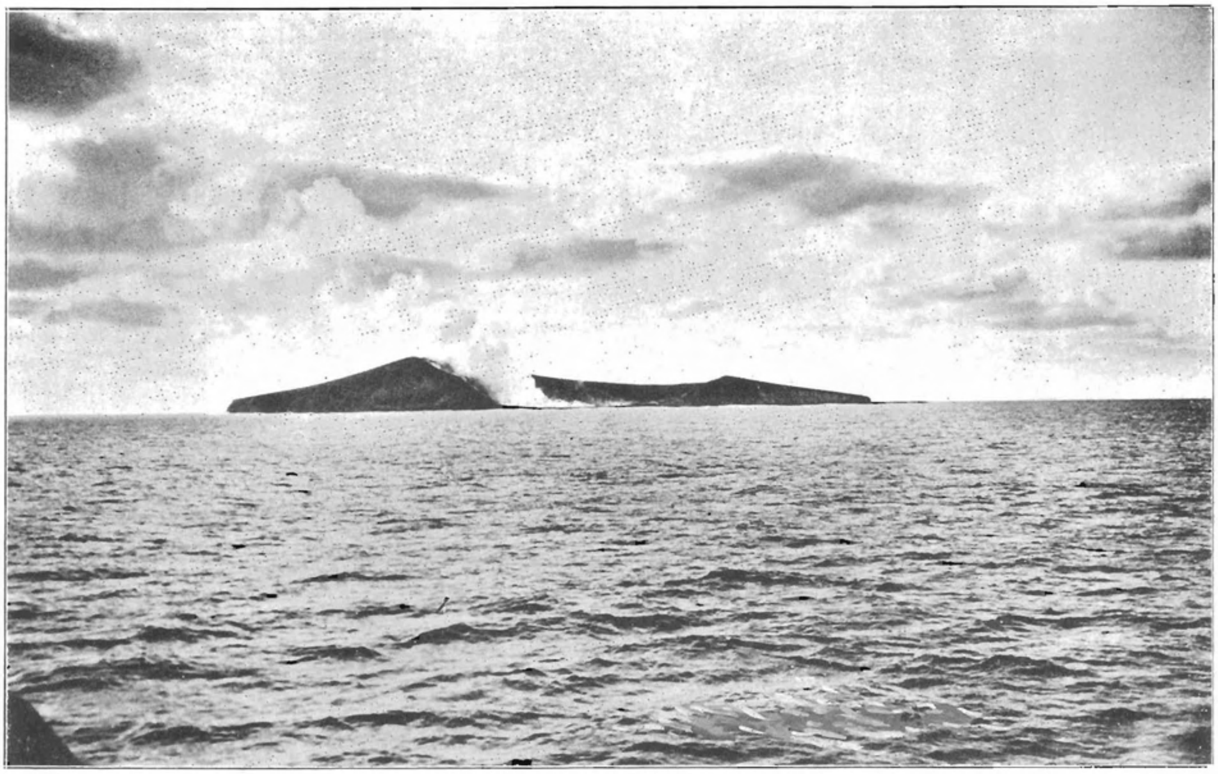
The recent disastrous earthquake in the mountains near Murchison, at the northern part of the South Island of New Zealand, makes the study of rift lines or faults carried out by the New Zealand Geological Survey of great importance in connection with the meaning of volcanoes. Mr L. I. Grange, of that Survey, has been making a detailed geological survey of the active volcanic zone of the North Island, and believes that the area of greatest interest for earthquakes and volcanoes is the 72 miles in a generally NNE direction between Lake Rotorua and Lake Taupo. An active fault, the Paeroa Rift, has been located through the volcanic district trending northeast in the direction of White Island from Lake Taupo, and if this fault were projected southward 200 miles it would go through well known earthquake centers in the western part of Cook Strait, and then pass through Nelson. If projected it would pass close to Murchison. The big displacement which has been studied at White Creek is eight miles farther west. The New Zealand geologists do not connect the fault movements of the South Island with anything but mountain-building forces. There are no volcanoes in the South Island. But large, active faults of both islands trend NE-SW, and the possibility should not be overlooked that deep volcanic faults with intrusive magma extend under the southern mountains.

This relationship makes the volcanoes of the New Zealand belt worthy of review Along this great crack south of Lake Taupo lie the three big volcanoes Tongariro, Ngauruhoe, and Ruapehu, the last farthest south. These are in the National Park. Ngauruhoe is 7,515 feet high and has had eruptions 11 times since 1839. Its eruption of March, 1928, was reviewed in the Volcano Letter (No. 216, February 14, 1929).

The crater of Ngauruhoe has recently been described by F. W. G. White, and the inner crater has been continually changing. The walls of the outer crater are very precipitous, and in 1896 there was a hole on the southwest side of the level floor of the main crater. Earlier there had been an inner crater toward the northwest, and this all suggests what is so common in Hawaii, that the central level floor is the top of a lava plug, and that the gases of explosive eruptions churn out their vents around the wall crack at the borders of this plug. The southwest hole has become enlarged to be the principal center of activity.

In January, 1929, the activity was so slight that White went to the bottom of the innermost pit. The old northwest pit had become a rounded depression covered with ice. The walls of the southwest active pit were partly precipitous. In a conical hollow on the northeast side, Grange had seen lava in this pit in 1928. Its slopes were now steaming and there were two holes in the bottom from which hot air was issuing, each a foot and a half in diameter. The remainder of the bottom was covered with sandy material washed in among bowlders, and there was very little sulphur in the crater. The only other solfataric place that was steaming was well up on the edge at a rock projection east of the northern lip of the outer crater. The crater contained more ice and showed less activity than usual, at the time of White's visit (N. Z. Jour. Sci. and Tech. June, 1929, p. 48).

As has been pointed out in the review of J. Allan Thomson's admirable summary of the New Zealand volcanic belt (Volcano Letter No. 158), the question of lava flows from Ngauruhoe in 1869 and 1881 has been disputed. An aa flow now at the foot of the mountain is attributed to the 1869 eruption, and inside the conelet of March, 1928, wholly within the crater, Grange saw red-hot lava that appeared viscous, with blue smoke escaping through it with a tremendous roar, which flung up red-hot fragments 50 feet. The presence of lava in the center is thus unquestionable. The great explosive disaster at Tarawera Volcano in 1886, in the North Island, about midway between the active volcano White Island in the Bay of Plenty and the National Park group of volcanoes, has given New Zealand the reputation, like Java and Japan, of producing chiefly ash explosions. In all three of these lands we are learning more and more that andesitic and



Falcon Island, reported to have disappeared in 1913, reappeared with a violent series of explosions October 4, 1927. building up basaltic ash, scoria, pumice and lava blocks to make a cone and crater in the Tonga Islands. Photo from Andrew Thomson, Apia Observatory.

basaltic magma, or underground lava, which occasionally comes to the surface, is the prime mover of volcanism. but does not flow out so freely as in Samoa and Hawaii.

It seems likely that if we could know of all the submarine lava flows which come out through cracks in the bottom of the sea, between New Zealand and Samoa, we might discover that lava outflow is not so rare as has been imagined. The photograph reproduced on the second page is quite like the lava flows of western Samoa. and this unquestionably was pouring over the surface of the Island Niuafou in 1912. The description of the 1929 eruption of Niuafou, which follows this article, leaves no doubt that lava flow is characteristic of this island, and Niuafou is not more than 250 miles from Savaii where the great lava floods of western Samoa occurred in 1906-11.

The recent eruption of Falcon Island (Volcano Letter Nos. 151 and 210) has been newly reviewed by the investigators who studied it for the Bishop Museum (Amer. Journ. Sci. Dec. 1929, Falcon Island, by Hoffmeister, Ladd, and Alling. See photograph this page) to the effect that the great volcanic crack in the earth's crust which has piled up the line of Tonga-New Zealand volcanoes, starts at Savaii and extends across Cook Strait into the South Island of New Zealand. The formations along the line are said by Park to be "broken, sharply folded, faulted, sheared and up-tilted" Niuafou lies off the line to the west 150 miles, but it is doubtless part of the same system. These explorers of Falcon Island reach the conclusion that many of the atolls, or horseshoe-shaped coral reefs of the southwest Pacific, may have been started by corals and other organisms building on a circular bank built up by a temporary volcano such as Falcon and later cut down by the waves. It may be added that while such volcanoes exhibit chiefly fragmental material, it must be remembered that a pile of solid lava in the form of a dome probably exists beneath. How an outflow of liquid lava like one of the Mauna Loa flows, would behave under deep, cold water is a matter of theory, not of observation.

ERUPTION ON NIUAFOU, TONGA ISLANDS

Niuafou is a roughly circular wooded island about 20 miles in circumference in the middle of the triangle of ocean between Fiji, Tonga, and Samoa. It is about 600 feet high. There are many craters, including a large main lagoon near the center of the island, where there are hot springs. The shoreline is worn into lava cliffs.

There is difference of opinion as to whether lava flows have occurred; Sapper cites destruction of villages by lateral lava flow in 1853 and 1867 (Vulkankunde, p. 336) Thomson allows only explosive eruptions (N. Z. Jour. Sci. Tech. 1926, p. 369) as the 1886 outbreak destroyed the coconuts and covered the surface with 2 to 20 feet of ash.

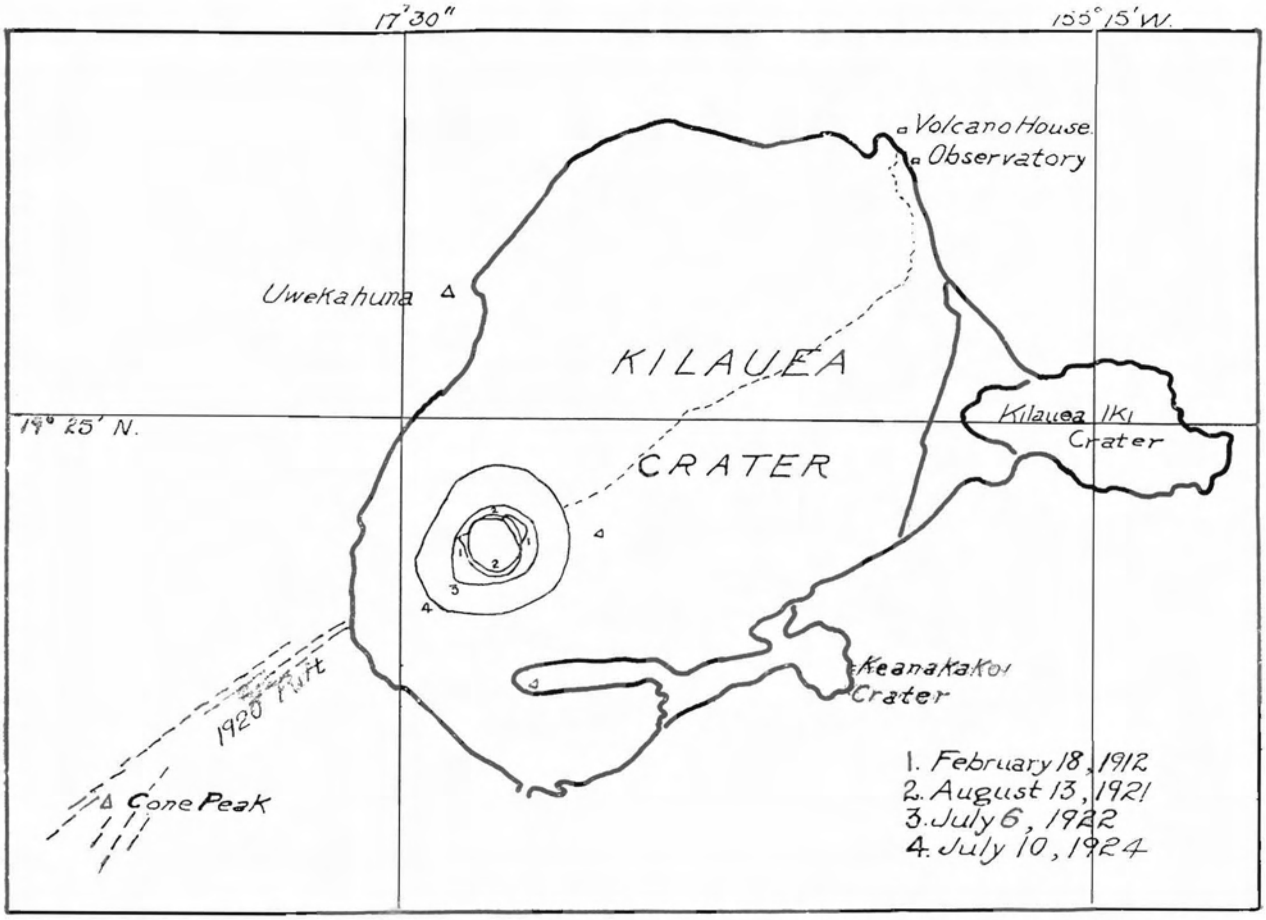
In spite of 5 eruptions in 115 years, Niuafou has nine seaboard villages with a population near 1,000, and bebelongs to the Tongan monarchy under British protectorate.

The last eruption was in 1912, when 30 craters were in action between the lagoon and the strandline near the village Futu, on the west side of the island. Pahoehoe lava flowed into the sea. Of this we possess a photograph taken in 1913, (see second page).

The new eruption July 25, 1929, was similar and wrecked Futu. It began at 4 a. m., overrunning a long strip of coast a mile wide. Copra crops, houses, horses and pigs were burned and buried.

Three craters burst open without warning to the south of Futu. The populace hurried to Agaha, the larger village at the northwest, and took refuge on the high ground back of it. Their discomfort was increased by rain and wind.

The correspondent (Auckland Star, Aug. 6, 1929) climbed on horseback to Hala-gutu, the high lip of the interior crater lake, and saw that a chain of craters was forming along the low coast land. Each vent belched out molten rock and deep red flames. "Among the clouds and swirls of smoke and fumes were to be seen streams of lava thrusting their way in tortuous twists and turns through the rich vegetation, scorching it to brown and black cinder."



The recent enlargement of Halemaumau Pit, the inner lava cauldron of Kilauea is here shown. The lava rose and overflowed, and the pit grew smaller, for outlines 1 and 2. The pit enlarged by collapse for 3 and 4.

The smoke cleared July 26. At the extremity of the flow 40 acres of new ground had formed, altering the contour of the coast line. Halfway between there and Futu, goats were marooned on a new islet. Sulphurous fumes were bad, but the explorer with his two native companions finally reached the ruins of Futu by boat. The village site was a field of smoking lava, only a third of the habitations escaping destruction. Native houses were found battered to the ground by the hot wind blasts. Numbers of animals, including horses which had broken tether, were found alive in the village remnant. The stone Roman Catholic church was burnt out, and the lava had flowed round a cemetery, leaving the stone cross intact in its center. The Wesleyan mission church escaped. No lives were lost.

The foregoing account is sufficiently definite and circumstantial to indicate that this eruption was a lava flow. There is no mention of darkness or ash fall. It seems likely that Niuafou is the crest of a volcano recently built above sea level, liable to both outflow and steam blast.

Niuafou is reported to have many earthquake shocks, "almost of daily occurrence" (Sydney Morning Herald, Aug. 2, 1929). These are attributed by the natives to their god Maui, rocking the island by his troubled subterranean sleep. It is hard to imagine a better place for the study of tilt and volcanic earthquakes, and this island is strategically placed for very interesting geophysical and oceanographic observations. There ought to be a seismograph station there with a permanent staff in close touch with the Observatory at Apia.

T. A. J.

KILAUEA REPORT No. 939

WEEK ENDING JANUARY 19, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

The week has produced no change in the Hawaiian volcanoes, new snow has fallen on the mountains, and in Halemaumau pit of Kilauea Crater all that is noticed is the presence of a few new scars due to slides along the north and northwest walls. On January 15 in the afternoon of a dry day there was almost no steam in the bottom of the pit, but in the forenoon of January 18, after heavy rain, much visible vapor rose from cracks. This is characteristic also of the outer floor of the greater crater.

The seismographs for the week ending midnight January 19 registered 10 local disturbances, of which five were tremors less than one minute long and five were very feeble local earthquakes, one of which indicated distance from Observatory 48 miles. A weakly recorded distant earthquake began 6:50 a. m., January 17 and registered for 4 m. 47 s. Microseismic motion was moderate for the week, and tilting of the ground was strong SW.

THE VOLCANO LETTER

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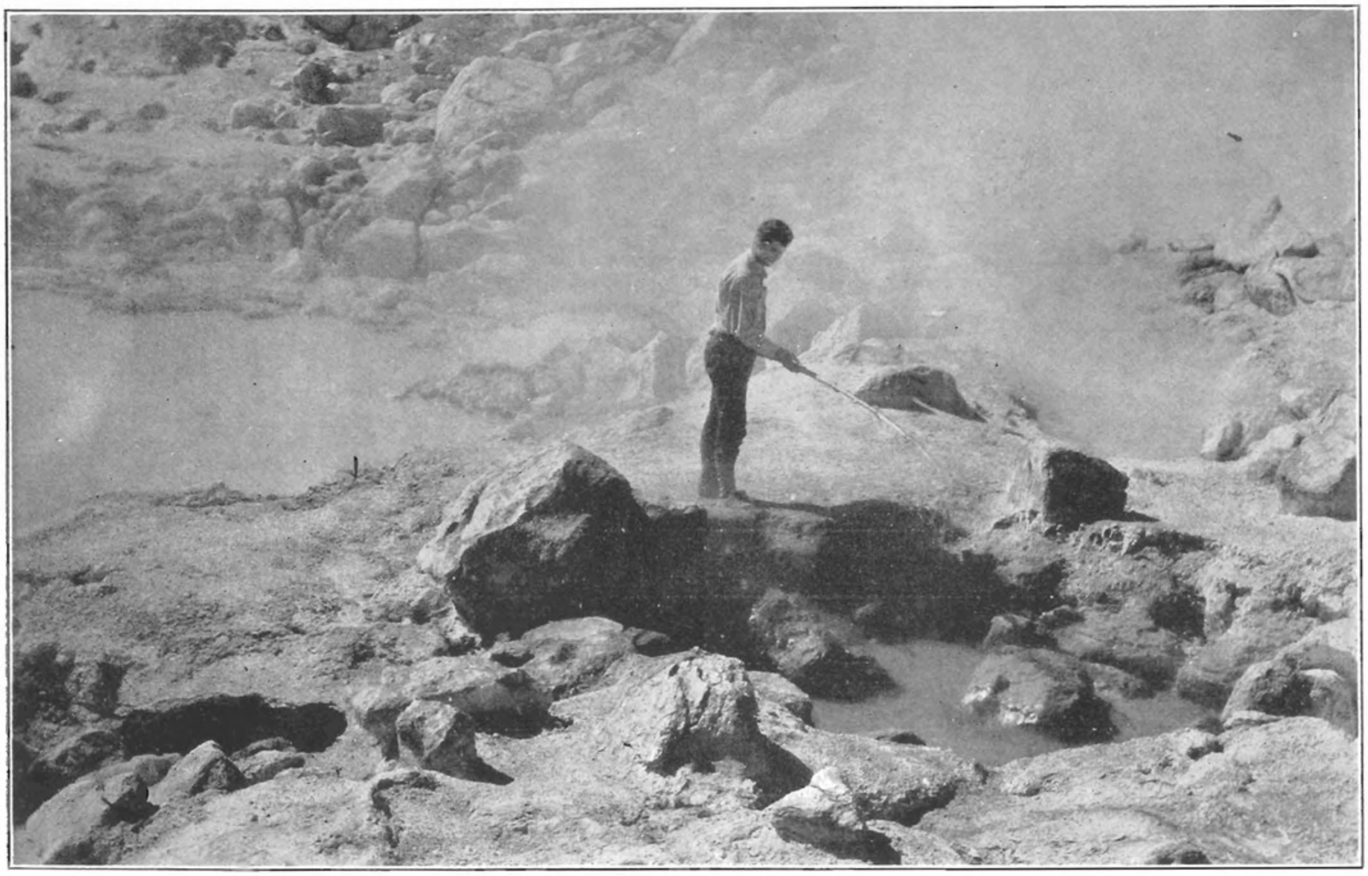
The Volcano Letter

NO. 266—Weekly Hawaiian Volcano Observatory, National Park, Hawaii Jan. 30, 1930



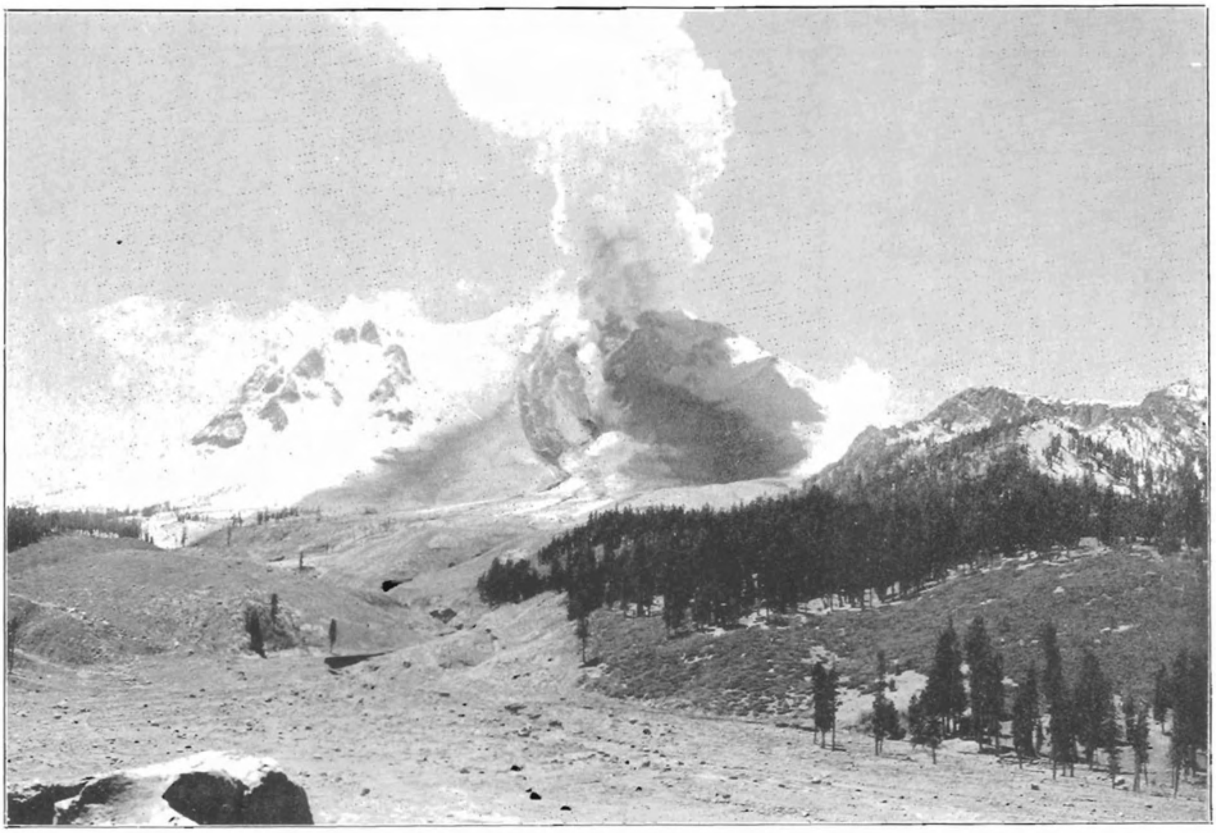
Bumpass Hell, one of the solfataras with boiling waters far up the slopes of Lassen Volcano in California The pool is black because of a scum which covers it consisting of minute particles of sulphide of iron, or pyrite. The observer from Lassen Volcano Observatory is at work immersing a thermometer in the scalding waters. Photo R. H. Finch, August 26, 1927

MUD FLOW ERUPTION OF LASSEN VOLCANO

On May 30. 1914. the old crater depression on top of Lassen Peak, a volcano in northern California, ejected dust and steam, the crater hole enlarged, explosions increased in number during the year, occurring every few days and rarely lasting more than 20 minutes. A big eruption occurred May 19, 1915, which devastated the creeks northeast of the volcano with a mud flood. Three days later, May 22, a much bigger explosion occurred, producing a down-rushing steam blast which overturned trees and cut a swath through the forest in the same direction as the preceding flood for at least four miles. The explanation of the mud flood has been problematical, as Lassen had no crater lake, as in the case of Mount Pelee in Martinique. Lassen was, however, covered with snow. The resident photographer and creator of the Lassen Museum, B. F. Loomis, believed that both Lassen eruptions gave vent to liquid water from within the mountain, a region of many hot springs, and that the water was followed by steam. (A Pictorial History of Lassen Volcano, Anderson, California, 1926.)

Dispute centers about this water question. Day and Allen (Volcanic Activity in Hot Springs of Lassen Peak. Carnegie Institution) attribute the flow to the melting of snow by the several agencies hot rain, hot volcanic ash, and a hot blast of gas. Day has shown that the mud flow started some distance below the crater rim. The flood originated in an embayment on the northeast slope of Lassen Peak that was uniformly covered by snow with a depth of several feet over most of the area. (See third picture on page 3).

It is hard to believe that hot water came out of the mountain in such volumes, but the writer agrees with Loomis that the evidence does not indicate the occurrence of a hot blast or any considerable explosion just prior to the mud flow of May 19, 1915 Except for a small flood below the western flow of aa lava that came out of a notch in the crater, the notheast flood was the only important one of this date. Even if there had been an explosion, any rain accompanying it would probably have been but little warmer than any other rain—certainly not hot. It is also doubtful under the conditions existing on Lassen Peak at



Lassen Volcano in eruption, photographed from the northeast by B. F. Loomis at 2:30 p. m., May 22, 1915, a few hours before the biggest eruption. Flood wash of May 19 in the foreground. Note the crateral gash, the cut in the snow, and the ash stain on the snow at the left. This is the critical picture. No sign of horizontal blast.

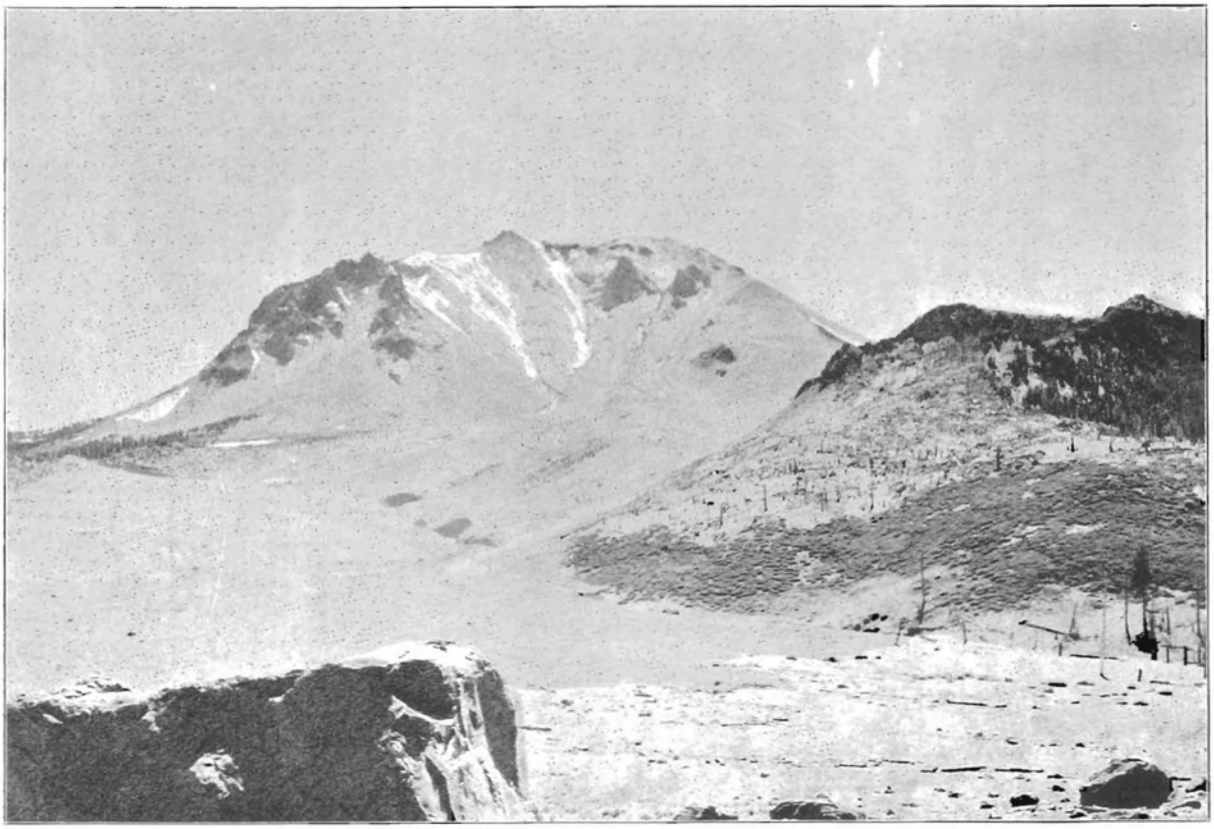
that time, whether a rainstorm unless of very unusual intensity, could cause a flood of the magnitude observed. If there were no explosion and no hot blast, then there would not have been any hot ash deposit nor warm rain.

It is true that the known explosions of May 22, 1915, three days later, produced several small mud flows. The behavior of rain on snow is worthy of some discussion. A few feet of snow of uniform covering can absorb several inches of rainfall so that the rain produces but little immediate run-off. If there had been bare spots in the snow field, water could have accumulated so as to run under the snow in considerable quantities in caverns and, in a place as steep as the Lassen slope, might have undermined so as to start avalnches. A hot blast, unless long continued, or a slight deposit of volcanic ash would produce much the same effect as a rain—a melting of superficial layers of snow and an absorption of the water by lower layers. A hot blast or a hot ashfall on a steep slope not uniformly covered with snow, could start streams under the snow as in the case of rain, and might thereby cause avalanches. It would seem that the Day and Allen theory of rain and ash may be questioned as a sufficient cause for the tremendous Lassen mud flow of May 19, 1915.

An examination of enlargement of the photograph (see illustration top of page) taken by Mr. Loomis immediately after the mud flow of May 19, 1915, and just before the maximum explosive eruption which occurred on the evening of May 22 (this photograph was taken at 2:30 p. m. that same day, May 22, and the great explosion occurred while the party was returning home), and of other photographs, and of the material transported by the mud flow, all indicates that a large volume of hot lava poured through this eastern notch of the crater where the V-shaped column of steam extends down the mountainside.

There is much new lava that was carried in fragments down the flood. The source of this at the flow in the notch was not only much more voluminous than the one through the western notch of the crater, but as would be expected it was probably as a whole more molten and less viscous. The lava flow could easily have melted the snow down to the ground and have sent a stream of warm water under the snow lower down the slope. An avalanche mixed with hot rock could have been started in this way and might have produced a flood of the magnitude observed, if great snowdrifts were present.

Minor mud flows did accompany the explosions on May 22, 1915. There was a horizontal component of this explosion that was parallel to the course of the upper part of the mud flow on May 19, 1915. The area affected by this blast was much wider than the area devastated by the mud flow of May 19, so that the blast encountered snow banks with exposed edges. The largest mud flow that accompanied this explosion followed the course



Lassen Volcano after it had quieted down, summer of 1924, showing linear remnant snowdrifts in summit gulches only. All the rest is the debris of May 22, 1915, and later, showing removal of the forest by the blast Photo Loomis.

of the one on May 19th. Much hot ash was thrown out by this eruption, and at places where there was still a uniform snow covering, the mud flows occasioned by hot ash and possibly by mud rain at this time for the most part remained on top of the snow R. H. F

THE LASSEN MYTH

In 1915 the Lassen eruption awakened the public to the knowledge that this volcano is active. It was immediately dubbed "the only active volcano on the mainland of the United States". Nothing could be more erroneous.

Geologists have long known that the volcanoes of the northwest are potentially active. Tradition has it that Mount Saint Helen's and Mount Baker have both had eruptions in historic time. The Cinder Cone east of Lassen was well known to the Indians and to geologists as the maker of a modern lava flow within a century. Eighteen volcanoes lie along the Cascade fault in Oregon, and many more extend north through Washington into British Columbia. At Geyserville just north of San Francisco there is rushing volcanic steam under high pressure. This was in the epicentral belt of the San Francisco earthquake.

Mount Shasta or any of the volcanoes exhibiting fresh lava flows in the northwestern United States might erupt at any time. Intervals between outbreaks are long in continental volcanoes of this class, and the white man's history is short. T. A. J.

KILAUEA REPORT NO. 946

WEEK ENDING JANUARY 26, 1930

Section of Volcanology, U. S. Geological Survey

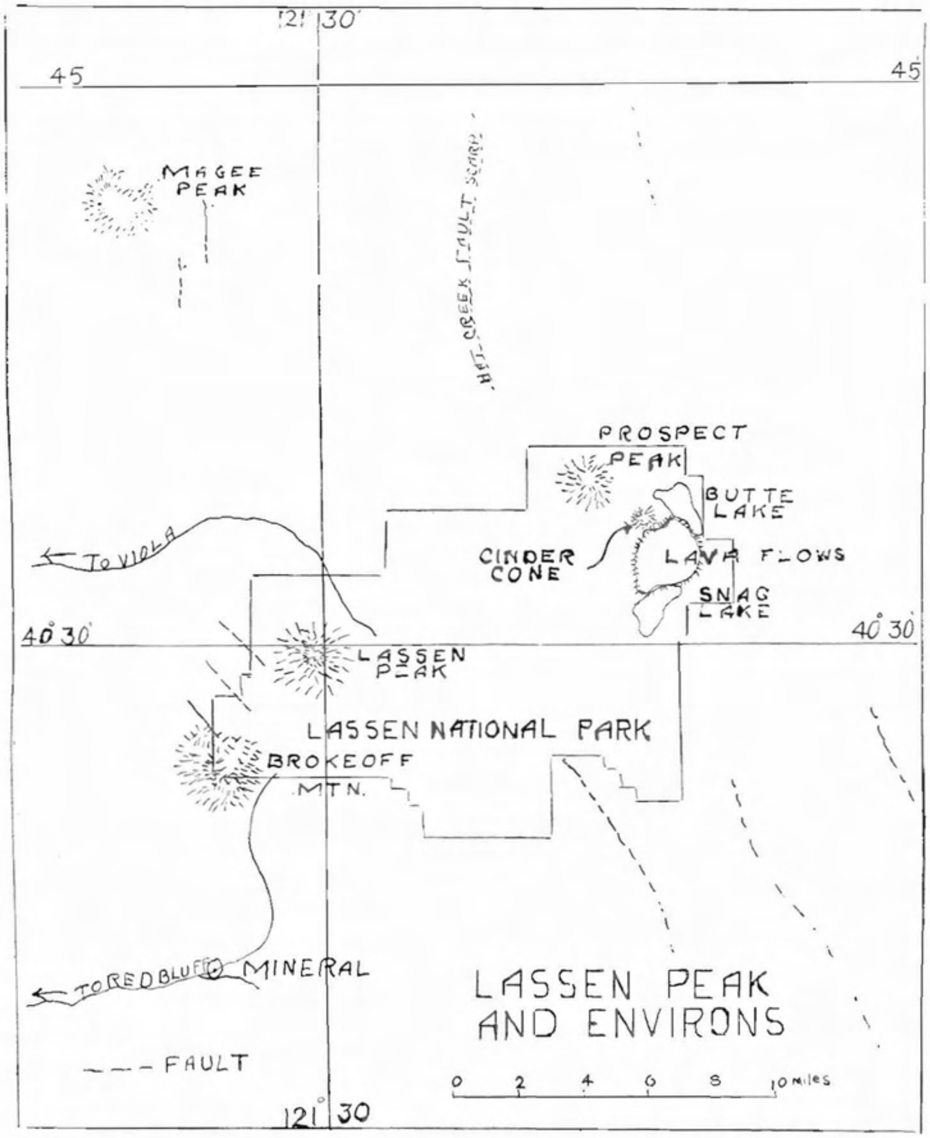
T. A. Jaggar, Volcanologist in Charge

There are still no changes in the appearance of the Kilauea fire pit to be construed as indicating lava activity. The volcano remains quiet.

On January 20 there was very little steaming. A new scar was seen on the northeast wall, caused by a slide. Early on the 22d considerable steam rose from the various Kilauea floor vapor vents and two large columns rose from the Halemaumau rims south and southwest. A new scar from a slide showed on the north wall. At 11:45 a. m., January 23, thin gray dust from an avalanche rose over the northeast corner of the pit At 4 p. m. dust rose on the north side. On the 24th, at 6:15 and 7:30 a. m. more dust from slides was seen.

The instruments at the Observatory recorded six tremors and three very feeble earthquakes. One of the latter, occurring at 2:09 a. m., January 23, indicated 34 miles as the distance to origin.

Tilting of the ground at the Observatory accumulated moderately to the NNE. Microseismic motion was slight.



Sketch map of Lassen National Park showing position of Lassen Peak. Observatory is at Mineral, R. H. Finch in charge. The eruption flood devastated a sector due northeast from the summit in the direction of the Hat Creek fault scarp, making flood damage down Lost Creek due north of the mountain.

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.

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HAWAIIAN VOLCANO OBSERVATORY
Founded 1911

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The Volcano Letter

No. 267—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | February 6, 1930

New lava filling bottom of Halemaumau as seen from east side of pit, 5:30 p. m., July 9, 1927. Torrent pouring in from high cone on talus at the left. Three inflows have occurred, burying this floor, since 1927. Photo Tai Sing Loo, copyright.

KILAUEA'S LIGHTED FURNACE

Travelers do not realize, when they visit the silent, sleeping fire pit, that the live smelting furnace of Kilauea is ready for action at any moment. It is hard for them to imagine that it is possible for the liquid lava to spurt up through the rocks at the side of the black lava floor while they are watching, and without doing them any harm. The liquid lava of the inner pit never does anyone any harm. Pele comes back with the silent gleam of a beacon light at night, with only a wisp of vapor, and then the slag fountains wax in vigor and majesty. All of this happened twice, with magnificent fireworks, during the past year.

These demonstrations that the pilot light is always burning have occurred seven times since the summer of 1924. That summer the lava began to flow into the bottom of Halemaumau, two years later gigantic floods of lava streamed to the sea from Mauna Loa, and in midsummer of 1927 four beautiful fountains of fiery melt appeared in the bottom of the Kilauea fire pit. They came quietly in the midnight hours of July 6-7, sending up fume which reflected the glowing jets beneath. They covered up the earlier lava floor, and the liquid basalt spread out into a molten lake so as to drown the vents of two of the fountains. The vents lay in a line tending to be parallel to the great west cliff of Kilauea Crater. And this bluff in turn is parallel to the cracks that lead out into the southwestern desert. These facts mean that under the round craters there are straight fissures going down deep, and it is up these fissures the lava comes.

The first picture is looking toward the west from the eastern rim of Halemaumau near where tourists stand at present. It shows on the left the two new source cones of 1927, and the top of the higher one stood 122 feet above the level of the liquid lake below. This vent had broken out through the slide-rock slope far above the bottom of the pit. The picture was taken two days after the beginning of the eruption when 30 acres of new lava had spread over the bottom. The jets on the first day had begun with blue flames and rushes of gas, followed by light basaltic pumice with the gas jets, and this in turn became more viscous although all such lava is more or less a froth. At the fountain jet it is bright yellow, but the blobs of freezing froth which drop back on the cones change color to orange, scarlet, crimson, maroon, purple and black. By "freezing" is meant consolidating from a molten condition. The material is a true glass containing

Halemaumau bottom from the east, 8:15 a. m., January 11, 1928, when the two black flows had squeezed up cracks in front of landslip shown in background. Foreground is floor of July, 1927. Photo Wilson.

much iron oxide which gives the thin edges a greenish brown translucent color. The ingredients are silica, alumina, iron, lime and the alkalies as in the slags of commerce. The temperature is around 2,000 degrees Fahrenheit. The gases which maintain this temperature and are actually burning in their upward rush are hydrogen, sulphur and the oxides of carbon.

After the first day only the large southernmost vent (the left-hand cone of the picture) was visibly working, and after 13 days the eruption of 1927 ceased. It will be noticed from the picture how strikingly the process inside Halemaumau resembles a river and its delta. The molten streams meander and distribute on their flood plain and build lobes penetrating the hollows between the different talus slopes. Then the lower portion actually becoems a liquid lake, within ramparts of its own solidification, and when the eruption ends the slag pool loses gas and shrinks, leaving the ramparts standing up as a border, which shows in the picture. There is just such a border in the bottom of the present pit at the beginning of 1930, and this is remnant from the solidified pool of July, 1929. To return to 1927, the molten lake filled to a depth of about 80 feet, most of this pouring in during the first day, and the diameters were 1,760 by 1,420 feet.

The psychological effects on the community are characterized by intense enthusiasm, and a rush to see the fireworks, which is like the opening of a world's fair. In the early morning of the first outbreak in 1927 there were 50 spectators at Halemaumau, during the first day there were 1,800 visitors, and on succeeding days the numbers diminished to just such extent as the spectacular quality of the performance decreased.

When the lava sinks away after such a release of gas pressure, and the eruption comes to an end, there is a tendency to collapse of the mountain blocks which were held apart before. The walls of the pit lean inward and large rock slides occur from time to time. The eruption of July, 1927, came to an end on the 20th of that month and on July 21 slides were incessant and the air above the pit was heavy with dust. Also the mountain blocks grate against each other and this makes perceptible earthquakes. These local seismic movements do no damage and are mostly known only by the records of the delicate instruments at the Observatory. There are tremors all the time everywhere in the world. The volcano observatory is feeling the pulse of the ground, and the lists in the weekly Kilauea Report are merely adding statistics, that point the way to the meaning of the next outbreak of fireworks. There are quick-period tremors and tippings of the ground, suddenly increasing at time of outbreak. Otherwise the tippings are seasonal as recorded for January, 1930, in this number of the Volcano Letter. (last page)

January of 1928 produced an upwelling of new lava shown by the small black flows that came up cracks in the lava floor left by the July eruption of 1927 (see second picture). The photograph is from about the same point of view as before. It will be observed that the July floor was squeezed down by an immense avalanche in the background, which had fallen from the wall at midnight January 10-11, 1928. Red glow immediately appeared, the outflow was sluggish with only a slight blue flame, and the measurable flowing lasted only an hour or two. The effect was as though liquid lava were present as a remnant from July under the crust, but peculiar seismic disturbances in December, 1927, the month before the outbreak, makes it more probable that it was a half-hearted eruption brought into being by the shock of the avalanche.

The year 1929 was ushered in, by such a disturbance underneath the pit, that an immense avalanche carried away the tourist station in January, and this was followed February 20, 1929, by a new eruption of lava, in the bottom of Halemaumau, of short life and great intensity. The Volcano House watchman saw a black dust cloud rise from the pit, followed by white steam in the moonlight, at the usual hour near 1 o'clock at night. He notified the community by a bugle call. A bright glare developed over the pit. At 2 a. m., a line of fountains lay across the bottom of the pit in a northeast-southwest direction as before but close under the west wall of the pit, and this time the biggest fountain was at the north end of the crack. It shot out its jets diagonally eastward to a height of 225 feet and built up a big pumice cone. The line of fountains was about 1,000 feet long, spraying upward in a cluster of jets that soon became engulfed in the new lake under the west wall of Halemaumau but made a magnificent display, doming up the golden fluid with a boiling 50 feet high, and making concentric and radial cracks of incandescence in the dark crust of the pool, the blocks of which eternally streamed into the center of activity and sank. Meantime there developed an even pattern of bright lines streaming outward like a fan from the huge northern fountain. The rumbling thud of the fountains became deep and heavy with occasional detonations. The cone at the north changed to an armchair in shape, and on the second day the southern group of fountains (left-hand in third and fourth illustrations) went out of action in the forenoon, the lake subsided and left a border rampart, and at 1:10 p. m., February 21, 1929, the eruption came to an end. The two pictures show the new flood on the bottom of the pit from the same point of view as the earlier photographs, the first exhibiting the high activity at the beginning and at night, the second the dwindling activity of the second day after a lava shore line had solidified. The other activities of 1929 will be described in a later issue. T. A. J.

KILAUEA REPORT No. 941

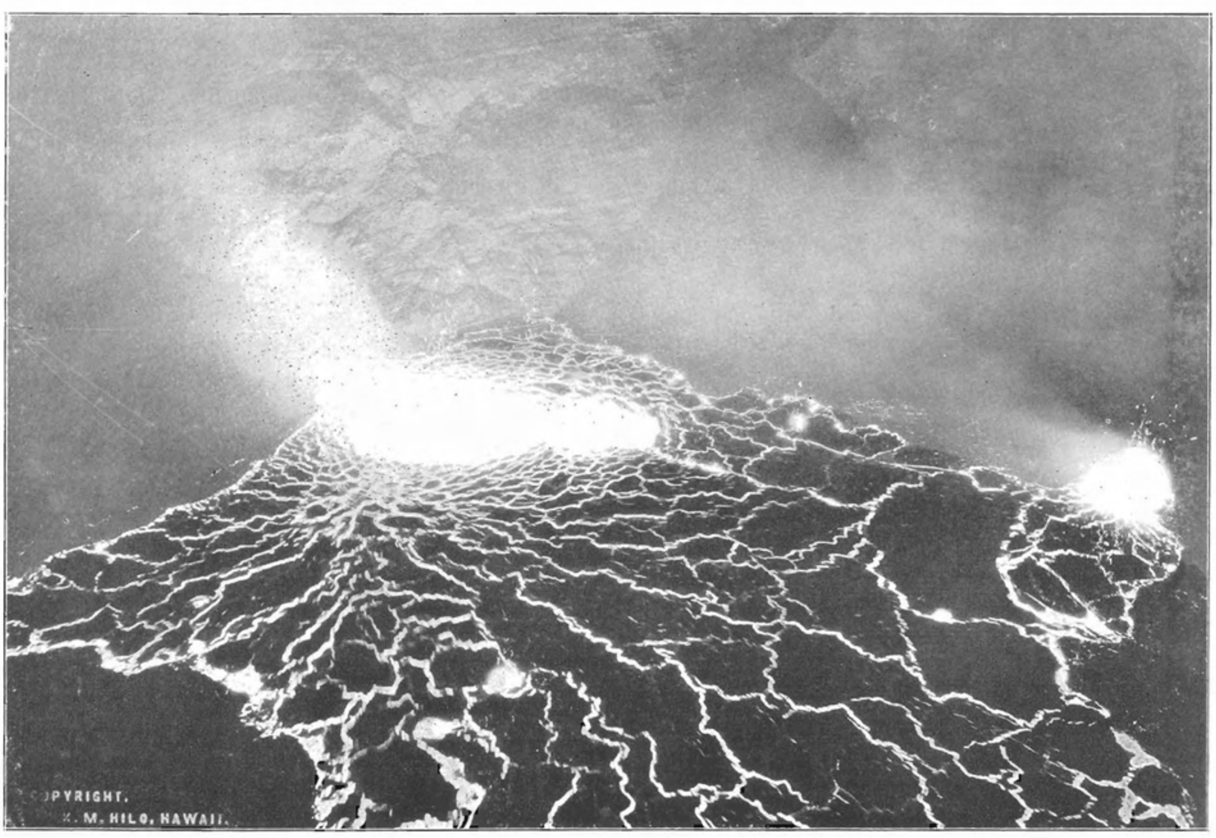
WEEK ENDING FEBRUARY 2, 1930

Section of Volcanology, U. S. Geological Survey

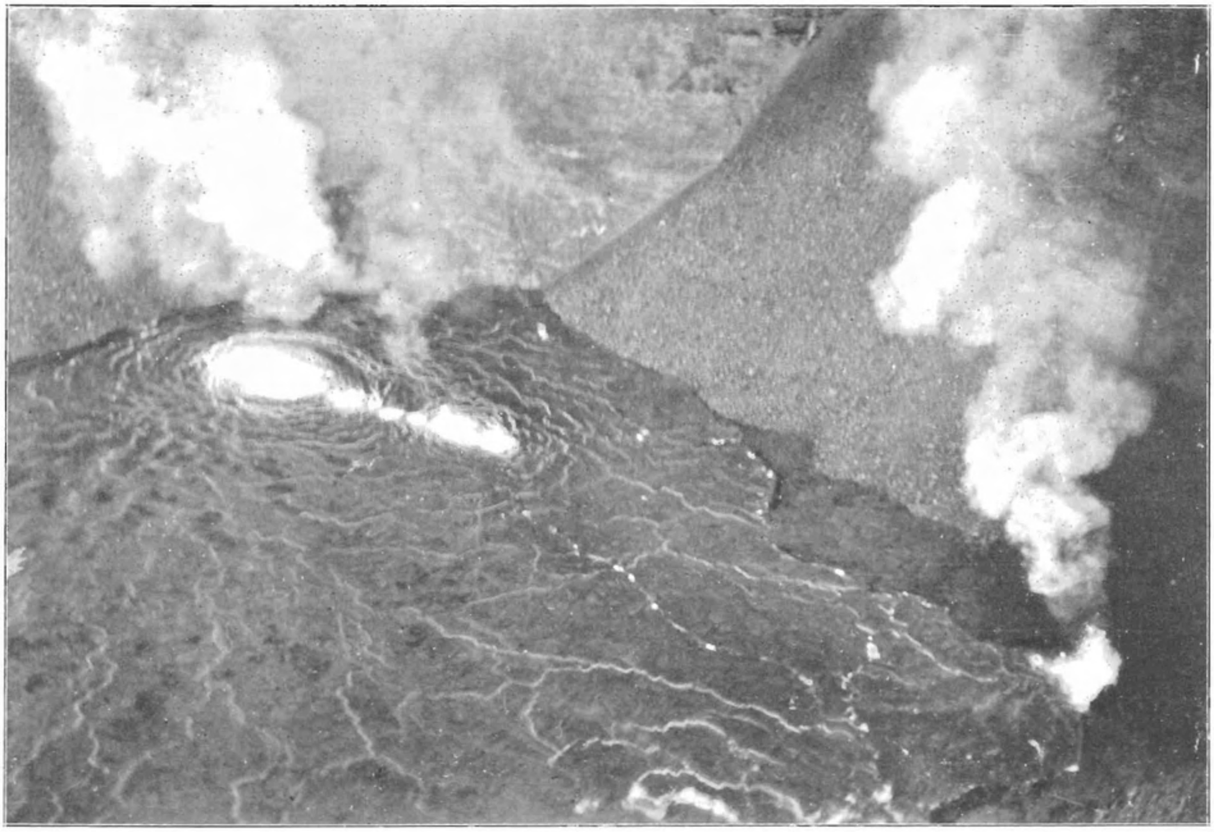
T. A. Jaggar, Volcanologist in Charge

On January 27 at 2 p. m., dust rose from a slide at the northern wall of Halemaumau, and at 3:30 p. m. more thin dust was seen over the pit. On January 29 at 1:30 p. m., the wind was blowing a heavy gale from the south, and the Halemaumau orifice was nearly hidden from view of the observatory by the dust. Great clouds of dust were blowing in the Kau Desert. The wind increased during the day so that wind tremor was strong on the seismograms. On January 31, after a rainstorm, the walls were dark red with wetting, there was the usual steam, and some fresh debris was observed on the northeast talus.

Fifteen seismic disturbances were registered at Kilauea. Seven were tremors and six were very feeble local seisms, three of which indicated average distance to origin 41 miles corresponding to the North Kona center. One very feeble seism indicated origin 18 miles away, possibly corresponding in origin to another feeble shock, origin distance 23 miles, at 2:38 a. m., January 29. A slight shock



Glowing and fountaining liquid lava pool at dawn February 20, 1929. Interior of Halemaumau from the east, big north fountain on right. This buried the floor of July, 1927, to a depth of 64 feet. Photo Maehara, copyright.



This photograph is a daylight view, same scene as the last, at 6:30 a. m. of the second and last day of the eruption, February 21, 1929, when the fountains had dwindled. In the background is the northwest talus. Condensation of fume over the fountains and deep rumble had increased. Solidified rampart shore of lake is shown. On the right is the grotto which had been built high by the large fountain. The source crack lay along the line connecting this grotto with the line of fountains at the left, all of which at first had been a fissure following the edge of the plug left by the July eruption of 1927. The former plug lifts like a cork in a funnel, and the slag froth escapes between the cork and the wall. Photo Maehara.

was more strongly felt at 6:42 p. m., January 29, origin distance 48 miles, probably felt generally on the island of Hawaii. Very feeble, feeble and slight are technical terms of increasing intensities.

Microseismic motion for the week was moderate both E-W and S-W, and tilting of the ground was very strong SW.

JANUARY TILTING OF THE GROUND

At the Hawaiian Volcano Observatory, on the northeast edge of Kilauea Crater, just opposite the Volcano House, the tilting or tipping of the ground as measured with seismographs in a concrete basement was as follows for the five weeks following December 29, 1929. This is expressed as angular change and direction of motion of the plumb line.

December 30-January 5	3.21 seconds SW
January 6-12	1.33 seconds SSE
January 13-19	3.75 seconds NNE
January 20-26	2.06 seconds NNE
January 27-February 2	5.38 seconds SW

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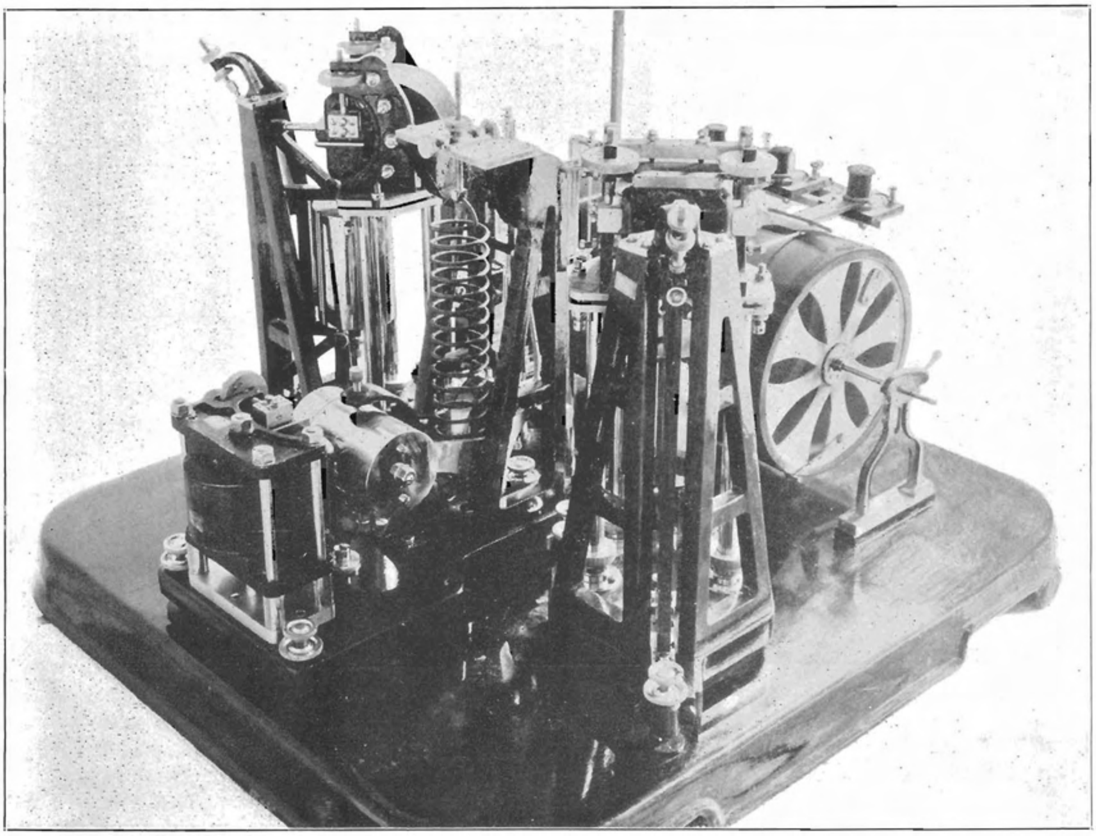
Persons desiring application blanks for membership should address the Secretary, Hawaiian Volcano Research Association, 300 James Campbell Building, Honolulu, T. H.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 268—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | February 13, 1930



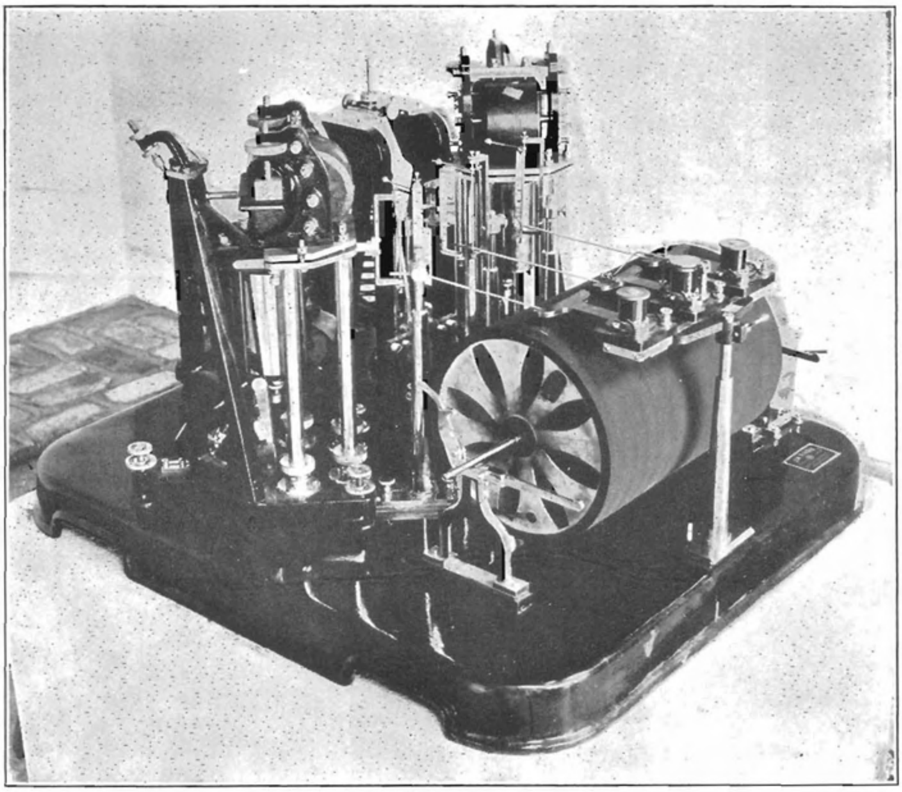
Back of Imamura seismograph as installed at Uwekahuna Observatory, Kilauea Crater. Vertical component pendulum on the left, recording drum on the right. Large gleaming cylinder in background is one of the horizontal pendulums under its damping magnet.

HOW THE SEISMOGRAPH WORKS

There is much misunderstanding about seismographs and earthquakes. One woman visited the seismograph cellar at the Hawaiian Volcano Observatory, and was observed to be looking around in all the corners of the room, seeking for something. When asked what she was looking for, she remarked that she was searching for the main wire. It later appeared that she thought the seismograph was connected in some mysterious electrical fashion with the inside of the volcano. Probably most travelers who see for the first time the excellent little seismograph, made in Japan, exhibited in the alcove of the Uwekahuna Observatory and Museum at Kilauea, as shown in the above picture, imagine it is far too complicated for them to understand. As a matter of fact the principles involved are extremely simple.

The reason the picture looks so jumbled is that this instrument attempts to combine six different things. These are respectively three different pendulums, a damping or clogging apparatus to keep the pendulums from swinging too much on their own account, a recording machine to compel all three pendulums to write their autographs on smoked paper all the time with high magnification of their relative movement, and a time-keeping device which also is compelled to mark the minutes on the paper. Each of these things by itself is very simple, but to make all work in harmony on one piece of paper is like asking a wrist watch to make a record of everything the wearer does.

There are three japanned openwork iron frames in a line across the baseplate, each holding a 13-pound cylindrical weight lightly hung on pivots. These are the pendulums and these are at the heart of the apparatus. Two of them are hung like doors at right angles to each other; their free motion is much like that of the needle holder of a gramophone. If with the sound box turned back, you hit with your fist the side of the gramophone cabinet, the sound box will jump towards your fist. If you hit the other side it will jump the other way. If you let the sound box hang down without any record under it, and imagine it immersed in a tumbler of oil, it will move through the oil by the amount that you have displaced the cabinet, but it will not waggle back and forth afterwards. That is what is meant by damping. It is an oil damper. The machine in the picture uses magnetism for damping, the rounded objects at the top and at the left being horseshoe magnets with a plate between the poles which is attached in each case to the cylindrical weight. The magnetic forces restrain the weight from waggling. The left-hand weight is hung on a spiral spring as shown, and differs from the other two in that its motion is up and down like the child's wooden ball hanging from an elastic band.



Imamura Seismograph, Uwekahuna Observatory, showing the pendulums at the back, the three slender pens, the clock-driven drum covered with smoked paper, and the three electro-magnets (spools) at the right. These lift the pen points once a minute.

This is called the vertical pendulum and registers up-down motion of the ground. The other two are horizontal pendulums and register east-west and north-south motion of the ground.

Now let us look at picture No. 2. This is the same instrument seen from the front. The heavy baseplate is set on concrete, this is on bedrock, and the alcove is protected from wind currents. Three very dainty slender levers protrude from a magnifying connection with the three pendulums. They are the three straight lines that look like strings protruding horizontally from the group of pendulums, and at their right-hand outer ends they hold tiny pivoted steel pens which rest on the smoked paper that covers the surface of the big cylindrical drum. If there is a north-south movement of the ground, the farther pen will move back and forth on the smoked paper 50 times farther than the ground itself moves; the middle pen similarly magnifies 50 times the up-and-down motion of the ground, and the near pen the east-west motion. Accordingly the single sheet of smoked paper will receive a back-and-forth white line for all three motions of the same earthquake, and we may compare side by side at that place on the paper, how much the motion was north-south, up-down, and east-west.

A digression is necessary here, because the reader thinks that the pendulum moves. It is perfectly true that if I move the pendulum with my finger, the pen will move 50 times as much. The seismograph, however, is not designed to ask the earthquake to move the pendulum. It rather asks the pendulum to stand still while the earth oscillates under it. This is what you ask the gramophone arm to do when you move the cabinet sidewise. If the iron door of a basement furnace is hanging open, and an earthquake moves the cellar sidewise, the door at first swings (apparently) in the opposite direction from the cellar. What it really does is to stand still by its inertia, while the furnace does the moving. So it is with the seismograph pendulums.

The time when the earthquake began at the instrument, the time when its vibrations changed from very short tremors to longer movements, the time occupied by each independent back-and-forth movement (known as the "period" of the earth wave), the time when the long movements slowed down to short movements again, and the time when the last trace of quaking stopped, are all important features of a seismogram. The seismogram is the paper record, the seismograph is the instrument itself. It will be seen above that if the paper stood still and an earthquake happened, we would get three short lines scratched on the smoke of the smudged white paper surface. This smoking, by the way, is obtained by merely twirling the paper-covered drum over a smoking kerosene lamp. The three short lines on stationary paper would tell us that there had been an earthquake, and how long its biggest oscillations were, respectively north-south, up-down, and east-west. But it would not tell us how long it lasted, nor at what o'clock it occurred. Here is where the drum comes in.

The surface of the drum is turning around all the time on a screw spindle that passes through the center of the drum, turned by a clockwork at the end of the drum. A fresh paper is wrapped around the drum and started every morning when the clockwork is wound. The three pens are thus writing lines round and round the drum, and the screw spindle pushes the drum along lengthwise, so that when a complete revolution is made each pen is offset a little from its previous position. Thus each pen writes a band of lines, each line corresponding to an hour say, and the band of 24 lines corresponding to the pen's work for the 24 hours of the day. If the ground does not move, the lines are straight and smooth and owe their existence solely to the rotation of the drum. If, however, an earthquake occurs each pen departs from its straight line and writes a zigzag, lasting as long as the earthquake lasts, its back-and-forth scrapings being close together if the earthquake is of quick period, and being far apart if the earthquake motion is slow. This is best understood by reference to the print of an actual seismogram on Page Four. There is an upper and lower band of lines, the upper south-north, the lower east-west. Near the bottom of each band there are big back-and-forth scrapings of very slow earthquake waves that came from a center in southeastern Alaska October 24, 1927. Right in the middle of this there are quick back-and-forth scrapings, the record of a local earthquake here at Kilauea Volcano at 6:20 a. m., feebly felt, on the same day. Possibly the slow wave motion of the big distant earthquake, 2,700 miles away, released the accumulated friction of the local mountain block in Hawaii, which slipped and jarred the island.

In the middle of the close-set lines of the local earthquake will be seen a gap in the record. There are in fact gaps of this kind a little less than an inch and a half apart on all the lines, marking the minutes. These are marked in on the seismogram by the three electromagnets, which look like spools at the right of the drum in the pictures.

The electromagnets are connected by wires through a battery with a big pendulum clock that hangs on the wall of the seismograph alcove. This clock closes a contact once a minute with its second hand, and once an hour with its minute hand, and the electric impulse lifts the three little pen points off the drum for about a second, and thereby creates a minute mark in the form of a gap in the line. A longer gap is made on the hour. The operator, when he puts on the drum in the morning, writes on the smoke the time of starting, and the rest is easy. With these time marks we may measure all the facts of time and duration of the earthquakes, and their several phases.

The picture on the third page shows a simplified single-pendulum seismograph set on a concrete shaking table, which is attached to a lathe chuck, through which in the shop of the Observatory artificial earthquakes may be made. This is a horizontal pendulum, and the big black cylinder is its swinging weight. At the right-hand end, also on the concrete table, are the drum and driving clock with a single writing pen and electromagnet. The lever from the lathe has its motion reduced at the steel rollers underneath the concrete table, so that the very small motions of the ground, which are characteristic of a local earthquake, may be imitated. T. A. J.

KILAUEA REPORT No. 942
WEEK ENDING FEBRUARY 9, 1930

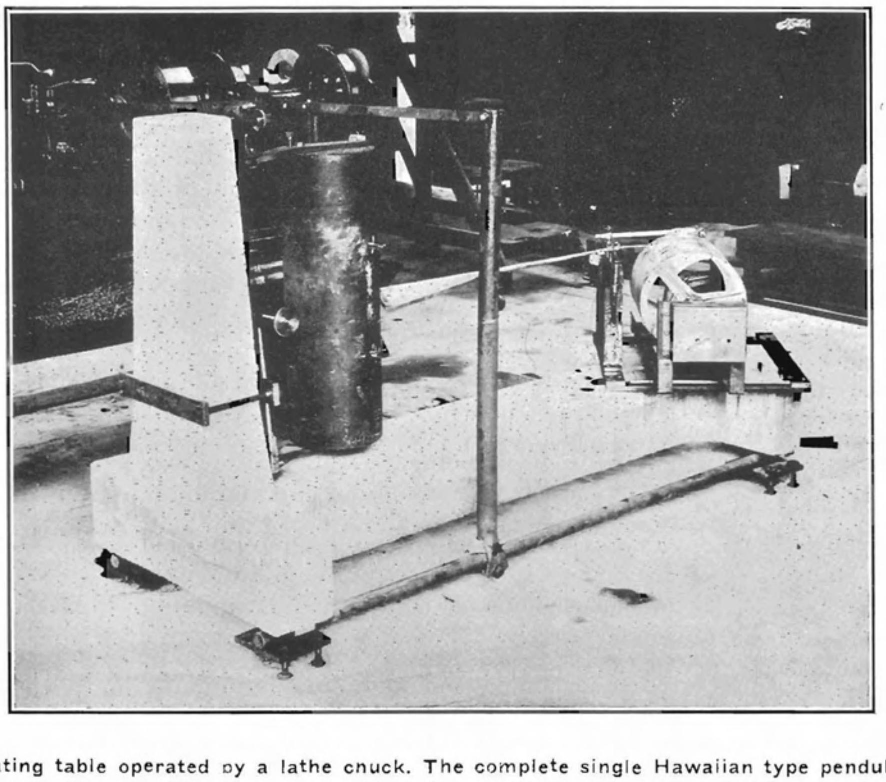
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Halemaumau pit continues quiet On February 5 a few big bowlders from a recent avalanche lay on the southeast talus. A fresh streak of debris was also on the same talus heap. Steam was absent on the crater's floor. On February 8 no changes were observed, and there was very little steam.

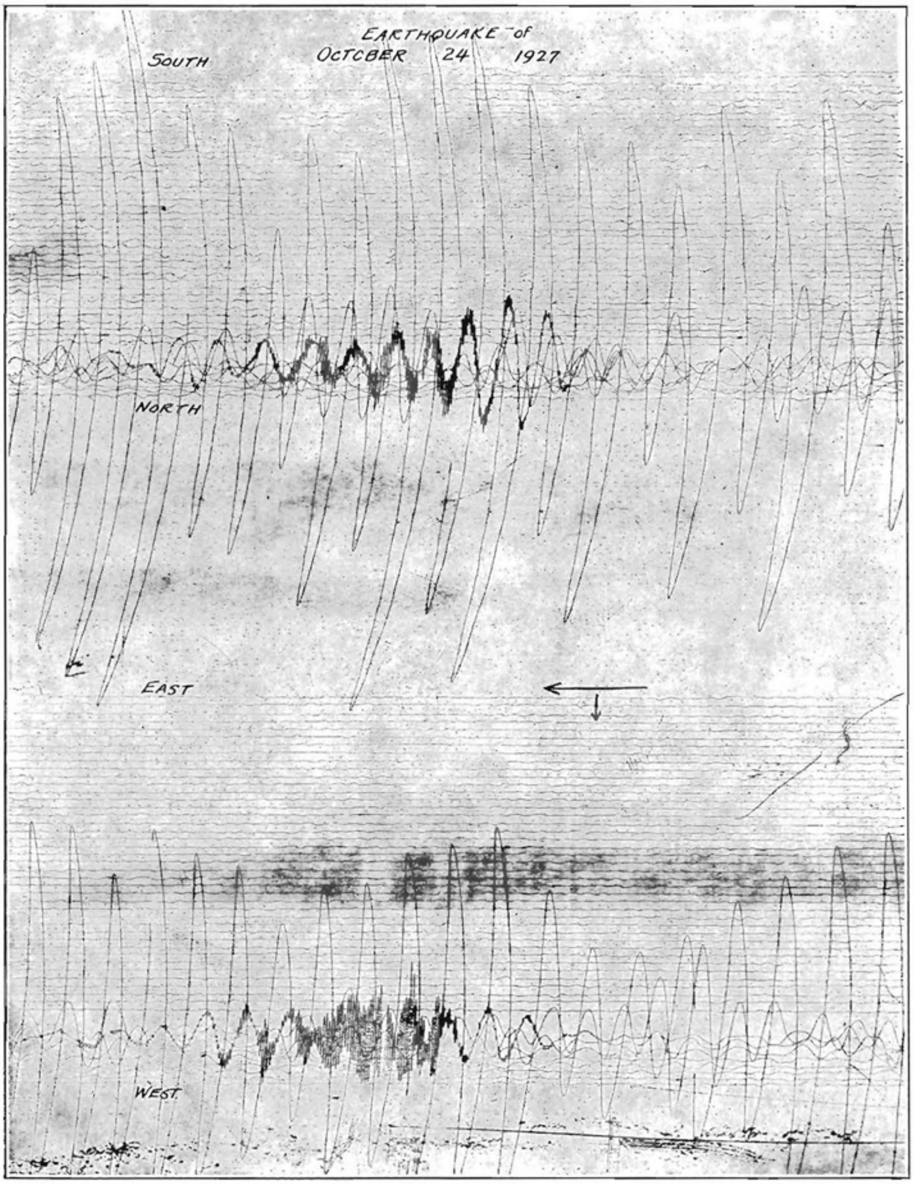
The seismographs at the Observatory recorded eight tremors, two very feeble and four feeble seisms. The feeble shocks were felt in some places on the island, and occurred as follows:

February 2, 6:02 p.m., indicated distance 32 miles
February 8, 8:06 p.m., indicated distance 32 miles
February 8, 8:13 p.m., indicated distance 23 miles
February 9, 9:43 a.m., indicated distance 40 miles

Microseismic motion was slightly stronger than normal early in the week, decreasing to normal on the 6th. Tilt accumulated moderately strong to the northeast, directly reverse to the direction of tilt during the previous week.



Concrete oscillating table operated by a lathe chuck. The complete single Hawaiian type pendulum is hung on the table, along with its recording drum, and subjected to artificial earthquakes. In Hawaiian Volcano Observatory shop.



Seismograms of the two earthquakes October 24, 1927 The upper and lower bands of lines register a night's work of the seismograph. The upper is north-south motion. The lower is east-west motion. The big oscillations shown are the faint slow waves of an Alaskan giant earthquake as registered in Hawaii. The close-set zigzags, like shading in the middle of the large motions are made by a local Hawaiian earthquake, which possibly was "touched off" by the big earth waves. Lines read from right to left, and begin at the top. The breaks in the lines are minute marks, or time signals.

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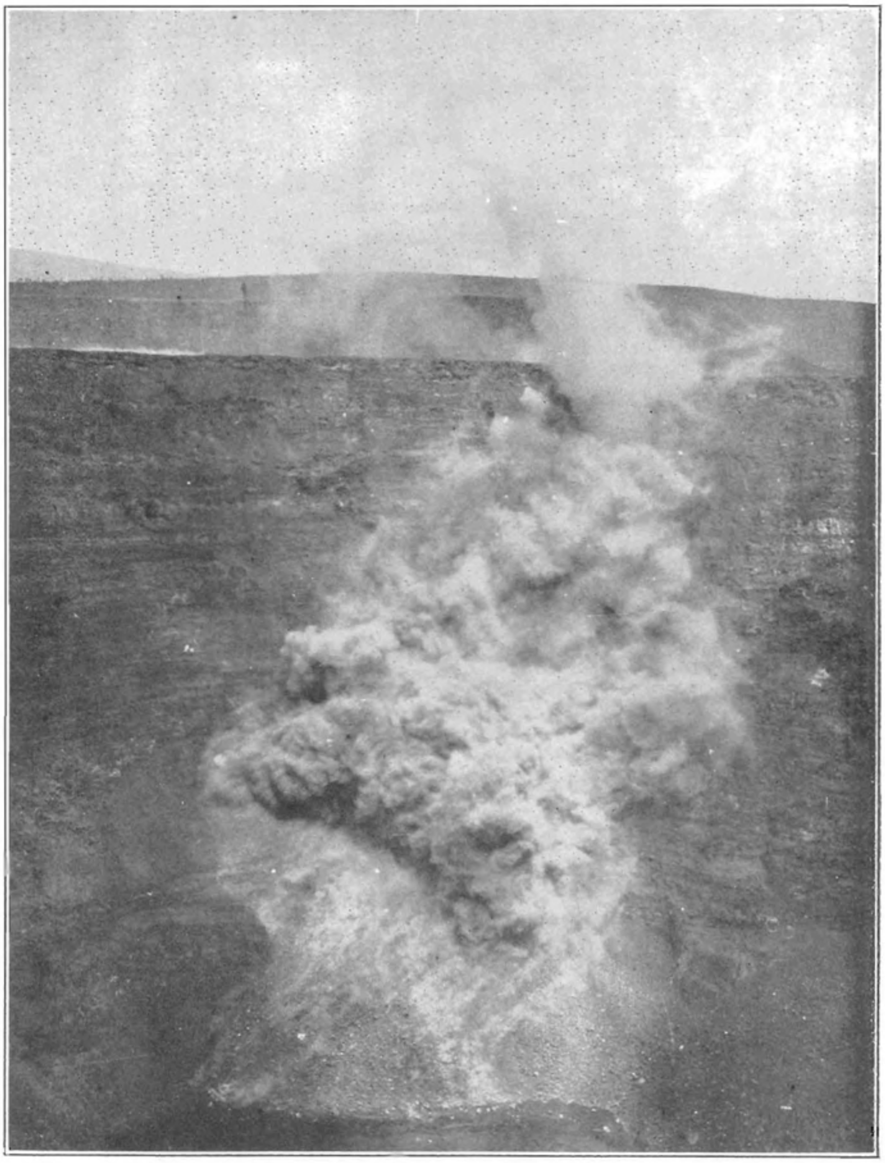
No 269—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | February 20, 1930

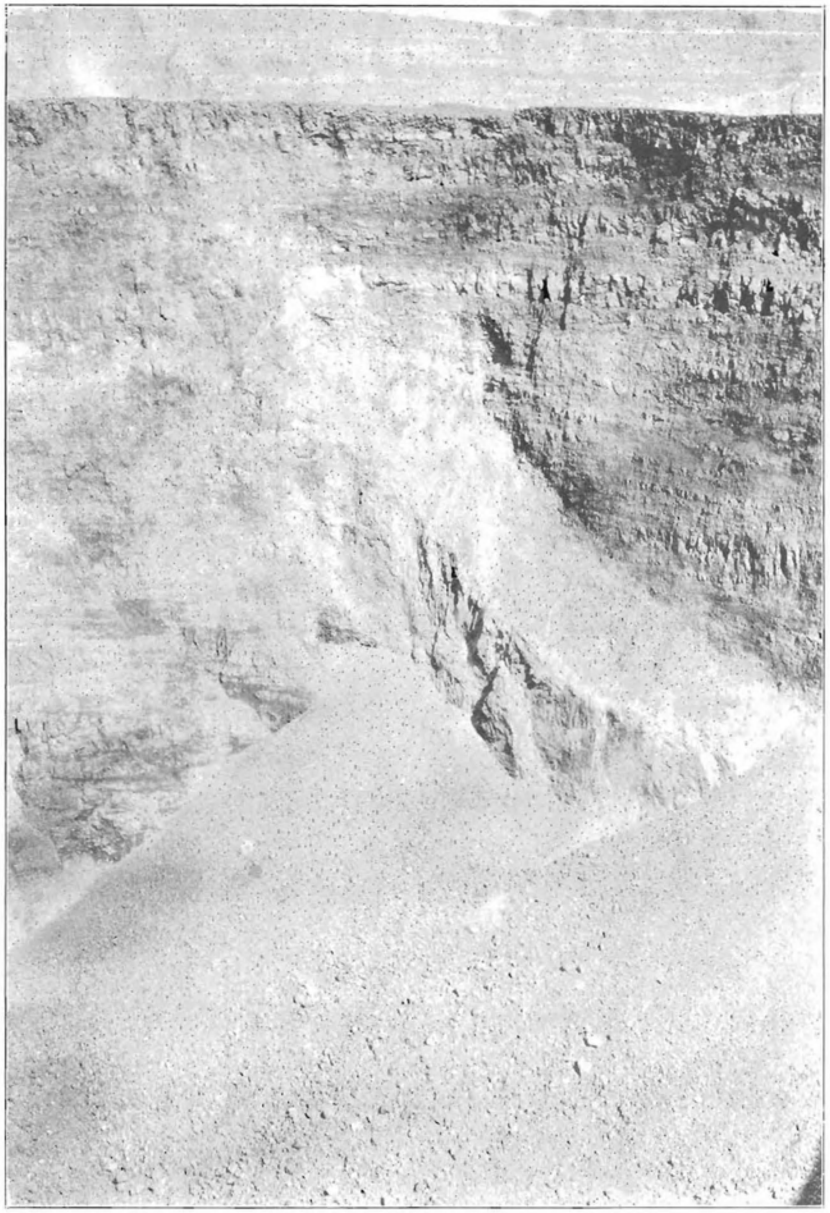


Avalanche falling on northwest talus of Halemaumau 10:27 a. m. October 5, 1927. This picture shows how cauliflower clouds of dust are easily generated by the grinding of falling rock. An exaggeration of this with all the walls falling at once, and steam rushing up, is what happens in an explosive volcanic eruption. Photo Evans.

MEANING OF CRATER AVALANCHES

Many visitors to the fire pit of Kilauea happen upon the adventure of seeing and hearing large or small slides of broken rock that fall from the walls of the pit. A splendid motion picture of such a slide is exhibited to tourists at the Uwekahuna Observatory. The lower portion of the rock wall begins to "work", and black cascades of gravel and dust are seen streaming down the notches to the talus. Then pieces of the wall flake off higher up. Finally a very large piece shows itself to be in process of separating from the face of the wall, with black cascades on each side, the moving portion being a flat cake of wide area often extending to the very top edge. All the rock matter breaks up on its impact below, and during the crushing and grinding of its separation from the wall, hundreds of tons being involved. The talus or slide rock slope below receives the impact, is built up at the top, and tends to become steeper than the angle of rest. This starts a sliding in the debris slope, and great clouds in "cauliflower" form carry the dust boiling above the edge of the pit. These slides have been renewed from time to time during the past six years, becoming very vigorous from no apparent cause.

The photograph on the first page and the map on Page Four show one of these avalanches and the contour plan of its results. The place where this avalanche occurred in 1927 is the wall in the upper left-hand rectangle of the map. The evenly spaced contour lines of the lighter portion of the map of the pit are mostly slide-rock slopes of about 30 degrees inclination. The flat of the bottom lava is out-



Two photographs of the north corner of Halemaumau pit showing the detail of the wall before and after avalanches of February 18 and 20, 1928. The first January 2, 1928, shows two talus cones, the prow of the big sill next above, and a light band above that which is a cross section of an old debris slope with lava flows on the right lapping against it. The second February 26, 1928, shows the same scene after the avalanches had scoured the talus cone and the wall above had flaked off all the way to the top. Photo Wilson.

lined in dots. The rock wall shows close-set and irregular contour lines. This wall exhibits a flat bench of light shading in the upper right-hand rectangles. This bench is the top of a thick sill or sheet of intrusive lava which was red hot but hard at the end of the explosive eruption of 1924, when that wall of the pit broke and started red hot avalanches from this sill. The sill is well shown in the first of the two pictures on Page Two as a rock ledge shaped like the prow of a boat next above the talus slopes and to the right of the sharp pointed talus cone.

When this map was made in July of 1928 the surveys showed that there had been four cavings-in from the rim during the preceding 12 months. Over this northwest talus a strip 700 feet long and containing nearly an acre of rock was missing. The picture on Page One shows how it happened, but a still bigger avalanche here January 11, 1928, had caused the debris slope below to break away as a landslip and flow out over the floor. Other portions of the rock wall, totally changed since the surveys of a year before, were at the southwest, at the north-northeast, and a long, narrow strip three-quarters of an acre in extent at the east-northeast. When we add to this the tremendous southeastern caving in of the rim of the pit which occurred in January of 1929, making it necessary to change the inspection station at the road terminus, it will be seen that two years of wall-breaking had pretty well encircled the pit.

This gradual encircling of the pit by slides was noticed during the early years of the work of the Observatory, when lava was almost continuously present, rising and falling in the pit. The times of maximum avalanching were also times of maximum subsidence of the lava, of maximum local earthquake frequency, and of maximum inward tipping of the ground toward the center of subsidence. The jarring of earthquakes doubtless loosens the wall material, but no conspicuous causal relation whereby earthquakes make avalanches has appeared. In some definite cases, on the other hand, avalanches conspicuously make earthquakes. The greatest of these was the grand avalanching that enlarged the pit during the explosive eruption of 1924. Since then there has been instituted measurement of the width of cracks close to the edge of Halemaumau. In January, 1928, when the big avalanching at the northwest was starting, crack measurement showed an opening of five inches in 11 days, and leveling revealed a lowering in eight months of nearly half a foot for the ground at the edge of the pit. The ground was tipping in toward the crater center during these weeks. During a time of similar opening of cracks in August, 1928, an avalanche of large size occurred which produced a tremor record much larger on a seismograph nearer to the pit than on the Observatory seismographs, and showing other evidence that the slide was the cause of the tremor.

Now if we examine the map on the last page, we shall see these border cracks as dotted lines just back from the edge of the pit, and parallel to the edge in many places. It also appears that the pit is a pentagon rather than a circle, the five angles being at the tops of the taluses southwest, northwest, north-northeast, east and south. Each of these angles has a reason for its existence, and the reasons are evident. The straight sides of the pit southeast and northwest roughly conform to the rift system that extends far out into the desert. The steep southwest wall is a cross fracture between these two more gently sloping rift walls. The northeast side is very steep and clearly determined by the two ends of the big sill which have been places of motion and weakness since 1924. The short north wall is a cross facture between the sill wall and the rift wall, a remnant, so to speak, adjusting the big hole, during its engulfment, to the controlling deep joints. This formation of a pentagon has repeatedly been observed in photographs of the craters on the moon, which are also engulfment pits. The fundamental cause, then, of straight sides to an otherwise circular pit, is a guidance by deep straight fissures or lines of weakness in a process of breaking which is controlled by a small center of engulfment.

The meaning of crater avalanches reverts to a center of engulfment. Why should there be a center of falling in? This takes us back to how a volcano begins. It begins by lava welling up a crack. If it kept on welling up the whole length of the crack it would make an even ridge. It does not do this. Cracks are not regular and the narrower places become clogged. Then the wider places become centers rather than linear fissures. They become centers because the upflow is through the soft material of their own overflow. The crack is buried far below and an oval or circular heap of new lava becomes the dominant structure up which the eruptions are building. If the eruptions were perfectly continuous, without alternations of gas and liquid, and without alternations of rising and falling, there would be no craters. There would be a lava lake eternally overflowing. There is no visible pit when Halemaumau fills to the brim. The pit is the product of a sinking back of the lava whereby the hardened walls fall in, and reveal something of the shape of the well. The volcanologist as a detective has to learn from what happens by cracking, shaking, steaming, and tipping of the outside ground, what is the probable shape of the bottom of the well when the lava retreats.

This is no simple matter, and the accumulated learning of the world from the mapping of cross sections of old volcanoes, from the study of volcanic earthquakes, from the reports of explosive eruptions, and from studies of physical geography of craters, needs study in order to make an accurate guess as to what the lava column would look like if we could cut a slice through the volcano straight down for seven miles. For there is seven miles of lava building if the Hawaiian ridge started in a deep part of the Pacific. Computations suggested that the lava column sank about a mile under Kilauea in 1924, and that previously it may have wedged out right and left several miles in some kind of underground reservoir. The pit was left a rather flat funnel, but some of the flatness is due to the debris plugging the bottom. Our work with instruments is like that of the surgeon with the X-ray and the stethoscope. We must learn the internal organs of a volcano, the chemistry of its digestion and excretion, the cycle of its breathing, and the shape of its alimentary canal.

The avalaches grow more or less frequent as the walls of the pit are more or less undermined. Under the debris is a rock wall of flat slope. Is this a wall, or is it a congestion of gigantic wall slabs? Have these slaps slipped down? And are they jammed about the center? Such a notion of the structure agrees with the fact that eruptions start through crevices high up around the border of the inner pit bottom. Are these slabs the top of a column of debris which fell in, in 1924? And is this whole column being infiltrated with lava? If so, does the column lower when the stiff lava lowers, and so start earth tremors and avalanches? And does it rise when the lava expands, and so stop all undermining?

This would cause the outside country to tip away. Such is the fact when lava rises. And also the avalanches cease when lava rises. Thus it appears that the rock slides are not only what creates these pits and keeps them circular. The slides are also indicative of what is going on far below. T.A.J.

KILAUEA REPORT No. 943

WEEK ENDING FEBRUARY 16, 1930

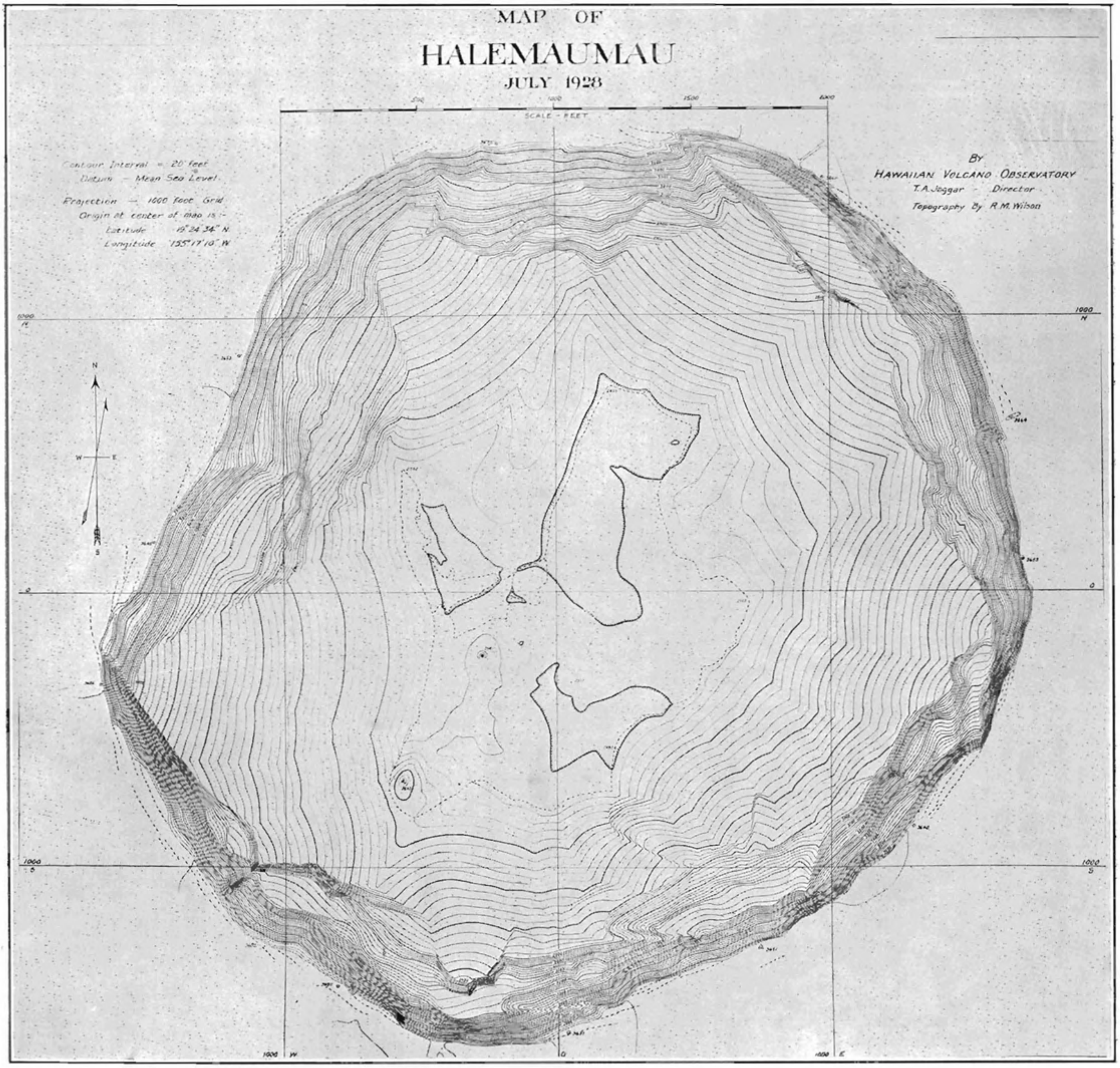
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

On February 11 at 1:30 p. m., gray dust rose from an avalanche within Halemaumau pit apparently from the west side. This lasted for several minutes. Another was reported at the north wall of the pit at 4:10 p. m. Inspection on February 12 indicated that the slides had been voluminous, leaving much dust. At 8 a. m. February 14 a convection cloud hung over the pit, and a similar condition at 9 a. m today, February 17, appeared as a high column of vapor from the northeast wall of the pit, occasioned by unusually calm conditions which had covered the whole floor of Kilauea Crater with a steam fog.

The seismographs at the Observatory registered 16 tremors and 7 very feeble local seisms during the week ended at midnight February 16, two of the shocks indicating origin distance 23 miles and one a distance of 43 miles. These distances correspond closely to Mauna Loa and Hualalai. The tremors did not exceed one minute in duration.

Microseismic motion for the week has been slight, and tilt accumulated strong SW, again reversing the direction of the previous week. Such strong pulsations of tilting sometimes indicate underground lava movement.



Map of Halemaumau Pit, contour interval 20 feet, surveyed July, 1928 by R. M. Wilson. Dotted outline is lava bottom of July 1927. Dotted lines at edge of pit are cracks. Talus slopes make the open contours of the lower area. The rectangular net marks 1000-foot intervals. Bottom is 2482 and top 3692 feet above sea-level. The rock wall extends clear to the bottom in funnel shape northwest and southeast, between the northwest and west taluses, and between the southeast and south taluses. The two black spots in the southwest wall are caverns on the Kau Rift, and the line of four cones across the bottom follows this fissure, which determines the longer axis of the pit.

ILLUSTRATED LECTURES IN HONOLULU

A course of five illustrated lectures by T. A. Jaggar on "How the Volcano works" is in progress in Honolulu, and the dates have been changed. The place is the ballroom of the Royal Hawaiian Hotel, the hour nine in the evenings of February 11 and 24, March 14 and 24, and April 14. These are open meetings of the Hawaiian Volcano Research Association during the tourist season.

THE VOLCANO LETTER

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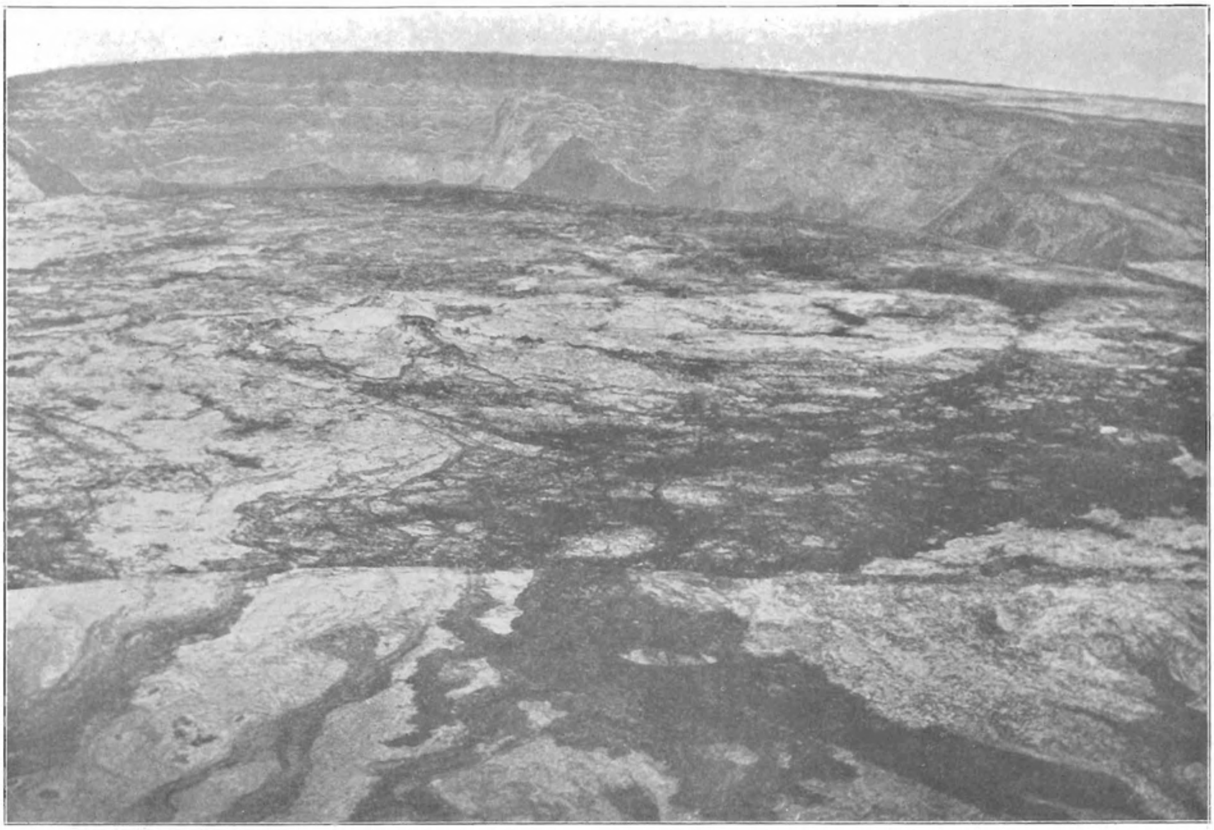
The Volcano Letter

Two dollars per year | Ten cents per copy

NO. 270—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | February 27, 1930



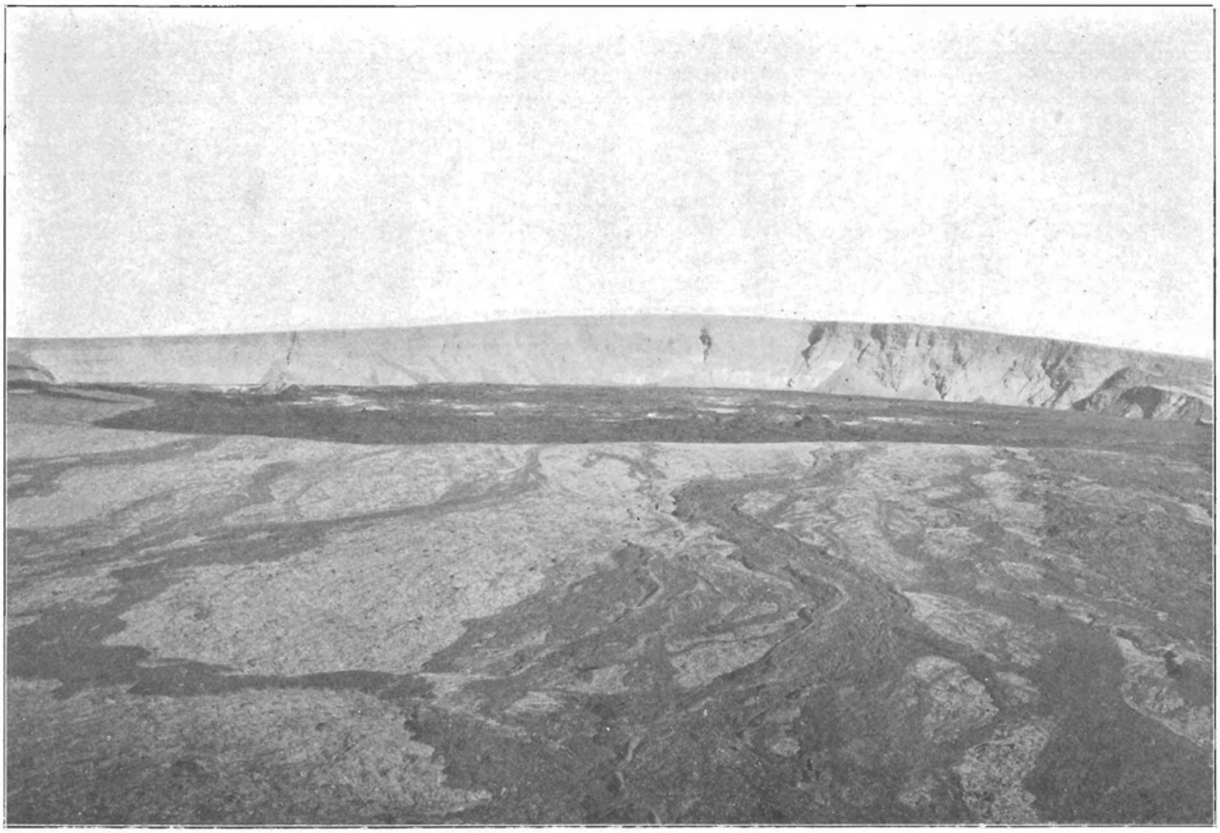
Mokuaweoweo, the summit crater of Mauna Loa, at 8:45 a. m. October 9, 1929, photographed from the east from an airplane at elevation 15,200 feet. This shows part of the northern half of the crater mantled with a light snowfall, the high western wall, and the cone of 1896 in the bottom, with the eruption crack of 1914 athwart it showing a line of spatter heaps of lava. In the foreground are clinker flows of the east edge of the cauldron. Photo Bureau of Aeronautics, U. S. Navy, by permission of Rear Admiral George F. Marvell, Commandant Pearl Harbor, Hawaii.

AIRPLANES FOR VOLCANOLOGY

The volcano Pelee in Martinique developed gas and ash eruption in the autumn of 1929 which was renewed in December (Volcano Letter No. 262, January 2, 1930). The following is a picturesque statement of our modern birdseye viewpoint: "A student of the Imperial College of Tropical Agriculture, who returned to Trinidad January 12, 1930, from leave in the United States, in an airplane of the West Indies Airways, says that Martinique was hidden in a volcanic cloud through which could be caught glimpses of silent villages and deserted cocoa estates. The northern part of the island has been evacuated and public gatherings are prohibited." (London Times January 14, 1930.)

Thanks to the U. S. Army and Navy air services, planes and air photographers have been placed at the service of the U. S. Geological Survey so that mapping of the culture and the drainage of southeastern Alaska, the Mississippi Valley and the island of Oahu in Hawaii, as well as many other places, is more perfect and less expensive than ever before. Repeatedly airplanes with photographers have been supplied to the Hawaiian Volcano Observatory, in times of stress, on the island of Hawaii, and the results have revealed the meaning of lava outbreak on these vast flat volcanoes, in a way that could never be approached by land expeditions. Over Vesuvius both motion and still pictures have been taken of the crater activity. One of the most remarkable monographs on craters ever published is entitled, "Volcano Studies in Java," by N. J. M. Taverne of the Netherlands East Indies Volcano Service, issued in 1926, containing supurb photogravures of 24 craters pictured from the air over a wild mountainous country of savage jungles. The pictures reveal the cones in profile, the gullys on their flanks, extraordinary lava plugs standing in relief, the distribution of hot springs and solfataras in the jungle, double craters and inner benches, details of relief in adjacent peaks which it would take years to map, inner lava floors and domes, crater lakes, flank craters and sharp peaks with lava plugs, and all the manifold complexities of unsuspected pits in the jungle and erosion of ash covered surfaces that might be missed entirely by a land expendition.

During the recent seismic activity in September-October, 1929, on the western side of Hawaii, the writer was privileged to inspect the whole eastern, southern, and western flanks of the island mass in a Naval plane at elevations from 10,000 to 12,000 feet, traveling about 160 miles from Hilo over Kilauea Volcano, across the great rifts that extend down the southwestern flank of Mauna Loa, and then northward over Kona across the divide between Mauna Loa and Hualalai. The relief of the great Hawaiian turtleback mountains, with the straight fault cliffs and sink craters, the lines of circular pits on Kilauea, and the lines of pumice cones on Mauna Loa, all revealing meandering black aa flows like giant serpents leading to the



Mokuaweoweo from the southeast, photographed from an airplane, June 25, 1929, showing on the crater floor the cone of 1914 on the left and the cones of 1896 on the right, both amid patches of solfataric whitish stain. Photo by permission 11th Photo Section Air Corps, U. S. Army.

sea, is in marked contrast to the steep cones of Java. The visibility was excellent on this flight and no trace of new outbreak correlated with the earthquake spasm was found. It would have taken weeks to explore the same territory with pack train, and even then a small outbreak might have escaped notice.

Thanks to the courtesy of Rear Admiral George F. Marvell, Commandant of the Pearl Harbor Naval Station, U. S. Navy, we are permitted to exhibit on Page One a photograph of Mokuaweoweo, the summit crater of Mauna Loa, made by J. A. Pringle with a hand-held 4 by 5-inch camera and 10-inch lens at 8:45 a. m. October 9, 1929, from the east at elevation 15,200 feet. This was photographed from a small scout plane capable of flying at these high altitudes. The far rim of this sink crater is at elevation 13,653 feet above sea level, and the area is coated with a light fall of recent snow. This serves to exhibit on the floor of the crater the old cone of 1896, cut across from left to right with the gash and line of driblet cones that were formed in 1914. In the foreground is the east edge of the crater with aa flows, and the dark objects under the distant cliffs are talus slopes. If there had been new activity it would have appeared as spurting lava sending up clouds of blue sulphurous gas.

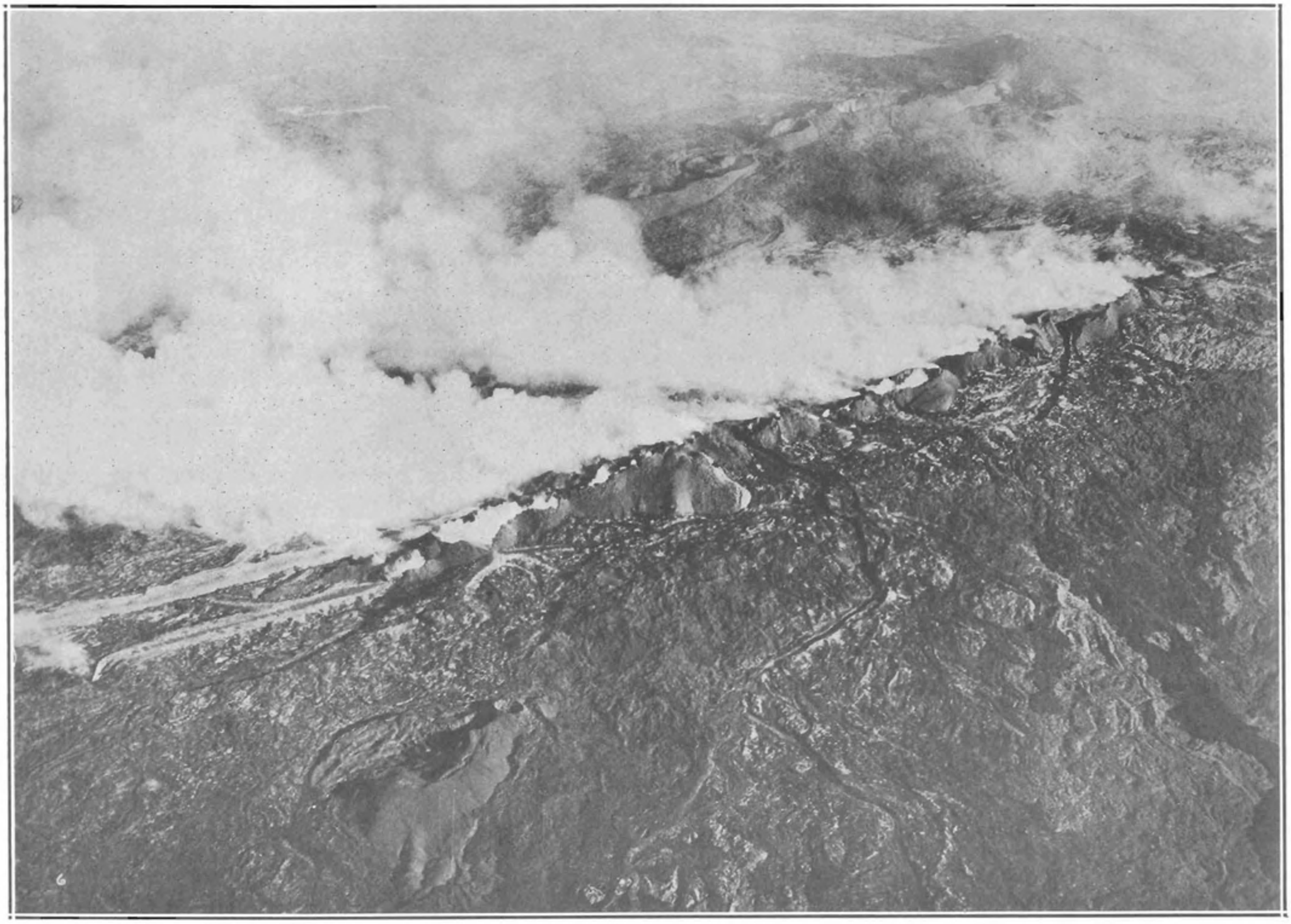
It is of interest to compare this same scene, photographed without snow from a greater distance by the Eleventh Photo Section of the Air Corps, U. S. Army, June 25, 1929 (Page Two). Here there is sulphurous stain on the black lava floor of the crater, and as this picture is taken from the southeast the 1896 cones appear on the right and the cone built by the large fountain of 1914 is shown at the left. The angle in the high cliffs at the back where the white expanse changes to shadowed bluff, is the angle in plan between the southwestern and northeastern rifts of the Mauna Loa dome. Extended down the mountain the northeastern rift is the seat of a line of cinder cones that poured flows toward Hilo in the nineteenth century. On the other side of the mountain the Kahuku rift gave vent to an increasing succession of flows from 1868 to 1926, the later ones devastating portions of South Kona.

The photograph on Page Three follows the eruption of April, 1926, down the southwestern ridge of Mauna Loa and presents a most comprehensive picture from the air revealing how the mountain ruptures along a belt of parallel cracks. This place is the source, about 7,600 feet above sea level, of the actual flood of slag which swept down on the village of Hoopuloa at the sea shore, and destroyed it. The aviators were flying along the southeastern side of the rift belt and the wind was blowing from the eastward so that the fumes sweep off to the west in the picture. In the foreground is shown an old cone containing a large crater and two smaller ones over a crack in general parallel to the active fissure, and in the background the line of dead cup craters, also parallel to the 1926 rift, is the scene of the tremendous eruption of the Alika flow of 1919. Here then are several active cracks parallel to each other, all constituting a rift belt, or fractured zone of the mountain, several miles wide. The active crack of 1926 is very straight and had built up a dozen cones each 50 to 75 feet high along about two miles of length shown in the picture. The right-hand end is up the mountain and the left-hand end shows two white streams of lava flowing in very straight courses down the mountain. The nearer one is flowing along the fissure and has found an open vent on the fissure into which it cascades. There are other live streams behind the smoke, vented by the middle and lower cones shown. The upper cones on the right have gone out of action, and one of their dead river beds is shown in the lower right-hand part of the picture. All of the live streams were distributing over the flat upland, but they united in a single torrent when they passed over the shoulder of the mountain and went down the steep slope through the forest into South Kona. A characteristic detail of the actual lava river is the dark line of rafts and partly congealed crusts carried down the middle of the stream, while the border portion remains bright and glowing with escaping gases along the belt of friction on the banks.

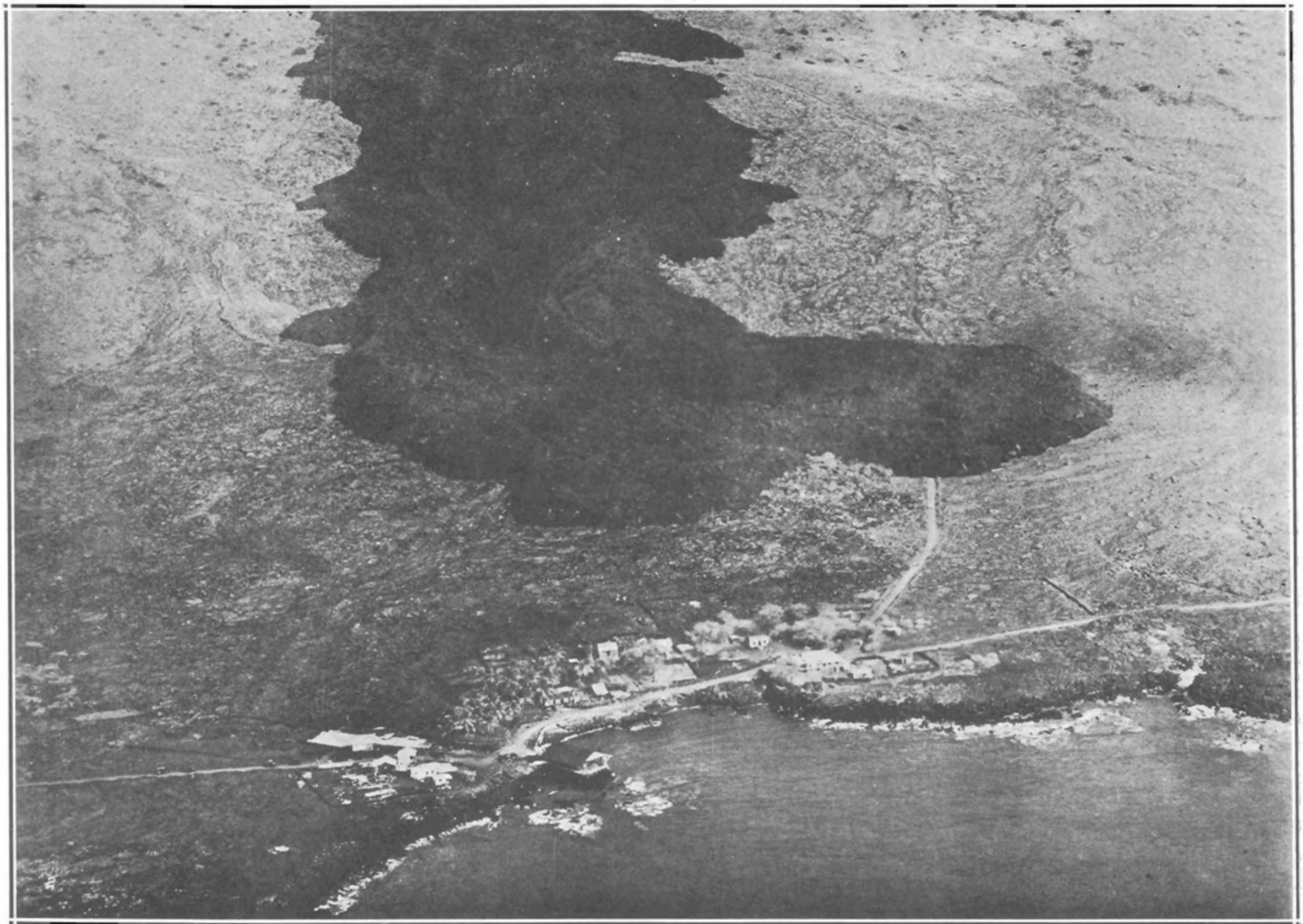
These pictures illustrate the alignment stage of volcanic outpouring, before the accumulations have built high enough to obscure the fissure and to produce a dome rather than a ridge. There are many heaps and pittings along fracture belts on the moon which are strikingly similar to the detail of this Mauna Loa fissure eruption. It is the occurrence of pits in direct relation to fracture lines around the edges of the big craters, and to straight fault fissures, on the moon, that effectively denies the validity of the impact theory of lunar craters. This theory imagines pits to have been made by the impact of meteorites. When the pits are definitely grouped along fractures, and smaller ones are structurally related to the lines of breakage around the edges of the bigger craters, it is incredible that meteorites should have sought out lines of cracking for their impacts. There is every reason for believing that the lunar craters resemble the Hawaiian pits in a sequence beginning with rampart rings of large diameter, and ending with small pits along curved fractures, the curves being guided by the older and larger domes and rings, which broke down when they became decadent.

The last air picture of the Army aviators gives a wonderful map of the western shore of Hawaii at Hoopuloa April 17, 1926, at 4 p. m., about 12 hours before the front of aa lava entered and burned the town, obliterated the harbor and the road, and crushed and buried the wharf. Here the winding stream through the flow is only faintly seen, and the main character of the advancing fronts, 20 to 40 feet high, is that of a caterpillar tractor. An upper layer of bowlders and gravel is rolled forward on a viscous red-hot paste inside, tumbles down at the front in a debris slope, and this is eternally overridden by the advancing mass for which it lays the track. The flow consists of four different mechanisms. There is the main river, the overflow fields of clinkery bowlders, the main front, and the subordinate fronts at the sides of the flow which build lobes and widen the slag flood as a whole at the expense of its height. It is interesting to observe in this picture the two ancient lava rivers right and left of the 1926 stream. It is the notch between their two deltas that had created Hoopuloa Harbor. It was the valley between their two heaps that guided the Hoopuloa flow straight down on the village which had unwittingly assembled its houses in this fatal lowland. Exactly the same lesson has been taught again and again by Vesuvius, and never has been learned. The lowlands and bays are attractive to the vine growers and the fishermen, but if they sought safety in a volcanic land they would be compelled to rebuild on the ridges and the points of land.

T. A. J.



Southwest slope of Mauna Loa giving vent to fissure eruption of lava April 18, 1926. This is the rift source of the lava flow that destroyed Hoopuloa fishing village. The line of cones is at elevation 7,600 feet, photographed from an airplane looking north showing lava source of 1919 in background, ancient cone in foreground, live lava streams on left, and dead flows of the new eruption on the right. Photo 11th Photo Section Air Corps U. S. Army.



Airplane photograph of Hoopuloa at 4 p. m. April 17, 1926, 12 hours before the village was buried. Aa lava flow with front 1,100 feet wide, 30 feet high, advancing 3 feet per minute. The tongues would push forward now here, now there. The two old lava stream beds on each side show how the new flow crept down the valley in between. Photo 11th Photo Section, U. S. Army Air Corps.

KILAUEA REPORT No. 944

WEEK ENDING FEBRUARY 23, 1930

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

Many avalanches have occurred during the week at Halemaumau. The whole north wall has been working between the niches extending upward from the tops of the north and northwest taluses, rocks trickling almost continuously. Dust from the slides lay thickest on the west side of the floor. Avalanches were sometimes heard at the Uwekahuna Observatory, the rumbling of the sliding masses of debris preceding by several seconds the appearance of the dust clouds above the rim of the pit.

Cracks along the east rim show a slight widening, and one of the measured points, No. 14, widened nearly two feet since December 4, 1929. Here the ground shows much cracking and settling, as though this end of the big sill were working in sympathy with the north end. Few slides have been noted here, however

There was increase of copper salt southeast noticed February 17. With dry weather steaming has been very slight at Halemaumau.

There were 13 tremors, nine very feeble seisms, and one slight seism recorded by the seismographs. The slight shock occurred on February 19 at 5:42 p. m., with indicated distance to origin 27 miles. and was felt strongest in Kau District.

Microseismic motion was slight. Tilt accumulated moderately SSE.

THE VOLCANO LETTER

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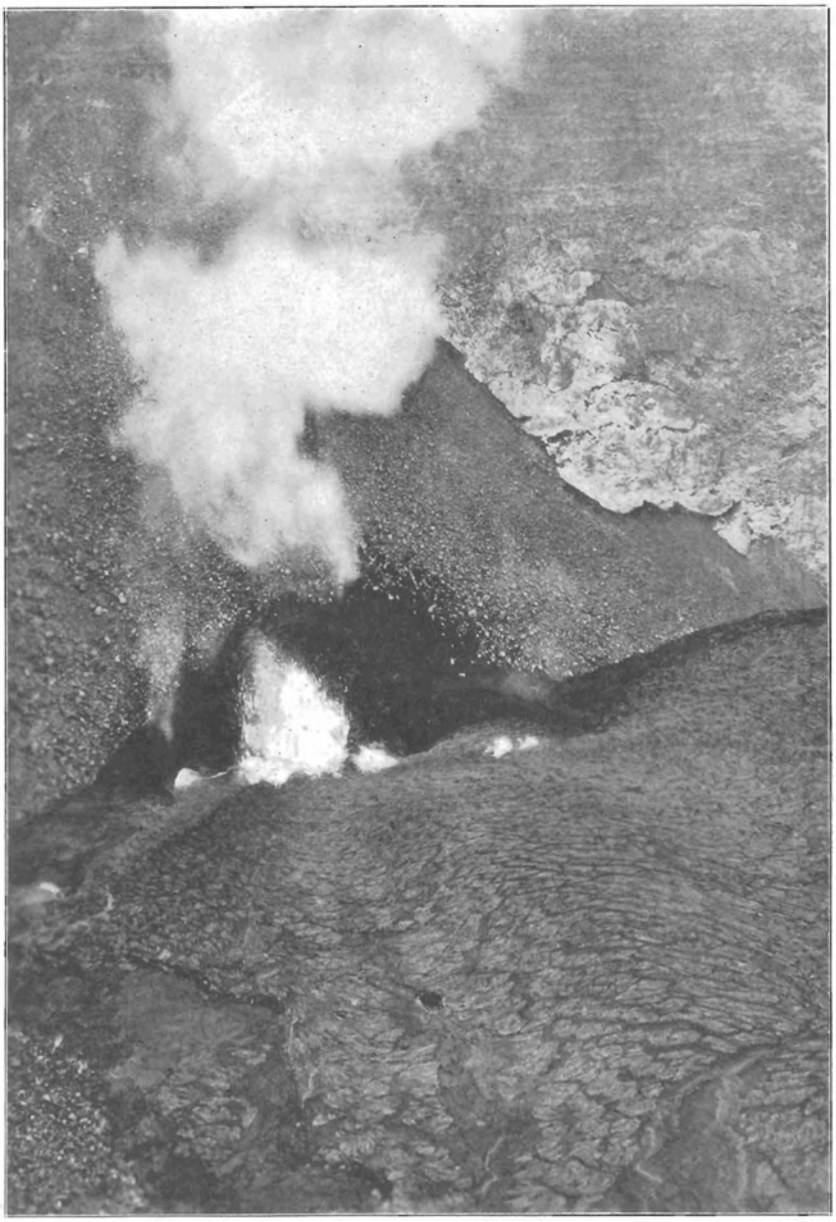
No. 271—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | March 6, 1930

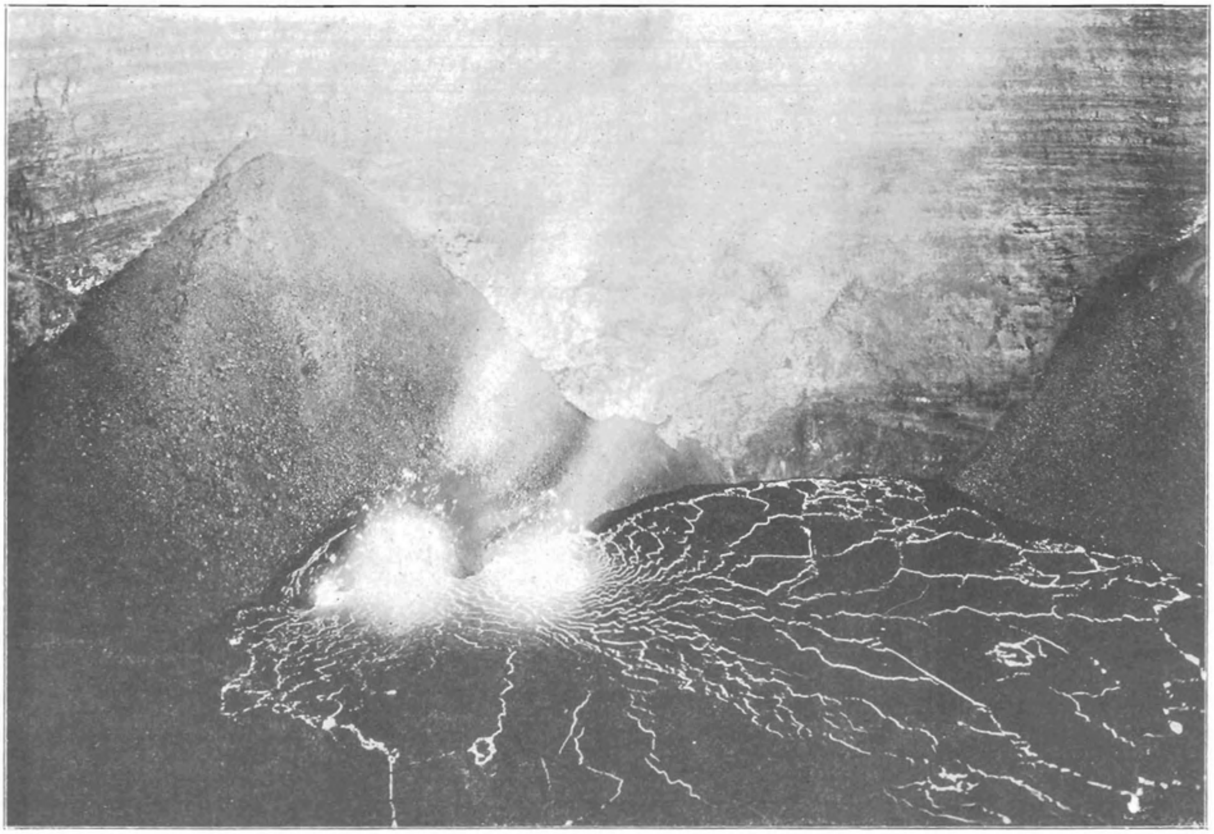


Interior of Halemaumou pit July 28, 1929, showing west wall, the great west talus slope the triple fountain niche with condensing fume, and the built up rampart around the borders of the new lake. Photo M. Furuya. Copyright.

KILAUEA ERUPTION IN JULY, 1929

The fiery activity of the bottom of Halemaumau pit, the inner cup of Kilauea Crater, which was described in Volcano Letter No. 267 as being so brilliant in February of 1929, now seems to visitors to be a myth, particularly as recent avalanches coated the black lava floor with pinkish dust. But the inrush of lava in spectacular fountains was not limited to February of last year. The process was repeated during the last week of July, with a performance of magnificent fireworks that lasted four days, when thousands of automobiles brought a vast flock of visitors from near and far to stand spellbound night and day on the edge of the fire pit, like a congregation of worshippers. At such times the psychological effect on the community is one of the wonders. The Observatory workers surveying at the far edge of the cauldron, looking across at the tourist station, see a stationary line of human beings four deep in coats of many colors, fringing the top edge of the abyss. Behind them is a steady stream of newcomers, and still farther back the endless snaky line of motor cars winding up the cliff, like ants at the approaches to an ant-hill. And at night the ants are all aglow in their progress, and those clustered on the rim twinkle like fireflies with their flashlights, while the volcanic fires illumine the line of white faces stationed motionless above the cliff. And the cliff is flooded with glaring rosy light.

This July outbreak developed its maximum inflow of



Halemaumau at dawn July 28, 1929, showing the active grottoes and bright line pattern of new lava lake with the west and northwest taluses in the background. The active belt of February had been along the base of the right-hand talus shown (see photograph Page Three). The new active crack was along the base of the left-hand talus. Photo Hilo Photo Works.

lava at the western edge of the floor of February, and on a line of cracking intermediate between the February fissure and the crack straight across the middle of the pit which had been the source of the 1927 inflow. This can be understood by an examination of the picture on Page Two, where the line of the new July fountains is parallel to the base of the big left-hand talus cone. Comparing the picture on Page Three it will be seen that the February fountains extended from the extreme right, which is the north corner of the floor, to the big belt of boiling lava that lay under the wall between the two taluses. This last photograph shows the shape of the lava pool of February and the floor left behind when it cooled off. The new crack of July followed the upper left-hand shore line of the pool shown on Page Three, that is, the lava cracked its way up one margin of the February fill, doubtless lifting that fill as a wedge-shaped cork and tipping it a little away from the western talus slope. It may have been the same mass of lava, still liquid below, recharging itself with gas until it could lift the plug.

What happened in July to inaugurate the new eruption was, firstly, a series of very small earthquakes a few minutes apart about 4:35 a. m. July 25, 1929, registered on the seismographs but not felt at the Observatory on the edge of the greater crater next to the Volcano House. These little jarrings were each accompanied by a tilting of the ground to the east. Then spasmodic tremors developed in the lines written on the smoked paper of the instrument by the tiny steel pens, and after 6:30 a. m. this became a strong continuous tremor well known to the seismologist as the volcanic vibration which is a sure sign of lava fountains in Halemaumau pit, two miles away. At 6:10 a. m. a cloud of bluish smoke was rising from the pit.

The observers at once drove to Halemaumau and found inside the pit two fountains of lava spurting high from above the lower edge of the large western talus cone. The blue smoke that rose from them smelled strongly of sulphurous acid gas, and sometimes there were puffs of brown sulphur fume. Then the new heat made a billow of moisture cloud shape itself high above the pit. The fountains gained strength, always sending a cascade down to flood the February floor of the pit, and began to fling blobs of pumice-like lava 200 feet into the air, along with strings and shreds of brown spun glass. This material falling back built up a greenish brown mossy bank against the slide-rock slope. New lava vents opened between the two groups of fountains and the glowing melt oozed up through the crevices of the slide rock, trickled down to the floor below, crusted over, and left a glowing hole at the top and a bright cavern at the base. From this cavern a steady stream of golden fluid poured. Within an hour two-thirds of the February floor was covered.

The next event was a tunneling, under this floor, of the new lava, which ridged up the old slabs like a mole hill and sent a blast of gas out through a small orifice with a roar. Then sputtering lava fountains broke through the cracks along with flames and hot brown fume, and the roaring became spasmodic. By 8:30 a. m. the fragments of slag from the big fountains were falling forward on the new pool, the jets rising with a slow, majestic, steeply curved trajectory, of bright blood-red color, and made up of light weight material which fell lazily. By noon there were whirlwinds at the edge of the pit created by the tremendous updraft over the hot lake, and one could collect pellets of brown pumice, some of them two inches long, which were falling outside of the pit. There were also many glassy needles sometimes clustered together in straight sticks resembling golden straws. Tangles of Pele's hair were falling. This is made by the sputter and bluster of the gas rushing through the puddles of glass of which the fountains are composed, and so spinning siliceous cobwebs.

Quickly the older floor became covered ,and it was possible to estimate how deep was the new fill from the peak of the cone of 1927 which stands 2,643 feet above sea level near the south edge of the February floor, and from the February grotto of the north fountain which had built up a high bank 2,635 feet above sea level. There was a terrace 30 feet high left by slumping in February, and this new fill of July had 30 feet of central saucer to fill up before it could surmount the terrace. On the second day, July 26, the new lake surrounded the remnant peak of the 1927 cone and about 10 a. m. it half encircled the north grotto heap of February, 1929. During the first 24 hours the lava rose 44 feet, 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. After 85 hours of inpouring, the afternoon of July 28, and just before the eruption stopped, the maximum elevation of the new lake surface was 2,640 feet above sea level, or 94 feet above the floor it had flooded. This entirely drowned the grotto heap of February, and left the 1927 cone protruding only three feet above the new fill. Then there was a sinking back, leaving a border terrace as before and lowering the central floor about 40 feet.

The eruption remained very brilliant at night during the three evenings of activity. Glowing cascades poured over ramparts along the edges of the new fill. The source fountains built up grotto niches like armchairs as shown on Page One. The surface crusts of the lake cracked up and foundered, and as in the February eruption there was a streaming-out of the surface skin on the slag pool making radial bright lines incessantly in motion away from the source region of the fountaining jets. The built-up spatter walls at these fountains would cave in and leave red-hot walls. A tropic bird flying around the interior of the pit was overcome by the gases, fell into the lava lake, and it was a pitiful sight to see it burst into flame. Broad spatter banks were built back of the large fountain group. Once or twice a fall of rocks occurred at the north wall of the pit. The source fountains finally developed three niches as shown in the pictures. The lava would slop down, making a glistening bank in daylight against the talus slope. This bank was eternally breaking down in red-hot landslides. Finally irregular clotted crust islands were left over the surface of the floor. The bottom had increased in length from 1,500 feet to 2,100 feet, and in width from 1,000 feet to 1,700 feet. Its area is about 50 acres, the volume of frothy lava that poured in, in three and a half days, was 127 million cubic feet, and the new rock that remained after shrinkage was 98 million cubic feet, equalling about 8 million tons of new matter. The pit before had been 1,105 feet deep, afterwards it was 1,050 feet deep.

T. A. J

KILAUEA REPORT No. 945

WEEK ENDING MARCH 2, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

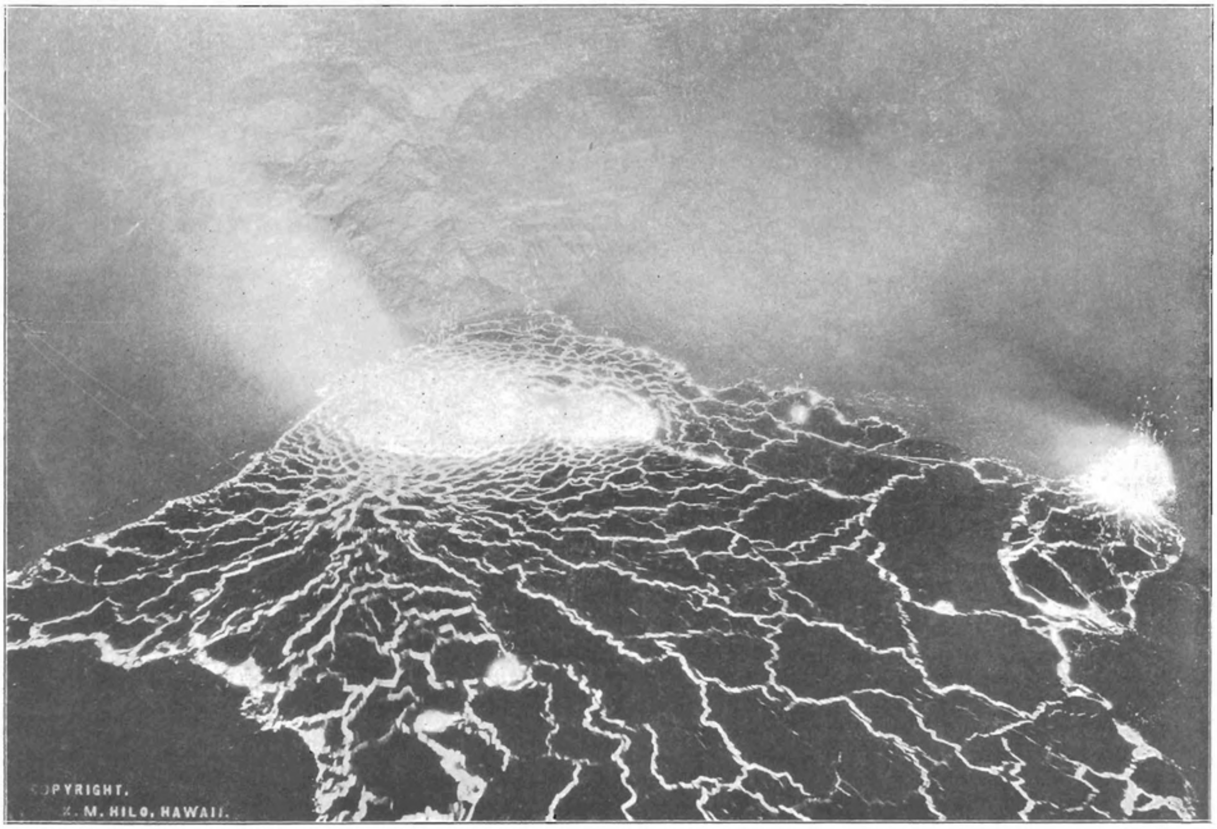
Little of importance has happened at Halemaumau pit during the past week. On February 25 the dust on the crater floor had been washed away by heavy rains. Dust from slides was seen occasionally during the week, notably at 12:30 p. m. and 1:08 p. m. February 26. Vapor was notably absent from the usual places March 1.

The seismographs registered three very feeble local seisms indicating distances of origin 34, 44, and 51 miles; and 8 spells of tremor. Microseismic motion increased February 27-28 along with strong northeast wind, and has otherwise been moderate. Tilting of the ground was strong NE.

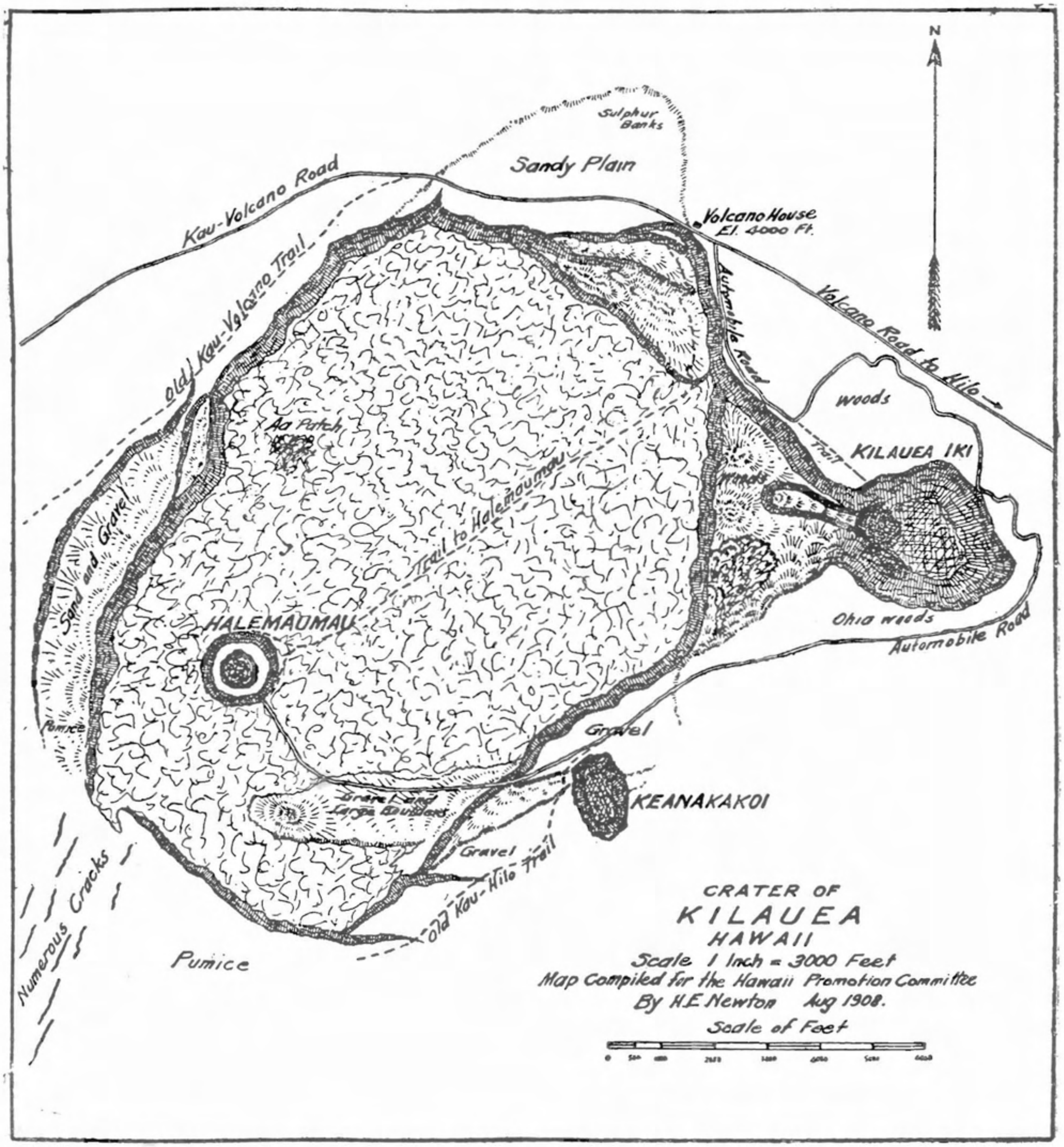
FEBRUARY TILTING OF THE GROUND

At the Hawaiian Volcano Observatory, on the northeast edge of Kilauea Crater, just opposite the Volcano House, the tilting or tipping of the ground as measured with seismographs in a concrete basement was as follows, expressed as angular change and direction of motion of the plumb line:

January 27—February 2	5.38 seconds SW
February 3—9	3.03 seconds NE
February 10—16	2.66 seconds SW
February 17—23	1.39 seconds SSE
February 24—March 2	5.26 seconds NE



The eruption of February 20, 1929, for comparison, showing approximate outline of the floor over which the new eruption poured its lava. The new eruption source was at the extreme left, and all the area here shown had become cold and solid when the July flood began. Photo Maehara. Copyright.



Old map of Kilauea, showing general relation of Halemaumau to Kilauea Crater. Present inner pit is much larger, and the new Chain of Craters Road now extends off to the southeast.

THE VOLCANO LETTER

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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. 272—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | March 13, 1930

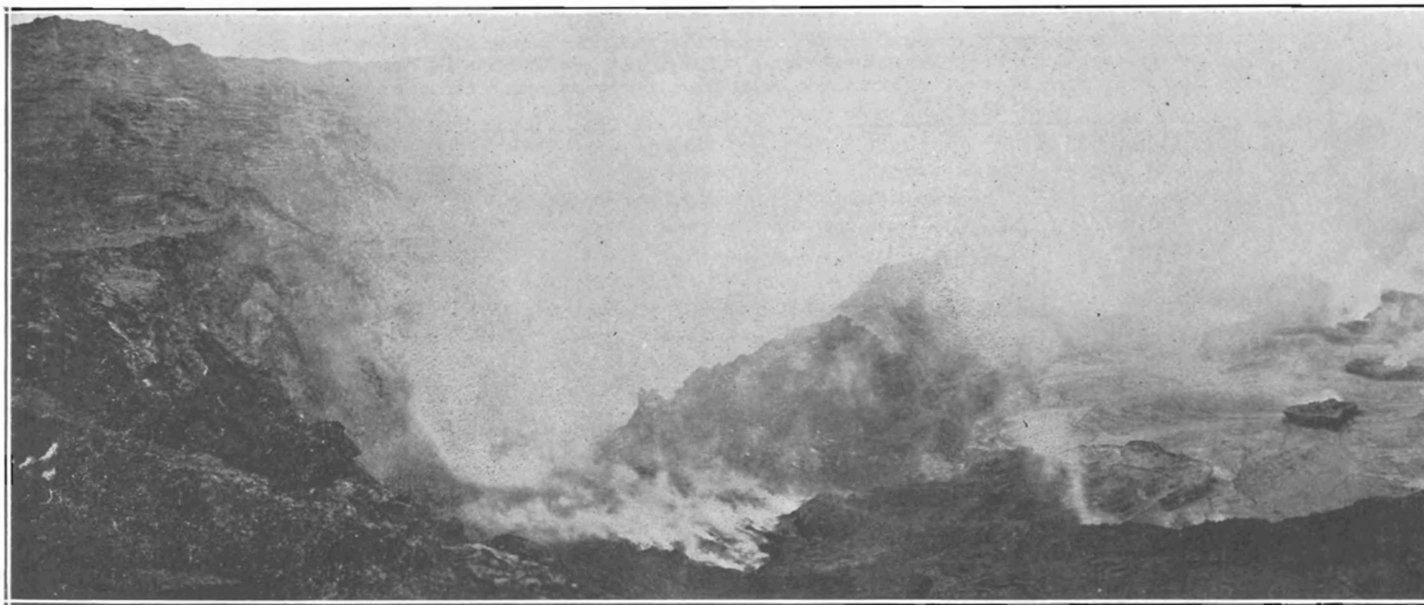
Interior of Halemaumau pit September 20, 1921. Crust of the north pool of the main lake in the foreground is being overflowed with liquid lava by the cracking up and sinking of the surface blocks. The crags are old overflow platforms, inside the pit, swollen up and tilted. Photo Jaggar.

LAVA FROTH AND LAVA PASTE

One of the most far-reaching discoveries made by continuous observation of the liquid lavas in the fire pit at Kilauea is that the lava in motion divides itself into two substances. This fact has been misapprehended in the past, owing to the supposition that the one substance is the liquid or molten material, and the other substance is the portion which has solidified. What are here referred to are two substances, both of which are liquid. Generally their viscosity differs, so that the one substance is highly fluid, and the other substance, forming the bottoms of the lava lakes, the side walls of the lava lakes, and forming the beds and marginal fields of the lava rivers, is semi-solid or pasty but mobile and red-hot. And this mobility shows itself in that the bottoms and side walls of the lava lakes, and the overflow fields of the lava flows all move with the liquid torrents, but with a more uniform pasty flow.

In the photograph on Page One the observer is looking toward the middle of Halemaumau pit from the north rim in September, 1921, when the lava column as a whole was rising. The black cliff in the background is the rim of the pit. There had been a strong lowering of the entire circle of crags and lava lakes during the preceding six months, and now the lava was rising again. The lowering in question had followed the tremendous overflowing of the pit rim in March, 1921. So the two equinoxes had produced risings. When the picture was taken, the very day of the equinox, there was a flood of glowing liquid lava welling over the border of the liquid lake and up through the crusts of the north pool in the foreground. A lake of liquid lava is often crusted over like a frozen pond in winter. The crusts burst apart if the pond below rises, and as the hardened crusts are heavier than the gassy froth beneath, they tip up and sink. That is what is happening in this picture and the jumble of peaks is a part of the paste on top of which the liquid lake maintained an irregular shallow saucer of its own. The platform in the foreground was a part of the rim of this saucer. The flat crusts being flooded on the left were the frozen surface of the main lake. The high peak on the right stood 105 feet above the lake which was boiling and liquid in the central region among the crags. The lake surface stood 75 feet below the pit rim.

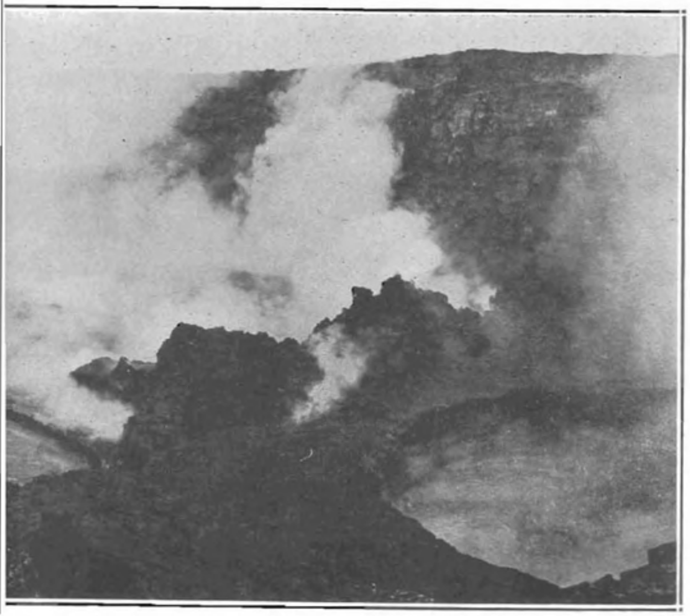
The reader may well ask, "How can a jumble of peaks be a paste? Surely these are floating islands in the lava?" This conception of floating islands is a time-honored fallacy. Solidified basalt has a higher specific gravity, therefore is heavier, than liquid basaltic melt. Much more is it heavier than gas-foamed liquid basaltic melt of the fountaining and flaming lava lakes. Therefore solidified crusts sink, and solid crags and peaks certainly do not float on liquid lava. These solid crags grade downward into a red-hot, dense, heavy substance which from time to time has revealed itself as continuous with the rock of the crags, extending under the liquid lakes as submerged



Halemaumau from the north September 14, 1920, after many months of low and smoky lava. The small island in lava lake is the same as the one suddenly uplifted in the picture below. Photo Hilo Photo Works.

incandescent cliff or bank or shoal. The nature of the revelation has been by sudden uplift, forty feet in a few hours, of the shoreline of a lava lake, or by sudden downward drainage of the lake itself. These processes have revealed smooth glazed surfaces under the lake, and comparatively small wells or tunnels feeding the liquid slag into the shallow lake basin. The half-hardened paste of the inner crag matter is the substance from which these basins are sculptured. All the lake basins are shallow, because the lakes are puddles of rapidly cooling melt maintained liquid by the hot gases which are rapidly escaping. The lakes cool and partially solidify on the bottom and

Island in the central lava lake of Halemaumau which was lifted suddenly March 15-16, 1921, by the swelling up of the lake bottom, revealing a mushroom stem and a broad base. This heaving of the lava paste preceded the gushing of the liquid lava March 18.
Photo Jaggar



at the sides. The side solidification forms a rampart over which the rising lake floods in short-lived fills which stratify. The feeding well, up which the hot lava froth rises through a deep accumulation of this lava paste, has its walls continually congealing inward in proportion to the volume and heat of the oncoming new lava from the depths.

The two pictures on Page Two exhibit a small flat lava islet which lifted itself suddenly just before the intense overflowing of March, 1921. This performance was one of the revelations above referred to. The first picture, in September, 1920, was taken when the lava lake had reached a low position of 280 feet below the rim of Halemaumau, and the jumble of crags and lakes was very smoky. The whole lava column had been lowering during 1920. About the September equinox of that year it started to rise just after this picture was taken. The flat triangular islet represented the top of a shoal in the lake, and appeared or disappeared according as the lake lowered or rose more than the pasty lava column of the crags. The islet was a part of this stiff lava column through which a honeycomb of wells fed the lake. When measurements were made with transit from the edge of the pit during the next six months, both the crags and the liquid rose together, the liquid greatly gaining on the crags and partially drowning them about January 1, 1921. Then there was a temporary lowering when the crags emerged again, but the crags also lowered more slowly than the lake. This kind of alternation is the rule in measurements of the rise and fall of the lava column, and these measurements are part of the proof that we have to deal with two substances in the pit, a slow and steady larger mass of paste, and a more tumultuous and erratic smaller body of froth.

The lower picture, and the map on Page Four show what happened just before the intense effervescence and overflow of Halemaumau of March 18, 1921. The islet had reappeared and is shown on the map just under the words "Cent Lake". This central lake was 110 feet below the rim March 14. Then crags and lakes began to rise. This inconspicuous little island, a few feet across, between March 15 and 16 suddenly lifted from beneath the lake, and became a huge ungainly gray monster with rounded back, flat topped head, and slender neck. This great bulk of lake bottom substance, which was pushed up faster than the liquid in the center of the pit, demonstrated a swelling in the under paste that was exceptional.

During the next 24 hours the crags rose 10 feet, and then came the intense fountaining up of the liquid in artesian fashion so as to fill the whole vast cylinder of Halemaumau to overflowing in six hours. Approximately 283,000 cubic feet of liquid entered the pit in that time, allowing 50 per cent of the space to the hard paste. This would imply an inflow of more than 47,000 cubic feet per hour.

The lifted islet in the third picture stood like a thin-stemmed wine glass on top of the newly uplifted hill of lava dross. The summit stood 40 feet above the lake like a tilted toadstool threatening to fall at any moment. A portion of it broke away the next day. The lower hill was a rounded black elephant's back with a smooth surface and some shore marks steeply upturned. Evidently the stem of the islet had narrowed just below lake level in the days before the uplift and during the uplift the whole mass was toppled over towards the west.

In the cross-section under the map (Page Four), a feeding well is indicated at the southeast, and one of the connecting tunnels following the wall crack, or edge region, of the fill, at the northwest. These tunnels have the same kind of history as the wells. They represent a solidifying inward of the walls of a surface stream of slag, until the stream is flowing in a sewer pipe of its own making. The cross-section shows how much bulkier is the paste or craggy matter, as compared with the liquid. There is good reason, based on experiment, for thinking that the rising liquid gets hotter upward, being heated by reactions between the gases that are escaping from solution to the bubble form, and are increasingly mixing with oxygen. Technically we speak of the paste as the "bench magma," the word "magma" meaning dough, and the liquid lakes or flows as "lake magma." This dual quality of basaltic lava we shall have to consider further in treating of smooth-lava and clinker-lava flows. T.A.J.

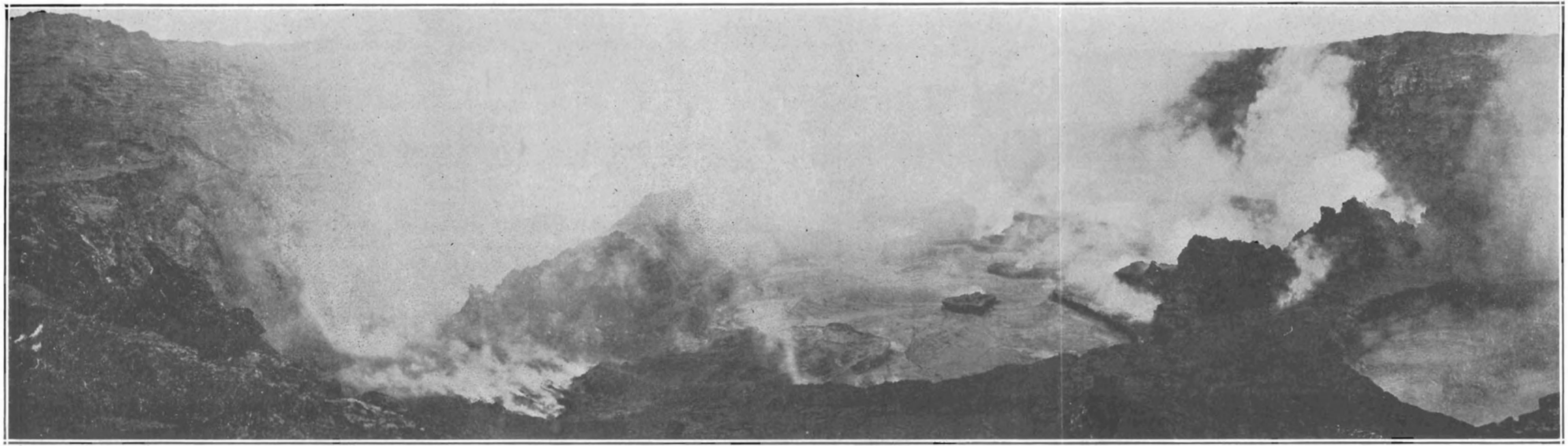
KILAUEA REPORT No. 946

WEEK ENDING MARCH 9, 1930

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

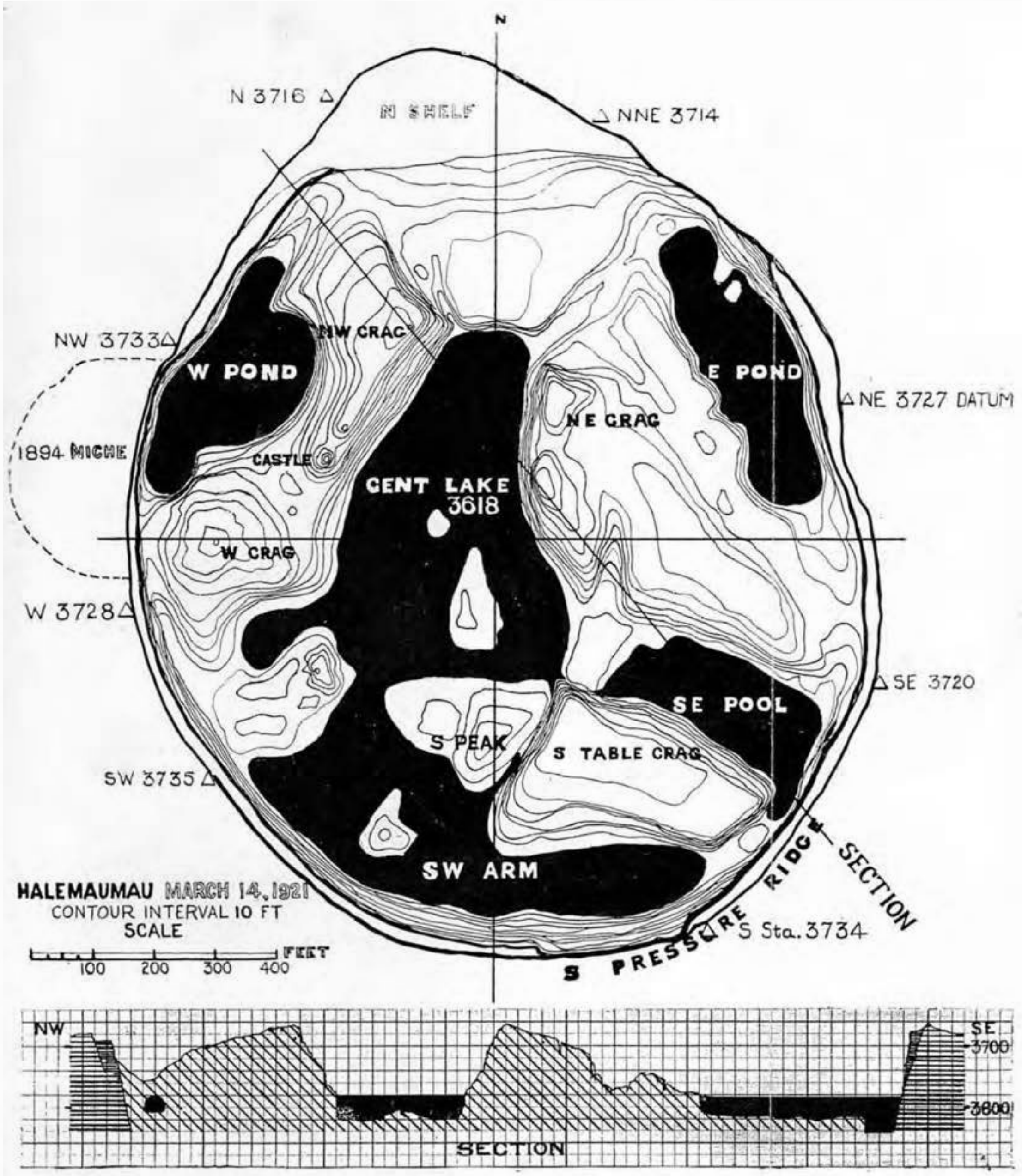
On March 5 it was evident at the north wall of Halemaumau that sliding had been resumed leaving fresh breaks in the wall. About six slides were noted by workmen during the day. The roar of a slide was heard at 2:34 p. m., and another was seen a few minutes later, both causing dust to rise. The pit seismograph indicated 12 avalanche tremors during the preceding day. At 3:15 p. m. there was another dust cloud. Two dust clouds at 11:15 a. m. and 11:40 a. m. March 6 indicated fairly large avalanches. On March 8 there were slides at the north and northwest walls, and on March 9 slides were numerous during the forenoon, one making a large dust cloud at 10:50 a. m. About 4 p. m. a very large cauliflower cloud rose over the whole pit from an unusual avalanche.

The seismographs at Kilauea registered during the week 5 tremors, 7 very feeble local seisms, and one rcorded as feeble indicating origin distance 9 miles 10:56 p. m. March 8, and reported as felt in Hilo. Three other distances indicated for very feeble shocks were 31, 38, and 46 miles. Kapapala reports numerous recent shocks. The tremors lasted from one-quarter to three-quarters minute. Microseismic motion was slight, and tilting of the ground was slight to the north.



Halemaumau from the north September 14, 1920, after many months of low and smoky lava. The small island in lava lake is the same as the one suddenly uplifted in the picture below. Photo Hilo Photo Works.

at the sides. The side solidification forms a ram



Map and profile section of Halemaumau, surveyed March 14, 1921. Shows the very small central islet before its upheaval March 16. Elevations in feet, bench lava in 10-foot contours referred to lake level, liquid lava black. Surveying stations indicated by triangles. Survey by Jaggar.

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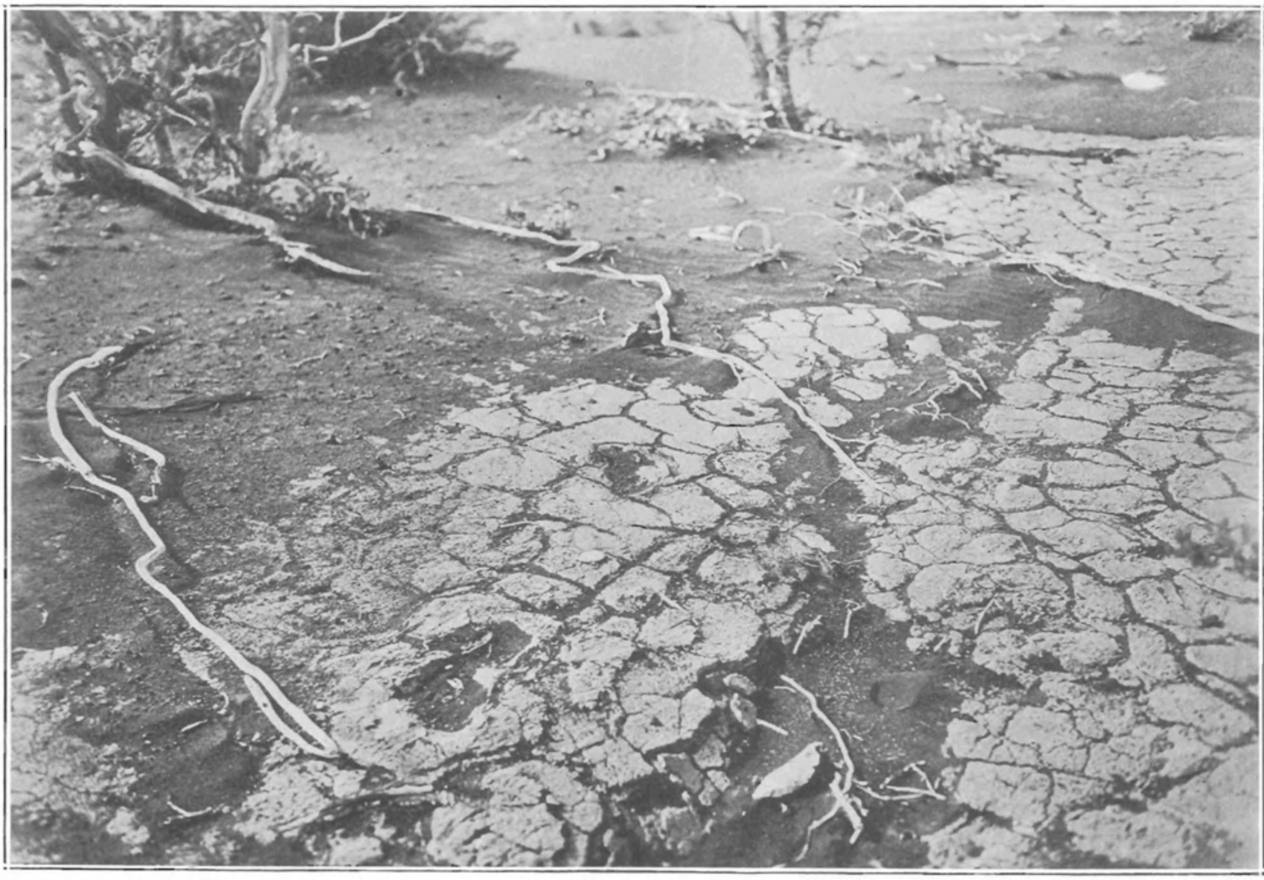
The Volcano Letter

Two dollars per year | Ten cents per copy

No. 273—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | March 20, 1930



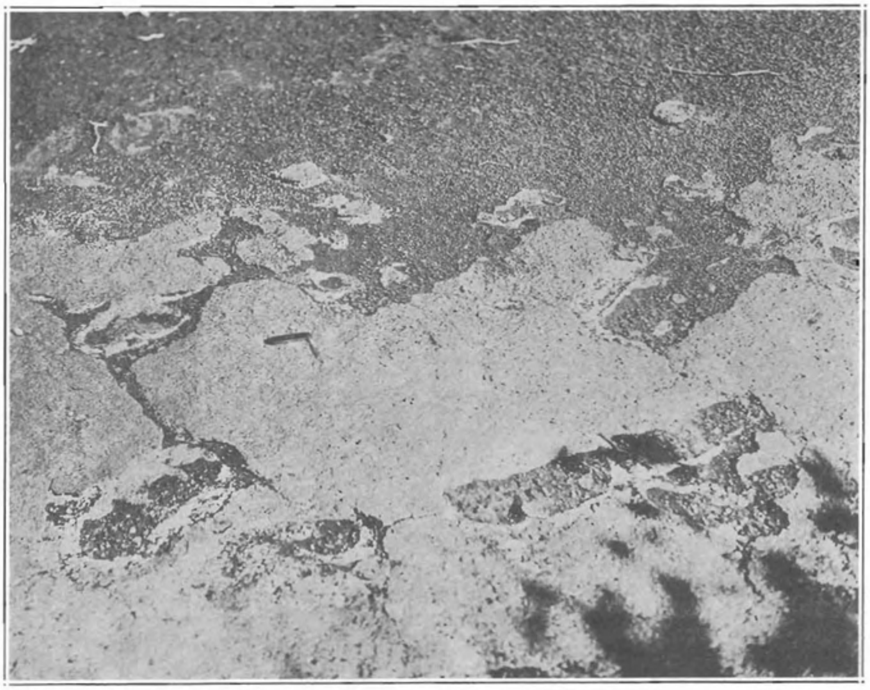
Photograph of fossil human footprints in the lower of two layers of Kilauea ash mud of 1790. The upper layer is here eroded away. There was black sand and cinder between the two layers. The ash is a hardened natural cement. As these footprints are in the ash of the first ash eruption, and are elsewhere buried under the second ash layer, they must date from the eruptive period. Photo Jaggar.

THE HUMAN FOOTPRINTS IN KILAUEA'S ASH BED

Two archeological discoveries of interest as bearing upon the human side of the ancient eruptions of Kilauea were made in 1919 and 1920 as incidents of the work of the Hawaiian Volcano Observatory. One of these was the finding by R. H. Finch of well preserved hardened footprints in what had been the ash-mud of heavy rainfalls in the Kau Desert southwest of Kilauea Crater, dating from the explosive eruption of that crater about 1790. The other was the unearthing of a skeleton on the second shelf of Uwekahuna bluff by the late Joseph Hedemann. This discovery was made February 21, 1919, among the big bowlders a little way below the Uwekahuna Museum, and the remains appeared to represent a very ancient burial of a woman in reclining posture, half covered with ash and washed soil, and walled in between two large rocks. The evidence indicated a time of burial not far removed from 1790. The locations of these two finds may be identified on the accompanying map of Hawaii as just to the west of the head of the flow of 1920 at the edge of the National Park, for the footprints, and the west cliff of Kilauea Crater, for the skeleton.

The photograph shown on Page One exhibits a surface of ancient, sun-cracked mud which consists of what geologists call pisolitic ash. Pisolites are little pea-shaped balls occurring all through a layer of the ancient rock dust that fell over the country during an explosive eruption. This dust was hurled upward in the midst of clouds of steam, and fell round about like snow. It is characteristic of such times that the atmospheric moisture condenses as heavy rainfall ,usually with thunder and lightning. When the dust is caught in the raindrops, the rain falls as mud. If such mud drops fall along with dry ash, or into beds of dry ash, they will form a layer of pellets. These pellet layers were common in the explosive eruption of Kilauea in 1924, and at Vesuvius in 1906. If the rain is abundant the ground may be muddy while still preserving the identity of the pellets. If this muddy ground is afterwards heated by the sun, it will shrink and crack in irregular blocks as shown in the picture. The volcanic dust had been greatly roasted by the combined fire and steam activities of the eruption of 1790, and this made it into a weak Portland cement. On drying it would harden and resist erosion for many years.

Between the two white sticks in the foreground of the picture may be seen two footprints which are the impressions in this muddy cement of large, naked, human feet advancing toward the observer, the left foot at the back with its ball joint and big toe clearly seen on the left-hand side of the impression, and the right foot in front showing complete heel and toes, the print being filled with drifted black sand. The stride was long and in a direction down the mountain with the ball of the foot digging in as though the man were hurrying. It will be observed that the drifted dune sand and cinder lie over



Footprints of adult, probably the mother, in hardened ash of foreground, and of child in background. They show the impress of separate toes. These were progressing to the right, or down the mountain. Penknife shows scale. This is the upper ash layer, without sun cracks, and the little white pellets are fossil mud raindrops. Photos Jaggar

this layer of sun-cracked mud. This fact is of importance, for in the second photograph on Page Two, footprints are shown in another and higher layer of the same kind of ash filled with fossil raindrop pellets, having the dark cinder underneath the ash layer. This upper layer is also cemented, but it is everywhere lacking in the sun cracks, which are characteristic of the lower layer. The upper layer has pebbles which fell during the eruption, the lower layer has none. Everywhere the two layers may be found in this same relation, with the dark sand and cinder in between, and the whole thickness from two to six feet of beds in different places. What they mean is that there was a first eruption that deposited the lower ash and pellet layer without any pebbles; then there was a more violent eruption which buried this layer under sand and cinder; finally came more fine ash, mud pellets, and a little cinder to pepper this last layer with pebbles. These several eruptions may have been hours or days apart.

Now we have shown in photograph No. 1 that after the first layer was formed and before the sun had come out and dried it, a big native strode down the mountain and left his footprints, before the violent flurry of ash and cinders buried them up. The surface that we see in this photograph has been washed clean by more recent rains, for nine-tenths of the ash of this period has been eroded away. It is only in a few fortunate hollows that this footprint record is preserved. A few other footprints have been discovered in the lower sun-cracked layer, and they usually show that the makers were running and going down hill. On the other hand, the footprints in the upper layer are more leisurely, are crowded in large numbers and represent men, women, and children, and are progressing both up and down the mountain. In other words, the persons present at the time of the lower layer were there in the midst of the dangerous period, with more eruptions yet to come. This succession proves conclusively that the footprint-making was contemporaneous with those explosive eruptions.

Who made the footprints? Why were natives in considerable numbers crossing the mountain just at the time of this dangerous eruption? The missionary Ellis tells us (Narrative of Tour Through Hawaii, by William Ellis, Hawaiian Gazette Company Ltd., Honolulu, 1917) that Keoua considered himself the legitimate heir to the throne of the island of Hawaii and in the year 1789 marched from Hilo with all his forces to attack the warriors of Kamehameha in Kau and Kona. He crossed Kilauea Volcano, and "an eruption took place that very night, and destroyed the warriors of two small villages, in all about 80 men." The Hawaiians told Ellis that Pele favored Kamehameha, and aided his cause by destroying Keoua's soldiers. Keoua had broken the tabu of Kilauea, Pele was exceedingly angry "and soon after sunset repeatedly shook the earth with the most violent heaving motion, sent up a column of dense black smoke, followed by the most brilliant flames."

"A violent percussion was afterwards felt, streams of bright red lava were spouted up, and immense rocks in a state of ignition were thrown to a great height in the air. A volley of smaller stones, thrown with much greater velocity and force, instantly followed the larger ones, and striking them caused the larger stones to burst frequently with a report like thunder, accompanied by the most vivid flashes of lightning."

"Many of Keoua's people were killed by the falling fragments of rocks, and many were actually buried beneath the overwhelming mass of ashes and lava." Not intimidated by this event, Keoua continued his march, and the volcano continued its action, confining its operation within the boundaries of Kilauea. Ellis states that he heard this account several times from natives with some little variation as to the numbers killed, and a variant of the story said that Pele appeared to Keoua, in the column of smoke as it rose from the crater. The main facts about the natural history of the eruption he believed to be true.

Other accounts of this eruption indicated that Keoua camped three nights at the volcano while eruptions were in progress, especially at night. On the fourth day he divided his people into three companies, with the chief's division in front, and they had not proceeded far before the ground shook violently, and then an immense black cloud rose out of the crater and produced darkness. Black sand, stones, and dust came down in a destructive shower, some of the first party were killed, and all of the second division were asphyxiated with the hot dust and their corpses were discovered by the third division, some lying down, others sitting up and clasped in farewell embrace. The warriors had their families and livestock with them, and the only living being discovered was a solitary hog.

It is probable that the fossil footprints were made by Keoua's people. The second picture shows the footprints of an adult in front and a child in the background headed down the mountain at the locality west of Mauna Iki where probably the natives were beyond immediate danger, trudging through rain-soaked puddles of muddy ash. This material now is hard enough for a man to walk over it with heavy boots without breaking the shell. Some broken crusts may be seen in the foreground on Page One. This trail of fossil footprints has been followed uphill from the southwest for seven miles in the direction of the west side of Kilauea Crater to a point a mile and three quarters southwest of Uwekahuna bluff. Here the material of the upper layers is coarse and pebbly, but a lower layer of fine ash, corresponding to the mud-cracked stratum of Photograph One, reveals footprints at the margins of erosion patches where the bottom layers protrude. The track of a barefoot adult was found headed south, with stride 24 inches long and foot 10½ inches long, and some of the ash surfaces showed raindrop imprints as well as the pellets. Other tracks were headed north, made by a smaller person, with long strides as though running. There are several places along the trail where the walkers converged to narrow passes so that the ash was beaten down by many feet. (For discussion see Bull. Hawn. Volc. Obsy., July and October, 1921.)

The burial represented by the skeleton (now in the Bishop Museum) lay just on the line of this trail where it would have passed Kilauea. The ash there is too pebbly to preserve any footprints. The skeleton may have been one of the priestesses of Pele. There was formerly a heiau or Hawaiian temple to Pele somewhere in this vicinity. It is also possible that this was one of the victims of the eruption among Keoua's people. T.A.J.

KILAUEA REPORT No. 947

WEEK ENDING MARCH 16, 1930

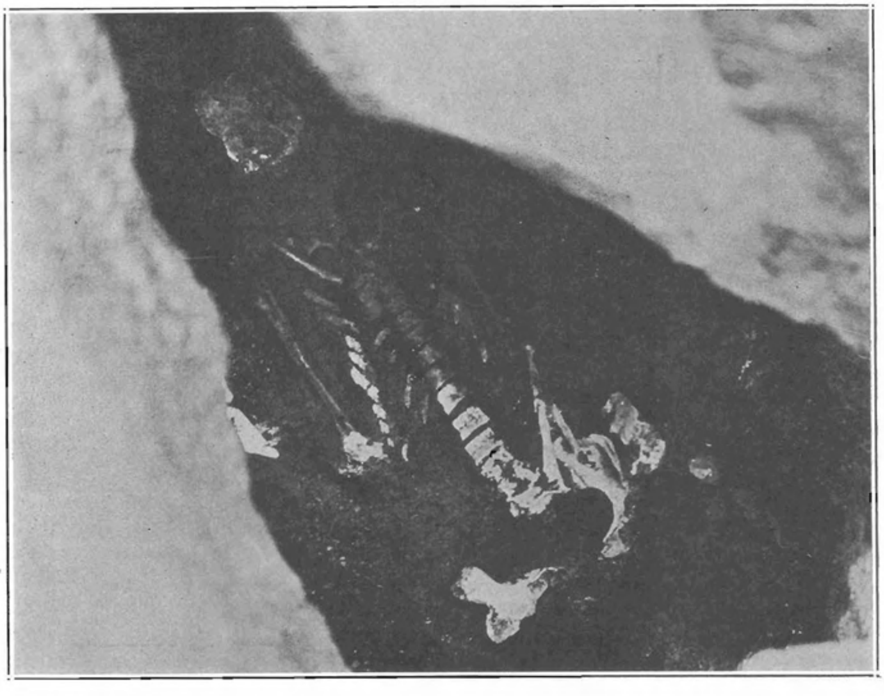
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Numerous slides occurred at Halemaumau March 10 to 14. These were mostly from the north rim and wall, as during previous weeks. The seismograph near Halemaumau recorded many avalanche tremors not strong enough to be registered on the Observatory instruments farther away. Probably the largest slide during the week was at 8:35 p. m. March 12. Sliding was nearly continuous between 6:30 and 7 a. m. March 14, and a few light falls of rocks were heard later in the day.

Heavy rains fell, causing much steam at times. Steam was as usual on the south talus and wall.

A total of 15 seismic disturbances were recorded by the instruments at Kilauea, divided as follows: nine tremors, five very feeble seisms, and one feeble seism felt locally and in Kau at 6:01 a. m. March 13. Its indicated distance to origin was 10 miles.

Tilt at the Observatory was moderate to the southwest. Microseismic motion was slightly stronger than normal.



Skeleton burial found lying in niche between bowlders on high east face of Uwekahuna bluff, the west cliff of Kilauea Crater. The skeleton was in a half-seated position, facing toward Halemaumau, walled in in front. Length from skull to end of spine 27.5 inches. Photographed February 25, 1919.

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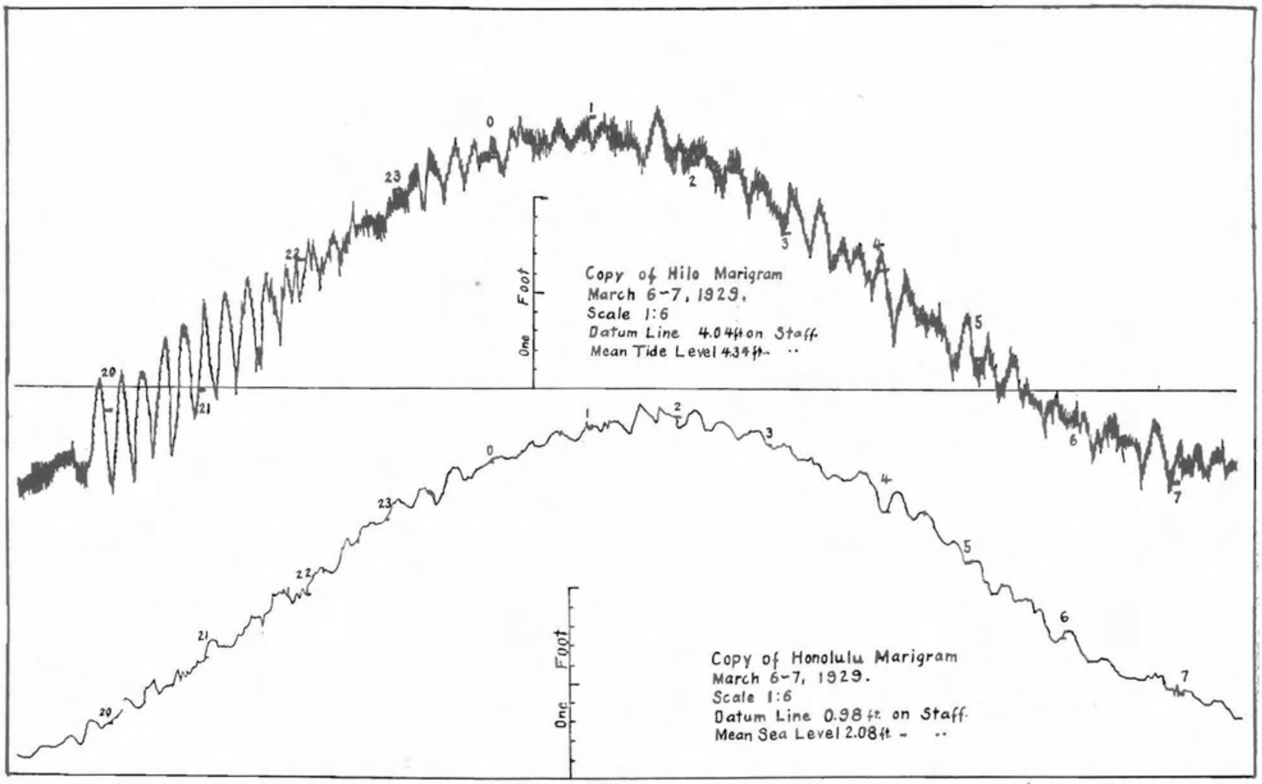
No. 274—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | March 27, 1930



Tide gauge writings at Hilo and Honolulu showing on the left of the Hilo marigram the pronounced waves of the ocean from a distant submarine earthquake off the Aleutian Islands March 6, 1929. The Honolulu record shows only a faint trace. The datum line for each marigram is at the base of the one-foot scale.

OCEAN WAVES FROM SUBMARINE EARTHQUAKES

In the Volcano Letter of February 13, 1930, a seismogram is shown, the autograph written by a pendulum at Kilauea Volcano recording slow waves through the mountain from a gigantic earthquake in southeastern Alaska. The earthquake originated in the mountains 2,700 miles away, and a few minutes later the magnifying apparatus attached to the pendulum in Hawaii indicated swayings with a period of 10 seconds, elastic wave movements swinging the rock of the Hawaiian ridge back and forth about one thirtieth of an inch. At the source the jolts may have shaken the mountains back and forth several inches in a period of a second or so. The waves slow down and widen out as they progress rapidly through the substance of the globe.

This earthquake was in the mountains and so did not affect the sea bottom. But there are many such earthquakes off the coast of Alaska and the Aleutian Islands which jolt the deep valleys under the sea, and probably drop the bottoms of those valleys, sometimes by several feet. On the coast there was a measured lift of over 40 feet during an earthquake spasm in 1899 at Yakutat Bay. These lifts of the continent are believed compensated by drops of the sea bottom. Such movements may be more than 100 miles long, and a large block of water of the ocean is instantly and violently disturbed. This water is thrown into what is called a tidal wave, or tsunami, having its own period and rate of propagation across the ocean dependent on reflection from the shores, on resonance with or opposition to the normal tide waves of that ocean, on the depth of the ocean both at the place of disturbance and along the route of travel, and finally, for any place where the tidal wave is received, on the shelving quality of the shore and the local complication with waves due to the wind.

There is popular misunderstanding about what a tidal wave can do when it arrives. Hundreds of sea waves due to earthquakes arrive at San Francisco, Los Angeles, Callao, Queensland, Japan and Hawaii which are recorded only by the tide gauges. The public does not know of their existence. When a very exceptional one piles up the waters in a confined bay back of a shelving bottom there may be a disaster, but these are rare. Much the same kind of a disastrous shore flood may be produced by persistent hurricane winds as in the Galveston, Mobile and Florida disasters. In all cases the piling of the waters goes into unfortunate rythmic harmony with the local waves and tides, for every bay has its own normal swing of several minutes duration, like a big pendulum.

The two tracings of tide gauge curves on Page One represent the swing of the same tide for 12 hours beginning at 7 p. m. (19 o'clock) March 6, 1929, the range be-

Wreckage in Wailoa River February 3, 1923, at Hilo, Hawaii, due to the piling up of the waters from a distant Aleutian earthquake under the Gulf of Alaska seven hours earlier. Sampans were thrown over the railway bridge which was destroyed, at Waiakea station. Photo Morihiro.

ing about two feet up to 2 a. m. March 7, and back again by the same amount around 8 a. m. of that date. The upper curve was written by a float under the wharf at the head of Hilo Harbor back of the breakwater, and the lower curve was similarly written for Honolulu Harbor. It will be observed that both curves in the right-hand halves exhibit three or four swings to the hour each 20 or 15 minutes long. These are the normal seiches or water basin swayings dependent on the sizes and shapes of the Hilo and Honolulu basins respectively. When the earthquake wave comes in, as strongly shown in the 15-minute pulsations at 20 o'clock on the left-hand side of the Hilo marigram, and hardly shown at all on the Honolulu marigram, this normal pulse of the bay is exaggerated into a pronounced oscillation which dwindles and dies in three hours.

This tidal wave movement of Hilo Bay was forecast on the seismographs in Hilo, at Kilauea, at Kona, and in Honolulu about 3:11 p. m. by the outbreak, so to speak, on the writing pens, of the record of a tremendous submarine Aleutian earthquake. The imperceptible underground waves caused the wirting pens on the Hilo seismograph to swing back and forth 10 inches and to write for more than three hours; and even to write the record of the earth wave that went around the other side of the globe remote from us so as to arrive here at the end of about four hours. This means a very big earthquake; the origin was indicated by the seismogram to be 2,200 statute miles away and that distance could not mean a mainland earthquake, therefore a submarine disturbance was a certainty. The evidence favored an origin either north-northwest or south-southeast of Hilo, which would be either near the Aleutian Islands, or else near the Marquesas Islands. If it were north, the expectable ocean wave would reach the north side of Oahu and the east shores of Maui and Hawaii; if it were south, the stronger movement of the waters might have been recorded at Honolulu, but past experience did not make a southern origin probable.

The nature of the seismogram resembled that of an Alaskan earthquake of February 3, 1923, which had made a destructive tidal wave at Kahului in Maui and at Hilo in Hawaii about seven hours after the earthquake happened in the north Pacific. The record had come to our seismographs about seven minutes after the jolt at the origin. There was thus plenty of time to notify Hilo of the possibilities in the case, and this notification was given, but was not on that occasion taken seriously. The indicated distance to origin in 1923 was 2,500 statute miles, and the origin proved to be under the ocean about 250 miles ESE of Unimak Pass in the Gulf of Alaska. There was probably a sudden inrush of ocean waters over a lowered sea bottom, and then a wave spread out across the Pacific with a speed proportionate to its size. It is this great speed which makes these waves comparable to tides, and the free wave of the daily tide lifted by sun and moon in the north Atlantic Ocean, a basin 3,000 miles wide, travels some 500 miles an hour. Either a tide or an earthquake wave may become dangerous if forced on a shelving shore. The Galveston flood was a wind-forced tide. The wave of 1923 at Hilo began about 12:30 p. m. and smashed sampans over the Hilo railroad bridge across the Wailoa River (see photographs Pages Two and Three). This wave reached Haleiwa in northern Oahu at 12:02 p. m., and it traveled thence to Hilo at about 5.18 statute miles per minute. At Waikiki in Honolulu the first movement was a long recession of the waters revealing new reefs during about 20 minutes. Then there were in-and-out surges at intervals of 15 to 20 minutes. This earthquake was strongly felt in Alaska, was registered on seismographs all over the world, and the sea wave was registered on tide gauges in San Francisco, South America, and at Adelaide, Australia.

Returning to the seismogram of March 6, 1929, although the origin was even nearer than the center of February 3, 1923, and the amplitude of the motion in Hawaii was greater, and although Unalaska reported a severe shock on land and telegrams from steamers confirmed the location as south of the middle Aleutian Islands, where the crews on the vessels felt the bump; yet the amplitude of the sea wave, as shown on Page One, was only about seven inches at Hilo and two inches in Honolulu, and the surge in the sampan basin of the Wailoa River, lasting from 7:45 p. m. until 10 p. m. at intervals of 15 minutes, was something over a foot. Even this movement at its maximum between 8 and 9 p. m. was sufficient to break the stern lines of a steamer at one of the wharves back of the Hilo breakwater. The sampan fleet anchored out in the bay until the disturbance was over. The harbor authorities are always notified of the facts by the Hawaiian Volcano Obesrvatory and take proper precautions, just as any sailor would do at the possible approach of a storm. There is usually much less danger than in the case of a storm, but it would be folly to be unprepared.

Of 11 sea waves due to earthquakes on the sea floor which have been discussed at the Hawaiian station, the rate of propagation has varied from 284 to 481 statute miles per hour. An earthquake 3,915 statute miles from Kilauea in the Acapulco deep, jolted coast towns of Mexico at 4:49 p. m. June 16, 1928, and the sea wave arrived at Hilo 1:18 a. m. June 17, traveling 7.7 miles per minute. The waters at Hilo rose and fell 1.32 feet, the periodic oscillations were 15 to 22 minutes, and the water disturbance was indicated for more than 24 hours. The record was very feeble on the Honolulu tide gauge. On the other hand, an earthquake near Kamchatka December 28, 1927, 3,310 miles away made a tide record as well marked in Honolulu as in Hilo, the sea wave traveling 7.3 miles per minute. (See Page Four.) T. A. J.

KILAUEA REPORT No. 948

WEEK ENDING MARCH 23, 1930
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

There were fewer slides at Halemaumau than during the previous week, though avalanche dust was observed on the 17th, 18th, and 19th. On March 22 a big scar was noticed above the northwest talus. There was little change in steaming.

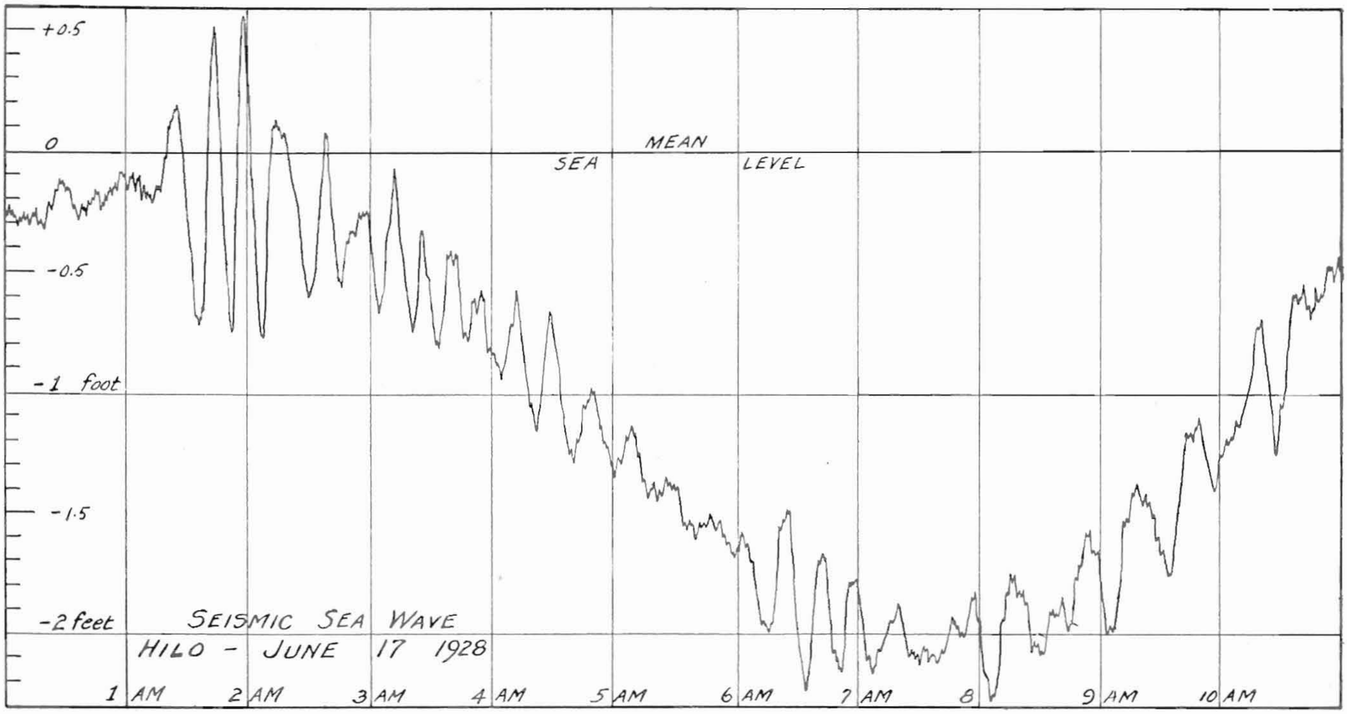
Seven seisms, the smallest number since early September, 1929, were recorded by the Kilauea instruments. Two were tremors and five were very feeble seisms.

Tilting of the ground was slight southwest. Microseismic motion was normal.

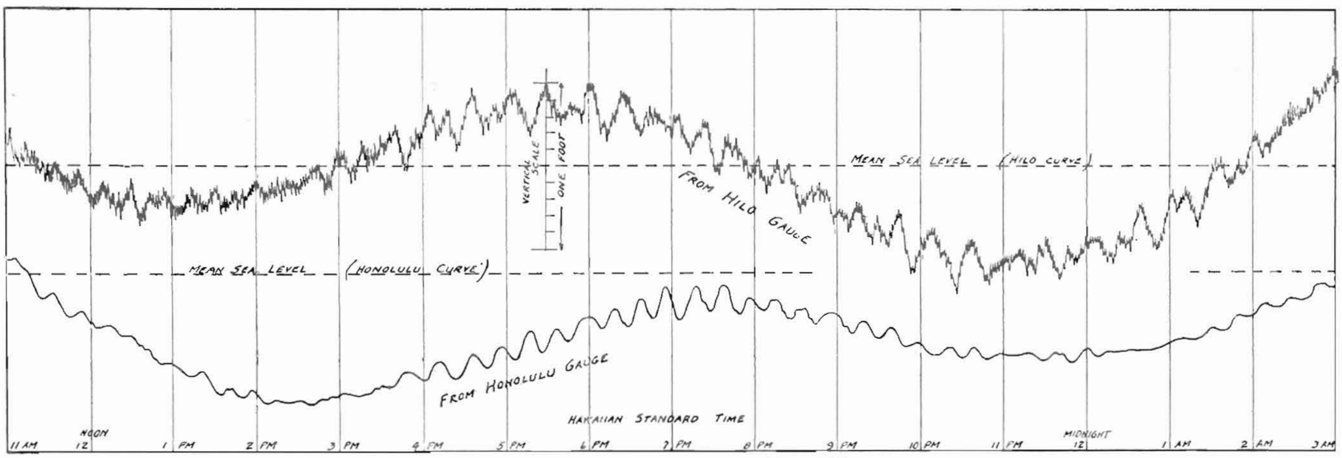
NOTICE

Copies of the Title Page and Index for 1929 have recently been mailed to all persons on the Volcano Letter mailing list during that year. A copy will be sent to any person sending application to the Hawaiian Volcano Observatory, National Park, Hawaii.

Railroad embankment washed down by tidal wave between Hilo and Kuhio Wharf February 3, 1923. The major wave at Hilo was the third noticed visually, and the waters rose over 20 feet in places damaging wooden houses and wharves. Damage was done also at Kahului in Maui. Photo Morihiro.



Tide gauge record of seismic sea wave, Hilo, Hawaii, June 17, 1928 This was made by an earthquake off Mexico.



TIDAL WAVE, DECEMBER 28 1927

Tide gauge records for Hilo and Honolulu compared. These were written December 28, 1927, by a seismic sea wave from an earthquake off Kamtchatka in a direction N 22 W. from Hawaii, and so registering more strongly in Honolulu than in the figure on Page One.

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.

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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.

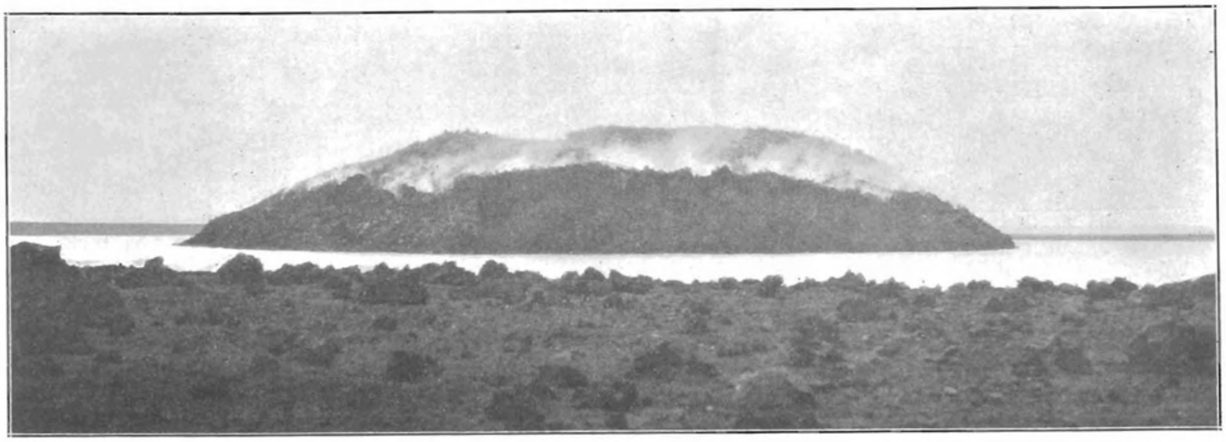
The Board of Directors includes Lorrin A. Thurston, President; Frank C. Atherton and Walter F. Dillingham, Vice-Presidents; L. Tenney Peck, Treasurer; Wade Warren Thayer, Arthur L. Dean, and Richard A. Cooke.

Persons desiring application blanks for membership 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. 275—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | April 3, 1930



Bogoslof Volcano in the Aleutian Islands, belonging to the United States. New lava heap in warm salt lagoon, surrounded by a ring of explosion debris, about June 28, 1928. The two older peaks are right and left outside the picture. Photo looking southwest, by Captain Roy A. Wheeler, Alaska Game Commission.

RECENT ACTIVITY OF BOGOSLOF VOLCANO

If the reader studies the map on the back hereof, he will find that nearly all of the steamship courses radiating from Honolulu either reach or pass by lands of active volcanoes. The northern course reaching Unalaska in a distance of 2,016 nautical miles, touches the middle of the Aleutian chain containing forty cones which have had historical eruptions. To the east this curve extends up the Alaskan Peninsula, to the west it goes through the Aleutian Islands to Attu, the whole length being some 1,500 statute miles. On the globe this is nearly a circular arc about the inner bight of the gulf of Anadyr as a center. None of these island volcanic arcs is truly circular; they are always somewhat straight at one end and hooked at the other. So in this case the curvature is greater at the western end. As in most of the island arcs, the active volcanoes tend to line the inner side of the curvature, toward the shallower ocean, in this case the Bering Sea .The same thing is true of the Caribbee Islands confining the eastern of the Caribbean Sea; and Martinique with its destructive volcano Pelee ,is the gem in the midddle of that volcanic necklace.

When the real meaning for this hook and curve alignment of volcanic islands has been discovered, we shall know much more about the globe than we know now. Underneath the volcanoes in the Aleutian Islands there are old granites and sedimentary rocks, exposed especially on the Pacific side, which protrude from the Alaskan continent, folded and pinched along axes parallel with the island line, and falling off to a profoundly deep trench to the south. This trench is also straight on the east and hooked northward at the west. This trench is over 20,000 feet deep. A basin more than 10,000 feet deep extends into the southwestern half of Bering Sea, but the rest of this inland sea is very shallow. The Aleutian Islands are really a submerged peninsula extending westward from Unalaska with the mountain peaks rising above the waves. Just in the eastern corner of the deeper basin of Bering Sea, and 40 miles north of Umnak, the large island next west of Unalaska, some rocky pinnacles stand in the ocean where on either side the water is 6,000 feet deep. These rocks are sometimes connected into a single island called Bogoslof, and at other times a channel between two of them has been washed clear by the sea. They are of enormous interest, for they consist of nothing other than the peak of a 6,000-foot volcano which during the last two centuries has been squeezing up stiff lava like paste from a paste tube, to add to the volume of its apex.

The rise of the first rocky spine above the water at Bogoslof was reported by early navigators about 1768 and was called Ship Rock. Another stiff aa crag of andesite, Castle Rock, rose to the southeast of Ship Rock with much explosion and oceanic disturbance in 1796, alarming the natives of Unalaska. According to Krusenstern, who made

Sea lion herd at east end of Bogoslof, June 1928. Photo Wheeler

a map in 1826, Castle Rock was then two nautical miles long, 4,000 feet wide, and 350 feet high, without summit crater, and with pinnacles on top. Castle Rock was extensively washed away and made smaller during the nineteenth century. In 1883 a new eruption began and a huge tabular crag of lava rose precipitously from the sea more than a mile to the northwest of Castle Rock and enclosed Ship Rock in its debris in the space between, the bombs and gravel and sand beaches joining the two peaks to form an elongate island. For more than a decade the boiling continued at Grewingk, as the table rock was called, but the erosion of the arctic storms, and explosive outbreaks, destroyed Ship Rock, and opened a channel between Castle Rock and Grewingk, which were apparently dead at the beginning of the twentieth century.

In 1906 new lava monsters began to rear their heads from the squirming lava tangle inside the undersea volcanic mountain, and these first appeared as a steaming new heap about midway between the two older islands, connected with the northwest table Grewingk by a low flat ridge of debris but separated from Castle Rock by a channel seven fathoms deep. The new mound was conical in appearance, with sulphurous eruptive rocks emitting large volumes of steam, and showing at the summit a broken horn bending to the northeast like the famous Pelee spine in Martinique, and consisting of a mass which had been forced up through an aperture while in a plastic condition, with smooth and scored sides. The new hill was named Metcalf Cone. The heat of the steam jets varied from 94° to 224° F., and cracks in the rock were hot enough to light paper. Metcalf Cone measured 2,000 feet across the base and 400 feet high. There were the usual alternations of explosive eruption with rising stiff lava, and at the beginning of 1907 Metcalf Cone was broken in two, while the channel between it and Castle Rock had filled itself with a new steaming heap of lava, McCulloch Peak.

At this time the writer visited Bogoslof, and on August 7, 1907, landed in a dory in the midst of a herd of roaring sea lions. The precipitous cliffs were covered with millions of murres and herring-gulls, and the air was darkened by myriads of them in rapid flight. Bogoslof was now a continuous island two miles long, the two active cones were 400 and 500 feet high, McCulloch Peak was three-quarters surrounded by steaming salt water at 90° F., and it looked like a huge lumpy potato with the bulbous lumps split apart, and the whole jagged mass encircled by debris slopes that led down into the orange-colored warm water of the lagoon. Immediately adjacent to it was the Metcalf half-dome, with the central spine wonderfully revealed in cross section. The spire appeared in the cliff like an inverted fish horn, its base 360 feet across and its top rounded both in plan and profile like a beak. There were regular markings on the rounded surface horizontally, as though the horn has been shoved up at intervals. It was like a great worm rising from its burrow with its head turned toward the east. It was 400 feet high and at the top it was broken away through lack of support into a ragged 40-foot precipice, overhanging the back slope.

Bogoslof in 1907 was at its maximum of volume above the waves, for the period since the big island of 1796 had been eroded away. It was now four rocky hills, Castle Rock at the southeast, then McCulloch Peak fuming and tumbling and encircled by sand bars and lagoons, then the half-dome of Metcalf Cone with its spine, bordered by a dry lagoon on the north, and at the northwest the tabular rock Grewingk with gravel banks piled against it. Our party discovered elevated rock platforms backed by sea caves which had been at sea level a year before, so that everything indicated that the huge pressure inside the submerged volcano, which was pushing up McCulloch Peak, was also lifting the volcano on its back and carrying the chain of islets with it. This heaving of the older land was particularly interesting, because the main island of Unalaska showed elevated sea benches, and now we know that at Kilauea, during the rising lava period of 1913-1922, the mountain top surrounding Kilauea Crater was lifted more than two feet, and carried the Volcano House up with it. In other words, the turtle-back of a volcano swells when the lava rises and flows out, and shrinks when the lava sinks back.

September 1, 1907, a dense black cloud rose from Bogoslof, ash and sand fell at Unalaska mantling everything with a snowstorm of rock powder a quarter inch deep, and there were rain and lightning and distant rumbling. McCulloch Peak had blown itself up. A steaming lagoon was left in its place, the rest of the island was piled high with fallen debris, and the backslope of Metcalf Cone had the smooth concave cone profile of a Vesuvius. There appeared to be a rythmic sequence to the events whereby Metcalf Cone built itself up 400 feet high and 2,000 feet across, lived 10 months and exploded, then McCulloch Cone was built up 450 feet high and 2,000 feet across, lived 10 months, and was destroyed. It is probable that this means a pulsation of rise and fall of lava, and when the lowering comes, the sea water penetrates the hot voids below, under great pressure and by many inlets, generates steam, and the path of least resistance for the exit of the steam is through the crannies of the wall crack, around the crater edges of the risen lava column.

In July, 1908, the remains of Metcalf Peak had subsided and there had probably been another explosion the previous winter. There was renewed activity in the bay surrounded by beaches that lay between Castle Rock and Grewingk, in September, 1909. A new lagoon was formed shut off from the sea, and two small lava islands arose which in June, 1910, had united and reached a height 178 feet above the water. A survey September 10, 1910, made the island one and a half statute miles long and three-quarters of a mile wide. The old rocks were becoming smaller. A new explosion September 18-19 1910, sent up immense clouds of vapor, smoke, and ashes, flames were reported, and a true crater was opened in the top of the central peak. This was the first time that a real crater within one of the lava domes was ever seen and photographed by the Coast Guard officers who have done so much valuable work in making these reports on Bogoslof. In July, 1913, this crater had steam and smoke slowly issuing from it, but the following year all smoking had ceased. During the next eight years Tahoma Peak, as the new hill of 1910 was called, was eroded away, and a channel was again opened between Castle Rock and Grewingk so that a boat could sail between the two older islands. Grewingk had greatly diminished in size, and Castle Rock was now two rocky horns with a big accumulation of sand and gravel heaps piled against them, especially on the northern and eastern sides, these trailing off into a long sand spit at the north, and the whole of this larger island was surrounded by sand beaches.

The writer visited Bogoslof for the second time July 6, 1927, and found a new period of moderate lava activity inaugurated, with a pile of steaming lava rising from a warm lagoon in the midst of sand banks, and again these banks joined all of Bogoslof into one island with a complete ring-shaped salt water lagoon, surrounded in turn by a complete ring of sand permitting no connection with the sea except by seepage. The lagoon was at 70° F., there were the usual herds of sea lions and myriads of birds, the bottom sand and pebbles of the lagoon were all coated with orange colored ochre, the lagoon was everywhere only two or three feet deep, there were numerous skeletons of dead birds on the beach, and in the sand were impact craters made by newly fallen bombs having rough aa surfaces. There were blocks of pumice one to two feet in diameter. The central lava heap (see Page One) was about 200 feet high and 1,000 feet wide. Its crest consisted of uniform aa clinker, steaming much more heavily than in this picture of a year later. It made no noise, and it is characteristic of Bogoslof that during most of the visits reported noise has been absent. In September of 1910, however, a week before the explosive eruption, roaring steam jets were found. in 1927 the annular ridge of gravel, sand, and explosion products stood about 10 feet above tide.

The new activity had started in July of 1926 when there was open water between the two older rocks. An explosive eruption was then seen by a whaler, and the natives reported explosions July 17 as seen from nearby islands. The water was greatly muddied and the whaler on August 12 saw black smoke with darkness accompanied by thunder and lightning, ending with a cloud of white steam and "fire" about 2 p. m. There was also an explosion in December, 1926, and it is probable that the lava dome of 1927 emerged thereafter. Probably the eruption began with a series of lava pulsations, alternating with explosion. In 1928 the activity was mild as shown in our pictures. A landing party on Bogoslof July 27, 1929 reported all quiet.

T. A. J.

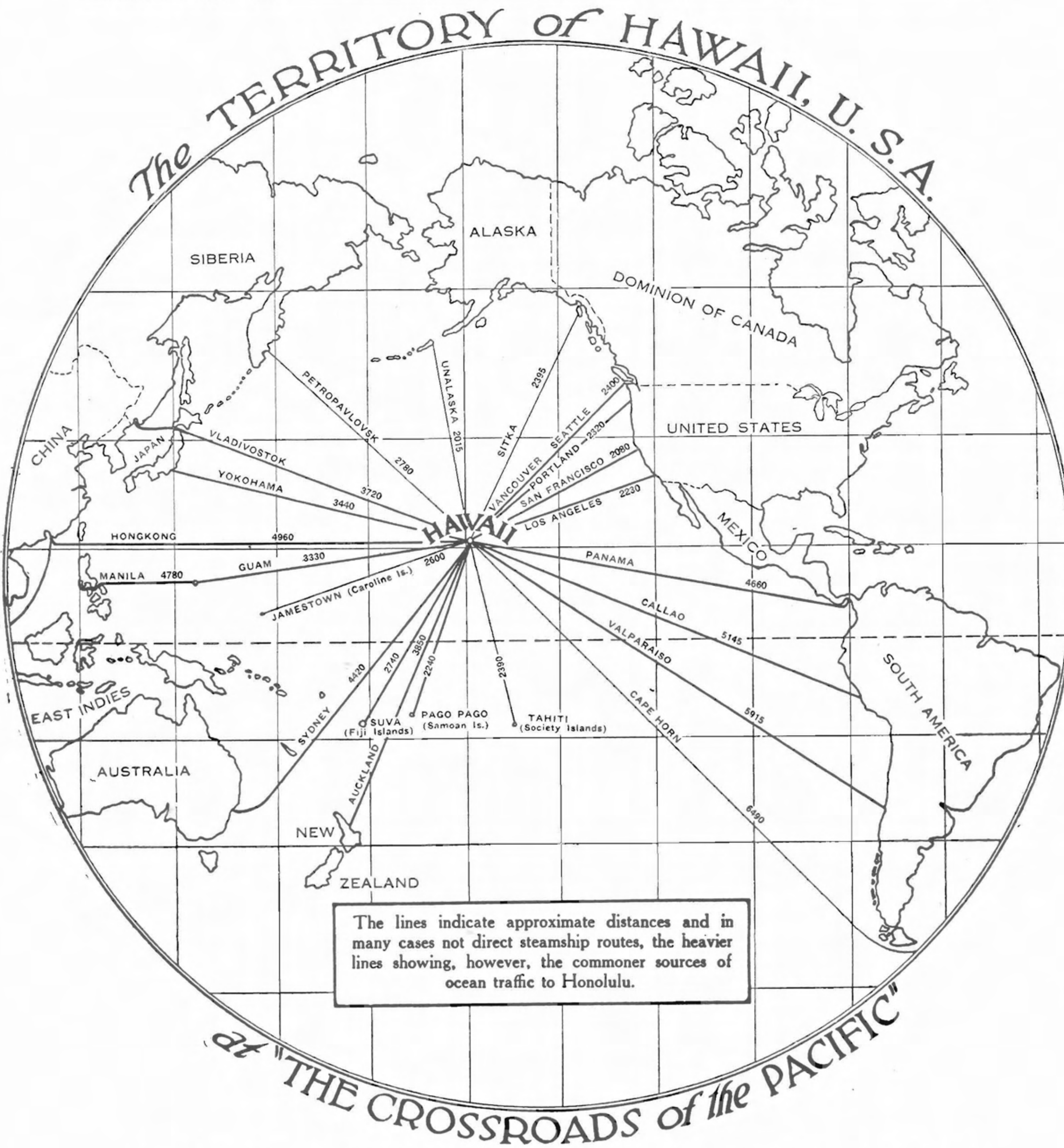
KILAUEA REPORT No. 949

WEEK ENDING MARCH 30, 1930

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

Kilauea remains quiet. Halemaumau on March 26 exhibited a few fallen rocks at the north, and the pit seismograph showed some avalanche tremors. At 10:30 a. m. March 28 a little dust arose from the northeast wall, and such dust was seen occasionally March 30. At 3 p. m. March 30 there was fresh dust on the northwest wall and a triangle on the floor below was stained with dust. Otherwise the floor was mostly washed bare. A wide area of greenish-white solfataric stain has developed at the south edge of the floor. New bowlders extend out on the eastern floor. The talus NNW has increased in height, and a deep notch in the wall above the north talus has been extended upward.

Four very feeble local seisms have occurred during the week showing tendency to east tilt accompanying the shocks. Nine tremors are recorded each lasting less than a minute. Microseismic motion has been very slight, and tilt was moderate NNE.



Pacific Ocean, showing distances in nautical miles from Honolulu to the surrounding girdle of volcanic lands. Seismographs of the Section of Volcanology, U. S. Geological Survey are at Hawaii, California, Kodiak on W. side of Gulf of Alaska ,and Unalaska.

THE VOLCANO LETTER

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The Volcano Letter

Two dollars per year — Ten cents per copy

No. 276—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — April 10, 1930

Tarumai Volcano in Hokkaido, North Japan, from an airplane looking northwest, photographed by the Otaru Shimbun 1:45 p. m. October 19, 1926. New activity of gas eruption through the summit lava dome of 1909, and through cracks south of the dome. Lake Shikots in the background. Photo from H. Tanakadate

ERUPTIONS OF TARUMAI VOLCANO

Tarumai is in the forested mountains of southern Hokkaido, the north island of Japan. It is one of several volcanoes in that vicinity which have had many eruptions, of steam, sulphurous gases, and stiff andesite lavas. Ta rumai is a cone of ash and pumice 3,300 feet high which renewed its activity after a long repose in the spring of 1909. It had been quiet since 1894.

From January to April of 1909 there were numerous explosive "cauliflower clouds" that went up from the cup in the summit cone. April 19th revealed a new lava dome on top of the crater. A very stiff aa flow upward had taken place, lifting the crater floor, opening outward like a flower in its calyx, and finally filling the former crater and rising above it 440 feet. The dome was all covered with jagged lumps and had a diameter of 1,400 feet. The rock was hypersthene andesite. The mountain was now 130 feet higher than it had been by reason of this addition to its summit. (See photograph Page One).

The lava dome of Tarumai was much like the several domes of Bogoslof in the Aleutian Islands, and made of similar rock. On May 9, 1909, the writer visited Tarumai and with a thermo-element thrust into a crack a foot deep in the tumble of crags at the side of the lava heap determined a maximum temperature of 855° F. (457° C.). This was more than hot enough to burn wood. The dome was steaming, particularly around the edges. This new lump remained on top of the mountain.

In 1917 the gas activity through a fissure in the lava dome started new eruption sending up fire, sulphurous smoke and ash, with much trembling. Such activity continued in 1918, 1919, 1920, 1921, and 1923, forming craterlets in the dome precipitating ash and lapilli over the surrounding country. Small stones fell on a village Tomakomai in 1919, eleven miles to the southeast of the mountain. In 1923 ash fell on the city of Sapporo, the capital of Hokkaido, 25 miles to the north of Tarumai.

The photograph on Page One was kindly furnished by Professor H. Tanakadate and was taken from the airplane of the Otaru Shimbun at 1:45 p. m. October 19, 1926. At this time a new series of gas-made ruptures broke athwart the lava mound as well as across the mountain summit to the south of it. Stones fell about the mountain, the usual cauliflower clouds shot into the air, and ash fell 220 miles to the east. The picture was taken from the southeast, and shows both the lava heap of 1909 and the ground to the south of it smoking, while off to the north two and a half miles away stands Tarumai's twin volcano Fuupushinupuri, and behind it in the distance stands lake Shikots.

Halemaumau January 14, 1918, showing the hard top of the lava column swoll ing from the outside edge inward. The steaming cliff on the left, and the dist lava lake is in the fume amid the central crags. Photo Jaggar.

Tanakadate has classified the volcanoes of Japan, (Proc. Fourth Pac. Sci. Cong., Java 1929 pp. 621-631) as ranging from abortive eruptions with no explosions or outflow, to liquid lava lakes in a crater. The abortive eruptions have many earthquakes localized about a dormant volcano. This is the same kind of activity as was localized in Hawaii in October, 1929, about the volcano Hualalai. Hakone is a district adjunct to Fujiyama which has frequently shown swarms of earthquakes, and in the Izu Peninsula south from there such earthquakes are producing damage and alarm at this moment.

At Oshima Island out in Sagami Bay opposite the Izu Peninsula is a fuming volcano, seen by tourists arriving at Yokohama, which is characterized by liquid lava, of rather stiff aa type usually, that rises and falls in its crater. This is Mihara Volcano, and comes nearer to the Kilauea type than anything else in Japan. Sakurajima produced a stiff lava flow, Tarumai dome was still stiffer. Usu, a few miles to the south of Tarumai, produced earthquakes and a lifted block of the mountain flank in 1910, with no lava except what was thrown up as bombs. Bandaisan in 1888, in central Japan, disrupted a mountainside with steam explosion, and other volcanoes throw out crater lakes and make mud floods, with no apparent lava. Many of these produce elevation of the country.

GROUND MOVEMENT IN A VOLCANO

The Volcano Letter has called attention (No. 264) to the swelling of volcanoes and in describing Bogoslof last week we pointed out that the eruptions of 1907 indicated uplift of sea shore in a year. A publication entitled "Topographical Changes accompanying Earthquakes or Volcanic Eruptions," by A. Imamura (Publ. Earthq. Invest. Comm. Japan No. 25, 1930), makes the following statement: "The character of the acute earth tiltings which accompany an earthquake is inferable from the chronic tiltings that precede the earthquake, and vice versa. And topographical changes which take place prior to volcanic eruptions have characteristics in common with those that take place prior to earthquakes."

These statements may be paraphrased by saying that either a great earthquake or a volcanic eruption indicate that acute earth tilting or tipping of the surrounding country is taking place. This tilting may accompany either a lift of the country or a dropping of the country. Experience shows that the center of the rising or the lowering of the country during the crisis may involve a mosaic of crustal blocks in case of an earthquake, but is apt to involve the crater itself in case of an eruption. And finally this accute uplift or lowering of country indicates that chronic tiltings of the region may be inferred as preceding the crisis, and these chronic tiltings are now being measured. This measurement is of the utmost importance for the future of seismology and volcanology. The reason for this importance is that probably prediction of cycles and crises may be based on knowledge of chronic movements. Chronic tippings have been measured for years in Hawaii and Japan, and their relations to small local earthquakes are like the relations of strain in a timber to its creakings. It seems probable that there is here open to view a new vista in volcano-earthquake science.

The review of Tarumai eruptions in the preceding article exhibits a pair of volcanic mountains close by a de-

the crust on a pudding as an incipient dome with stages of higher and higher swell-
h cliff with stone shelter on top at the extreme right, are the edges of the pit. The

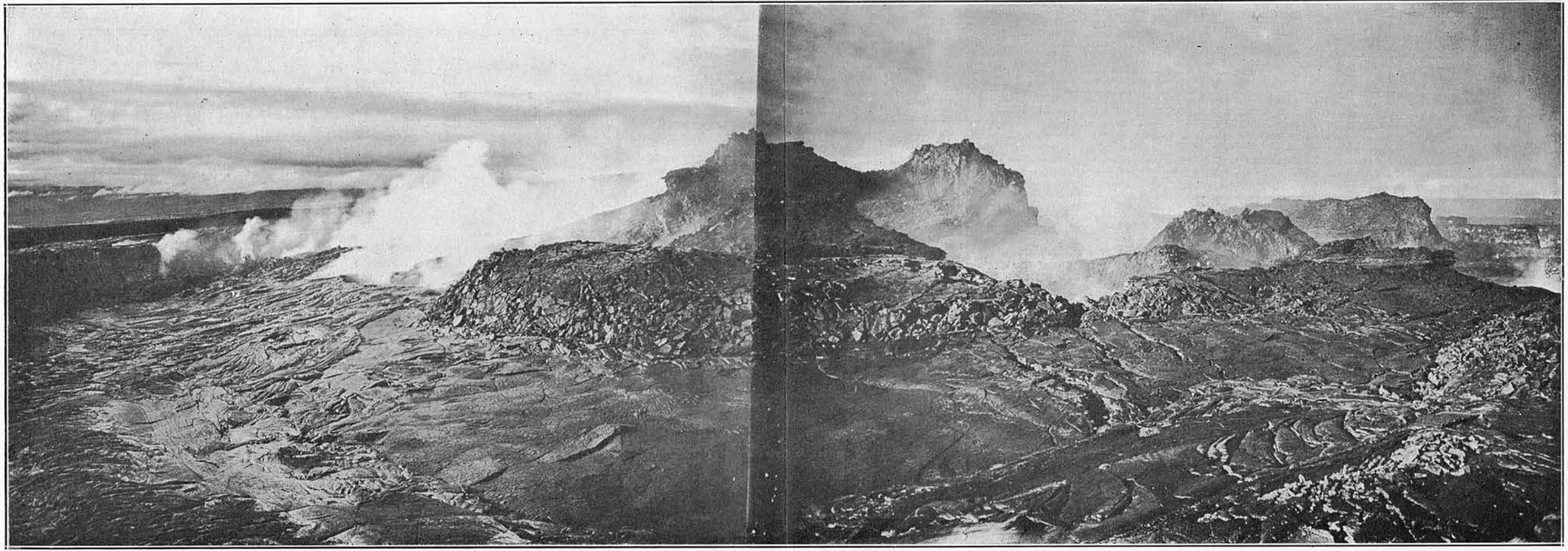
pressed lake basin. This relationship in Japanese volcanoes is very common. It appears to mean fault blocks which are tipped or warped down in the mosaic of the earth's crust under the lake basin, and swollen up under the volcano. The pairing of the two follows some definite and important law in the mechanism of the earth's crust. The lake basin lowers through the ages and the volcano dome swells up.

The picture (Pages Two-Three) of the inner floor of Haleamumau pit at the active center of Kilauea Volcano in a time of great activity of rising lava, and just before the first overflows within Kilauea Crater during the last eleven-year cycle, as shown above, is comparable to Tarumai. If the reader will examine carefully the left-hand side of this picture, he will see that within the low cliff the curve of a swollen dome, like the crust of a pudding, circles into the foreground of the picture and passes on around to the right of the big cluster of crags in the middle. If he will look still farther inside the curve, he will see a swollen inner dome in a half circle between him and the central crag. And beyond this is the group of central crags pushed up still higher as irregular blocks, and amid these blocks lay the liquid lava lakes fountaining and streaming among the wells that led up from the lava column below to the apertures amid the crags. This is all just as true a lava dome as the one on Tarumai.

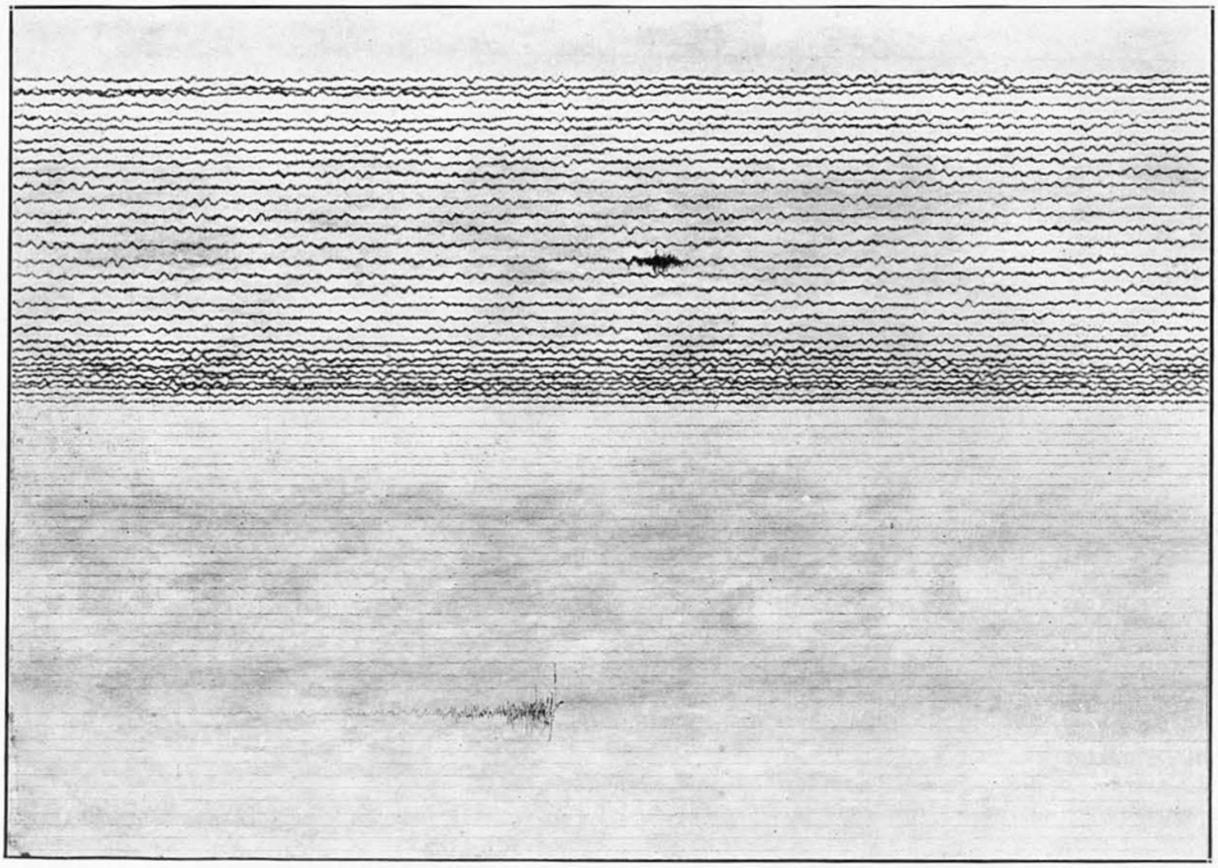
Now this deep lava in its rising at Kilauea was lifting the surrounding outer country. This was proved by leveling in 1912 and again in 1922. The edge of the pit was lifted from five to fifteen feet, and the edge of the outer crater was lifted over two feet. The seismographs there showed a strong and progressive tilting away of the ground.

The illustration on Page Four is a part of the wonderful seismogram described in Volcano Letter No. 264 as the autograph written by a pendulum hung like a door parallel to the edge of Halemaumau with a pen attached to it that wrote the lines round and round a drum turned by clockwork. The drum moved on a screw during the day toward the pit so that the pen would normally have written lines one-twentieth of an inch apart. This normal writing is shown by the light lines in the lower half of the picture. The autograph of the earth here shown is a record of the activity of big fountains of lava in Halemaumau pit half a mile away. The top line was the beginning of the autograph of the ground the morning of February 21, and this was the day when the fountaining stopped. Each successive line from the top downward is part of a half hour following the preceding line. The dark lines of the upper half of the seismogram are full of tremor from the lava fountaining. They open apart at first because the gas pressure was high, the crater was lifting, the seismograph cellar floor was tilting away from the center of the pit, and the writing pen moved away from the lines it had previously written. In the midst of this came a little earthquake showing black on the diagram.

Then at noon the gas pressure gave out, the lava began to go down, the ground tilted back toward the pit, and the lines became crowded, though the fountaining and the tremor still continued. Just before the fountaining stopped between 1 and 2 p. m., the record of tremor also stopped, everything became stationary, the tipping of the ground toward the pit ceased, and the lines on the seismogram recorded the event perfectly by no longer exhibiting tremor and by becoming normally spaced without any crowd-



Halemaumau January 14, 1918, showing the hard top of the lava column swollen up like the crust on a pudding as an incipient dome with stages of higher and higher swelling from the outside edge inward. The steaming cliff on the left, and the distant whitish cliff with stone shelter on top at the extreme right, are the edges of the pit. The lava lake is in the fume amid the central crags. Photo Jaggar.



Seismogram of February 21, 1929, written at the edge of Halemaumau pit in a closed hut by a horiontal pendulum with the writing boom hung tangential to the curvature of the pit. Tremor due to lava activity at the top, inward tilting due to sinking lava shown by crowded lines in the middle, cessation of activity and a local earthquake shown by normal lines at the bottom.

ing. About midnight February 21-22, as shown in the lower part of the seismogram, a normal local earthquake was felt and this as shown was accompanied by a widening apart of the line as though upward pressure were restored and the earthquake were a creaking of a block tending to tilt suddenly. This is what is meant by tilt accompanying local earthquakes. It is hard to imagine a more fascinating earth autograph than this one showing the tremor and centrifugal tilt above, the centripetal tilt in the crowded middle lines, and the sudden resumption of normal conditions at the bottom, all corresponding to observed volcanic activity.

T. A. J.

KILAUEA REPORT No. 950

WEEK ENDING APRIL 6, 1930
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Dust from slides has been seen at Halemaumau at 2:35 p. m., 3 p. m., and 4:15 p. m. March 31, and at 4 p. m. April 2. These slides produced much fresh material on the eastern talus heaps. On April 3 steaming on the south talus was very slight. A big slide occurred NE at 2:45 p. m. April 4 producing important changes in the region of the 14-ton bowlder northeast of the tourist station. The next day a number of large stones lay on the lava floor at the east side and steam was noticeably absent. At 10:25 a. m. dust again rose at the NE.

The Observatory seismographs have recorded 5 very feeble local seisms and 12 tremors during the week. Microseismic motion has been slight, and tilting of the ground slight NE.

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The Volcano Letter

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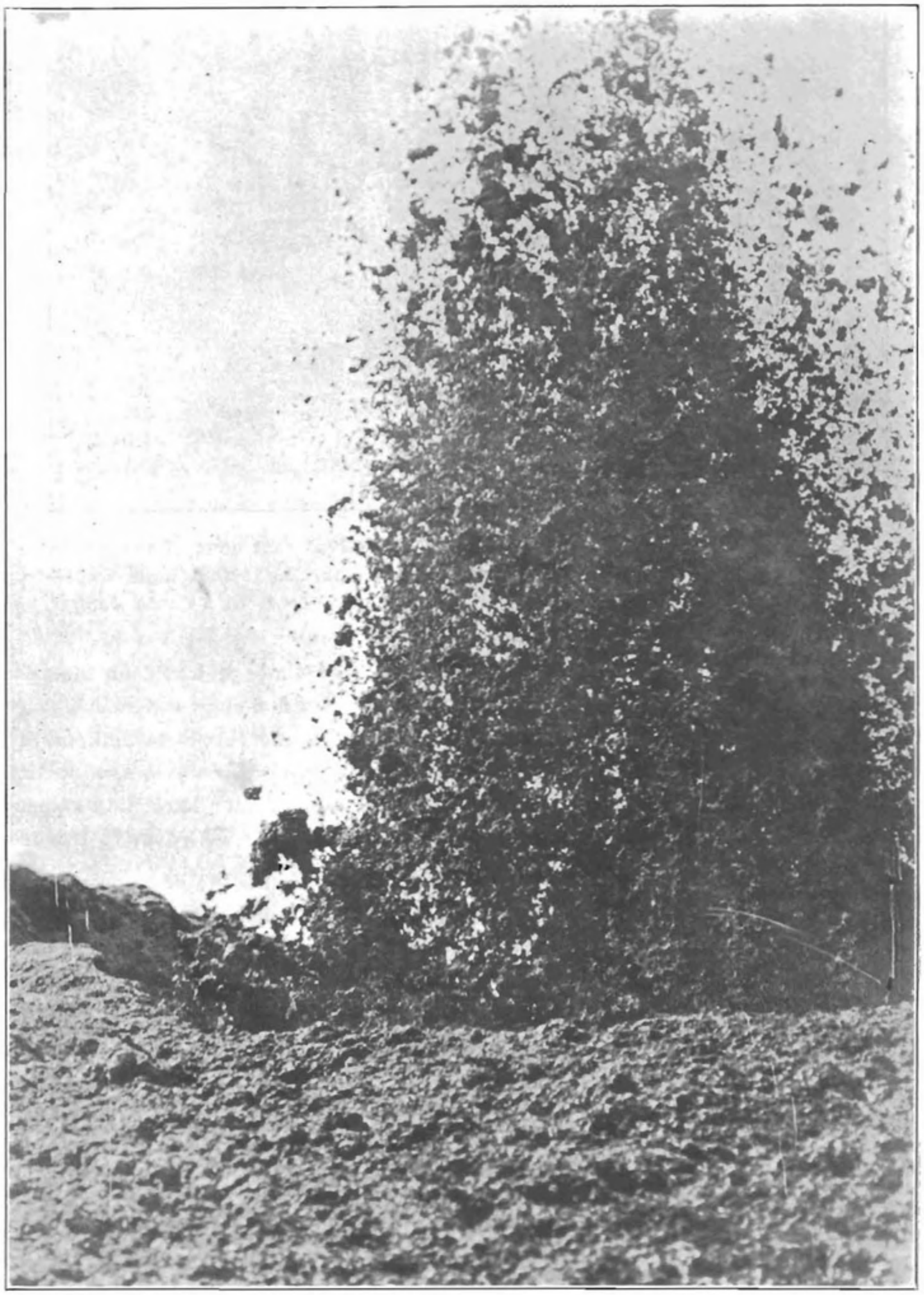
No. 277—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | April 17, 1930

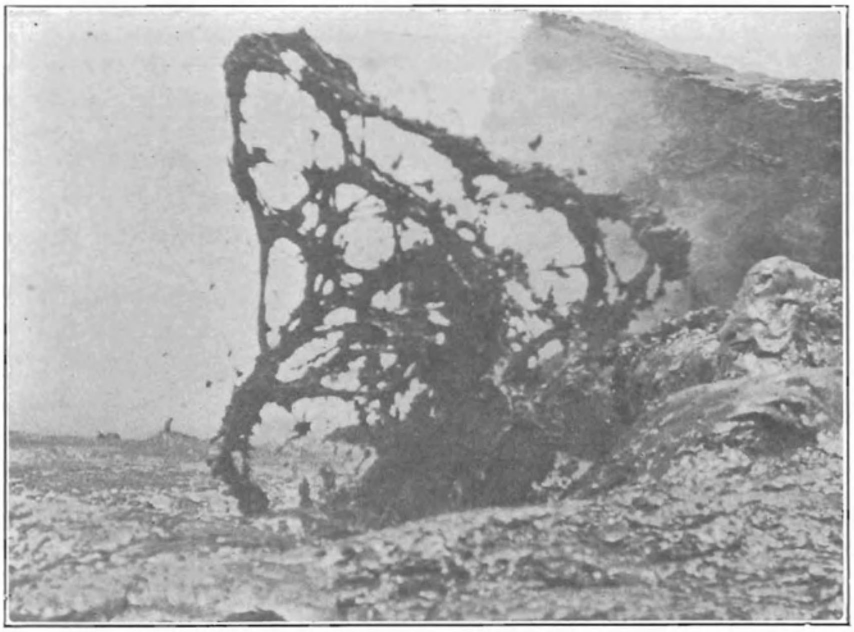


Gigantic incandescent lava froth fountain at north crater of Alika flow source, eruption of Mauna Loa October 25, 1919. Fountaining 50 feet away and 200 feet high, looking west from edge of new cone 200 feet above surrounding country. Southwest rift of Mauna Loa 7,834 feet above sea level. Photo Jaggar.

THE BUBBLING AND GUSHING OF LAVA

If a volcano enthusiast among Hawaii residents had written the title of this article, he would have called it "lava fountains."

Such is the common term used in Hawaii for the uprush of liquid lava at one place. This upward rushing of slag makes in the liquid lava lakes of Halemaumau the clustered burst of big bubbles through the slaggy skin in the middle, called "central fountains." The agent that lifts the central fountains is gas, but W. L. Green in the nineteenth century thought it was air. When these bursting bubbles recur about once a minute at Kilauea, they have often been called "Old Faithful," and for many months about 1910-12 Old Faithful stayed in nearly the same place. In 1913 there came a time when there were two pools, and the new pool had a "New Faithful." Then in 1916 and



Eorder fountain of heavy lava spinning Pele's hair at east cove of main lake May 23, 1917, interior of Halemaumau pit. Lava spurt is 15 feet high. Exposure 1/100 second. Photo Jaggar.

thereafter when experiments were conducted at the edge of the lava lakes, many fountains were studied which had a tendency to migrate along the surfaces of the streaming pools with repeated bursts of gas, the gas sometimes flaming, at other times making puffs of unburned, brown, sulphur fume. These migrations commonly ended at a "border grotto," a place of continuous marginal fountaining or bubble bursting, where the black vitreous melt was flung over the bank and built up an oven. The continuity of the effervescence here indicated some localized disturbance such as a subsurface streaming against the bank to determine a continued release of gas bubbles. And sometimes these continuous fountains formed in the middle of the lake indicating a subsurface pouring of lava down a well, and thereby a stirring out of the bubbles, which rose and burst eternally.

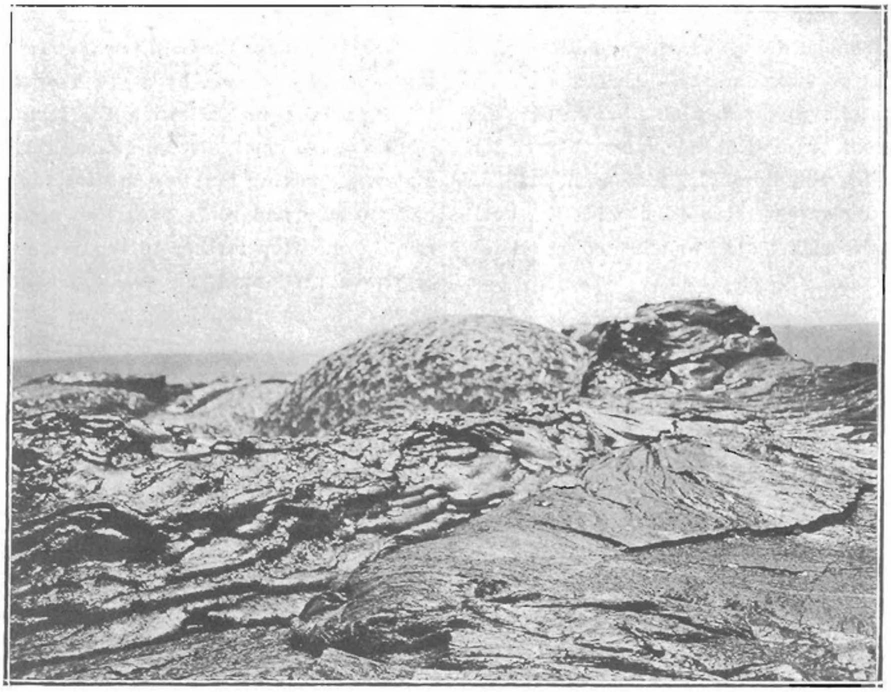
When a pot of porridge boils, it is not customary to call the bubbling places "fountains." "Fountain" is a misnomer for the golden slaggy dome bursts of incandescence in a liquid lava pond. The layman conjures up a picture of a spouting jet over an artesian well or an oil gusher when he hears the word "fountain." Just such fountains occur in lava. The picture on Page One, a very lucky snap shot, shows a true lava fountain 200 feet high. This was made at the time when in 1919 Mauna Loa had opened a crack in its flank releasing gas-charged lava from the depths to spout up like an oil gusher. After a month this had built up a cone 200 feet high with a marvelous cauldron of violently seething golden glassy froth boiling inside, and from the tube below a jet of this molten basaltic pumice was shooting into the air through the pool without interruption. Sometimes it would go higher, sometimes lower. For weeks it was going continuously. The material separated into lumps and shreds as millions of bubbles expanded in the pool, some of it was drawn out into hairs and membranes, and the larger hardening skeins and slops of this molten rock matter were four to five feet long.

In order to take the photograph, it was necessary to clamber up through hot pumice of buff color on the outside of the cone to windward, where over the summit edge lay the fountaining basin with its gigantic waves surging forward to a cascading outlet at the right. From under the back wall of this cup rose a geyser of fiery fragments, the pieces bright red-hot and very porous, and at the edge there were occasional fragments still glowing, showing that from moment to moment the jet was turned, like a lawn sprinkler, first in one direction and then in another. This made it necessary to take some chances in running in to within 50 feet of the nearest falling jets, on the summit edge, point and snap the camera, and get away without being bombarded. The sensation of looking up at that towering curve of rising and falling bombs, the highest pieces shooting from 200 to 300 feet above the summit and the lighter ones seeming to float like burning paper, all with intolerable heat and a complex of rumbling, whirring, and pounding noises as the larger lumps flopped down on the ground close at hand and stuck there, viscid and glistening, was an adventure to be remembered. More than a second or two of that heat would have ruined the camera. The crater was like a titanic open chalice of fiery liquor foaming in scarlet surges, these being impelled continuously forward by the geyser jets behind, the flood lifted by the jets losing its liquid aspect almost instantly, and the expanding gas within giving it the appearance of very loosely knitted worsted. The beaten foam quickly quieted down to form black curds where the pond cascaded through the sluiceway leading to outflow. The color of the molten stuff is bright yellow at night, but in daylight is a reddish transparent tone with a luster like jelly, brightly glistening in the sunlight, and with purplish shadows, the jet distinctly changing color with the cooling from orange on the rising side to wine color on the falling slope of the arch.

Such is the most magnificent of the true lava fountains and it may well be compared to the prominences on the sun, but the latter are wholly of gas. Probably in both cases hydrogen is the dominant gas. A tremendous banner of burning gas stands above the Mauna Loa fountain at night, salmon and rose with bands of green. The motive power is gas expansion, just as it is in the bubble bursts of Kilauea. In the picture on Page Two the camera is 25 feet from a border fountain in Halemaumau, the lava lake being beyond and to the left, and the foreground is the lake margin. This shows the process of spinning Pele's hair. Gas is rushing up through a stiff, viscous lava, and carrying the lava with it, drawing it out into shreds, and the bank reflects it back into the lake like a surf repelled from a rocky shore. The tangle of fine glassy cobwebs, puffed and blistered by the endlessly bursting glass blisters on the melt, is caught up by rising heat currents of air and carried away by the wind.

This same corner two months before was building a border cone through the closing in of a marginal grotto so that the oven became entirely enclosed except for a crater through the top (see Page Three). Here we have a beehive cone with a lava fountain inside, connected by a tunnel with the lake, only a few feet away. Such cones are generally formed by a crack opening in one bank of the lava lake, and allowing the lava to penetrate it and start convectional streaming with release of gas. This makes a spurting fountain in the crack which opens a circular crater and roofs over its cupola and its tunnel. It is only one step farther to the place where such gushing of gas-charged molten glass, escaping from Halemaumau through a large radial crack at a place 500 feet from the pit (Page Four) wells up in a dome through a shell or half-cone of its own spatter and marginal congealing and keeps on welling up like an artesian gusher with its surface eternally coated with a net of bubble membranes, as shown in the picture, and so forming a "standing fountain," the source of a flow which was pouring off to the south on the Kilauea floor during the great crisis of overflow at Halemaumau in March, 1921. Thus we see that there is a transition from the central to the border fountains, and from the border fountains to outflow fountains. The explanation of the rhythmic fountains such as Old Faithful appears to be that they are always over a small well under the shallow lake, where the convectional circulation is draining the gas-charged liquid downward, and stirring out an accumulation of bubbles which cluster together and escape at regular intervals through the viscous lava of the lake surface. Whether there shall be rhythmic release or continuous escape probably depends on the depth and viscosity. T.A.J.

Same east cove of Halemaumau as Page Two, on March 30, 1917, in the evening. Flaming and spurting cone, exposed for 30 seconds, and exhibiting a succession of jets. Photo Jaggar.



Smooth dome fountain at source of flow outside of Halemaumau 500 feet to the southwest, March 20, 1921. The liquid part stood nine feet high, of orange incandescence, rising from under the knob on the right and pouring away into the background. Photo Jaggar.

KILAUEA REPORT No. 951

WEEK ENDING APRIL 13, 1930

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

On April 9 a big scar on the east wall under the 14-ton bowlder showed as the location origin of the avalanche of April 4, which threw immense rocks far out on the lava floor of Halemaumau. The 14-ton bowlder is doomed to fall into the pit with the ledge which helps to support it on the east rim. This was the largest rock blown out during the explosive eruption of May, 1924.

The sulphur stain on the south bottom of the pit has become whitish in color. Steaming is as usual, and no other changes are to be reported.

The seismographs at the Volcano Observatory registered 12 tremors, the longest having a duration of three-quarters minute; and one very feeble seism. The net accumulation of tilt for the week was slight south. Microseismic motion was normal.

MARCH TILTING OF THE GROUND

At the Hawaiian Volcano Observatory the tilting or tipping of the ground in the seismograph cellar, expressed as angular change and direction of motion of the plumb line, was as follows:

March 3—9	1.03 seconds	NNE
March 10—16	2.32 seconds	WSW
March 17—23	1.06 seconds	SSW
March 24—30	2.05 seconds	NNE

This computation is by overlapping seven-day means. January and February were by direct reading (Volcano Letter No. 267 and No. 271).

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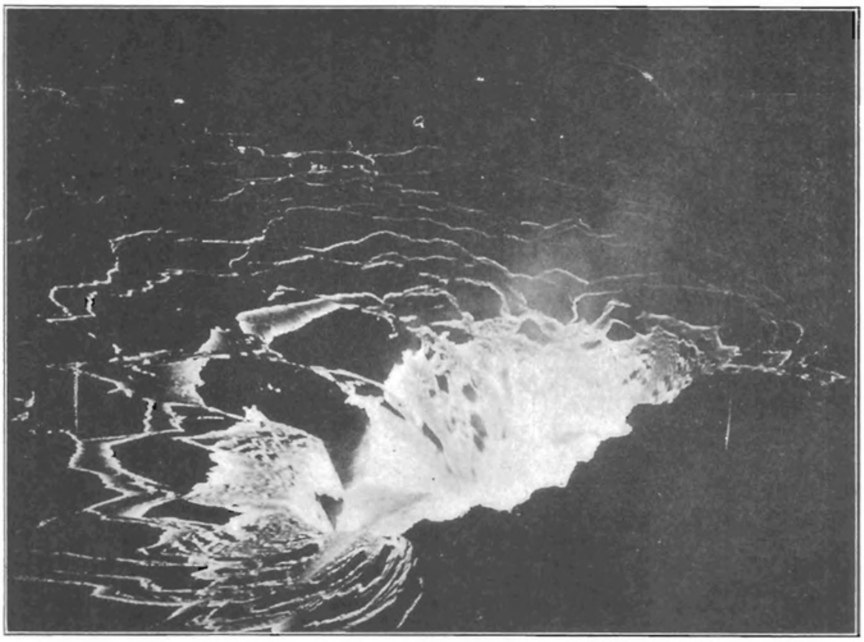
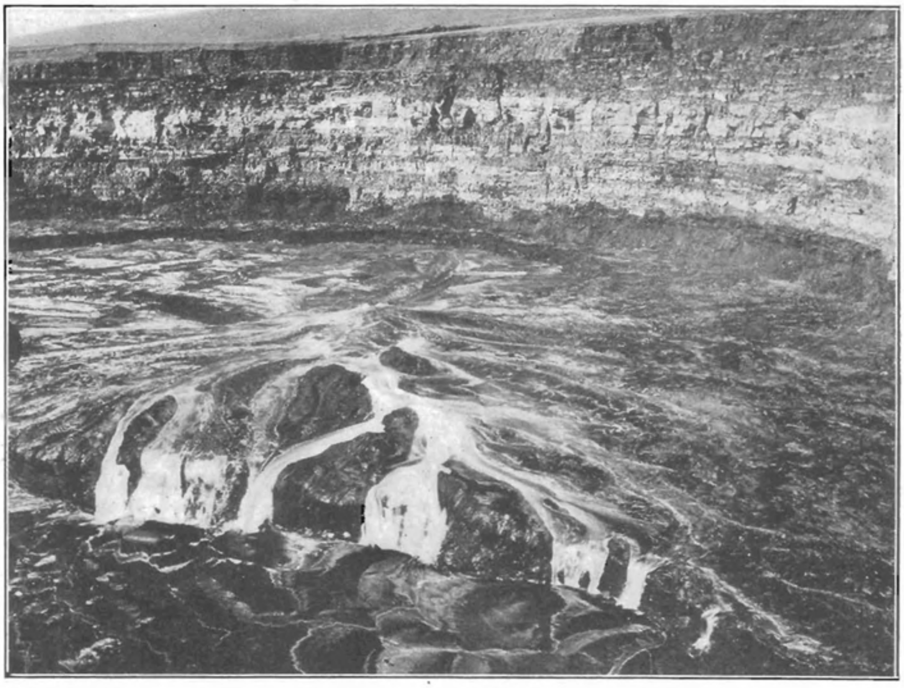
No. 278—Weekly Hawaiian Volcano Observatory, National Park, Hawaii April 24, 1930



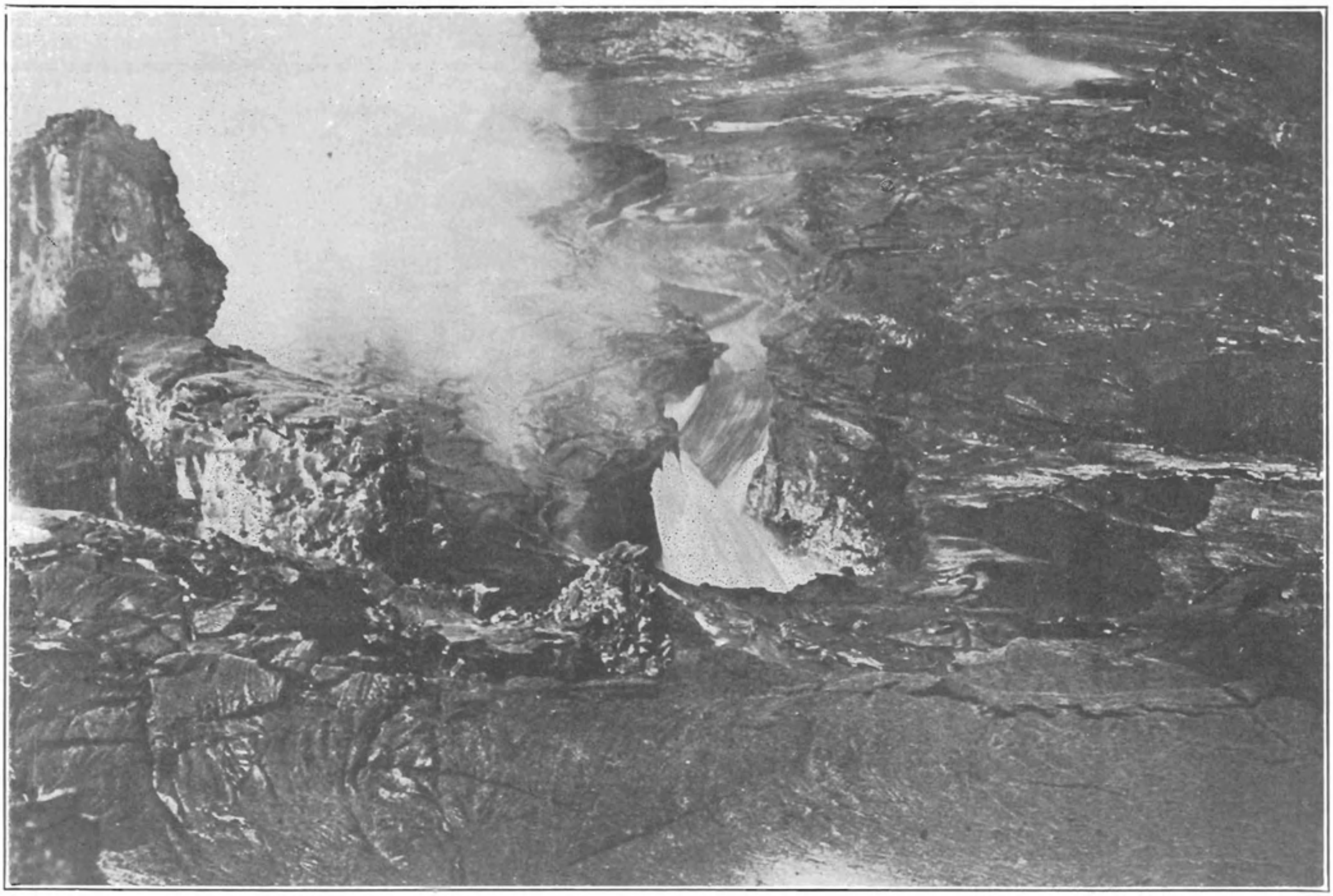
Lava cascade into North Pool of Halemaumau, 7 p. m. December 21, 1923, showing the concentric breaking of crusts as the incandescent fluid was sucked down a well which had temporarily become a sinkhole. Photo Finch.



Overflow flood of lava from North Pool of Halemaumau January 8, 1924, the North Pool lying in the middle of the radial flows. These cascade into the main lake in eight fiery ribbons shown in the foreground. Photo Emerson.

LAVA CASCADES IN HALEMAUMAU

To understand the distinction between lava paste and lava froth in Halemaumau pit of Kilauea Volcano, the observer should compare the happenings of different periods, when in the one case the froth (liquid lava) fountains up in artesian fashion through one of the wells or shafts that leads down through the paste (bench lava); and in



Cascade from remnant lake after a subsidence, into a sinkhole in what had been lake bottom in January, 1917. Photograph was taken February 14, 1917, revealing the former bottom of the lake as a shallow affair about 40 feet below the former lake level. This bottom is the lava paste or bench lava. Photo Jaggar.

the other case the froth lowers in its well so that the remaining liquid lava rising through other wells streams across the lake area and cascades down into the evacuated shaft. Lava pulsations up and down for periods of a week or more are characteristic of a time of high activity, and the feeding well, which this week is overflowing on one side of the pit, may next week be receiving a cataract of golden incandescent fluid from its neighbors.

The general arrangement at a time of high rising, when the lava was actually level with the rim of Halemaumau, and had just been overflowing on the northeast, is shown in the map on the last page. This was in January, 1921, when there had been a big December rise, and the lava paste, shown by the shaded block in the cross-section, had been lifted bodily within the funnel, so that wells for the liquid lava were developed at the two wall cracks right and left (shown in black). The section goes from southwest to northeast, and the northeast margin of the pit is shown freshly overflowed in plan and section. This of course was a cascade into the open country. Now if we suppose the well, shown at the left in the section, to lose its supply of feeding lava in the depths and reverse its flow from up to down, while the right-hand well, connected by tunnels with all the lakes, keeps on bubbling up strongly, there will be developed a cascade into the left-hand well. Whatever may be the cause, it is a fact that the wells maintain different levels in the circulation, from time to time. (See Volcano Letter No. 272.)

The most intense fluctuation between different wells in the paste, with domings up and outflow over one well one week, and siskings down with inward cascades in the same well the next week, occurred during the last great rise of Halemaumau lava that preceded the explosive eruption of 1924. There had been a big subsidence in the pit of 400 feet in August, 1923, accompanied by the outflow in the forest near Makaopuhi on the Chain of Craters road. There was immediate rapid recovery in Halemaumau throughout the autumn of 1923, developing an enormous lava fill, from wall to wall, only 114 feet down January 21, 1924. At times this was a sea of liquid lava when all the bench lava was flooded, at other times it was a large shallow heart-shaped pool surrounded by a flat platform, with four low islands, and at the north an isolated pond of liquid lava in the platform between the two lobes of the heart. This was called the North Pool.

It is of interest to note that the lava paste, represented by the islands and platforms, was doing some horizontal moving which the islands exhibited. Thus in November, when at the beginning of the month the lava was 320 feet down and by fairly uniform rising stood only 260 feet below the rim November 30th, an island in the main pool, which had been there for several weeks, moved nearly to the southeast bank during November 24-25. A second island had appeared in the main pool November 10, disappeared on the 12th, reappeared on the 13th, and soon thereafter became joined to the larger island. In December the lava showed numerous oscillations in level, making a net gain of 39 feet.

These oscillations of December, 1923, are what produced the spectacular cascades. The dominant rising was at the south, and on December 7 there was a very strong spurt with downrushing cascade into the North Pool. These performances were repeated about once a week so that on the 14th and 21st December (see first photograph) similar torrential cataracts into this pool reached still greater size. On the 27th the influx was repeated with very rapid fluctuations, so that during a half hour more than ten million cubic feet of lava was poured out, and over 40 acres were covered with the molten flood that drowned all islands and individual lakes. Then tumultuous fountains would break out at various places, some of the source wells would become sinkholes, and in all five wells were located.

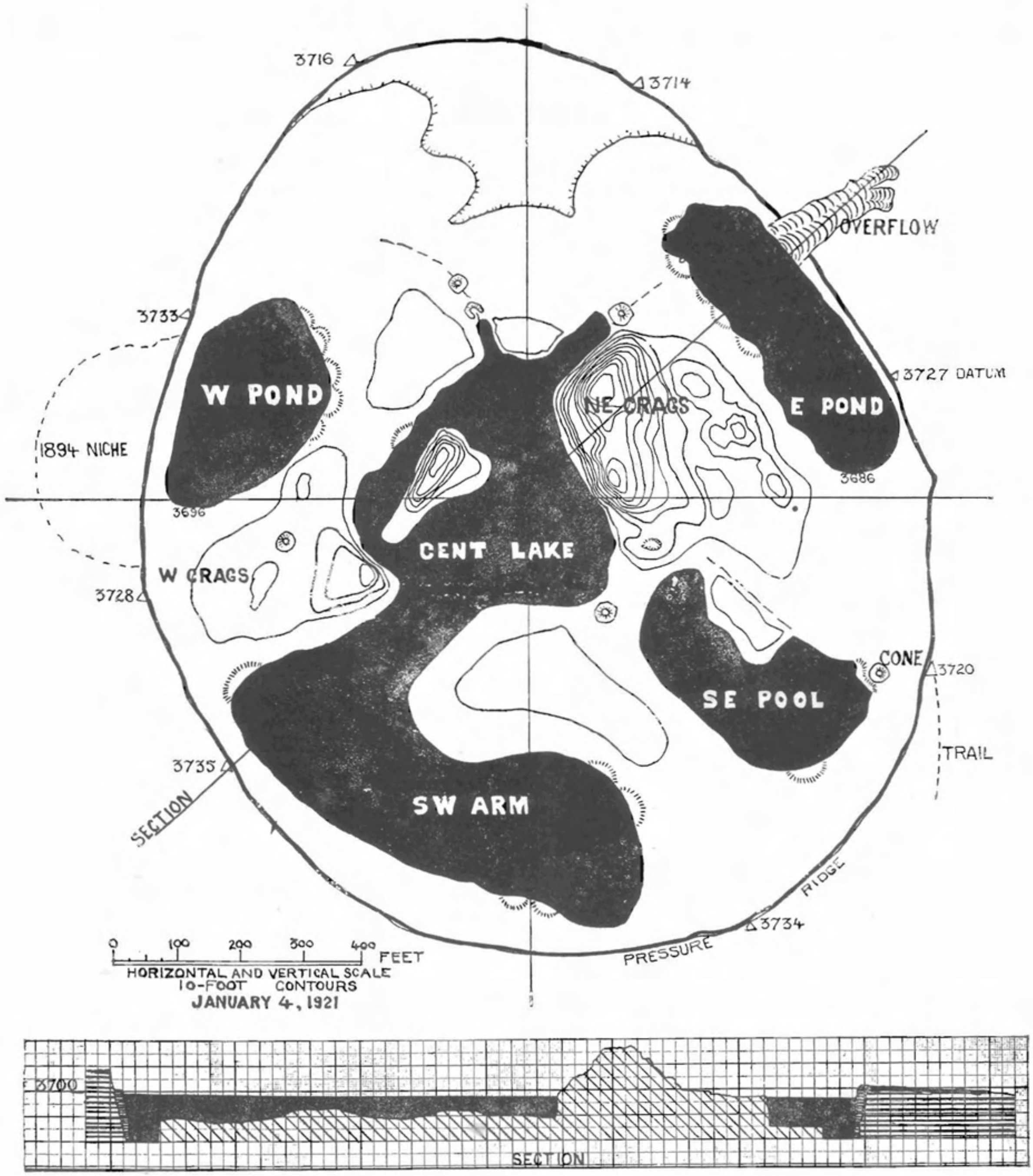
In January, 1924, the weekly periodic flooding continued, but the North Pool sometimes became a source, and on January 8 (see second photograph) this pool was sending out extremely liquid radial torrents which cascaded into the main lake, as shown in the picture. The heat was almost unbearable at many places on the rim of the pit. A cone at one side discharged gas through a crack near its base. Several islands were drowned. On January 18 the liquid rose 65 feet in less than 16 hours so that on January 21 the lake was 45 acres in extent with no islands or separate pools visible, and the tumultuous fountains often hurled up spray 100 feet into the air. These violent fluctuations continued in February, but after February 12 the whole lava column including the paste lowered gradually until by February 21 the floor was 380 feet below the rim, the cascades into the North Pool being repeated February 15, 17 and 18, sometimes with a drop of 40 feet, while the main source was a south feeding well from which bright lines radiated. The topography of the paste lava reappeared and then collapsed around the northern pool along with the development of fume. Glow was last seen at the southeast, where there had been a conelet. In April came the subsidence and earthquakes in Puna, and in May the gigantic collapse at Halemaumau, accompanied by steam-blast eruption.

What process causes a well to be a feeder one day and a sinkhole the next is a matter of speculation, but there are many measurements on hand at the Hawaiian Volcano Observatory, the study of which may help to solve this problem. If the map and cross-section on Page Four are compared with those of Page Four of Volcano Letter No. 272, it will be seen that January 4 differs from March 14 of 1921 in that the paste lava block had been lifted clear of the two walls so that there were cracks filled with liquid lava on each side, whereas in March the level was lower and the cake of paste, which must be shaped like an inverted cone to fit the funnel of the pit, was settled differently within the tapering shaft. The lift of the paste as a whole is somehow connected with the gas expansion of the deep magma, from solution in which the gases escape and unite with increased heat and consequent liquefaction of the melt in which they formed bubbles, and it is highly probable that the few wells of the upper part of the combined lava column fork out into a network of wells down below. This network expands and lifts the whole sponge. If this is what happens, probably the upper harder part of the paste, with its crags and floors and overflows, is always breaking into blocks with doming and splitting of the crust, and this motion changes the relation of the different wells to each other. There is a circulation of the liquid froth with a maximum of rising where it is lightest and hottest, and of sinking where it has lost its gas and become heaviest. It is also eternally solidifying here and liquifying there, the partial solidification adding to the material of the paste. Thus the source wells and sinkholes shift in accordance with the equilibria of all these processes.

The photograph on Page Two shows the southern part of what had been the lava lake of Halemaumau a few days before, in February, 1917, when a sinking spell had revealed a well under the lake where the fountains had been. Into this well now there was a mighty cataract of molten lava with hot flame of pale bluish aspect rising from the sinkhole, and fume condensing above and to the left. This was the first great topographic demonstration of the shallowness of the lava lakes. The picture on Page Three, shows a marginal cataract of 1919 of the same character, with the whole lake pouring continuously into a void, tearing great skins on its surface, all of this ac-

Main lake in Halemaumau cascading into a well at the Northeast cove June 9, 1919, a process that kept on for 11days without altering the relative level of the lake, though the entire lava column was sinking at this time.

Photo Jaggar.



Map of Halemaumau and profile section January 4, 1921. Elevations above sea level in feet. Liquid lava black, diagonal shading bench lava, broken lines are cracks. This situation followed a marked rise in December when the liquid lava had gained at the expense of the crags and islands, and had overflowed the rim of the pit from the East Pond.

companying subsidence of the lava column and disturbance of the bench lava, but all a part of normal circulation phenomena, and not an outflow, for the level of the lake remained relatively constant for 11 days while the cascade persistently poured into the gulf. The lava lake even rose at times, relative to its own banks, while this was going on. T.A.J.

KILAUEA REPORT No. 952
WEEK ENDING APRIL 20, 1930

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

No changes in Halemaumau have been noted except additional rocks on the bottom below the 14-ton bowlder. The bowlder has not changed its position. Crack measurements show no changes near the tourist observation station.

Dense steam was rising from Halemaumau on the afternoon of April 18 and the morning of the 19th due to light rains.

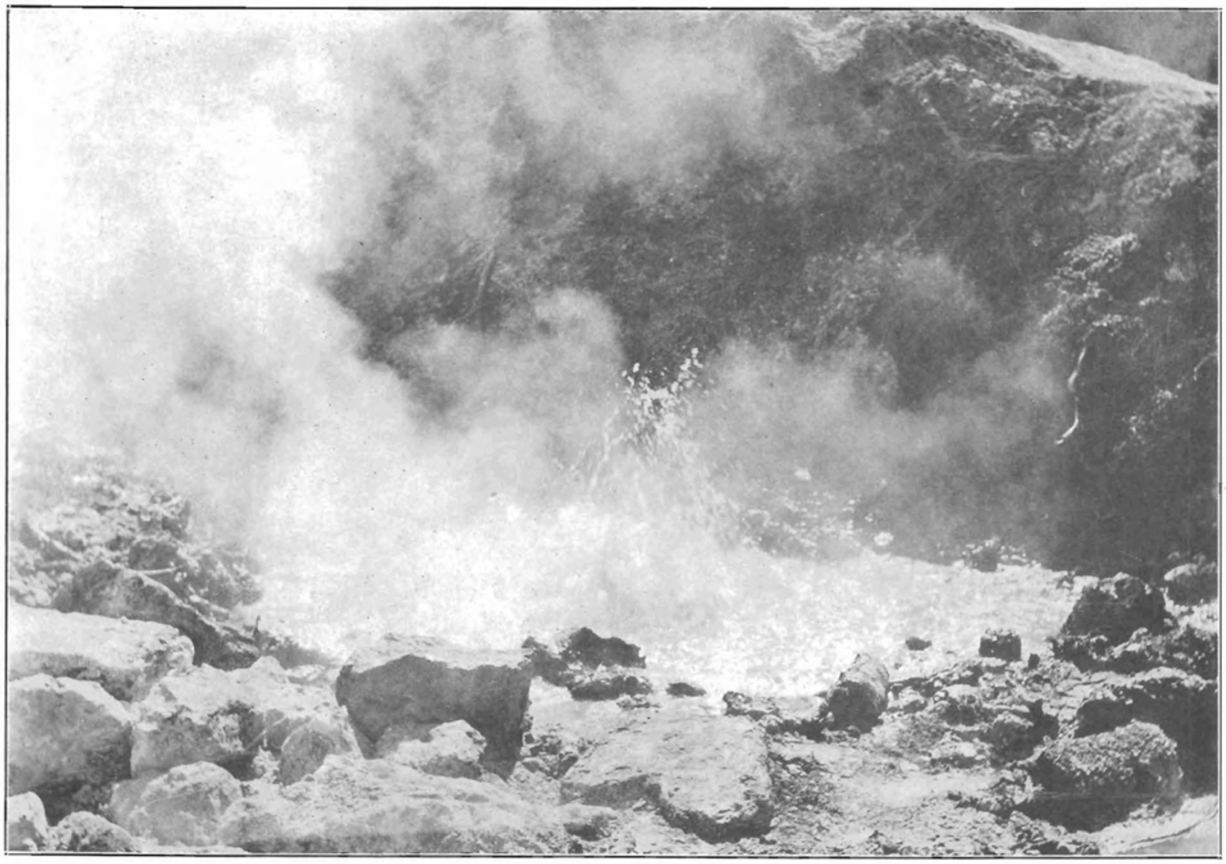
Ten seismic disturbances were registered by the instruments at the Observatory during the week, classified as follows: Six tremors, the longest with three-fourths minute duration; three very feeble seisms, one showing an origin 18 miles away; one distant earthquake, the long wave recording feebly at 9:09 p. m. April 15.

Tilt accumulated moderately SW. Microseismic motion was slight.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 279—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | May 1, 1930



Boiling pool of solfataric water in Devil's Kitchen, five miles southeast of Lassen Peak, August 17, 1929. Photo C. A. Huff.

LASSEN REPORT No. 25
LASSEN VOLCANO OBSERVATORY
R. H. Finch, Associate Volcanologist

SEASONAL VARIATIONS IN HOT SPRINGS

During the summer of 1928 the most active vent in the Supan solfatara, Lassen National Park, showed the following temperatures:

Early Summer	194° Fahr.
July 28	240° Fahr.
Sept.	235° Fahr

Similar variations of this vent have been noted in other years.

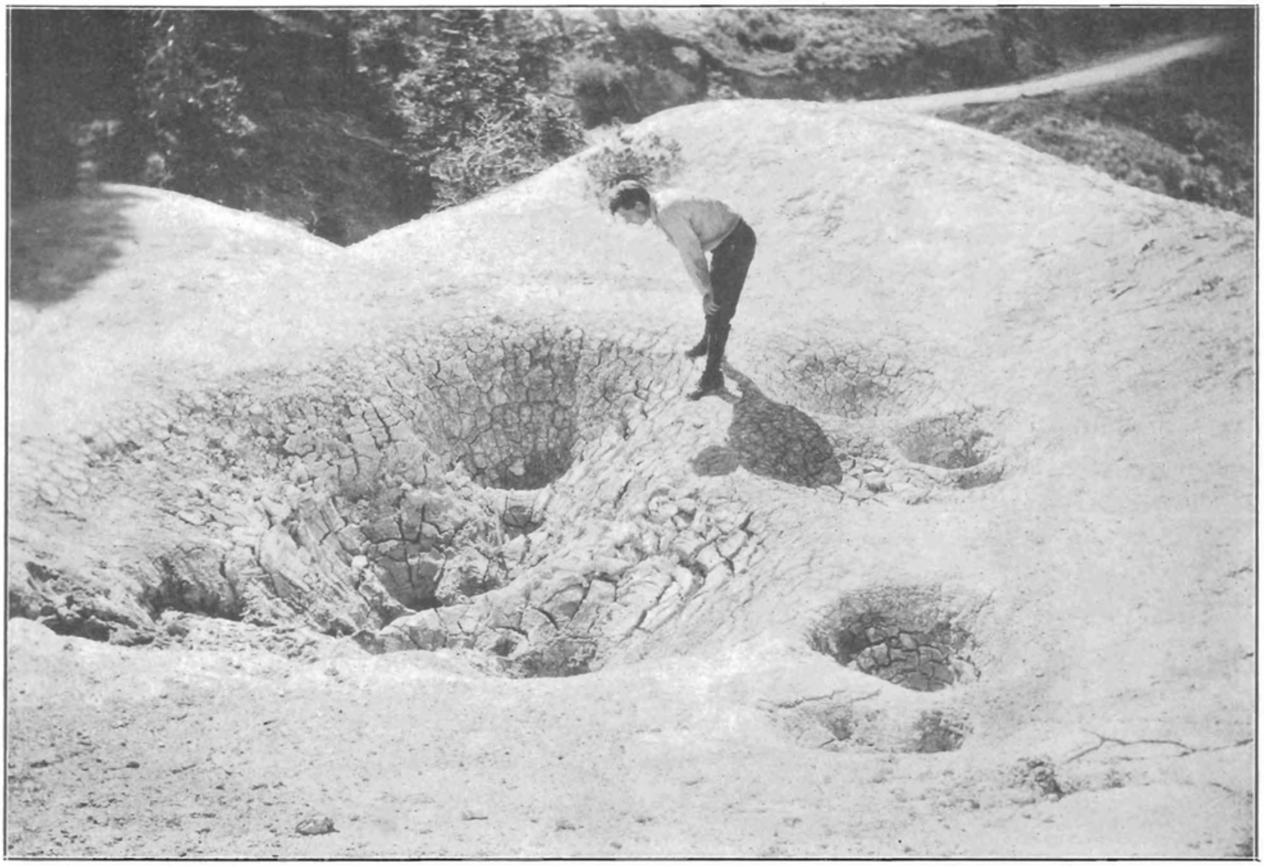
Whatever the ultimate source of the heat of hot springs a decrease in the amount of discharge should allow the smaller volume to be more highly heated. As is to be expected, there is a seasonal variation in the temperature of many hot springs, the highest temperatures occurring in the dry season and the lowest temperatures in the wet season. Why, then, should the hot spring under discussion show a maximum temperature in July instead of in September. There was no rain between July 28 and September 5.

Now it is commonly noted that with the shorter days and increasingly cooler nights that are reached in September and October, there is a tendency for many springs to show an increase in discharge. Some that ceased to discharge in July or August or earlier will start flowing in September or October without any rain having fallen to furnish additional moisture. This phenomenon is especially striking in California where in many places there is commonly no rain between June and September. It is also noticeable at many other places with less seasonal contrast in precipitation. The increased discharge in the autumn is undoubtedly due to a decrease in evaporation.

The mud pots shown on page two, which are near the active hot spring under discussion, showed no water on August 27, 1929, and on September 30th there was over one foot of water in the largest hole with no rain having occurred between the two dates. The unexpected decrease in temperature of the hot spring noted must have been due to a slight increase in discharge.

SLIPPING AT SUPAN SLOPE

At Supan Solfatara a line of stakes placed 50 feet apart in November, 1927, parallel with the valley, and across a belt of fissures where slipping is in progress in the highly solfataric soil, has been remeasured from time to time with both tape and transit. Some of the stakes were disturbed, and in general the region of stake No. 0, one thous-



Mud pots in the Supan Solfatara, three miles south of Lassen summit, showing no water August 27, 1929. A month later water had risen in the large hole without any rain in the intervening period. Photo Finch.

and feet up the slope from stake No. 20, moved downhill 3 inches toward No. 20 as shown by transit measurements. Some of the intervening cracks diminished in width, the upper land overriding the lower land, so that some of the 50-foot intervals between stakes show a minus change. The following are the changes:

Stake Interval	Nov. 1927 to July 1928	July 1928 to Aug. 1929
No. 0-1	+0.1 foot	+0.3 foot
No. 2-3	+1.4	—0.4
No. 3-4	+1.3	0.0
No 4-5	0 0	+0.2
No. 5-6	—0 6	—0.2
No. 6-7	—0.4	0.0
No. 7-8	—0 2	0.0
No. 8-9	—0.2	0.0
No. 10-11	—0.1	0.0
No. 11-12	+0.2	0.0
No 12-13	—0.4	0.1
No. 13-14	—0.1	0 0
No. 14-15	—0.1	—0.1
No. 15-16	—0.2	0.0
No. 18-19	0.0	+0.2

EARTHQUAKES AT LASSEN VOLCANO OBSERVATORY

The number of earthquakes of local origin recorded at the seismograph in the Lassen Volcano Observatory at Mineral, California, during the calendar year 1929 was 96. The indicated distance to origin for the local shocks ranges from 8 to 12 miles, which is about the distance of the Lassen Volcano mass. The numbers of shocks recorded during the three complete years since the establishment of the observatory are:

Year	Number of Quakes
1927	266
1928	37
1929	96

Tilting in 1929 was much the same as during the preceding two years, and frequent adjustments of the instruments were necessary. The accumulated tilting of the ground appears to be greater than what can be accounted for by the changes of atmospheric temperature. In the winter season of 1928-29 there was a pronounced accumulation of southwest tilt, possibly due to a doming of the Lassen volcanic mass.

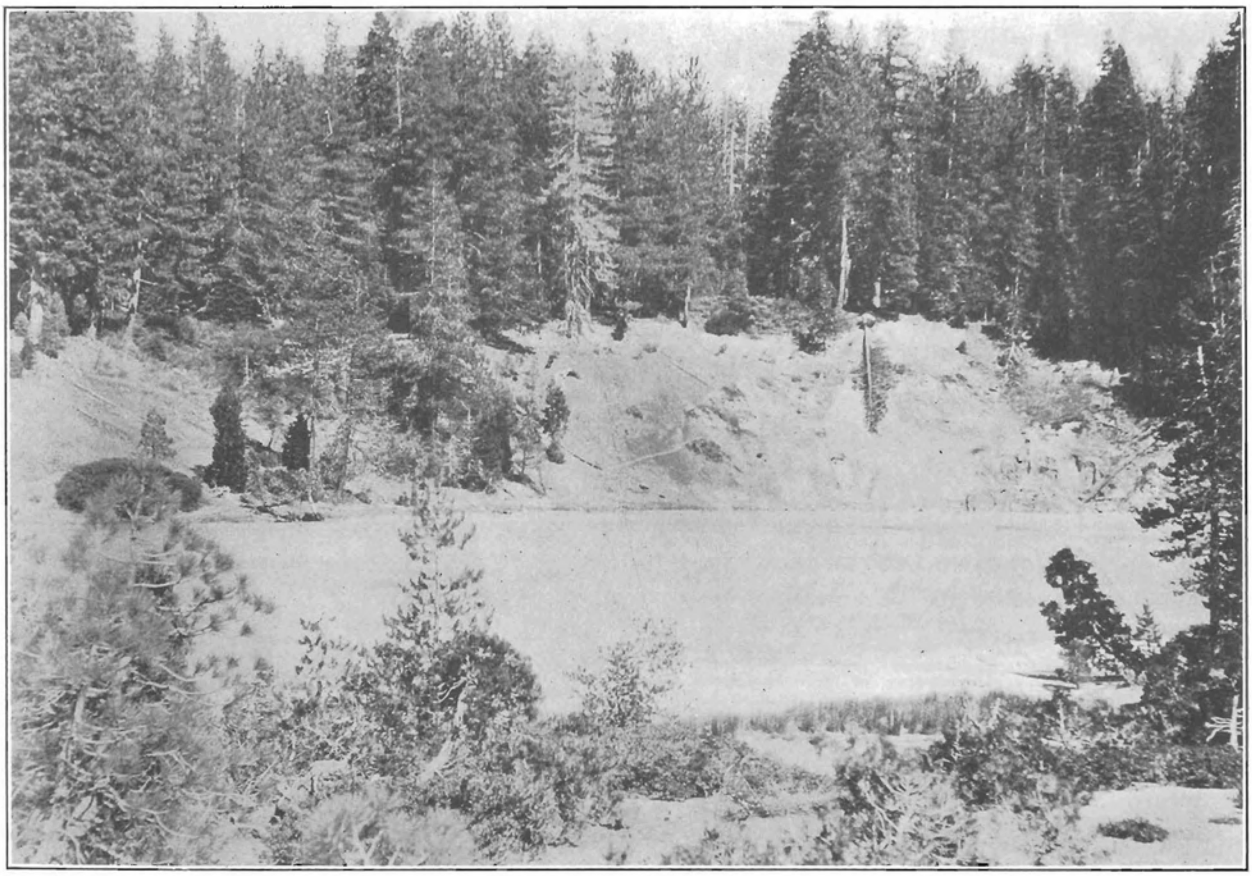
TEMPERATURE CHANGES LASSEN HOT SPRINGS

The following are a few of the measurements made at the different hot springs in Lassen Volcanic National Park, to show comparative data for different years. The later measurements made by Lassen Volcano Observatory are compared with each other and also with the records of Day, Allen and Diller between 1915 and 1923 (See Volcano Letter No. 238).

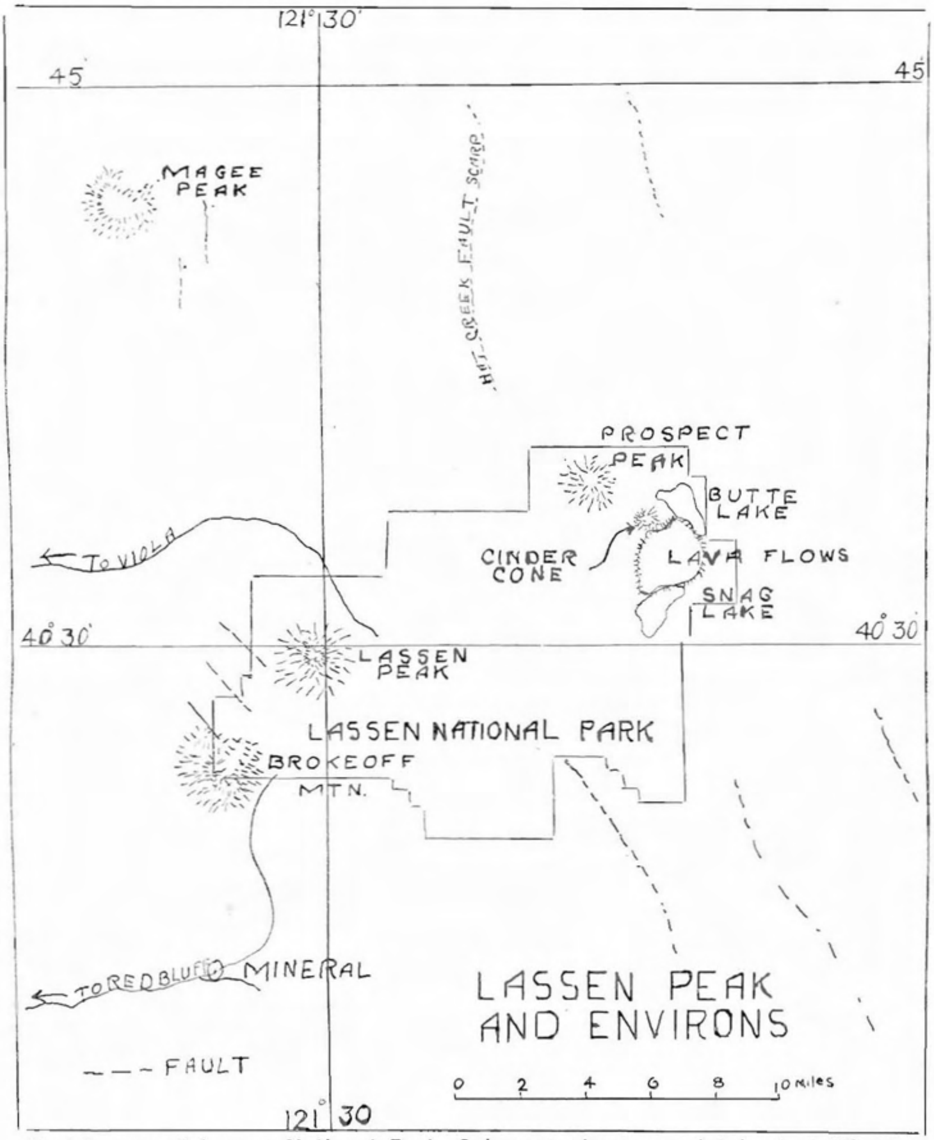
Location	Day-Allen	OBSERVATORY 1927	1928	1929
Supan's Solfatara				
Big Steamer, Aug. 11, 1923	185°F	Jan. 13 .... 194°F.	July 28 .... 240°F.	Aug 27 .... 197°F.
		July 6 174	Sept. 5 235	
		Sept. 23 240		
Bumpass Hell				
Large steam vent west of northwest pool, July 3, 1922	196	July 6 183	Sept. 5 192	Aug. 26 176
Spring No. 8, June 5, 1916	242	Aug. 26 194	Sept. 5 194	Aug. 26 198
Spring No. 10, Aug. 10, 1923	198	Aug. 26 194	Sept. 5 174	Aug. 26 198
Spring No. 14, Aug. 11, 1923	201	Aug. 26 217	Sept. 5 190	Aug. 26 197
Boiling Lake				
Steam vent south end, June 30, 1922 (The ground here subsided several feet 1927-28)	201	July 8 212	Aug. 11 204	Aug. 17 200
Boiling pool south, July 3, 1922	201	July 8 200	Aug. 11 192	Aug. 17 198
Devil's Kitchen				
Northwest boiling pot, June, 1922	196	July 8 198	Aug. 11 189	Aug. 17 195
Southern pool, June, 1922	201	July 8 199	Aug. 11 198	Aug. 17 199
South pot, July, 1915	201	July 8 198	Aug. 11 199	Aug. 17 197
Morgan Springs				
The Growler, (Diller) 1921	204	Aug. 24 200		
Spring No. 1		Aug. 24 175	Aug. 7 177	Aug. 22 168
Steam pool No. 17		Aug. 24 201	Aug. 7 201	Aug. 22 201
Spring No. 6, NE		Aug. 24 146	Aug. 7 176	Aug. 22 195
Spring No. 23		Aug. 24 183	Aug. 7 192	(Many of the spgs. were dry)

The above are not necessarily entirely identical places as the springs shift and vary and the thermometer exposure differs. In 1929 the Morgan Springs showed increase in incrustations and the volume was diminished.

R. H. F



Boiling lake near Drakesbad, Lassen Volcanic National Park, July 8, 1927. This is six miles southeast of Lassen Peak. Photo Finch.



Sketch map of Lassen National Park. Seismographs are maintained at Mineral and Viola. Morgan Springs are south of the Park; the other solfataric areas are close to Lassen Peak.

KILAUEA REPORT No. 953

WEEK ENDING APRIL 27, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

Halemaumau pit remains very quiet, only slight rock slides being noticed April 21 and 26.

Seven local seismic movements were registered by the Observatory seismographs during the week, of which four were tremors, each lasting from a half minute to a minute; and three were very feeble seisms. Microseismic motion was normal or slight, and tilting of the ground was strong NNE.

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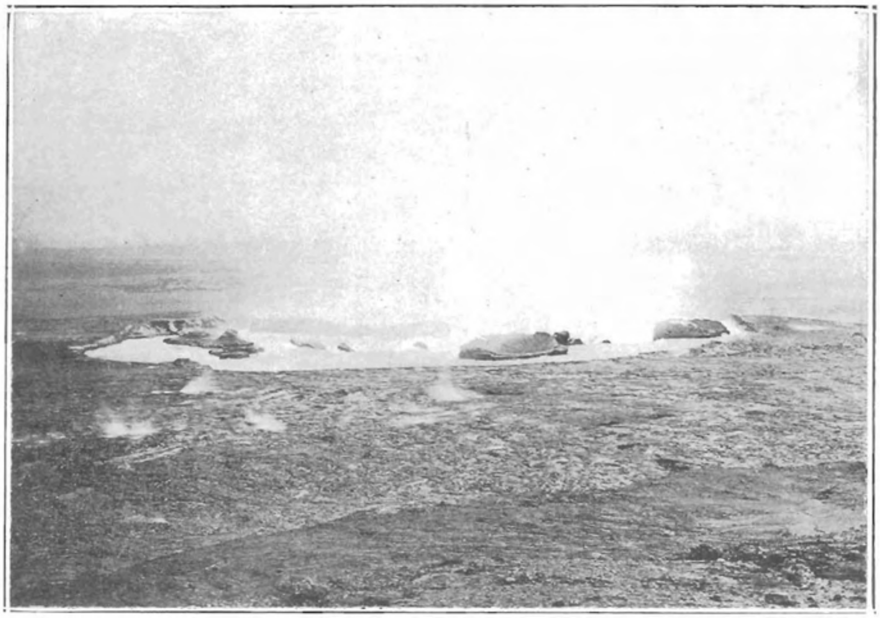
The Volcano Letter

Two dollars per year | Ten cents per copy

No. 280—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | May 8, 1930



Distant photograph of Halemaumau pit March 25, 1921, from the summit of Uwekahuna Bluff, near where the museum now stands. Shows the entire circle of the pit filled with overflowing liquid lava that was rushing around the islands to the south cauldron in the background.—Photo Jaggar.

WHEN KILAUEA FIRE-PIT OVERFLOWED

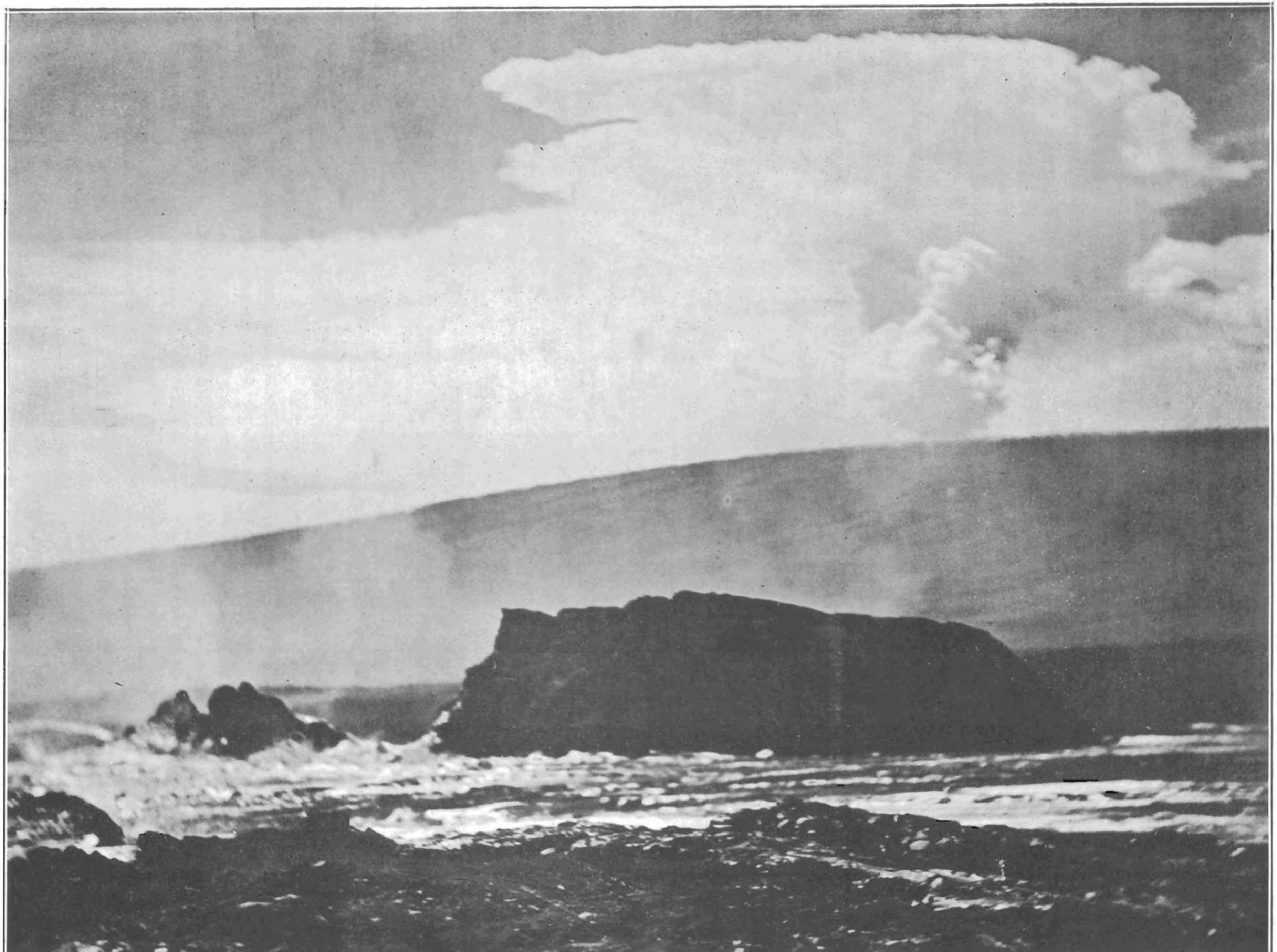
To the visiting traveler it seems quite incredible that the vast yawning cauldron of Halemaumau, the lava pit of the inner floor of Kilauea Crater, was overflowing its lips in five directions at the March equinox of 1921, only nine years ago. The following is condensed from the Journal of the first three weeks of March, 1921:

"At the beginning of March the continued subsidence of the lava in the pit made the scene surpassingly impressive owing to the great inner crags towering above the five lava lakes. The walls around the several lakes were sheer precipices, 70 feet high in places, and the rim of the pit stood 90 feet above the liquid lava. Some of the crags on March 6 were still subsiding steadily. The second week in March produced slow subsidence, both lakes and crags lowering a foot or two per day. The glow from the pit at night was dark red.

"The third week produced a spectacular rise, after beginning with dull, crusted, stationary lakes." March 15 inaugurated the rising by a swelling up of the lake bottom and heaving into the air the elephantine island exhibited in cut three of Volcano Letter No. 272. "Suddenly March 18 the crusts broke up, violent fountaining began, the lakes rose 40 feet in a few hours and united into one around the crags as islands, and the overflows escaped from the rim of the pit on three different sides. The overflow northeast swept down for a mile in the Volcano House direction, crossed the trail, and made aa lava at its front." This is what tourists see when they walk out to the pit from the Volcano House.

"The gas release which followed the overflowing produced three sinkhole cauldrons inside the pit which developed enormous clusters of roaring fountains, inrushing cascades (see Volcano Letter No. 278) and upthrown slaggy flings that formed ramparts. (Volcano Letter No. 277). Showers of grit and spun glass fell to leeward. The eruption continued steadfastly, with pit in adjustment to overflow, and the crag islands, which had risen less than the liquid, began to disappear. The longest flow was pouring all over the southern end of Kilauea Crater and out through a gap in the wall of Kilauea Crater, where it advanced a third of a mile into the desert and stopped."

"This activity was accompanied by whirlwinds generated by uprush of hot gas carrying shells and fragments of glowing basalt hundreds of feet into the air and lifting the fountains and burning gases into streamers of fire. These whirls made loud roaring noise, and the larger fragments fell several hundreds yards from the pit. At night the illumination was so great that print could be easily read at the Observatory two miles away.



Halemaumau pit brimming full, with its hot lake and crag in the foreground. In the background stands Mauna Loa with a remarkable convection cloud over it, probably due to a gas eruption at its summit crater. Photograph by Jaggar, March 19, 1921.

"The end of the month started a rapid sinking of the lava column, crags and lake lowered 10 feet or more per day, whirlpools and shifting sinkholes formed, the crags increasingly emerged from the liquid, fume became thicker the outflows of course ceased, and glowing wells were left over underground chambers at the source cones of the flows."

The first picture the visitor may compare with what he sees today when standing at the Uwekahuna Observatory, where the motion pictures are shown. This is a view taken March 25, 1921, looking down at what had been Halemaumau pit. Except that the pit at that time was somewhat smaller than at present, the effect is exactly as though one looked down at the present cauldron filled brimming full of liquid molten lava which was overflowing off to the right. At the far side of the white lake of molten stuff is seen at the left the pressure ridge of the southeast rim, which was near the road terminus. When the picture was taken, there was a great sinkhole cauldron at the pressure ridge, and most of the surface streaming of the lava through channels amid the crags was toward this sinkhole. The dark foreground is the terrace of Uwekahuna Bluff making this somewhat of a birdseye view, with the observer looking down at a landscape 500 feet below him.

A group of earthquakes immediately before and during the first days of this March rising of 1921 was felt in the southern and western parts of Hawaii, showing that the lava under Mauna Loa took part in the movement that was vented at Kilauea. There was almost certainly some gas effect of outrush at the summit crater of Mauna Loa, for at 3 p. m. March 19, 1921, a remarkable mushroom cumulus of what appeared to be a steam cloud with a stem, developed over the summit of Mauna Loa, its substance an ordinary cloud, but its persistency and situation suggesting a heating effect, in or near the summit crater of Mauna Loa. There was no activity of Mauna Loa otherwise reported. The large picture on Page Two shows this mushroom over Mauna Loa, taken from the east side of the boiling, rushing, lava lake of Halemaumau, and showing what was left of the great northwest crag of the fire-pit with the streaming and fountaining melt all around it. In the foreground is shown the glistening spatter lava and the general shimmer is due to the intensely hot gas rising from a million bubblings.

This overflowing of 1921 was the last of a series of such floods from Halemaumau which had been building up the Kilauea Crater floor at different times during the years 1918, 1919, 1920, and 1921. The last picture on Page Four shows the detail of a portion of the actual southwestern rim of Halemaumau in process of overflowing in 1919, and this was a third time within a twelemonth that this had happened. The light-colored surface at the left in the photograph is the Kilauea Crater floor with the western bluff behind it and the northeastern slope of Mauna Loa still farther in the background. All the dark lava on the right is the Halemaumau interior brimming full of lava, and in the foreground streams of this lava are seen flooding over the broken rocks of the rim in pahoehoe festoons like treacle or candy. These flows are pouring away to the left. The white post on a small bluff near the middle of the picture was the southwestern trig station of the Halemaumau rim. Here again the observer of the present day sees what it would be like to have the lava of the floor of the pit up to his level and trickling over a low part of the present rim, while he stood beside it, and watched it flow. It is extremely difficult for most travelers to visualize this, or to imagine that that still black floor of the pit as he sees it today is capable of breaking out in a moment and making lava floods, tending in the course of years to fill up the cauldron. T.A.J.

KILAUEA REPORT No. 954

WEEK ENDING MAY 4, 1930

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

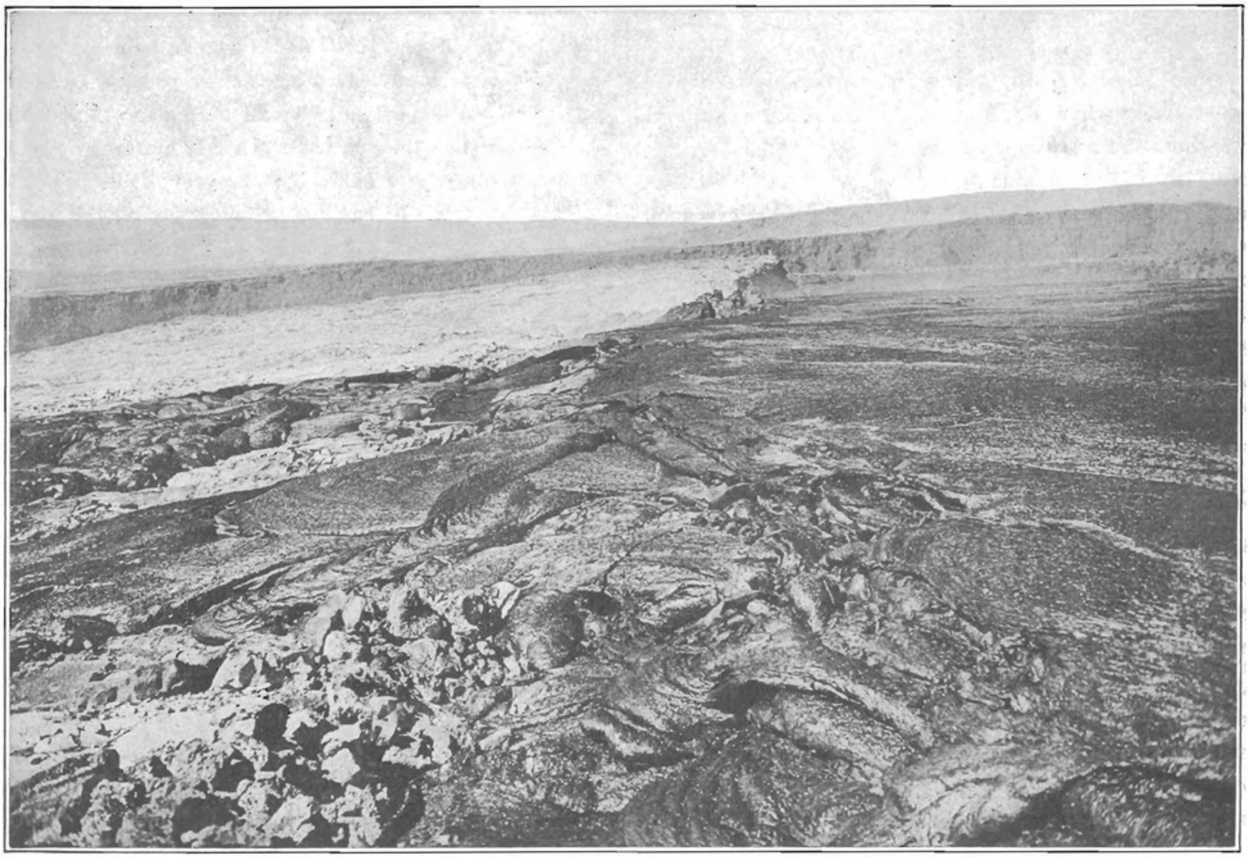
Halemaumau remains quiet, but a few rocks were heard falling from the north rim at 10 a. m. April 28. A white sulphurous spot was noted in the southwestern wall, and with very rainy weather steaming is seen at the south talus.

Eleven seismic disturbances of local origin were registered during the week, of which five were very feeble seisms. One of these indicated origin distance nine miles and was accompanied by tilt east, and another origin distance 16 miles and was accompanied by tilt south. There were six tremor spasms lasting each from one-quarter minute to one minute. Microseismic motion for the week was slight, and tilting of the ground was slight NW.

APRIL TILTING OF THE GROUND

At the Hawaiian Volcano Observatory the tilting or tipping of the ground in the seismograph cellar, expressed by overlapping seven-day means, in terms of angular change and direction of motion of the plumb line, was as follows:

March 31-April 6	1.11 seconds NE.
April 7-13	0.79 seconds SW.
April 14-20	1.03 seconds SW.
April 21-27	2.42 seconds NE.



Looking along the south margin of Halemaumau January 19, 1919, Uwekahuna Bluff in the background. In foreground lava of Halemaumau overflowing the rim in trickling streams.—Photo Jaggar.

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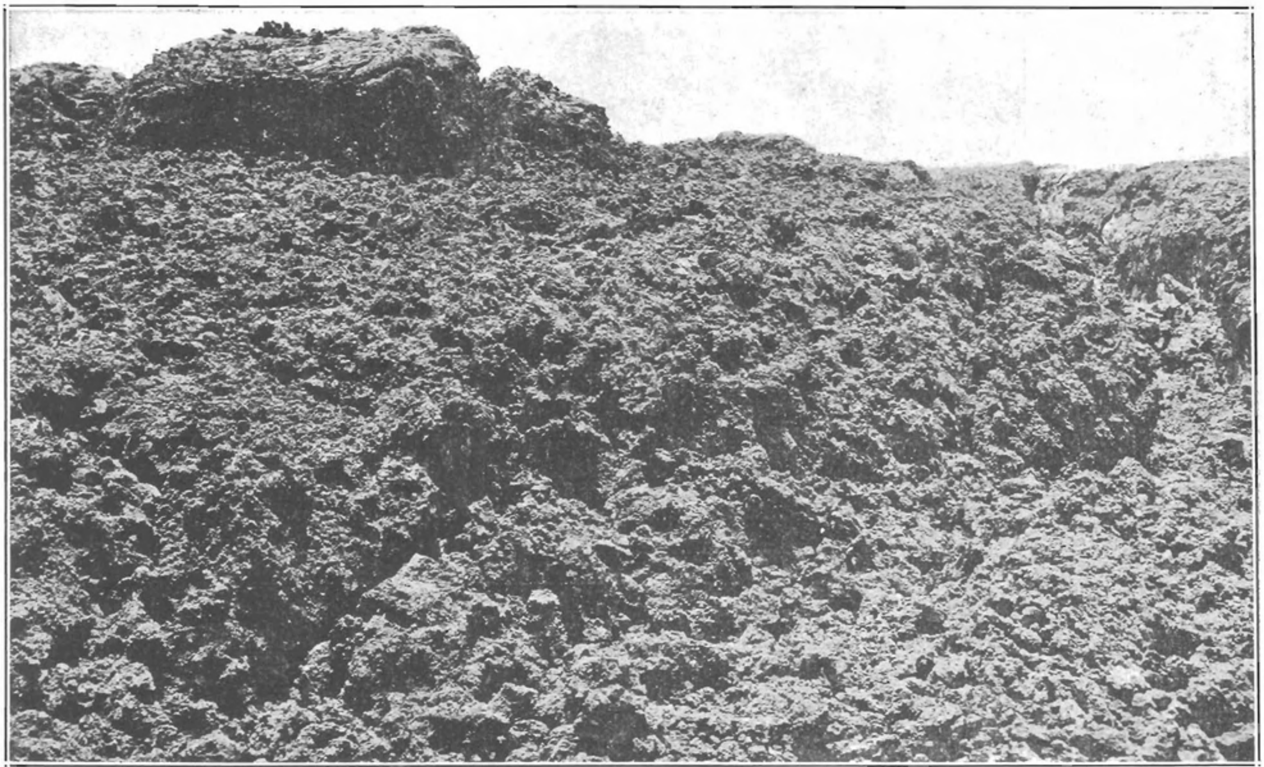
No. 281 Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | May 15, 1930



Aa lava and channel of Alika flow in South Kona on the slope of Mauna Loa, 1919. This shows typical aa texture on the bank that congealed after the glowing stream ceased flowing. This stream, 40 feet wide, swept through the channel for days at eleven miles per hour.—Photo Kanemori.

DISTINCTION BETWEEN PAHOEHOE AND AA OR BLOCK LAVA

The picture shown above represents a characteristic surface of what the Hawaiians call aa lava (pronounced ah-ah), in contrast to the smooth candy-like surfaces (pahoehoe) of basalt shown on Page Two. In the experience of the Hawaiian Volcano Observatory four eruptions of Mauna Loa have been studied, many years of lava activity in Halemaumau pit at Kilauea have been occupied with photographing and note-taking amid spouting and streaming basaltic melt, and three times the flanks of Kilauea Mountain have given vent to flowing lava, with both the aa and pahoehoe types represented. It is generally agreed by investigators that there is no essential difference chemically between aa and pahoehoe, and it is well known on Mauna Loa and Kilauea that the fountaining pahoehoe at the source of a flow may turn into aa clinkers within a half mile of the vent, and remain aa for the rest of its course down the mountain into the sea. It must not be inferred from appearances that pahoehoe is more liquid and rapid flowing. Some aa flows have rushed down Mauna Loa very rapidly, the source region making a glassy and frothy pahoehoe which quickly transformed itself to clinker a short distance away from the source. Some pahoehoe flows at the end of an eruptive period have found their way down the mountain very slowly as the end-stage of the outflow, the progress being through tunnels and crusts of their own making. When an observer stands on the bank of a golden, liquid torrent of lava flowing so rapidly as to make no crusts or skins, he can not tell from the appearance of the liquid whether it will solidify as pahoehoe or aa.

It thus appears that both pahoehoe and aa may occur on the same flow, that they both have the same chemical composition, that they both flow rapidly at times and slowly at other times, that they both may be very sluggish and viscous or swift and liquid, and that in general pahoehoe is conspicuous around the summit craters and near the vents of outflow, and aa is characteristic of the long flows far down the mountain slopes. Two notable exceptions to this last generalization were the last stages of the eruptive period of the 1881 flow from Mauna Loa to Hilo, which was pahoehoe, and the last stages of the

Rift floods of pahoehoe in the timber of the Mauna Iki region, December 24, 1919, six miles southwest of Kilauea. These flows came up a crack in the mountain, drained down the level of Halemaumau, poured out for seven months, and built up a hill.—Photo Finch.

eruptive period of the 1920 flow from Mauna Iki on Kilauea, which also was pahoehoe. The former flowed 30 miles from the vent as smooth lava in tunnels, and the latter five miles from the vent. In both these eruptions the early stages of the eruptive period produced aa flows whenever the scurce heap (pahoehoe) gave vent to a long flood down the mountain slopes. There is a suggestion here that crystallization is stimulated by free flowing of highly liquid frothy melt, that more crystallization or "sugaring" due to stirring may be the characteristic of the clinkering that is distinctive of aa lava, and that such internal stirring is stimulated by the greater gas-bubble content of the lava at the beginning of an eruptive period.

The photograph on Page One shows on the right the channel which had been occupied by a torrent of brilliant yellow molten slag for many days in September-October, 1919, where the Alika flow in South Kona crossed the road about 1,400 feet above sea level. On either side for a width of 2,000 feet this torrent had created a clinker field by backing up and overflowing from time to time during the eruption. The progress downhill through the forest was first a tongue of aa lava that pushed over the brow of the mountain into the steeper country and marched forward like a caterpillar tractor dumping talus over its front and then overriding the fragments beneath. This advance was about one mile per hour. After it reached the sea the congealed sides of the flow became the clinker field, and the stream inside rapidly narrowed and started its pulsations of backing up and making lateral tongues of overflow, now here, now there. Wherever any of the lava congealed, except within a half-mile of the source crack at 8,000 feet elevation, it solidified as clinker or aa as shown on Page One. The narrowed torrent was very brilliant, flowing perhaps eleven miles per hour, bringing large rafts or blocks of material broken away from the banks, and occasionally dumping these on one side or the other during a spell of overflow. Such a raft is shown in the stranded lump on the left of the picture. The process of solidifying, when one watched a tongue of overflow cooling, proceeded without any skins forming, and with the development of small black dots on the surface of the incandescent liquid, these becoming centers of congelation accompanied by a sprouting or crumpling action which made the whole hardening area appear like a bed of coals, with cherry red glow in the cracks. Flames are often seen among the cracks, but they are deceptive in a flow of this kind, because it contains so much burning vegetable matter that it is impossible to distinguish true volcanic flames. The surface of a cooling aa flow is excessively hot, with intense radiation like a bed of coals. In contrast to this, the surface of a pahoehoe flow starts to skin over with a membrane of glass the moment it begins to cool, this membrane draws out millions of oval bubbles so that the appearance is like layers of netting one above the other, and the result is a thickening, glassy skin which wrinkles into ropes and folds the size of which is dependent on the thickness of the flexible crust available. This vesicular crust is an excellent heat insulator, so that one may approach close to the front of the bellying toes of a pahoehoe flow before he perceives that the sluggish monster is hot and creeping forward. There is no suggestion of cracks or flames, unless a heavy hardened crust breaks open and gives vent to a new tongue, which emerges as a rounded bulb encased in a newly formed skin.

It will be seen from this description that the surface of pahoehoe lava is characteristically glassy. The surface of the lumps and sprouts of aa lava is an endlessly broken jumble of partially crystalline rock, bounded by broken gas vesicles. After both kinds of flows are cold and solidified, the rock of the interior is a continuous sheet of largely crystalline basalt with many gas blebs or vesicles, and such interior rock is just the same for both kinds of flows. The broken bowldery appearance of the surface of an aa flow is largely an illusion, as many of the bowlders are not loose at all, but are sprouts and crags connected with the continuous ledge beneath. There are, however, many flows which break up these crags into bowlders which are rolled along on the surface of the paste and become plastered like snowballs into rounded spheres coated on the outside with lava layers.

Dr. O. H. Emerson made experiments in 1926 (American Journal of Science August, 1926, page 109) by melting Hawaiian lava in crucibles and stirring the melt. It was found that the tendency to crystallize was greatly enhanced by the stirring, the material along the walls of the crucible being glassy with some crystal nuclei, while the stirred parts consisted of a mass of small crystals with some glass in the interstices. Both aa and pahoehoe lava from Hawaiian flows were ground to powder and melted, and both when stirred produced typical aa clinker or arborescence. The mass was at a yellowish white heat and had the consistency of honey; it was allowed to cool in the dying fire, being at the same time constantly stirred with an iron rod. When the ball of slag was broken open the interior was aa and the outside was pahoehoe. It thus appears that higher crystallinity favors congealing as aa if the material is stirred in the open, and from this it might be argued that the more crystallized material under a pahoehoe skin should flow out as aa if it were allowed to escape. Exactly this has happened at Kilauea. Repeatedly lava domes of pahoehoe have formed, like the one at Mauna Iki which invaded the forest six miles southwest of Kilauea in December, 1919 (see photograph Page Two). When this dome reached a certain height, it burst open and gave vent to aa lava rivers repeatedly (see Page Three). On Page Four is shown the lower slope of aa beneath an island in Halemaumau which was suddenly lifted 40 feet in a night in 1917. This indicated that a sudden disturbance of the equilibrium of the pahoehoe crusts in the Kilauea fire-pit so as to cause a sudden congealing of the lava paste, may reveal crystallinity in that paste quite capable of making aa. By thrusting steel pipes into the lava lakes, the stirred melt which crystallized on the outside of the pipes in clots was drawn out as typical aa lumps, although the lakes themselves maintained an equilibrium which made only pahoehoe skins and crusts on their surfaces and at their shores. T.A.J.

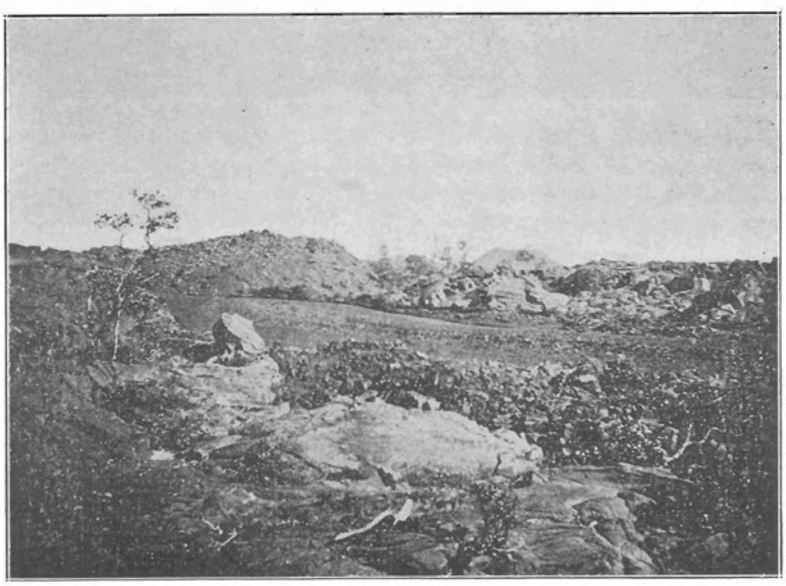
KILAUEA REPORT No. 955

WEEK ENDING MAY 11, 1930
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

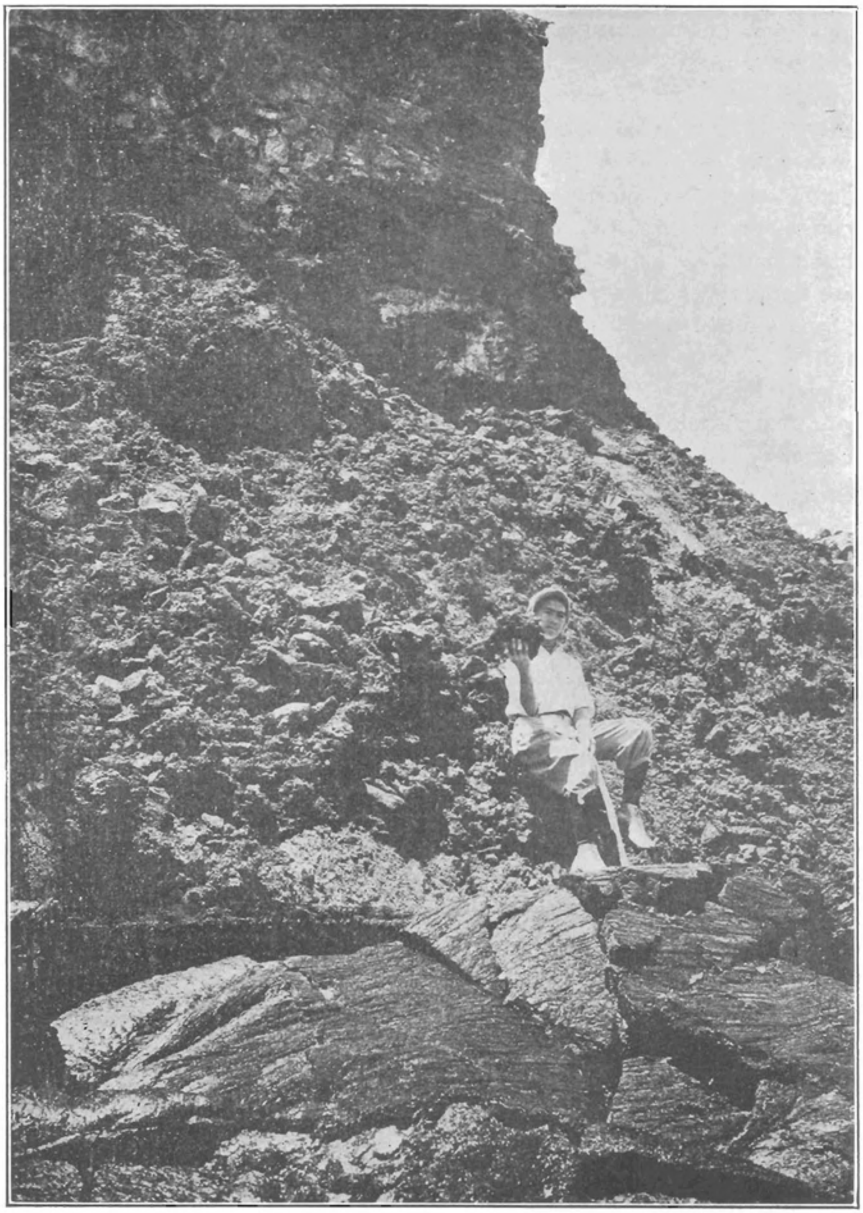
No changes have been observed at Halemaumau during the past week. Steaming is slight at all vents, and working of the walls has been negligible. Small slides on the north wall were noticed on May 10 and 11.

The Observatory instruments have recorded seismic disturbances as follows: 11 temors, the longest with duration 1.5 minutes; 3 very feeble seisms; 1 distant earthquake very feebly recorded on the north-south component at 3:54 a. m. May 9.

Microseismic motion was slight; tilt accumulated slight SSW.



An aa lava river which flowed five miles down the mountain from Mauna Iki, and was pahoehoe lava at the source. It turned into aa a few hundred yards away from the source and was first observed December 31, 1919. This shows the characteristic dark stream with clinkery surface, so different from the glistening folds and festoons of pahoehoe.—Photo Finch.



Aa pedestal of island in Halemaumau April 5, 1917. Two weeks earlier this island had been pushed up suddenly while an adjacent larger crag subsided and the underpinning of the island was revealed as a raw reddish wall of aa lava, in contrast to the slabs of pahoehoe in the foreground.—Photo Jaggar.

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The Volcano Letter

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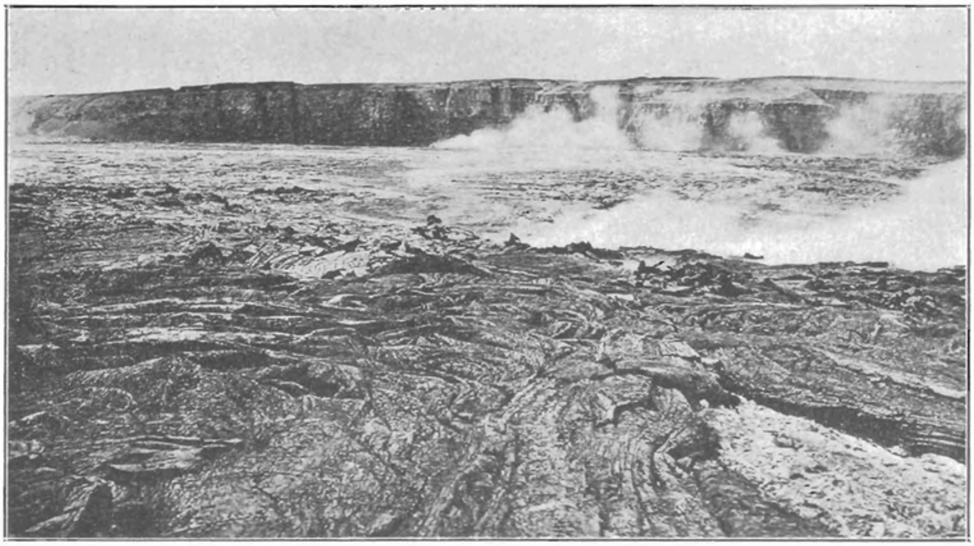
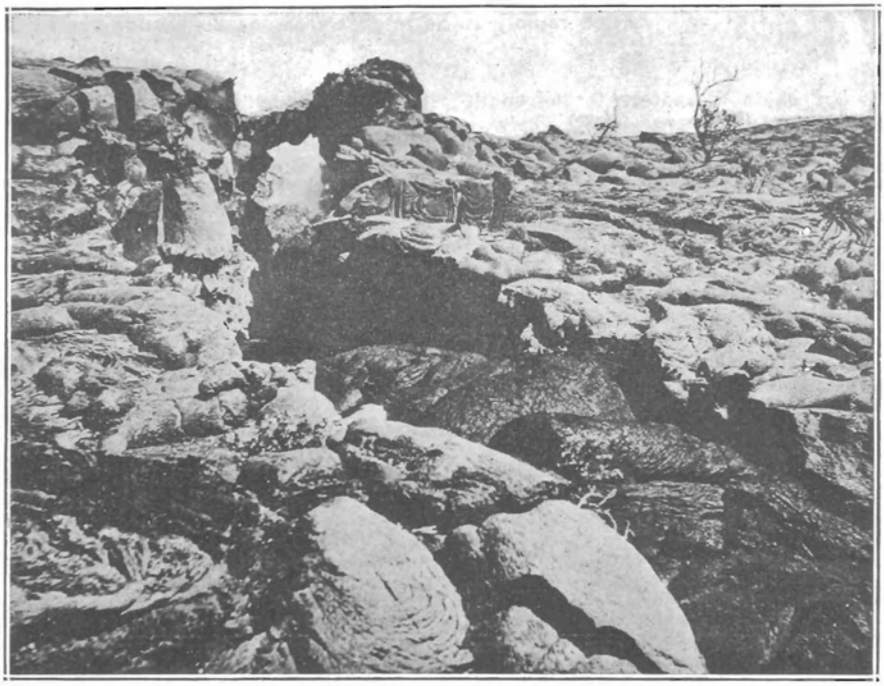
No. 282—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | May 22, 1930



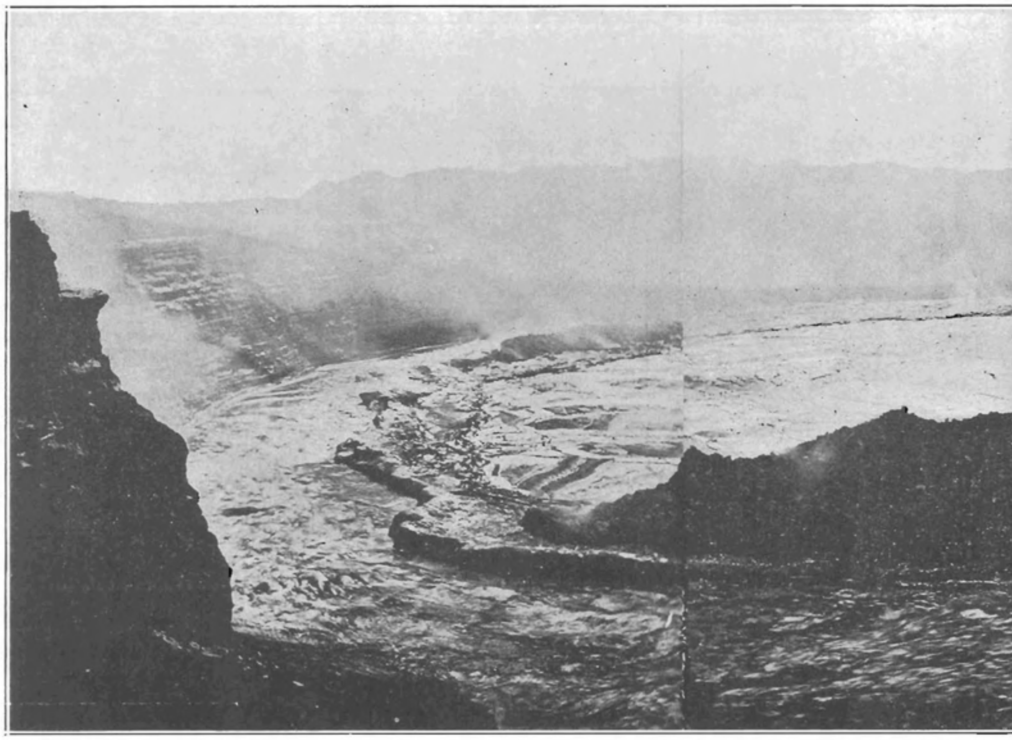
The steam belts border a flood of liquid lava, fed by about 50 fountains spurting from a radial crack, extending from Halemaumau to the southwest wall of Kilauea. December 15, 1919, 11:30 a. m..



The Kau Desert rift, opening and showing black pahoehoe lava rising up the crack, here about four feet wide. The western of two fissures about five miles southwest of Halemaumau, December 22, 1919.

WHEN KILAUEA MOUNTAIN BROKE OPEN 1920

Flank outbreaks down the sides of the mountain at Kilauea Volcano, by the splitting open of the ground and letting out the lava from Halemaumau through underground fractures extending all the way from the crater to the place of outbreak, are rare on Kilauea, though similar fissure eruptions have been common on Mauna Loa since the first white explorers came here. The map on the last page indicates the main Kilauea outflow fissures along the chain of craters to the east extending all the way to Ka-



Ring-island of bench magma in Halemaumau looking SSW with outer ring-pool fountaining lifted rapidly so as to part from its containing funnel and let the liquid fill the wall-crac

poho, and along a similar chain of craters to the southwest marked by the flows of 1920 and 1823. There is another small flow area of 1868 between the last two. These eastern and southern belts mark definite rift zones of very ancient origin extending from Kilauea Crater as vertical cracks, somewhat curved in plan, down the slopes below sea level. They mean that a slice of the mountain southeast of the crater is broken and tending to fall away toward the ocean, and the fault cliffs back of Keauhou are parallel slices already slipping into the sea.

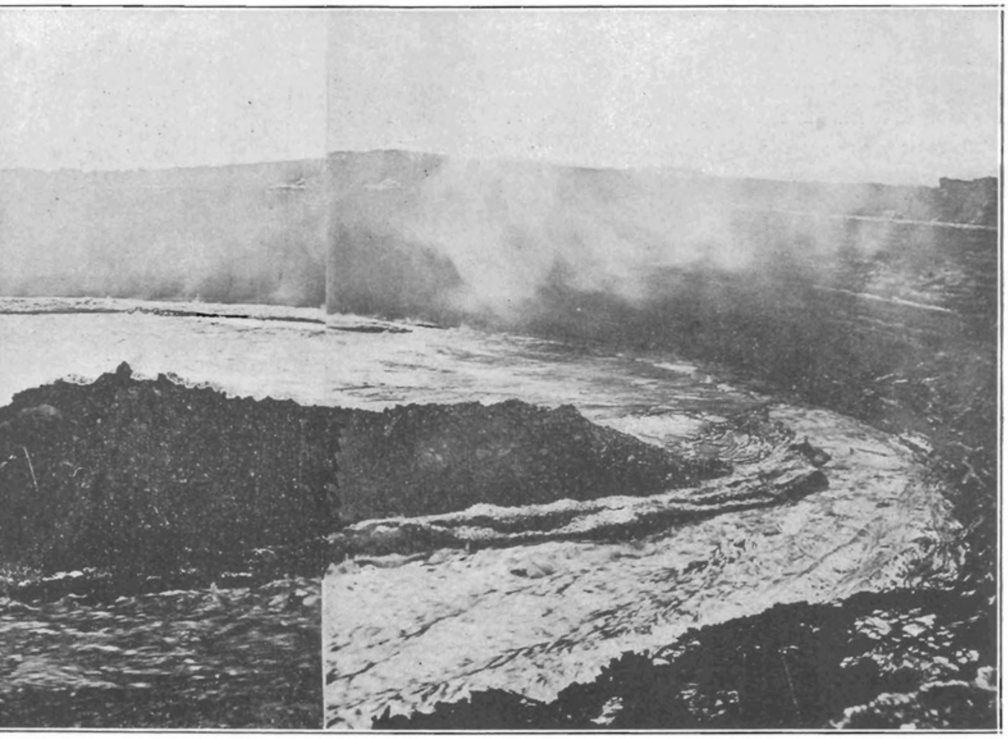
Some visitors to Hawaii National Park take the trail to Mauna Iki in the Kau Desert. Mauna Iki is a fresh lava hill so hot through cracks on its top that sticks burst into flame when thrust inside. Mauna Iki was completely built by lava welling up the southwest rift beginning December 15, 1919, and continuing action until the autumn of 1920. The breaking open of the mountain began by a radial split across the floor of Kilauea Crater southwest from Halemaumau December 15, 1919, at 11 a. m. whereby floods of lava formed steaming lakes along the foot of the southwestern walls of Kilauea. (See first photograph Page One.)

The next thing that happened was the rising of steam along the southwestern Kau Desert cracks outside of Kilauea Crater, and when these old cracks were examined, a freshly opened zone was found of many parallel cracks showing new breaks in the dirt, extending for a mile and a half away from the edge of Kilauea Crater. This zone was a quarter mile wide. The larger chasms had yawned open and engulfed their dirt fills. Creaking and tumbling could be heard within them. One of them, on this day of the outbreak across the Kilauea floor, was found in the afternoon to be 80 feet deep and five feet wide, away down to a narrower space that led below to black depths. Acid sulphurous steam arose with a temperature above 100° F., and along the line of the principal crack five steam columns had appeared, four of these being in a group near to Kilauea.

This gushing of the first day on the Kilauea floor pulled the level of the lava lake in Halemaumau down from 35 feet below the rim, to 148 feet on December 16, but the outflow in the south part of the greater crater stopped within an hour of its first eruption. In the afternoon of December 15 a swarm of earthquakes recorded on the instruments indicated that a sharp readjustment was going on along the rift belt, and doubtless lava was pouring from Halemaumau into underground cracks that were opening in that direction within the larger mountain edifice. When the first outflow on the Kilauea floor was seen, the cliff bounding the big crater, along the line of the gushing crack in the floor, was seen to make little avalanches, indicating that the crack in motion extended beyond the mere crater fill. After December 16 the lava in Halemaumau rose again until the liquid was even five feet higher in the pit (30 feet below rim) on December 22, than it had been on December 15. This created a new tension in the mountain and the flank rifts which had been opening in the Kau Desert started flowing so that the level of Halemaumau lowered again. Outflow on the southwestern Kilauea floor was resumed December 19 as soon as the liquid in the pit reached the level of the outflow vents.

The splitting open of the outside mountain was dramatic in its quietness. It seems quite incredible that a vast rocky dome made of heavy black basalt can split asunder along nine miles down its slope and give vent to increasing lava flows without any big earthquakes or explosions. But this is just what happened.

The writer followed these events day after day and watched the splitting of the ground farther and farther away from Kilauea Crater. December 21, starting at the southwest edge of Kilauea Crater, he found an open network of gaping fissures, and the five-foot crack of December 15 was now a chasm 15 feet wide, broken through rock below and volcanic ash above, the sand continuously slipping on the inner slopes and thereby giving evidence of motion in progress. Farther away down a crack four feet wide sluggish pahoehoe lava could be seen 50 feet below the surface, welling up in heavy snake-like folds, throwing out incandescent toes, and making a crackling noise by reason of the heating and snapping of the adjacent rock.



...trongly, and inner lagoon quiet. The island is the top of a lily-shaped cake of lava paste
Photos Jaggar.

No vapor arose here, the steam columns always coming from small cracks of presumably wet ground adjacent to the lava fillings.

Beyond Cone Peak, which lies on the rift zone a mile and three quarters from Halemaumau, the ground was freshly broken along an active zone a quarter mile wide with two main cracks, and these two cracks in the region west of Puu Koae showed live lava inside which reached the surface level of the mountain along a half mile of the surface about five miles from Halemaumau. As one walked down the mountain live lava was seen in the western crack at considerable depths, and a half mile farther this lava rose to the surface level, filling the crack with heavy black pahoehoe through which hissing gas vents were flaming and either building small spiracles or heaving the skin on roundish puddles. An occasional deep detonation suggested that the crack was being heaved open in the depths by the expanding lava. Ot one place the crack overflowed in two small pools 30 to 50 feet in diameter. The pools were crusted over and glowing toes oozed out from under their marginal skirts. A line of 15 spitting and spurting driblet cones followed the crack through the pools, and farther downhill this crack narrowed and was marked only by vapor jets. Thereafter the activity was transferred to the eastern crack which extended farther down the mountain and emitted bluish-brown fume and was full of hardened lava apparently stagnating level with the surface of the country. The gas hissed through spatter cones and the adjacent ground was splashed with spatter lumps from a previous spurting action which had ceased. The character of these cracks with their black fills is well shown by the second photograph, Page One.

After this about Christmas time of 1919 the fissures in the desert split their way day after day to a point nine miles from Halemaumau where the live crack opened beneath deep banks of dune sand, and the lava built up a hill 80 feet high in the forest. The outflowing pahoehoe made tree moulds, and when it penetrated old caverns in the forest the mixture of carbon gas and air made explosions that ruptured the cavern roofs and flung rock fragments away from the holes. Then the activity of outflow centered about floods of pahoehoe lava two miles long and three quarters of a mile wide with liquid lakes and pits on top. This was Mauna Iki, the new "baby Mauna Loa" in shape, and so named "little mountain."

The remarkable ring-shaped island in Halemaumau exhibited on Page Two-Three was the conspicuous feature of the interior of the pit at the time of these ups and downs that accompanied the Mauna Iki flowing. This ring-crag of bench magma was surrounded by an outer ring-pool fountaining violently, and contained an inner circular pond of quiet lava. The ring-island was the top of a lily-shaped column of the stiff lava paste moulded to the funnel shape of the containing pit, and lifted very rapidly so as to part from the walls between November 28 and December 15, 1919. Up the space between it and the walls boiled the foamy or liquid lava following as usual the wall-crack, or marginal fissure between wall and plug. This was the very peak or climax of the 1913-1924 cycle, when Mauna Loa had just been flowing, and Kilauea was about to flow.

T.A.J.

KILAUEA REPORT No. 956

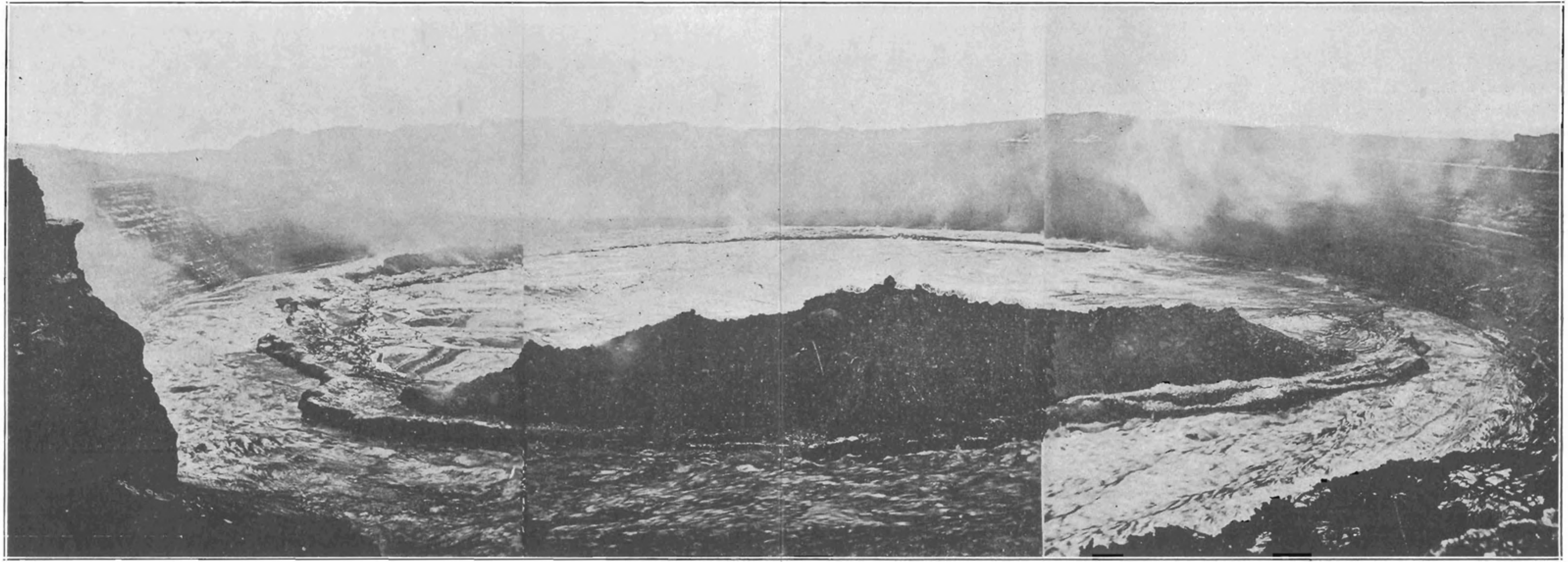
WEEK ENDING MAY 18, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

At Halemaumau pit in Kilauea Volcano the steam on the south talus disappears entirely on dry days and rock slides are infrequent and very small. The pit is unusually quiet.

At the Kilauea Volcano Observatory eight very feeble local seisms have been registered during the week, three of them idicating respective distances of origin 15, 16, and 23 miles. Eleven spasms of tremor have been recorded, mostly from one-half to three minutes long, but two unusual periods of tremor lasted 10 and 12 minutes. Microseismic motion was normal, and tilting of the ground was slight SW.



Ring-island of bench magma in Halemaumau looking SSW with outer ring-pool fountaining strongly, and inner lagoon quiet. The island is the top of a lily-shaped cake of lava paste lifted rapidly so as to part from its containing funnel and let the liquid fill the wall-crack. Photos Jaggar.

THE VOLCANO LETTER

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

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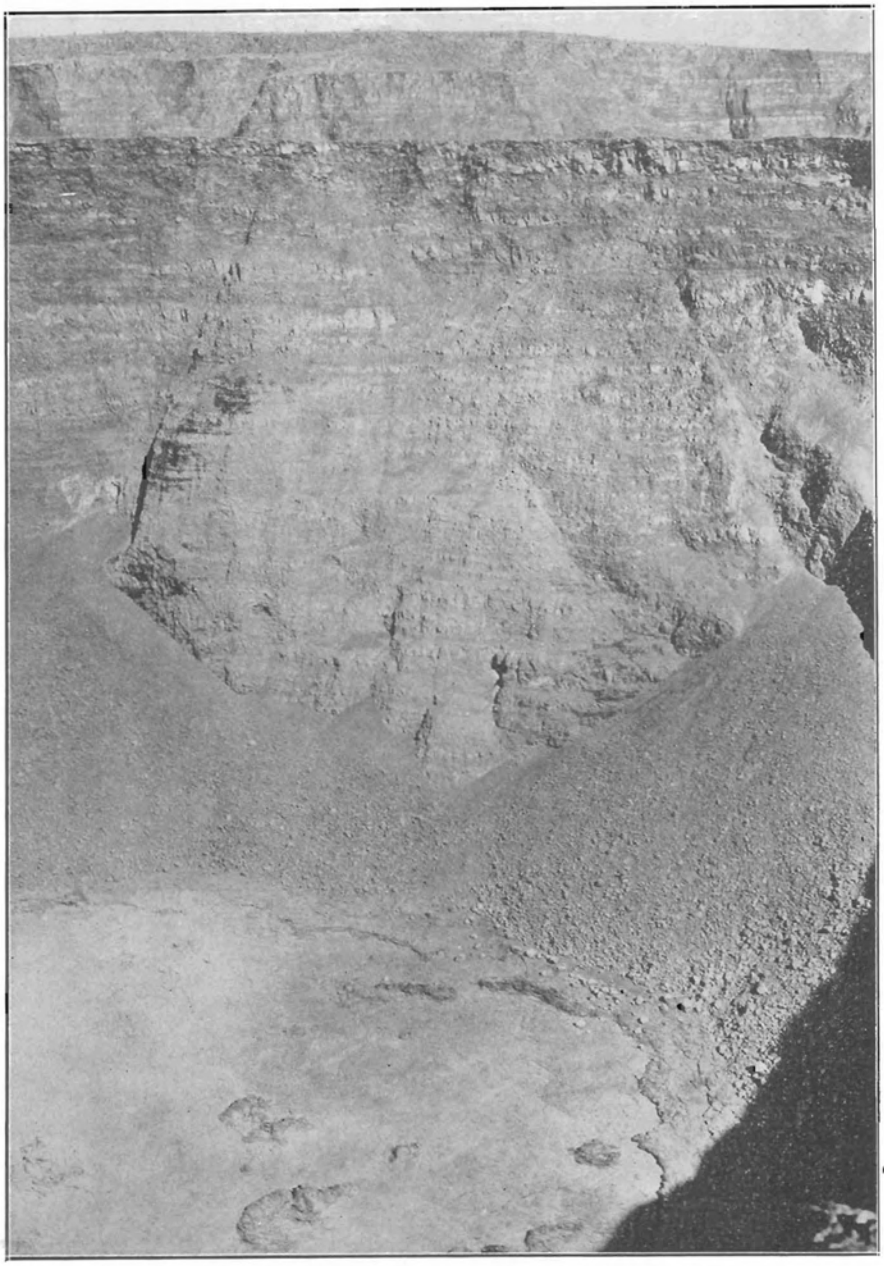
No. 283—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | May 29, 1930



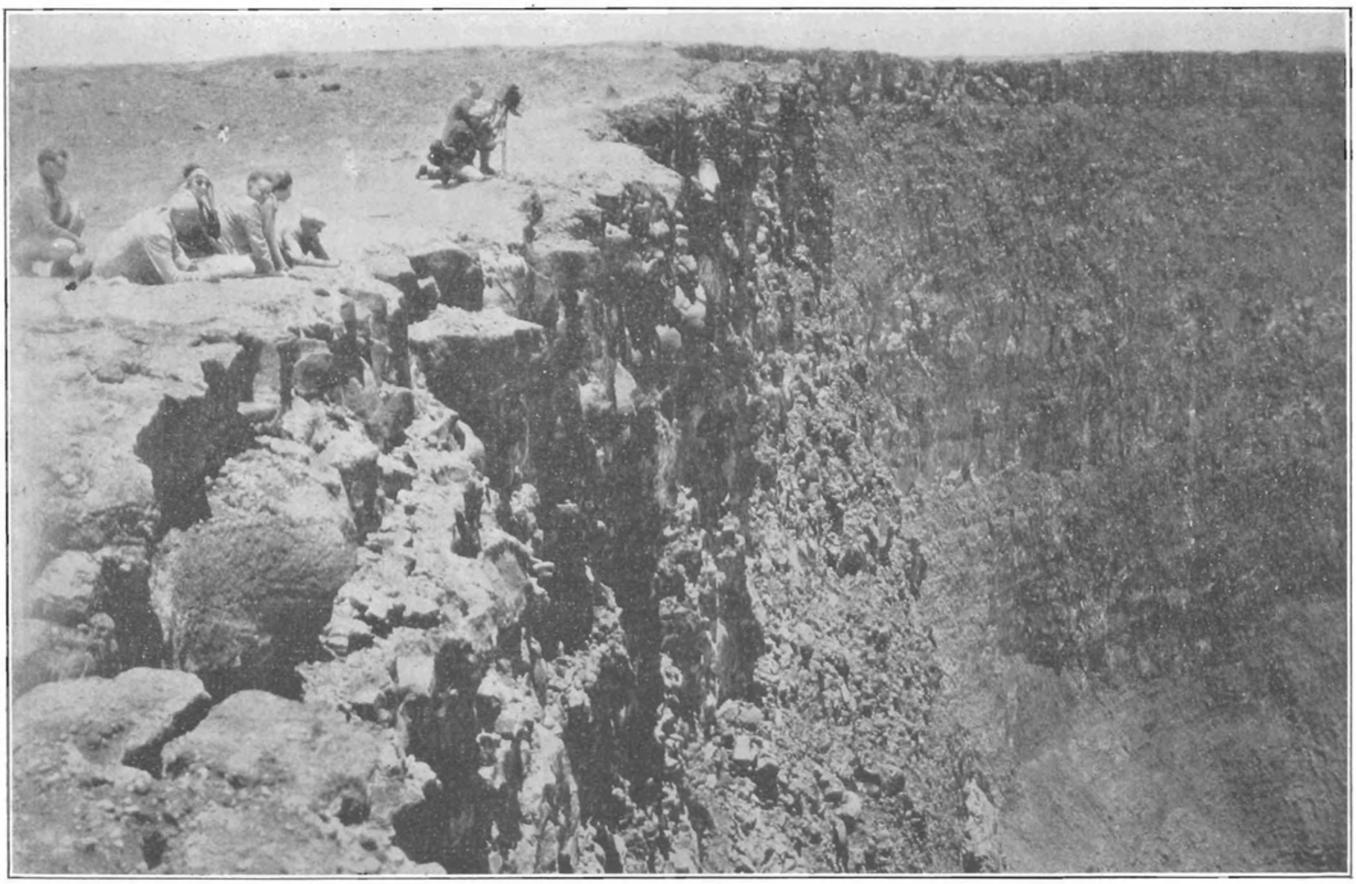
North rim of Halemaumau February 20, 1930, showing wall newly stripped off to build a new small talus between the two large taluses, thus coating the lava floor with dust. Avalanching has developed cracks into gulches up the wall right and left. Photo Jaggar.

RIM CRACKS AND CRATER SLIDES

The tourist visiting Halemaumau pit at Kilauea Volcano is now barred from the immediate edge of the pit by a rope fence which guides him to a station off to the east, which is safer than that part of the rim of the pit which is immediately opposite the automobile terminus. This breakage of the upper rim of Halemaumau so as to destroy the usefulness of the National Park station at the southeast, which had hitherto been considered very safe, occurred unexpectedly early in January, 1929, when big avalanches occurred at the south corner of the pit.

Referring to the map on Page Four, it will be seen that there are numerous cracks indicated as more or less parallel to the pit rim, but lying outside the edge of the pit and expressed as dotted lines. These indicate that the rock of the steep upper wall surrounding the pit is everywhere weak and tending to split off through the undermining action of the movement of the lava under the central part of the bottom of the pit. This was explained in Volcano Letter No 269.

It is of interest to note that big spells of avalanching occurred in January, 1928, at the northwest; in January, 1929, at the south, and in February, 1930, at the north and northwest again. The photograph on Page One was taken on February 20, 1930, from the eastern rim of the pit, and shows the lava floor which had been left by the July eruption, 1929, completely coated with new pinkish dust from slides



Southeast rim of Halemaumau looking south during activity of July, 1927. There are other cracks back of the observers. Photo Tai Sing Loo.

which had been falling from the eastern, northern, and western walls throughout January and February, becoming strongest during the week ending February 23, 1930. These avalanches send a cloud of dust downward and forward when the falling rock matter strikes the floor, the dust cloud boils vortically, and as it loses velocity it dumps its dust on the ground beneath. In the picture it is evident that dust from the slides lay thickest on the west side of the floor, and the wall above was seen to be scarred and streaked from repeated falls. It will be seen that the north-northeast talus, on the right of the picture, and the northwest talus on the left, are both surmounted by gulches which extend up the wall above, and these gulches terminate at the upper rim in cracks which are shown at the top of the map. The rock wall between these gulches constitutes a buttress or slab backed by these cracks, the slides are eating away the cracks and weakening the buttress, and so the buttress is breaking up, making the small middle talus, and getting ready for a big slide from the top.

Now it is a remarkable thing that when these spells of general sliding occur, the rim cracks tend to widen, even on sides of the pit remote from the avalanches of that particular time. Thus we find the statement in the Kilauea Report for February 23, 1930, that crack No. 14 (easternmost of the cracks just below right side of the map) widened nearly two feet since December 4, 1929. These cracks along the southeastern side of the pit have been marked with paint at a number of points, and the places have been numbered.

This work was started by R. M. Wilson on July 6, 1927, after observation of the Halemaumau rim during the previous month had shown that cracks were widening and slides were occurring simultaneusly, with increasing effect to the date mentioned. This action at that time was chiefly at the east. Mr. R. B. Hodges was detailed to conduct the measurements of the cracks from time to time and has done so since 1927. It happened that this month of working of the Halemaumau wall slabs immediately preceded the outbreak of July 7, 1927, and this made the measurement of the cracks doubly interesting. There was every suggestion that the widening of the cracks, the working of the walls, and the consequent avalanches accompanied tumescence or uplift of the rock structure surrounding the lava column just prior to its outbreak.

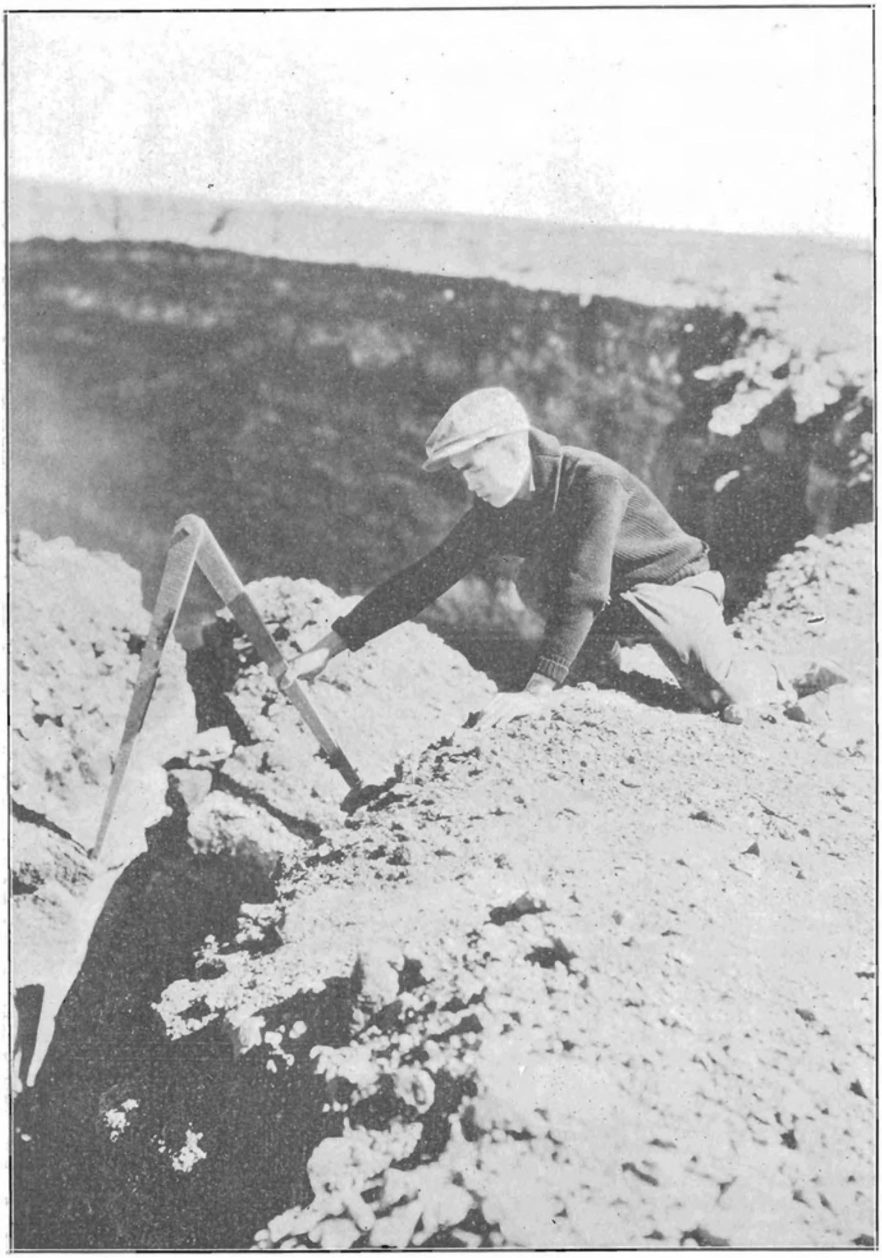
The procedure of crack measurement is very simple. The photograph on Page Two shows a characteristic small crack in the foreground at the left, this being that portion of the rim of Halemaumau looking south where excessive opening of cracks occurred in January, 1919, back of where the group of people is shown. This photograph shows the change of angle on the right from steep cliff above to funnel slope below. The photograph on Page Three shows the caliper used as adjusted to two paint marks on opposite sides of a crack at a numbered location. The caliper is adjusted to the crack, and the departure of its two points is measured with steel tape. Fifteen points along cracks were so marked and measured along the southeastern rim of the pit. These fifteen locations had dwindled to five remaining unbroken and accessible on April 14, 1930. The others had either caved in over the rim of the pit, or had become dangerously inaccessible as wide chasms, or had broken down at their marked points. The striking obvious feature of the motion of the cracks was that they had been opening and collapsing, and the pit rim had been enlarging, during these two and three-quarters years.

Measurement on six selected crack locations progressively northeastward back from the southeastern rim of the pit, the last No. 14 being in the vacinity of the fourteen-ton bowlder of 1924, is shown in the table for 15 of the 34 dates of measurement since 1927. This table shows the actual widths of cracks as they changed from date to date, reading downward. Reading from left to right for the same date cracks 10, 13 and 14 are on the same fissure growing wider as it approaches the place where it emerges on the edge of the pit. Cracks 3 and 4 are a little farther west. (These cracks extend from trig station 3641 to 3646 on the southeast side of the map Page Four.)

OPENING OF RIM CRACKS SOUTHEAST OF HALEMAUMAU

Caliper Measurements in Feet, of Distances Apart of Paint Marks on Opposite Sides of Each Crack, from 1927 to 1930

Date	Crack 3	Crack 4	Crack 5	Crack 10	Crack 13	Crack 14
July 6, 1927	2.14	1.17	0.42	0.77	1.54	1.63
July 24, 1927	2.17	1.25		0.77	1.61	1.65
Sept. 3, 1927	Gone in	1.65	0.44	0.79	1 61	
Oct. 1, 1927		1.83	0.45	0.80	1.67	1.82
Dec. 6, 1927		1.83	0 44	0 81	1.77	1 96
Feb. 13, 1928		1.83	0.50	0.84	2.35	2.75
April 21, 1928		1.83	0.51	0.87	2.41	2.90
June 18, 1928		1.83	0.57	0.84	2.46	3.00
Sept. 10, 1928		1.83	0.54	0.88	2.47	3.17
Dec. 4, 1928		1.83	0.56	0.89	2.50	3.24
Mar. 29, 1929		1.91	0.70	0.90	2 52	3.36
July 7, 1929		1.96	0.72	0.91	2.57	3.60
Dec. 4, 1929		2.20	0.73	0.95	Broken	3.96
Feb. 19, 1930		2.22	0.74	0.96		5.71
April 14, 1930		2 25	0.73	0.98		Inaccessible



Marked crack where it emerges southeast rim of Halemaumau, showing method of measurement with wooden calipers at painted spots.

The table shows that all the cracks have tended to open gradually, and that the same crack has widened the more the nearer it approached the pit rim as an open chasm. The cases of a crack becoming narrower are only three, and of a few hundredths of a foot. As the cracks fill below with fallen debris it is natural that they should fail to close. The two remarkable features of the table are the steadiness of the process of yawning open in all the cracks, and the greater opening the wider the crack. It is evident that this belt of cracks at the southeast has been steadily yawning open and that it was stimulated in its opening along with eastern avalanches of June, 1927, preceding the eruption of the following month, and that it was stimulated extensively along with southern avalanches of January, 1929, preceding the eruption of the following month. That eruption of February, 1929, produced five seconds of accumulated tilt away from the pit (see Volcano Letter No. 264). This confirms the notion that the yawning open of the cracks is an upward swelling of the inner dome of Kilauea. The first large change in the crack of Nos. 10 to 14 followed the eruption of January 11, 1928, and there were considerable changes after the eruption of July 25, 1929. The big avalanching spells circled the pit as follows: E, June, 1927; SSW, September, 1927; NW, January, 1928 S, January, 1929; NNW, February, 1920. The study of cracks coupled with study of tilt and avalanches is evidently a profitable activity for volcanology at craters.

T.A.J.

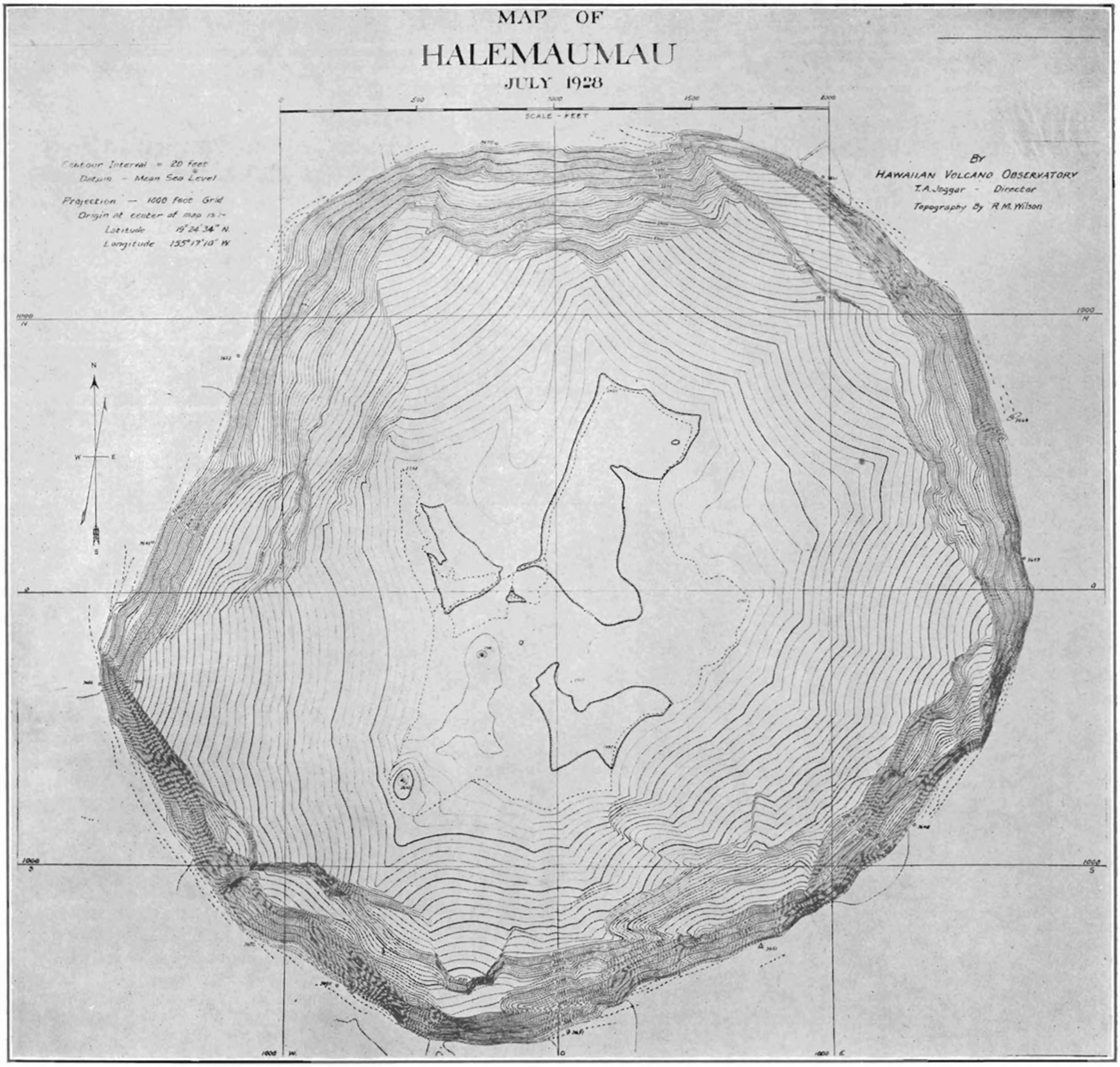
KILAUEA REPORT No. 957

WEEK ENDING MAY 25, 1930

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

The inner pit of Kilauea Crater has shown nothing of interest during the week. Some fresh debris lay on the east talus May 23 and a few rocks were heard falling on the north wall.

The seismographs at Kilauea Volcano, at Hilo, and at Kealakekua have registered some unusually intense local disturbances. The Kilauea instruments recorded 11 local



Map of Halemaumau pit, contour interval 20 feet, showing cracks by dotted lines at edge of pit. The long, straight sides of the pit are SE and WNW, and these are backed by curved cracks completing the northeastern circular curve of the pit. Pit axis follows rift NE-SW.

seisms, of which five were tremors, three very feeble, two feeble, and one a moderate earthquake. The tremors lasted from one-quarter to one minute, and one of these was accompanied by tilt to the east. One of the very feeble shocks indicated origin distance 16 miles, and another showed tilt to the east. The two feeble shocks indicated origin distances 106 and 61 miles, respectively, were felt locally, and the times of beginning were 2:47 a. m. and 6:52 p. m. May 20. The perceptible periods of vibration were rather slow on the east side of the island, and quicker in North Kona, suggesting an origin in the Hualalai direction. Like the Hualalai shocks of October, 1929, the perceptibility was more pronounced in North Hilo than at Kilauea.

The moderate shock occurred at 8:17 p. m. May 25, was strongly felt all over the island, no overturning of objects has been reported, and the accounts indicate stronger motion in Kau and Puna than in Kohala and Kona. At the Kilauea Obseravtory all the seismographs were dismantled, but the Uwekahuna instrument restored its pens and recorded the declining vibrations. The vertical component instrument showed a heavy downward fling as though the earthquake were epicentral at Kilauea. The first movement flung off all the pens instantly at Kilauea, but is reported to have written a short preliminary on the seismograph at Kealakekua in Kona. The first fling of the ground at Kilauea was downward to the south and east, and the restoration of the pens indicated tilt to the south and west. Keaau Beach in Puna, where the Hualalai shocks of 1929 were barely felt, perceived this shock strongly. At a Hilo theater the motion began with a swaying, followed by strong jerks that quickly ended, first to the northeast then to the southwest. The motion was not prolonged like the Hualalai shock of October 5, 1929. Puwaawaa reports a long vibration not particularly strong, Honokahau a moderate shock accompanied with thunderous noise, Kealakekua an alarmingly sudden quake, but without the overturning power of the Hualalai shocks. All of these facts suggest a deep movement somewhere under Kilauea and Mauna Loa.

Microseismic motion for the week was slight, and tilt at Kilauea was slight to the west.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 284—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | June 5, 1930

Eruption of Calbuco Volcano, Chile, January 6, 1929, photograph taken from Puerto Varas probably in early forenoon. Photo Karl. Steam apparently issuing with force. Pall of ash to the left.

EDITORIAL NOTE

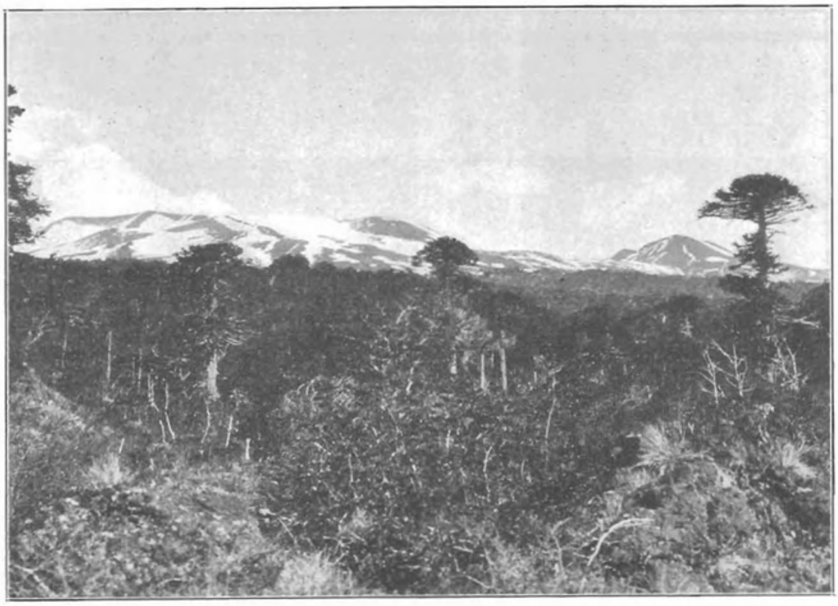
As reported in Volcano Letter No. 235, Dr. John B. Stone during the winter 1929-30 completed on February 12, 1930, at Valparaiso an exploration of some volcanoes in south-central Chile occupying three months and six days. This was done under his appointment as Research Fellow of the Hawaiian Volcano Research Association. Starting from the scene of the recent disastrous earthquake at the city of Talca, Dr. Stone passed by the active volcano Quizapu near Cerro Azul, and then visited in turn the volcanoes Chillan, Antuco, Llaima, Villarica, Osorno, and Calbuco, climbing several of these. He observed from a little distance the volcanoes Trolguaca, Lonquimai, Quetrupillan, Shoshuenco, and Puyehue. All of these are potentially active and all lie between the latitudes 35° and 42° S. This region offers a great field of volcano research in the midst of a land of serious earthquakes, and it is to be hoped that Dr. Stone's investigations will stimulate public and private endeavor to create volcano observatories in Chile. The following is a first note on Chilean volcanoes.

TWO ACTIVE VOLCANOES OF CHILE

By JOHN B. STONE

The Chilean volcanoes east of the capital city, Santiago, lie near the crest of that portion of the Andes chain that includes the highest summits of the western hemisphere, but farther south the volcanoes are lower down on the west flank of the cordillera. In the region between the cities of Temuco and Puerto Montt, or roughly between the latitudes of 38° 30′ and 41° 30′ south, they lie along the line where the farms of the central longitudinal valley give way to the forests and mountains of the high Andes, and their summits reach only 6,000 to 10,000 feet above sea level. The two most active volcanoes of this region are Llaima and Calbuco. Both lie in a rainy belt and as a consequence their lower slopes are heavily wooded and their summits are capped by snow and glacial ice.

As seen from the southwest Llaima is an elongated cone with one principal summit and another slightly smaller and lower one off to the southeast. In December



Llaima Volcano, Chile, from the west. Araucanian pines and old aa lava in foreground. Photo Stone.

1929, the mountain was still covered far down its slopes by the snows of the preceding southern winter, and both the summit craters were emitting streamers of dense white fume.

The journey to Llaima is best begun from the provincial capital Temuco. A branch off the main north-and-south railroad extends for nearly 35 miles across partly cleared and cultivated lands and past several large, prosperous farms to the little village of Cherquenco. Beyond Cherquenco the forest is less broken by farms but is dotted with little sawmills producing rough lumber, which is hauled to the railroad on clumsy two-wheeled ox-carts. One of the sources of good lumber is the sharply defined belt of Araucanian pines that girdles the upper slopes of the volcano. The Araucanian pine or "monkey-puzzle" tree is similar to its close relative the Norfolk Island pine, familiar in the Hawaiian Islands (see Page Two). A sawmill high up in the pine forest on the northwest slope of Llaima was a convenient base of operations for the writer during the bad weather that prevailed at the time of his visit.

The double cone of Llaima stands on a broad base or platform built by earlier volcanic activity. Part of this platform and of the cone also are covered by basaltic aa flows, but the northwest summit cone and the southern slope of the mountain are largely concealed from observation by glaciers. Shiny black scoriae are common on the surface, and a layer two or three inches thick covers the glacial ice on the south side. Llaima was active from October 5 to 8 and again from November 27 to December 5, 1927, and at that time a "river of fire" is said to have been seen on the south slope. No recent flow could be distinguished by the writer beneath the winter snow, but a line of cones was seen far around to the southeast. These cones may mark the source of a flow as well as the site of the fountains which produced the fresh scoriae. Unfortunately it was impossible to reach them. Another possibility is that the scoriae were produced by fountaining in the summit craters and that the "river of fire" consisted only of the freshly fallen and still glowing cinders.

Calbuco is the farthest south of the volcanoes in the continuous mainland part of Chile, although others are known in the region of fiords and glaciers extending from Puerto Montt to the Straits of Magellan. Calbuco was observed in activity by Darwin in 1835, but had long been inactive before 1893 and had accumulated a thick cap of ice and snow. In the latter year the volcano returned to life. The heat of the eruption melted the ice and snow and caused floods that swept down the mountain leaving paths which can still be seen. Fortunately the country affected is very sparsely settled even now so that little damage was done, but the occurrence illustrates the most serious danger in this land of intermittent volcanic activity and heavy snowfall. An even greater flood occurred at Villarica volcano in 1910.

The last eruption of Calbuco was on January 6, 1929 (see Page One), and lasted only a few hours. Dull underground noises in the night of January 5 had warned the few people living on the north side of the volcano and they had fled from their little farms taking with them what livestock they could collect. At about 2 a. m. on the 6th a great flash shot from the top of the mountain and was followed by an enormous cloud of ash accompanied by much lightning. The ash eruption continued until the early hours of daylight. Only coarse sand reached the highest house on the mountain, but before the west wind the fine ash drifted far off to the east so that a layer a few millimeters thick was formed at Peulla 35 miles away, and light dust reached the end of the State Railway in Argentina more than 100 miles away. A terrific blast blew down the valleys on the north slope killing and leveling the brush and small trees growing there (see Page Three). Floods from the melted snow and ice rushed down the stream channels killing the trees along their margins and dumping volcanic sand on a few cultivated fields near the lake. For two weeks after the eruption no rain fell to wash the covering of ash from the grass and leaves so that cattle had to pick a meager nourishment from the tips of the highest bunch grass which had shed some of the dust.

On January 19, 1930, the writer and a Chilean helper made the first ascent to the crater of Calbuco since the eruption of the previous year. The route from Ensenada on Lake Llanquihue leads up a valley swept by the floods of 1893 and 1929. Exposures in the steep walls of the stream channel show a history of past explosive eruptions. Lava flows reaching the lower slopes are rare and none is seen on the surface, but everywhere there is a deep cover of broken rock and sand like that thrown out by Kilauea in 1924. The new crater of Calbuco is a straight-sided hole perhaps 500 feet across (see Page Four). The rim, especially around the northeast edge is deeply covered by gravel and ejected blocks. Thick white fume escapes in several places from the talus slopes inside the pit. The crater plainly owes its present shape in part to collapse after the explosions.

KILAUEA REPORT No. 958

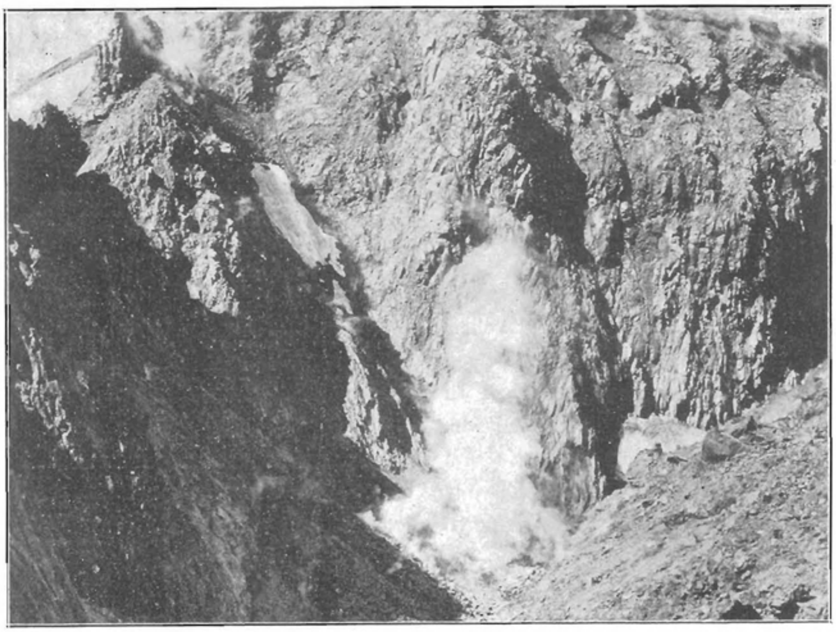
WEEK ENDING JUNE 1, 1930

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

Kilauea Volcano continues to be quiet and without visible signs of magmatic change. Early in the week numerous small rock falls occurred from the north wall of Halemaumau, the slides at times accumulating sufficient material to make dust clouds. Much fine debris has piled up against the foot of the wall between the two large north talus heaps. The fire pit was without sounds and with very little steam at the end of the week.

The seismographs registered nine tremors, two of which lasted one minute each; one very feeble seism, with origin distance 28 miles; and one distant earthquake recording feebly at 12:08 a. m. May 31. Microseismic motion was slight throughout the week. Tilt accumulated very slight WSW.

Brush in valley of Rio Caliente killed and bent over by eruption of Calbuco Volcano in Chile in 1929. Photo Stone.



Looking into the new crater of Calbuco Volcano, Chile, from the north. Photo January 19, 1930, by Stone. Thick white fume issuing from talus.

THE VOLCANO LETTER

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The Volcano Letter

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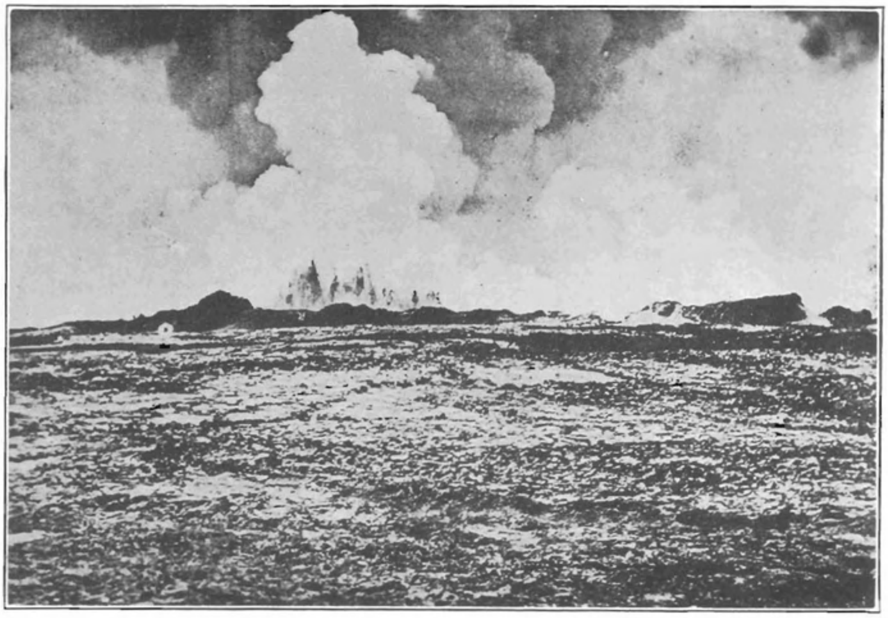
No. 285—Weekly Hawaiian Volcano Observatory, National Park, Hawaii June 12, 1930



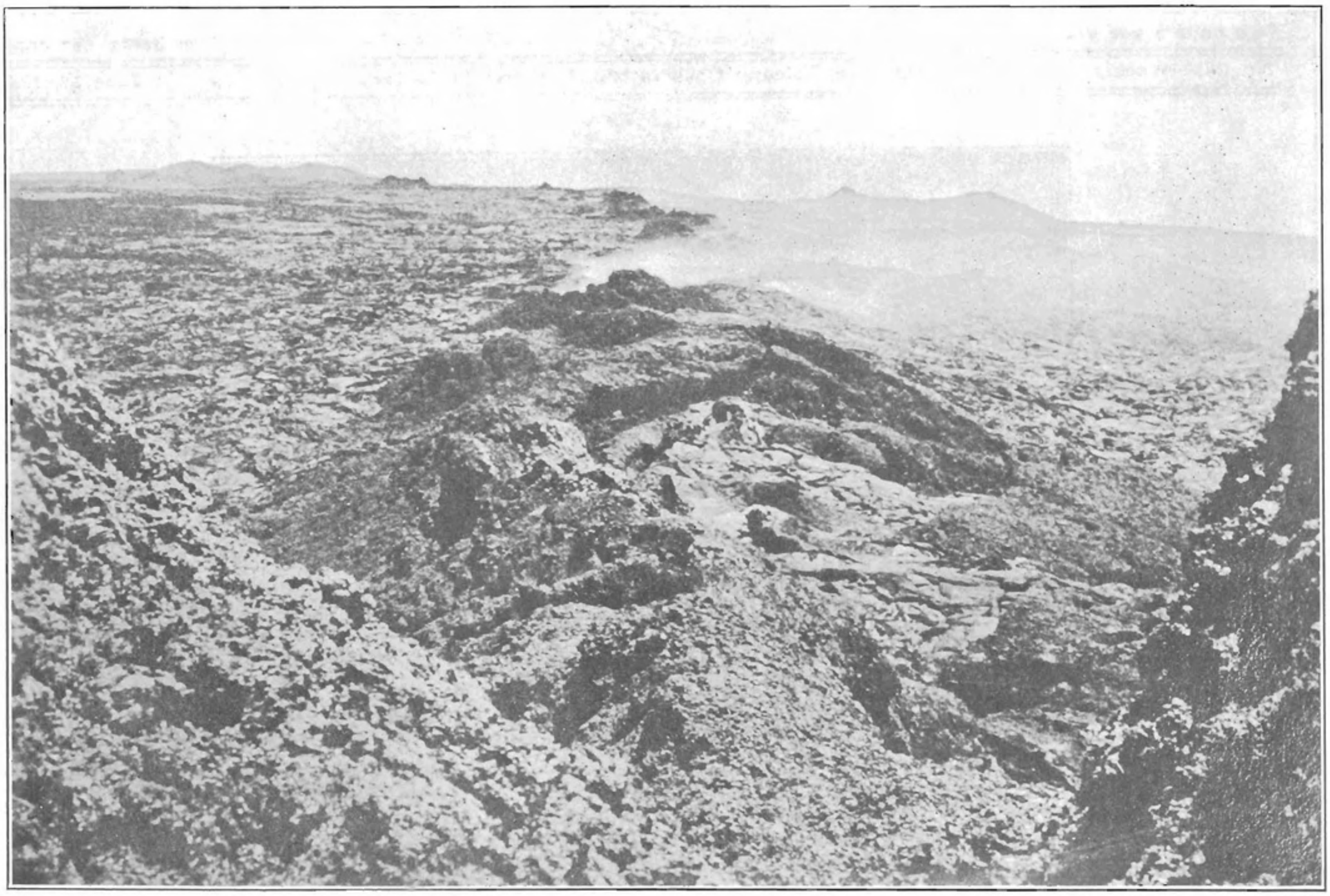
Mauna Loa rift source from the east, October 1, 1919, showing lava fountains, steam, and fume spouting up within ramparts of pumice. The new cones extend right and left outside the picture. Photo Jaggar.

SOURCE VENTS FOR MAUNA LOA FLOWS

There is apt to be much confusion in the mind of a visiting traveler when he hears talk of a lava flow. Careless writers are apt to speak of a lava flow in Halemaumau pit. An eruption of lava in the bottom of this great pit depressed below the southern floor of the larger crater of Kilauea is not a lava flow in the Hawaiian sense. A lava flow means to the residents of these islands an outbreak on one of the volcanic mountains which courses down the flank and is prone to enter the ocean if it lasts long enough. While it is possible for such a flow to arise by lava overwelling the brim of a summit crater, and although there have been short historical flows which originated in or near the summit craters of Kilauea, Mauna Loa, and Hualalai, none of these has ever traveled far. Usually such flows are confined within the compass of the large summit sink-craters by the overflow of the inner pit or the development up a crack of a new cone by rupture of the crater floor. The great lava flows of history, in the Hawaiian sense (see map last page), have emerged from the mountain flank along well known rifts that have been the sites of many outbreaks. The places of outflow have been from one to twenty miles away from the large summit craters, but there is generally a preliminary gush of some sort at the summit region.

Several pictures of Mauna Loa rift sources have recently been printed in the Volcano Letter (Nos. 270, 277). The well known rifts on Mauna Loa extend southwest and east-northeast from the summit. Indeed there is a strong suggestion that about the Rest House at the north at elevation 10,060 a new hump or dome is building up about the eastern rift, and that similarly a separate volcano is building about Puu o Keokeo as a center at elevation 6,870 to the south. An understanding of these rift belts as zones of potential weakness on volcanoes is essential to the understanding of lava flows. These radial fractures in a volcanic edifice may be curved or straight, several or few, but they stand for a deep-seated breakage in the dome, and along these broken belts there is underground connection along upright fractures with the central pipe, and this in turn is nothing more than the upright line of meeting of the rifts. Observation of the miniature slag lakes and overflow floors of the inner pit of Kilauea has shown how this fracturing of a dome happens. The overflow about a vent forms a slag heap. The slag heap becomes hard inside while remaining red hot. Renewed overflow at the central vent is accompanied by swelling gas pressures which rupture the heap. The lines of rupture are apt to be along the boundaries of three or more sectors. These sectoral cracks open widest along the contour of the heap which is lengthened the most by the swelling action. This is where the summit plateau changes its grade to a steeper marginal slope. There is probably a systematic geometry of building up domes and breaking them which has produced the strikingly uniform distances and triangular arrangement of crater summits on Hawaii.

The picture on Page One was made on October 1, 1919, when the writer was approaching the spouting source crack of the Alika flow from the east and looking from an old red cone at the new constructions of the active belt at a place about five miles north of Puu o Keokeo. After tethering the riding animals and walking across some ten alternations of rough aa and smooth pahoehoe, the aa making the most terrible footing on earth, there could be seen the line of rift cones, some 40 of them visible at one time, extending from near Puu o Keokeo northward. The source of the outbreak was revealed in panorama, consisting of a line of new gushing hillocks of slag, a true fissure eruption. Here great fountains were spouting continuously for a thousand feet like a wall of red flame, and in detail they were seen to be made of incandescent, light, crumbly material, yellow when it shot up, and red when it came down. Gas was rushing through a lava pool filling the rift, churning it to a foam with a noise like surf, and flinging up the foamy matter to solidify as it fell. Northward the smoking patches and driblet heaps became progressively smaller. This activity had all started by a simple splitting



Mauna Loa eruption of 1926, line of cones formed along rift, dying crater of main flow in foreground. Looking down mountain toward distant Puu o Keokeo on left. The flows poured off to the right. Taken May 4, 1926. Photo Jaggar.

open of the mountain flank along a new line within the belt of fracture generally known as the rift, and the splitting had progressed from the summit crater region downhill. The process had begun by strong earthquakes September 14 and 18, followed September 26 by a gush of smoky cauliflower clouds with chocolate-colored edges from the region immediately southwest of the summit crater of Mauna Loa. Two distinct columns of smoke developed side by side and a mile or so apart. The top of the jet reached 7,000 feet above its base, and with nightfall the cloud was illumined a bright orange-red. These gas jets waned so that by 10 p. m. only one fume jet could be seen, and by 3 a. m. the preliminary eruption was over.

The glow illumining the summit smoke in the first eruption was undoubtedly caused by a gush of frothy lava. There was then a lull from early morning of September 27 to 1:45 a. m. September 29, when moderate red glow and fume appeared over the southwest rift of Mauna Loa about the 8,000-foot level and both spread southward. This was the activity which quickly built up the line of pumice cones shown in the picture on Page One. There had evidently been a first release of gas from the expanding lava column up the central pipe, this in turn produced an expansive swelling that took two days to open the southwest rift, and thereafter the path of least resistance lay at the 8,000-foot locality and the outflow gathered volume there and maintained the release for several weeks The eruption gradually dwindled in November. No sudden event was observed to mark its termination on Mauna Loa, but on Kilauea, where there had been continuous outflow in the big crater for many months, the lava suddenly subsided in Halemaumau on November 28.

An earlier published airplane picture (Volcano Letter No. 270, Page Three) showed well the straight lines of cones built up from 50 to 100 feet on the southwest rift of Mauna Loa in April, 1926, when there was another lava flow of the same quality as the one just described for 1919. In fact the photograph in question shows the line of cups within cones that had been built in 1919 about a half mile to the west of the new fissure that was opened in 1926. The same picture also shows in the foreground a short line of still older cones with their interior cup-craters lying to the east of the 1926 crack. The characteristic initial structure is an elliptical cone at each of the many openings along the crack, with an egg-shaped cup inside, and in many cases as the eruption dwindles there will be two cups where a revival of activity has made an inner cone at some larger spindle-shaped crater whence the activity had shifted elsewhere and returned during the progress of the eruption from many vents.

The photographs on Pages Two and Three show the line of cones made at the source of the 1926 eruption looking towards Puu o Keokeo and the older cones of that district, and an excellent airplane picture of the western flank of Mauna Loa above the forest line and below the rift belt exhibits the torrent of molten lava in the midst of a band of solidified aa. The source vent picture was taken May 4, 1926, just as the eruption ceased and shows the place where the final source fountain had been in the foreground, still fumy with sulphurous acid, with very hot air rushing up the cracks, a depression 5 to 10 feet deep floored with a swirl of lava. The flow picture was taken on the same day (April 18) that saw the destruction of the fishing village of Hoopuloa by the front of the flow at the sea shore 10 miles farther down the mountain (Page Four Volcano Letter 270). The surface of the golden torrent shows a dark line of crusts and rafts down the middle and a tendency to form distributaries around islands, the rapid stream maintaining in general a middle position along the band of semicongealed black clinker produced by earlier overflows of its banks. At the top of the picture this band is seen to change to lighter colored lava under the fume and cloud of the source vent region, and this lightness is due to the presence of pahoehoe or smooth lava, with glistening surfaces on all the upper heaps within a half mile of the rift. This transition from pahoehoe to aa a short distance from the Mauna Loa source cracks is characteristic, and shows the results of stirring on a steeper slope as described in Volcano Letter No. 281.

We see then that the source vents for Mauna Loa flows create true fissure eruptions, with many cones and cups along miles of cracked mountain flank, and that a new eruption tends to start at the top of the rift belt and to split its way down the mountain to that place on the flank where the lava finds a path of least resistance for continuous flowing. Quite commonly the splitting of the crack extends below the place selected for final adjustment to outflow· this happened in 1919 and 1926 on Mauna Loa, and in 1920 on Kilauea. Thus the lowest opening on the crack is not the vent selected for most voluminous flowing, showing that the outpouring is not strictly hydrostatic, but is rather selective of that portion of the rift which may be opened widest by the swelling of the mountain.

T.A.J.

KILAUEA REPORT No. 959

WEEK ENDING JUNE 8, 1930

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

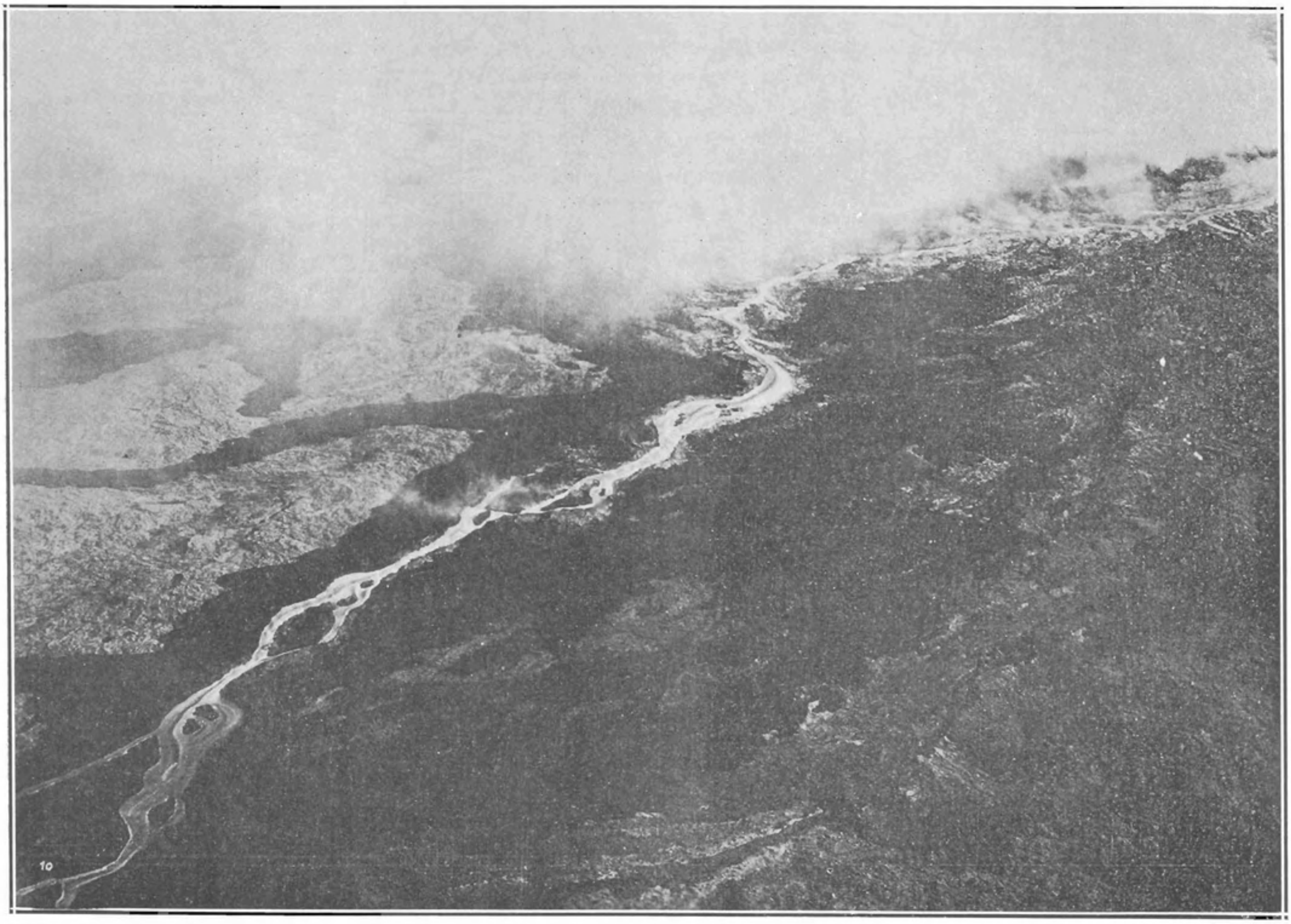
Halemaumau pit in Kilauea Crater remains quiet. At 11 a. m. June 5 no steam could be detected at any of the interior vents of the pit, though the vapor rising from cracks back of the west rim was as usual. On the morning of June 7 a little vapor could be detected at the south talus.

Ten local seismic disturbances were registered, of which six were short tremors lasting less than one minute, one was a very feeble seism, and three were feeble quakes. Two of these were felt on both east and west sides of the island, the times being 4:54 a. m. June 3, indicated distance from Kilauea 67 miles along with southeast tilt at the Observatory, and 6:32 p. m. June 4, probable distance 14 miles. The other was at 3:39 a. m. June 5, distance 28 miles. Tilt for the week was slight NE, and microseismic motion was slight.

MAY TILTING OF THE GROUND

At the Hawaiian Volcano Observatory on the northeast rim of Kilauea Crater, the tilting or tipping of the ground in the seismograph cellar, expressed by overlapping seven-day means, in terms of angular change and direction of motion of the plumb line, was as follows:

April 28-May 4	1.03 seconds	WSW
May 5-11	1.33 seconds	WSW
May 12-18	0.48 second	ENE
May 19-25	0.85 second	WNW
May 26-June 1	0.85 second	WSW



Airplane view of Hoopuloa lava flow of April 18, 1926, showing incandescent stream within aa fields at about 5,000-foot contour of mountain. Mauna Loa eruption of 1926 from southwest rift pouring westward above Puu o Keokeo. Transition pahoehoe to aa upper right. Photo Eleventh Photo Section, U. S. Army Air Service.

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The Volcano Letter

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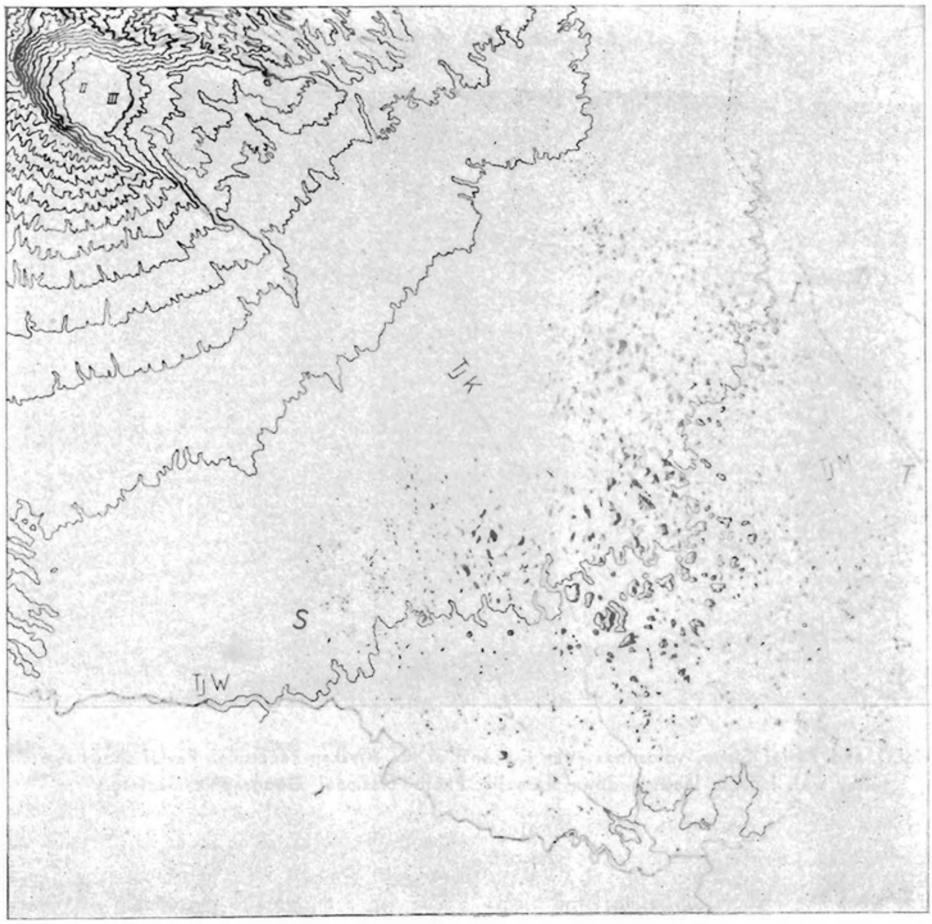
No. 286—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | June 19, 1930



Map of southeast slope of Galounggoung Volcano in Java. The many hills indicated by mottling southeast. Crater valley at northwest is four miles long. Tj=streams, S=Singaparma, T=Tasik Malaja, I=Indihiang. May by Escher.

THE CRATER OF GALOUNGGOUNG

In west central Java the active volcano Galounggoung is a big cone 2,168 meters high with an amphitheater hollowed out of its eastern side, and from this amphitheater three streams drain off to the south in a flat country where many villages were devastated in a terrific eruption accompanied by mud floods in 1822. This flat country is covered by many hundreds of prehistoric small hills from 10 to 250 feet high. The map above shows the crater trenching the east-southeast flank of the cone, and the roman numerals I, II, and III at the head of the crater valley mark eruption centers. The principal historic eruptions were in 1822, 1894, and 1918, the last developing a lava dome below point III on the map. The first two eruptions were explosive and produced great floods in the rivers. In addition there was a landslip in 1868, just as there was in the same year on the southeastern flank of Mauna Loa in Hawaii Indeed this amphitheater crater of Galounggoung is strongly suggestive of the gaps of Haleakala Crater, which open into valleys toward the sea, and of the Waipio, Mohakea, and Wood Valley embayments on the island of Hawaii. The hundreds of preristoric hillocks of Tasik Malaja bear some resemblance to some of the moraine-like hills on the north and west sides of Mauna Kea near the base of the mountain, these hills consisting of a jumble of mud and bowlders, possessing very irregular forms, and exhibiting no craters such as are characteristic of true cinder cones.

The places on the map of the Tasik Malaja hills marked Tj are streams, the hills are indicated by the mottling, and their disposition with the largest ones out in front of the crater valley certainly suggests a relationship between their origin and some ancient discharge from the valley. As Professor Palmer pointed out in his review of Escher's paper (Volcano Letter No. 253), 3,648 hills have been mapped, and the map here reproduced is taken from that paper, published by the Geological Society of Leiden in 1925.

Pavlof Volcano (right) and Pavlof Sister, volcanoes near the end of the Alaskan Peninsula. Pavlof shows summit crater and open valley with hillocks leading down from it. Photo National Geographic Society.

Each hill is composed of very fine material enclosing large blocks of andesite rock. The cubic content of all the hillocks taken together is about one twentieth of the material missing from the cone of Galounggoung at the great amphitheater. Underneath the hills, however, there is an underlying mixture of bowlders, gravel, and mud some 70 feet thick in the middle and thinning out toward the margin of the hilly area. If we add this under layer to the volume of the hills, we still fall far short of the volume lost from the big crater.

According to Escher the material of the hills had slid down from the crater in the condition of mud, probably from a crater lake. As a succession of eruptions had migrated from a summit crater to the southeast, it is probable that the crater lake broke through and caused a violent and watery landslide. "The hillocks represent the fixation of the last material of the slide, clots that remained standing higher, the principal mass having slowed down because of increasing bottom friction as it spread out fanwise and lowered, and as it lost part of its water." The finer mud and surface material flowed on down the slope, leaving the clots in relief where irregular clusters of bowlders clothed with mud made the remnant hills. The largest of these were in the middle of the landslide fan and opposite the middle of the crater valley. Taverne (Vulk. Med. No. 6, Mining Bureau of the Netherlands East Indies, Galounggoung and Telaga Bodas, Weltevreden 1924, page 29, and plate III) has reproduced an old map of Galounggoung after the eruption of October, 1822, and the area devastated and buried by this eruption corresponds closely with the area of the hills.

The following second review kindly sent us by Professor Palmer presents another explanation for the hills of Tasik Malaja. T.A.J.

THE BOWLDERY HILLS OF GALOUNGGOUNG

A paper by the eminent Dutch geologist, B. G. Escher, relating to the "Ten Thousand Hills of Tasik Malaja," was reviewed in the Volcano Letter for October 31, 1929 (No. 253). Escher considers these hillocks to be stranded masses of landslide material, the rest having swept on down the slope.

A short paper by Dr. F. X. Schaffer, head of the Division of Geology of the Naturhistorisches Museum in Vienna, has been received and suggests another origin for these hills ("Die Zehntausend Hugel von Tasikmalaja," Centralblatt f. Min. etc., 1926, pp. 207-209). Dr. Schaffer visited the region a year before read-

ing Escher's paper. At that time he was of the opinion, which he still holds, that the hillocks are man made. Most or many of the hillocks bear houses and friut trees. As dwelling sites they offer some protection from the numerous mosquitoes and rats which infest the rice fields at the bases of the hillocks. They offer some immunity from attack by hostile persons, and they insure dryness for the dwellings. They also offer places of refuge from the volcanic mud-flows that from time to time rush down the depressed sector of the volcano where they are to be found. The gently sloping, fan-shaped region built up by the mud-flows is very favorable for rice cultivation, which has undoubtedly been practiced from time immemorial. However, the preparation of the rice fields has involved the movement of great volumes of rock and earth in order to bring them to grade. In the process of clearing the land it would be probable that the people would make dumps of the bowlders and cobbles from the mud-flow material. Thus the dumps have become hillocks, and it was a simple matter to take advantage of the favorable characteristics of the hillocks that are favorable for house sites. The objection might be raised that the volume of man beings. This might be true of occidentals, but is not beyond the powers of the numerous and ant-like industrious Malays.
material moved is too great to be conceivable as the work of hu-

The reviewer has attempted to give Dr. Schaffer's views and nothing else on this occasion, which is what he attempted on the previous occasion for Professor Escher's paper. Schaffer concedes that the cores of the larger hillocks are not man-made. It is to be regretted that we have no information as to native legends of the origin of the hillocks. H.S.P.

SOME ANALOGOUS BOWLDER HILLOCKS

The foregoing discussions of bowldery hills in fan-like grouping in front of a crater valley in Java are too important to pass without some comment. This question of crater sinks merging into collapsed valleys has been splendidly reviewed and illustrated by Friedlaender, (Volcanological Review, Berlin, Vol. II, page 186, 1916, "On volcano fault-valleys," with maps of Bandaisan in Japan, of Hawaii, of Brava, San Thiago, and Fogo in the Cape Verdes, of Palma in the Canaries, of Stromboli in Italy, of Savaii and Tau in Samoa, and of Crater Lake in Oregon.) As mentioned in the last Volcano Letter, the Hawaiian volcanoes are breaking down by faulted sectors. When such downbreak is accompanied by explosion at the volcanic center, big downblasts, floods and landslips are common. The accompanying photograph of the north face of Pavlof (Page two) cones shows down-broken sectors, the right-hand peak, Pavlof proper, exhibiting an open A-shaped gash, clotted rocky hillocks of debris below it and under the crater, and a vast jumble of bowlders and wash spread out in a fan farther down the slope. This jumble contains hundreds of mounds like those described under Galounggoung. (See Nat. Geog. Mag. January 1929, pp. 130 and 134).

The most perfect parallel to the Galounggoung cluster of hills is to be found on the north slope of Bandaisan volcano in Japan, and these mounds were created by the explosion and landslip of the great eruption of July 15, 1888. They were described as follows (The Eruption of Bandai-san, by Sekiya and Kikuchi, Jour. Sci. Coll. Imp. Univ. Tokyo, Vol. III, Pt. 2, 1889, page 110, plates xv, xviii, xxi, xxii): Large and small conical mounds stand out from the surface of the debris in immense number. There are big bowlders, measuring from five to ten meters, carried along as part of the mud current, and thousands of mounds, large and small, have been formed on the vast sea of mud, standing out of the debris like so many miniature Fujiyamas. They consist of disintegrated crumbling rocks, and the refuse falling around their bases has assumed a conical shape by forming taluses around them.

The writer examined this field of landslip of Bandaisan in 1914, where a huge amphitheater was quarried out of the flank of the mountain by the eruption, making just such a map as that of Galounggoung on Page one. The hillocks are clustered fan-like amid the tumble of rubbish in front of the crater niche. There were scars on the sides of the valley devastated, 75 to 100 feet above the debris, showing how the mud and earth had sunk away from its highest level. This high level corresponded with the tops of the mounds. The mounds had mostly a hard bowldery core, and many of them stood as islands in the lake which the eruption had produced by damming. One hill sketched was a pyramid with four surfaces fallen away, its summit sharp, made of earth and stones. The explanation adopted by the writer was that the first rush of the landslide was a thick fan while the huge rocks were grinding up, then the vast amount of water acquired by the finer material made this finer stuff rush much farther as a mud flood, carrying smaller bowlders and bowlder clots, and spreading as a thinner layer. This outspreading of the lower fan drained down the deposit from the scar level to the final level, and the larger rock fragments in units and groups remained in relief, as mounds which resisted farther progress. This would leave the larger clots nearer the crater, the smaller ones farther away, and precisely that effect is shown by plate XV of Sekiya and Kikuchi, and by Escher's map on our Page one. There is every reason to suppose that Galounggoung has had the same type of eruptions as those of Bandai. In both cases the same expression is used by scientific observers, "thousands of conical mounds." Escher's explanation appears to the writer to be correct, and to account for the gradation in size, and the distribution relative to the crater, and the rocky cores, while Schaffer's observation concerns human selection after a cataclysm had created the hills. T.A.J.

KILAUEA REPORT No. 960

WEEK ENDING JUNE 15, 1930

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

There are no changes in the crater of Kilauea, and only once during the week was a little sliding observed at the pit walls.

The seismographs at the Observatory have registered one slight earthquake, three very feeble local seisms, two of them accompanied by easterly tilt, and four tremors lasting each from one-half minute to one and one-quarter minutes. The slight earthquake was generally felt on the east side of the island at 12:25 a. m. June 14, the seismogram indicating distance of origin about 12 miles from Kilauea Observatory. The felt movement was prolonged and moderate at Kilauea, shorter and ending in a sharp jerk at Hilo. The vertical component was very pronounced on the Kilauea seismogram.

Tilt for the week was stationary, and microseismic motion was very slight.

Note on this map the horseshoe valley west of Pahala and the depressions northeast of Kohala summit, as well as Kilauea Crater, all amphitheaters similar to Galounggoung Crater.

THE VOLCANO LETTER

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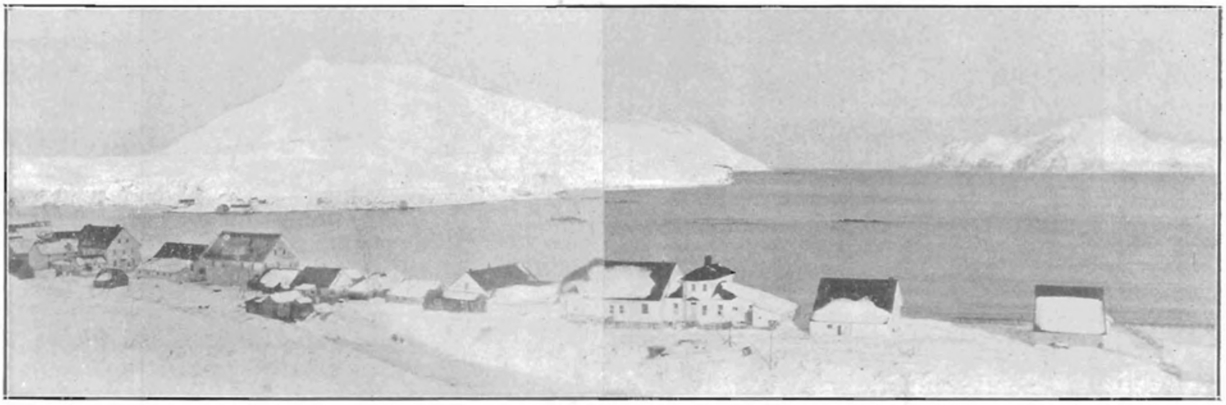
The Volcano Letter

Two dollars per year Ten cents per copy

No. 287—Weekly Hawaiian Volcano Observatory, National Park, Hawaii June 26, 1930



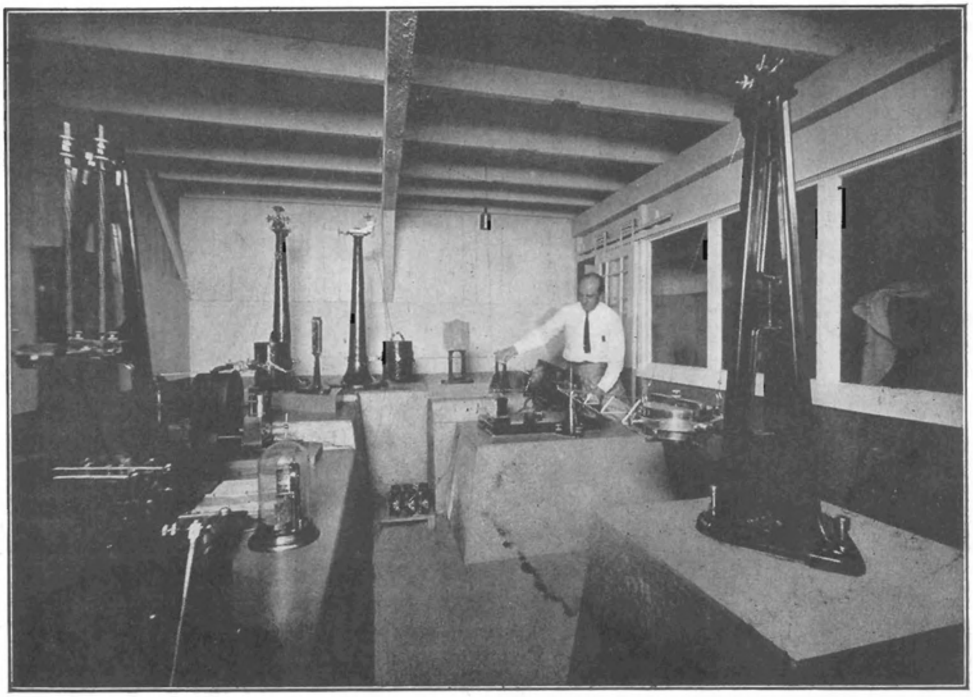
Unalaska harbor, in the Aleutian Islands, looking north in winter time, showing the village in foreground and on the left Amakmak Island, where are Dutch Harbor and the Naval Radio Station that houses the seismograph of the Volcanology Section, U. S. Geological Survey. Photograph by Yatchmeneff.

THE PULSE OF THE PACIFIC

How the seismograph works has been the subject of another number of the Volcano Letter (No. 268), and one of the first objects of investigation when the Hawaiian Volcano Observatory was started in 1912 was the pulse of the ground at an active volcano. For fifty years the Japanese have been taking the pulse beats of the earth crust in Japan, led first by John Milne, second by Professor Omori, and third by Dr. Imamura. All of these were stimulated by their researches to give attention to the active volcanoes of Japan, and recently the work has been narrowing down to what Imamura calls chronic earth tilting. The San Francisco earthquake of 1906 revealed a great rift extending for hundreds of miles, and the Coast Survey determined horizontal movement whereby the two sides of the rift shifted in opposite directions during the earthquake. Monuments have been set up to learn how much of such movement is chronic and continuous. The Carnegie Institution of Washington has set up sensitive instruments in southern California to learn how many small jarrings are associated with such faults. The Section of Volcanology of the Geological Survey has extended the Hawaiian work to Lassen Volcanic National Park in California and to Kodiak and Unalaska (see photographs Pages One and Three) in Alaska in order to take the pulse of new places. New Zealand and the Dutch East Indies are at work on the same problem.

All of this may be regarded as a big experiment requiring both time and space, the half century of time and for space the whole fiery circle of the Pacific, in order to find out, for local seismology, what movements of the ground are sufficiently continuous, chronic, or frequently repeated. One subject of local seismology at the volcano belts is to determine important cycles leading to recurrence of eruptions. For the geography or space side of the argument, the object is to determine what volcano or vent will erupt. For the places where volcanoes are not active, like Wellington or San Francisco, the object is to determine the earthquake danger, and what are the cycles in time for big earthquakes at the same place, and what are the places where the snapping of the earth's crust may progress through the ages from point to point, not accidentally, but because of some deep-seated law of which hitherto man was ignorant.

Thus in Hawaii the volcano observatory is seated on a comparatively simple structure, an island with three active volcanoes and two old ones. We have five active seismograph stations where pendulums register the tremblings, jolts, and tiltings of the ground and the lists exhibit thousands of earthquakes where in the year 1800 the only lists were in the memories of the natives or the log books of explorers. In 1800 there was an eruption with lava flows down the west side of Hualalai Volcano, and we know nothing of what spasms of earthquaking then preceded the bursting open of that dormant mountain. Ten years before Kilauea on the other side of the island had a bad explosive eruption with much shaking



An early photograph of seismograph cellar, Hawaiian Volcano Observatory, which is dug down to bedrock. The concrete tables hold the rigid posts on which pendulums are swung equipped with chronographs that register movements on the rock on smoked paper. Station near Volcano House, Kilauea Crater.

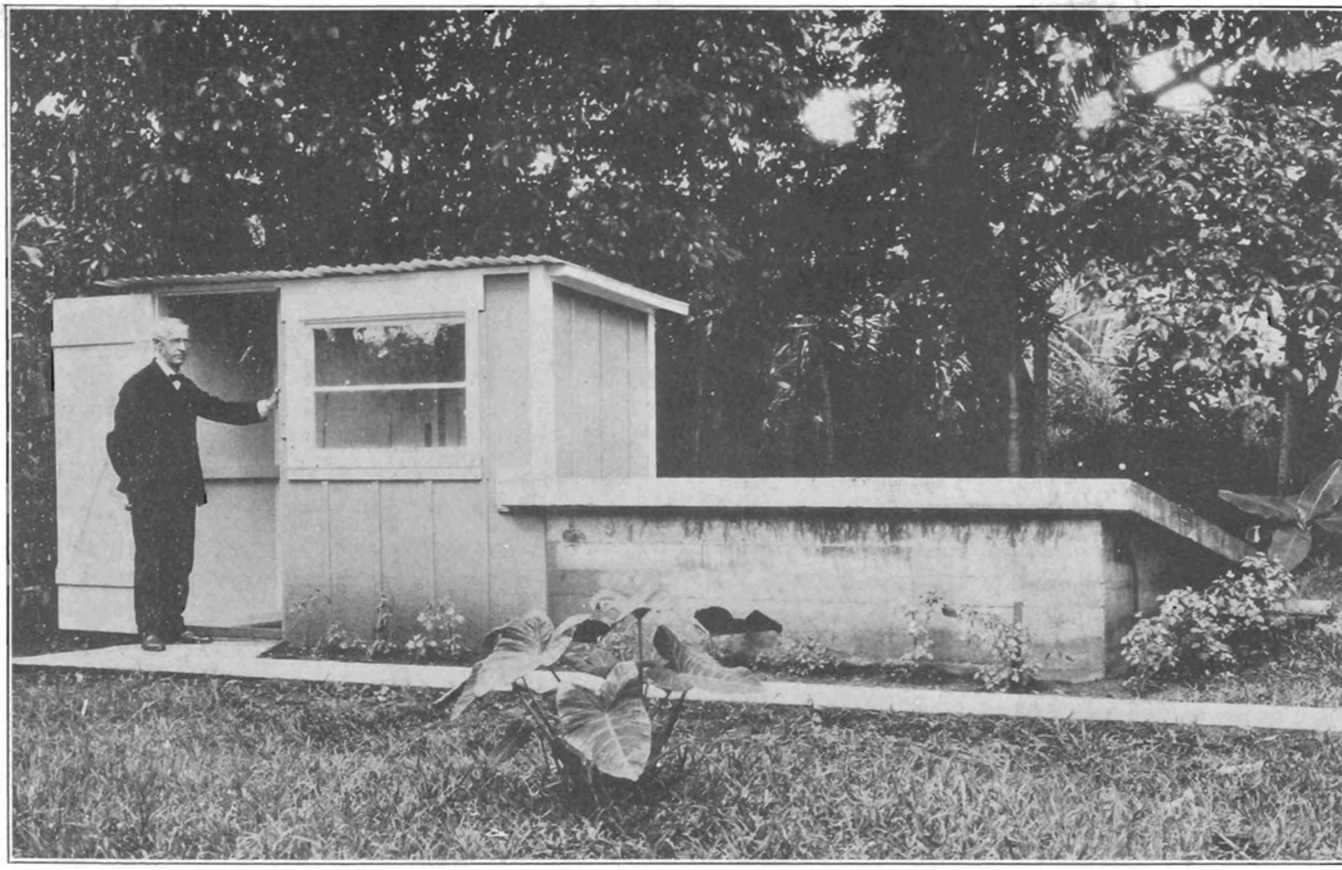
and an enormous sinking of the bottom of its crater. Here were two events in a decade and two volcanoes somehow related. Compare with this the decade 1924-1934. Kilauea in 1924 had an explosive eruption with much shaking and sinking of its crater. Hualalai in 1929 had two months of shaking in excess of anything experienced there for a centry. Here were the same two volcanoes somehow related, but this time harnessed with seismographs. The transference within six years of the underground activity from Kilauea to Hualalai hints at a repetition of 1790-1800. The seismographs and tilt machines and leveling instruments, as well as continuous notes on Mauna Loa and Kilauea, had proved a rise and fall of the east side of the island, accompanied by rise and fall of lava in both Mauna Loa and Kilauea, for the eleven years preceding 1924. We see from all these facts that the observatory notes of only 20 years of work have enabled the scientists to sketch out an important eleven-year cycle, and the adjustment of this cycle to past history enables them to sketch out an important forecast relating to the geography of adjacent volcanic craters. Underlying these researches is the pulse of the crust of the earth measured by recording pendulums, and these have been writing the autograph of the bedrock since the summer of 1912.

The cut on Page Two shows the seismograph cellar built on the bedrock under the Hawaiian Volcano Observatory back from the edge of Kilauea Crater on its northeast side. A number of iron posts are seen, bolted into the concrete. Heavy beams support the floor above, so that the building rests on the outer margins of the cellar, and the walking of people on the upper floor does not press down the floor of the cellar locally. This is important, for every time an observer enters the cellar to change the chronograph drums as shown in the picture, his weight in walking by a post is sufficient to swing the magnifying pens a half inch across the smoked paper. The instruments are very sensitive, and are designed to record on different chronographs strong motions and weak motions, up-and-down motions, east-west and north-south motions, and to distinguish between tiltings, tremblings, local earthquakes, and distant earthquakes. A local earthquake makes a quick motion, a distant earthquake makes a slow motion. With all of this goes continuous registration of time from a clock, and correction of the clock by wireless. With 15 or 20 local earthquakes a week, numerous distant earthquakes throughout the year, small wave movements in the ground due to lava in the pit, the action of a storm, the pounding of a distant surf, or the passage of a steam roller: with hundreds of earthquakes when an eruption begins: with tilting and certain kinds of tremor always in progress; it will be seen that it requires experience to decide what seismograms to study, and where to place seismographs in order to cover geographical questions. As a matter of fact, the published seismograph records from volcano stations are unsatisfactory, because the volcano seismologists have too much to study.

It is popularly supposed that we look at a seismogram and predict an eruption. But neither eruptions nor big earthquakes herald themselves in this manner. The science of local seismometry is steadily working to narrow down all these many movements so as to reject the unimportant ones, and then to measure intensively, with distributed instruments, those chronic movements that are directly related to the lava underground. Japan and Hawaii have both concluded that chronic tilting or tipping of the ground goes with chronic rise and fall of the land. In Volcano Letters 264 and 283 we have shown how gradually Kilauea swells and how gradually the rim cracks of the pit spread open. From week to week we publish changes of tilt at the seismograph cellar, because big changes accompanied big risings and fallings of the lava. Imamura has shown that in Japan both volcanic eruptions and earthquakes are preceded by years of important tilting. Large earthquakes near volcanoes are proving themselves to be in a different class, involving deeper movements, than the small surface jarrings of an active lava period. Here there is a gradation that can only be explained by placing many seismographs in geometric relation to a single volcanic mountain. There is undoubtedly some relationship between numbers and intensity of earthquakes on the one hand, and the magnitude and direction of tilting on the other, but to discover this relationship a limited piece of ground must be studied.

The Hawaiian station is now at work on its records of 18 years with a view to narrowing down the problem of earth motion in relation to underground lava as applied to Kilauea Crater alone. The most hopeful line of attack appears to be the measurement of tilt at a number of stations all equipped with the same instrument, and a determination of policy and of instrument construction that will permit the operation of the system so as to eliminate earthquakes, tremors, temperatures,

Lassen Volcano Observatory at Mineral, California. This simple house in the forest is over a concrete cellar containing the seismographs of the Section of Volcanology, U. S. Geological Survey. R. H. Finch is in charge of the station, designed to study the seismic movements of Lassen Volcano.



Special seismograph cellar at St. Mary's School, Hilo, Hawaii, operated by Brother J. B. Albert for the Hawaiian Volcano Research Association. This houses a pair of Hawaiian-type seismographs made in the shop of the Kilauea Volcano Observatory. The records are compared with those of the crater, 30 miles away.

storms, and artificial disturbances, and a routine sufficiently simplified as to make possible the measurement for a term of years at reasonable expense. T.A.J.

KILAUEA REPORT No. 961
WEEK ENDING JUNE 22, 1930

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

The Hawaiian volcanoes continue without action, and nothing has been observed in motion at Halemaumau pit of Kilauea Volcano except the sliding of a few rocks at 2:20 p. m. June 18 and at 10:25 a. m. June 20.

The seismographs at Kilauea recorded six very feeble local seisms, two of these indicating distances of origin 18 and 23 miles. Seven tremors were registered lasting from one-quarter to three-quarters minute each, and easterly tilt accompanied one of these and one of the above mentioned local seisms.

General tilt for the week was slight NNE, and microseismic motion was slight.

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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.

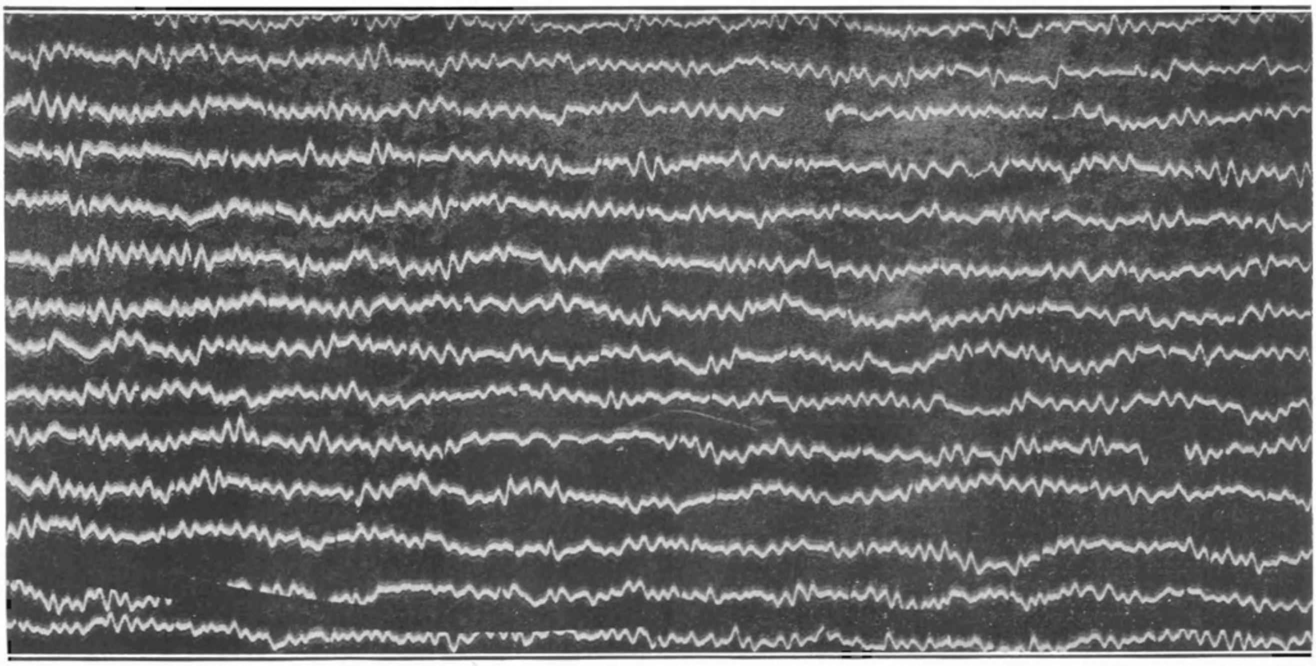
The work of volcano research so supported is in collaboration with the work of the United States Geological Survey, but supplements it with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision. The Geological Survey maintains 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. 288—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — July 3, 1930



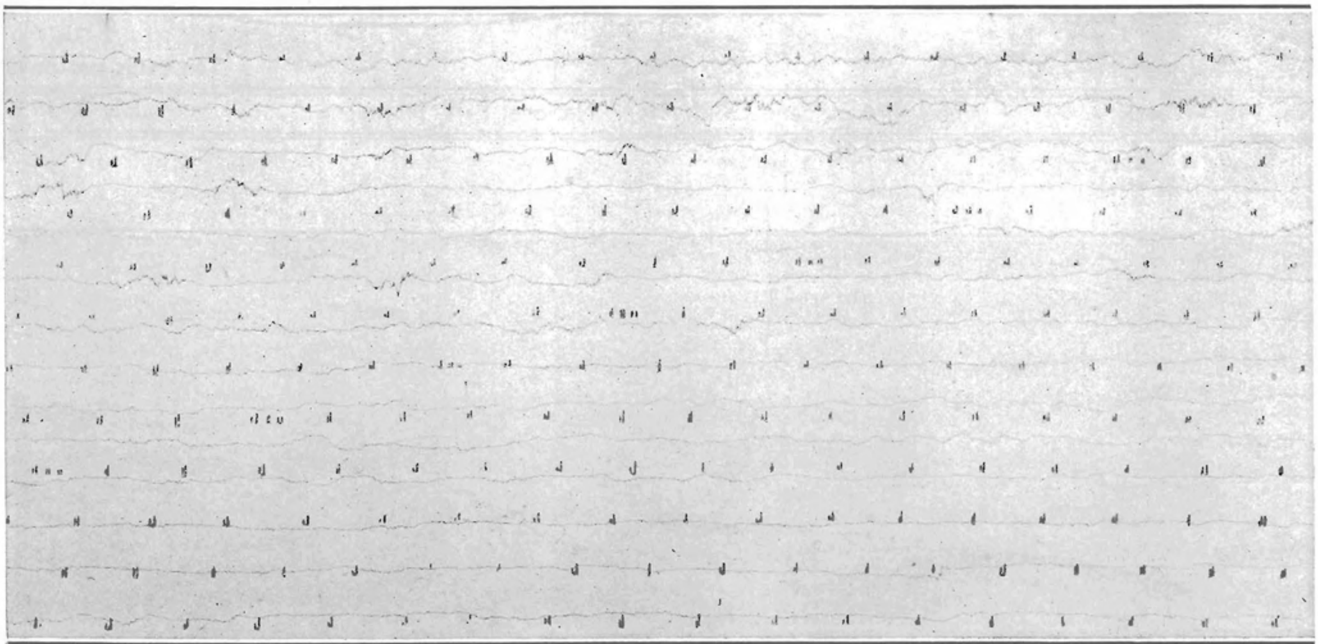
Seismogram, showing the lines written with a beam of light on a Kodak film in June, 1918, exhibiting microseisms as the principal wave movements. Minute marks are exhibited as gaps in the line. Registration of experimental seismograph pendulum of high magnification, Hawaiian Volcano Observatory.

SOME TECHNICALITIES OF VOLCANO STUDY

The reader of the bulletins and reports of the Hawaiian Volcano Observatory will be helped to understand the descriptions of the seismic movements at Kilauea, and of the rising and falling lava in the inner pit Halemaumau, and of the flowing of lava down slopes, if the observers at the stations of the Geological Survey will turn aside occasionally from technical description in order to explain the meaning of terms. Harmonic tremor, local seisms, avalanche vibrations, microseisms, streaming, fountaining, the wall crack and rim cracks are everyday structures, processes, and events at a volcano station equipped with seismographs. But the visiting traveler finds even such a simple word as "tilt" incomprehensible. He is not accustomed to a land which is tilting, and even if the house he lives in tilts back and forth between noon and midnight under the stress of the neighboring ocean tide and the weight of the changing water on the shore, he probably does not know it.

It has been the purpose of some recent numbers of the Volcano Letter to explain lava flows, rim cracks and crater slides, pahoehoe and aa, the bubbling, gushing, and cascading of lava, the swelling of the mountain, the seismogram of a distant earthquake as foretelling a tidal wave, the distinction between lava froth and lava paste, the working of a seismograph, and the heating of lava tunnels and wells by gas. Tilting or tipping of the ground was described last week in Volcano Letter No. 287 as an interesting chronic motion whereby a volcano is breathing through the weeks and months and its breast is accordingly rising and falling (Volcano Letter No. 264).

The present article is designed to show some seismograms and a diagram exhibiting movement of the ground in the shell of a mountain which is over a hot lava column. By lava column is meant an upright body of natural slag charged with gas in solution and occupying a natural shaft or well which goes down many miles and widens out in subterranean forms which it is the object of Volcanology to discover. Just as General Gorgas and Walter Reed discovered by experiment in Cuba that the mosquito carried yellow fever, so by experiment is it possible to show eventually that the lava under these great volcanic mountains swells out into a bulb, or a dome, or a lens, or a net of upright cracks. Experiment at the Kilauea Observatory has already shown that the mountain swells with rising lava and that the local ground always swells at the crack where rising lava is coming out. Leveling has shown that this swell extends down Kilauea Mountain to within 14 miles of Hilo, and that after the great collapse at the crater in 1924 there was subsidence of a foot or more at two stations in the National Park near Volcano House, and farther down the road very little effect. During the gradual rising of lava in Halemaumau from 1912 to 1921, the marked stations along the road



Seismogram printed directly from smoked paper, the quick tremors shown here and there being spasmodic volcanic vibrations. The slower waves are microseisms. Minute marks are dots. Hawaiian Volcano Observatory.

from Hilo to Kilauea showed in tenths of feet a rising approximately as follows:

Distance from Hilo Wharf	Change Between Levelings of 1912 and 1921
10.9 Miles	+ 0.0 tenths feet
14.1 "	+ 1.3 " "
17.2 "	+ 2.4 " "
20.4 "	+ 4.1 " "
31.3 " (Park entrance)	+ 8.1 " "
32.5 " (Volcano House)	+10.1 " "

The graded increase of change in these figures as the crater is approached leaves little doubt of actual rising of the ground that has been discovered to a still greater degree close around and within the crater of Kilauea (Monthly Bull. Hawn. Volc. Obsy. Vol. XV No. 6, p. 40). The tilt measurements of a single year at the Observatory are shown in the diagram on Page Four as though the trace of a hanging fountain pen were enormously magnified. The bend July 8 coincided with an eruption.

There is suggestion that the underground lava rising in Kilauea Crater between 1912 and 1921 was spreading out underground as a wedge for 16 miles in the direction of Hilo. The implication is that the tipping up of the country over this wedge grows less and less so that 21 miles away it is zero. There is a quantity of other information derived from running levels in the direction of Pahala and across the Kau Desert. The placing of instruments in small chambers in the solid rock in many places that would measure this tipping from year to year would furnish evidence of the rate at which the changes in level take place and the times of sudden changes if any.

As explained in Volcano Letter No. 268, the seismograph may be made to measure several things. Here are some of the terms used: A microseism is a slow, wavy movement in the ground consuming about four seconds to each wave as shown in the optical seismogram on Page One. Each line there represents a part of a different hour, the minutes are marked by gaps in the lines, and the lines were written by a tiny spot of light on a moving Kodak film, the light beam being reflected from a little mirror oscillated by a pendulum, and the pendulum registered the movement of the ground. It will be seen that the wavy movement comes in spells which wax and wane every minute or two. Microseismic movement is common everywhere and is variously explained.

Volcanic tremor is shown in the seismogram on Page Two, where the lines were written by a scratching pen on smoked paper and the time marks for minutes are closer together and are made by little double dots from a mechanical marker. Many spasmodic groups of tremors are shown, much quicker than microseisms, and these are common at Kilauea when there is active lava in Halemaumau. Such was the case when this seismogram was made by a pendulum set up two miles away from the pit. A complete wave motion for this tremor occupies two tenths of a second. Sometimes the tremor becomes continuous and even, when it is spoken of as "harmonic," and this has been found to agree with times of fountaining lava in the pit.

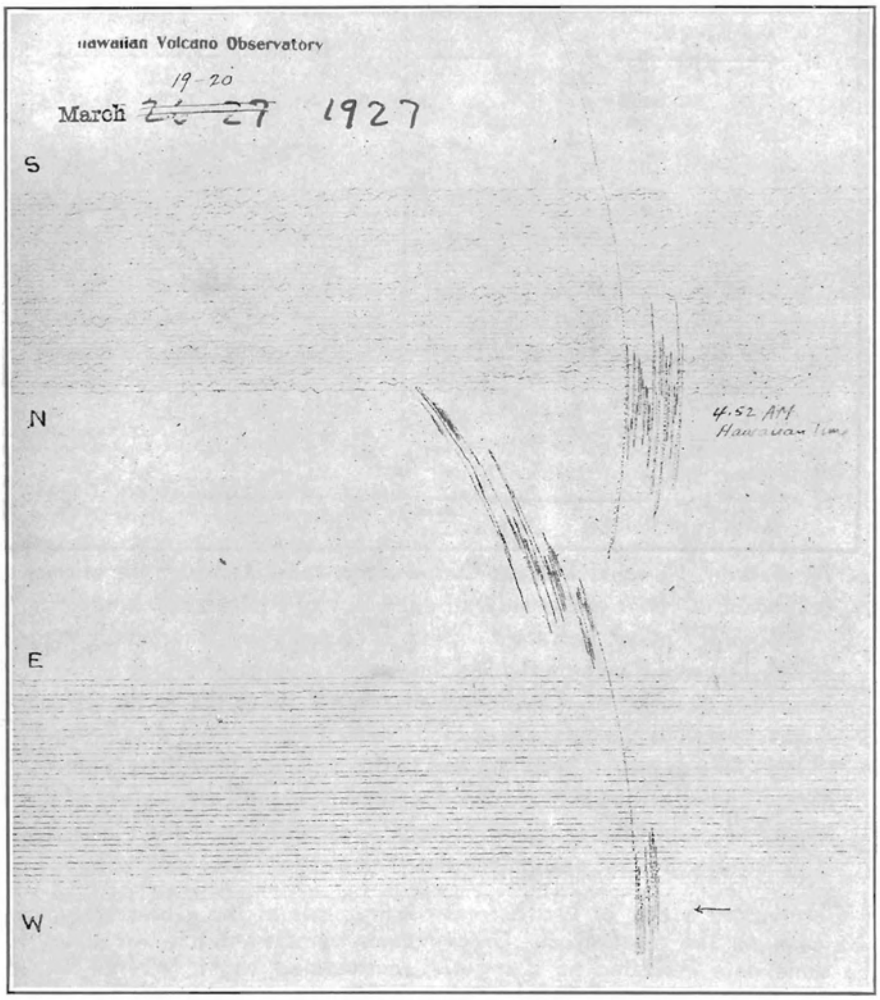
Local seisms are merely local earthquakes and the ordinary ones registered on instruments at Kilauea are technically defined as very feeble (of which we have thousands), feeble, slight, and moderate. The first two are totally unfelt, but when an instrumental earthquake gets so big as to be "slight" it is usually felt by everybody. To those who do not understand technical grades of intensity, it is hard to understand how seismologists can say to each other, "Do you mean to say that earthquake was slight at Hilo? At Kilauea it was only feeble." In other words, slightness is stronger than feebleness. In the same way "moderateness" is quite big, dismantles the high magnification instruments by throwing the pens clear of the drum (see seismogram Page Three), and the shock is referred to by inexperienced people as "terrible" or "strong." It is not "strong" technically, because it does not knock over anything, and we have to reserve some words like strong, very strong, and disastrous for the grades of very big earthquakes.

The "indicated distance" for the moderate earthquake shown on Page Three is indicated by the duration in seconds of the preliminary motion. In the upper south-north band of lines, just to the left of "4:52 a. m.," there is registered a group of vibrations about an inch wide up and down and occupying a quarter inch in the direction of the lines. Then there comes a big sweeping movement where the pen goes off the paper. In the lower band of lines (east-west) the pen starts to go off sooner. The quarter inch corresponds to so many seconds of time of preliminary motion, or the first phase of the earthquake, and by Omori's formula for local earthquakes four seconds means 18 miles, eight seconds 37 miles, 12 seconds 55 miles, etc., of distance horizontally to the place on the earth (or on the map) which lies over the place underground which bumped or scraped or snapped. The place underground is called the center or origin, and the place above it the epicenter. Sometimes the ground at the instrument tips suddenly at the time of the earthquake and this widens or narrows the space between the lines on the seismogram, while gradual tilt of the ground widens or narrows the lines gradually (see seismogram Page Four, Volcano Letter No. 276). Avalanche vibrations are occasioned by the falling of great masses of rock from the crater walls (see Volcano Letter No. 269), and these write their records on the seismogram as quick waves gradually increasing to a maximum and then dying away. An earthquake is different, with a small preliminary, and then the sudden wide movement of the long waves, followed by gradual decline. T.A.J.

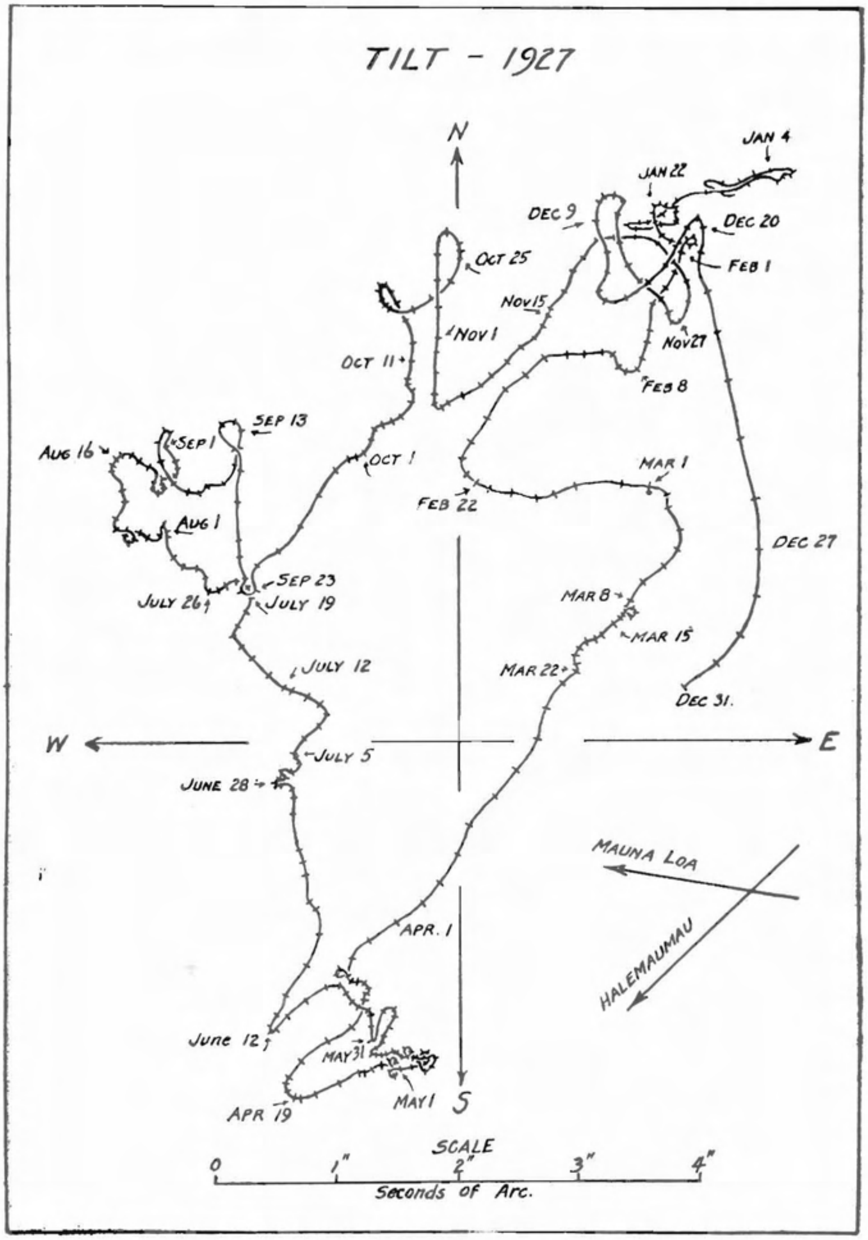
KILAUEA REPORT No. 962
WEEK ENDING JUNE 29, 1930

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

Kilauea Volcano remains quiet and without visible changes. On June 28 a small scar at the top of the west Halemaumau wall appeared to mark the location of a



Seismogram showing two bands of lines registering horizontal motion, the upper south-north, the lower east-west, made on smoked paper originally, and showing a local earthquake 4:52 a. m. March 20, 1927, of moderate intensity. Shows preliminary tremor, and then the pens are flung off. Magnification about 100 times.



Tilt diagram, Hawaiian Volcano Observatory, calculated from the seismographs for direction and amount of departure of a plumb bob in seconds, as though the plumb bob were writing its record in ink, enormously magnified. Linear distance on the line shows daily change of tilt, direction of line shows direction of change, and a marked bend to the northwest July 8 corresponds to the outbreak of Halemaumau the previous day. Seasonal tilting to the southwest in spring, and to the northeast in autumn is normal here. The two arrows indicate the directions from the Observatory of the Mauna Loa and Kilauea crater centers. Comparing January 1 and December 31, net change for the year was four seconds south.

slide seen from the Observatory a day or two before. No steam was to be seen on the pit bottom. Crack measurements on the same date indicated no changes.

Only six seismic disturbances were recorded by the instruments at the Observatory, of which five were volcanic tremors and one was a very feeble local seism. Tilt accumulated slight WNW. Microseismic motion was slight.

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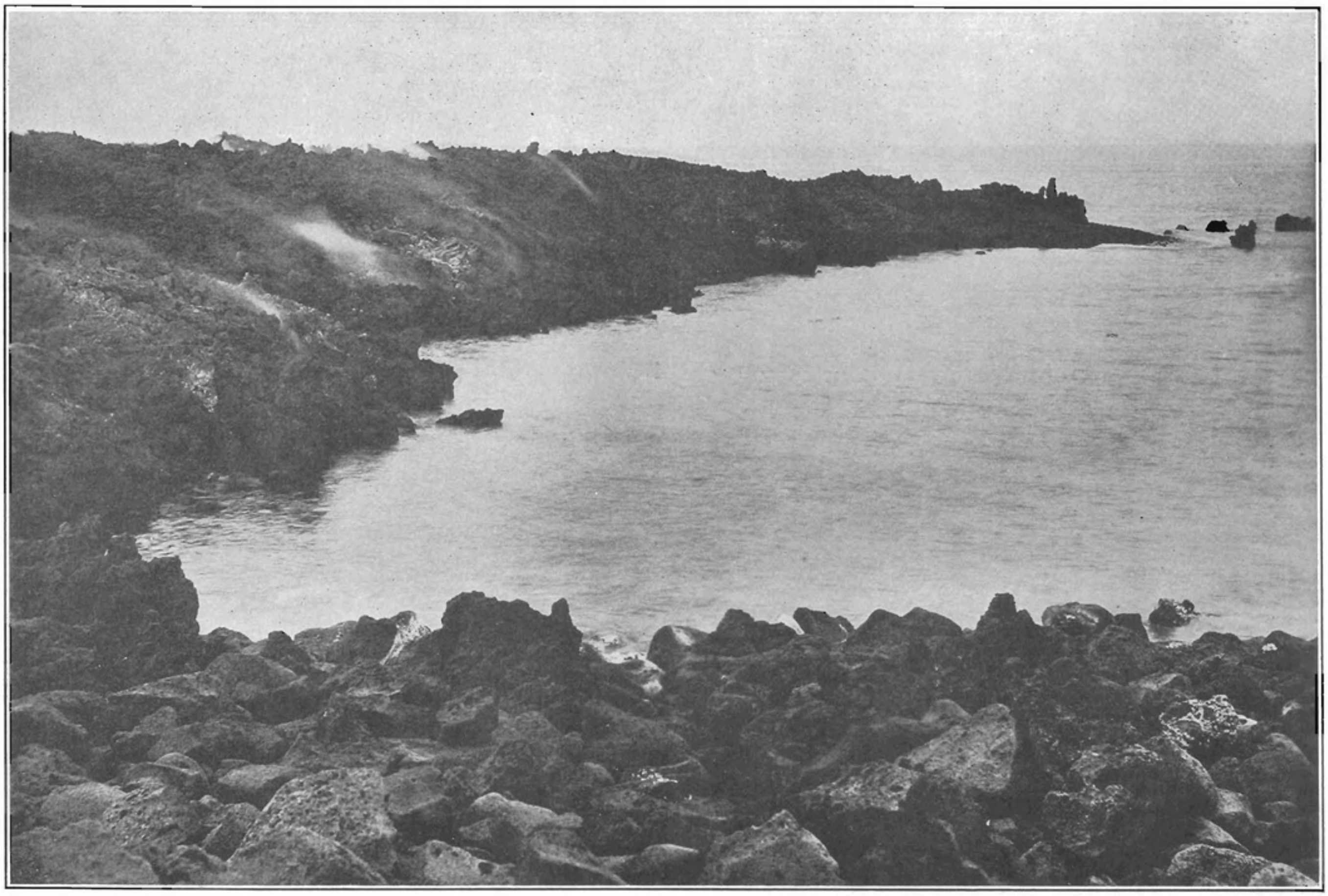
No. 289—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | July 10, 1930

Hoopuloa when the first buildings were burning and the lava front had just reached the sea, at 6:21 a. m. April 18, 1926, looking south. Photo Tai Sing Loo.

MARINE EROSION AT HOOPULOA FLOW

In 1926 during the month of May Mauna Loa produced one of its periodic displays with outpouring of molten lava, first from near the summit, then spreading down the southwest rift, and finally settling down to a steady flood of basalt from a vent at about the 8,000-foot level. This puddled on the flattish upland as usual for this district, the edge of the pool spilling in several directions before settling down to a final flow. The progressive feeling for an outlet in such a flow is partly conditioned by the tendency of the source crack or rift to open its way down the mountain. A vent is formed at a certain place on the crack, builds up a cone, overflows to the east, the cone-building clogs the hole, the crack opens a new vent farther down the mountain, and the escape of lava there is easier than at the first hole. The new cone overflows to the west, where the country is flatter, the slagheap backs up, the source is impeded, and a new place on the crack still farther down makes a freer outlet. In this way vent after vent is opened down the rift line. Finally a lower series of vents clog themselves and force the oncoming fluid from the depths to adopt one of its first openings a little farther uphill. The spouting melt is now dammed above and dammed below, and keeps flowing at one place. The flood



The site of Hoopuloa April 26, 1926. The foreground is old rock. Notice beginning of sand spit at point. The lava is still steaming. This is the cove which was later shut off. Photo Jaggar.

accordingly feels its way to the nearest declivity where finally it crushes a path for itself down a steeper grade through the forest, and this flow forms an adjusted canal through its own clinker fields to the ocean.

The flow of 1926 adopted this program, and the canal selected was a slight sag in the steep mountain slope of South Kona. This sag or valley, between old lava flows (see airplane pictures Volcano Letter No. 270, Page Four, and No. 285, Page Three) ended as is natural, in a shoreline indentation. This bay was where the fishermen naturally had chosen a landing for their canoes, here in some shelter had been built a wharf for the steamer landing, a beach had accumulated at the head of the bay, and dwellings had followed the demands of fishing and transportation. So this was the ancient fishing village of Hoopuloa, built to be sure on old and desolate rough lava flows, and only a short distance away from where in 1919 the Alika flow cascaded over the shore platform into the ocean, and made some short-lived tidal waves which wrought havoc at the Hoopuloa wharf. There was threat of danger, but why worry? There are lava flows everywhere.

The choice of a bay of the coast by men is also the choice of the fire goddess for good sledding on her lava. The aa flow of 1926 pushed right through the village ruthlessly, spared neither wharf nor dwellings, and nearly filled up the bay. There was left only a small cove at the northern quarter of the indentation where the wharf had been. Our pictures show the sequence of events.

At 6:21 a. m. April 18, 1926, we would have looked southward across Hoopuloa Bay (Page One), as the spectators and photographers in the foreground of the picture are doing, and we would have seen the crumbly incandescent front of the lava enveloping the village houses with flames, and just touching the water to start columns of white steam. The palms and the dock in the foreground are soon to be swallowed in molten rock. Jets of gravel will shoot up in zigzag trajactories, and the great steam-cloud will be blackened with exploded sand, while the heated and poisoned sea-water will kill small fish by thousands.

Within twenty-four hours, by 9 a. m. of April 19, all motion in the flow at the sea front had stopped, and the new point of lava, thirty to forty feet high, extended out 300 feet. The photograph on Page Two, taken a week later, shows the old sea worn rocks in the foreground, and the new lava promontory still steaming. Not a single building was left of Hoopuloa village. The destruction could not have been more complete if it had been a deliberate engineering enterprise. Of the original harbor there was now only a small cove shown in the picture. A canoe reposed in this cove. A large beach had been formed by the sea on the flow itself. Some of this is shown at the tip of the cape. These new beaches were evidently growing very rapidly in several places.

The hot gas rising, smelling strongly of ammonia and carbonaceous products, appeared to indicate that buried wood of the forest and the habitations was still smoldering under the flow. These smells were common at places remote from former habitations. When the large number of heavy sap-filled trees which the flow overwhelmed are taken into account, and when it is realized that they had no time to burn when they were smothered in the lava, it appears reasonable to suppose that all this carbonaceous matter may continue to burn slowly, with what oxygen it can get from the lava vesicles, for many months. This process will supply heat as well as gas, and the many explosions which are heard at old caverns when a flow is progressing through vegetation are occasioned by mixture of carbon monoxide, from the burnt wood, with air. Such explosions do not occur at the lava front when it advances over bare rock, where it has not travelled through vegetation.

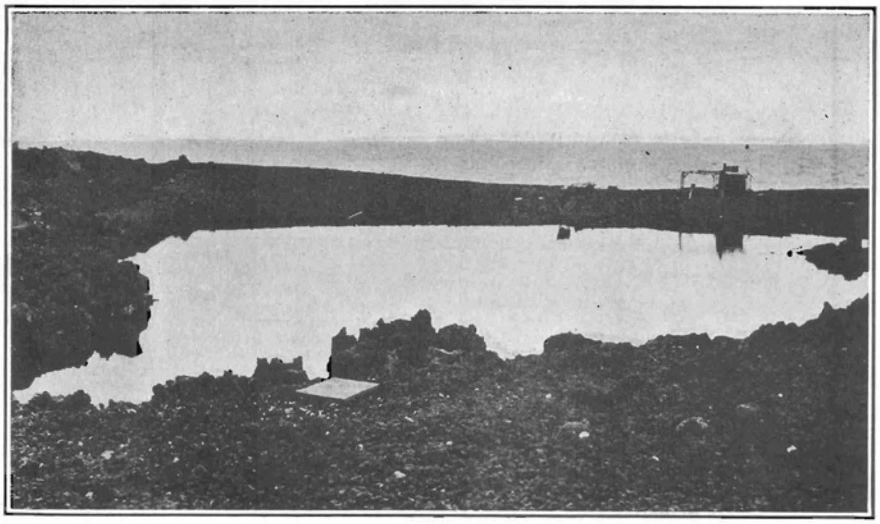
Less than a year after this destruction of Hoopuloa even their little cove was denied the fishermen. The abundant loose material of triturated and tortured clinker that forms the upper surface of an aa flow, furnished a rich harvest to the mowing machine and reaper of the winter storms from the south in 1926-27. This building of beaches, so rapid within a month, created big sea-walls within the year and a barrier beach was thrown straight across the entrance to the cove, straightening up the entire shore-line. The cove became an enclosed fish-pond of the type prized for mullet storing by the Hawaiians, but all trace of a harbor was lost. The new beaches are of gravel and sand with steep fronts sloping rapidly into comparatively deep water (Pages Three and Four). The observation of this rapid shore process of erosion and filling acting on a fresh lava flow, suggests the possibility of interpreting the age of a past lava flow by the amount of wear of the stones and the arrangement of the beach fills.

T.A.J.

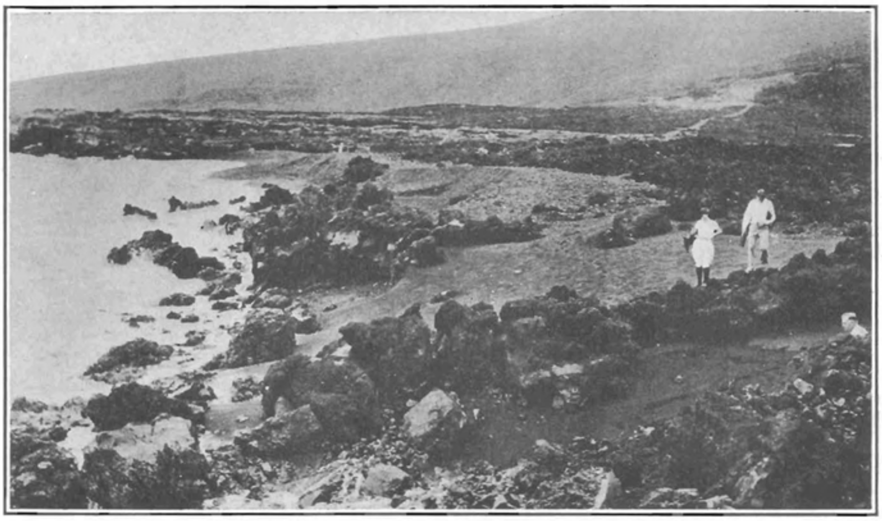
JUNE TILTING OF THE GROUND

At the Hawaiian Volcano Observatory on the northeast rim of Kilauea Crater, the tilting or tipping of the ground in the seismograph cellar, expressed by overlapping seven-day means, in terms of angular change and direction of motion of the plumb line, was as follows:

June	2- 8	1.08 seconds NE.
"	9-15	0.48 second NW.
"	16-22	0.97 second NNW.
"	23-29	0.48 second N.



Looking west at Hoopuloa Cove converted by barrier into a fish pond. Hut is on the new beach ridge. Compare Page Two. Photo Godfrey.



May 29, 1927, shore wash of the new flow at Hoopuloa thirteen months after. Sea wall beaches built up from winter storms. Looking north, showing barrier beach that cut off Hoopuloa. Photo Godfrey.

KILAUEA REPORT No. 963

WEEK ENDING JULY 6, 1930

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

Very few slides have occurred at Halemaumau during the week. White dust was twice seen rising on July 4. A little steam was observed on the south talus early in the week. The south sulphur area had a little whitish color.

The instruments remained very quiet seismically. The only disturbances were three volcanic tremors, each of one-half minute duration. Tilt accumulated slight WSW. Microseismic motion was slight.

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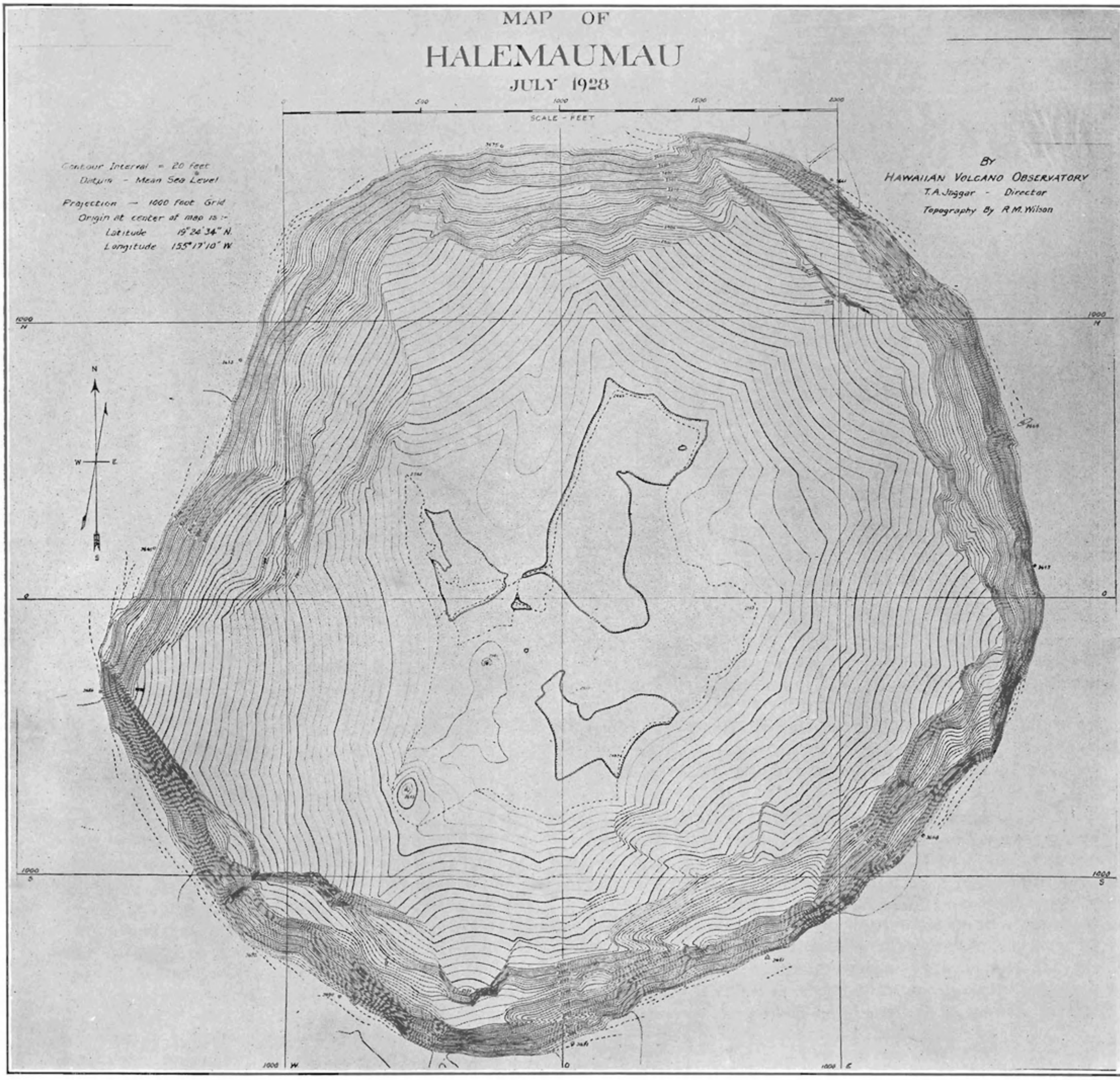
The Volcano Letter

Two dollars per year | Ten cents per copy

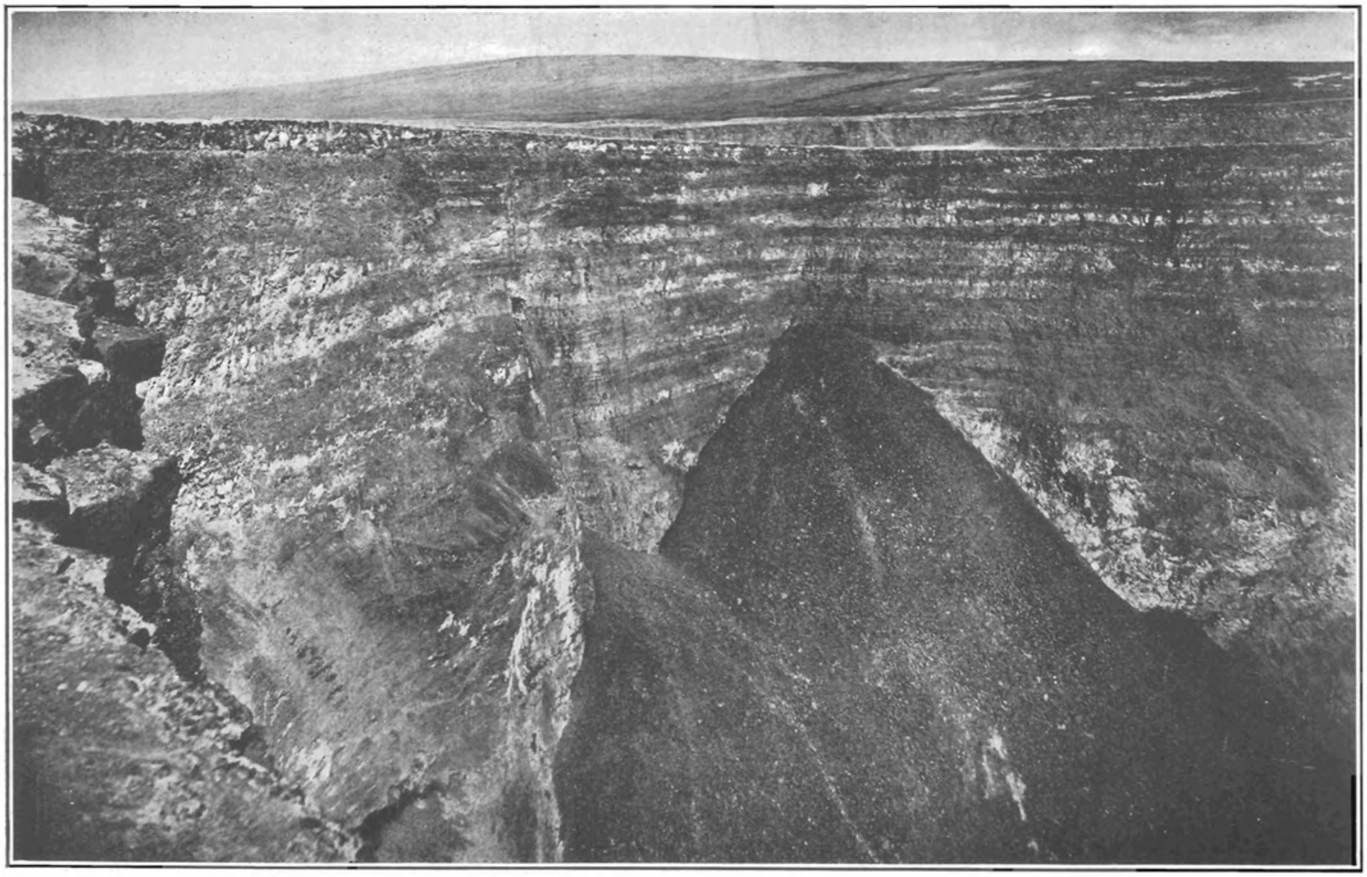
No. 290—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | July 17, 1930



Map of Halemaumau, with twenty-foot contours, showing pentagonal form and star-shaped peaks of the big talus conoids at the five angles of the pentagon.

THE WALL PLANES OF HALEMAUMAU

There is much evidence in the manner of eruption of the lava pits of Hawaii to prove that these pits, although apparently circular, are really guided by definite upright planes. This applies equally to the large sink craters, like Kilauea and Mokuaweoweo, and to the small pits, such as Halemaumau or Makaopuhi. It is clear enough, from an inspection of the map, that the Chain of Craters extending to the southeast from Kilauea, is on a curved line, and this curved line must be guided by some geometrical echelon of cracks, if not a single crack. The outstanding event of the last twenty years at Halemaumau, which



Angle between southwest and south walls of Halemaumau showing the big west talus and Mauna Loa in the distance. Photo Wilson.

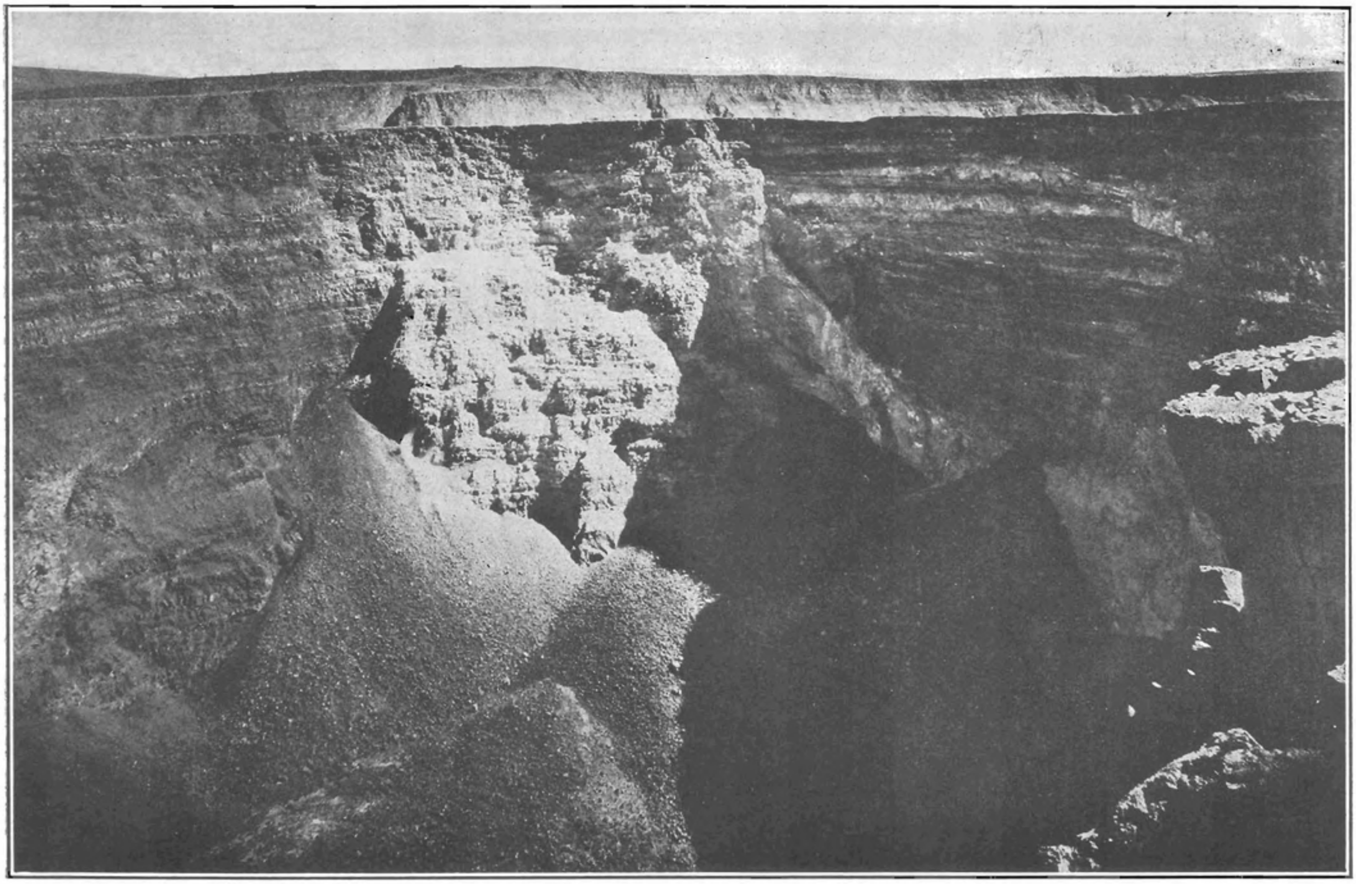
proved connection between a deep crack in the mountain and the opening of the pit, was the cracking open of the southwestern desert flank of Kilauea in 1919 to make a flow, and the visible drainage of Halemaumau at the same time through an upright crack in the wall of the pit (see the two black caverns in southwest wall, map on Page One above).

This map was made in July, 1928, with much care, and reveals a five-sided cauldron, with well marked angles between the five sides, and the light shade of open contours rising into a point at each of these angles indicate the peaks of conical talus slopes. In between these taluses there are rock walls. Four of these walls are fundamentally important planes in the mechanism which has generated the pit. These are the ones northeast, northwest, southeast and southwest. The fifth side is the north wall (Page Three), a remnant buttress between two gulches which are tending to join behind it at the extreme north corner of the map. That buttress has been undermined by avalanches right and left for years past, and threatens some day to fall into the pit and make a big avalanche, which would leave the pit four-sided.

If the reader will consult the outline map on Page Four, and there study the shape of Kilauea Crater, within the floor of which Halemaumau is an inner pit, he will find that the larger sink is also five-sided, with the two longer dominant walls northwest and southeast, and two shorter end walls northeast and southwest. Here also at the north there is a cross wall between the Volcano House and the Military Camp which is backed by the Sulphur Banks platform, an ancient remnant of a former crater floor, which if removed, along with the downfaulted Byron's Ledge, would leave the crater four-sided. Byron's Ledge is the triangular piece separating Kilauea from Kilauea Iki. It is thus clear that the outline of Halemaumau is a miniature of the outline of Kilauea, and both have their longer axes in a northeast-southwest direction on an extension of the 1920 rift. This rift is a deep fracture in the mountain, which has given vent to many lava flows off to the southwest.

The appearance of the Halemaumau walls is clearly shown by the photographs on Pages Two and Three. The picture on Page Two shows the great western talus with the western angle of the pit above it, a small talus cone adjoining it on the left, and this immediately below the rift caverns of 1919, and on the extreme left the south angle of the pit. Here are shown three of the wall planes, the ragged edge of the left hand foreground being part of the southeastern wall.

The picture on Page Three exhibits the north wall of the pit in bright sunlight, with a talus on each side of it, and this shows what is meant by referring to that wall as a lumpy buttress likely to fall away and leave a single angle behind it where the northeast and northwest walls meet. These two wall planes are shown right and left, the right hand one exhibiting the great white sill with a talus athwart it in the shadow, while in the foreground on the right is seen a craggy bit of the southeastern wall.



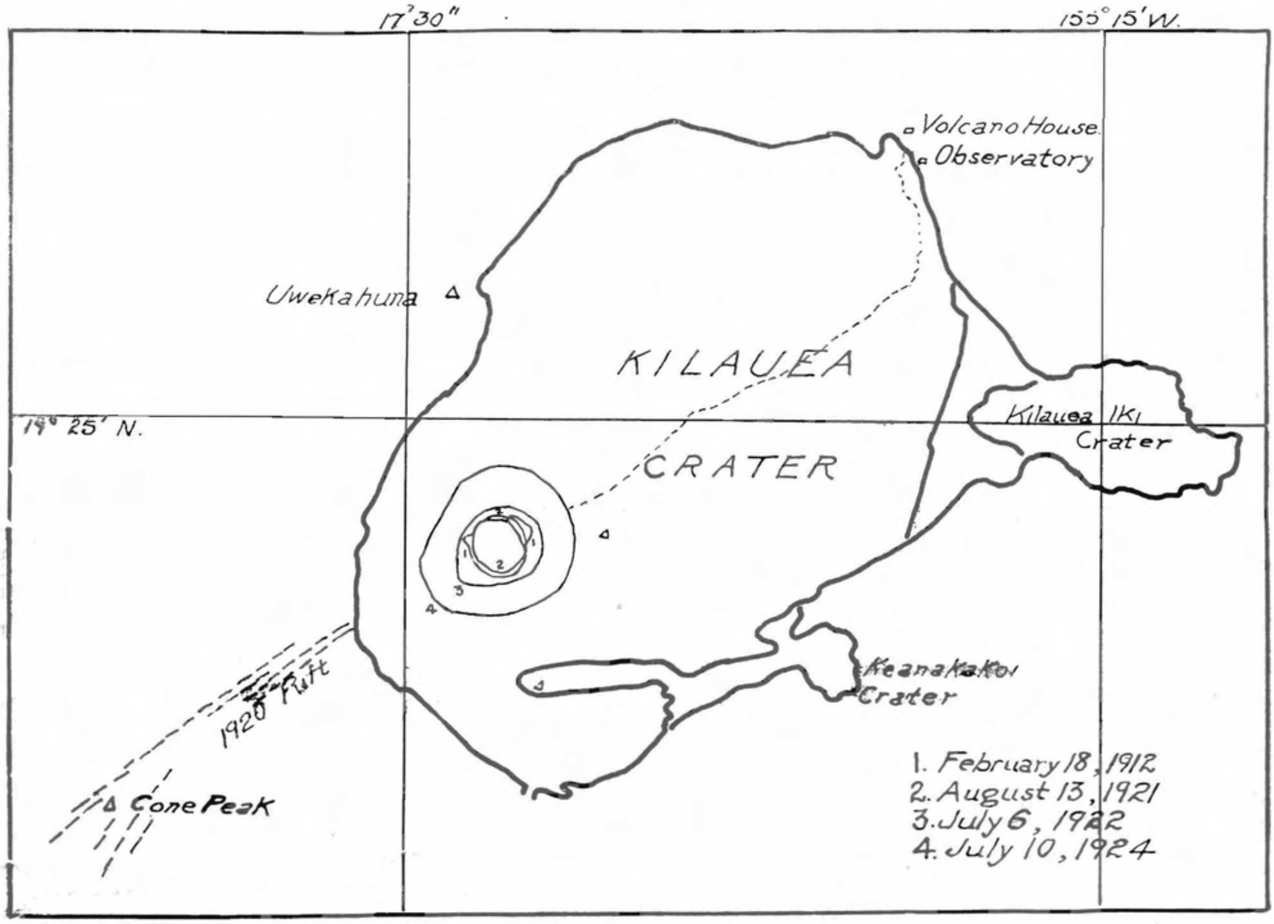
North wall of Halemaumau showing north and northwest taluses and protuberant buttress at north corner of the pit. Uwekahuna bluff in background. Photo Wilson.

Now if we go back to the map of Halemaumau, there will be seen across the bottom of the pit four small circles in a NE-SW line, which line if extended coincides with the rift tunnels at the southwest, and with a dyke or fissure filling which extends up and down the northeast wall (see upright line athwart the great sill on the right of the talus in the shadow in cut on Page Three). These bottom vents lay along the crack which opened in the bottom of Halemaumau July 7, 1927, the southern one building up into a big cone. A huge landslip from the north fell on the floor which was left January 11, 1928, and apparently cracked the floor in a semicircle around the lobate front of the landslip so as to let fresh lava ooze up and well out in a short-lived eruption. The fundamental crack of 1927 was approximately parallel to the northwest wall of the pit, and also to the northwest wall of Kilauea Crater. We may conclude from this that when Halemaumau revived after three years of repose, the deep rift which guided the revival was the great southwestern crack. And this great crack, in the original downbreak that formed Kilauea Crater, guided the production of the northwest and southeast walls of that crater.

The map on Page One shows that the northwest and southeast walls of Halemaumau have comparatively gentle slopes toward the center, and in plan they tend to converge toward the southwest. The northwest and southeast walls of Kilauea Crater (Page Four) also converge in plan toward the southwest. Apparently the great southwestern rift tends to have its cracks fan out or diverge in the direction of the rounded dome of the summit of the mountain and this is what has shaped the breaks which have determined the longer axis of both inner and outer craters.

All of the activities of rising lava in the pit since 1924 appear to have been controlled largely by the southwest rift. The big lava cone of July, 1924, was at the base of the western talus. The line of active vents of February, 1929, was at the base of the northwestern talus. The line of activity of July, 1929, was again at the base of the western talus. The surface fractures in each of these cases were doubtless determined by the breaking of the cake of lava left in each case at the bottom of the pit by the next preceding eruption. But there is no evidence in any of these outbreaks of lava that the northeast and southwest walls lay parallel to the crack which ruptured under the pit in order to permit the extrusion of lava.

The northeastern and southwestern wall planes of Halemaumau have very different quality from the walls of the pit which lead to the southwestern rift. They lie right athwart this rift and they are almost vertical down to the places where they join the talus. (See left wall, Page Two and right wall, Page Three). In plan these two steep walls also tend to converge, and this time it is to the southeast that the convergence points, which would take us to the Chain of Craters in Puna District off beyond Keanakakoi and Kilauea Iki. This is the second great flow rift of Kilauea mountain, and the two walls northeast and southwest of Kilauea Crater also trend in that direc-



Outline of Kilauea Crater and the stages in growth of Halemaumau pit as mapped on four different dates. Shows control of longer axis by southwest rift.

tion, as though the Chain of Craters rift tended to fan open into several major cracks as it approached Uwekahuna, the summit of the Kilauea dome (see Page Four).

If now we imagine the primitive Kilauea dome covered with lava flows from a summit well at the height of the top of Uwekahuna bluff and over the middle of Kilauea Crater, it appears likely that the flank of the mountain fractured and let out floods of lava southeast and southwest. When this period of big flooding ceased in prehistoric times, the top of the mountain tended to cave in about the meeting points of these two sets of rifts, each of which tended to finger apart and to cross each other at the summit region. This crossing of convergent southeast and southwest cracks determined the polygonal outline of Kilauea Crater as a sink, and it in turn determined the polygonal outline of its inner pit as a secondary sink.

T.A.J.

KILAUEA REPORT No. 964

WEEK ENDING JULY 13, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar, Volcanologist in Charge

There are very few changes to be reported at Kilauea Volcano. The sulphur area on the south floor of Halemaumau remains whitish and appears to be spreading slightly. Steam vents within the pit remain inactive. On July 10 thin, light dust rose at 2:50 p. m. and at 3:25 p. m. Small rock slides at the north corner were observed July 11 and 12. The west wall has had additional dusting from small slides.

The seismographs recorded eight disturbances on the 7th, 8th, and 9th. Of these four were tremors of less than one minute each, and four were very feeble local seisms. Two of the latter showed distance phases of 14 and 18 miles from the Observatory. One was accompanied by tilt to the east. No disturbances were recorded after the 9th.

Tilt accumulated moderately NNE, with movement strongest to the north. Microseismic motion was slight.

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The Volcano Letter

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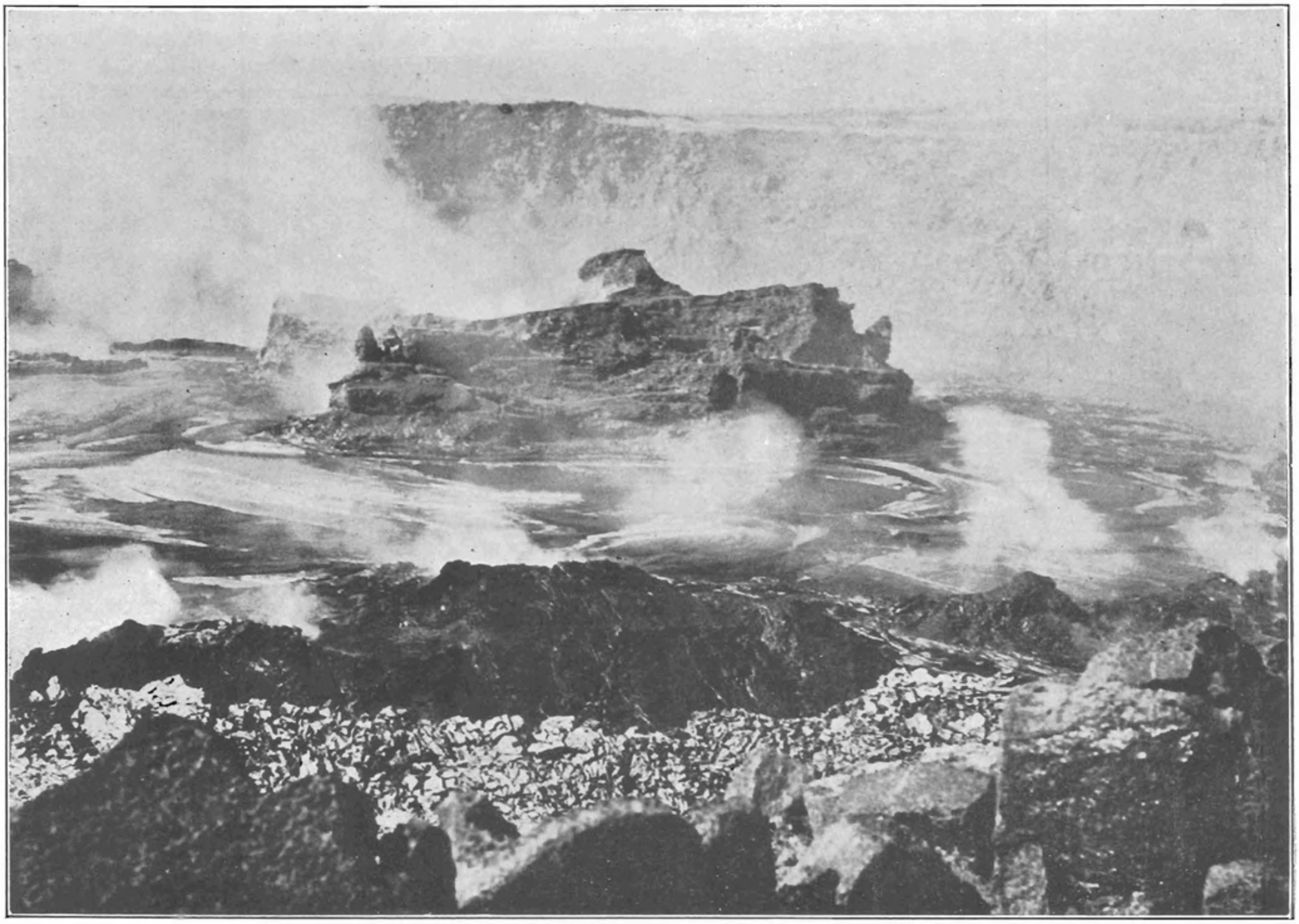
No 291—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | July 24, 1930



Rising lava lake and crag mass December 15, 1916, from northeast rim of Halemaumau. The several terraces on the crag mass are overflow benches which have slowly tipped up. A time of strong rising. Photo Jaggar.

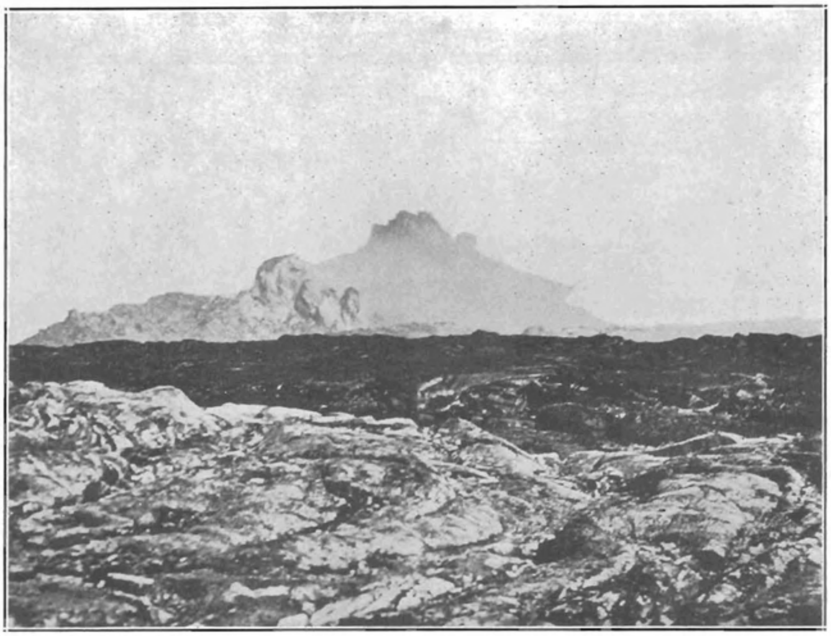
WHEN THE PIT LAVA RISES

To the observer on the brink of Halemaumau, that vast cauldron of the present day some 3,400 feet in diameter and 1,000 feet deep, the rising of the lava in the bottom is a very slow process. At present the bottom has shallowed more than 300 feet since June of 1924, but this has proceeded entirely by the building of layers in several eruptions in 1924, 1927, etc. The rising of the lava column in the bottom of Halemaumau becomes a continuous process very different from this piecemeal building of layers when the inpouring of the slag behaves as it did between 1914 and 1924. This was a real rise of the lava column, and the phenomena distinctive of rising lava are worth examining.

During the six years beginning with 1914 the top of the live lava in the bottom of Halemaumau pit rose gradually from a position 600 feet below the rim of the pit to the top, so that the rim was building up, lava flows occasionally poured over the rim, and other lava flows in great volume poured for months at a time up cracks a little way back of the rim. These last were just as much "overflows" as the spillings which crossed the actual rim of the pit. They equally were draining the pit lava, but by mechanism of internal expansion of lava gas which permits the fluid to well up small outlying cracks to higher levels than are occupied by the broad open effervescing lakes. The mechanism of lava overflow as contrasted with flank outflow has been reviewed in Volcano Letters Nos. 280 and 282.

The rate of rising during a big rising spell was thus approximately 100 feet per year, but this is merely the statistical result, for the actual risings were often much quicker, and the prolonged rising spell was interrupted by many sinkings of hundreds of feet, each occupying either a few days, a few weeks, or several months. Sudden subsidences of from 50 feet to 400 feet occurred repeatedly, and rapid risings averaging about 30 feet per month were common.

These risings of 30 feet per month were themselves



Halemaumau full of lava in September, 1918, showing lifted crags from the west. Observer is at level of pit rim. Looking across fresh flows dating from March, 1918. Photo Jaggar.

punctuated by risings and fallings of 10 or 15 feet from week to week, this being particularly noticeable at times when the curve of major rising tended to flatten out to a spell of relatively stationary lava preparatory for a temporary decline. The same thing was true of a stationary period at the end of a temporary decline, when the lava would fluctuate more from week to week than during a term of steady strong rising. There were times during the early years of work at the Observatory (and something of the same sort has been noticed for earthquake frequency during recent years) when the observers thought they detected a periodicity of three weeks in the fluctuations.

The most rapid rise ever recorded at the Observatory was during the month following November 28, 1919, when both liquid lava and crag lava rose 30 feet a day, making the crag lava into a ring-island as recorded in Volcano Letter No. 282. Excessively rapid rising of this sort is accompanied by unusually strong effervescence of gas, implying an exceptional release of pressure on the underlying magma. In this particular case, Mauna Loa had just finished an eruption, its underground lava had presumably sunk back into the depths, and this in connection with the Kilauea lava had released pressure by causing an enormously rapid subsidence of the Kilauea lava column of some 400 feet in two hours, which was immediately followed by the rapid rising above referred to. Such happenings as this lead to the inquiry, "What makes the lava column rise at all?" This in turn leads to a second query, "Is the sinking of lava an exact reversal of the process that makes it rise?"

These are very pregnant questions. What Dana called the "ascensive force" in lava has been a subject of much controversy and much doubt. This was because the early observers of the Mauna Loa lava fountains describe them as glistening jets like molten metal ejected hundreds of feet into the air, and these observers did not perceive that they were impelled by gases. They were looking for steam, the traditional gas of the Italian volcanoes, and when they saw no steam condense, they inferred that the spouting must be hydrostatic. To get hydrostatic spouting in a molten slag free from gas, on the top of Mauna Loa 13,000 feet above sea level, it was necessary to imagine expanding forces within the liquid itself, or else to imagine a pressure on the reservoir deep under the mountain such as might be produced if blocks of the earth's crust were settling on top of the liquid.

All of this presumed liquidity for the underground lava as a matter of course, and such an assumption created great difficulty if one attempted to connect Mauna Loa with Kilauea hydrostatically. If Kilauea were open at 3,500 feet elevation, necessarily it ought to drain Mauna Loa if the two were connected. Both were open at times and erupting together, yet Kilauea did no draining. Therefore, so ran the argument, the two are totaly unconnected. William Lowthian Green combated this, and insisted that the two show a sympathy of alternation of eruptions.

These difficulties disappear when lava is understood to be a dense glass at high temperature, with many times its volume of hydrogen, sulphur and carbon gases dissolved within it. Deep in the cracks under the mountains this glowing gas-charged glass is so compressed as to be almost a solid. In such condition it may be thought of as an enormously expansible and combustible paste. If Nature pulls apart the crack which it occupies, the gases puff it up like beaten foam. If the gases thus by release of pressure unite in bubbles, they mix with air and burn. If they burn they heat the foam more than before and make the mass more liquid. Greater liquidity means more mobility and a foam pressure capable of opening cracks and doing work like a steam engine. But here we have rather a chemical engine, a multiple expansion engine and a heat engine all combined in one. This engine is dependent on Nature for cranking it, and for supplying the gas-charged glass, or "magma." Given an age-long supply of magma up the cracks, and a systematic self-starter which will pull the cracks apart once in so often, and volcanic eruptions will result.

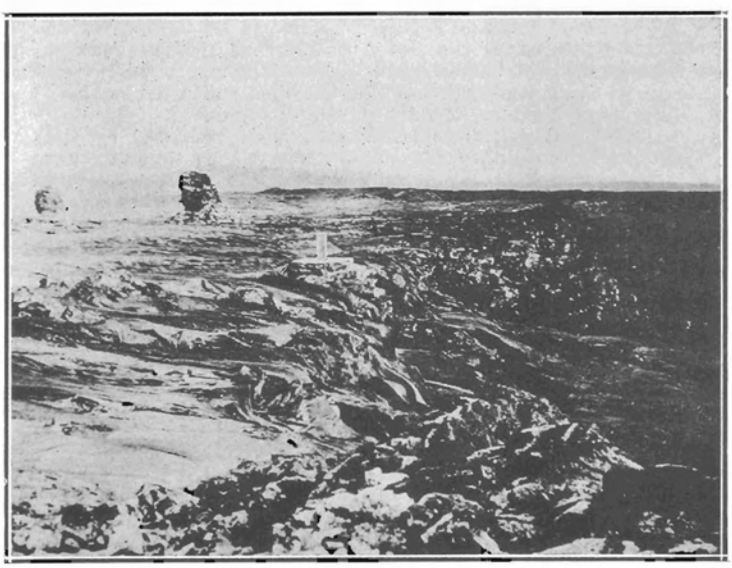
The supply of magma in Hawaii and similar basaltic volcanoes is unquestionable; it builds new layers of land and new promontories in the sea, and swells up the islands by intrusion. It makes the island ridge bulker than it was before. Probably this is at the expense of the sea bottom round about, which may sink proportionately lower than it was before. If so, the magma is the matter of the primitive substratum of rock-forming glassy paste under the crust 30 miles down. It is eternally rising until the ridge of its own building becomes so massive that its weight balances the downsinking blocks of sea floor. Then and then only will volcanic eruption become "extinct."

After outpouring of lava ceases, intrusive irruption of lava in cracks and among strata may continue and swell the country and heat the springs, long after the volcanoes have ceased to give vent to lava. This continuity of internal activity ought to be measurable on the surface of the country, if we study changes of the plumb line, changes of elevation, relation of these to earthquakes, and changes of temperature and composition of hot springs. There is little sense in laboriously studying things like earthquakes and hot springs unless we study them IN RELATION to something. These time and change relations are worth while. There is no fixed observatory in the hot spring belt north of San Francisco to tell us how the ground changed its tilt, and how the ground-water changed its salt content, its temperatures, and its flow after the great earthquake of 1906.

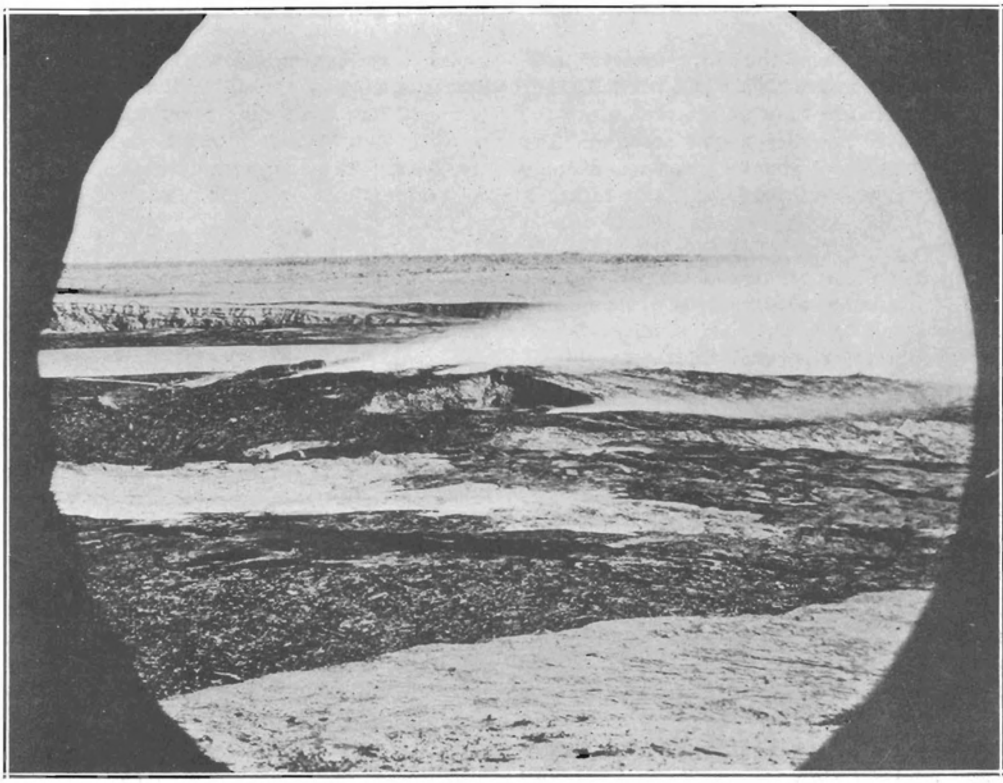
But what is the systematic self-starter that makes lava rise? In 1924 in Hawaii the "eruption" came to an end. Lava immediately reappeared in the bottom of the pit. It froze there. In 1926 it reappeared in great force on the top of Mauna Loa. In 1927, 1928, and 1929 it reappeared mildly in Halemaumau. In the autumn of 1929 its intrusion shook up Hualalai. Perhaps after all nothing came to an "end." Perhaps after all the engine is always running and Nature puts her foot on the accelerator rather than on the self-starter. Her accelerator is any force that will pull the trigger to ease the pressure on the gas-charged paste.

There are the crust blocks of the sea bottom acted on by centrifugal force as the globe whirls. There are the changes in that force as the sun and moon make tides in the earth itself. There is the greater diameter of the equatorial protuberance of the globe, acted on angularly by these forces. There is the cracking down of the great Hawaiian ridge along its old fault or rift planes as the lava flows drain its reservoirs, or fracture it with steam blasts, or upset its water drainage, or settle its crater wedges, or weight down its flanks. The "yielding of the edifice," as an engineer would say, is probably the most potent control of the accelerator, and a cone would not build itself in a circle without a geometrical law of control of the vent by the arrangement of the structure. It is the final task of volcanology through the ages of man to discover this law.

T.A.J.



North rim of Halemaumau November 2, 1918, with floods of fresh lava pouring from an outside crack at a level higher than the lava lakes in the pit. These flows as shown were cascading inward to the pit on the right. Photo Jaggar.



Telephoto of Halemaumau May 9, 1919, from west bluff of Kilauea. Fresh overflows in foreground. The lava column was now topped with a swollen dome above rim of pit, punctured with lava lakes. Photo Jaggar.

KILAUEA REPORT No. 965

WEEK ENDING JULY 20, 1930
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

Steam continues to be absent from the vents in Halemaumau pit. This may mean that the top of the Kilauea lava column lies close to the surface of the volcano edifice and thus dries up moisture seepage. Dry weather has been prevalent, however.

A large section of the east rim fell on July 15 at 10 a. m. This leaves the 14-ton bowlder of 1924 nearer the edge of the pit. Small rock falls on the north wall were noticed from time to time. Some slides southeast on July 19 were caused by visitors dropping rocks.

Thirteen seismic disturbances were recorded by the seismographs during the week, classified as follows: Six tremors, the longest having duration two and one-quarter minutes; six very feeble local seisms, two showing origin distance 23 miles from the Observatory and one showing 14 miles; and one teleseism which registered faintly at 12:41 p. m. July 14. No disturbance was perceptible.

The net accumulation of tilt was very slight SW. Microseismic motion was slight.

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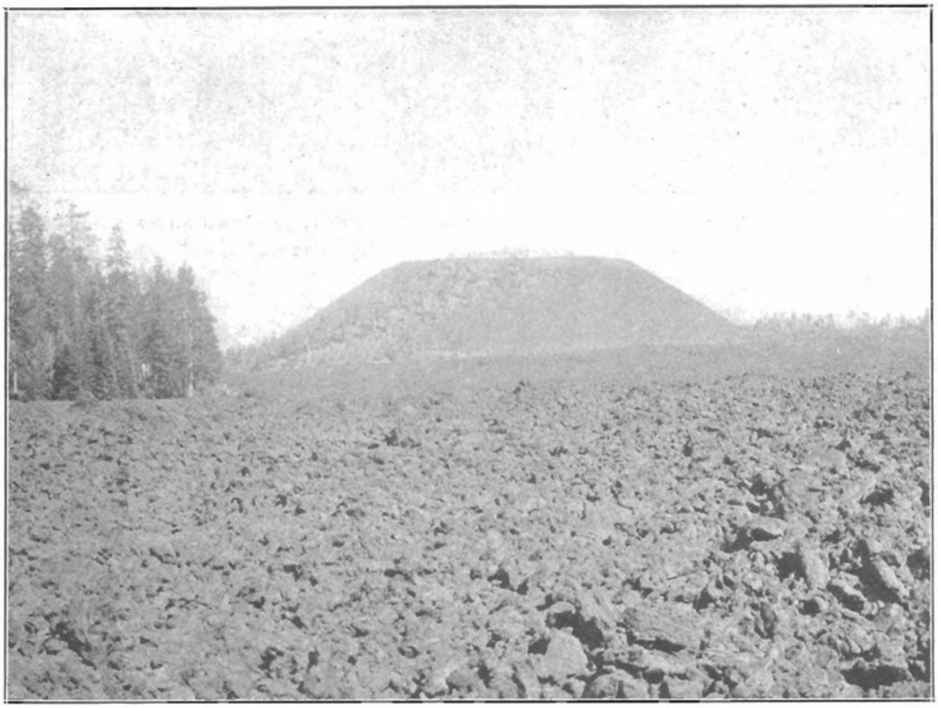
No. 292—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | July 31, 1930



An aa flow of basaltic lava and the cinder cone associated with it called Burnt Lava Flow. Photo Powers.

THE GLASS MOUNTAINS OF NORTHERN CALIFORNIA

Among the legends of the Modoc Indians of northern California are stories of an ancient time when their hunting grounds trembled beneath their feet, when the silence of the forest was broken by strange thunder, and the mountains around their Medicine Lake were lighted up by unearthly fires. Today, the presence of a number of flows of fresh looking lava and mountains of pumice in this area suggests that the Indian legends describe the last activity of a small volcano. Medicine Lake, in the heart of this region of recent volcanic activity, is located north of Lassen Peak and about 30 miles east of Mount Shasta in northern California.

This interesting volcanic region may be easily reached by automobile from Shasta City, California. Since it lies within the boundaries of the National Forest Reserve, one must first obtain permission to build fires in the forest from the Forest Supervisor at Shasta City, who also makes sure that every automobile in the party is equipped with a shovel and an ax as a rough and ready fire control. This is a regulation passed for the protection of public property and is very rigidly enforced. On one occasion two prominent government officials were ordered out of the National Forest because they had failed to equip their car with an ax and shovel.

Leaving the Pacific Highway near the city, one passes over a long ridge built up by lava flows from Mount Shasta. The flows are of great age and their surface is mantled with a rich soil which supports a luxuriant growth of pine and fir. The road soon drops down into the valley of the McCloud River and passes through the flourishing little lumber town of McCloud.

A few miles beyond, the road becomes extremely dusty and many dead and dying trees are noticed in the forest. This is the country which was buried by a so-called mud flow from Mount Shasta in 1925. This mud flow was not of volcanic origin; in fact, quite in contrast, it was caused by a glacier on the high slope of the mountain. As the river of ice moved slowly down its valley, it ground up quantities of rock into a very fine powder called rock flour. At the lower end of the glacier, this rock flour piled up with unpowdered rocks and other debris to form a sort of dam called a terminal moraine. During a period of very hot weather in 1925, a great deal of the ice of

A flow of rhyolitic lava north of Medicine Lake, with a flat but rugged top and a nearly vertical flow front over 100 feet high. Photo Peacock.

the glacier was melted and this terminal moraine became so saturated with the water from the melting glacier that it became a huge pile of very slippery mud. It immediately began to slide and the slope of the valley was so steep that it became a veritable river of mud which flowed for several miles, burying the underbrush and piling up around the trunks of the forest trees in its path.

Soon after leaving the mud flow, the road begins a long, gradual climb up the gentle slopes of an old volcanic dome. This was built up by lava flows from a little satellitic vent on the eastern slope of the mighty volcano which formed Mount Shasta. After the lava stopped flowing from this little volcano, the top of the dome began to settle and a circle of cracks was formed around the summit. If this settling and cracking had continued it would have yielded a large crater in the top of the dome very comparable to the large crater on the top of Kilauea. However, the sinking of the top was interrupted by another outburst of lava which issued from a number of places along the circle of cracks around the top of the dome. These numerous small eruptions built up a circle of cinder and lava cones which formed a crown upon the top of the older volcano. Futhermore, the crown of small volcanoes formed the rim of a large basin-like depression, which was filled with water to form a large lake. The water for the lake was supplied by the melting of many small glaciers at the end of the Ice Age. Since that time, the supply of water by ordinary rain and snow fall has not been great enough to keep pace with the evaporation from the lake, and the original large lake gradually decreased in size until it became the present Medicine Lake. Thus it is that Medicine Lake is located on top of a volcano and yet is not a simple crater lake.

Long after the end of the Ice Age, the old volcano took a new lease on life and broke out with many small eruptions on its flanks and its top. Those from its top emitted lava and pumice of rhyolitic composition. They are very rich in silica and low in iron and magnesia, contrasted to a basalt which is low in silica and high in iron and magnesia. While all of these summit eruptions happened much more recently than did the main eruptions of the volcano, they did not all take place at the same time.

The earliest of the late flows came out of a crack in the top of the volcano just north of Medicine Lake and spread out over a square mile of the old lake bed. The lava was extremely viscous and spread somewhat after the fashion of very cold tar. As a consequence the outer edges of the flow were maintained as nearly vertical walls over 100 feet high. Since the lava cooled, the rock has been broken a good deal by freezing and thawing and by the prying action of the roots of trees which grew on the flow. These broken blocks have fallen to the foot of the flow front and form talus piles which hide much of the original steep wall of the flow. However, the slopes are much too steep for safe climbing, especially in view of the fact that the lava is almost like a glass and breaks into knife-edged fragments. The photograph on Page Two shows the edge of this flow. It also brings out the fact that the top of the flow is very rugged. Broadly viewed, the surface of the flow is quite as flat as the surface upon which it spread, but in detail it is made up of a maze of crags and depressions. During the movement of the lava, the upper parts of the flow cooled quickly into a thick crust, but the lava beneath was so viscous that it could not flow quietly beneath this crust as does the Hawaiian basalt in a pahoehoe flow. Therefore,the movement of the flowing lava continually shattered the frozen crust and carried the blocks along on the surface of the lava stream. These blocks were titled and jumbled together, and when the flow ceased its movement and all of the lava consolidated, the blocks were frozen in the top of the flow in every conceivable position. It is this haphazard chaos of broken blocks which makes the top of the flow so rugged.

In the last phase of the summit eruptions, which is probably the one described in the Indian legends, there were both flows of lava and ejections of pumice. At one locality west of Medicine Lake and just outside of the cones which form the crown of the mountain, the explosions were so violent that they built up a mountain of pumice about 800 feet high. This huge pumice cone is the white knoll in the right background of the picture on Page Three. It is formed entirely of white and grey pumice in pieces ranging in size from that of small peas to that of a man's head. All of it consists of volcanic glass blown so full of volcanic gas bubbles that even the largest pieces will float on water.

Two of the lava flows of this last eruption are of enormous size and thickness and form what are called Big and Little Glass Mountains. Both mountains are almost entirely devoid of vegetation. Big Glass Mountain lies to the east of Medicine Lake and its lavas cover more than nine square miles and are piled up in the center to a height of about 1,000 feet. It is not easily accessible, but it is actually only a larger model of Little Glass Mountain which is passed by the road into the lake. Little Glass Mountain is made up entirely of volcanic glass with the chemical composition of a rhyolite. The outer edges of the flows are very similar in structure to the edge of the older flow shown in the photograph on Page Two. The broken edges of the glass from this flow are even sharper than those described before. The lava of the Little Glass Mountain flow has frozen in a great many different forms. Much of the top of the flow is really a froth of volcanic glass and looks very much like a rubber bath sponge except that it is made of glass. At the other extreme, much of it is a dense, black glass which is called obsidian. This is the material from which the Indians made many of their arrowheads and cutting implements. Then between the two extremes can be found all intermediate stages, from obsidian with a few large bubble holes to bath sponge stuff with streaks of solid obsidian drawn through it.

The frothy top of the flows have been thrown into waves and troughs by the movement of the flows so that the surface of the mountain when viewed from the forest lookout on Little Mount Hoffmann presents somewhat the appearance of a lake of froth with ripples roughly concentric about the center from which the flow issued. This phenomenon is poorly apparent in the photograph of Little Glass Mountain on Page Three.

The many small eruptions from the flanks of the old volcano yielded lava and cinders of basaltic composition, very similar to the lavas of Kilauea. Most of the flows are small and incline more to the aa than to the pahoehoe surface texture. Over each small vent from which a lava flow issued was built a cone of cinders and slag. The small vents were so numerous and so close together that large areas of the mountain flanks are covered with rough basaltic lava and dotted with cinder cones. This broad waste land on the north flank is called the Modoc Lava Beds and formed excellent hiding ground for the small band of Indians which resisted a large force of American troops in the Modoc Indian War.

One of the youngest flows of this basaltic lava with its associated cinder cone is called Burnt Lava Flow and is located on the southeast flank of the mountain. It is so young that it supports almost no vegetation as can be seen from the photograph on Page One. Mr. Finch and a party from the Lassen Volcano Observatory are planning to determine if possible the exact age of this flow. Its eruption probably occurred within the last 500 years, though it is actually older than the pumice eruptions from the top of the volcano near Medicine Lake since little pockets of the pumic can be found on the surface of Burnt Lava Flow. H.A.P.

KILAUEA REPORT No. 966

WEEK ENDING JULY 27, 1930

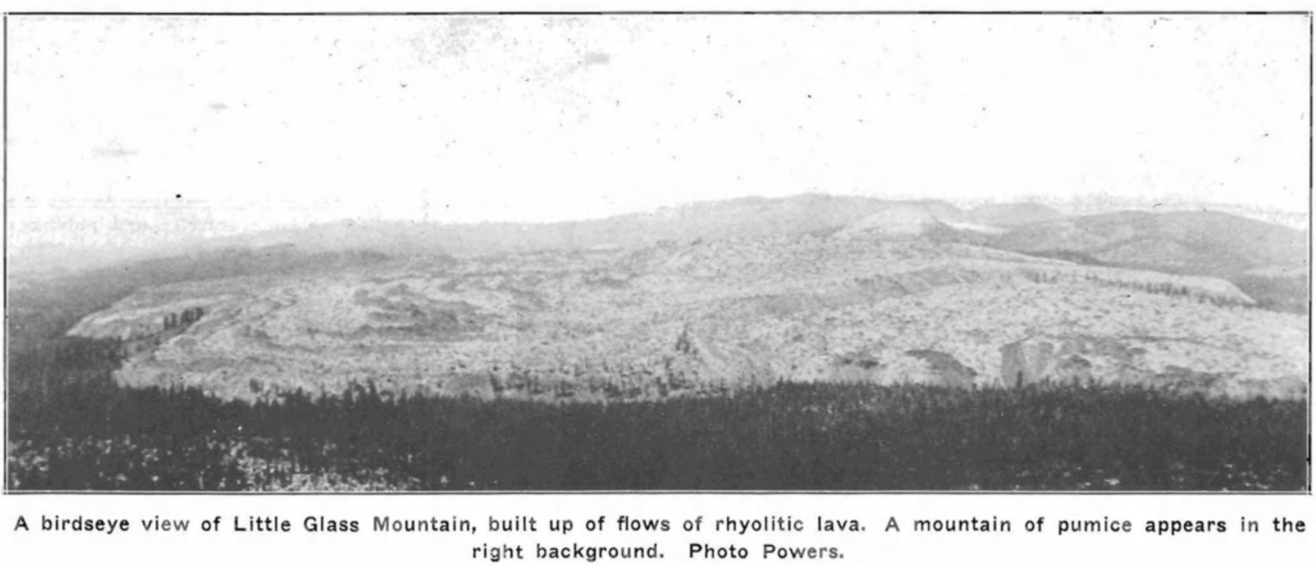
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

On July 21, after week end rains, steam reappeared on the south talus in Halemaumau. Still more steam was noticeable in the pit during rain on July 26. A few wall slides occurred during the week, notably one at 5:50 p. m. July 25. There was no change at the 14-ton bowlder.

An earthquake at 1:53 p. m. July 22 was felt generally all over the island, especially in North Kona. Workmen at the halfway house on the Mauna Loa trail were severely jolted. No damage was reported, but the shock was alleged to have been the strongest since the Hualalai series of the previous autumn.

The instruments recorded a total of 10 seismic disturbances for the week. Four of these were short tremors, five were very feeble seisms, and one was a moderate shock felt as described above. Its epicenter appears to have been in the saddle between Hualalai, Mauna Kea, and Mauna Loa. Two of the very feeble seisms were also perceptible; one at 3:10 p. m. July 22 at Paauilo, and one at 3:54 p. m. July 27 at Kapapala Ranch, Kau.

Tilt for the week was slight ENE. Microseismic motion was slight.



A birdseye view of Little Glass Mountain, built up of flows of rhyolitic lava. A mountain of pumice appears in the right background. Photo Powers.

THE VOLCANO LETTER

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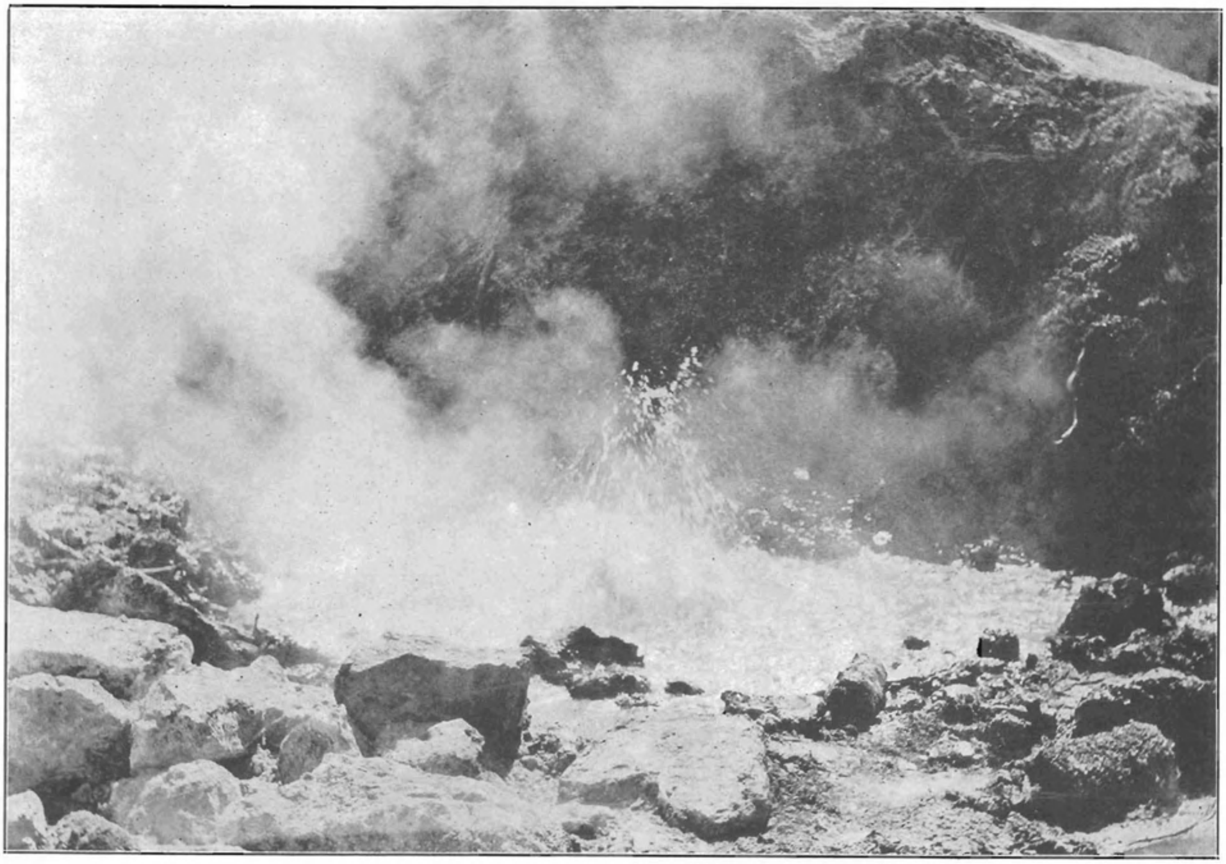
The Volcano Letter

Two dollars per year | Ten cents per copy

No. 293—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | August 7, 1930



A pool of boiling, solfataric water in Devil's Kitchen, Lassen Volcanic National Park, California. Photo Huff.

HOT SPRING PHENOMENA OF LASSEN VOLCANIC NATIONAL PARK

(From "Volcanic Activity and Hot Springs of Lassen Peak," by Arthur Day and E. J. Allen.)

Location

The springs are located mostly in Lassen National Park in northeastern California. Geologically, they are found in a region of thick lava flows, composed mainly of andesite and dacite, with a little basalt on the edges. The springs themselves are all found in the dacite areas. They occur on the line of faults between the Sierra Nevadas and the Klamath mountains. For the most part they are found on normal faults.

Number

There are about eight groups at intervals of a few miles, their allignment suggesting that they follow two intersecting fissures, A. and B.

Fissure A.

1. Geyser springs.
2. Boiling Lake.
3. Drake Springs.
4. Devil's Kitchen.
5. Bumpass Hell

Fissure B:

1. Mill Creek Springs
2. Supan's Springs.
3. Morgan's Springs.

Most of the work here discussed was done upon the Boiling Lake, Devil's Kitchen, and Bumpass Hell, but the springs all seem to have similar characteristics.

Description

1. The Geyser: This is the principal spring of a group of three connecting pools, about 25 feet in diameter, the Geyser being the first. The temperature ranges from 20° C. to the boiling point, which is 94° C. Sometimes it spouts as high as eight feet, though it is often without action.

2. Boiling Lake: It has an oval basin of hot water. Its greatest diameter is 200 yards. The banks are steep for the most part, and it suggests its origin as the basin of an ancient crater. There is a small inlet of cold water at the south end, and a larger outlet of warm water at the north. Both of these become entirely dry in summer. Gas bubbles rise over the surface of the lake. The temperature is about 50° C. Much muddy sediment makes it appear shallow. Algae may be present. It is almost encircled by

a chain of small springs and mud spots, most of which are near the boiling point in temperature. Most of them are near the lake shore, but a few are farther up the slopes. The northern shore is red in color and composed of decomposed lava which has been dyed by iron oxides.

3. Drake's Springs: These are three-fourths of a mile north of the Boiling Lake. They differ in appearance from all of the others. They have a much lower temperature, the highest noted being 62°C. They are, probably because of this lower temperature, choked with bright green vegetation. They are all small, and the individual ones are not well marked. Their mineral content is similar to that in the other springs. but they contain no free acid, or H_2S.

4. Devil's Kitchen: Its site is a deep narrow valley, with a swift, cold stream, called Warner's Creek. The Kitchen, which is rather a flat area, is surrounded on nearly all sides by high steep walls. There is almost no sign of activity on these slopes, but there are many mud pots and hot springs upon the floor. There is no vegetation near them, but the area is forested elswhere. The temperature is about that of Boiling Lake, but the amount of the hot water indicates much greater thermal activity. The Devil's Kitchen also shows an area of precipitated sulphur, while there is almost no free sulphur at Boiling Lake. The Kitchen has many pools which are covered with pyrite as a thin scum, of dark material. The ground near Warner Creek is reduced by decomposition to a dangerous thin crust of earth over hot, sticky mud.

5. Bumpass Hell: This has a crater-shaped basin which is 500 by 1,400 feet in area. It is located high in the mountains, and has almost no vegetation. The thermal action is more concentrated, and the spectacle much more striking in appearance than the others. It contains many boiling fountains, sulphur springs, etc. The rocks are much decomposed at the surface, and the ground is undermined, and easily broken through. The pools are large in size and few in number. There is much free sulphur as a precipitate in some of the pools, and it is also found in needle crystals in many small fumaroles in the west. There are fewer mud pots here than in the Devil's Kitchen. The temperature is usually just below the boiling point, but one fumarole in 1916 gave a temperature of 117.5° C.

6. Supan's Springs: These cover a small area, and most closely resemble the Devil's Kitchen, but they are much smaller. The temperature range is like that of Bumpass Hell. There are many sulphates present, and previous to man's entrance much free sulphur, but this has much of it been removed, though there is apparently not enough present to pay the expenses of a real mine.

7. Morgan's Springs: These were not studied by this party, but the description of them has been taken from Waring. They occupy an area in a meadow, and are composed of quiet pools with a small flow, which are quite shallow and contain some algae, native sulphur, and deposits of calcium and silicon. There are also many chlorides present. The highest temperature is 95.6° C., thus showing the boiling point of springs at this altitude to be lower than that of the others.

Types of Springs

1. Hot Springs. The Lassen hot springs are of the solfataric type.

2. Mud pots. The characteristics of these are a limited water supply, large amount of heat, and no visible outlet. The mud itself may be the result of local chemical action, or may be transported.

3. Mud Volcano. This is caused by drying of mud pot to allow escaping steam to force out clods of mud which build up the cone.

Field Work

1. Maps were made.

2. Temperatures were measured by means of a thermometer in a brass cage. There was no great attempt at accuracy. Their findings showed that the variations in temperature were too great to be accounted for on the basis of change in barometric pressure.

3. Tests for H_2S with $Pb(C_2H_3O_2)_2$ paper showed that though H_2S was widely distributed, only small quantities were escaping from the springs. Also the rise of the gas was not uniform over the entire surface of a pool.

4. Rough litmus paper tests, later borne out by titrations in the laboratory, proved most of the springs to be either neutral, or slightly acid, only a very few being slightly alkaline.

5. Ferrous iron was also tested for at camp, and conclusions were that practically all the iron was in the ferrous form.

6. The amount of free acid was also determined in camp.

7. The water was then carefully bottled and sent to the laboratory.

Laboratory Conclusions

The water was found to consist of sulphates almost entirely, and to be practically free of Cl and Al. The Al present seemed to depend upon the acidity of the water, the greater the acidity the more Al. The springs had no ferric iron present at all, while Boiling Lake had no ferrous, being entirely ferric iron.

The volume of gases given off was found to be very small. The analysis showed the presence of CO_2, H_2S, CH_4, H_2, N_2, A, O_2, and the order of these as given indicates roughly the order of the amounts found.

Deposits of soluble salts are to be found about the springs at various times, though no one has been able to determine as yet just what causes them to appear and disappear when they do. These salts upon analysis gave tests for Al, Fe^{++}, Mg, Na, K. and So_4 in all cases, and for these additional ones in some cases: Fe^{+++}, Ti, Mn, Ca, Li, NH_4 H, S_3O_6. One case showed Cl. S was also usually present. (It is rather surprising that, if the statement that these springs showed the presence of NH_4 as salts is true, the gas analysis showed no NH_3 present in the water.)

Pyrites were found at Geyser, Boiling Lake, Devil's Kitchen, and Bumpass Hell. They were not looked for elsewhere.

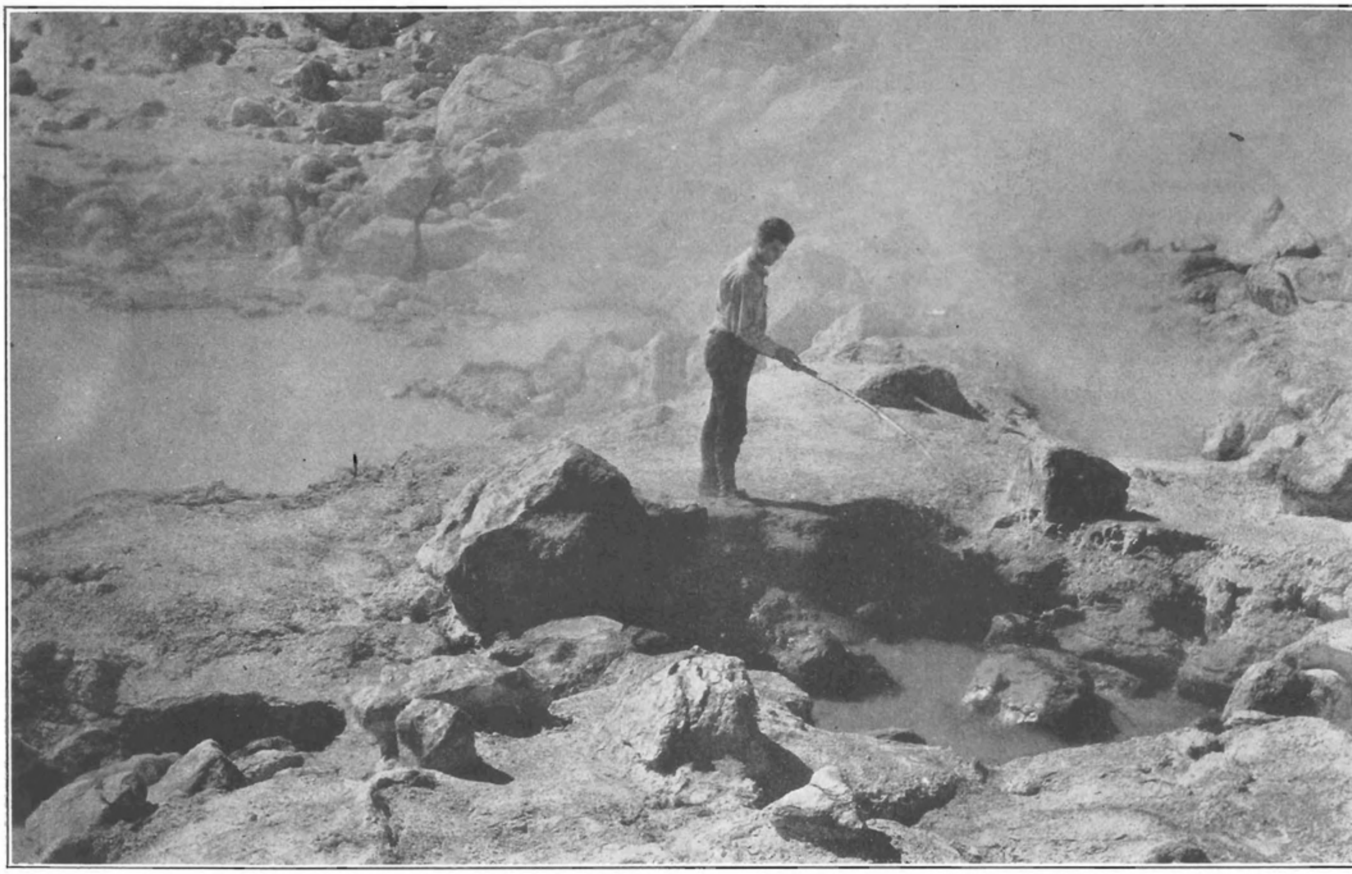
Chemical Effects

1. The formation of pyrite. Problematic, possibly from $FeSO_4$.

2. The formation of H_2SO_4. From S by oxidation. (Park—possibly from oxidation of pyrite.) (Bunsen—by oxidation of SO_2 and combination with water.) But this last would also produce H_2SO_3 and there is none at all present. There is evidence, however, that H_2S is directly changed to H_2SO_4.

Chemical Decomposition of Lavas

Silica is always the final residue. There are two types of reaction: (1) Those which produce kaolin and no $Al_2(SO_4)_3$; (2) those which produce silica and $Al_2(SO_4)_3$.



Method of taking pool temperatures by immersing thermometer in the scalding water. Pool at Bumpass Hell. Photo Finch, Lassen Volcano Observatory.

Pentathionate is probably the decomposition product of lava due to the action of SiO_2 and H_2S.

Original of Hot Springs and Their Relation to Igneous Activity

The heat supply must be great. Possible sources are

1. Radioactivity. This has absolutely nothing to do with it since it was shown that the cold water in the Yellowstone was slightly more radioactive than the warm.

2. Chemical Processes. This is a minor factor, and the reactions are not rapid enough or extensive enough to yield either a heavily mineralized water or much heat.

3. Volcanic. Therefore since the other possibilities have been proved false, the only possible explanation is that of heating by means of magma. That this is the fact may be proved by the location of these springs along cracks or fissures, and the fact that gases are emitted.

Conclusion

The conclusions reached are that the springs are fed chiefly by surface water, derived from precipitation, and that another portion of the water rises in the form of very hot water or steam, from an underlying batholith, which mingles with the other and thus heats it. This shows the close relation of the hot springs to fumaroles, and explains both the variations in temperature of the water and in size, and appearance on the basis of the amount of precipitation. Hazel G. Robinson.

JULY TILTING OF THE GROUND

At the Hawaiian Volcano Observatory on the northeast rim of Kilauea Crater, the tilting or tipping of the ground in the seismograph cellar, expressed by overlapping seven-day means, in terms of angular change and direction of motion of the plumb line, was as follows:

June 30-July 6	0.60 second	SW.
July 7-13	1.09 seconds	S.
July 14-20	0.36 second	NW.
July 21-27	0.48 second	NE.

KILAUEA REPORT No. 967

WEEK ENDING AUGUST 3, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

No changes were observed at Kilauea Volcano throughout the week. Steam was absent from the interior of Halemaumau except a little seen on the south talus at 2 p. m. August 1.

In addition to three very feeble seisms recorded by the seismographs were 10 minute volcanic tremors, three showing tilt to the east during registration.

Tilt for the week accumulated moderately NNE. Microseismic motion continues to be light.

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The Volcano Letter

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No. 294—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | August 14, 1930

Front of the 1926 flow of aa lava from Mauna Loa as it crossed the government road above Hoopuloa. The resemblance to a pile of huge cinders is shown well in this picture. Photo Boles.

A REVIEW OF THE AA-PAHOEHOE QUESTION

(By G. L. CHANG)

Most of the lava flows at the basaltic vents of Kilauea and Mauna Loa in Hawaii assume surface forms known commonly to us as "aa" or "block" lava and "pahoehoe" or "ropy" lava.

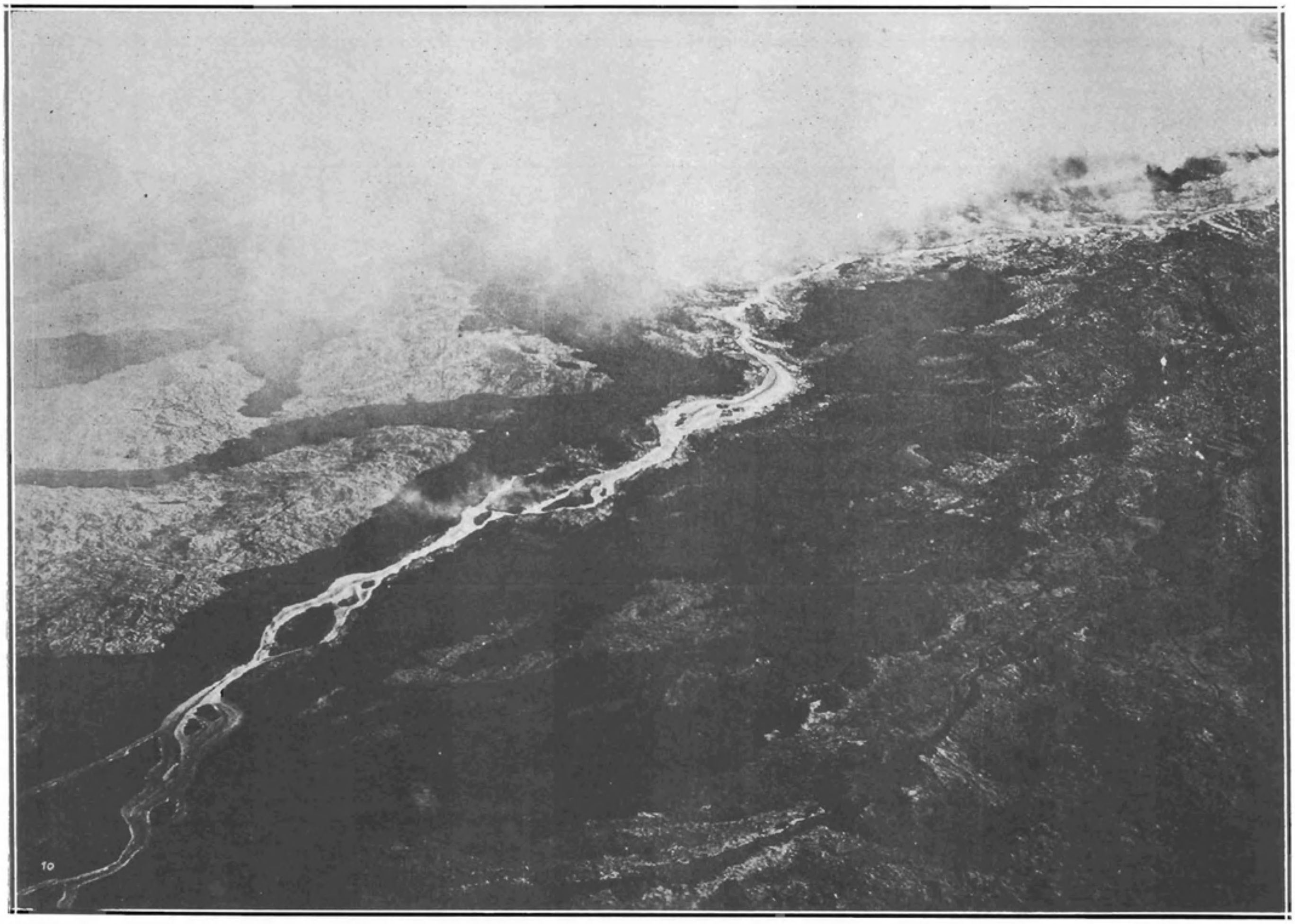
The rough aa surfaces are formed by material which is essentially crystalline, while the smoother pahoehoe surface is formed by a definite layer of glass. This glassy skin varies greatly in thickness; also in vesicularity it varies from a froth to an almost continuous solid. A surface that is not glassy is commonly more or less rough and aa-like, and not infrequently such surfaces are found in pahoehoe flows where cracking of the surface crusts has exposed crystallizing lava.

That there is no noteworthy difference chemically between aa and pahoehoe is generally accepted. The crystalline parts of a lava mass generally have a higher proportion of ferric oxide than the glassy ones, and the cause of the difference may be complex. A flow frequently starts as pahoehoe and changes to aa, but the reverse apparently never occurs, although in a great eruptive period like that of Mauna Loa in 1880 and 1881 the earlier discharges are dominantly aa and the later ones pahoehoe. In the transition zones the two forms are often intimately mixed, and, further more, hand specimens can be found having the glassy pahoehoe skin on one side and the rough features of aa on the other.

By several experiments it has been proven that the formation of aa is due to crystallization while the flow is in motion. When a given mass of lava has crystallized to the extent that it ceases to flow readily, and the forces acting on it are sufficient, it crumbles into loose blocks, some of which subsequently stick together giving the fantastic shapes so characteristic of aa. In the field, crystallization must frequently take place rapidly as the transition from a liquid stream to blocks of solid aa is often very short both in time and distance. However, if the flow is slower, allowing skins of chilled glass to form over the surface and if the force of the flowing lava is insufficient to break them, pahoehoe is formed.

The flank eruptions of Mauna Loa start with giant fountains which pour out enormous and rapid streams of lava. They may flow a short distance as pahoehoe, but usually soon change to aa. The Alika flow of 1919, which broke out from the southwestern flank of Mauna Loa at an elevation of about 8,000 feet, was fed by a series of fountains some 200 feet high, and the lava which cooled near the source was a glassy and frothy pahoehoe. Farther down, the lava flowed in a definite channel at a rapid rate, and where it crossed the government road in Kona 10 miles from the source it was still intensely hot and liquid. At times the stream rose and overflowed its banks and the resulting flood cooled as aa. Dr. Jaggar, who observed all this, said that at no time was there any tendency to form glassy pahoehoe skins. A thin section of some of the lava, collected where the main Kona road now crosses the flow, contains about 10 per cent of phenocrysts (large crystals), chiefly feldspar, enclosed in a matrix made up largely of glass (lava which has frozen too rapidly to crystallize). This composition indicates that comparatively little crystallization had actually taken place before the overflow.

It is in the declining phases of the Mauna Loa activity that most of the pahoehoe is formed. Crusts form over the lava until the stream of liquid lava flows continuously in tunnels and so may flow for long distances without los-



Airplane view of Hoopuloa flow of April 18, 1926, showing the incandescent lava stream flowing through a field of aa already frozen from the same flow. Transition from pahoehoe to aa lava is shown in the upper right. Photo Eleventh Photo Section, U. S. Army Air Service.

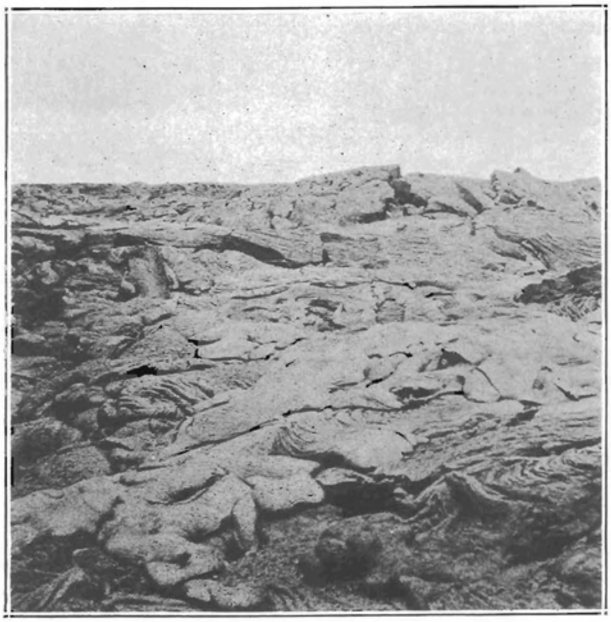
ing much heat. The flow advances by pushing out bright toes along the edges, which flow gently compared with a raging torrent like the Alika lava river.

In Kilauea crater there is little aa. Most of the overflows of Halemaumau have spread out over the gentle slope in large sluggish sheets or have been the thin shelly variety without any body. However Dr. Jaggar has observed several times that when the lakes in Halemaumau are drained, the bottom is covered with aa.

The eruptions from the flank of Kilauea in 1823 and 1840 appear to have been similar to the Mauna Loa outbreaks and much aa was produced. A significant feature of the 1823 flow is that the change from pahoehoe to aa took place just as the lava reached the edge of the gentle slope upon which it was discharged and started down a much steeper incline. An excellent record was kept of the 1920 flow which was probably the greatest discharge from Kilauea during historic time. The main activity took place some six miles southwest of Halemaumau where there was a rapid and voluminous flow which in a very few days travelled six miles. The extreme upper part of this was pahoehoe, but farther down it quickly changed to aa. Subsequently this vent poured out a series of short pahoehoe flows which built up a broad low dome. The summit crater behaved very much like Halemaumau with its bubbling and fountaining, and all of the flows from it were pahoehoe. Occasionally the flank of the slag heap was ruptured, discharging a mass of aa which resembled a landslide more than a flow.

An attempt was made to see what differences there are in the crystallinity of pahoehoe interiors and aa. Accordingly thin sections were made of representative types of lavas from the flows of 1868, 1887, 1880, 1881, 1907, 1919, and 1920. There was also a sample of aa from the bottom of Halemaumau which was exposed in May, 1917. This brief study indicated little tangible difference between the two.

It has been suggested that gases dissolved in the melt, of which water is the most abundant, are important agents in controlling crystallization and the formation of aa and pahoehoe, the theory being that aa is formed from lava containing and releasing the greater quantity of gas. Concerning this view, Dr. Jaggar said, "I know of no quantitative proof. Flames about aa are very apt to be due to



Toes of pahoehoe lava advancing slowly in the Mauna Iki flow of July 23, 1920. Kau Desert, near Kamakaia. Photo Jaggar.

burning vegetation. Pahoehoe crusts over so much that it confines its gas rather than gives it off. Pahoehoe pools remote from the source region often form blowing cones with flames at the orifices. Live streams of both pahoehoe and aa show bubbling, the former making blisters or small fountains, and the latter, occasional heavy, viscous bursts." In vesicularity, both aa and pahoehoe vary within wide limits, but the total volume of vesicles in aa is inclined to be less in a unit volume of rock than in pahoehoe, and the individual aa vesicles are inclined to be more irregular in both size and shape.

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KILAUEA REPORT No. 968

WEEK ENDING AUGUST 10, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

To the casual observer, there have been no important changes in the appearance of Halemaumau during the week August 3 to August 10. Some new scars left by small rock slides were noticed on the north and east walls on August 5, and the steaming from the wall and talus cracks was slight during the early part of the week. During the heavy rain of the week-end intense steam clouds rose continually from the pit and from the cracks of the Kilauea floor.

However, the instrumental records show a number of interesting features. Two feeble earthquakes, one at 8:52 a. m. August 5 and one at 11:14 a. m. August 8, were felt in the National Park area. The center of the first was located 9 miles from the Observatory and that of the second was located at Kilauea. There were three very feeble shocks which were not felt in the Park timed as follows: 10:03 a. m. August 4 distance 14 miles, 3:09 p. m. August 8 distance not known, and 5:50 p. m. August 9 distance not known. There were several small tremors recorded (each lasting a fraction of a minute), with more of them showing on the two instruments close to Halemaumau than on the instrument at the Observatory which is nearly two miles from the pit. This would seem to mean that the feeble tremors had their origin in or under Halemaumau. They were recorded as follows:

Date	Observatory	Uwekahuna	Pit
August 4	1	2	2
August 5	0	7	5
August 6	2	2	2
August 7	0	1	0
August 8	0	5	2
August 9	2	4	3
August 10	0	0	1

Measurements of the tilting of the ground under the Observatory show that the average accumulation for the past week has been a slight tilt to the northeast. In other words, the rim of Kilauea crater under the Observatory has been tilted up and away from the pit, possibly by an increase of lava pressure under Halemaumau. Heretofore, the weekly tilt report has been taken from the difference in tilt between the last day of the current week and the last day of the preceeding week. From now on, the tilt report will express the difference in average accumulation of tilt between the current week and the preceeding week.

The small seismograph on the edge of Halemaumau indicates that the rim at that place has been tilted up and away from the pit. If one imagines a vertical wand standing on the edge of the pit, the tilting of the ground under it during the past week would have inclined the wand over 10 seconds of arc from the vertical position away from the pit. This is an extremely strong tilt and is much more than the Kilauea rim under the Observatory has been tilted during the same time.

Microseismic motion was strong from August 7 to August 10 accompanying the high wind and the heavy surf. This microseismic motion is a very slight vibration of the earth which causes the seismograph pens to write a wavy line, but is probably not caused by any volcanic forces.

The conclusion drawn from all this evidence is that lava pressure is increasing under Halemaumau. **It is impossible to say whether or not this will result in an eruption,** but it can be said confidently that conditions look more favorable now than at any time in the past several months.

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Two dollars per year | Ten cents per copy

No. 295—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | August 21, 1930

Dr. E. S. Shepherd and Alec Lancanster collecting gases with vacuum tubes from the edge of a lava lake in Halemaumau. From Journal of Geology, April-May, 1925.

COMPOSITION OF GASES OF KILAUEA

(A review by A. N. LIKE)

The search for the sources of energy back of volcanic phenomena requires not only a continuous observation of the physical activities of the volcano but also an examination of the material thrown out from the crater, i. e., lava in all its forms and gases. It is the latter with which we are concerned in this review. The gaseous emanations have necessarily attracted much attention.

The chief gas collections made at Kilauea in 1912 were from a flaming cone on the floor by Day and Shepherd. The somewhat crude apparatus used in this collection was a train of collecting tubes and pumps. On account of the condensation of water in the tubes, quantitative results could not be reported on the gas as a whole. In 1917, Shepherd endeavored to collect gases by thrusting vacuum tubes into flaming holes in the crust of the lava lake. The difficult part of such collecting is to get the gas in the tube sealed off without having the tube filled with air during the process. During 1918 and 1919, Dr. Jaggar made a number of gas collections from various sources at Kilauea with intent to discover not only the nature of the gases evolved but also the most favorable sources.

In 1912, the gases collected at Kilauea by Day and Shepherd had the following approximate average composition by volume for one thousand liters of gas:

H_2O	CO_2	SO_2	CO	H_2	S_2	N_2
.04	.25	.50	.02	.03	.02	.14

This collection by Day and Shepherd demonstrated the presence of the three combustible gases, CO, H_2, and S_2, and of the products of combustion, CO_2, and H_2S. There was an abundance of nitrogen in these collections.

The samples collected in 1917 gave the following analyses:

Table I, volume per cent at 1200° C.

Tube	CO_2	CO	H_2	N_2	A	SO_2	S_2	CL_2	H_2O
1	2.65	1.04	4.22	23.22	n.d.	0.16	0.70	n.d.	67.99
2	17.95	0.36	1.35	37.84	n.d.	3.51	5.49	n.d.	38.48
3	33.48	1.42	1.56	12.88	0.45	29.83	1.79	0.17	17.97
4	11.12	3.92	1.42	......	0.51	......	8.61	0.02	77.50
5	9.54	1.12	1.53	10.47	......	9.90	2.72	......	64.71
6	1.97	0.82	0.21	3.50	0.07	0.95	2.70	......	89.77
7	17.25.	0.62	0.76	5.88	0.18	9.75	1.07	0.25	64.18
8	15.27	0.45	0.70	0.87	0.14	6.98	0.49	......	75.08
9	8.32	0.82	1.82	8.92	0.29	16.80	2.49	1.01	59.97
10	1.54	0.43	0.37	2.44	0.39	......	3.56	1.34	89.93
17 (°)	11.61	0.37	0.58	1.29	0.04	6.48	0.24	0.05	79.31

(°) Collected by T. A. Jaggar, March 17, 1919.

These analyses bring out certain relations. CO is usually present in less quantity than H_2. Next to H_2O, CO_2 is the chief constituent and often the rare gases (computed as argon) are no more than would be required on the assumption that the nitrogen came in as air. The chlorine content is surprisingly low. On the other hand, tube 4 shows over 7 per cent of sulphur which agrees with the observation that at times fountains break which set free violent brown fumes which look like sulphur vapor. The water is surprisingly high in all the samples and it is always present. Either we must allow some validity to the thesis that salt water diffuses through the earth's crust and reappears in the volcanoes, or admit a thesis by Dr. T. A. Jaggar that the combustible gases are burned at and below the lake surfaces by air carried down by sinking crusts, air sucked by fountaining, and oxygen diffusing into the lava as it rises in the conduit. These analyses

Direct photograph with a Wratten Panchromatic Plate of pale yellow-green flames about five inches long from a distance of five feet, August 23, 1918. Photo Jaggar.

indicate perhaps that all three of the processes postulated by Dr. Jaggar are active. Trapped air would call for a great deal more of nitrogen, but this does not apply to oxidation along the conduits or at the lake surface. Dr. Shepherd tends to accept the surface combustion as an important factor in the maintenance of the lake's heat supply. On the other hand, the great variations in composition of all samples collected lends support to Day's thesis that a part of the energy may be derived from the shifting of gas equilibria due to a lack of equilibrium among the gases rising in the magma.

Tube	CO_2	CO	H_2	N_2	A	SO_2	S_2	SO_3	CL_2	H_2O	A/AN
2	5.97	0.00	0.00	7.92	nd	4.76	0.00	2.41	4.08	75.09	0
3	6.63	0.22	0.15	2.37	0.56	3.23	0.00	5.51	1.11	80.31	0.191
4	6.79	0.14	0.17	2.33	0.00	1.38	0.15	3.43	0.62	84.98	0.000
6	0.87	0.16	0.07	20.01	0.00	0.01	0.00	0.13	0.03	78.71	0.000
8	47.68	1.46	0.48	2.41	0.14	11.15	0.04	0.42	0.04	36.18	0.054
10	16.41	0.11	0.10	15.03	0.21	13.57	0.05	3.56	0.03	50.88	0.013
11	20.93	0.59	0.32	4.13	0.31	11.42	0.25	0.55	0.00	61.56	0.069
12	1.42	0.05	0.08	0.68	0.05	0.51	0.07	0.00	0.03	97.09	0.068
13	16.96	0.58	0.96	3.35	0.66	7.91	0.09	2.46	0.10	67.52	0.139
14	14.81	0.47	0.17	2.91	0.00	3.65	0.10	1.03	0.00	76.84	0.000
15	11.53	0.13	0.10	6.20	0.16	6.14	0.03	1.70	0.10	73.89	0.025
16	18.03	0.56	0.67	3.11	0.08	8.53	0.15	2.53	0.08	66.25	0.025
17	11.61	0.37	0.58	1.29	0.04	6.48	0.24	0.00	0.05	79.31	0.030
18	17.55	0.74	0.83	4.50	0.12	10.81	0.22	3.22	0.13	61.88	0.026

Table II. Gases collected from Kilauea, 1919. Volume per cent at 1200° C.

A comparison of these figures with the Shepherd collection of 1917 and with the two gases from Mauna Loa shows a general agreement in major constituents, a general agreement in the degree of oxidation, and a lack of any uniformity in the quantities of the minor constituents. One can definitely say that there is no evidence of equilibrium obtained from among the various sources.

Summary

The analysis of some 25 samples of gas taken at Kilauea between 1912 and 1919 shows that:

1. The major emanation from this volcano is water (H_2O), the average of water in all analyses being about 70 per cent of the gas evolved.

2. Second in order of magnitude comes carbon dioxide (CO_2) with sulphur dioxide (SO_2) following in the third place.

3. Sulphur trioxide (SO_3) occurs in variable amounts, in one instance rising to five per cent, whereas, in the two samples from Mauna Loa, it reached the high value of near eight per cent

4. Sulphur, while usually small in quantity, sometimes makes up as much as eight per cent.

5. In general, the 1917 collection, obtained from passing crusts at the lake edge, contains higher amount of hydrogen and carbon monoxide than that of 1918-1919. The general inference is, however, that, quite regardless of the

source from which the gas is obtained. it reaches the surface almost completely burned or else is actively burning in the upper layer of the lake.

6. In general the ratio of argon to nitrogen is about three times as great as in atmospheric nitrogen.

7. Chlorine occurs in relatively small amount The presence of fluorine could not be tested satisfactorily in the volumes of gas which were analysed. In the 1912 collection there was evidence that fluorine was present in about twice the volume or amount of chlorine.

8. Hydrocarbons are apparently absent or else present in inappreciable amounts.

9. The water present may well be partly due to oxidation of evolved hydrogen, but such oxidation must occur in the body of the lake presumably near the surface. It does not seem probable that this combination could occur at the actual surface since any such quantities of hydrogen as would be implied by the great amount of water would certainly show marked explosion phenomena. Certainly the highly oxidized condition of these gases taken as they are from all sorts of promising sources argues strongly for the hypothesis that combustible gases are burned at and below the lake surface.

The outstanding fact about the samples of gases from Mauna Loa is the high degree of oxidation. Hydrogen is practically absent and carbon monoxide is nearly as minute in quantity. Certain unexplained eccentricities in the analytical data might indicate very small amounts of hydrocarbons but with such minute quantities, a definite decision is impossible In any case, everything that could oxidize has done so yet the amount of nitrogen is not excessive. Here, as in Kilauea gases, the amount of nitrogen is insufficient to account for the water present. Perhaps the next important fact is that SO_3 is present in relatively large amount and this accounts for difficulties both in breathing and smelling. It is common experience that SO_3 particles or even sulphuric acid particles are not easily removed from the air. Rare gases computed as argon are relatively high, and chlorine is notably lacking. On the whole the Mauna Loa gases seem to be like those from Kilauea.

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KILAUEA REPORT No. 969

WEEK ENDING AUGUST 17, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

On Monday and Tuesday of last week, during and immediately following the heavy rains, huge clouds of steam were rising from Halemaumau. They were so unusual in appearance that they formed the basis of a rumor circulated in Hilo to the effect that the pit was active again. By Wednesday, the steaming of the Halemaumau floor-cracks had ceased except in the small sulphur-stained area in the southwest part of the pit. Even these had stopped their steaming by Sunday. There has been no avalanching from the walls, and the weekly measurement of the cracks around the 14-ton bowlder showed that no movement has occurred at that point.

The average accumulation of tilt at the Observatory for the week was moderate to the S-SE, which would indicate a depression of the Kilauea wall toward the south.

Northwest cone from which gas was escaping under high pressure and burning as soon as it reached the air. The photograph on page two was taken on the side of this cone at 11 p. m. Photo Jaggar.

It was interesting to note that much southerly tilt was recorded on August 10, 11, and 12, during the heavy rain, but slight recovery to the north began on the 13th after the rain had stopped. Two very feeble quakes which seemed to center on Mauna Loa were accompanied by tilt to the east as if the ground at the Observatory had moved a little up and away from the center of the quakes. The ground under the instrument at Halemaumau sagged slightly toward the pit on Wednesday after the rain ceased, and has remained almost stationary for the rest of the week.

Three very feeble earthquakes, not felt in the National Park, were recorded as follows: August 14, 12:12 a. m. distance not known; August 16, 3:46 a. m. distance doubtfully 23 miles; and August 17, 7:30 p. m. distance doubtfully 55 miles. Small tremors lasting less than a minute have not been as numerous as during last week, but more of them still are recorded on the Pit and Uwekahuna instruments than on the one at the Observatory. Between 9:16 and 9:45 p. m., August 15, all three instruments recorded about twenty minutes of slight but continuous tremor. Microseisms, caused by the constant vibration of the earth, have been slight since August 11, which date seemed to mark the end of the heavy storm of last weekend.

It would seem from this information that the pressure under Halemaumau has moderated during this past week. The coincidence of the abrupt tilting to the south with the heavy rainfall suggests that the weight of the water added to the surface of the mountain may have caused the tilting, but this cannot be proved without a number of parallel cases to support it.

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The Volcano Letter

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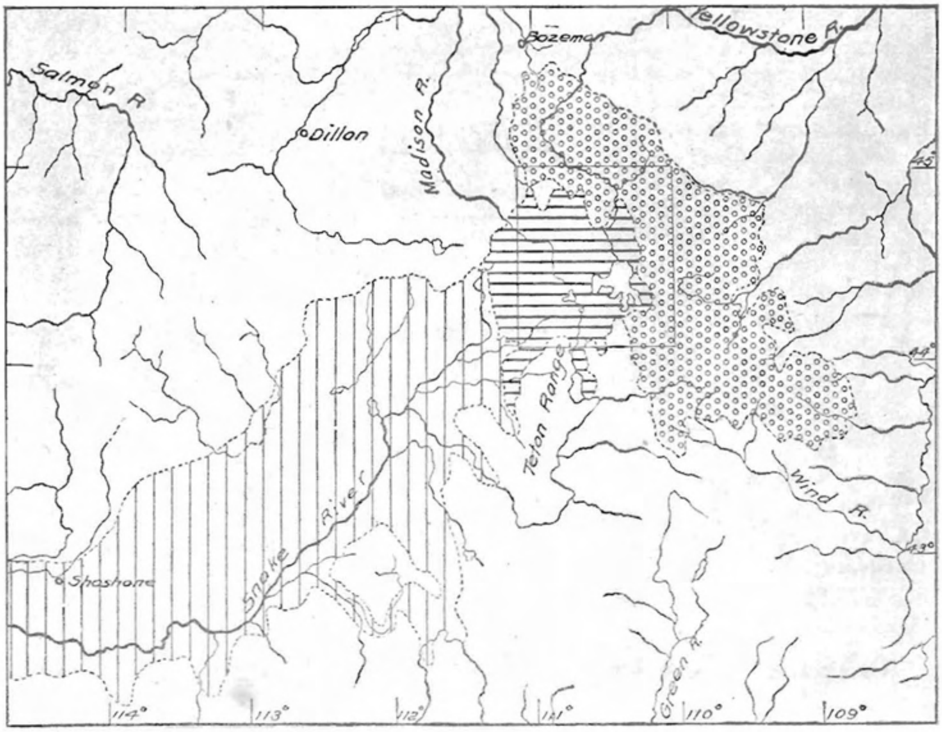
No. 296—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | August 28, 1930



Region of Shoshone and the Snake River Basalt (vertical lines) in relation to (Pliocene) Yellowstone Rhyolite (horizontal lines), and andesites of the early Tertiary (circles). Proc. Amer. Acad. Arts and Sci., June, 1911, p. 64

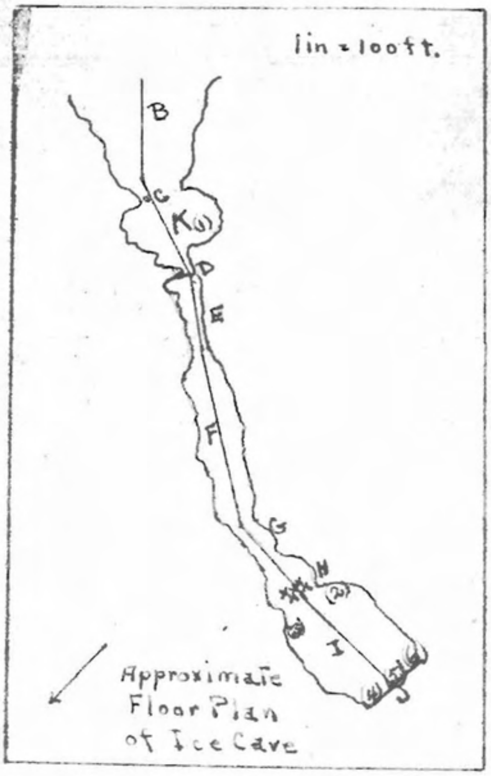
THE SHOSHONE ICE CAVE, IDAHO

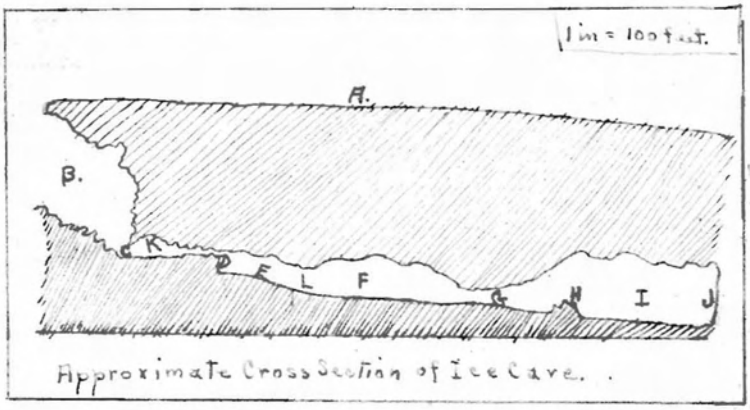
(By H. G. ROBINSON)

This ice cave is located in south central Idaho about thirty miles north of Shoshone, just off the state highway leading to Hailey. The entire region is underlain by Pleistocene lava, but in several places there are Recent lava flows. The most famous of these are the Craters of the Moon, which are located about eighty miles north of the Shoshone Cave. The cave is situated in another small Recent flow, the surface of which has been undermined by huge gas bubbles, which have subsequently caved in, leaving the otherwise fairly smooth surface of the flow broken by many crater-like depressions from one to two hundred feet in diameter. Several caves, or apparent remnants of the old tubes, lead off from these "craters," and one other of these besides the Ice Cave has ice in it near its entrance at certain times of the year, thus obtaining the name of Little Ice Cave.

The Shoshone Ice Cave opens at the bottom of the western end of one of these craters, and extends back in a southwesterly direction for four hundred feet, where it is abruptly terminated by a solid wall of ice. A study of the cave was made during the first part of 1930 in an attempt to determine the causes of the phenomenon.

The first visit was made Saturday, January 4. The weather was clear and cold. The temperature outside the cave was -7 degrees Centigrade (seven degrees below freezing). There was a fall of several inches of snow upon the ground. The party set iron stakes in the ice at various points, measuring the amount which protruded, in the hope of obtaining some idea of the amount of melting or freezing during the succeeding months. Measurements of the length and breadth of the cave were also made and heights were estimated. The party took several flashlight pictures also. There was much hoar frost on the ceilings and walls, and many ice stalactites and stalagmites might be observed. There was no water to be found upon the floor of the cave, but instead a sheet of solid ice, several inches thick, covered the entire floor between two points marked "C" and "J" on the diagram. This fact was noticed with great interest, since the local tradition is to the effect that "the ice melts in winter, and freezes in summer." This was proved untrue by the absence of water on the floor during this visit in the dead of winter—one of the very few, if not the only one, that has been made at that time of year. There were, however, two places near the rock pile marked "H" where a slight dripping from the ceiling was noticed, sufficient to make the ice somewhat slippery under foot.





Key

A - Surface
B - Part of "Crater"
C - Where Ice Begins
D - Abrupt Drop
E - Incline
F - First "Room"
G - Tunnel
H - Rock Pile
I - Second Room
J - Ice Wall
K - Entrance
L - Foot of Slide

	Temperatures in Degrees Farenheit.							Amount of Stake Protruding in Inches.					
Date	Outside	Entrance K	Foot of Ladder D	Foot of Slide L	Tunnel G	Rock Pile H	Ice Wall J	Entrance (1)	Left Floor (2)	Right Floor (3)	Right Wall (4)	Center (5)	Left Wall (6)
Jan. 4	13°	32°	35°	39°	34°	34°	34°	Flush	1¼"	1"	4⅞"	3¾"	1¾"
Feb. 15	50°	28°	30½°	33°	31½°	33¾°	31°	¼"	1¾"	⅞"	2¼"	3¼"	1⅛"
Apr 6	78°	32½°	35°	—	—	34°	33½°	½"	1¾"	1½"	2¾"	Removed	2⅛"
May 18	80°	34°	35°	—	—	—	37°	⅜"	1⅜"	1¼"	Removed	"	2¾"

A plan and section of the Shoshone Ice Cave (above) and the table of measurements showing changes of temperature and amount of melting ice. H. G. Robinson.

The second visit was made on Saturday, February 15, 1930. There was still much snow on the ground. The members of the party had to wade through knee-deep drifts in the "crater." The weather was clear but not as cold as on the last visit, the thermometer registering about 50 degrees Farenheit in the sunlight. Conditions at the entrance seemed much the same as on the last trip, despite the much warmer weather outside. But we had not gone far into the cave before we heard the sound of dripping water. Hurrying through the first cave, at the end of the tunnel which leads into the larger room we found several ice stalagmites from six inches to a foot in height on the floor of the tunnel. A little farther, at the rock pile "H," water was dripping steadily from above. and there was enough water on the floor to wet the feet and splash a little as we went through it. This was the same point at which the moisture was noticed on the last visit, but at this time it was much more abundant. At all other parts of the cave the floor was solid ice as on the first visit.

More pictures were taken of the ice wall at the rear, and some excellent views of the stalagmites were obtained. On throwing the beams from our flashlights upon the roof we noticed much more crystallization there than on the first visit. In fact both the walls and roof were covered with the most glorious and fantastically shaped ice crystals. Several flashlight pictures were attempted but proved to be disappointments. It was not until a few months later when we got a portrait attachment for the camera that we were able to get anything like satisfactory pictures of these crystals, and even they do not do justice to the original.

The third visit was made on Sunday, April 6, 1930. The thermometer registered about 78 degrees F. The day was clear and hot. No icicles were seen on this trip. Stalagmites were still present and much crystallization on the roof. A new feature of this visit was the presence of great quantities of ice on the rocks outside the entrance between "C" and "B." This was not present on any of the previous visits, and is hard to explain since the ice-covered rocks were under the overhang of the "crater" wall where the drip from the melting snow could not have easily reached them. Patches of snow were seen occasionally. The dripping at the rock pile "H" had almost entirely ceased, the floor being only a little slippery from the presence of a thin film of water on the surface. The ice was everywhere as thick as usual, in fact, we have reason to believe that it was thicker than on our first visit. A newspaper brought in with the flashlight powder on the first trip had been left on the rock pile. This paper was now covered with ice to a depth of at least four inches, the ice undoubtedly having come from the freezing of the water which dripped in above the rock pile.

The fourth visit was made on Sunday, May 18, 1930. The weather was clear and quite warm. Upon this, the last visit, several more pictures were taken, in particular several of the crystals, with the portrait attachment, and one of a huge stalagmite at the top of the rock pile. There was still ice to be seen at the entrance outside, though it seemed to be melting rapidly. The crystals were not as perfect as on the previous visit, but some very fair pictures were obtained. There was no water at all in the bottom of the cave, though the ice was very slippery for an extensive area about the rock pile, and the rock pile itself was so slippery, being practically covered with ice, that it was almost impossible to climb it. Since there was no drip from above, this seemed to indicate a true thaw.

The accompanying table gives the temperatures of the cave as recorded on the several visits, and also the readings of the lengths of iron stakes projecting beyond the surface of the ice. It can be seen that no appreciable melting took place during the season observed. Also, though the temperatue of the cave varies, it is invariably colder right at the entrance than at any other point, even when thawing is apparently taking place as on May 18.

As a result of this study it is easy to understand the method by which the ice on the floor and sides of the cave is renewed. The water from the melting snow upon the surface of the ground seeps down into the cave, where the low temperature maintained by the wall of ice in the end causes it to freeze in the winter and spring. People who have been there in the early summer state that the floor of the cave is then covered with water, and that this water disappears later in the summer leaving the floor entirely dry during the late summer and early fall. This may be explained by the fact that early in the summer the level of the water table is high enough to prevent the water escaping, and as the water table lowers during the dry summer, the cave floor becomes dry. However, it is easy to see how this condition has led to the local tradition that "it melts in the winter and freezes in summer," since the first people to go there in the spring often find it full of water, which indicates thawing to them, and later the dryness makes them think it is freezing again. Though this study has outlined the cycle of the yearly accumulations, it has given us no clue to the method by which the great ice wall itself was formed, and that remains, at least for the present, a mystery and a matter for speculation.

KILAUEA REPORT No. 970

WEEK ENDING AUGUST 24, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

There have been no visible changes in the condition of Halemaumau during the week ending August 24. No avalanching from the walls of a magnitude sufficient to cause dust clouds has been noticed, though isolated rocks are still dropping from the rim almost continually. Steaming from the wall cracks and talus piles has been much less than usual, in fact, during two visits to the pit, no steam could be seen issuing from the cracks within the pit.

The number of earthquakes recorded is very small. One feeble shock which was felt only by a few parties in the National Park was registered at 10:43 a. m. August 21. The distance to its origin was measured as 8 miles. Three very feeble shocks which were not perceptible were registered at 7:47 p. m. August 21, 11:39 p. m., August 23, and 5:52 a. m. August 24. It was not possible to measure the distances from these records, but two of them were accompanied by tilt to the east. There were 25 records of small tremor of volcanic origin during the week. Most of these tremors lasted for less than a minute. but at 11:00 p. m. on August 22 a vibration started which continued for 18 minutes. The non-volcanic continuous vibration of the island has been slight during the entire week.

There was no significant tilting of the crater rim under the Observatory during the week. The tilt reading varied slightly from day to day and the average of the week compared to that of last week showed a slight accumulation to the southeast. The instrument at the pit recorded no conspicuous movement of the walls of Halemaumau.

The number of small tremors recorded is somewhat greater than the usual number for the past few months. The tilt record suggests that there has been no notable swelling or settling of the crater walls. It must be concluded from this that lava is neither rising nor falling at present.

THE VOLCANO LETTER

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No. 297—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | September 4, 1930

View of the great aa lava flow of 1783 on the north side of Asama Volcano, Central Japan. Photo Omori, 1911, Bull. E. I. C., VI, No. 1, 1912.

ERUPTIONS OF ASAMA-YAMA, JAPAN IN 1873

(A Review by I. Toyama of part of "The Eruptions and Earthquakes of Asama-yama" by F. Omori, Bull. Imp. Earthquake Investigation Comm., 6, 1912.)

Date of Occurrence. The series of explosions of Asama-yama, in third year of Temmei (1783) ended in a tremendous catastrophe of August 5. It is a memorable circumstance that the great Calabrian earthquakes were recorded in the same year on February 5.

The frequency of the eruptions of Asama-yama is subject to an annual variation which indicates two maxima occurring respectively in April and August.

Weather at the time of Eruptions. It rained slightly in Yedo, the present Tokyo, on the 28th of July; in the province of Kotsuke which lies east of Asama, the weather was clear on July 31 and August 1, and fair on August 2 and 3. Considering all reports, the weather was dry and fair in the central part of Japan during the one week period before the main eruptive period, while on the 3rd, 4th, and 5th of August the weather was calm in the vicinity of the volcano. This shows that an area of high barometric pressure existed over Asama and the central part of Japan during the later part of the eruption. Immediately after the catastrophe, a strong cyclone swept across the country.

Course of the Eruptions. The eruptions which lasted for 88 days, began on May 9. On June 24 detonations like distant thunders began to occur at about 7:00 a. m. On the 25th, between 10 and noon, loud detonations were heard, accompanied by a strong explosion. The sounds also occurred the next day, June 26. between 4 and 6 p. m. The mountain then remained quiet for twenty days until July 16, when loud detonations occurred during that night and the night of the next day. After eight days, on the 25th, detonations continued from 8 a. m. to noon, although smoke emission was slight during the day. This marked the beginning of the last stage of the great eruption.

On the 26th of July, at 4 p. m., there were detonations accompanied by an explosion which threw out smoke toward the east. The detonation lasted until evening. On the 27th, when it rained heavily, there were detonations and emission of smoke toward the southeast at 4 p.m. Volcanic manifestations became greatly intensified in force on the 28th when, in fair weather, there occurred at noon a powerful explosion which was stronger than that of June 25th, and which threw out smoke toward the east. From this time, the effects of the eruptions could be felt in such distant places as Yedo, where ashes fell on July 28. The people of this region wondered why the houses and doors were shaken, although the ground and the water remained undisturbed.

On July 29th, burning began at 3 p. m. which continued until 5 p. m. On the 30th, the explosion which began at noon became excessively great between 2 and 8 p. m. and came to a temporary end at 4 a. m. July 31. The eruptive activity continued to increase during that day and on the following day.

On August 2, the weather was fair and clear. The eruption reached its maximum violence and the volcano emitted fire from 6 p. m. until midnight. A large quantity of stones and sand were thrown out and Maikake-yama, which was near by, was converted into a litteral sheet of fire. The eruption ceased for a short while in the morning of the 3rd of August and resumed its violence on the same day from 2 to 10 p. m., covering Kiba-yama, another nearby mountain, with red hot stones of different sizes.

Map of Central Japan, showing Asama Volcano in the shaded ellipse, which is the area of strong sound during the eruption of April 3, 1911. Wind direction is shown by arrows, and black dots indicate spots where detonations were heard. There was a zone of silence or sound shadow between the two shaded areas. From F. Omori, Bull. E. I. C. VI, No. 1, 1912.

On the 4th, explosions began with detonations at 8 a. m. and caused such an excessive fall of ashes between 1 and 4 p. m. that people as far distant as Fukaya in the province of Musashi had to use lanterns during the day to see their way through the darkness caused by the falling ashes and sand. On the 5th the weather was fair. Outbursts which began at 4 a. m. became extremely violent from 8 to 11 a. m. A little after 10 a. m. a huge mass of burnt rocks, lava and hot mud descended with deafening detonations from the crater and swept down the northern side of the mountain, rushing into the valley of Azuma-gawa.

The Course of the Eruptions in Four Stages.

First stage, commencement, May 9.
Second stage, outbursts, June 24 to 26.
Third stage, outbursts, July 16 to 17.
Fourth stage, outbursts, July 25 to August 5.

The Lava. The great lava flow of 1783 which forms an imposing spectacle on the northern flank of Asama-yama, descended into the Rokuriga-hara plain. The lava mass terminated in an abrupt manner, forming a slope of about 40 degrees which runs for a considerable distance. Its height varies from 30 to 50 meters. The area covered is somewhat of the shape of a triangle, 6 kilometers along the base of the flow.

The Great Volcanic Avalanche. The great torrent of volcanic material, which swept down the slope with a very high initial velocity, caused much damage and devastation in all the villages along the northern slopes and base of the Asama-yama and those along the Azuma-gawa. The principal course of the flow was along the deeply cut ravines that run from the foot of the mountain toward the north.

The volcanic avalanche blocked the flow of the Azuma-gawa for a while, producing a temporary decrease of water in the lower course of the river. At about 11 a. m. August 5th, the water broke forth through this newly formed dam of debris, and together with the steaming volcanic material, rushed down sweeping and carrying with it houses, furniture, and everything that blocked its way.

Ash and Smoke. Ash fell at Yedo, Choshi, Maebashi, and the surrounding regions during the morning of August 6. Mud rain fell in Karuizawa, Sakamoto, and Isobe on the fifth of August. In the city of Takasaki, 44 kilometers away from Asama-yama, ash accumulated to a thickness of 6 inches. The old and weakly built houses were crushed, and endangered the lives of the occupants.

The area covered by the fallen ash and stones measured about 220 kilometers long and 100 kilometers wide, or about 11,000 square kilometers. The thickness ranged from one to six inches, and taking the mean thickness as 2 inches, the quantity of fallen volcanic material will be about 0.9 cubic kilometer.

Conclusion. This great eruption of Asama-yama was not the beginning but the result of the outburst of the volcanic energy accumulated during the course of many years. The eruptions were caused by powerful underground explosive forces, that were suppressed until the last stage.

The shallowness of the crater caused the immensely large mass of molten and burning rocks and lava and mud to overflow and cause the dreadful volcanic avalanche. Had the crater been deeper and larger, the catastrophe and disaster caused by the eruption would not have been as severe nor as terrible.

KILAUEA REPORT No. 971

WEEK ENDING AUGUST 31, 1930

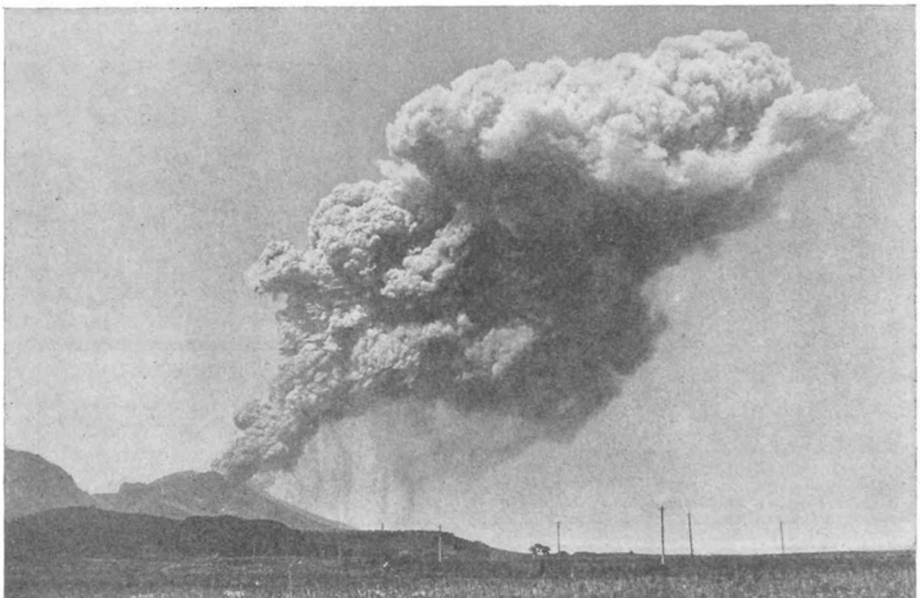
Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

But one thing of interest has happened at Halemaumau during the week from August 24 to 31. On Saturday, August 30, about 3:30 p. m., a large slab of the wall between the 14 Ton Bowlder and the pit loosened itself and made an avalanche which was heard at the Military Camp over a mile from the pit. Other than this, the fire pit has been exceedingly quiet. The amount of steam from the wall and floor cracks has been variable but has averaged even less than usual. A number of small quakes were felt in Pahala and other nearby towns of the Kau district.

The seismographs at the Observatory registered five very feeble shocks as follows: August 26, 4:19 a. m., 5:01 a. m., 10:26 a. m., and 2:38 a. m.; and August 30, 8:54 a. m. distance 32 miles. Judging from all the available information, these quakes probably had their centers somewhere in the region of Puu o Keokeo. The instruments also recorded 31 very small tremors of less than a minute duration. Of these, 17 occurred on August 30 during the time that several avalanches were observed in the pit. Some of the tremors may have been caused by these rock slides. The continuous trembling of the earth (microseisms) which is probably not of volcanic origin has been very slight during the week.

Measurement of the tilting of the ground under the Observatory show that there has been a slight accumulation of tilt to the southwest. In other words, if one imagines a vertical wand placed on the ground at the Observatory, the tilt during the week would have inclined this wand a little bit toward the southwest. The ground at the edge of Halemaumau has shown a similar movement, which suggests that this tilting has not been caused by any changes of pressure under the fire pit.

It may be concluded that there has been no measureable change in the volcanic conditions at Halemaumau. However, slight movements of the flanks of Mauna Loa similar to a series which occurred last spring have been resumed.



A modern strong eruption of the Asama-yama, May 8, 1911, seen from Komoro looking northeast. Photo Uozu, from Bull. E. I. C. VI, No. 1, 1912.

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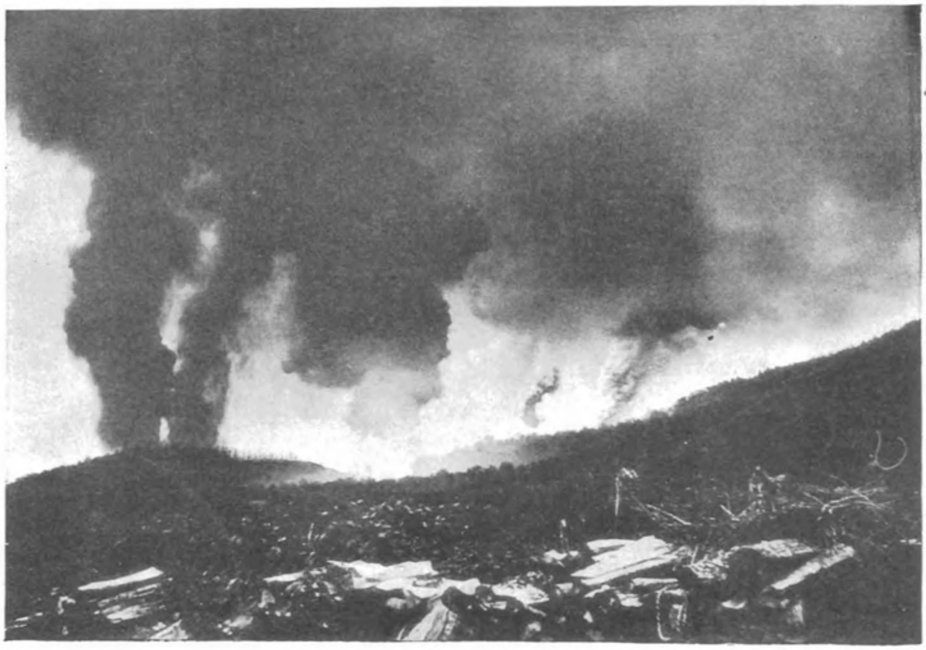
No. 298—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | September 11, 1930



Eruption of the north flank of Usu Volcano in Hokkaido, north island of Japan, August 2, 1910. West Maruyama is the forested hill on the left. From Omori, Bull. E. I. C. vol. I, 1911.

ERUPTION OF USU VOLCANO IN 1910

(From Oinouye, "1910 Eruption of Mt. Usu," J. G, 25, 1917, pp. 258-88. Reviewed by K. Onishi.)

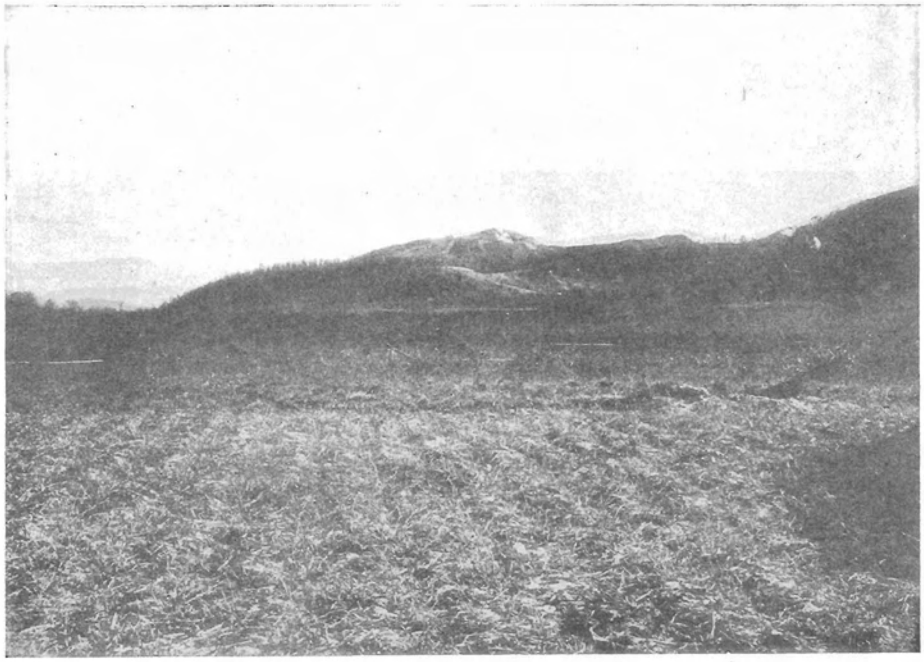
Mt. Usu, a volcano located in northern Japan on the island of Hokkaido, rises 736 meters above sea level and is approximately two kilometers in diameter. Two domes crown the top of the volcano, their names and elevations being O-usu and Ko-usu and 736 meters and 609 meters respectively. Since the craters resemble in shape the "usu," a Japanese mortar used in making "mochi" a kind of pounded rice cake for festivals, the people have named the two craters "usu" with the prefixes "O" and "Ko" to indicate the sizes, the former signifying big and the latter small. Hence O-usu is the larger of the two craters.

The clear and able report by Oinouye deals particularly with the interesting phases of the eruption. The author narrates in detail the following observations of the outbreak: earthquakes, mud cones, explosions and their processes, explosion craters, the changes in topography of the land, and the damage done by the overflow of mud and the scattering of ash and other material from the pits.

Prior to the eruption, four days to be exact, frequent earthquakes had disturbed the people. The occurrence of these undulations of the earth's crust grew more numerous as the days passed after the first shock. On July 23, 1910, 110 shocks were recorded, about 350 on the following day, and 163 on July 25, the day of the first outbreak. Two violent shocks, one on July 24 at 4:30 p. m. and the other on the following day at 5:00 p. m., thoroughly alarmed the people. The results of the quakes were some fissures made on the west side of the volcano almost parallel to the coast line. These varied in width from 3 cm. to 40cm. There also resulted two faults going in an east and west direction on the western foot of the mountain.

Another result of the quakes was the formation of mud cones on the flat land north of the volcano. The first resulted from the severe shock of July 24. The cones were formed of mud and sand, well stratified and flat and conical in shape and ranging from 6cm. to 3 meters in diameter and from 3cm. to 60 cm. in height. The water level in the neighboring wells rose and the volume of the water was doubled. Several new springs were formed but the water everywhere was turbid and dirty.

The first explosion took place on July 25 at ten o'clock in the evening from the northwest slope of the main volcano. Red hot bombs were thrown into the air. July 26



View from the same point as Figure 1 taken on November 9, 1910. The "New Mountain" is shown elevated back of the right shoulder of West Maruyama. From Omori, Bull. E. I. C. vol. I, 1911.

witnessed the explosion accompanied by black and white smoke that rose to a height of 700 meters. July 28 was a dreary day with two explosions, rain, thunder, intense lightning, huge columns of dense smoke, and low roaring noises contributing to the general atmosphere of gloom.

The explosions were quite remarkable. A cannon-like sound announced the arrival, a "V" shaped vent opened the path, and a procession headed by black smoke, sand, and ashes came into view. This material helped to form the cones, each requiring a day or a week to complete one, the time depending on the amount of matter ejected and the size of the vent.

During the period of greatest activity, from July 25 to August 2, fifteen new craters were formed, the number increasing to 45 for the ten weeks of the eruption. These craters were grouped into two groups of 16 and 29 lying in two parallel lines. The distance between the two lines of vents was about 800 meters. All of these craters emitted quantities of black smoke, ash, sand, and bombs. Five of them spit mud and hot water as well. The greatest distance to which the ash was carried was 44 km. In places the land was covered to a depth of 30 cm. A mud flow to the lake at the foot of the mountain measured 200 meters in width, 500 meters in length and 1.5 meters in thickness.

The chemical composition of the mud flows, the sand of the seashore, and the substance in the mud cones was practically identical, showing evidence that all the material came from the same source, a brown pumice at the base of Mt. Usu.

Bombs hurled into the air produced a sound like a firecracker when they were struck in midair by other ascending bombs. They were basaltic in composition, dark grey, porous, somewhat round, and not more than 25 cm. in diameter. An abundance of pores filled with ash and sand on the exterior of the bombs was contrasted with a scarcity of pores in the interior.

The topography of the land was changed materially. The water in Lake Toya rose 30 cm. on the north margin of the lake and the slope of the south shore tilted to 30 degrees from the original 5 degrees. Before the eruption, Nishimaruyama could be seen from the village of Nishikohan, but after the activity of the volcano, the view was obstructed by the so-called "New Mountain." The maximum height of this newly constructed ground is 120 meters.

Professor Omori is of the opinion that an intrusion of lava in the form of a dome or spine caused the elevation of this new mountain. Sato believes the intrusion to be a laccolith. Oinouye, the author of this article, thinks that the uplifting of the new land was caused by a plug which was intruded in the midst of the activity, the intrusion being materially helped by the faulting of the land.

The damages incurred included the destruction of a fine forest on the slope of the mountain, and the burial of houses and farm lands within a radius of two kilometers.

Many houses suffered cracks in the walls and a number were completely destroyed.

TILTING OF THE GROUND IN AUGUST

A graph showing the tilting of the ground from day to day is plotted at the end of each month. The position of the tilt recorder with respect to an assumed fixed point in space is read each day. However, these daily tilt readings are affected to a certain extent by causes other than true volcanic tilt such as rapid temperature changes, heavy rainfall, and slight instrumental errors. To eliminate as many as possible of these outside influences, the curve showing the daily tilting is "smoothed" by computing "overlapping seven day means." This means that the tilt reading plotted on the graph for each day is actually the average of seven days, ie. the three days preceeding and the three days following the day in question. This smoothed curve thus shows a truer picture of the tilting of the ground as caused by volcanic forces of comparatively long duration. The curve obtained by this method of plotting may be figuratively described as being the curve traced by a wand placed rigidly in a vertical position in the earth at the observatory, with the upper tip of the wand writing the curve on a piece of paper held above it in a fixed position in space. As the earth tilts, the wand is tipped from its vertical position and the tip of the wand writes a curved line on the paper. The net change in position of the top of this wand for each week in August is expressed in a compass direction and angular degrees of arc in the following table. For example, from July 28 to August 3 the wand had tipped through 0.96 seconds of arc in a northeasterly direction.

July 28-Aug. 3	N.E.	0.96 sec. of arc.
Aug. 4-Aug. 10	S.S.E.	0.87 " "
Aug. 11-Aug. 17	S.E.	1.45 " "
Aug. 18-Aug. 24	S.E.	0.72 " "
Aug. 25-Aug. 31	S.W.	1.45 " "

KILAUEA REPORT No. 972

WEEK ENDING SEPTEMBER 7, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

The famed 14 Ton Bowlder has advanced one more step on its journey back into Halemaumau. The sliver of th rim which supports the bowlder has slipped downward until the top of the bowlder is several feet below the level of the solid rim behind it. This slipping occurred during a spell of almost continuous avalanching which began about noon on Thursday, September 4, and stopped sometime Saturday evening, September 6. Most of the larger avalanches, however, fell from the northeast part of the rim a considerable distance from the 14 Ton rock. Aside from this, at the risk of being very monotonous, it must be reported that little excitement has happened at Halemaumau.

National Park Rangers have reported that two avalanches have fallen from the walls of Kilauea Iki during the past ten days. It is entirely possible that these resulted from blasting which has been done in the course of the construction of a new trail into this crater.

Six very feeble quakes, probably originating in the Puu o Keokeo area, have been recorded during the week as follows: Sept. 1, 7:41 a. m.; Sept. 3, 6:45 a. m.; Sept. 4, 8:34 p. m.; Sept. 5, 3:17 a. m.; Sept. 6, 6:28 a. m., distance questionably 20 miles; and Sept. 6, 6:51 a. m. Twenty-six small tremors were recorded on the Observatory instrument. The larger number of these occurred during the spell of avalanching and probably are records of these rock falls. Microseismic motion was slight during the entire week.

Tilting, both of the Kilauea rim and of the Halemaumau rim, was slight to the southwest.

It must be concluded that pressure under Halemaumau is decreasing from the maximum attained during the second week in August. There is no evidence as yet that lava pressure is building up under Puu o Keokeo even though there have been a number of recent quakes which seemed to center in that region.

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No. 299—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — September 18, 1930

Mihara Crater in the summer of 1907. Diameter 825 meters E-W. (Nakamura)

The same crater, January 1, 1913. (Okamura)

The same, 1916, showing block lava, terraces, spatter cones, ditches, pits, and fuming holes. (Tsuboi)

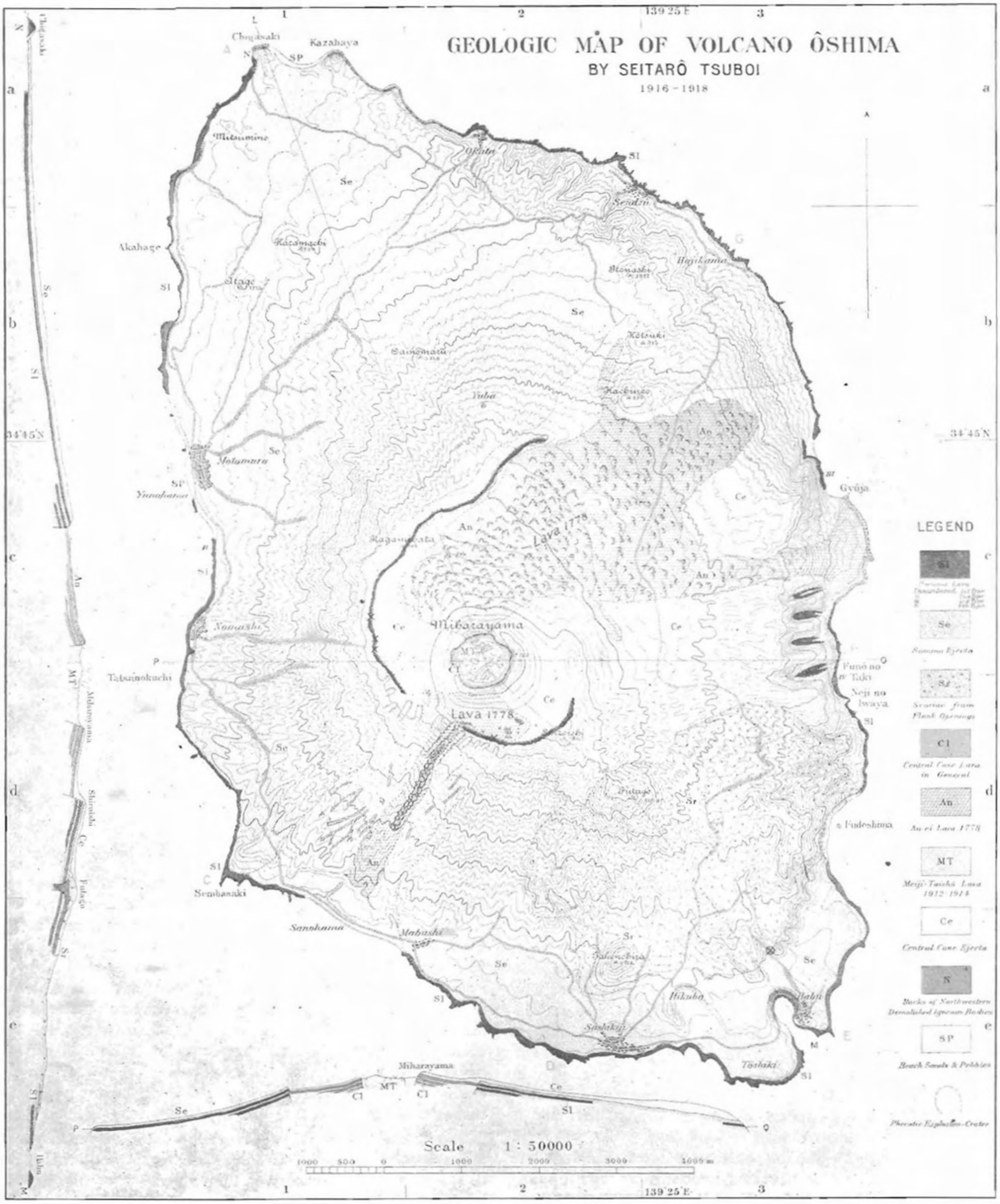
STRUCTURE AND ACTIVITY OF OSHIMA VOLCANO

(Review by Y. Yamamoto of "Volcano Oshima, Idzu," Seitaro Tsuboi, J. C. S., Imperial Univ. of Tokyo, Vol. 43, 1920.)

Geographic Sketch. Oshima is the largest number of a group of volcanic islands off the Idzu peninsula, and lies in the sea of Sagami about 110 km. southwest of Tokyo. The island itself is a gigantic lava and ash volcano with an elevation of 755 m. above sea level. It consists of a central cone called Miharayama, with an active crater at its summit. The outer slopes of the insular volcano vary greatly in different directions. On the western side the slope is regular and makes a fine concave curve. On the eastern side it is abnormal, varying from 15 to less than 5 degrees, and continuing from the summit half way down, until on approaching the shore, it becomes suddenly as steep as 40 degrees. The relief of the cone surface is further diversified by a number of parasitic knobs on its flanks, but as a whole, the shape of the island is that of a cone, and its outline viewed from a distance conveys a strong impression of the volcanic origin of the island.

Structural Outline. The volcano is a composite stratified one consisting of double cones—a somma and a central one—and is built up of numerous layers alternately accumulated of lava and fragments of basaltic nature. The somma has several satellitic bodies. On the flanks of the main body of the somma there are eight parasitic knobs. The top of the somma is truncated with a ring-wall that surrounds a huge oval caldera. The wall is not completely closed but there are two gaps, a greater one on the northeastern and a smaller one on the southwestern side. The active central cone, Miharayama, stands in the caldera, and its volcanic products not only cover the ground within the encircling wall but have also spread down to the sea shore through the gaps in the wall.

The Central Cone. The central cone, Miharayama, which is a perfectly preserved undissected heap, stands somewhat to the south of the center of the caldera. The cone is very simple in its structure, being composed of superfluent lavas and ejecta, the alternately accumulated layers of which may be well observed on the inner wall of the summit. The volcanic products of the central cone, both lavas and ejecta, not only fill the caldera but are also spread down to the sea shore through the northeastern and southwestern gaps of the ring-wall of the somma. Especially on the



Geologic map of Oshima Volcano in Sagami Bay near Yokohama, with profiles N-S and E-W. After Tsuboi, Jour. Col. Sci. Tok. 43, 1920.

eastern part of the island, the products of the central cone are so distributed over the surface of the somma body as to conceal its original slope. The present crater seems to have attained its size in 1684 according to historic records. The features of the inside of the crater are always changing. It is habitual that when the volcanism displays its full energy, lava fills the crater, and on declining, the layer of lava depresses more and more due to its own weight, leaving the peripheral parts in the form of terraces.

The Meiji-Taisho eruption (1912-14) began with the outpouring of lava from the vent. During this interval, the extrusion of lava took place intermittently, five times, of which the second and fourth can be considered as the after effects of the first and third respectively. In the first period during March-June 1912, the lava reached a level of 62 meters below Kawajiri, burying half of Naumann's cone and forming a new Nakamura's cone. The second eruption in July was the squeezing out of a new molten lava due to the depression of the lava layer at the crater bottom and resulted in the breaking up of Nakamura's cone. In the third activity, September-October 1912, the extrusion of the lava took place from a new vent at the western part of the crater bottom and was accompanied by the formation of a new spatter cone, Omori's cone, around the vent.

The whole crater is at present in a state of deep tranquility. No motion is seen and no sound is heard to cause any uneasiness. Activity is only indicated by fumes with a faint peculiar choking odour of sulphur dioxide. The fumes rise calmly at varying places from pits and clefts of the elevations on the crater bottom and from cracks and fissures traversing the lava which fills the crater floor, depositing sulphur in a yellow crust on any objects.

Volcanic Activity in Historic Times. The first eruption ever recorded in Japanese chronology took place on November 29, 684 A. D. Several authors are of the opinion that the area now occupied by the villages of Motomura and Nomashi was formed by this eruption. During the period from the eighth to the eleventh century there was no eruption at all. In the twelfth century, on November 18, 1112, there was one eruption. Two eruptions took place during the fifteenth century. In the seventeenth century there were four eruptions. There was one eruption in the eighteenth century in the years 1777-78. This eruption of the An-ei era was the most violent one ever recorded in the history of the volcanic activity of Oshima. Five eruptions were recorded in the nineteenth century. The last one of this period which occurred in 1876-77, was a rather violent eruption. The activity lasted forty days. Lava was poured out in the crater of Miharayama but it did not run over the brim of the crater. The eruption of 1912-14 lasted for two years and three months. During this eruption, lavas were extruded in five periods with short intervals of quiet between spasms of activity. They did not run over the brim of the Miharayama crater, but they changed the state of the inside of the crater. The activity in the month of October in 1915 continued about twenty days but ceased without having poured out any lava.

KILEAUEA REPORT NO. 973

WEEK ENDING SEPTEMBER 14, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

The 14 Ton Bowlder fell to the bottom of Halemaumau during the evening of September 10. No one was present to watch the manner of its going, but a little news was yielded by the seismogram from the pit instrument. About 9:30 p. m. a landslide initiated a series of fourteen different slides large enough to record on the instrument. Two of the largest occurred at 10:30 p. m. It is probable that the 14 Ton Bowlder was carried in by one of these two. A section of the rim over fifty feet long and thirty feet wide dropped in during these avalanches. As a rough estimate, over 65,000 tons of rock fell from the wall of the pit.

Aside from the series just mentioned, there has been little avalanching during the week, and the steaming from the cracks in the pit has been slight except during one half day of rain.

Only one very feeble earthquake was recorded on the instrument at the Observatory on September 11 at 11:39 p. m. A total of 46 small tremors were registered during the week, of which a small number are probably avalanche records. Microseisms have been slight during the entire week.

The average tilt for the week showed a slight gain to the north at the Observatory. A careful analysis of the records suggests that the tilting is being influenced more by Mauna Loa than by Halemaumau. The tilt seems to be a series of small movements to and from Mauna Loa, and gives no evidence of increasing pressure under that mountain.

Again it must be concluded that things are very quiet at Halemaumau ,and that nothing of obvious consequence is happening at Mauna Loa.

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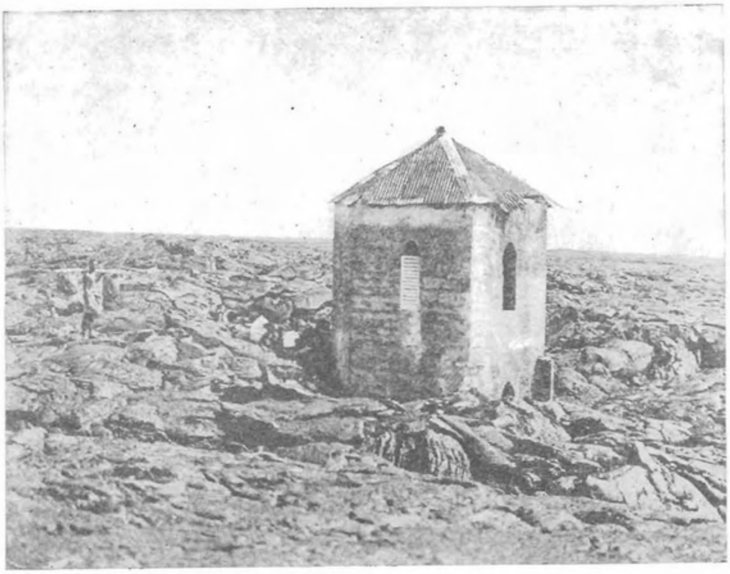
The Volcano Letter

Two dollars per year | Ten cents per copy

No. 300—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | September 25, 1930



Tower of the stone church of Sataputu, Savaii, all that remains to mark the site of a village buried under thirty feet of lava. There is subsidence around the tower, probably due to fluid lava entering the building below. After Tempest Anderson, Q.J.G.S. London, 1910.

ERUPTION OF MATAVANU, SAMOAN ISLANDS, 1905-10.

(Review by L. Smith. Reference: The Volcano of Matavanu in Savaii, Tempest Anderson, Quart. Jour. Geol. Soc., 66, 1910, pp. 621-639.)

Before the eruption of 1905, a sort of elevated plain surrounded by mountains stood where the crater of Matavanu is now. A deep valley extended from near this place down to the sea. On the western side of its coast were the villages of Saleaula, Salago, and Toapaipai. Farther to the east of Toapaipai was a stretch of "iron-bound" coast, or a coast made of old lava not protected by an encircling coral reef. Still farther east were the villages of Malaeola and Sataputu. These were on a part of the coast protected by coral reefs.

The eruption began August 4, 1905 with an explosive phase, sending forth mostly solid ejecta which did not cover an extensive space.

September 2 to September 4 saw molten lava pouring out and extending for a distance of two miles.

October 28 found the lava at Saleaula, and on November 3, this lava-stream was a quarter of a mile across. The side of the crater fell out and from the collapsed part a flood of lava issued.

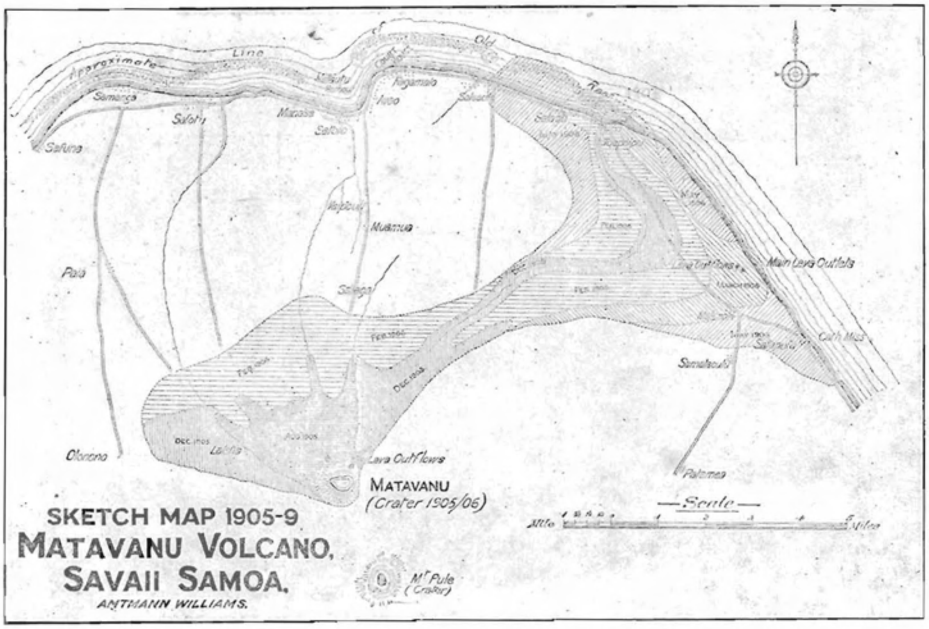
The lava reached the sea at Toapaipai on December 7, filling up the lagoon between the shore and the coral reef, then taking a westward turn along the reef, leaving untouched a part of the lagoon which was not filled up until later.

From January 28, 1906 to the middle of February, there was a great increase of activity. The lava extended along the coast from Salago to Saleaula, filling the space between the shore and the reef. Farther east, half the town of Malaeola was destroyed.

The lava ceased running in the swamp behind Saleaula on March 3, 1906. Near the coast about half the town of Saleaula had been destroyed. The lava filled up the space between the shore and the reef at Saleaula and extended westward, blocking up one of the entrances to the lagoon. The lagoon between the shore and the reef was not filled up until later.

On March 6, 1906, the lava extended eastward along the coast to two hundred yards from Sataputu which was destroyed somewhat later. Where the coast was "iron-bound" its formation was little changed for the lava flowed directly over the sea cliff into deep water.

Around the first of September, 1906, the lava-flows near



Map of the northeast side of Savaii Island showing the region of the crater and lava flows (shaded) of 1905-9 of Matavanu Volcano. After Tempest Anderson.

the sea coast extended eastwards, overwhelming the village of Sataputu, filling up the lagoon which was thirty feet deep in places, and pushing the coast-line seawards about 3000 feet. The total length of sea-front covered at different times by the lava was nearly nine miles.

It was noted on August 7, 1908, that the lava continued to run strongly into the sea, making its course mainly in the direction of that district where Toapaipai formerly stood.

A visitor to Savaii in the year 1910 or thereabouts would have seen a crater, 2000 feet high, surmounted by a canopy of white steam shaped a little like a pine tree, often breaking into cauliflower lobes, rising to a height of 8000 to 10,000 feet. Great fields of black lava, whose rough and irregular surface had large areas of both the aa and pahoehoe variety, comprised a considerable area around the cone, but on its southern and eastern sides their journey has been checked by hills. They are greater toward the west and north where they have filled the upper parts of several valleys. In the northeast, toward the sea, is the most extensive field of the fresh lava.

Of course, all vegetation overwhelmed by the lava was killed, but much more damage was done by the "Ua Sami," or poisonous gases, discharged from the crater or formed by the action of the hot lava on the sea water. Descending the crater from the west, the destruction of trees was complete, and for a distance of nearly two and a half miles, their bleached skeletons alone were left. It was only in a few sheltered places that the low undergrowth was beginning to return from the old roots. The towers and other parts of two churches are nearly all that remains of the villages of Saleaula and Sataputu.

The bottom of the crater is oval, entirely occupied by a lake of liquid lava, all in rapid motion and of such fluidity that it continually beats in surging waves against the wall. The lava is at a brilliant white heat with a darker scum continually forming on the surface, especially when the trade wind blows strongly on it. These pieces of scum break up and flow down to the north-eastern end of the crater where they disappear along with the liquid lava down a tunnel about 30 feet at the foot of the cliff. The surface of the cone is composed mostly of a series of flows of basaltic lava, and a number of bombs or ejected blocks of lava of similar character are scattered over the surface.

KILAUEA REPORT NO. 974

WEEK ENDING SEPTEMBER 21, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

A large part of the badly cracked section of the southeast rim, near the old site of the 14 Ton Bowlder, has fallen into the pit. Starting last Sunday, September 14, the avalanching was almost continuous until daylight the morning of Thursday, September 18. Between midnight and 4:30 a. m. of the 18th, a number of very heavy slides formed the climax to the series and produced the most visible changes in the rim. The edge of Halemaumau moved back about fifty feet through a distance of more than one hundred feet as a result of the avalanching.

Other than this sliding from the wall, there have been no events of interest at the fire-pit. Steaming has been very light and none of the earthquakes of the week has had its origin under Halemaumau.

The seismograph at the Observatory registered five very feeble earthquakes during the week, one of them on September 20 being felt in Kau. The times of the shocks were: September 15, 7:27 a. m.; September 18, 2:50 a. m. and 4:14 a. m.; September 20, 5:24 a. m.; and September 21, 6:08 p. m., distance 28 miles. During the spell of avalanching, 36 small tremors were recorded at the Observatory, while the pit instrument showed a total of 90 small shocks caused by the rock slides. During the last three days of the week, 13 tremors registered on the Observatory instrument of which none seems to be due to avalanching. The ordinary microseismic trembling of the ground which is thought to be of non-volcanic origin was slight for the week.

The tilt of the Kilauea rim under the Observatory gained slightly to the southeast, and the rim of Halemaumau showed the same amount and direction of movement. The daily tilt diagram shows continued small movement back and forth from the south ridge of Mauna Loa, but no gain of pressure under that mountain is indicated. Kilauea does not seem to be affecting the tilt to any appreciable extent at this time.

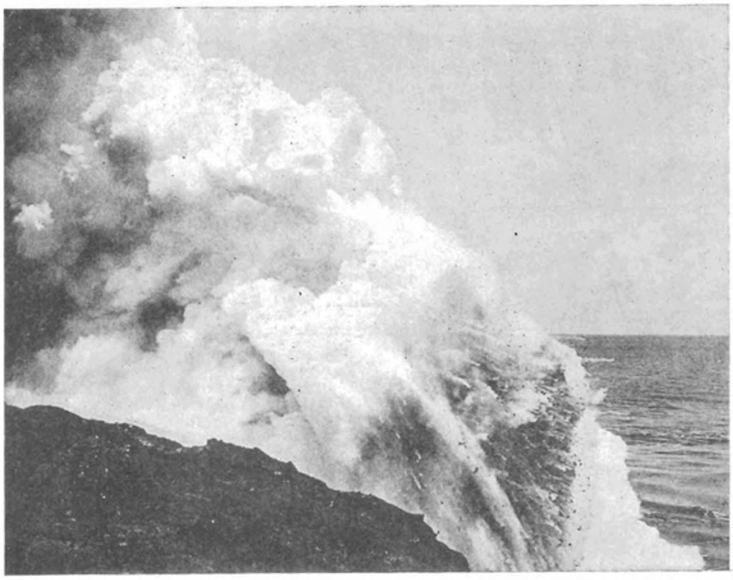
LAVA "SQUEEZE-UPS"

The Sunset Crater Lava flow, northeast of Flagstaff, Arizona, not only presents the most recent evidence of volcanic action in the San Francisco Mountain area but also contains a curious phenomena on the surface of the flow. These are fissures filled with basalt which have been given the name of "anosma," or "squeeze-ups." Through the middle of the main flow from Sunset Crater is a fissure, varying in width from a few feet to seventy feet, and a mile and a quarter in length. Through this fissure, basalt, apparently in a plastic condition, has been squeezed, under pressure, several feet into the air. The sides of the protruding basalt tongue are grooved conforming to the walls of the fissure, and slickenside surfaces are usually present. In the wider fissures, the more plastic inner layers of the mass have slid over the outer less plastic plates so that we get a condition of a series of vertical layers pushed into the air.

That the mass was plastic like stiff clay is evident from the rough surface of the sides of the mass that have been in contact with the walls, a condition often seen in the moulding of bricks. Further, the plates of basalt, as they have been thrust into the air, have bent under their own weight to form graceful arches in some places.

Besides the long squeeze-up, others are known of which many are less than 100 feet long. Most of these squeeze-ups are found on or near the edge of the main lava flow and form the source of smaller secondary flows. These secondary flows must have been more or less contemporaneous for in many cases they have coalesced.

It is thought that the formation of the squeeze-ups is related to the fact that the lava is contained in an intercone basin, a basin with no outlet surrounded by cinder cones. Into this basin, lava has poured from a vent near the high side of the basin. The remains of numerous fumeroles and the altered condition of much of the surface of the primary flow indicate that the main flow was deep and long in cooling. The squeeze-ups, in some way, seem to be associated with this condition.—HAROLD S. COLTON.



Lava of Matavanu entering the sea through a tunnel near Toapaipai. Fragments are being thrown up, each with a trail of steam, by the force of the explosions which occur when the lava enters the water. Photo Allen, after Tempest Anderson.

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The Volcano Letter

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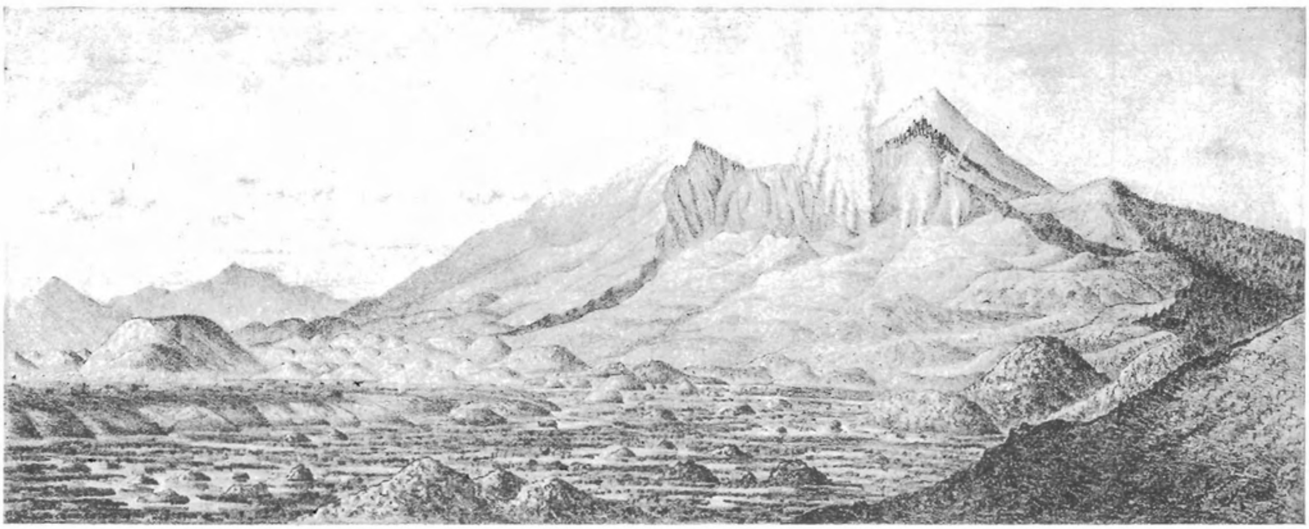
No. 301—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | October 2, 1930.



Crater of Bandai-san three weeks after eruption, looking south, showing the many conical mounds, similar to Galounggung (Vol. Letter No. 286). Bare hillsides on the right were scored by the mud torrent. After Sekiya and Kikuchi.

THE ERUPTION OF BANDAI-SAN, CENTRAL JAPAN, 1888.

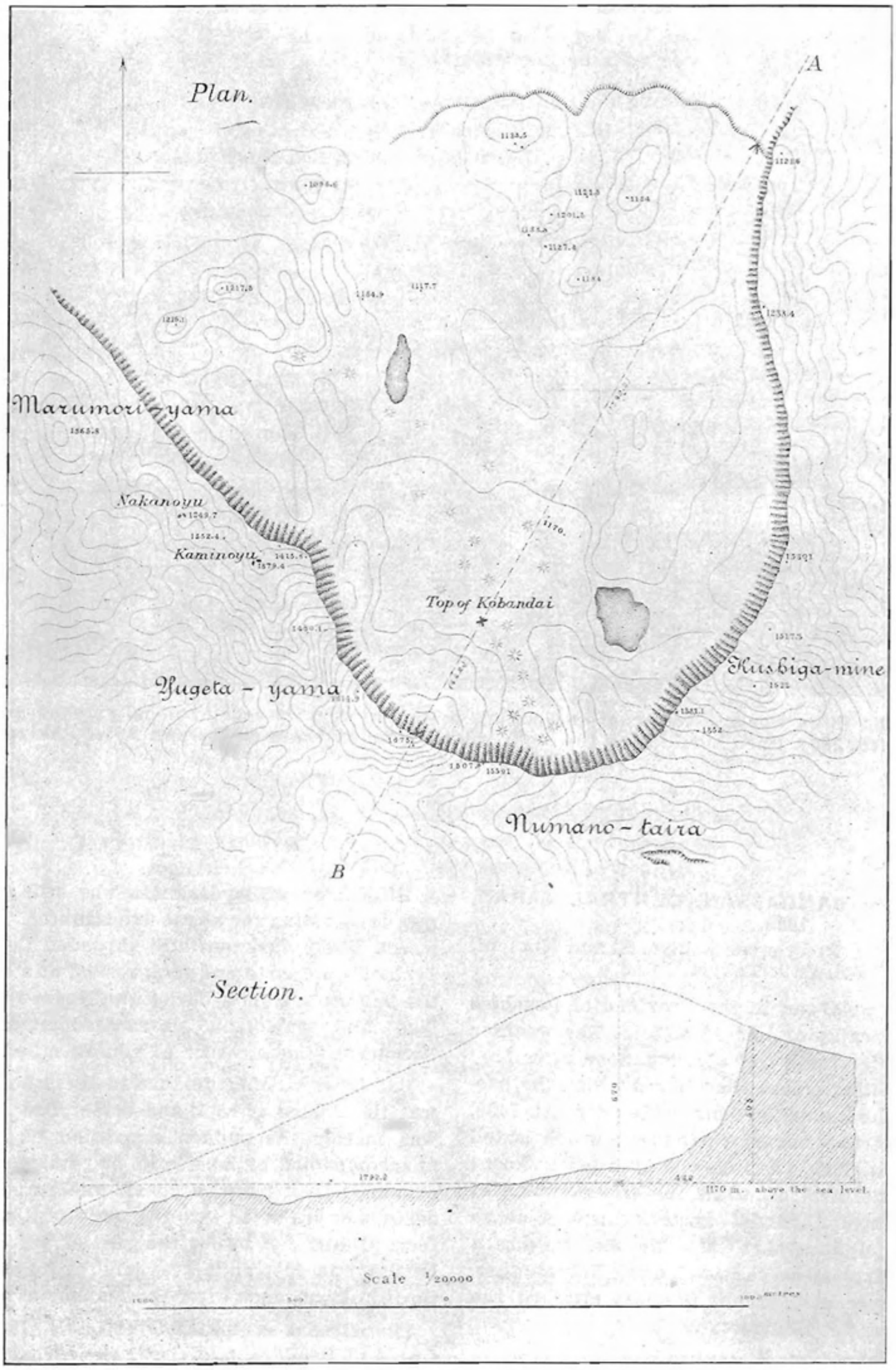
(Reviewed by L. K. Fo. Reference: Sekiya, S. and Kikuchi, Y.. Jour. Sci. Coll. Tokyo, Vol. 3.)

The eruption of Bandai-san in the Province of Iwashiro took place on the morning of July 15th, 1888. The weather was clear and a gentle breeze was blowing. Soon after 7:00 o'clock, curious rumbling noises were heard which the people thought to be the sound of distant thunder. At 7:30, there occurred a tolerably severe earthquake which lasted more than 20 seconds. This was followed by a most violent shaking of the ground. At 7:45, while the ground was still heaving, the eruption of Kobandai-san took place. A dense column of steam and dust shot into the air, making a tremendous noise. Explosions followed one after another, the steam on each occasion except the last attained the height of 1280 metres or 4200 feet.

The last explosion, however, is said to have projected its discharge almost horizontally towards the valley on the north. It is probable, from the topography and form of the crater, that previous discharges were also more or less inclined to the vertical in a northerly direction. The main eruptions lasted for a minute or more and were accompanied by thundering sounds which continued for nearly two hours. Meanwhile the dust and steam rapidly ascended and spread into a great cloud like an open umbrella in shape. At the immediate foot of the mountain there was a rain of hot scalding ashes, accompanied by pitchy darkness. A little later while darkness was still great, a shower of rain fell, lasting for about five minutes. The rain was quite warm. While darkness still shrouded the region, a mighty avalanche of earth and rock rushed at a terrific speed down the mountain slopes, buried the Nagase Valley with its villages and people, and devastated an area of more than 70 square kilometres or 27 square miles.

The most striking feature in the whole of this eruption was the deluge of rock and earth. The destructive agency was merely the sudden expansion of imprisoned steam, unaccompanied by lava flows or pumice ejection. When the explosion took place, a considerable amount of rocks and earth was projected into the air, and a part diffused in the form of dust, but by far the greater part of the bulk of Kobandai was just split into mighty fragments which were thrown down much after the manner of a land-slip.

The stream of materials of July 15th, ran down the slopes of Bandai-san, dividing as it went into two principal branches. The main branch flowed northward. Kobandai sloped on the north towards Nagase Valley in an unbroken descent, and as the mountain burst on this side, the debris dashed with great violence down this northern slope in the direction of Hibara, 9 km. away. One part of the rock torrent actually ran up the valley, toward the source of the River Nagase, burying on its way the three hamlets of Akimoto, Hosono, and Osuzawa. A part, however ran down the valley reaching Kawakami spa and submerging it to a depth of probably more than 40 metres. The other and



Plan and profile of Bandai-san as destroy ed by the steam blast eruption of July 15 1888. Heights given in meters, dotted lin e shows former profile. After Sekiya and Kikuchi.

much smaller branch took quite a different route making an angle of 120 degrees with the main stream.

The combined volume of these two great streams entirely covered an area of 27 square miles with a solid sea of mud and rock, beneath which were buried all features of the landscape together with cattle, people, and all other living things.

The mud current also carried along numerous big boulders, some of them measuring from 5 metres to 10 metres each way.

The explosions were accompanied by terrible wind blasts. In some exposed parts, houses were levelled to the ground and trees torn up by their roots. Marumori-yama, situated near the mouth of the crater, and fully exposed, received the most severe damage. This hill was formerly covered with a thick forest, but now presents a melancholy appearance, the few trees which were left standing being as naked as telegraph poles.

This eruption of Bandai-san was more destructive than constructive. The materials which had accumulated in past ages gave way and were thrown down from a higher to a lower level in less than an hour in a gigantic landslide. The loss of property is said to have been immensely great. There is absolutely no hope of recovering or reclaiming the buried land.

Formation of new lakes due to the damming up of the river Nagase by the shattered mountain was also a striking effect of the eruption. There were four lakes formed in this manner, called Osuzawa, Hibara, Onogawa, and Nakatsu. Fifteen days after the eruption, the village of Onogawa was covered with water from the gradual accumulations in these lakes.

Out of the total of 461 dead, only 116 bodies were recovered, the rest remaining buried under the mud from the avalanche. Seventy individuals were injured by the hurricane of hot ashes and falling stones.

TEMPERATURE OF STEAMING CRACKS

The steaming cracks on the rim and floor of Kilauea Crater are, at present, the most visible indications of the presence of latent volcanic forces. They inspire numerous questions and are worthy of considerable study. Where does the steam come from? Are all of the cracks of the same temperature? Does the weather have any effect on the amount and temperature of the steam? These and many other questions of a like nature easily come to mind.

Since the beginning of the constant observation of the volcano, some notice has been taken of the steaming cracks. Measurements of temperature both at the surface and in holes bored beneath the surface have been made at a number of different times since 1912. At the present time, a daily record is being kept of the temperature and behavior of three accessible steaming cracks.

In February and March, 1912, a comprehensive survey was made of the temperature of steaming cracks in the entire crater area. The results of this survey are reproduced here in the following table:

Locality	No. of Cracks	Maxima	Minima.
Sulphur Banks	6	95.5 C. (204 F.)	66.0 C. (151 F.)
North edge Kilauea	2	70.0 C. (158 F.)	55.0 C. (131 F.)
Steaming Cliff	13	80.5 C. (177 F.)	47.8 C. (118 F.)
Observatory	2	59.0 C. (138 F.)	25.5 C. (78 F.)
North floor Kilauea	11	89.0 C. (192 F.)	36.7 C. (98 F.)
Northeast floor Kilauea	5	81.7 C. (179 F.)	57.8 C. (136 F.)
East floor Kilauea	7	84.0 C. (183 F.)	39.0 C. (102 F.)
Southeast floor Kilauea	7	94.5 C. (202 F.)	43.4 C. (110 F.)
South floor Kilauea	2	73.3 C. (164 F.)	66.6 C. (152 F.)
Around Halemaumau	6	145.5 C. (294 F.)	64.0 C. (147 F.)

The table does not include the Postal Rift which maintained temperatures varying around 320 C. (608 F.) for a number of years before it was buried beneath a flow of lava in 1919.

In June 1922, a hole was bored in the Sulphur Bank to a depth of 50 feet, and the temperature was found to be consistently about 96.0 C. at the bottom of the hole. A surface reading in one of the steaming cracks was made at the same time which showed a temperature of 95.5 C., identical with the maximum temperature of these cracks in 1912.

At the same time, temperatures of about 65.0 C. (149 F.) were measured at the bottom of an eighty-foot hole drilled in the south floor of Kilauea Crater. A surface crack gave off steam at a temperature of 55 C. Two cracks measured in this area in 1912 had temperatures of 73.3 C. and 66.6 C.

In January 1925, temperatures were recorded from cracks on the rim of Halemaumau as follows: west rim, 75 C. (167 F.); southwest rim, 86 C. (187 F.); south rim, 72 C. (162 F.); and southeast rim, 76 C. (169 F.). These temperatures taken when there was no lava in the pit contrast with those of 1912, taken when lava was present, which showed a maximum of 145.5 C. and a minimum of 64.0 C. Two cracks on the south floor of Kilauea showed temperatures, in 1925, of 87 C. (189 F.) and 90 C. (194 F.).

A reading of 66.4 C. was obtained from the bottom of the eighty-foot hole in January 1926, and the steaming crack near the hole showed 57 C. These compare with 65.0 C. and 55.0 C. for the two localities in 1922.

Three generalizations are obvious from these earlier records. First, the temperature of the steaming cracks in the vicinity of Kilauea varies over a wide range. Second, three individual "hot spots" show very little change over a period of several years. Third, the temperature shows no definite relation to the presence of lava.

Since May 1930, a continuous record has been kept of the temperature of a narrow steam crack about one hundred yards south of Halemaumau. During May the temperature averaged about 71 C. (160 F.); during June, 70.5 C; during July, 70.0 C.; and during August, 69.5 C. (157 F.). For comparison with the curve of variation of the temperature of the steam crack, records have been kept of the daily rainfall, daily average air temperature, daily range of air temperature, daily barometric pressure, daily wind condition, and air temperature at time of reading the steam temperature. The results obtained so far seem to indicate that the temperature of the steam from the crack does not depend on any one of these outside influences.

In an effort to test this information more fully, daily records have been started on two more steaming cracks, one about 100 feet south of Halemaumau, and one on the Steaming Cliff on the northeast Kilauea rim. It is hoped that comparison of all of these records will permit some definite conclusions as to the origin and control of the temperatures of the steaming cracks.—H.A.P.

KILAUEA REPORT No. 975

WEEK ENDING SEPTEMBER 28, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

There have been very few avalanches, and steaming from the cracks in the crater has been very light during the past week. Sunday evening, September 28, at 8:35, a few people in the National Park felt an earthquake which was also reported as felt in Kona.

Between September 22 and September 27, four very feeble quakes were recorded on the Observatory seismographs as follows: September 23, 5:09 p. m. distance 37 miles; September 24, 4:16 a. m. and 9:03 a. m.; September 25, 7:55 a. m. None of these was felt in the Park. At 8:35 p. m., September 28, a quake of moderate intensity dismantled (this means that a small safety device is disconnected which prevents serious damage to the writing pens) all of the instruments at the Observatory and was followed by a number of feeble and very feeble shocks as follows: 8:59 p. m. very feeble, 9:05 p. m. feeble, 9:08 p. m. very feeble, 9:13 p. m. very feeble, and 10:56 p. m. feeble.

The moderate shock at 8:35 gave some interesting but puzzling records. On several of the instruments, the distance to its center was measured as 12 miles, while on the others its distance was 20 miles. It had a strong vertical movement, yet it was felt as a very gentle rocking motion by a very few people. The best guess which can be made from the conflicting records is that the quake had its origin at great depth under the island and cannot be assigned definitely to either volcano.

Twenty-three short tremors, probably of volcanic origin were recorded during the week, and the non-volcanic microseismic trembling was somewhat stronger in the middle of the week.

The tilt for the week still seems to be controlled more by the southern part of the main Mauna Loa rift than by Kilauea. The ground at the Observatory was tilted moderately to the northeast.

The deep seated earthquake probably indicates deep movement of lava, but it is too soon to tell whether the lava is rising into one of the volcanoes.

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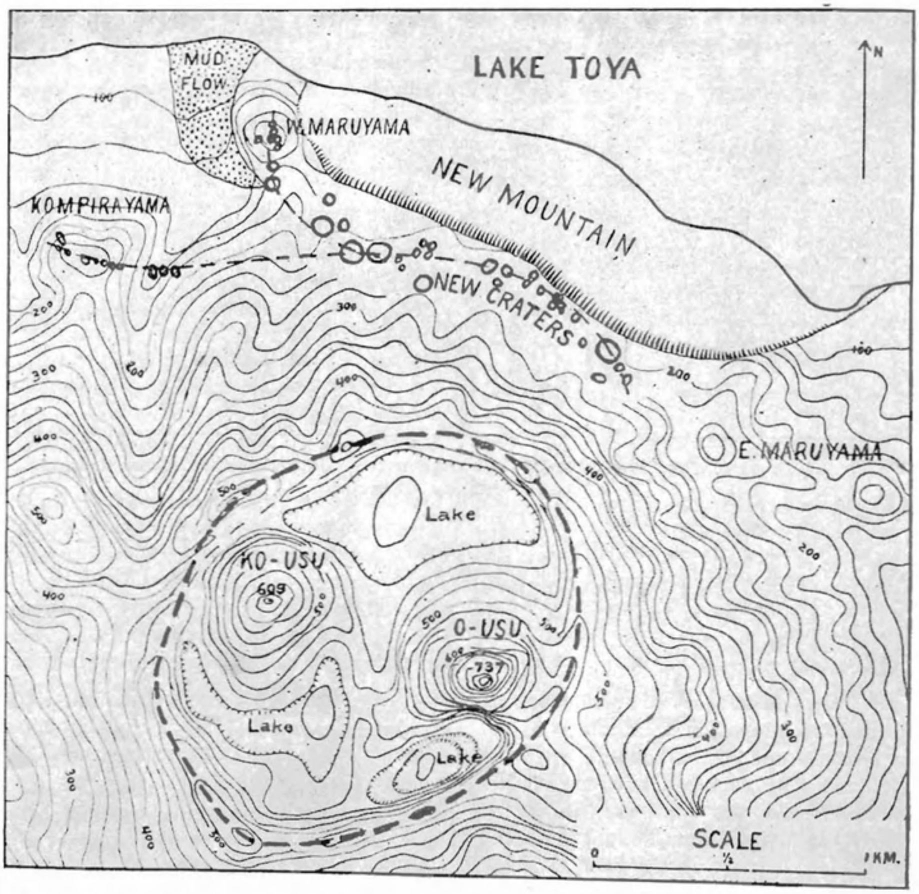
No. 302—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — October 9, 1930.



Map showing old somma ring and domes of Usu, the line of active craters of 1910, and the uplifted segment which makes the "New Mountain" escarpment. After Daly.

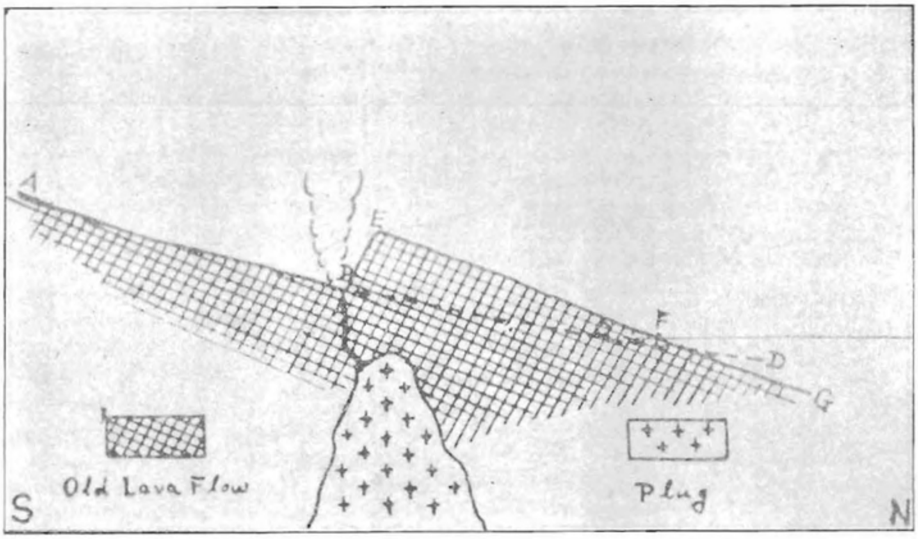
CHANGES OF ELEVATION AT USU VOLCANO, JAPAN

(Review by D. Malone of the paper by F. Omori, Bull. I. E. I. C., 5, 1913)

The volcanic outbursts in 1910 of the Usu-san volcano were followed by the formation of the "New Mountain." The elevation phenomenon was not confined to Usu-san but in November, 1910, in the town of Auta on the southwest base of Usu-san, a fence surrounding a field which had been level was at the time invisible from one side to the other. The Military Survey Department, in 1911 and 1912 undertook the determination of the heights of the first order benchmarks on the lines of precise-levelling running along the northeast coast of Volcano Bay and along the western foot of Usu-san.

In the summer of 1911, the height was examined along the Volcano Bay coast from the vicinity of the town of Benbe southeast to Abuta-Tokatan, then along the southwestern base of Usu-san to Tokotan on the Toya Lake and then to Muko-Toya along the western coast of Toya Lake. The total distance was about 25 km. In the summer of 1912, the measurement was repeated, being further extended 12 km. southeast along the coast of the bay to the town of Nishi-Monbets which is about 8 km. southeast of the central crater of Usu-san.

As may be expected from the proximity to the site of the "New Mountain," the benchmark at Tokatan was elevated 2.4244 meters, while benchmark Number 6596, situated midway between Toya Lake and Volcano Bay, was elevated 1.1601 m. At Abuta-Tokotan, on the coast of Volcano Bay, the elevation was 0.358 m., although the distance from New Mountain is 6 km. On the other hand, the benchmark No. 6597, not far from 6598 (at Tokatan), suffered a depression of 0.0739 m. while Nos. 7192 and 6599, at the distance of 2 km. to the northwest of Abuta-Tokotan and



Profile of uplift of the "New Mountain" segment at Usu Volcano in north Japan, as conceived by Ouinoue.

Tokotan respectively, were each depressed about 0.022 m. It will be seen that marked elevation took place at all benchmarks between Tokotan and Abuta-Tokotan, with the exception of No. 6597, and also at those between Abuta-Tokotan and Nishi-Monbets. As the southeast corner of the lake shore in front of the West Kohan School indicated an upheaval of some 1.333 m., it may be assumed that the whole mountain mass of the Usu-san and its base suffered an elevation, doubtlessly extending some distance beneath Toya Lake.

A comparison of the heights of the different benchmarks determined in 1911 with those again determined in 1912 shows that a sort of a level adjustment was going on both in the upheaval and the depression regions to no small degree. It may be seen that the three benchmarks Nos. 6596, 6598, and 6597 (the first two of which had been elevated by the greatest amount of 1.16 and 2.4244 m.) now indicated depressions of 18.4 to 29.2 millimeters. On the contrary, the three others, Nos. 7192, 6599, and 6600, which had been depressed by the maximum amount of 22 mm. were now raised to the amount of 2.0 to 3.1 mm. The ratios of the downward and the upward restitutions were thus greater than the former. It is likely that the process of the level fluctuatio ncontinues for many a year to come or at least as land as the volcano is in more or less active condition.

The problem of level change in volcanic districts forms an exceedingly interesting branch of geophysical research. Seismologically it is exceedingly desireable to investigate the changes in level which may take place in districts belonging to active earth-quake zones, previous to the occurence of destructive disturbances.

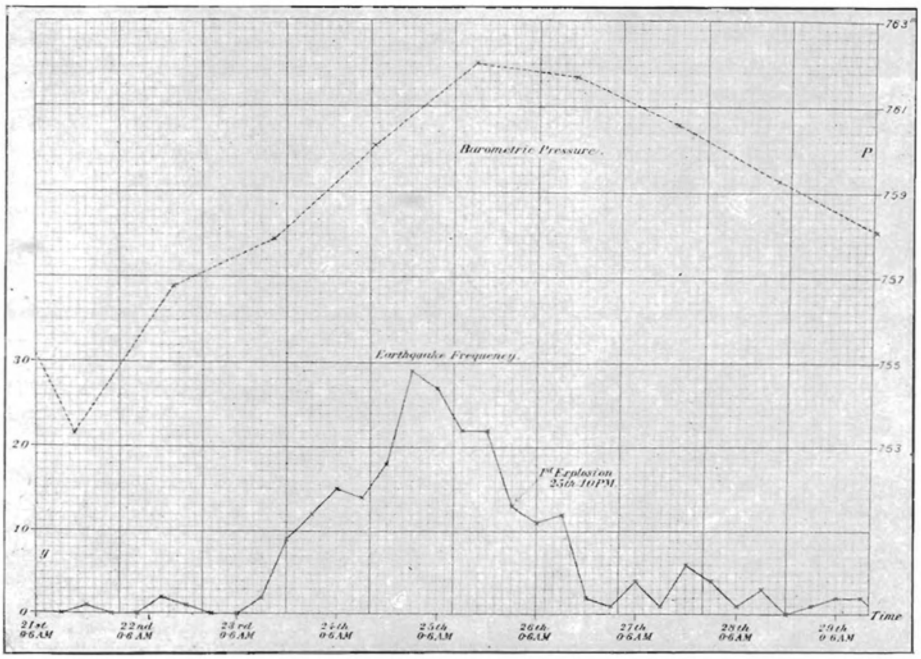
CYCLES OF VOLCANIC ACTIVITY

K. von Sapper, pp. 270-74. Translated from the German by H. C. Flattery.

The cycles of volcanic outbreaks and their possible connections with cosmic or terrestrial occurences are a subject that has been brought nearer to a solution by the keeping of statistics. Above all, a connection with sunspots has been accepted. J. Jensen finally came to the conclusion, through various experiments, that the greater frequency of outbreaks occurred simultaneously with the maxima and minima of sunspot coverage. Later W. Koppen, who has gone over this field again, found by studying the outbreak statistics of E. Kluge and de Marchi that the outbreaks were most frequent at the time of sunspot minima and most rare at the time of maxima. However, the record of outbreaks of K. Schneider gave a greater number of outbreaks for the time of maxima than for the time of minima. On account of these contradictory results, I have tried to examine my material with this in view: are the periods noticeable for the whole earth, or does an increase in certain districts equalize to some extent the decrease in others? For this purpose I have determined year by year the number of known activity units, and for the smoothing of the curve, I have, in each instance, considered the preceding and the following figure at its weighted value—b equal ¼ (a plus 2b plus c). I ignored the continuously active volcanoes as they do not influence the curve. The southern hemisphere, on account of the greater number of continuously active volcanoes, is ahead of the northern hemisphere in general frequency of activity. But it shows a lower frequency figure, if one disregards the continuously active volcanoes, which is in keeping with its smaller land surface. Only seldom does the southern hemisphere gain a preponderance. The beginning of the list is in the year 1749 as only from this time on is the sunspot curve known through observation. The absolute number of outbreak units is continually getting higher, the nearer we approach the present time. This can be explained through better reporting and the addition of new volcanic districts. The frequency curve plainly shows a number of periods. They are not of equal duration, but vary from six to twelve years. Very often they approach the duration of sunspot periods, so it is not remarkable that several times a high frequency of outbreaks coincided with sunspot minima and at other times with maxima. According to my figures there were seventeen frequency periods from 1749 to 1914. During the same time there were only fifteen sunspot periods. This shows that a fundamental connection cannot be established between the two. Nevertheless. a certain relation is not out of the question for it is noticeable that during a time of the pronounced flattening of the sunspot curve (1798-1825) the frequency curve too is less sharply defined. Gigantic outbreaks sometimes correspond with a high, and sometimes with a low point of the curve, or even in between, so that no particular regularity can be read from this material for the occurence of great volcanic catastrophes.

Even though the sunspot theory may fail to be proved, positive causes of terrestrial or astronomic nature may yet be found in the course of time for the periodical volcanic outbreaks. Perrey and Falb (during the second half of the 19th century) believed to be able to predict the earthquakes and volcanic outbreaks under the supposition that there was a flow of the molten liquid of the earth's core. This theory has now been abandoned, but there is still much speculation as to the influence of the constellations of sun, moon, and planets on these phenomena.

F. A. Perrett came to the conviction, after careful observation of the activity of various Italian craters, that the position of the moon and also the sun to each other and to the earth has a decided influence on volcanic activity. Perret took into consideration the distance of the moon from the earth, the quadratures and syzygien, and the changes of the declination of sun and moon. He found fortnightly and half yearly maxima. The first show a stronger swing. H. O. Wood, who was at the Kilauea Volcano Observatory from 1912-1917, criticised Perrett's curve, because it showed the fortnightly amplitude as greater than the half yearly one. He emphasized the great value of declination. The observations at Kilauea showed that high lava levels and strong surface activity occurred at solstice, low lava level and little activity at equinox. T. A. Jaggar, who has had charge of the Kilauea Observatory since 1917, calls attention to the fact that from 1911-1913 the lava measurements may have corresponded with these data, but not so from 1914-1918. He shows that occassionally solstice and equinox have high lava levels, but at other times they may be accompanied by low lava levels. He found that on the average the lava in Kilauea had a tendency to rise in April-May and October-November, and to fall in July-August and January-February. From these various views one might well draw the conclusion that the observations have not been recorded for a sufficient length of time to show reliable results. H. O. Woods pointed out that in a cycle of 18.6 years the moon exerts an increased influence on the earth. This is caused by the regression of the occuring moon (nutation) while the change of breadth of the same is completed in



Curve showing the rise of barometric pressure and of earthquake frequency just before the first explosion at Usu eruption. After Omori.

a seven year cycle. It is remarkable that the multiplication of these two periods is about 130 years. Half of this is 65 years. Woods notes that Omori, in examining the eruption history of Asama-yama, finds the mean interval to be 63.5 years and in doubling it, 127 years. Dr. Jaggar prophesied in 1918 that in 1920 (the 130th year after the great eruption of Kilauea) another such eruption would take place. In fact, great lava flows occurred in this year and the explosive outbreak repeated itself in 1924. As such successes lead us to hope that through the careful collection of observations of all kinds and through the consideration of the outbreak history of the various volcanoes it may yet be possible to shed light on the causes and the origin of these eruptions.

For a long time one has tried to connect eruptions not only with astronomic events but one has also thought of the possibility that atmospheric influences, above all heavy rainfall, at least in case of explosively active volcanoes, might be the cause of eruptions.

Systematic observations were first made by G. de Lorenzo at Mt. Vesuvius. He found that heavy precipitations increased the activity of this fire mountain. F. Stell-Starrabba extended the observations to Etna and later on to Japanese volcanoes on information furnished by H. Tanakadate's paper "On the Activity of Japanese Volcanoes from January 1914 to August 1924." Lately the work referring to Japanese volcanoes was continued, using Karl Sapper's catalogue of the historical volcanic eruptions. This gave information on volcanic outbreaks since earliest times. Both sources showed the coinciding of rainy and eruption times. In looking over the entire eruption activity, the maximum seems to be delayed several months, during the short period from 1914 to 1924. This retardation is explained, according to Starrabba, by the fact that the general eruption list shows only major eruptions while in Tanakadate's compilation, even less important manifestations of activity are recorded.

KILAUEA REPORT NO. 976

WEED ENDING OCTOBER 5, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

On Monday and Tuesday a few dust clouds were caused by small avalanches from the walls of the pit. Since then it has been so rainy that any slides which might have occurred did not raise clouds of dust. The heavy rains which began on Wednesday, October 1, and have continued all week have caused an excessive amount of steaming from Halemaumau. A number of times, large cauliflower steam clouds have given a perfect imitation of eruption clouds.

One feeble earthquake was recorded on October 1 at 7:14 a. m. with a distance to its origin of 28 miles, and three very feeble shocks were recorded as follows: September 29, 12:31 a. m.; October 1, 1:05 p. m.; and October 5, 10:51 a. m. Twenty-five small tremors registered on the Observatory instrument during the first four days of the week, and three were recorded on October 5, the last day of the week. On two days there were neither tremors nor quakes. The microseisms, which indicate the non-volcanic trembling of the ground, were slight during the early part of the week but increased to moderate intensity over the weekend.

The Kona and Hilo records of the earthquake of September 28 give additional evidence which shows that the quake had its origin at great depth under the crater, Mokuaweoweo, on the main Mauna Loa rift line. Late reports also show that the quake was felt by some people in all parts of the island.

During the past week the ground under the Observatory has titled moderately in a south south-west direction. Unfortunately, the heavy rainfall of the latter part of the week has caused some tipping to the south, which tends to obscure the significance of the tilt record so far as volcanic pressure is concerned. Only one thing is certain, that is, if any excessive change of pressure had followed the deep seated quake of September 28, it would surely have made itself evident in the tilt record in spite of the obscuring outside influences

TILTING OF THE GROUND FOR SEPTEMBER

The general movement of the ground under the Observatory during the month of September was a slight tilting back and forth along a northeast-southwest direction. The net amount of tilting for each week, taken from the curve which is smoothed by calculating progressive seven-day means, is given in the following table:

September	1— 7	N. E.	.97 seconds of arc
"	8—14	N. E.	1.20 " " "
"	15—21	S. S. W.	.90 " " "
"	22—28	N. N. E.	1.33 " " "

THE VOLCANO LETTER

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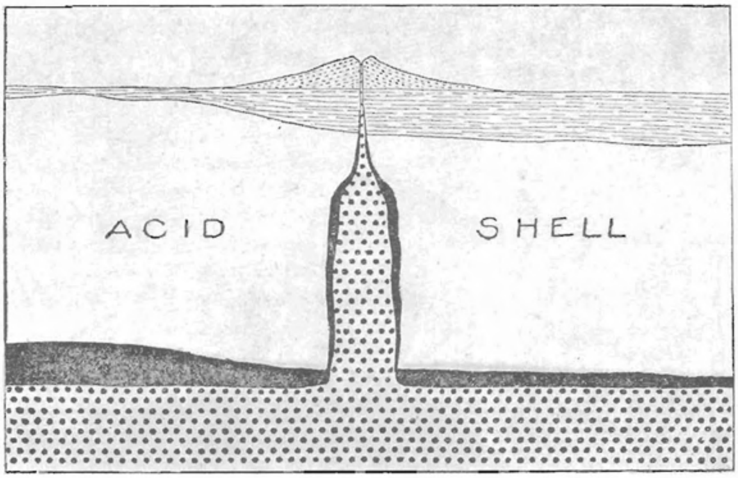
The Volcano Letter

Two dollars per year — Ten cents per copy

No. 303—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — October 16, 1930



Diagramatic section through the earth's crust showing sediments under a volcano, siliceous (acid) shell, black solidified layer of basalt, dotted liquid basalt of the substratum partly crystallized on the walls of the fissure leading to the volcano. The volcanic cone is represented as 5 km. in height. After Daly.

JOLY'S THEORY OF SURFACE CHANGES OF THE EARTH

(Reviewed by M. Gauntlett. The appendix of "Surface History of the Earth" by John B. Joly.)

After a sinking of the earth's crust with inflowing of the seas over the land masses, sedimentation takes place and then a gradual rising of the continental blocks again. Before the final climax of the renewed rising, floods of basalt arise and flow out through the cracks in the earth's surface. The geosynclines, or places which have received the most sedimentation, are lifted up to form mountain ranges. These periods of great crustal movement, or Revolutions, have occurred about four times, the last ushering in the present geologic age with the rising of the Eurasian chains.

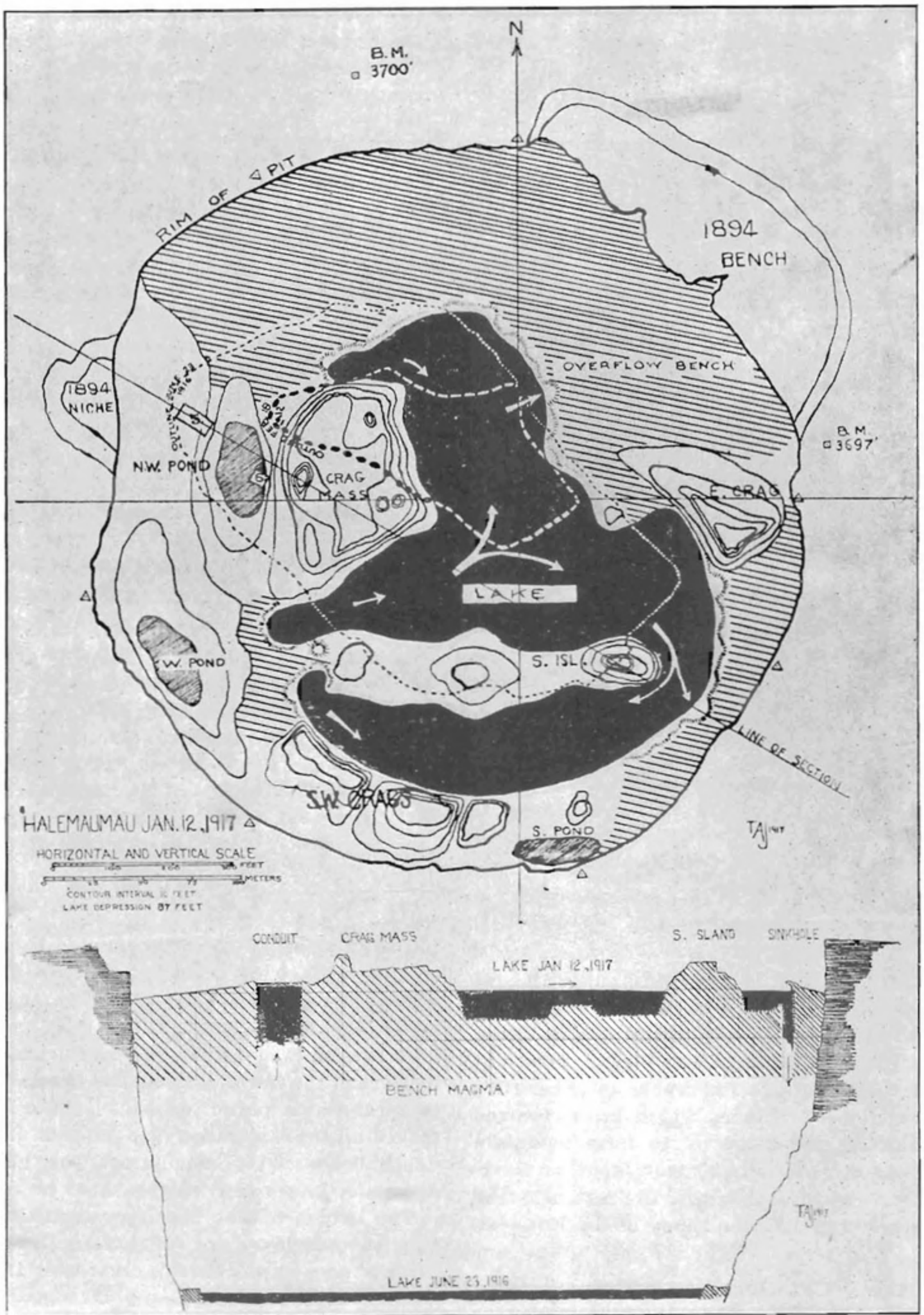
In the article, the origin and interrelations of these events, the sinking and rising of continental blocks, is traced in reference to: (1) the existence of a general basaltic magma-ocean or isostatic layer in which the continents float and upon which the oceans rest; (2) the presence of a certain amount of radioactive materials throughout this magma-ocean; (3) the maintainence both in past and present of isostatic equilibrium of the land masses; (4) certain forces acting on the earth's surface crust.

The general distribution in the rocks of energy-producing or radioactive elements was demonstrated by Lord Rayleigh about twenty-two years ago. This shows that there is everywhere in the rocks a perpetual source of heat which is unfailing whether the heat is accumulating or escaping. More thermal energy was evolved in past ages. Joly feels that this accumulated energy has been a dominating factor in the history of the changes of the earth's surface for all time.

The question of isostacy connoted the existence near the earth's surface of a layer of dense, plastic material in which the continental masses of lighter rock float and upon which the oceans rest. The law of compensation works here to a marked degree, the continental masses displacing more than the lower oceans. The greater mass of the mountain ranges is permitted because the lighter rock which makes up the mountains also extends downward to a great depth beneath the mountains. The Himalaya mountains are about 80 per cent compensated by this method.

The evidence that basalt or basaltic magma composes this isostatic layer are very strong. It is found that during disturbances on the earth's crust vast amounts of intensely heated, fluid basalt come up through the fissures. Basalt has a very high density. It is the most prevalent effusive rock on the globe. The oceanic islands are predominantly basaltic. Experimentally it has been found that basalt directly underlies the oceans. Joly designates the continents as a granitic scum which has separated out. The continents float in this underlying magma layer and the oceans rest upon it as oil on water.

From astronomical study and seismology it is found that at present this substratum must be solid and behave as an elastic solid towards rapidly changing physical forces. However, it is in the solid state very near its melting point, and in the past it has been in the fluid state just above its melting point. Now heat is being generated by



Pit plan and profile of Halemaumau. Shows in profile the bench magma shaded) as a narrow rim in June, 1916, and as the principal fill of the pit in January, 1917. Map shows lake, crags and western source wells. After Jaggar, A. J. S., Sept. 17, 1917, p. 168.

radioactive elements, and heat from a solid is given off only by slow conductivity, so heat is accumulating since it has no rapid means of escaping. It will take some 30 million years for enough heat to accumulate to change the basaltic magma back into the liquid state.

When this takes place there will be an uprising of the entire earth's crust due to the expansion of the basalt during melting which is 11 to 12 per cent, but there will be a sinking of the continental blocks because of the decrease of density of the basalt during melting. After liquifaction is complete, the rate of loss of heat is enormous due to the convection currents in the liquid mass. The heat will be lost mostly through the ocean floor. The loss of heat causes the magma to solidify again and the entire surface of the earth sinks again with the continents rising due to the change in density of the supporting magma-layer. This is a cycle which occupies from forty to sixty-five million years as well as may be judged with the scarcity of known facts.

It is quite probable that, during this time of liquifaction, there are great tides in the magma and the continents shift with the ocean in respect to the deep lava.

In the formation of mountain ranges, Joly holds to the theory that the folding and over-thrusting of the layers of sediments are done long before the mountains are elevated. The sedimentation in large geosynclines, or troughs, forces these areas to bear down much more heavily into the superheated isostatic layer beneath, and later, when the horizontal mountain-making forces come into action, they do not push the mountains up but rather further down. The mountains do not rise until solidification of the underlying magma increases its density and the forces tending toward compensation become great enough to force the whole crushed mass of sediments upward as elevated mountain ranges. This elevation is due to vertical forces and not horizontal as has been stressed in earlier theories of mountain building. The energy comes from the expanded magma and is traceable to the accumulated radioactive heat.

According to astronomers this liquid layer of basalt has tides and the tidal movements greatly exceed in energy those of an ocean of water. There arises a west-to-east pressure transmitted from the rotating earth in opposition to the lunar and solar gravitational forces. This acts on the submerged westerly coasts of the continents. It is a fact that all of the great lava flows have occurred on the western sides of the mountain ranges and continents. The magma expanding about ten per cent would increase the equatorial width of the Pacific about thirty miles and that of the Atlantic eleven miles. The approximated thickness of the ocean floor would be twenty miles in twenty-five million years, and the thickness in inter-revolutionary times would be fifteen miles. During the period of thermal dissipation it will be attacked by super-heated currents and greatly reduced in thickness by melting of the bottom. It will rupture along the coasts of the continents, and the fractures will be filled rapidly by congealing basalt, forced in under pressure. During this time the heat is being dissipated and the ocean floor again thickens and strengthens. Then, when this thickened and enlarged oceanic crust sinks due to the cooling of the underlying magma layer it pushes against the coasts of the continents and causes buckling.

Earth movements and volcanism must result from this breaking down of solid to liquid. Also it is difficult to separate horizontal and vertical movements because of the tensional properties of the rocks and the fact that molten lava fills all cracks preventing return to the original dimensions. The vertical oscillatory movements become a source of ever-extending lateral pressures.

The relative amounts of land and water are explained by thermal equilibrium. If the temperature becomes too great, the continental rocks liquify and either rise vertically in great intrusive bodies called batholiths or expand laterally until the thermal equilibrium is reached again.

By the theory as represented many great facts of earthly tectonics are explained. Such cyclic changes not only arise consistently and naturally, but it may be said inevitably from the conditions present. "The events of the past cease to be mysterious, but become the natural outcome of the physical structure of the earth's surface."

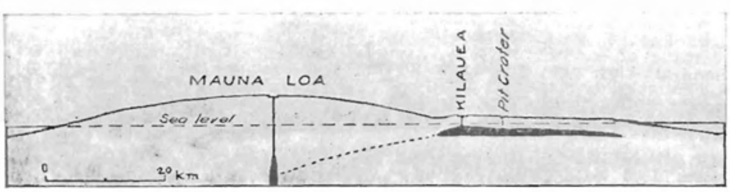
TILT AND RAINFALL

In Kilauea Report No. 969, August 17, the remark was made that abrupt tilting of the ground to the south was coincident with a period of heavy rains in the region around Kilauea crater. Additional data have thrown more light on this occurrence.

On several different occasions during the past few months, rainfall has been so heavy that streams of water have formed numerous short-lived water falls over the walls of the crater, and the crater floor has been dotted with countless pools of standing water which last for several hours after the rain ceases. One of these water-catching basins is located about 30 feet south of the building which houses the Halemaumau seismograph, and during the heavy rains it holds a pool of water perhaps 20 feet in diameter and one foot deep on the average. Thus approximately 4000 pounds of load are added to the surface of the ground just south of the seismograph.

The observer at the pit has noticed that this small basin has been filled on five different occasions, and, at each time, the seismograph has registered abnormal tilt to the south.

Date	Amount of tilt	Duration of abnormal tilting
Aug. 10, 1930	S—1.2 sec. of arc	4 hours
Aug. 11,	S—1.1 " " "	3 "
Sept. 10,	S—3.1 " " "	5 "
Sept. 19,	S—0.3 " " "	2 "
Oct. 8,	S—3.0 " " "	5 "



Profile of Mauna Loa and Kilauea after Daly, imagining Kilauea fed from a remnant lenticular intrusion. Daly, Proc. Am. Acad., June, 1911.

The exact amount and duration of these rains is unknown, so that a quantitative correlation between rainfall and tilt of this instrument cannot be made. However, observations have been sufficient to make certain that these short periods of abnormal southern tilting of the Halemaumau seismograph are coincident with the heavy rains which form the pool of water just south of the instrument pier.

The heavy rains at the pit on August 10 and 11 were a phase of a very heavy general rain which affected the whole area. During the three days, August 10, 11, and 12 about 12.5 inches of rain were recorded at the Observatory. On these same three days, the Observatory seismograph showed an abrupt tilt to the south which amounted to 3.5 seconds of arc. The other three instances of sharp tilt at the Halemaumau instrument were not coincident with any unusual rainfall or tilt at the Observatory. However, during the three days, October 3, 4, and 5, about 6.8 inches of rain fell at the Observatory, and a rather abrupt tilt to the south of 1.2 seconds of arc was recorded. These two instances from the Observatory are not sufficient basis for any generalizations on the correlation of rainfall with the general tilting of the Kilauea rim. It is evident, however, that abnormal tilt may be shown on the Observatory instruments which does not affect the Halemaumau station, and vice versa.

In an article appearing in the Bulletin of the Seismological Society of America in March, 1929, T. A. Jaggar and R. H. Finch discuss the relation of regional tilting to regional rainfall distribution. They point out that the northeast slopes of Kilauea receive many times as much load from rainfall as do the southwest slopes of the mountain. They conclude that "such a loading might be expected to give a northeasterly tilt at the Observatory. There is, (judging from their study of a three-year record) however, practically no correlation between tilt and rainfall, either daily or seasonal.—If the winter irregularities (in the tilt curve) were due to rainfall, we would expect that in 1918, the wettest year, the winter curves would be more irregular than for 1919, the driest year, but such is not the case."

The local instances cited in the present article do not affect, in any way, this conclusion on regional rainfall and tilting. They indicate simply that local loading of the surface may cause a temporary local bending of the lava structure of sufficient magnitude to show up as abnormal tilting on the seismograph records.

KILAUEA REPORT No. 977

WEEK ENDING OCTOBER 12, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge

There have been no conspicuous avalanches from the walls of Halemaumau during the week. Large steam clouds have accompanied or followed several heavy showers, and on the evenings of Oct. 8 and 9 very striking cauliflower clouds rose over the pit. The wind was light enough so that they were not blown away immediately upon their formation.

At 12:04 a. m., Hawaiian Standard time, October 8, the instruments recorded a very small disturbance which was caused by a distant earthquake. The record is so poor that it is impossible to estimate either the distance or probable direction to the source of this teleseism.

Three very feeble earthquakes of local origin were recorded as follows: October 8, 8:16 p. m., and 10:30 p. m., no distance determined; and October 9, 7:46 a. m., distance to origin 35 miles. A total of 17 small tremors occurred during the week. This is the smallest number of these tremors recorded since the week ending August 17, 1930. The microseismic, or non-volcanic trembling decreased the early part of the week and has remained slight to the present.

The week's average of the tilt record shows that the ground under the Observatory has been tilted slightly to the northeast. The southwest rift of Mauna Loa still seems to be controlling the tilt movements, but there has been no notable increase or decrease of pressure to suggest movement of lava on a large scale since the deep earthquake of September 28.

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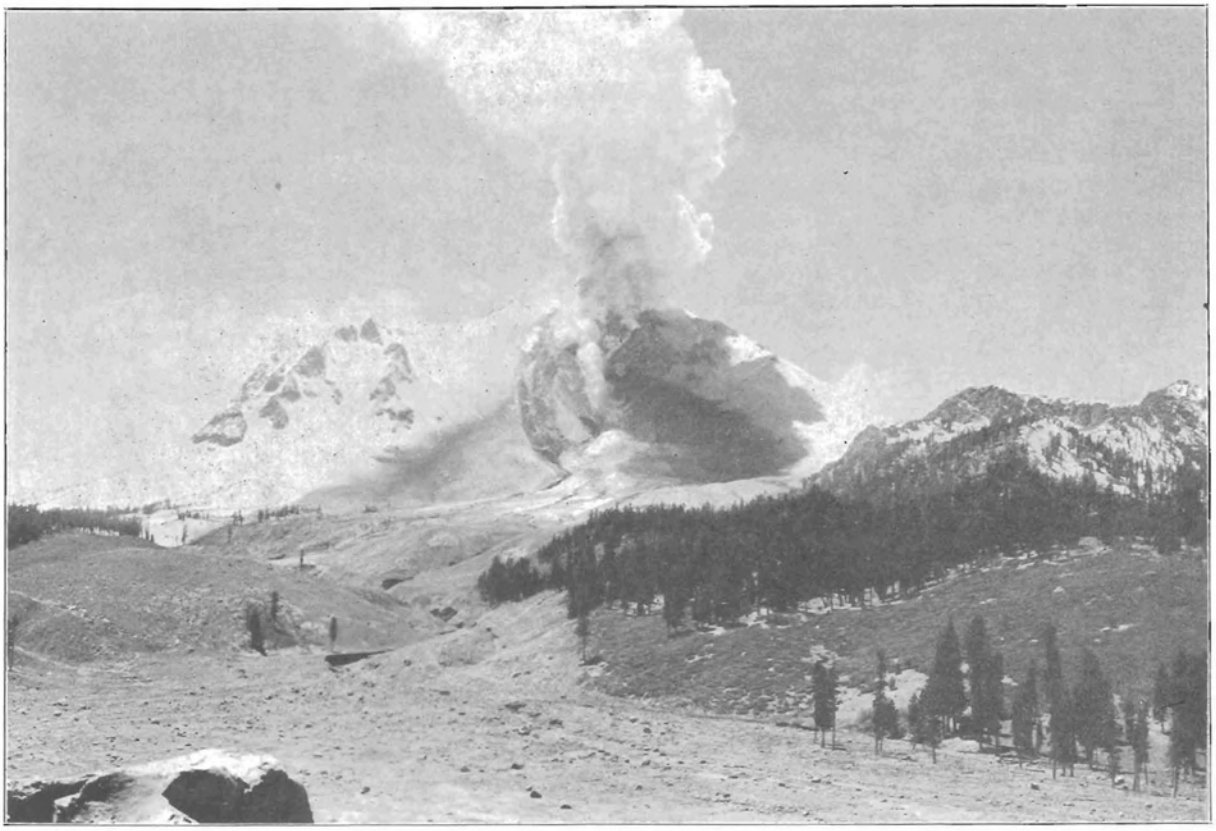
The Volcano Letter

Two dollars per year | Ten cents per copy

No. 304—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | October 23, 1930



One of the explosive eruptions of Mt. Lassen as seen from the northeast. The explosion is from the newly formed gash crater. The snow to the left of the crater is grey from the falling ash. Photo by B. F. Loomis.

ACTIVITY OF LASSEN PEAK, CALIFORNIA, UP TO 1915

By H. C. HANNA

References: Popular Science Monthly, March 1915, Professor Holway. Lassen Peak Folio, U. S. Geologic Atlas, Folio 15. U. S. Dept. of Interior Bulletin, June 1 to Sept. 15.

It is almost certain that no white man had ever witnessed an eruption of a volcano in the State of California until May 30, 1914. On that date Lassen Peak, a well known volcanic cone about seventy-five miles southeast of Mt. Shasta, suddenly burst into explosive action. During the six months that had elapsed when Professor Holway presented his article there had been an average of one eruption every three days, and no indication at that time that the activity had ceased.

A natural curiosity exists concerning the event that took place in view of probable developments of the future. Was this activity a sign of rejuvenation of a long quiescent volcano? Will this volcano again erupt lava?

Lassen Peak is located in the extreme southeastern corner of Shasta County, nearly two hundred miles from San Francisco. It lies on the southern tip of the great Tertiary lava field, some 250,000 square miles in extent, which covers not only northeastern California, but parts of Oregon, Washington, Idaho, and Nevada as well. Lassen marks the southern end of the Cascade Range and is the last of a series of volcanoes of which Rainier, Adams, Hood, Three Sisters, Pit, Mazama, and Shasta are familiar examples. South of this mountain range are the Sierra Nevada Mountains which were caused more by great faulting and uplift than by volcanic accumulation.

Until this recent outbreak (1914), Lassen Peak belonged to the class of doubtfully extinct volcanoes. As shown by the following statement, Diller did not consider the volcano extinct: "That volcanic activity is not yet extinct in Lassen Peak is shown by the presence of numerous solfataras and hot springs. At Bumpass' Hell, near the southern base of the peak, there are boiling mud pools and vigorous solfataric action."

Previous to the eruption of 1914, there have been several accounts of eruptions reported by the Indians who claim to have witnessed them shortly before the coming of the white settlers. Following is a report of Dr. J. W. Hudson of Akiak, California.

"I was in that region in 1904 collecting for the Field Museum of Natural History, Chicago, and heard much of

Lassen volcano in the summer of 1924 after all eruptions had ceased. Most of the light colored material on the flanks of the volcano and in the foreground is powered rock which was erupted during the activity of 1914 and 1915. Photo by B. F. Loomis.

Lassen Butte. An old Indian told me that when a child, an earthquake occurred at Lassen one summer day. The sun rose, but finally faded to the darkest night——. In many localities along the Pit River watershed, I heard similar reports amongst the aged Indians. The name of this volcano in Palinikau tongue is "Am bliikai," ie. "Mountain-ripped-apart."

Prompt investigation of the first eruption is due to the fortunate fact that the mountain is included in Lassen Peak National Forest, and that the U. S. Forest Service had built a fire look-out station on the topmost crag of Lassen Peak itself. When the eruption began in 1914, the lookout stations had not yet been occupied for the summer season. It can be seen that the interests of the forestry service made the activity on Lassen almost immediately investigatable.

The following is a report made by W. J. Rushing of the Forestry Service:

"Such wild stories are being circulated concerning Mt. Lassen that I am sending you the results of our observations to date. Saturday, May 30, the first outbreak occurred at 5 p. m. This was witnessed by Bert McKenzie of Chester who was looking directly at it when it occurred. Ranger Abbey investigated it on Sunday, May 31, finding a hole 25 by 40 feet in size and of unknown depth. Sand, rocks as large as a sack of flour, and mud were ejected. The heavier material was thrown over an area 300 feet across, while the ash was scattered over an area a quarter of a mile across. No molten material was thrown out. At 8:05 a. m., June 1, a second outburst occurred, throwing out large quantities of the same sort of material. Boulders weighing a ton were ejected. The vent was enlarged to 60 by 275 feet. On June 8, heavier volumes of steam were noted, and at night, another eruption took place, throwing out more ashes and fine material.

"Heavy volumes of steam are coming out of the vent today. We have watched it carefully, and at no time have we been able to see any flame or indication of fire. The vent is about one quarter of a mile from the fire look-out house, and if it continues eastward, as it has so far, it will finally break out on the east side."

Mr. Macomber, a member of the Forest Service spent the night of June 4 at the fire lookout house and reports: "The crater measured 275 feet long. It was then in a pause between explosions. Cracks appeared in the ground and sulphur smoke was rising from them. The walls of the crater were perpendicular and about 60 or 70 feet in height. In the center of the crater floor there appeared a pile of rocks."

On June 14, there occurred the heaviest eruption up to this time, and it was from this explosion that the only injuries during the whole six months period were incurred.

Mr. B. F. Loomis gives a brief summary of the experiences of the party that was caught by this eruption:

"Mr. Phelps party reached the rim of the old crater and sat down to rest a short time, watching the smoke from the crater, when the eruption began. Without any warning or explosion that could be heard, a huge column of black smoke shot upward with a roar, such as would be caused by a rushing mighty wind, and in an instant the air was filled with smoke, ashes and flying rocks from the crater. They all ran for their lives. Mr. Phelps hid under an overhanging rock, which sheltered him from the rocks which brushed past him as they fell. Lance Graham was a few feet away and was struck by a flying rock, which cut a great gash in his shoulder, piercing the thoracic cavity, and broke his collar bone. He was left on the mountain as dead for a time, but was then removed with great difficulty. He is now recovered. Another of their party ran down the mountain and coming to a snow drift, slid down the mountain like a shot. The cloud of smoke kept pace with him and when he reached the bottom of the snow drift, he found a clump of bushes and diving into it, buried his face in the snow to keep out the blinding smoke and ashes. The smoke is described as causing the blackest darkness, black as the darkest night."

Volcanic dust or ash from the different eruptions has been reported as falling from ten to twenty miles from the peak, the amount and direction varying with the wind. The limits of the heavier falls of ash were within a circle of less than a mile. The direction of the dust outbursts varied, irregular streaks of ash such as that of June 26 showing minor outshoots of dust in various directions. Exaggerated reports of the distance to which stones were thrown were based on the distance they were found on the outer slopes of the old crater. To avoid mistaking such stones for those thrown out by the eruptions, careful search was made on level patches of the old snow so located that it was impossible for stones to roll down on to them. Wherever such places were found, there was no evidence that ejected stones fell at a much greater distance than to the lookout house, and certainly no further than one-half mile from the crater.

The winter's snow had largely disappeared and near the top of the mountain snow was to be found only in patches and beneath a covering of ashes. These areas appeared black in contrast with the light grey of the greater part of the mountain crest due to the presence of dust. This dust was so fine that it was easily moved by the wind and at times a strong gust would send immense clouds into the air, thus giving the appearance of an eruption which would fool observers at a distance and to these probably were due the many false reports about new eruptions that never existed.

During the month of August there were eight eruptions, fewer than either of the preceding months. Seven out of eight of these threw dust as high as 10,000 feet and were considered quite severe. The record for September showed 17 eruptions, the largest number for any of the six months covered in this report. During this month there was an enlargement of the crater and new vents were opened.

The most remarkable change in the crater (new on the northeast side) occurred in September. The inner vent was 900 feet in length. The severity of these September eruptions is confirmed more or less by the fact that the lookout house there was completely demolished on the 29th of September. The forest lookout on Turner Mountain reported having seen red hot stones ejected. This was confirmed by other observers who claim to have seen flames. This, therefore, is the only observation during these eruptions that indicates such temperatures as molen lava.

The records of October and November are incomplete due to the severe storms in the vicinity which prevented observations. However, these two months are credited with 16 eruptions which shows that the volcano was by no means becoming quiet. Later in January 1915, the San Francisco Chronicle reported an eruption from a new crater on the east as equal to any that had gone on before. The article also stated that no one had visited the volcano for a period of three months.

Mr. Rushing in a letter to the author made some observations during November and states that the eruptions could be classed as medium. He gives a suggestion that this fact may be explained by the fact that a new vent had been opened at a lower level. A comparison of distant observations from the north and from the south would be necessary to test the correctness of Rushing's supposition.

The action of the "smoke" from Lassen is well described by Prof. C. F. Shaw who says:

"The smoke rolled up until practically the entire height of 12,000 feet was reached before any change in its form occurred, when just below the top of the column there was a tendency to stratification and a layer extended out toward the south and toward the north. When this appeared, the smoke column began to lean toward the north and, from our point of vision apparently toward the northeast, distortion took place with the inclination of the column, the upper part spreading out into streamers. As soon as the inclination of the smoke column became very plain, we could readily distinguish indications of falling material. The lower two-thirds of the column seemed to be dropping some material that was falling in a slightly oblique line, the obliqueness pointing back toward the mountain peak. As the eruption continued and the smoke column blew out more toward the north, the streaked condition indicating falling material become more and more apparent, but as the light was failing it became rather hard to distinguish the exact outlines of the lower portion of the column." c

The falling matter must have been the stones and coarser material in distinction to fine ash forming the top of the column of "smoke." Professor Shaw's observation is the only one received by the author that indicates the height to which the heavier fragments were thrown. His statement indicated a total height for coarser material of 8,000 feet.

All of the observers agree that there was no molten lava ejected. Samples of the ash were submitted to Professor A. S. Eakle of the University of California and his report states that the ejected material was composed entirely of fragments and dust particles formed by the shattering of the old volcanic rock which makes up Lassen Peak. The activity, accordingly, must have been all steam explosion, with no eruption of new lava to the end of 1914. (A plug of new lava did make its appearance in the crater of Lassen at a later date).

KILAUEA REPORT No. 978

WEEK ENDING OCTOBER 19, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

The early part of the week passed with no happenings of interest at the Volcano. About noon on Saturday, October 18, several medium-sized avalanches fell from the north wall of the pit, and small slides were noticed occasionally on Sunday. Steaming from the wall and floor cracks was very light during the entire week.

At 8:25 a. m., October 20, a moderate earthquake dismantled all of the instruments at the Observatory. The quake was felt over the entire island, with localities on the slopes of Kilauea receiving the strongest shock. This evidence corroborated the data from the seismograms which indicated that the center of the quake was under Kilauea crater. It is not yet possible to form an intelligent opinion as to whether or not this shock is the forerunner of an appearance of lava in Halemaumau.

There were two quakes of very feeble intensity during the week, recorded as follows: October 13, 4:12 a. m., and October 17, 7:31 p. m. Neither of them has been reported as felt anywhere on the island. Seventeen tiny tremors which may have been of volcanic origin registered on the seismograph at the Observatory. The non-volcanic trembling of the island which is reported as microseismic motion was slight throughout the week.

The average of the week's tilt recorded shows that the northeast rim of Kilauea has been tipped moderately (about 1.5 seconds of arc) in a north-northeast direction, ie. away from the pit. Tilting in this azimuth has usually been associated with changes of pressure under Kilauea crater, and the tipping away from the pit is considered as an indication of increase of volcanic pressure. The earthquake of Monday morning was accompanied by a sudden tilt of nearly 1.5 sec. of arc in the same direction, suggesting that the quake was associated with upward pressure under Kilauea.

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The Volcano Letter

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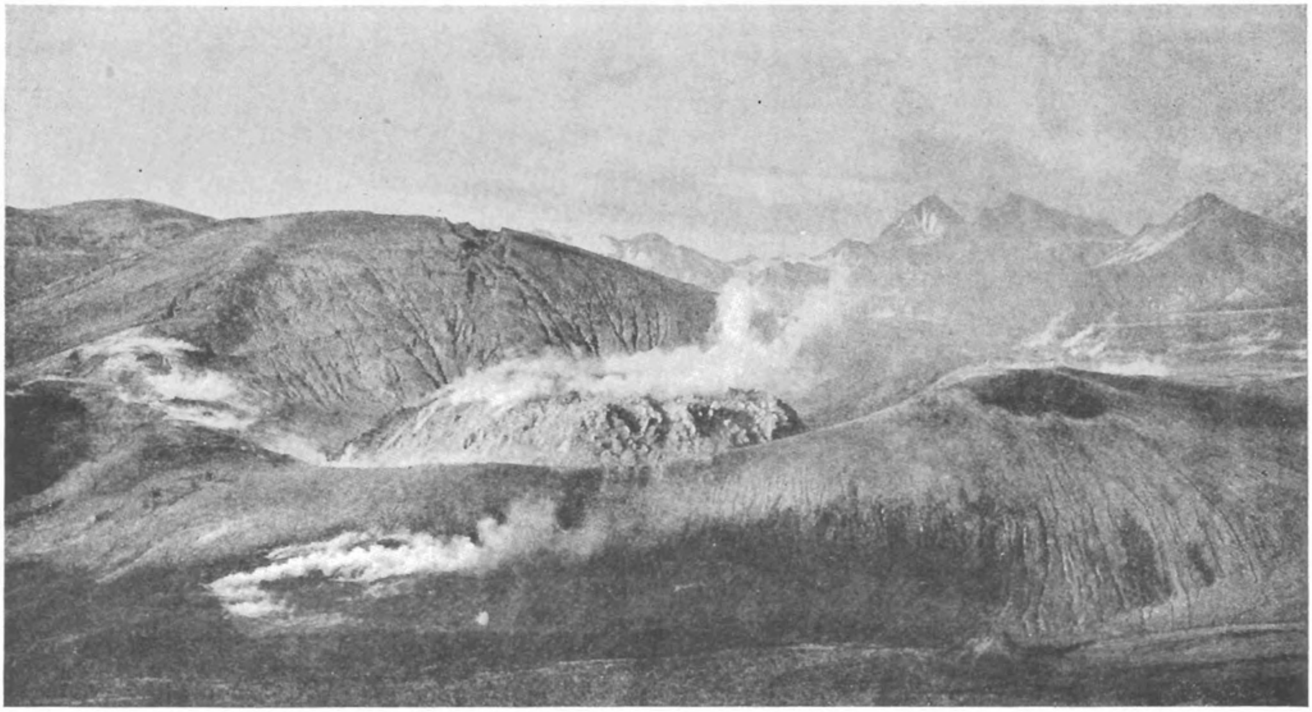
No. 305—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | October 30, 1930



Novarupta Dome, of siliceous lava, from the southwest, showing parts of the Valley of Ten Thousand Smokes beyond. Photo, National Geographic Society, 1919, from Katmai Series, No. 1.

THE ERUPTION OF KATMAI, ALASKA, 1912

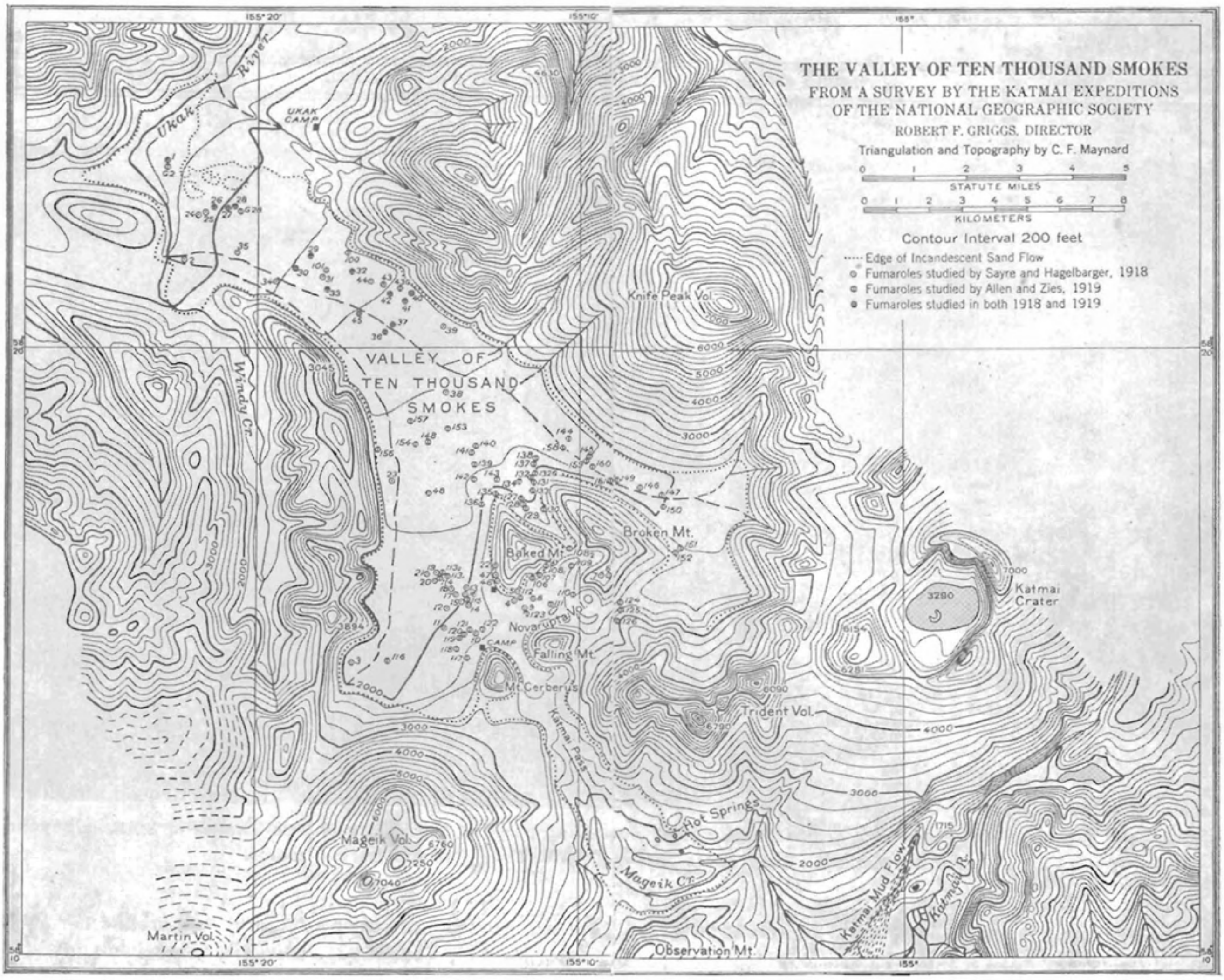
By H. Okimura. Reference: Robert F. Griggs, National Geographic, September 1921, pp. 219-292.

The explosion of Katmai Volcano in Alaska in June 1912 is ranked among the twelve greatest historic eruptions of the world. It is easy to see the justification of giving this rank when it is shown that as a result of this eruption, a town a hundred miles away was buried under a foot of ashes; that so loud were the concussions that the comments of people at a distance of 750 miles were excited; and that the quantity of dust thrown into the upper atmosphere was such that the intensity of the sunlight was diminished for many months throughout the northern hemisphere. The eruption giving rise to the Valley of Ten Thousand Smokes was a sequel to eruptions from the floor of valleys at a considerable distance from Katmai as shown by the fact that the stratified ashes from Katmai everywhere lie on top of the deposits of this earlier phase of eruption.

Lack of any eye-witnesses and any recorded happening resembling this sort of eruption made difficult the interpretation of the events of this great explosion. True, there was one, "American Pete" as he was called, who had witnessed the occurrence but aside from stating that it was dark and hot ashes fell, the only eye-witness could not much enlighten the explorers. The host of small volcanoes or vents which burst forth destroying the once beautiful green valley, presented a feature unusual in volcanic phenomena, for here no dormant vents had awakened, but volcanoes had been formed in areas where none had existed. The new volcanoes, made simply of holes blown through the floor of the valley, began to thrown out ash and pumice in enormous quantities soon after their formation.

It is believed that in addition to myriads of fumaroles, hundreds of vents must have been belching forth incandescent material in veritable torrents of fire. Quantities of red-hot solids and liquids, sands and stones, masses of fluid or semi-fluid lava rushed out of the vents and poured out on the ground to roll down the slope and consume everything along its path. It is also believed that had one been able to witness the scene, there would have been seen many separate volcanoes each pouring forth its own mass and giving rise to great black clouds to a considerable height in ever-expanding convolutions. The smoke, instead of deriving its source from the mass of incandescent material around the vent, originated from the gases that boiled out of the semi-molten lava. The quantity of gas given off was so great as to be able to puff up the lava into pumice and entirely disrupt it by the expansive force of escaping gas.

The valley was overgrown to an altitude of 1500 feet by a dense forest and except for the ancient lava flow the rocks of the valley are not volcanic, consisting of sand and shale full of fossils of marine shell-fish of Jurassic age. Long before fires that consumed the surrounding vegetation had time to run their course, the mass of incandescent fragments accumulating round the separate vents coalesced until they covered the whole area of the valley,



Map showing Katmai crater on the east, Novarupta Dome in the middle, and the pumice-filled Valley at the left. From National Geographic Society, Katmai Series, No 1.

converting it into a single fiery torrent of red-hot sand and rock which began to roll down the valley under gravity for seventeen miles and even at that distance the heat was so intense as to reduce every stick it touched to charcoal. This fiery mass is not comparable to ordinary lava, although undoubtedly a liquid in the beginning, it did not remain so, for the escaping gas converted it to solid fragments suspended by the enormous quantities of gas given off.

The main arm is toward Naknek Lake for seventeen miles while another completely encircles Broken Mountains. The greatest length is twenty miles while the greatest breadth is nine miles, the total area covered being 53 square miles. The magnitude of the operation by which it was produced could be conceived if it is said that the sand flow is equivalent to the output of all the stone crushers in the United States for a period of 100 years.

The highest temperature was 645 degrees Centigrade and a stick thrust into the hole was changed to glowing coal within a few seconds. Big fumaroles furnished any degree of heat that might be needed for cooking, while snowdrifts behind the tents gave water and provided refrigeration. The steam from the fumaroles was highly charged with either hydrochloric or hydrofluoric acid which ate the rope to pieces and made holes in aluminum pots. Bacon was fried in no time, while corn bread was baked satisfactorily in Nature's oven.

In some places, columns of very hot steam came out under considerable pressure. The emerging gas came with such a rush that when a cup of water was poured over it, the water was vaporized before it had a chance to touch the bottom and a hat thrown in was tossed up thirty inches in the air.

Although the explorers had been able to get a fair idea of the "Smokes" themselves, they had no adequate conception of the marvelous coloration of the valley. One of the men who had lived on the brink of the Grand Canyon was impressed with the striking colors which were altogether different from those of the Canyon. The colors of the Canyon being remarkable at a distance, the coloration is produced entirely by the wonderful atmosphere and brilliant light which floods its recess. The colors of the valley are more brilliant when seen at close range, but at a distance they are grayish or brownish due to the fact that all the colors of the spectrum, being present close together, blend into a neutral color. In some places considerable areas are leached out to a gleaming white by the acid fumes, while in some places pure yellow sulphur overlies other colors, and in still other spots where the ground is not too hot a bright green color is produced by the growing algae.

LASSEN REPORT No. 26

Lassen Volcano Observatory.

R. H. Finch, Associate Volcanologist.

During the summer of 1930 the National Park Service built a modern fire lookout building on the summit of Mt. Harkness, 8,039 feet above sea level. The United States Geological Survey installed seismographs in the basement of the building on August 21, 1930.

Eighty-eight tremors were recorded during the month that the seismographs were in operation. In addition to these tremors, there were, on many days, more or less slight continuous vibrations with a period of two seconds. This continuous shaking was stronger in the north-south direction than in the east-west. This type of vibration appears to be peculiar to the mountain top.

The entire mountain top is shaken by strong winds and the seismographs show a very irregular record on windy days. Puffs and gusts of wind produce records of tremor with considerable amplitude.

Good records were written of the southern California earthquake of August 30, 1930. The record of the Eureka, Cal., shake of August 23, 1930 was larger than that written by the instruments at Mineral. Several of the shakes that were recorded at Harkness were not recorded at Mineral.

Some time during July, the "Big Steamer" or uppermost large vent in the Supan Solfatara increased in activity and scattered mud for a distance of forty feet around the vent.

What was hitherto a large steam vent in the southeastern end of the Devil's Kitchen is now a boiling pool about 10 feet across. It boils constantly raising the main body of water to a height of four or five feet and occasional jets reach a height of 10 feet.

The Boiling Lake was the lowest during the summer of 1930 that it has been for several years.—R.H.F.

KILAUEA REPORT No. 979

WEEK ENDING OCTOBER 26, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge

A few avalanches in Halemaumau occurred simultaneously with the earthquake on Monday morning, October 20, which are thought to have been started by the quake. Since that time, no rock falls of noticeable size have been seen. The steaming of the wall and floor cracks has been very light except for short periods during rains.

The seismographs at the Observatory registered very slight traces of a distant earthquake on October 24. The record started at 9:55 a. m., Hawaiian Standard time. Only two local shocks were recorded during the week, the one moderate earthquake at 8:25 a. m. October 20, and one very feeble shock at 6:27 p. m. October 24. Fifty-seven very small tremors registered on the seismographs during the week, and the microseismic trembling of the island increased a moderate amount the later part of the week accompanying the few days of high wind and heavy surf.

During the earthquake of Monday morning, the ground under the Observatory was tilted to the north-northwest (errouneously stated last week as north-northeast). But since the quake, there has been practically no tilting of the ground as registered by the instruments. It would appear that the increasing pressure which caused the northeasterly tilting last week had culminated in the big quake. It will be interesting to see whether the first major change of pressure after this temporary standstill will be a decrease or a further increase.

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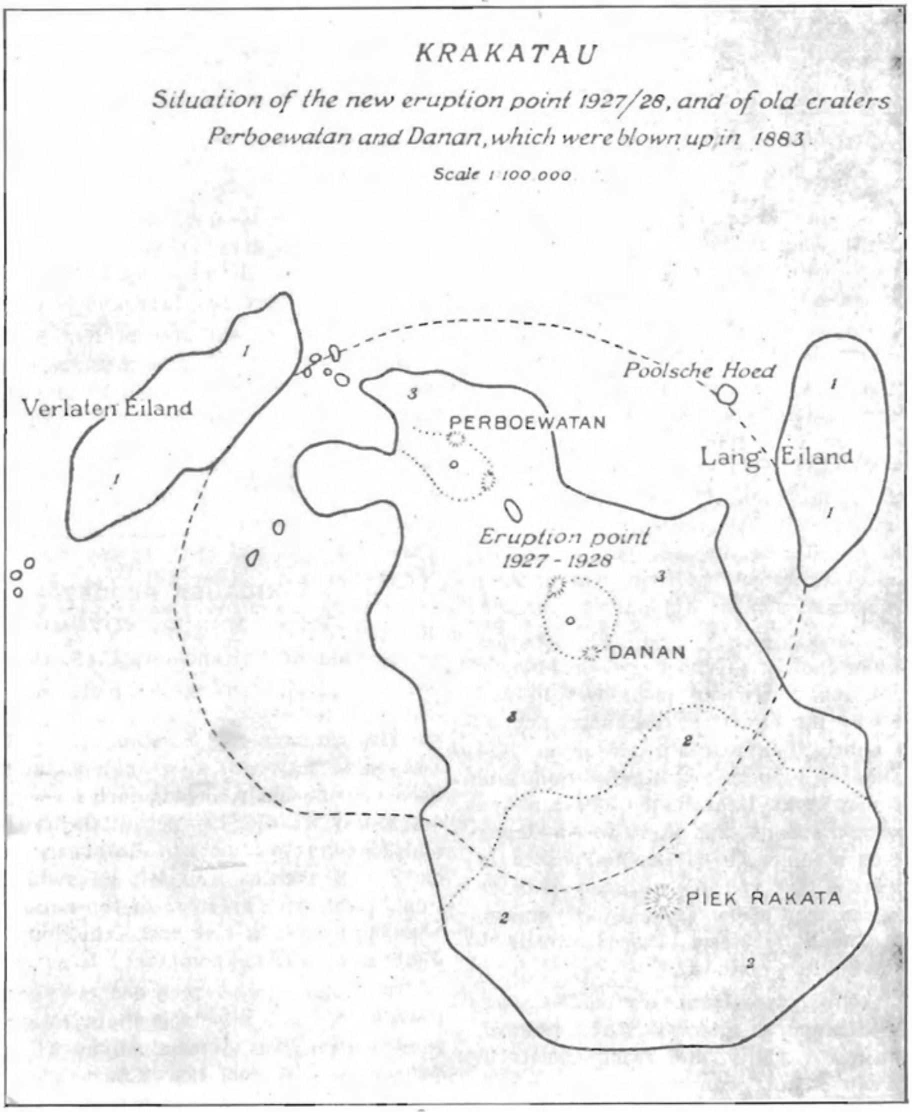
The Volcano Letter

Two dollars per year | Ten cents per copy
No. 306—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | November 6, 1930



.Arrangement of the three craters Perboewatan, Danan, and Rakata of Krakatoa in 1883. The area enclosed within the heavy broken line is that region which was engulfed in the 1883 eruption. The location of the 1927-28 activity also shown. After Stehn.

THE ERUPTION OF KRAKATOA, 1883

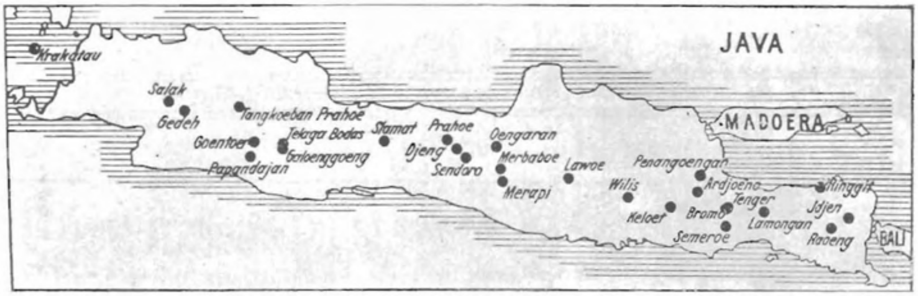
Review by R. A. Miyake of the Report of the Krakatoa Committee of the Royal Society.

Krakatoa is only a fragment of a great crater-ring rising out of the Sunda Strait, which separates Java from Sumatra. Along the line of this Strait we have evidence of a transverse fissure crossing the main fissure nearly at right angles. Upon this transverse fissure, a number of volcanoes have been built, namely: Pajung, in Java, with a height of 1,500 feet; the cone of Princes Island, 1,450 feet; Krakatoa, 2,623 feet; Sebesi, 2,285 feet; and Rajah Basai, in Sumatra, 4,308 feet.

In spite of the significance of its position at the point of intersection of these two great lines of volcanic fissure, Krakatoa had, until the year 1883, attracted but little attention.

On the afternoon of the 26th of August, and through the succeeding night and day till the early morning of the 28th of August, it was evident that the long-continued moderate eruptions (Strombolian stage) which had for some months been growing in intensity, had passed into the paroxysmal (Vesuvian) stage.

About 1:00 p. m. on August 26, the detonations caused by the explosions attained such violence as to be heard at Batavia and Brutenzorg, about 100 English miles away.



Distribution of active volcanoes in Java from Bali to Krakatoa. After Stehn.

One hour later, Captain Thomson of the Medea, then sailing at a point 76 miles east-northeast of Krakatoa, saw "a black mass rising up like a smoke in clouds" to an altitude which has been estimated as being no less than 17 miles. The great detonations at this time were said to be taking place at intervals of about ten minutes.

By 3:00 p. m. the explosions had so increased that their sound was heard at Bandong and other places 150 miles distant, and by 5:00 p. m. they had become so tremendous that they were heard all over the island of Java. The noise is described as being like the discharge of artillery close at hand, causing rattling of the windows and shaking of pictures and other objects hanging on the walls. Nearly all observers agree that there was nothing in the nature of earth-quake shocks, but only strong air-vibrations.

At 7:00 p. m., when the dense vapor and dust-clouds brought on early darkness, the whole scene was lighted up from time to time by the electrical discharge, and at one time the cloud above the mountain presented "the appearance of an immense pine tree, with the stem and branches formed with volcanic lightning." The air was loaded with excessively fine ashes, and there was a strong sulphurous smell. The steamer G. G. Loudon passed to the northwest and west of the volcano within a distance of 20 or 30 miles. It was seen to be "casting forth enormous columns of smoke" and the vessel passed through "a rain of ashes and small bits of stone."

The explosive bursts of vapor beginning on the afternoon of Sunday and continuing at intervals of ten minutes, increased in violence and rapidity, and from sunset till midnight there was an almost continuous roar which moderated somewhat towards early morning.

The constant augmentation of tension beneath Krakatoa in the end gave rise to a series of tremendous explosions on a far grander scale than those resulting directly from the influx of the sea-water into the vent; the four principal of these occurred at 5:30, 6:44, 10:20 and 10:52 Krakatoa time on the morning of August 27. Of these, the third occurring shortly after ten was by far the most violent, and was productive of the most wide-spread results.

After the great outbursts of the early morning of the 27th, it appears that there was a lull for a time inasmuch as no explosions were heard at Brutenzorg during the afternoon. At 7:00 p. m. the explosions began again, increasing in violence until 10:00 or 11:00 p. m., when they again declined and finally ceased to be heard at 2:30 a. m. on Tuesday, the 28th of August.

The soundings of the ocean bottom around the volcano after the eruption showed that a great depression or fissure had been formed, which extended eastward from Krakatoa for a distance of seven or eight miles, and extended nearly in the direction of the great line of volcanic activity which crosses Java and Sumatra.

The greatest outburst of Krakatoa in 1883 was the excessively violent though short paroxysm with which it terminated. The phenomena displayed during this eruption are to be accounted for, according to Judd, by the situation of the volcano and its liability to great inrushes of water from the sea.

KILAUEA REPORT No. 980

WEEK ENDING NOVEMBER 2, 1930

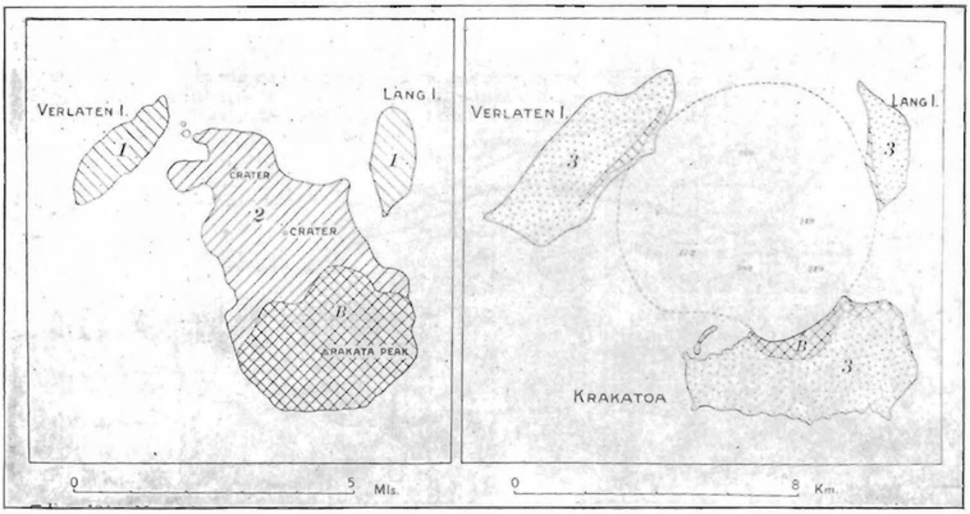
Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge.

Halemaumau still persists in showing no signs of reawakening activity. Even avalanching from the walls has been conspicuously absent during the past week, and the dry, sunny weather has permitted the steam from the wall and floor cracks almost to disappear. A slight earthquake on Friday evening was felt by many people in the National Park, and by some of the residents of Hilo. Probably it was felt in Kau and Kona, but was not sufficiently disturbing to cause comment.

The instruments recorded this quake at 6:23 p. m., October 31, as a shock of slight intensity. The distance to its origin was determined as 32 miles, which would place it as a Mauna Loa disturbance. Three very feeble quakes were also recorded by the Observatory seismograph as follows: October 28, 4:19 a. m.; October 29, 1:35 p. m.; and October 31, 7:41 p. m. None of these has been reported as felt, and the records were not clear enough to establish the distance to any of their origins. Small tremors which may have been of volcanic origin were more numerous this week, the instrument having recorded 42 of them in the seven days. Non-volcanic trembling of the island was slight during much of the week, but increased slightly with the strong winds of the week-end.

The average of the tilt readings for the week shows a very slight increase in a north-northwest direction. However, an analysis of the daily readings of tilt shows that there has been no consistent directional movement which would be the case if there had been a definite change in pressure conditions under either volcano. This makes the second week of apparent stagnation since the Kilauea earthquake of October 20. Some change, either an increase or a relaxation of pressure, may be expected during the coming week.



Plan of Krakatoa volcano before and after the great explosive eruption of 1883. After Daly.

THE ERUPTIONS OF CINDER CONE, LASSEN VOLCANIC NATIONAL PARK, CALIFORNIA

The existing knowledge of the eruptions of Cinder Cone, a small basaltic volcano near Lassen Peak, and descriptions and theories as to the origin of its rather remarkable lava are very well summarized in a recent paper by R. H. Finch and C. A. Anderson, "The quartz basalt eruptions of Cinder Cone, Lassen Volcanic National Park, California," University of California Publications in Geology, Vol. 19, No. 10, 1930, pp 245-273. The general descriptions of the eruptions is of considerable general interest inasmuch as the last lava flow from this vent is found to be one of the most recent flows in North America.

The first account of activity of Cinder Cone is a paper, published in 1874, by H. A. Harkness, "A recent volcano in Plumas County." He quoted statements from a number of independent observers which establish the fact that lights were seen in the Cinder Cone area on many different nights during the winter of 1850-51. Also two prospectors reported passing by an active volcano and hot rock in that region in the summer of 1851. On the strength of these reports and his own observation a little later, Harkness attributed all of the cinders and lava of Cinder Cone to activity in the winter of 1850-51.

J. S. Diller of the United States Geological Survey described a detailed investigation of Cinder Cone in several papers which appeared between 1890 and 1900. Diller showed that the volcanic features of this area are the product of two main periods of activity with a considerable time interval between. He showed that trees about 200 years old were growing near the old cinder cone, but that the more recent second period of activity might have occurred at some late date, though prior to 1840. He dismissed the Harkness evidence as in adequate proof of an eruption in 1850-51.

A. L. Day and E. T. Allen of the Geophysical Laboratory at Washington studied Cinder Cone in connection with their work on the Lassen Peak eruptions, and published their findings in 1925. They accepted Diller's idea of two periods of activity, but showed that a tree over 200 years old was growing at the edge of the younger flow. This new evidence was advanced against both Harkness' and Diller's dating of the late activity.

In 1927, R. H. Finch issued a preliminary statement to the effect that the later "flow" actually was made up of two or three flows of different age and that the youngest of these might be of very recent date.

In the same summer, A. E. Jones made a reconnaissance study of the magnetic properties of the flows at Cinder Cone. He found lava flows of at least five different ages; the three oldest belong to Diller's early activity, and the two youngest flows, to the late activity. The youngest flow was given an approximate date of 1846, and the oldest flow was dated about 500 A. D.

Finch and Anderson add a number of facts to this previously existing information. They show that the main cinder cone is the product of several different eruptions of pyroclastic material, probably separated by considerable intervals of time. Further several small cinder cones are found in different parts of the lava field, indicating that a number of vents were involved in the eruptive activity of the region.

They give a detailed discussion of the latest flow of black lava which is easily distinguished from the older flows by its fresh black color and its unweathered surface. This latest flow lies entirely on top of the older flows from Cinder Cone so that its hot margins never had an opportunity to destroy the vegetation which grows at the edges of the whole lava field. In view of this fact, the evidence offered by Day and Allen and by Diller to prove that the lava must be over 200 years old is not applicable to the youngest flow. Therefore Finch and Anderson conclude that this flow was formed by activity in the winter of 1850-51.—H. A. P.

TILTING OF THE GROUND DURING OCTOBER

A review of the tilt record for the month of October shows several features of interest. During the first few days of the month there was an extremely heavy rainfall at the Volcano. Accompanying this heavy rain, and perhaps caused by it, the ground tilted considerably to the south. Beginning about October 7, the ground tilted steadily and strongly in a north-northeast direction, which is up and away from the active center of Kilauea. Tilting in this direction has been found usually to accompany an increase of lava pressure in this volcano. This phase of the tilting was culminated by the earthquake of October 20 which produced a sudden tilt to the northwest. Since that date, there has been no consistent tilting of the ground, but only a very small amount of apparently aimless wandering. A tabulation of the amount and direction of tilt by weeks is as follows:

Sept. 20—Oct. 5	1.7 sec. of arc	—S.
Oct. 6—Oct. 12	1.3 " " "	—N.N.E.
Oct. 13—Oct. 19	3.1 " " "	—N.N.E.
Oct. 20—Oct. 26	1.1 " " "	—N.

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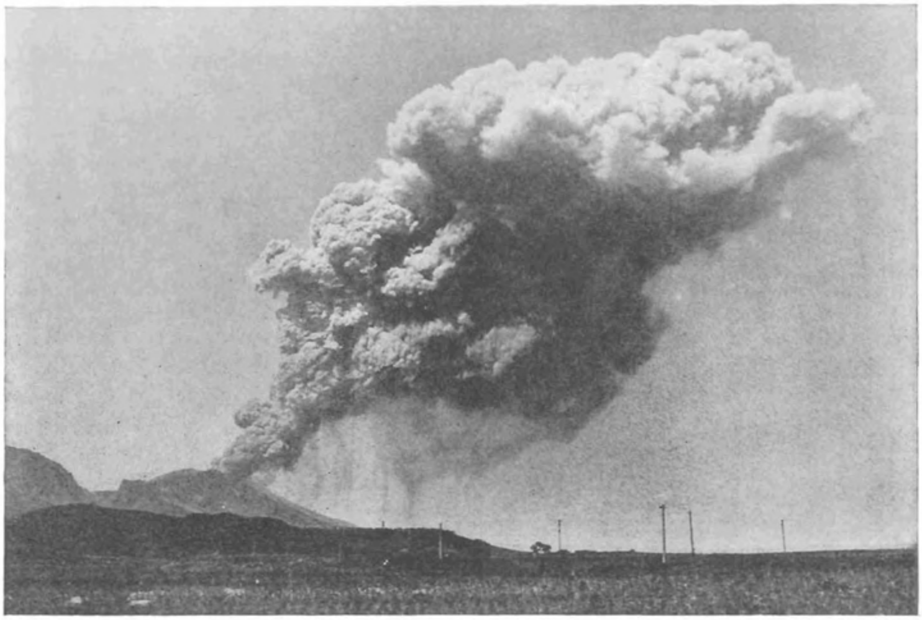
The Volcano Letter

Two dollars per year | Ten cents per copy

No. 307—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | November 13, 1930



An explosive eruption from Asama-yama in 1911. Much greater eruptions of this type from this volcano, Bandai-san, Krakatoa, Katmai, and others have thrown huge quantities of fine dust into the upper layers of the earth's atmosphere, creating a universal haze which affects the temperatures of the surface of the earth. Photo Uozo.

EFFECT OF VOLCANIC DUST ON EARTH TEMPERATURES

By H. C. HANNA

In June 1912, C. O. Abbot of the U. S. Geological Survey was in Algeria making measurements on the quantity of heat coming to the earth from the sun. At the same time, F. E. Fowle of the Geological Survey was engaged in making similar measurements at Mount Wilson in California.

At Bassou, Algeria, during Abbot's observations of June 19, 1912, he noticed streaks of dust lying along the horizon. These were joined by others and in a few days the sky appeared "mackereled" although no clouds were present. Finally the phenomenon became so marked that any observations were discontinued. On June 29, the whole sky was filled with haze which continually became worse until the expedition departed on September 10.

Thinking that this was merely a local condition, Abbot returned to the United States to learn of the eruption of Mt. Katmai in Alaska. He also found from reports of the Weather Bureau and European journals that these same atmospheric conditions had been noticed elsewhere.

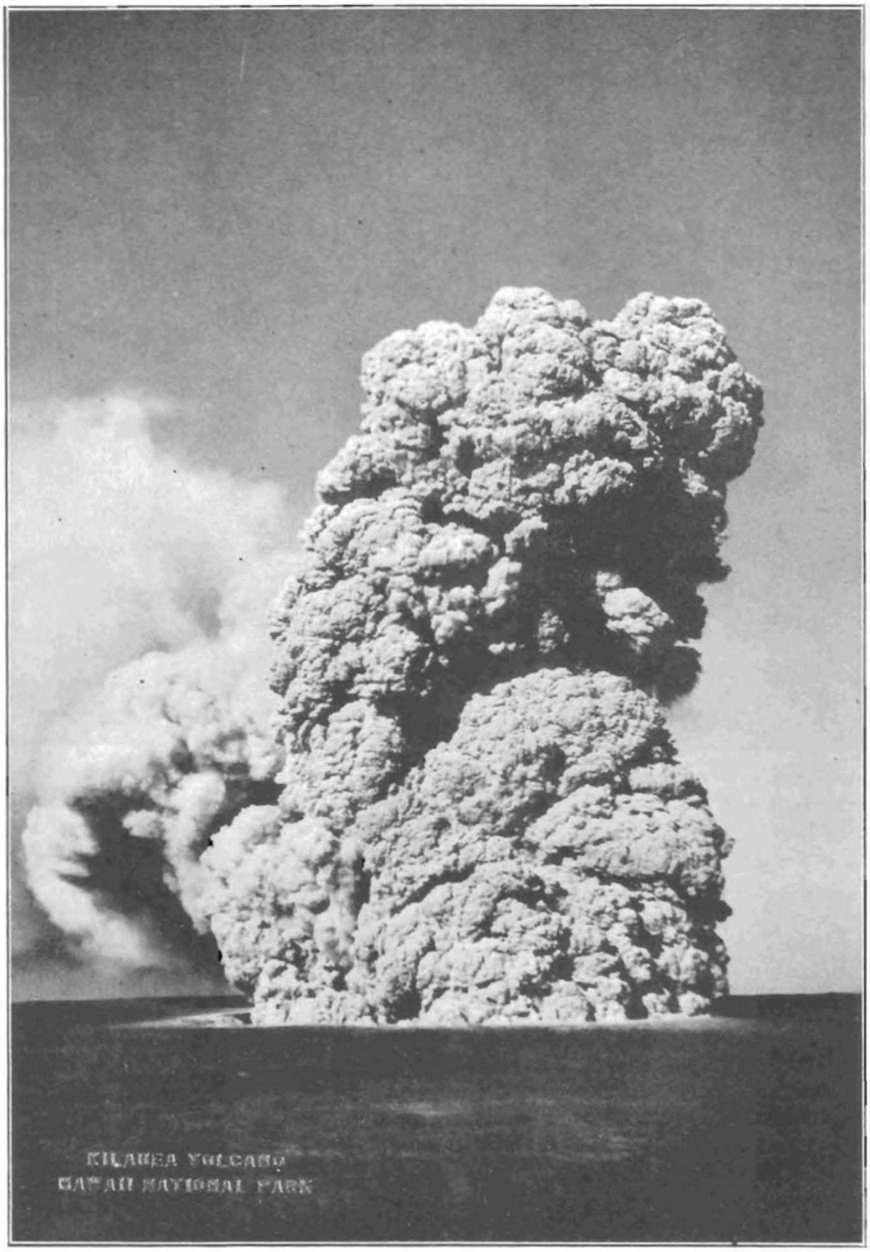
This effect was naturally assumed to have been caused by the Katmai eruption, and immediately estimates were made to discover the speed with which the dust reached certain distant points. Roughly the dust had moved at a rate of 40 miles per hour toward Washington; 25 miles per hour toward Basson; and 3 miles per hour toward Mt. Wilson. The small average speed toward Mt. Wilson probably is to be accounted for by the fact that it is more nearly south of Katmai and the high velocity winds follow a general course from east to west.

The nature of the observations made and the apparatus used should be considered; first, the pyrheliometer was used to measure the heating effect of the sun at the earth's surface; and second, the spectro bolometer, a device of Langley, was used to observe the excessively minute heating effects of the rays of different color in the solar spectrum. Using a thin, blackened thermometer, the heat produced by each ray of the spectrum from the ultraviolet to far beyond the red was measured.

Measurements were made at intervals of several hours. Then knowing the angular distance of the sun from the horizon at each time of observation, the thickness of the layer of atmosphere traversed by the solar beam was computed. After this it was possible to determine how much greater the heat intensity of the rays would have been had the observations been made outside of the earth's atmosphere—"for instance on the moon." Then it was possible to determine how much the ray of each part of the spectrum had been diminished by passing through the dust-laden atmosphere on its way to the earth's surface.

From these measurements it is shown that the haziness of the atmosphere during the summer of 1912 produced a very marked decrease in the direct solar radiation for all parts of the spectrum which reached nearly 20 per cent of the total heat at high sun.

There was naturally an increased brightness of the sky for this loss of heat in 1912. This was due to the



One of the explosions from Halemaumau in 1924. The Hawaiian volcanoes are not in the habit of erupting with a violence sufficient to throw dust into the uuper atmosphere.

reflection of the sun's rays from the dust in the air, thus making the sky bright as do the particles of dust in a room reveal the path of a sunbeam in it. One can easily see that since the light of the sky and the loss of heat by reflection into space both depend on the presence of the particles of dust in the atmosphere, an increase of the dust must make the sky brighter and the loss to space of sun heat greater.

In the main it is this that interested the observers for they wished to inquire how much heat was lost to the earth by the reflection of the atmosphere, owing to the dust which came from Katmai volcano. Abbot and Fowle constructed a formula involving the following factors: (A) is the direct solar beam; (B) is the skylight; (C) the rays absorbed by atmospheric water; (D) rays reflected into space from upper atmosphere; and (E) heat of solar beam outside the earth's atmosphere, approximately the sum of A, B, C, and D.

Measurements of (A), the direct sun rays, and (C), the absorbtion by water and other atmospheric vapors, are made each day. Abbot built an apparatus to measure (B), the direct light of the sky. Knowing, then, the value of (E), (D) could be found readily by subtracting from (E) the sum of (A), (B), and (C).

Following this proceedure, the results obtained at Bassou on the 5th, 6th, and 7th of September, 1912, were as follows, stated in calories per square centimeter per minute:

(A) Heating effect of direct beam of zenith sun.. 1.250
(B) Heating effect of entire sky .... .245
(C) Heating effect of rays absorbed by atmospheric vapors .... .175
Total of (A), (B), and (C) 1.670
(E) Heating effect of sun outside earth's atmosphere 1.950
(D) Heat lost by reflection from dust in atmosphere 0.280

Thus 0.280 calories per square centimeter per minute represents the heat reflected to the atmosphere in 1912. In previous years, it was found from experiments at Mount Wilson and Mount Whitney that this heat reflection was less than .050 calories. From these results, Abbot draws the following conclusion: "I am of the opinion that the difference between these results of 1912 at Bassou and those of earlier years at Mt. Wilson and Mt. Whitney (about 0.200 calory) represents approximately the radiation reflected away to space by the volcanic dust of 1912, or, in other words, the loss of heat available to warm the earth which we must attribute to the great haziness which prevailed in 1912. Hence I conclude that the dust of Katmai diminished the heat available to warm the earth in the north temperate zone about ten per cent during the summer of 1912. In accordance with the laws of heat and radiation, this might produce a fall of seven degrees Centigrade in the temperature of the earth as a whole if it were effective for a long enough period of time."

The question naturally arises as to whether volcanoes can really produce such world wide haze. Going back to the records of times of the great volcanic actions of the last 150 years, we have the eruption of Asama-yama, Japan, in the year 1783. In the same year occurred another extraordinary eruption, that of Skaptar Jokul in Iceland which took place on June 8 and 18th.

Arago records dry fogs in the upper atmosphere on about the same date at places distant from each other such as Paris and Avignon, Turin and Padua. It extended from the north coast of Africa to Scandinavia and lasted more than a month. In Languedoc, its density was such that the sun was not visible until it had reached a position 17 degrees above the horizon, and at the time of new moons the nights were so bright that small print could be read even at midnight.

In 1815 occurred the eruption of Mayou in the Philippine Isuands and on April 7 to 12, 1815, the eruption of Tamboro Sumbawa. For three days there was absolute darkness for a distance of 300 miles. Then came the long twilights and sunsets for which the year of 1815 is so notable in Europe.

Hecla and Vesuvius erupted in 1845 and 1846, and Merapi in 1872. In 1883 occurred the eruptions of Krakatoa and St. Augustine in Alaska. The extraordinary atmospheric phenomena which followed these remarkable volcanic eruptions were so in relation of effects to causes that there can be no doubt as to the reasonableness of ascribing the haze of the summer of 1912 to the volcanic eruption in Alaska.

Very great departures from the usual intensities of solar radiation occurred from 1803 to 1807, 1888 to 1893, and from 1902 to 1904. We have only to look back to the history of such volcanic eruptions as Wulano and Mayon in 1888, Meharaizan in 1889, Mt. Zoo in 1890, Bandaisan and Etna in 1892, Pelee and Santa Maria in 1902, Colnira in 1903 to see that the decrease in solar radiation over these periods had much volcanic action to cause it.

Abbot assembled data on recorded temperatures during the year 1912 which show that the surface of the earth was appreciably cooled, especially in the high mountain regions, by the haze from the explosion of June 1912.

He studied the temperature departures for Pic-du-Midi, Puy-de-Dome, and Lchneekoppe for the years 1882 to 1884 inclusive to determine the effect of the Krakatoa eruption. These results, however, were not so satisfactory, although, at some of the stations, daily temperature depressions were found beginning in September 1883. He says:

"The fact is that the temperature of the earth is a function of so many variable quantities that general or cosmical effects are often greatly obscured by local ones. Studies, however, are being made by several authors to detect if there is a periodicity of terrestrial temperature corresponding in time to the sun-spot cycle of about 11 years. It has been found that there is indeed an increased temperature at times of minimum sun-spots. This increase of temperature is greater than would be caused directly by darkening of the sun by sun-spots, so that it seems that there is accompanying the spots, some secondary influence affecting terrestrial temperatures."

These fluctuations in temperature not being accounted for by the variation of sun-spots, Abbot and Fowle have endeavored to see whether a combination of the effect of the sun-spot cycle with the effect of volcanic haze will produce a more exact correspondence between the cosmical phenomena and the temperature curve of the earth's surface.

Their work gives a set of curves comprising the sun-spot curve from 1880 to 1909, the curve of departures from the mean temperatures at 15 stations in the United States and a similar curve of departures for the world. These three curves show, quoting Abbot, "a considerable degree of correspondence yet it is not hard to see that there is also much discordance." This diagram tends to lead to the conviction that terrestrial temperature varies in accordance with fluctuations in the number of sun-spots and, in addition, that the intensity of the sun's direct radiation as measured at the earth's surface is much modified by such terrestrial phenomena as the dust of volcanic eruptions.

Humphreys follows a line of reasoning similar to the above writers though he carries his conclusions farther. The main differences between his views and those of Ellsworth Huntington (another student of the subject) are that (1) he regards variations in solar activity as of negligable importance so far as our present knowledge is concerned and (2) he strongly emphasizes the importance of volcanic dust. In his own words,

"Variations in the average temperature of the atmosphere depend jointly upon volcanic eruptions through the action of dust on radiation and upon sun spot members, through, presumably, some intermediate action they have upon the atmosphere.—Hence, as there appear to have been several periods of great volcanic activity in the past with intervening periods of quiesence, it is inferred that volcanic dust in the upper atmosphere was at least an important factor in some, if not all, the great universal climatic changes."

Huntington does not agree entirely with Abbot, Fowle, or Humphreys. After a lengthy discussion of facts, he concludes that the variations in the sun are the main factor in modifying terrestrial temperature, but their effect may be much modified by the presence of volcanic dust in the atmosphere.

It is thought that if volcanic explosions continue active through a more or less long geologic time they could alone, or in part, cause cold or even glacial climate. We should, therefore, expect an extremely cold climate at the end of a mountain-making era during the "critical periods." Huntington points out that we have had ice ages at the close of the Paleozoic and Cenoxoic eras, but that the close of the Mesozoic (an era of extreme mountain making and volcanic activity in North America) did not result in a glacial but only a slightly cooled climate. There is also evidence that volcanism was renewed in the Cordillera of North America throughout much of the Eocene, and yet there was no glacial climate at the end of this time. In the same way there was a marked temperature decline at the close of the Cenozoic in the Pleistocene. Equally extensive movements were going on in Europe in the rise of the European Alps and earlier movements did not affect the climate.

It seems however, although there is some difference of opinion among the authorities on the importance of volcanic dust, that the most logical conclusion to draw from these discussions is that volcanic dust in the isothermal regions of the atmosphere has caused serious effects upon the temperature of the sun's rays at the surface of the earth.

References

National Geographic Magazine, February 1913, an article by C. O. Abbot.

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Climatic Factor, Ellsworth Huntington, 1914.

KILAUEA REPORT No. 981

WEEK ENDING NOVEMBER 9, 1930

Section of Volcanology, U. S. Geological Survey
H. A. Powers, Temporarily in Charge.

Halemaumau is still remarkably quiet. Steaming has been almost nil during the daylight hours of the week. A rather striking cumulus cloud was noticed above the pit the evening of November 4 which was formed when the column of warm air rising from the pit was interrupted by a layer of cold air blowing across the summit of Kilauea. No avalanches in the pit have been noticed or reported.

The seismographs recorded only one very feeble earthquake on November 9 at 5:14 a. m. The distance to its center could not be determined. Forty-four small tremors registered during the week and the non-volcanic microseisms have been of moderate size accompanying the rather heavy surfs which have been pounding on the coasts of the island.

The average of the week's tilt record shows a very slight tilt to the northeast, up and away from the crater. However, there has been no marked change in the tilting of the rim which would indicate a change of pressure conditions under the volcano.

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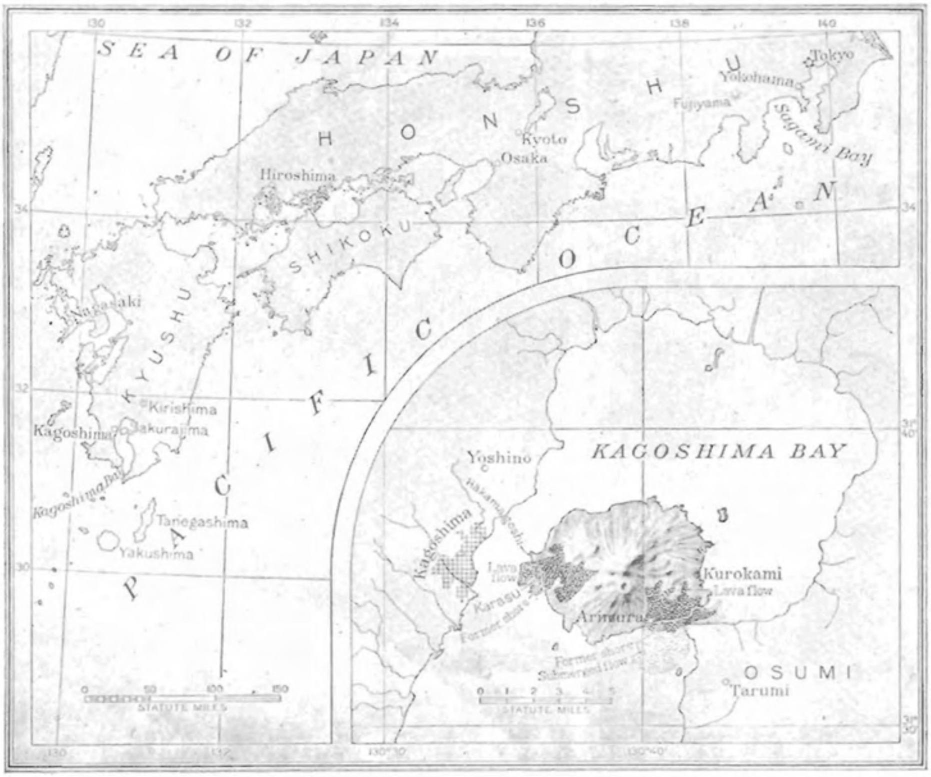
No. 308—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | November 21, 1930



Map of southern Japan and of Kagoshima Bay, showing Sakurajima and its 1914 lava flows. From National Geographic Magazine, April 1924.

ERUPTION OF SAKURAJIMA, 1914

Review by K. Onishi of F. Omori's article in the Bull. of the Imperial Earthquake Investigation Committee, Vol. VIII, No. 1, Sept. 1914.

Sakurajima volcano forms a small island in Kagoshima Bay on Kyushu, the southermost island of Japan proper. It is located on the great Kyushu rift, a crack which runs in a southeasterly direction from Japan to the Bonin Islands. The volcano has two high peaks, Minamidake and Kitadake, and a parasitic cone on the eastern flank called Nabeyama. A number of hot springs rise from its slopes. At the time of the eruption, the population of the island exceeded 23,500.

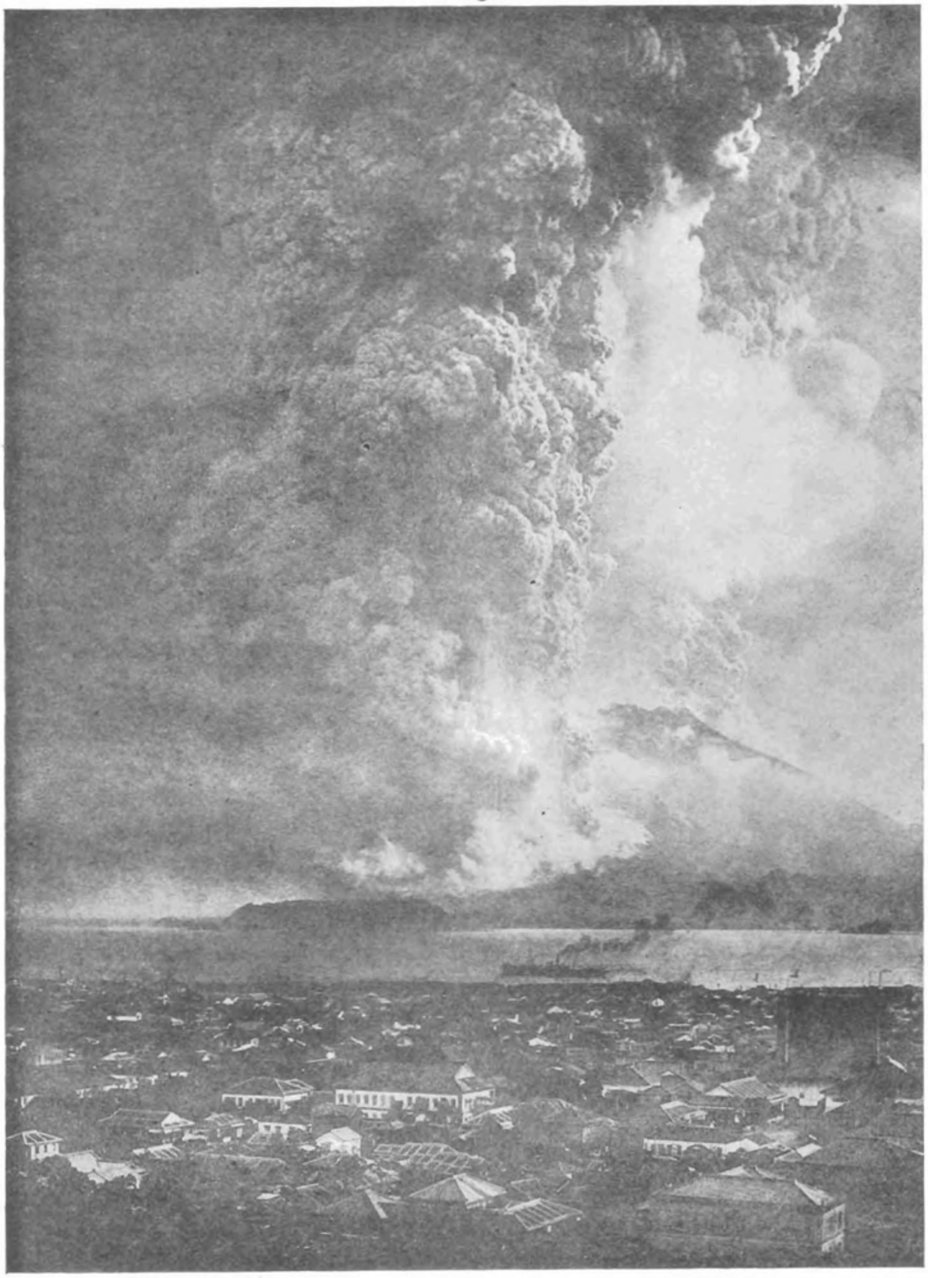
Investigations of the occurence of volcanic activity seem to point to a cycle of about 130 years in the Japanese volcanoes. In the years 1777-92, about 130 years previous to the year 1914, Oshima, Sakurajima, and Asama-yama had had tremendous outbreaks. Since Asama-yama, in 1908, and Oshima, in 1912, had produced numerous earthquakes and lava flows, Sakurajima was expected to follow suit not long after. Kirishima-yama, some 45 km. to the north of Sakurajima, finally burst out in November and December of 1913, and Sakurajima followed with an eruption two months later.

Warnings that Sakurajima was ripe for an eruption came in the forms of smoke, earthquakes, and an increased flow of water from the springs on the mountain. On the island, earthquakes were felt from the night of January 10, while the city of Kagoshima (on the shore of Kagoshima Bay) was mostly unaware of them until early in the morning of January 11. The frequency of the shocks increased with the progress of time, the greatest hourly numbers 28 and 27 being reached resepectively at eight to nine p. m. on the eleventh and three to four a. m. on the twelfth. As many as 66 shocks in one hour were felt on Sakurajima.

Early the morning of the 12th, the people noticed that water with a high temperature had started to issue from a number of places, and more could be seen bubbling up through the sea. On the opposite end of the island, the volume of water from the natural cold springs increased considerably while many wells had their water levels raised two to three feet.

At 8:00 a. m. on the 12th, a column of white smoke was seen rising from the top of Minamidake. Earlier in the morning, observers from Kagoshima had noticed slender filaments of white vapor above the mists that shrouded the mountain. Two hours after the smoke from Minamidake was seen, the first eruption occurred.

The unmistakable signs of the approaching disaster were sufficient to alarm the inhabitants who immediately began to desert their homes and seek refuge in Kagoshima



The eruption of Sakurajima on January 12, 1914 as seen from the heights back of Kagoshima. The peak is clear and the smoke and ashes are rising from rifts on the near and far sides of the cone. After Omori.

and the neighboring villages. The evacuation of the island was so exceptionally well handled that the whole population of over 23,500 was safe from harm when the final break came.

The first outburst came from the western side of the mountain facing Kagoshima about 500 meters up the slope, at 10:00 a. m. July 12. An interval of some 10 minutes followed when the east side of the island burst open with huge columns of smoke which rose to a vertical height of over 20,000 feet above sea level. This explosion completely enveloped the island in a mass of white and black smoke within a few hours.

On the evening of the first day of the outbreak, at 6:30, a strong quake took place. After this shock, the hot lava became stronger, reaching its maximum between 11:00 p. m. of the 12th and 5:00 a. m. of the 13th. After ten o'clock of the morning of the 13th, the violence of the explosions gradually decreased.

On the eastern and western sides of Sakurajima were formed seven small craters from which issued a lava of very high viscosity. The stream on the west reached the sea on the 16th, averaging 45 meters per hour during the first two and a half days. The lava continued to flow into the sea until it had invaded about two and one half square kilometers of former sea-bottom. The flow on the eastern (Nabayama) side was much faster, the lava finally blocking the narrow strait and joining the island to Osumi, intensity of the volcanic noises and the projection of red converting Sakurajima into a peninsula.

The total area covered by the western flow amounted to 8.33 sq. km., while the eastern portion covered approximately 15.41 sq. km. The estimated total volume of lava that was ejected was 1.6 cu. km., the western half contributing .33 cu. km. and the remaining 1.27 cu. km. being the contribution of the eastern flow.

The showers of hot pumiceous lava fragments and ashes did considerable damage to the whole island, the villages of Koike and Akobaru on the west and Kurokami being especially hard hit. The ash precipitation was slight in Kagoshima (about 3mm, deep) whereas the northern and central parts of Osumi on the opposite shore of the bay received from 3 inches in places to over 3 feet. The total amount of pumice and ashes which fell has been estimated to be in the neighborhood of .62 cu. km. or 40 per cent of the total volume of the lava output.

The total amount of material exuded from Sakurajima is thus 2.2 cu. km. which is equivalent to one twelfth of the volume of the whole mountain.

The strong quake of January 12 must have been one of very deep origin and not a shock immediately connected with the eruption, because the intensity of motion was nowhere in Kyushu excessively severe. It was probably caused by the stress accumulation along the whole volcanic chain in southern Kyushu. This quake took the only lives which were lost in the activity, 19 persons being killed.

Considerable excitement prevailed in Kagoshima during the course of the eruption. The fear of asphyxiation by the poisonous volcanic gases was reason enough for immediate evacuation. Rumors of a huge tidal wave helped to aggravate the fears of the nearly panic stricken people. The only real source of danger came from the one great earthquake. This quake was registered on very distant seismographs in Europe and America.

ACTIVITY OF A CALIFORNIA VOLCANO IN 1786.

The following quotation was brought to the attention of the writer by Dr. Max Ferrand, Director of Research of the Huntington Library and Art Gallery.

La Perouse, in voyaging along the California coast in 1786 witnessed a volcanic eruption, and the location given on his map is roughly in the Lassen region. A direct quotation from his observations is as follows:

> " . . . . our latitude, observed at noon, was 40° 48′ 30″ north; our longtitude, according to the timekeeper, was 126° 59′ 45″ west. I continued my course to near the land, from which, at night-fall, I was only four leagues distant. We there perceived a volcano on the top of a mountain, which bore east of us; its flame was very lively, but a thick fog soon deprived us of this sight. . . . '"

As Mt. Shasta might be visible from a ship at sea in the position given, it, as well as Lassen Peak, should be considered as a possible source of the witnessed eruption. Both peaks would be nearly east from the stated latitude. If the eruption were from Lassen, nothing but an explosion cloud would have been visible. Considerable volcanic activity occurred at the summit of Mt. Shasta since the time of general glaciation, and nothing on the peak at present indicates the impossibility of there having a minor eruption in 1786.

R. H. Finch.

LASSEN REPORT No. 27

Lassen Volcano Observatory

R. H. Finch, Associate Volcanologist

The western half of the Lassen edifice was shaken by a series of earthquakes on October 29, 1930. The shocks were strongly felt at Redding on the west and as far southeast as Mineral. The distance to the origin of the shakes from Mineral as determined by the seismograph of the Lassen Volcano Observatory was 27 miles, which makes the seat of the shaking to the northwest of Lassen Peak, or in the vicinity of Millville. Press reports indicate that the shake were stronger at Millville than elsewhere.

The series was ushered in by a very small and not generally felt shake at 4:10 a. m. The plainly felt shakes occurred at 4:34 a. m., 11:48 a.m., and 8:28 p. m. A light roar accompanied the shaking at many places.

On the 29th of April, 1930, a shake that was much stronger than any of the recent series occurred in the same region.

KILAUEA REPORT No. 982

WEEK ENDING NOVEMBER 16, 1930

Section of Volcanology, U. S. Geological Survey

H. A. Powers, Temporarily in Charge.

Steam has risen from the floor of Halemaumau and the amount of visible steam from the wall and floor cracks of Kilauea has increased several times during the heavy rains of the week. A few rocks have been heard tumbling from the walls of the pit, but there have been no avalanches large enough to attract attention.

A distant earthquake wrote a very small record on the seismogram at 8:57 a. m., November 12. There were ten local shocks of very feeble intensity timed as follows: November 11, 11:26 a. m.; November 12, 5:38 p. m.; November 13, 8:50 a. m. distance 22 miles, and 10:11 p. m.; November 14, 2:57 a. m., and 1:30 p. m.; November 15, 6:57 a. m.; November 16, 3:52 a. m. center in Halemaumau, 1:34 p. m., and 7:55 p. m. The Observatory seismograph on the rim of Kilauea crater also recorded 48 small tremors, of which 30 occurred during the last four days of the week. During these same days, the instrument at Halemaumau recorded 42 tremors. Many of them were stronger at the pit than on the Kilauea rim, suggesting that they had their origin in Halemaumau. The non-volcanic trembling of the island was moderately strong during most of the week.

The average tilt for the week showed a slight movement in an east-northeast direction, all of which was gained through a marked tilting of the Kilauea rim up and away from the pit during the last four days. During this same period, the Halemaumau seismograph indicated that the rim of the pit was also tilting up and away from its center.

The latter half of this week showed the first definite change of conditions from the "stagnation" which has existed since the earthquake of October 20. The tilt change and the increase of tremors suggest an increase of pressure and movement of lava under Kilauea.

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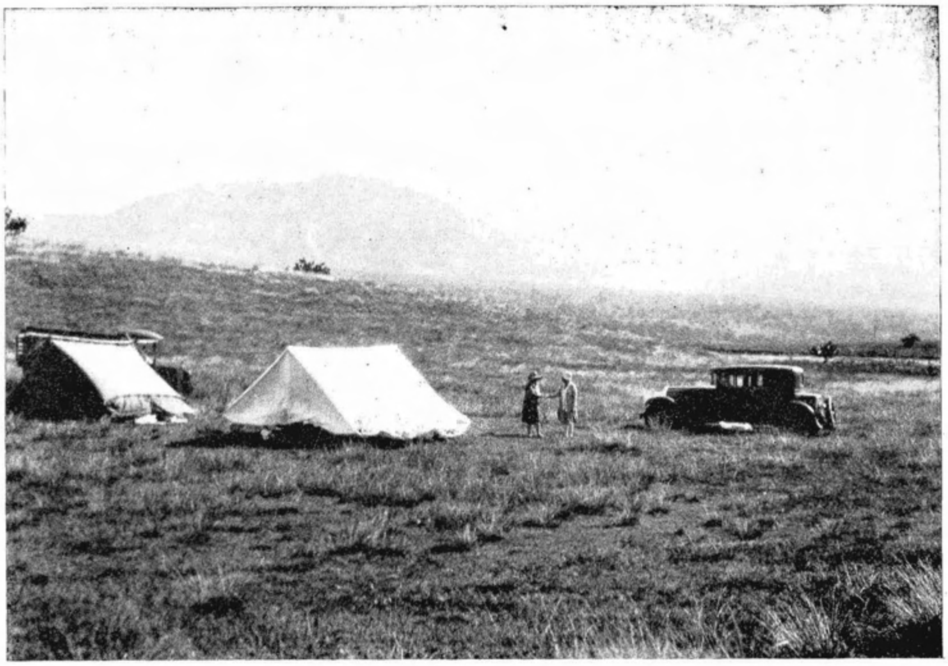
No. 309—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | November 28, 1930



Camp of ranch people at Puu Anahulu during the earthquakes of October, 1929. Looking toward Puuwaawaa from the northwest, with Hualalai volcano in the haze at the right. Photo Jaggar.

THE HUALALAI EARTHQUAKE CRISIS OF 1929

What Happened

During the week ending September 18, 1929, the seismographs at Kilauea Volcano. at Hilo and at Kealakekua on Hawaii island registered nothing remarkable. Then came a really tremendous swarm of earthquakes in North Kona on and near Hualalai volcano. Sudden shaking began September 19 and continued, racking the countryside, reaching culmination in big earthquakes September 25 and October 5, and destroying hundreds of thousands of dollars worth of property in houses, walls, tanks, stone fences and roadways. No volcano eruption followed on Hawaii until now, November 19, 1930, when lava returns quietly into the bottom of Halemaumau pit of Kilauea volcano, on the opposite side of the island from Hualalai.

The spasms of earthquake September 20 and 21, 1929 were at intervals of several hours. Then the intervals shortened and the spasms lengthened in duration. The area of felt earthquakes extended itself. Maximum motion was within a circle of 35 miles radius around the summit of Hualalai. The force of shaking increased. The strongest motion and greatest destruction was near Puuwaawaa. The highest frequency of shakes was on the southwest flank of Hualalai. Rumbling was heard there but not at Puuwaawaa.

At Kilauea 221 shocks were recorded for the week ending September 25, as compared with only 9 for the previous week. As to epicenters or places of origin measured from the seismograms by the distances from the instrument station indicated by formula: at the Kilauea Observatory, for four weeks to October 16, the successive average weekly distances of epicenters were 23, 28, 35 and 44 miles. This looked like a progression of underground jolts from about Mauna Loa to about Hualalai.

Big earthquakes of Grade IX Rossi-Forel occurred at Puuwaawaa September 25 and October 5. These were felt throughout the Hawaiian Islands.

Airplane inspection of all the craters revealed no eruption of lava. The shaking continued for a month but gradually quieted down in November.

Statistical Data

At Kilauea the weekly frequency of shocks as indicated by numbers of earthquakes counted on the seismograms, beginning with the week ending September 25, was as follows for four weeks: 221, 244, 129, and 97. The maximum was thus the week ending October 2, between the two strong earthquakes. The frequency and intensity varied together. The Kilauea total of shocks to October 16 was 691, many of them felt.

For the four days between the two greater earthquakes different places with seismometric instruments registered the following numbers of shocks:

	Oct. 1	Oct. 2	Oct. 3	Oct. 4
Kilauea	19	13	15	18
Hilo	38	26	13	74
Kealakekua	155	110	96	138
Puuwaawaa	241	117	97	114

The frequency increases just before the big shock of October 5. The geographical gradation is not wholly accordant with distance form Hualalai. Thus Hilo has more shocks than Kilauea, yet is farther from Hualalai.

The instrumental record of decline in frequency was as follows:

	Oct. 8	Oct. 9	Oct. 10	Oct. 11	Oct. 12
Kilauea	16	15	14	10	9
Kealakekua	94	61	42	41	43
Puuwaawaa	387	353	235	203	139

This is reasonably consistent as a decline with the passage of time, and as showing geographical decrease of numbers with distance from the center.

The shock recorder at Puuwaawaa of the type described in Scientific American for November, 1929, with magnification x25. registered numbers of shocks as follows during the first part of the time of maximum frequency:

September 26	599	shocks
September 27	541	"
September 28	400	"
September 29	334	"
September 30	321	"
October 1	241	"

The computed instrumental total for the central region for 26 days from Sept. 21 to Oct. was 6211 shocks. This averages 239 per day or 10 per hour. Most of these could have been detected by a person at rest indoors. Much of the time there was continuous jiggling of windows. Puuwaawaa registered nine times as many earthquakes as Kilauea. And that in a place not known as an earthquake district before this year.

The average of felt shocks listed by observers September 23-24 was 2.2 shocks per hour at Huehue, 3.3 at Puuwaawaa. and 6.0 at Honokahau on the southwestern slope of Hualalai. Observers listed about a third as many as the shock recorder.

Theoretical

The big earthquakes of September 25 and October 5 showed no preliminary tremor on seismographs forty and sixty miles apart. Both Hilo and Kealakekua in Kona behaved as though they were right over the center of the earthquake. So did Kilauea. In this they behaved quite differently from their registration of the ordinary earthquakes of the period, these always showing a preliminary tremor accordant with the theoretical distance of the focus or origin.

The absence of preliminary tremor is usually explained on the ground that these greater earthquakes are very deep. If such jolting is profound in origin, it may shake the whole of a small area like the island of Hawaii equally.

But even if the earthquake were a hundred miles underground the horizontal impulses at the pendulums of Kealakekua, Hilo and Kilauea would have been sufficient to exhibit **something** of the preliminary if the compressional waves had been present. There was no slightest trace of them, unless they were so enormous that they themselves dismantled the seismographs. This is improbable, by analogy with other records of earthquakes of like intensity, showing preliminaries, which have clearly registered with small ampltiude before the long waves dismantle the instrument. The pens at places sixty miles apart simply shot off the drums at the first impulse. Meanwhile the Honolulu seismograph registered a preliminary accordant with the distance of Hawaii.

If this failure to record preliminaries were due to depth of focus, the depth would have to be several hundred miles, and even in that case a vertical component instrument ought to register an excellent preliminary, characteristic of compressional elastic waves arriving vertically. There is no suggestion that such waves were present. Even a horizontal pendulum would give some thickening of the line.

There is another possibility. If hot magma were present under Kilauea. Mauna Loa and Hualalai equally, like a vast cake of dough, with localized injections of its substance as protuberances with each mountain, it is conceivable that the protuberance under Hualalai moved to make the localized earthquakes; and that the larger mass shifted the whole island shell for the greater and more generalized shocks.

Comparison with 1868

The 1868 cataclysm on Hawaii was a parallel to this. A new series of eruptions at the southwest was then begun, unheard of before. A great earthquake swarm began on the south flank of Mauna Loa culminating in a terrific shock.

On March 9 of 1868 there was an earthquake in Kona. On March 27 in Kau quaking became continuous and the next day there was a big shock of Grade IX. On April 2 came the big earthquake of Grade X, making a landslip back of Pahala, a tidal wave along the Honuapo shore, and bringing about the immediate collapse of very active lava in Kilauea Crater. April 6 the south rift of Mauna Loa vomited lava to the sea, the eruption lasting six days. Other big shocks occurred and a lot of aftershocks.

This combination of clustered quakes, big shocks and lava outpouring in a new district suggests that the underground shift of magma from the old northern district made the mountain labor. The same thing is suggested in 1929. There is a shift of activity from south to north. Recent Mauna Loa flows have all been in Kau. The Hualalai earthquake swarms were quite like those of Kau in 1868. But lava outbreak has not yet occurred on Hualalai. Presumably lava intrusion did occur.

In both 1868 and 1929 there were big shocks that were different from the small ones. Probably the small ones accompanied shifting of the blocks of the smaller mountain, and were shallow. Probably the big ones accompanied a shifting of the whole island shall and were relatively deep. But it may well be that mere depth was less important than the size of the shell which was shifted.

The present outbreak of Halemaumau November 19, 1930 is the first eruption in Hawaii which has followed the Hualalai earthquake crisis of September-October, 1929. The last outbreak known at Hualalai volcano was in 1801, about a decade after an explosive eruption which occurred at Halemaumau. A decade after our last explosive eruption of Halemaumau will be 1934. Is the present return of lava in Halemaumau preparing for a new activity on the north or northwest sides of Mauna Loa or Hualalai?

T.A.J.

THE CURRENT ACTIVITY IN HALEMAUMAU

Lava came back in Halemaumau at 1:29 p. m.. Wednesday, November 19. It broke through first in two fountains about one hundred yards out in the pit floor in front of the horn between the two grotto niches of 1929. According to Craik. of the National Park, the floor started to swell rapidly under this spot, then huge blocks of the old crust were thrown into the air by the first gush of fountaining lava. Craik immediately left to spread the news so he did not see the next fountains break through. When next seen half an hour later, lava was spouting perhaps fifty feet high from these two fountains; from twenty to fifty feet high from seven fountains closely grouped near the edge of the 1929 flow about half way between the old 1927 cone and the sulphur stain on the south edge of the pit floor; and about 150 to 200 feet high from a main fountain through the sulphur stained patch about 100 feet out in the 1929 floor from the edge of the south talus. The whole southwest corner of the old floor soon was covered by flows from all of the fountains, but the main flood came from the large fountain and spread rapidly out to the center of the floor.

By 4:00 p. m., the old cone peak of 1927 had disappeared in the south cove, and the main flow had reached a point three fourths of the way across the old floor. New lava covered about half of the area of the 1929 floor at this time. One fountain had disappeared from the south-southwest group leaving six small ones together, also the two near the 1929 grotto, and the main fountain. The small ones showed about their original strength, but the large one had increased so that it was throwing slag over 200 feet into the air. A crack opened along the contact of the northern small 1929 grotto and the talus behind it. and it was soon filled with a small ooze of glowing lava. All of the fountaining activity was still concentrated in the southwest part of the 1929 floor.

As the depth of the lava around the fountains increased, some of the smaller ones were drowned, so that by 6:00 p. m. only two remained of the original group of seven. The two near the 1929 grotto had built up spatter cones through which they only occasionally were able to spout visible spray. The main fountain had become more constant, and was throwing slag steadily to heights of about 100 feet. The main flow was still very strong, but was beginning to pile up on top of itself rather than spread farther over the old floor.

The main fountain was slowly building a crescent shaped grotto on its south side which had reached a height of about forty feet by 8:00 p. m. At this time only one fountain remained of the original cluster of seven. and the two near the 1929 grotto broke through their "hoods" only at long intervals. The activity of the main fountain remained constant throughout the evening. The big flow was definitely building a rampart over which small flows were cascading to the lower level of the floor. The main overflow seemed to concentrate on the northwest and the southeast sides of the lake near the main feeding fountain, with only an occasional flow over the northeast wall most distant from the fountain. The situation did not change materially during the rest of the night.

At 7:00 a. m., November 20, the vigor of the main fountain had not changed, but the smaller ones showed only an occasional spurt. They continued to smoke vigorously. The main flow from the big fountain was feeding a well defined lava-lake which covered approximately 25 acres, a little over one million square feet, of the 1929 lava floor and was oblong in shape with the long axis running northeast from the main fountain. The greatest overflow still took place near the fountain over both the northwest and the southeast ramparts. The level of the lake had been rising more rapidly than the grotto was being built by the main fountain so that it was not as conspicuous as it had been during the previous evening.

A measurement at the end of the first 24 hours, 1:30 p. m. November 20, showed that the surface of the lake at the big fountain was 90 feet above the level of the old floor at that point. The surface of the lake still sloped away considerably to the rampart walls so that there was a constant but slow movement of the cracking crust away from the big fountain. Overflows from the lake had covered about ten acres (435.000 square feet) of the old floor, so that flows and lake of new lava together covered an approximate area of 35 acres. The big fountain continued its steady spouting, throwing slag from 60 to 100 feet in the air. The two fountains near the 1929 grotto still smoked but no fountaining was visible. The one isolated small one had built a cowlshaped hood with the opening to the northwest so that its spray could not be seen from the main observation point.

It was reported that nine noisy explosions occurred at regular intervals of a few seconds about 11:00 a. m. No unusual behavior was noticed in the fountain but the sound seemed to have come from the large fountain.

Shortly after noon, a large stream of lava began to cascade over the southeast lake rampart and flowed toward the base of the east talus. It kept up a steady flow till after 6:00 p. m. and gradually formed a secondary lake between the talus pile and the main lake-rampart. Secondary flows from this small lake poured out along the flat between the east talus and the old pressure ridge and by 8:00 p. m. had covered the rest of the 1929 floor in this part of the pit. More overflows from the northeast end of the lake occurred during the late afternoon and evening, and slowly crept toward the north and northeast talus. By midnight November 20, only a few acres of the north part of the old floor remained visible.

This steady fountaining and overflowing from the main lake characterized the activity during the next morning, November 21. A second lake rampart had been built up inside of the northeast end of the lake during the night. Its location probably was determined by the position of a number of pressure ridges and domes in the old floor which may have obstructed the free flow of new lava and piled up blocks of the new crust. This inner rampart was built to a point at which the surface of the inner lake was very nearly level. As a consequence the migration of the cracking lake crust became so slow that it was not noticeable to the eye.

At the end of 48 hours of flow, 1:30 p. m. November 21, the surface of the lake at the fountain was 100 feet above the old floor, and the whole lake averaged a depth of almost 100 feet. It covered an area of about 15 acres (about 650,000 square feet). The overflows had encroached on the talus walls on the south side of the pit behind the big fountain, and had nearly covered the old 1929 lava floor. Thus the total area covered by new lava was about 50 acres (over two million square feet).

The main fountain began to show a tendency to break into two separate fountains of about equal size and a third one of small size and irregular frequency. The vigor of the fountaining appeared to remain the same. The activity of the afternoon and evening continued after the fashion of the previous day, with most of the overflow occurring on the northwest and the southeast sides of the lava-lake.

About 11:30 p. m. of November 21, a large cascade broke over the rampart at the far northeast end of the lake. It was falling down a steep incline of nearly fifty feet so gained in size very rapidly. Within fifteen minutes it had become the most spectacular feature of the eruption to date. It yielded a flow of such velocity that no crust had a chance to form, so that more than five acres was soon covered with the glowing red lava.

This river was still flowing the forenoon of November 22, but had split into two main branches, one of which was flooding the low area toward the northeast talus and one was pouring new lava into the depression at the foot of the northwest cliff.

Spouting from the small south-southwest fountain was no longer visible, but it and the two near the 1929 grotto still emitted a continuous volume of fumes. The large fountain continued its constant activity but the amount of lava taken from the lake by the three main overflow channels equalled the amount fed in by the fountain so that the level of the lake became fairly constant at 90 feet above the old floor.

During the evening of November 22, the spouting of the big fountain became slightly irregular. For a period of several minutes it would spout huge fans of slag over 300 feet in the air, and then it would relax for a time and resemble a bubbling mass of porridge. In these periods of relative calm, it could be seen that as many as seven separate spots were bubbling, which united in the larger spurts to give the appearance of one huge fountain. Overflow still continued from all three sides of the lake,, first one side showing the most active flow and and then another. The same general condition held during the night and all of the next day, Sunday, November 23. H.A.P.

SEISMIC FEATURES OF THE ERUPTION

The seismic events leading up to the eruption of lava in Halemaumau were not unusual but are none the less of interest. On November 13, the seismograph on the rim of the pit began to register a definite tilting of the rim up and away from the pit. It also recorded many small tremors which were not of sufficient strength to influence the instruments at the Observatory on the rim of Kilauea crater. These facts supplied the information that lava was moving and pressure was increasing under the volcano.

During the six days previous to the appearance of the lava, the rim of Halemaumau pit was tilted upward and outward through 10 seconds of arc. Half of this accumulated slowly, while the balance of 5 seconds of tilting took place in an interval of one hour and fifteen minutes immediately preceeding the gush of lava. As soon as the outlet to the surface was gained, the lifting force of the rising lava was lost and the pit rim tilted back through 7.5 seconds of arc during the first 18 hours of lava activity. Since then, equilibrium has been maintained and the tilting of the pit rim has been negligible.

On the morning of November 19, the pit seismograph recorded a series of 18 small shocks which culminated in a very feeble quake at 11:06 a. m. There was a slight tilting of the rim in toward the pit accompanying this quake. A series of 30 small shocks followed in rapid succession, many of them producing a little inward tilting. At 11:42 a. m., a quake of feeble intensity occurred under Halemaumau, causing a slight sudden inward tilt of the rim. During the next half hour eight small tremors were recorded, but no tilting took place. Then, between 12:15 and 1:29 p. m., 35 small shocks occurred and at the same time the rim of the pit was tilted up and outward through 5 seconds of arc.

Continuous tremor began at 1:29 p. m. and gradually increased for nine minutes. Then, at 1:38 p. m., the amplitude of the tremor suddenly increased. This sudden increase may mark the breaking of the lava through the bottom of the pit and the beginning of surface fountaining. The tremor continued with a constant intensity till about 4:00 p. m. when it gradually moderated until 7:00 p. m. From that time on it has continued evenly, except for an occasional more violent burst of a few moments duration.

H.A.P.

KILAUEA REPORT No. 983

WEEK ENDING NOVEMBER 23, 1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar. Volcanologist in Charge

Lava appeared in Halemaumau at 1:29 p. m. November 19. It broke through in three fountain groups, two of small size which disappeared during the first two days, the third remaining as the main fountain which is still spouting vigorously. Lava from the fountains spread rapidly over half of the 1929 floor in the first four hours. Then a central lake of molten lava was formed which is being fed by the main fountain. The lake rapidly built its ramparts upward until a depth of molten lava of about 90 feet was reached. This depth has been maintained, with overflow on three sides of the lake removing the new lava as rapidly as it is supplied. These overflows have completely covered the old floor of the pit and are encroaching on the surrounding talus piles.

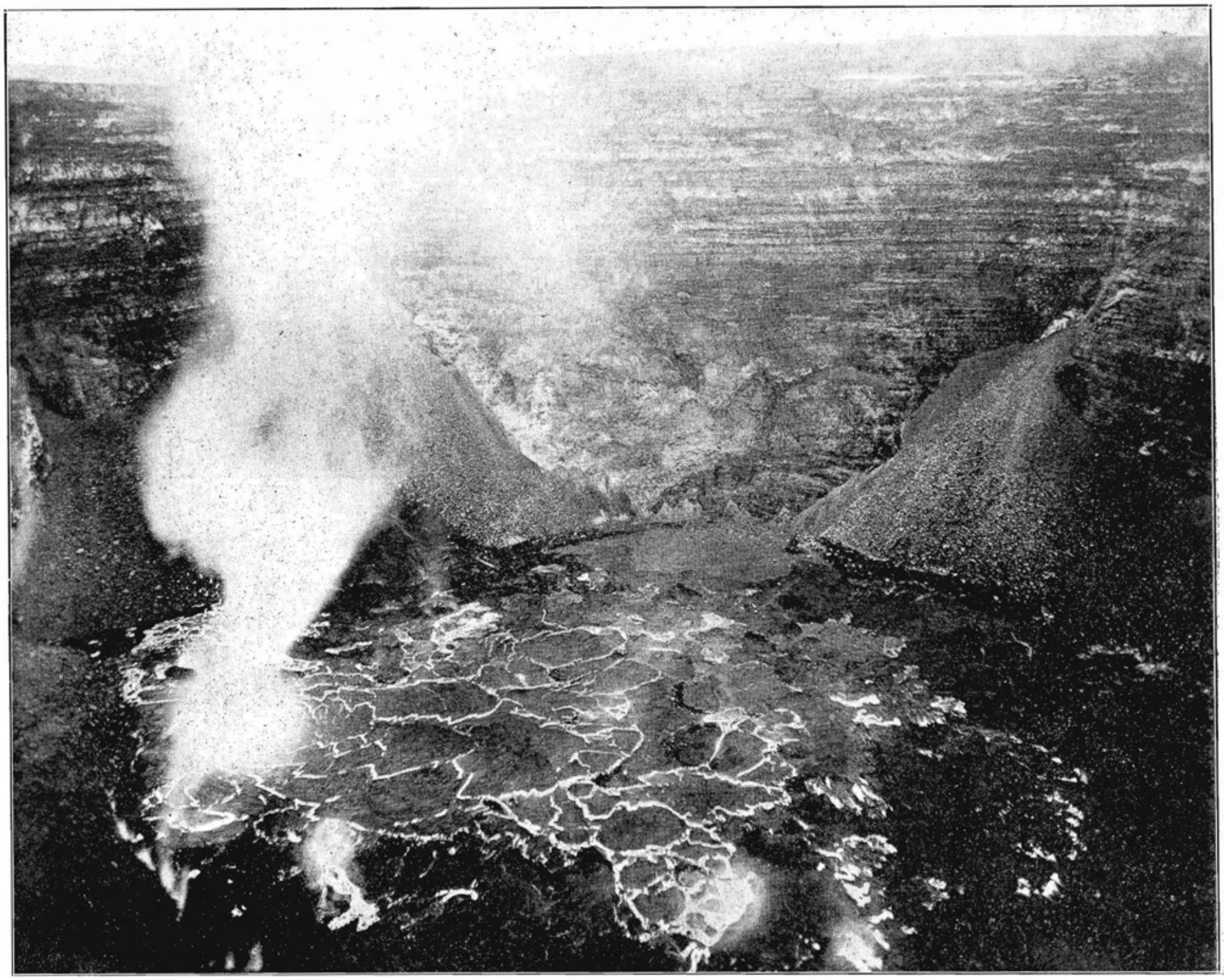
During the two and one half days of the week preceding the appearance of lava on November 19, the Observatory seismographs recorded seven very feeble earthquakes: November 17, 2:29 a. m., 2:56 a.m., centering in Halemaumau, 8:11 p. m., and 8:19 p. m.; November 18, 5:47 a. m. distance to center 4 miles; and November 19, 8:13 a. m. and 11:06 a. m. One quake of feeble intensity, felt at Uwekahuna, was recorded at 11:42 a. m., November 19, with a distance of 4 miles to its origin. One very feeble shock was recorded after the eruption started, i. e. at 7:34 p. m., November 19. There were thus nine earthquakes for the week at the Observatory. A total of 24 short tremors were recorded before the lava broke out, and 17 minutes of continuous tremor registered during November 18. Continuous tremor caused by the fountaining of lava is accompanying the eruption. The non-volcanic microseisms were slight during the entire week.

The average tilt for the week shows a slight westward tilting of the Kilauea rim compared to last week. Some southward tilting has accompanied the flow of lava as the lifting force of the lava is lost by its access to the surface.

The Volcano Letter

Two dollars per year | Ten cents per copy

No. 310—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | December 4, 1930

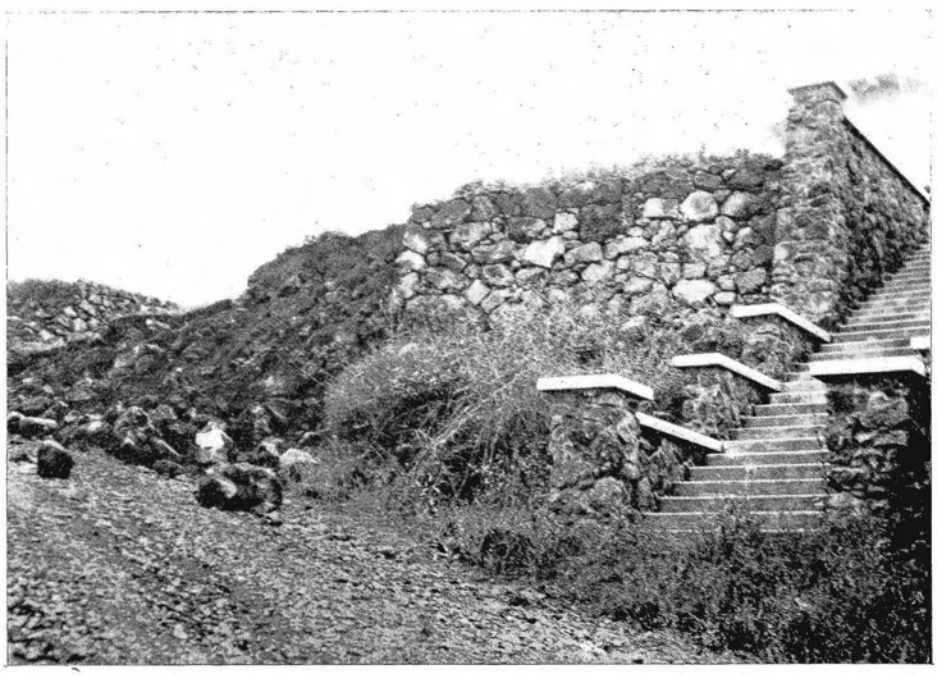


New lava in Halemaumau November 20, 1930. Photo Maehara.

HUALALAI EARTHQUAKE CRISIS
(Continued)

The earthquake crisis of 1929 on Hawaii, as described statistically in Volcano Letter No. 309, produced two earthquakes of grade IX Rossi-Forel. Grade ten is the intensity of a great disaster like those of San Francisco and Tokyo. Nine is disastrous; there are many grades of quick jerking between nine and ten, as represented by the earthquakes of history, some of them slow with wide amplitude and fatal continuity, others very sudden and quick with terrible results on weak structures. The greater earthquakes of the Hawaiian crisis were always led up to by numbers of minor ones, and by more or less continuous tremor which culminated from time to time in increasing numbers of large shocks, which happened both before and after the major ones. The earthquakes of this crisis were very impressive in demonstrating to an observer the difference between experiencing a large earthquake in a house or on the ground out of doors. In a house with an iron roof the rattle of the roofing, of the furniture, of the doors and windows, and the creaking of the timbers all made the quaking perceptible to the ear. Also the artificial structure acted as an inverted pendulum and magnified the motion. The writer was kindly permitted to dwell at Puuwaawaa Ranch House during the period of greater shaking, and to make experimental tests of earthquakes indoors and out. Shocks that were considered strong indoors, with much preparatory rattling leading up to a culminating jolt, were wholly imperceptible to an observer standing on the grassy lawn outside, except for a slight upward thudding sensation at the moment of the final jolt. Meanwhile the outdoor observer, with his feet planted firmly on the sod, could hear the roof of the house roar, and feel nothing during the rattling stages.

An interesting experience during the greater earthquake of 6:20 p. m. September 25, 1929, demonstrated that even a disastrous earthquake in a wooden house might go unperceived in an automobile in motion. This earthquake was so strong that it seriously damaged the Kealakekua



King residence, Honokahau, after the earthquakes of September and October, 1929. The retaining wall of the terrace was shaken down, being built at too steep an angle. Photo Jaggar.

seismograph, stone walls were thrown down, furniture was displaced and overturned, some buildings were moved, landslips were produced on steep slopes, masonry was cracked, and some water tanks burst. The road fills on steep hillsides were generally cracked and in many cases retaining walls on the downhill slope collapsed. The damage was enhanced by the weakening effect of the hundreds of large and small earthquakes, mostly with vibration from the mountain outward which preceded the larger shock for six days. These had loosened foundations, cracked the soil, and by minor damage had weakened structures through much swaying. The writer in his car was driving northward through Honokahau along the government road north of Holualoa and turned into a private driveway to stop for a moment at a residence there. He had felt nothing. The big earthquake had happened a few minutes before, and he found the house in a turmoil, with furniture overturned and strong aftershocks still in progress. It was demonstrated later, when many people left their houses and slept in their automobiles, that a modern car is an admirable earthquake-proof building. Even at rest a sedan on springs and rubber tires produced almost no sensation to the occupants, while adjacent homes were rattling and roaring with the aftershocks.

Prior to the big shock of October 5, 1929, there was a marked lull in frequency during the daylight hours, the big earthquake coming at 9:22 p. m. The effects of this shock were stronger than those of September 25, and the damage to buildings was extended northward into Kohala. Conspicuous effects were the cracking of road fills in new places, the overthrowing of embankments at the tips of road spurs, and the sliding downhill of rocks and vegetation on cliffs.

The intensity relations, obtained by counting the numbers of strongish shocks, indicate that these clustered around September 26 and October 5. There were about 200 earthquakes recorded as sharp between September 19 and October 5 in the North Kona region. September 23 at Puuwaawaa there were nine, September 24, twenty-six, with one in the morning described as the strongest yet, and the next morning came one described as still stronger.

The following figures show three series about the frequency maxima, September 26, October 5, and October 8. The lists show computed numbers of earthquakes as registered instrumentally at Puuwaawaa, and in each case the figures rise to a maximum on the date above mentioned, and decline afterwards.

First Series		Second Series		Third Series	
Sept. 21	39	Oct. 3	97	Oct. 7	136
" 22	237	" 4	114	" 8	387
" 23	258	" 5	141	" 9	353
" 24	432	" 6	89	" 10	235
" 25	513			" 11	203
" 26	599				
" 27	541				
" 28	400				

In the first and second series, the dates September 25 and October 5, both in the evening, were the occasions of great earthquakes. For the third series there were one strong and five moderate quakes October 8, one strong and one moderate October 9, two strong October 10, and one moderate October 11. There was an increase in numbers of strongish shocks October 14-15 accompanying a slight increase in frequency. It is worthy of note in the above second series that the total frequency on either side of the day of the biggest shock (Oct. 5) is much less than the daily frequency of the earlier and later periods.

There is reproduced on the last page the photograph of a model of Hualalai Volcano by kind permission of Mr. W. T. Pope of Honolulu. The scale of the photograph is approximately four miles to the inch. The model shows the linear character of the belt of cones that constitutes the summit ridge of Hualalai, and the trace of an old sink crater at its summit. The two recent lava flows indicated on Hualalai are both believed to date from 1800-1801. The fluted cone at the northeast is Puuwaawaa; and the hill north of it Puu Anahulu is made of very old basaltic rocks extending in a curved ridge southward through Puuwaawaa, as though the latter were a parasitic cone built on the edge of part of an old sink crater. The 1859 flow from Mauna Loa is shown at the northeast. The regions tremendously shaken in 1929 lay on the north and south slopes of the Hualalai ridge, and it may be seen from this model that these two regions are symmetrically balanced about a volcanic fissure. It seems reasonable, therefore, that the disturbance was due to intrusion.

It may be remarked that this region and these earthquakes of 1929 were the theme for the story recently published, "Lava" by Armine von Tempsky. T.A.J.

LASSEN REPORT No. 28

Lassen Volcano Observatory

R. H. Finch, Associate Volcanologist

On November 3 and 4, 1930 a spasm of small earthquakes were recorded on the seismographs at Mineral. The shaking began at 11:39 a. m. November 3, and when the trembling ceased at 3:31 a. m. November 4, ten shakes had been registered. None was reported felt though three showed an intensity well within the range of perceptibility. The indicated distance to origin was 11 miles or nearly equal to the distance between Mineral and Lassen Peak.

TILTING OF THE GROUND DURING NOVEMBER

The following presents a record of the tilting of the ground at the Hawaiian Volcano Observatory on the northeast rim of Kilauea Crater, showing the net amount for each week computed from the daily seismograms obtained by platting a curve which is smoothed by overlapping progressive seven-day means. As shown in Volcano Letters 302 and 306, the tilting of the ground in September and October was generally northeastward, as is usual for the autumn season. Therefore the tilt to the southwest for the week of the outbreak of Halemaumau (November 19) may have been stimulated by the release of gas and the inward dip of the country resulting therefrom.

Oct. 27-Nov. 2	0.72 second	N.
Nov. 3 - 9	0.48 second	S.
Nov. 10-16	1.57 seconds	NE.
Nov. 17-23	1.20 seconds	SW.

KILAUEA REPORT No. 984

WEEK ENDING NOVEMBER 30 ,1930

Section of Volcanology, U. S. Geological Survey

T. A. Jaggar. Volcanologist in Charge

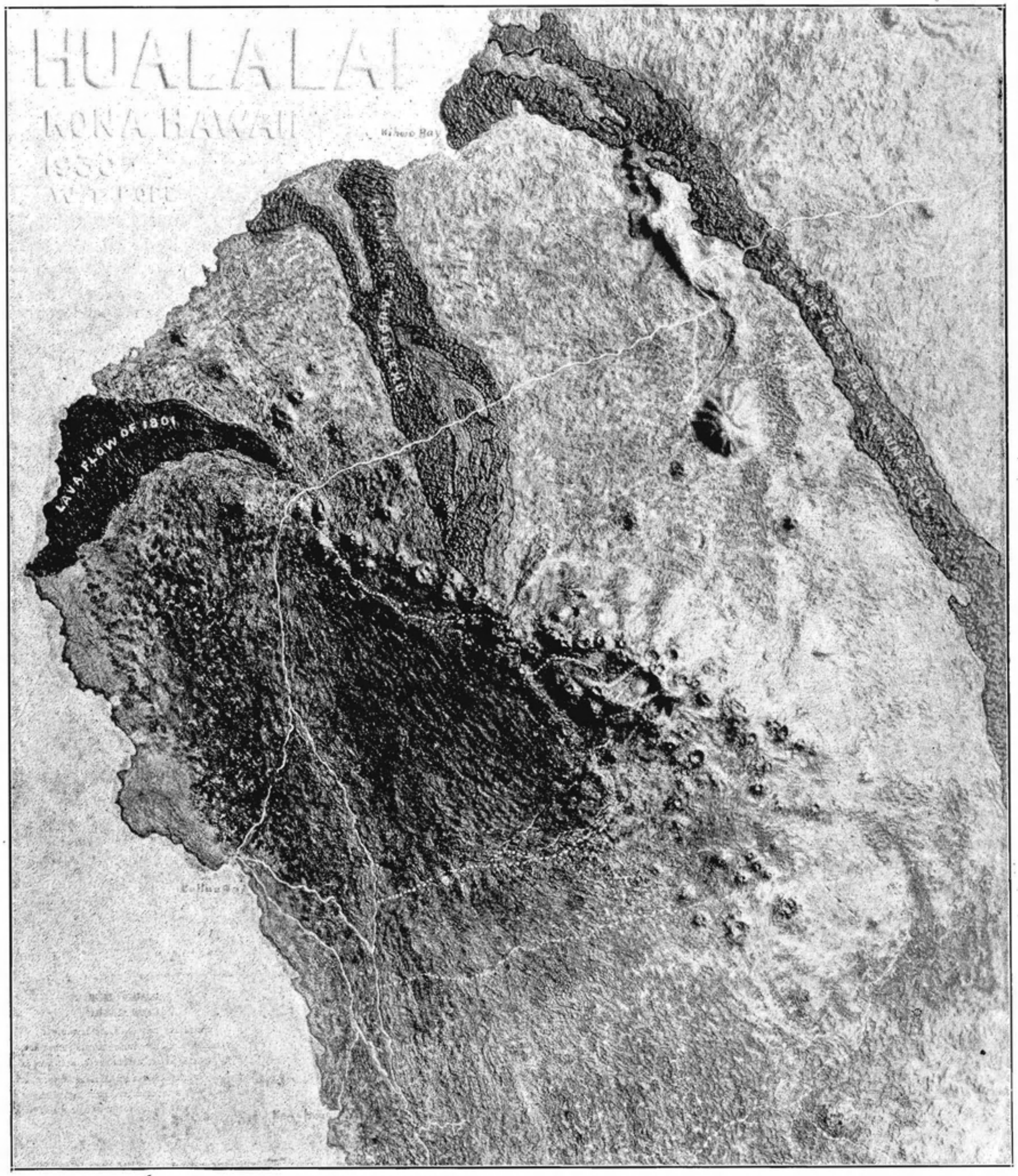
The pouring in of basaltic lava at the bottom of Halemaumau pit has continued during the week. On November 24 the fountain was building outer spatter ramparts on the side of the lake preparatory to formation of a spatter cone. The lake lava showed pahoehoe skins which wrinkled like satin. Festooned pahoehoe flows poured voluminously to the northeast and northwest. Small typical aa streams were sluggishly pushing out from the floor slag heaps in two places. The great delta-like fronts of the flows against the talus were half aa carrying pahoehoe crusts. Such crusts were cracking and sinking at the edge of the lake and elsewhere as the liquid lava welled up and weighted down the hardened surfaces.

Measurements made the floor 2,200 feet long south to north by 1,800 feet wide. The lake was one-fifth as large as the floor. The total area of new lava was 55 acres, covering the 1929 bottom 15 feet deep about the edges and 90 feet deep at the lake. The lake was thus at the top of a heap 100 feet high.

The same type of activity continued during the week, the heat diminished, the fountain enclosed itself with a spatter dome more than 100 feet high, the overflows of the lake rim dwindled, and the glow of the outer slopes of the slag heap became less. Sulphur stain increased along a steaming crack at the southeast edge of the floor.

The Observatory seismographs registered feebly two teleseisms at 9:22 p. m. November 27 and 11:23 a. m. November 30. There were no local earthquakes. Volcanic tremor was harmonic and continuous throughout the week, with a spasm at 5:56 a. m. November 29 accompanied by easterly tilt, and another spasm at 6:55 a. m. November 29. The tremor was weaker November 30. Tilt was very slight to the southeast, and microseismic motion was slight but somewhat increased November 26-28.

Collapse of partitions in cellar of Puuwaawaa Ranch House resulting from earthquake damage October 5, 1929. Note the wooden posts diagonally braced and footed in concrete, which saved the house when the cellar walls gave way.



Model of Hualalai Volcano, 1930, by Willis T. Pope Summit 8,251 feet. Shows trace of old sink crater and NW-SE summit rift marked by cones. Distance from Kailua bay to Keauhou in southwest corner six miles.

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.

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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.

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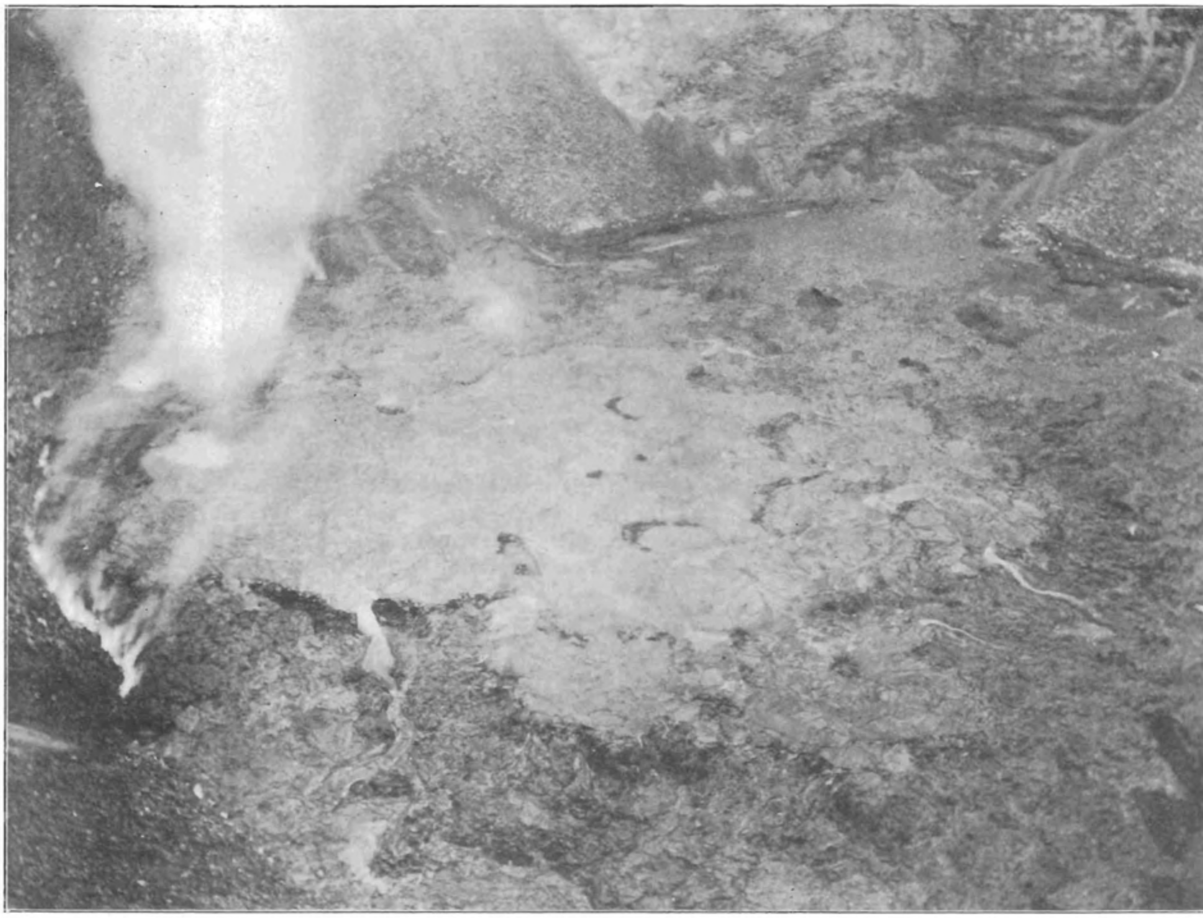
The Volcano Letter

Two dollars per year | Ten cents per copy
No. 311—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | December 11, 1930



Floor of Halemaumau from the east at 3 p. m. November 20, 1930. Shows the smooth lake area, the sulphur-stained crack with line of steam jets at the left, the fountain and its rampart under the large fume column, the 1929 lava heap against the talus at the back and numerous pahoehoe overflows from the terraced lake. Photo Powers

JOURNAL OF HALEMAUMAU ERUPTION 1930

As the eruption of lava in the bottom of Halemaumau pit of Kilauea Volcano came to an end so far as appearances go about noon December 7, 1930, it is appropriate here to show some pictures of special features and to review the daily sequence of events.

November 13. Pit seismograph recorded tilting of the ground away from the pit and many small tremors.

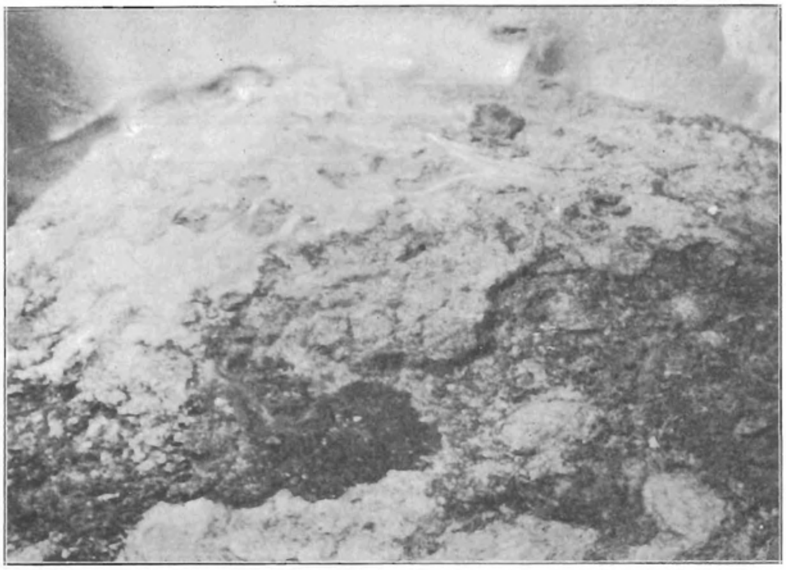
November 19. Tilt away from pit at 12:15 p. m. had accumulated to five seconds of arc. Then for an hour and a quarter 35 small earthquakes were registered and rim of pit tilted up and out five seconds more. This had been preceded in the forenoon by 57 small jarrings with slight tilting of the pit inward. This became continuous tremor after 1:29 p. m., becoming stronger at 1:38 p. m. moderating from 4 to 7 p. m., and thereafter continuing throughout the eruption, which had started with gushing of lava and gas at 1:29 p. m. Thereafter during the first 18 hours of lava activity the release of gas and escape of lava caused the pit rim to tilt back toward the center through 7.5 seconds of arc.

The lava broke its way up through the 1929 floor in the southwestern part of the pit. The floor swelled, broke, and the gush of lava carried up blocks of rock. Then seven fountains broke out southeast and finally a big fountain developed 100 feet from the south talus. The first fountains were 20 to 50 feet high, the big one was sometimes 200 feet high. The flood of lava spread over the 1929 floor and the smaller fountains dwindled. Oozing lava broke out back of the 1929 cone at the west. These events suggested that the new lava welled up through the 1929 paste, still hot under its thick crust.

The main fountain built a crescent grotto 40 feet high by 8 p. m., and the western fountains covered themselves with hoods. The outspreading flow began to pile up a slag heap with overflows northwest and southeast. Ramparts formed around a pool on the top of the heap.

November 20. At 1:30 p. m. the slag heap was 90 feet high, there was slow movement of crusting lava away from the big fountain, which now spurted from 60 to 100 feet into the air. The hooded vents of first action were smoking. About 12:30 p. m. a large flow cascaded over the southeast lake rampart and continued until the evening. By 8 p. m. most of the eastern remnant of the 1929 floor was covered, other flows crept toward the north, and by midnight only a little of the old floor was still uncovered.

November 21. The single large fountain continued its



Southwest corner of floor November 24, 1930, showing at the back the fume from the fountain vents which had sealed themselves, the 1929 heap at the right and the increasingly smooth lava from the border region in the foreground to the lake on the top of the heap. The small dark colored flow is the northeastern brown aa stream of November 24. Photo Powers.

activity and an inner lake rampart outlined an inner pond of lava with slow moving crust, the outer coves of the northern extension of the lake appearing like terraces at a lower level. At 1:30 p. m. the new lava covered 2,000,000 square feet and the lake was about 100 feet above the 1929 floor under it. The lake covered 650,000 square feet. The fountain was breaking up into two or three jets. At 11:30 p. m. a large cascade broke over the rampart at the northeast and produced a flow of such velocity that no crust had a chance to form so that 5 acres was soon covered with glowing lava.

November 22.. In forenoon the northern stream on the floor was flooding in two branches northeast and northwest. The drainage of the lake and the settling of the slag heap had lowered the lake level 10 feet while the margins of the floor were building up against the border talus of the pit. The fountain had become a group of spraying jets of the Mauna Loa type. The lake was oval feeding a flow which poured downhill spreading like a delta northward in the forenoon, and to the WNW in the evening. The flows were pahoehoe above and half aa below with a coke-like appearance. The fountains were quiet, but sometimes made a surf-like noise and puffed up brown fume, spurting up from 50 to 100 feet. The fragments were light pumice, for they floated down slowly, and much of this material along with Pele's hair fell to leeward of the pit. In evening glow edges appeared under the western lake rampart. Lava toes pushed out at the edge of the floor all along its western edge. There were three or more crust islands in the lake and irregular elevations in the lava slope west of the lake. Some 1929 lumps and terraces were detectable at the north side of the bottom. Smell of sulphur dioxide rose with the fountain gas.

November 23. The fume from the pit rose in a transparent brown veil these days, with a moisture cumulus above varying at different times and sometimes disappearing. The fume was blue in reflected light. A brown trail of smoke spread westward and northward over the valley between Mauna Loa and Kilauea. The glow at night over the pit was sometimes yellow, and at other times rosy. Large crowds of people visited Halemaumau.

At 9 a. m. the fountains continued with a deep rumble and occasional very high spurts. A scar up the west wall of the pit had been left by avalanches of November 20-21. The grotto at the fountain caved in continuously. Overflows from the lake poured south as well as north and northwest, the last appearing as a big stream. A protruding spur extended the slag heap of the lake toward the northeast, where chasms were caving in leaving red-hot aa walls, and lava trickles pushed out at the edge of the floor. The floor edge was building up so as to touch the WNW, S, and SE walls between the taluses. Bright yellow sulphur stain extended along a steaming crack at the edge of the floor nearest to the fountain to the south of the lake. Bluish-white salt appeared at seven steaming cracks in the slag heap to the NW and NE. Pumice of mossy green apparance lay on the backslope of the fountaining grotto.

At 5 p. m. the northwest stream had crusted, leaving V-shaped bright areas. The lake was covered with bright lines in flow pattern without apparent motion. The fountain showed none of the inrush and foundering of crusts toward its center characteristic of the old Kilauea fountains. The puddle around the fountain was thinly liquid on the side toward the grotto, but otherwise the jets seemed to rise from stiff quickly congealed material, sometimes flinging fragments in a high spire apparently 150 feet into the air. The glow of the crack pattern in the aa slag heap to the northeast was different from the lake. An aa flow from it to the northeast talus was like a forked coral or fungus with a herring-bone pattern which remained glowing like a coal quite different from the festoons of pahoehoe. The whole floor looked rigid but very bright, a fan of flows with two outstretched arms enclosing a dark space. The foundering blocks of the rampart next to the fountain rolled over and grounded on a shallow bottom. The dark areas of the floor were W and S and N.

November 24. Measurements at noon made the lake 90 feet above the former bottom and 435,600 square feet in area. The outlying slag heap was 40 feet deep, covering 1,306,800 square feet. The edge flows averaged 15 feet thick, covering 653,400 square feet. The total volume was estimated at 93,000,000 cubic feet. The diameters of whole floor were 2,200 by 1,700 feet.

At 10 a. m. two sloping ramparts outside of the fountain marked its enclosure by a cone. The lava was changing to true pahoehoe with spatter of glistening black glass. The lake was covered with pahoehoe festoons, but on the outer slag heap northeast and west two short brown typical aa flows emerged from cracks. Otherwise the pahoehoe overflows from the lake turned into large semi-aa areas at the edge of the floor NE and NW. The continuous fountaining of the active center was more suggestive of

1917 Kilauea activity than anything yet seen. All the 1929 floor was now covered except the big west spatter heap. At 5 p. m. the glow pattern was darker than before owing to the pahoehoe skins. The rampart around the fountain was closing in to a horseshoe and the overflows were dwindling.

November 25. Activity was more sluggish, flows were shorter. and the edge of the floor was building up.

November 26. The fountaining niche was becoming a cone, there was fresh lava along the east and northeast edge of the floor and also against the south wall of the pit. A new overflow from the lake poured NW.

November 28. The fountain had spells of high spurting and other times of unusual quiet. Flowing was weaker. The fountain cone was growing.

November 29. Weakening action continued. Fumes were strong. Eastern lobe of floor had raised 50 feet while the lake level remained the same; an intervening point stood 64 feet above the 1929 floor. The horseshoe cone around the fountain stood 75 feet above the lake with an opening toward the west and a frothing pool which cascaded steeply through the opening to the lake of clover-leaf shape. The cone had an outer crescent ridge at the south. There was glow around edges of the floor, strong at the NE and weak at the W and N. A flow broke out through a crust on the northeast side of the fountain cone. A dull flow pattern extended from the lake across the northeast floor, but outside pahoehoe flows had ceased. The glow and fume were lessening.

November 30. The fountaining cone was now the main feature. The heat at the edge of the pit had greatly diminished. There was festooned skin streaming across the lake. The edge of the floor had risen all around and the steaming sulphur crack southeast had increased in sulphur deposits. The cascade poured out of the cone growing weaker and crusting over, and the top of the cone caved in. The border lava was rising around the 1929 heap at the west.

December 3. After two weeks of action the area of the top of the slag heap containing lake and fountaining cone was roughly 500 by 800 feet. The cone was about 75 feet high and 200 feet in diameter at the base. The entire new bottom area was leaf-shaped 2,300 feet long by 1,700 feet wide and covered 62 acres or 2,710,000 square feet. The deepest fill was 175 feet at the top of the cone, or 100 feet at the lake level. The shallowest fill over the 1929 floor at the north side of the bottom was 50 feet. The volume of molten lava was 229,000,000 cubic feet which had come in during the first three days of the eruption at the rate of 25,000,000 cubic feet per day, and the last 11 days at 14,000,000 cubic feet per day. The process had been first piling up the center, and then spreading out at the edges. The weight of new lava was slightly more than 15,000,000 tons.

KILAUEA REPORT No. 985

WEEK ENDING DECEMBER 7, 1930

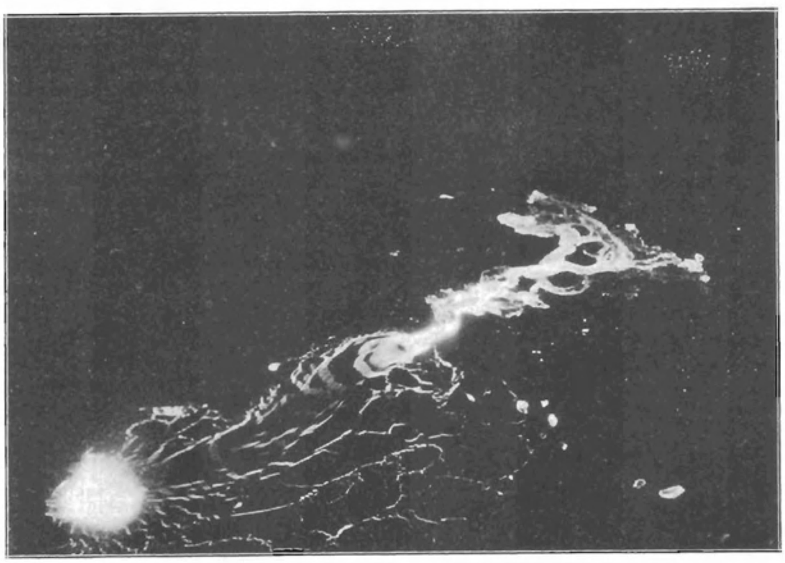
Section of Volcanology, U. S. Geological Survey

T. A. Jaggar. Volcanologist in Charge

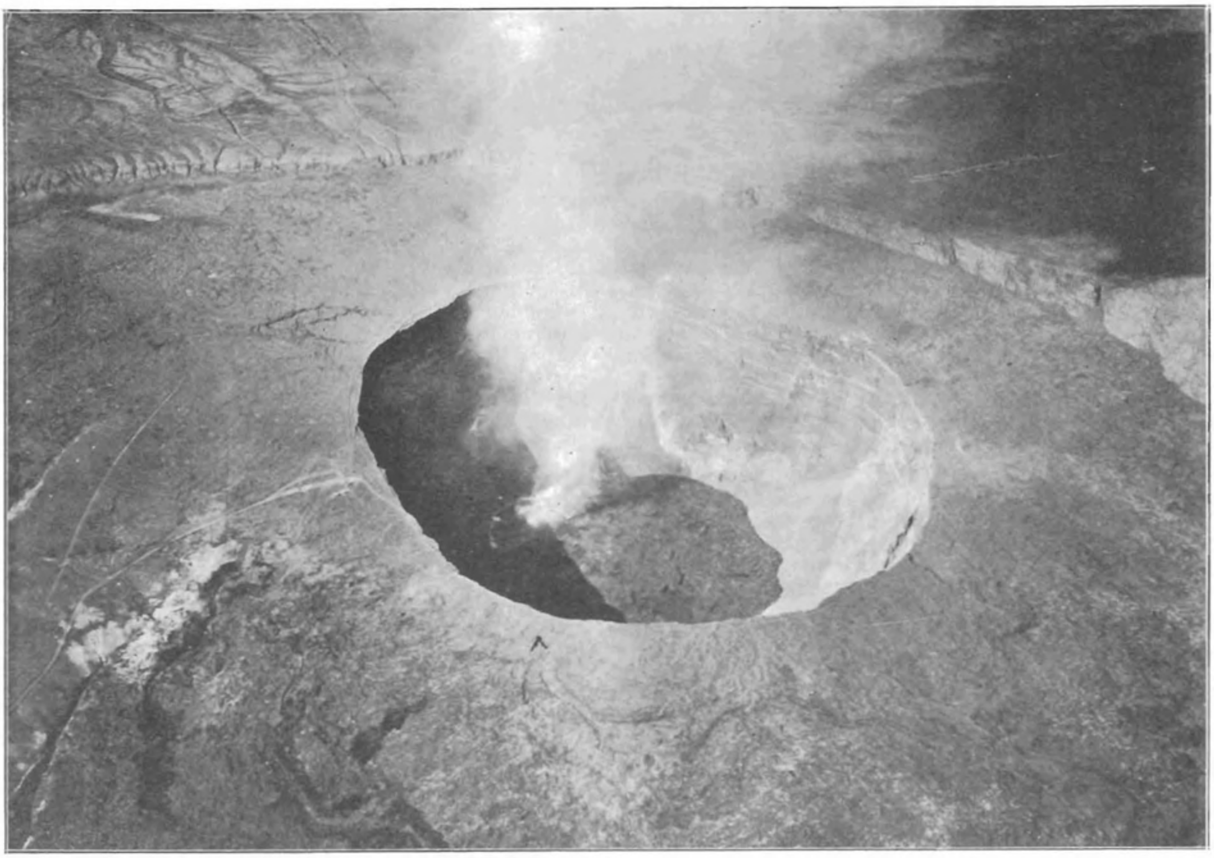
On December 1 the fountain in a cone of lava at the bottom of Halemaumau about 900 feet down was spouting variably. Its cone had grown big and the cascade down its side tended to crust over. The spectacular activity of the week came at times when the crust over the lake broke up and a rapid seething of glowing lava extended itself all over the surface along with sinking of the crust blocks. This process at intervals of from three-quarters of an hour to two hours continued until the evening of December 6, with increasing intervals. December 2 a stream from the big cone poured in a loop northward across the lake. December 3 a flow was building up the south edge of the floor. December 4 the cone was breaking down the edges of its cup. The break-up spells of the lake crust were brilliant accompanied with crackling noise. Bright yellow sulphur made a spicy smell at the southeast edge of the floor. The cascade from the fountaining cone renewed itself and poured flows over the lake crust. The fountain occasionally revived to high spurts. Then it dwindled to mere bubbling last seen the morning of December 7, and about noon that day all action ceased.

Volcanic tremor at the Observatory seismographs gradually weakened and stopped about 3:30 a. m. December 7. Two very feeble local earthquakes occurred December 1, one of these 8:55 p. m. indicated origin distance 32 miles and was felt from Hilo to Kona. Spasmodic tremors occurred four times December 4 to 7. Microseismic motion was moderate and tilting of the ground was moderate NE.

The action of tilting and trembling on the Halemaumau seismograph showed none of the sudden phenomena accompanying the end of the eruption which were observed when the lava ceased action in February, 1929. Strong trembling ended about 8 p. m. December 6, but minor tremor gradually dying away continued on December 7. At the end of that day it was nearly gone. There was no pronounced tilt of any kind. The effect is as though the lava pressure were still there without evident fountaining.



Night view of eruption November 21 at 11:30 p. m. This shows the spectacular cascade over the rampart, the bright line pattern of the lake, and the streaming away from the fountain. Photo Powers.



Halemaumau from the air at 9:30 a. m. November 25 showing the new fill in action burying up the talus slopes. The crescent at the base of the great western talus is the 1929 lava heap. Note the concentric cracks close to the rim of the pit showing how perfectly the caving tends to maintain a circle. All of the layers shown in the walls poured out during the 19th century. This picture shows that the floor of Kilauea crater is a dome. Photo by 11th Photo Section, Air Corps, U. S. Army.

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The Volcano Letter

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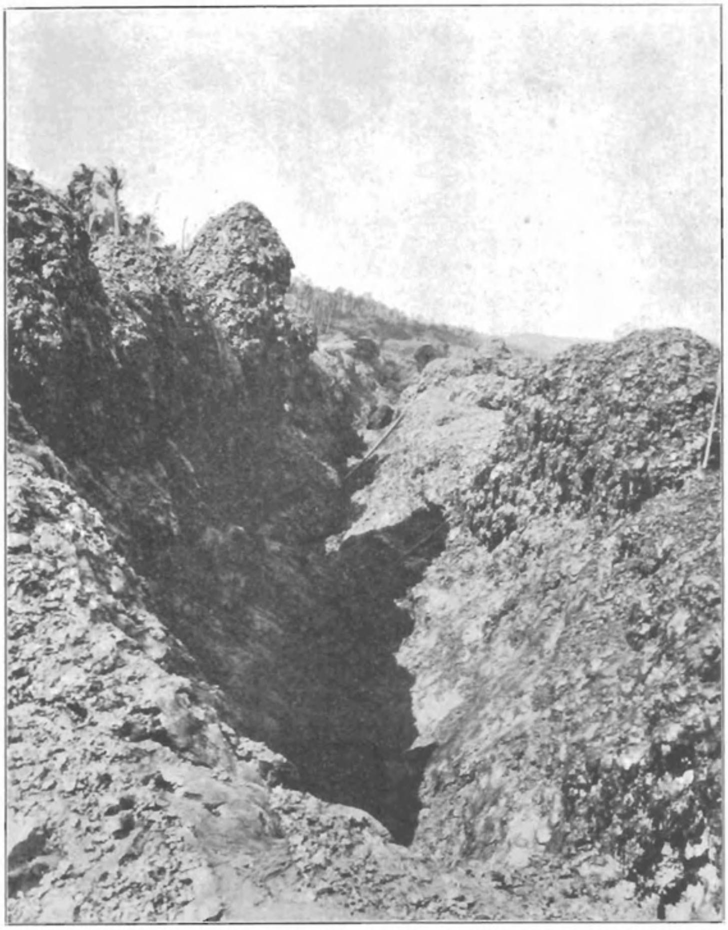
No. 312—Weekly — Hawaiian Volcano Observatory, National Park, Hawaii — December 18, 1930



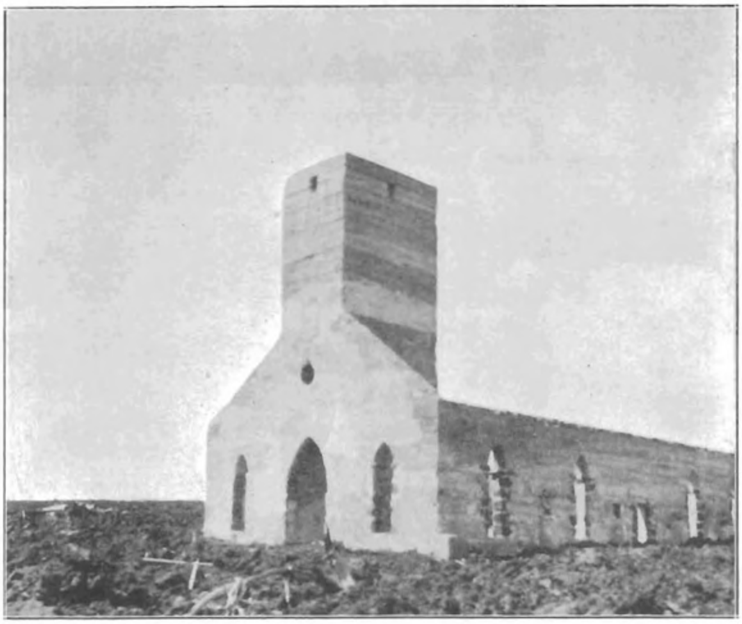
The great lava rift 30 feet deep back of Futu on the northwest side of Niuafoou Island, source of the destructive flows of 1929. The lava floods poured down to the right, and on the left are the unijured cocoanut palms of the ring ridge. There are spatter heaps on both sides of the chasm. Photo looking south September, 1930, by Jaggar.

THE ISLAND VOLCANO NIUAFOOU

Niuafoou, an active volcanic island belonging to Tonga, was described in Volcano Letter No. 265 in connection with the eruption of lava that poured out on the west side of the island and destroyed the village Futu July 25. 1929. The writer was privileged to visit the island as a member of the joint eclipse expeditions of the United States Naval Observatory and the New Zealand government from August to October, 1930.

Niuafoou is a splendid example of a crater ring, with lake in the crater, crowning a 6,000-foot volcano, most of which is below the level of the sea. It stands on the northeastern corner of the submerged portion of the Australian continent between Samoa and Fiji. It is an inhabited island, a paradise of cocoanut palms, the soil wholly volcanic, and lies 15½ degrees south of the equator. It is almost a perfect ring five miles across. The lake inside the ring is three miles across, of brackish water, surrounded by a ridge 600 feet high, with cliffs facing the lake and a gentler slope outside. It has islands and is much like Crater Lake in Oregon. Outside of the ring ridge there is a wider lava platform with cliffs facing the ocean. It is on this platform most of the people live in nine villages traversed by lovely avenues amid coconuts, ironwoods, mangoes, and other tropical trees and shrubs, and the usual pandanus near the shore. Copra is the principal crop, but there is much planting of yam, taro, papaia, sweet potato, bananas, melons, and manioc.

Seven villages are a short distance inland from the shore, two are on the ocean, one was destroyed by lava in 1853, one by hurricane in 1909, and Futu by lava in 1929. Futu is at the west, where the eruptions of the 19th century had created a lava desert with eruptions creeping northward. There are no lava flows about the crater lake, but here in 1814 and 1886 there were steam-blast eruptions which piled up sand islands and peninsulas, strewed the island with heavy blankets of dust and sand, and broke down the coconut trees with plastered mud that destroyed the crops and occasioned much suffering. About 1840, 1853, 1867, 1912, and 1929 the lava eruptions broke out along cracks trending chiefly north and south at the base of the ring ridge on the west side of the island and sending short flows for from half mile to a mile into the ocean. The 1853 eruption broke up through the center of the village Ahau and killed half the inhabitants. In 1929 the natives of



Church of the Marist Catholic Mission at Futu, a stone structure which was surrounded by aa lava and burned out July 25, 1929, and all the village houses around it were buried. Only a cross in the graveyard was left standing intact. Photo Jaggar.

Futu saw the fiery cracking of the flank of the hills in the distance, and fled to the heights in time to save themselves. But the northern half of their cluster of warehouses, churches, and habitations was buried under aa lava. They removed to a new village near Angaha on the north shore.

A remarkable adaptation of natural history to the uses of warm volcanic sand is the malau bird, a unique inhabitant of this island. At several places around the lake, and especially where the afternoon sun heats the explosion-made sand hills of 1886 this bird dwells amid the ironwoods and other growth. It is a small bush hen of the tribe Megapodius, meaning "big footed," which has another representative in Australia. It has large, yellow legs and claws adapted for digging in the sand. Its body is black, its head small and scrawny, and its size that of a small Leghorn hen. It whistles like a quail.

The malau hen digs a hole three to five feet deep in the sand slope, lays her egg in the bottom, scratches her way out filling the hole behind her with sand, and Nature does the rest. The sun heats the sand to from 85° to 95° F. Different hens reoccupy the same holes over and over again, even though the natives dig up the eggs for food. When a more fortunate egg hatches, the young bird digs its way out and is said to fly at once. The egg is long and pink, as big as a goose egg.

The people of Niuafoou are Polynesians with a civilzation much like that of Samoa, and they are strictly governed by a high chief, a magistrate, and police service representing the Queen of Tonga. There are usually seven or eight white people at Angaha, the principal port, where a rough landing may be made with boats. The people are completely Christianized, members of three denominations, are constant church attendants and lovers of religious music. The population is about 1,100, there are several motor cars, and the trails are broad and kept in good condition. Every man has his plantation, the people are splendid physical specimens, they are fond of tennis, cricket, croquet, boxing and swimming, and are very hospitable and friendly. They are not afraid of sharks, and meet the mail boat with swimmers. Hence the name "Tin Can Island."

The geology of Niuafoou indicates that it is the peak of a big lava dome under the sea, and thus it represents a more advanced stage of the same kind of volcano growth as White Island in New Zealand, or Falcon Island (Volcano Letter No. 265) farther south in the Tonga group. The central crater has been engulfing its walls along with explosive eruptions in recent geological ages. The lava plug under the crater tends periodically to erupt around its edges, or along the 'wall-crack" as we say at Kilauea, but the fractured caldera rim makes it easier to find a fissure up a crack in the outer lava platform than in the crater lake. Once in a long period, just as at Kilauea, the lava pressure is relieved and the plug lowers, letting in water and making a steam-blast eruption through the crater lake. The known last interval between these steam eruptions for Niuafoou was 72 years, whereas for Kilauea it was 134 years.

The ring ridge is made up of lava layers alternating with ash dipping a little more steeply away from the center than the heavy lava layers shown at the foot of the cliffs around the crater lake. The history, therefore, implies a lava dome below, becoming an alternation of lava and explosive eruptions in the later stages.

The eruption of 1929 was typical of all the western lava eruptions. The lava is a feldspar basalt similar to those of Hawaii except that olivine is not conspicuous. The southwestern desert of Niuafoou is what Kahuku and the Kau Desert are to Hawaii. In 1929 the old NNW-trending rifts of 1853 and 1912 at the inner border of the southwestern lava platform of the ring island were suddenly extended northward with an unheralded splitting of the mountain athwart its flank. Fiery slag shot up the crack without warning except for a few tremors. The frothy outflow swept west down to the sea. This happened about 4 a. m. July 25 by Tongan time, almost exactly 24 hours before a similar lava eruption occurred in Halemaumau pit.

The rifts in Niuafoou propagated themselves northward in overlapping gashes. These gashes showed such sympathy with the wall-cracks of the caldera as to indicate that if the intervening ring ridge broke down, the lava source cracks would promote the natural enlargement of the crater lake basin. The lava floods were pahoehoe above and aa near the sea. A dozen of them reached the water with islands of untouched forest in between. The length of the active spouting belt was approximately three miles. About 4,000 acres of coconut plantations were destroyed and traders' property estimated at $10,000. The eruption lasted only a little over a day.

The action was quite like the Kilauea flows of 1920 and 1923, fountains shooting up 20 to 50 feet, making Pele's hair and glassy needles, and building, as shown in the photographs herewith, long spatter ridges along straight chasms, fields of pahoehoe and aa, multitudes of coconut tree molds, and sand heaps along the sea front which were later converted into beaches. There was a little steam-blast action at the southern end of the rift belt, flinging up pieces of coral along with clinker. There were burning hydrogen and other gases at the vents making secondary glazes of many colors.

The straight wall of vents along the source crack was frequently double with heaps of glistening slag on both sides of the crack except where a torrent had maintained a flow gap. Steam still rises back of Futu and deposits sulphur and sulphates. The lava heaps there are 6 to 20 feet high above the former surface of the country, the visible V-shaped chasm in places is 30 feet deep, and collapse has revealed a cross section of old lava and ash beds where the original slope was rent asunder when the rift opened.

The explosive eruption of 1886 was a great event in the history of Niuafoou. It ranks the volcano in Class II among about 43 of its kind including Vesuvius. There was no direct loss of life owing to the good fortune, probably due to the trade wind, which forced the great cauliflower clouds of debris westward over the lake so that only 2½ feet of ash fell on the settlements. An earthquake gently swayed the island at 7 p. m. August 31, 1886, and shocks continued until midnight causing great alarm. Then with detonation a "rocket" ascended from the lake 3,000 feet, the shaking ceased, violent lightning storms developed striking the trees in many places, and big steam-blast vents piled up sand hills and shut off lagoons about an engulfment notch that was formed in the rim of the caldera on the northeast side of the lake. On the leeward side the deposits on the ring ridge were 20 feet deep. The material was broken fragments of rock, pumice, sand, and fine dust. The hills of this next to the lake are 200 to 400 feet high. The eruption lasted 18 days. It was accompanied by subsidence of border benches of the caldera. The Tarawera eruption in New Zealand happened only two months before, in June, 1886, was similarly explosive, and on the same line as the Tonga islands to the south. Here was another of the many cases of volcanic sympathy hundreds of miles apart where the same rift in the earth's crust is concerned. Falcon Island and submarine eruptions in Tonga were in action in 1927 and 1928, this activity continued into 1929 and so was sympathetic with Niuafoou in that year. Similarly Falcon Island had begun eruption in October, 1885, preceding Niuafoou in 1886.

The writer carried a shock-recorder this year to Niuafoou and set it up in a quiet place on concrete, and operated it in September and October. The records in 1930, 13 months after the activity of 1929, were singularly free from earthquakes, none was felt by any member of the expedition from August 19 to October 22, and earthquakes were not reported by the natives. They did, however, report underground rumbling in the lava belt October 3, and 9 small shocks during 4 minutes following 6:38 p. m. that day were registered on the shock-recorder. Felt earthquakes had been more numerous during the last half of 1929 and were reported as late as January, 1930, but thereafter seismic quiet ensued. T.A.J.

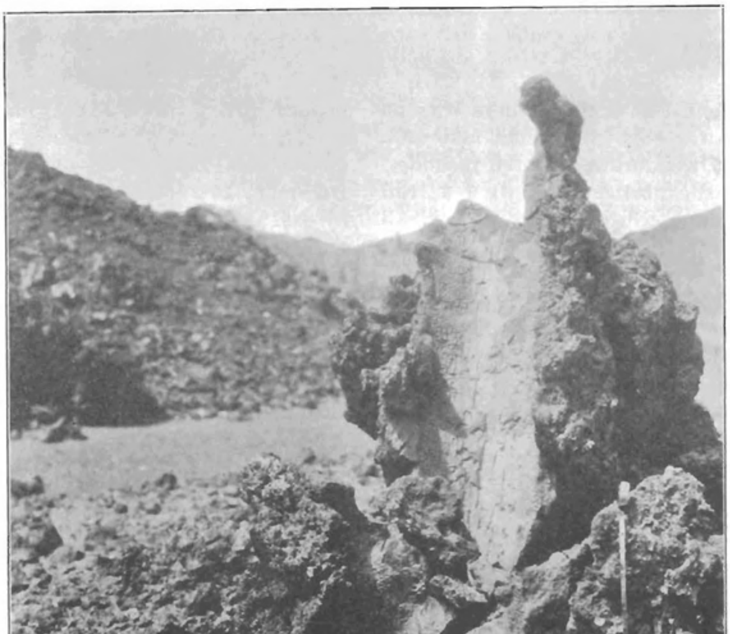
KILAUEA REPORT No. 986

WEEK ENDING DECEMBER 14, 1930

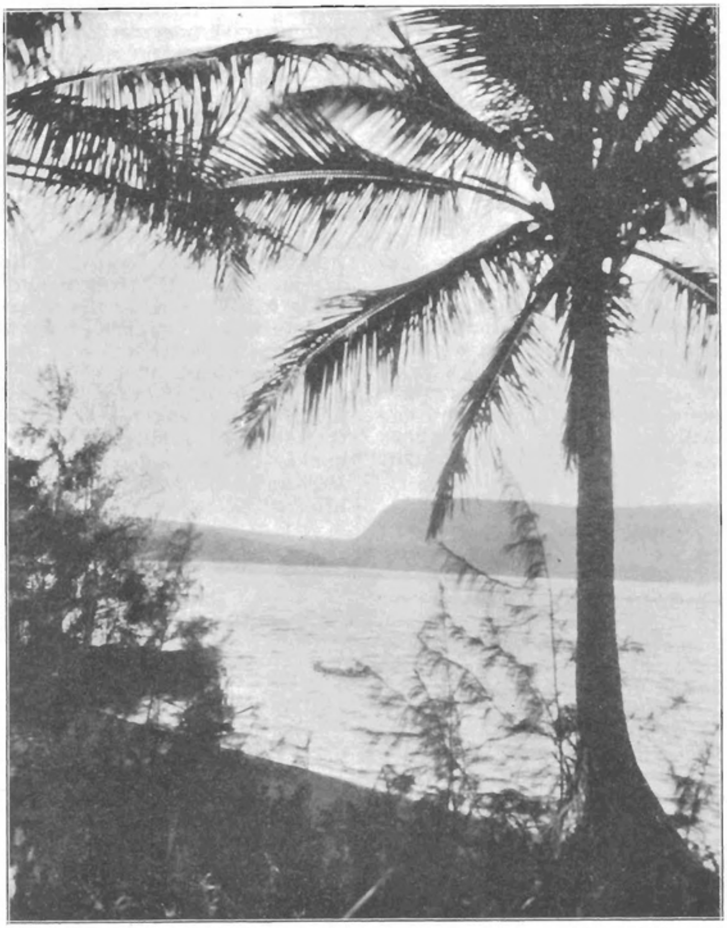
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar. Volcanologist in Charge

The week at Halemaumau pit following the recent lava eruption in the bottom of this inner cauldron of Kilauea Crater has produced no new visible activity, but the glow of the hot basaltic fill may still be seen in cracks through the floor, and the bluish fume continues to rise around the vents and at the sulphurous wall-crack at the southeast.

On Monday December 8 there was abundant fume rising from the pit as seen in the afternoon light when the sun is on far side of the vapor as seen from the Observatory. With the sun behind the observer in the morning



Interior of a coconut tree mold showing the bark pattern made by the pahoehoe lava of 1929 on Niuafoou. Thousands of coconut trees were molded so as to leave groves of stone trees 5 to 13 feet high. Photo Jaggar.



Glimpse of the crater lake of Niuafoou from the largest island, showing the eastern ring ridge in the distance, the ironwoods and coconuts on the island, and the black sand beach. Singular limey concretions are deposited on these lake beaches, containing tiny crabs a half inch in diameter. Photo Jaggar.

light the fume is less evident. At 8 p. m. there was no glow over the pit, but from the edge the recent lake area was seen to be well marked with orange-colored incandescent cracks. One spot at the northwest emitted a trail of light as though from an open grotto. There were small glow spots at the edge of the floor, N, NE, SW, and W. There was no noise. Fume rose from the side of the fountain cone, the southwest side of the floor, and at the bright yellow sulphur SE. December 13 there appeared to be settling of the lake area. Glow in cracks was still visible at night.

The pit seismograph December 8 showed no sign of inward tilting toward the pit and recorded spasms of tremor. At 3:45 a. m. December 13 it recorded an immediately local shock with tilt away from pit. At 5:07 a. m. December 14 a tremor at the Observatory was accompanied by east tilt. The Observatory instruments registered three very feeble local earthquakes for the week, one at 6:18 p. m. December 13 with origin 9 miles away. Four spells of continuous tremor occurred and 29 spasdomic tremors, probably a continuation of eruption tremor. Microseismic motion was moderate on the 8th and otherwise slight. Tilt was very slight north. The evidence suggests continued lava pressure upward.

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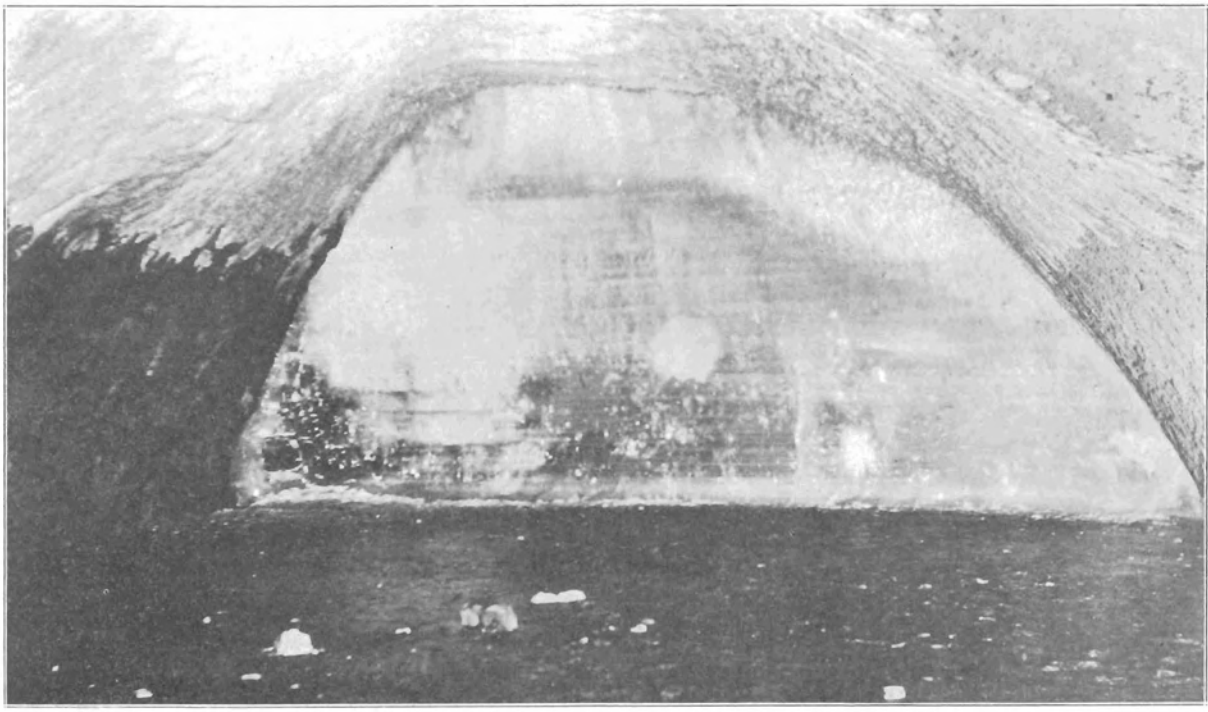
No. 313—Weekly | Hawaiian Volcano Observatory, National Park, Hawaii | December 25, 1930



Flash light photograph of ice wall 30 feet high and 40 feet wide at inner end of Shoshone Ice Cave. Note horizontal stratification, ice floor, and ice crystals on roof and on the face of the ice wall. Photo February 15. 1930, by Bruns.

NOTE BY THE EDITOR

The following paper may be prefaced by a brief summary of the ice cavern situation. This lava tube in recent basalt is 30 miles north of Shoshone in Idaho. It is 80 miles south of the Craters of the Moon National Monument. It is a pahoehoe flow with tubes leading from collapse-basins. Several of them foster ground ice in roof crystals, stalactites and stalagmites, and floor coatings.

The ice cave is 400 feet long in a southwesterly direction from one of the sinks, where it starts 100 feet below the level of the country, and progresses underground downward in steps at a flat angle. The inner part is floored with several inches of ice, the roof variously develops hoar frost and ice crystals, there is a rock pile 80 feet from the inner end, and at the end the cavern is abruptly terminated by a wall of solid ice. This wall of ice is 30 feet high, according to Miss Robinson's diagram (Volcano Letter No. 296), 40 feet wide. and its middle is 100 feet underground. There is a drop with a ladder 50 feet from the entrance. The coldest air temperature was always found just inside the entrance chamber, about 32° F. The innermost chamber was usually 2 to 5 degrees higher. On summer visits there was some water on floor and water drip. Accumulation of ice 4 inches deep went on between two visits of February and April, over paper which had been left.

It may be mentioned that the excessive radiation of solar heat at night, with rapid evaporation if the nights are dry, in contrast to solar melting of ground ice from snow in cracks and chasms daytimes, would be assisted by convection in a cavern system. The finding of the lowest temperature at the narrow entrance, the highest part of the floor of the cave, implies a rush of cold air confined in the narrow passage from within outward. This was found in daytime when the outside air was at 80° F. This shows that an ice box circulation is maintained with seepage of air from outside refrigerated along the same passages that bring down the water in daytime. Probably the night reaction freezes this new water at a lower level, and possibly the convectional circulation. aided by evaporation chilling, becomes stagnant or changes direction. It seems certain that the ice wall is fed by an unseen ground ice reservoir, operated by some such mechanism, and it would be interesting to know what air currents are present, night and day.

T.A.J.

THE SHOSHONE ICE CAVE, IDAHO

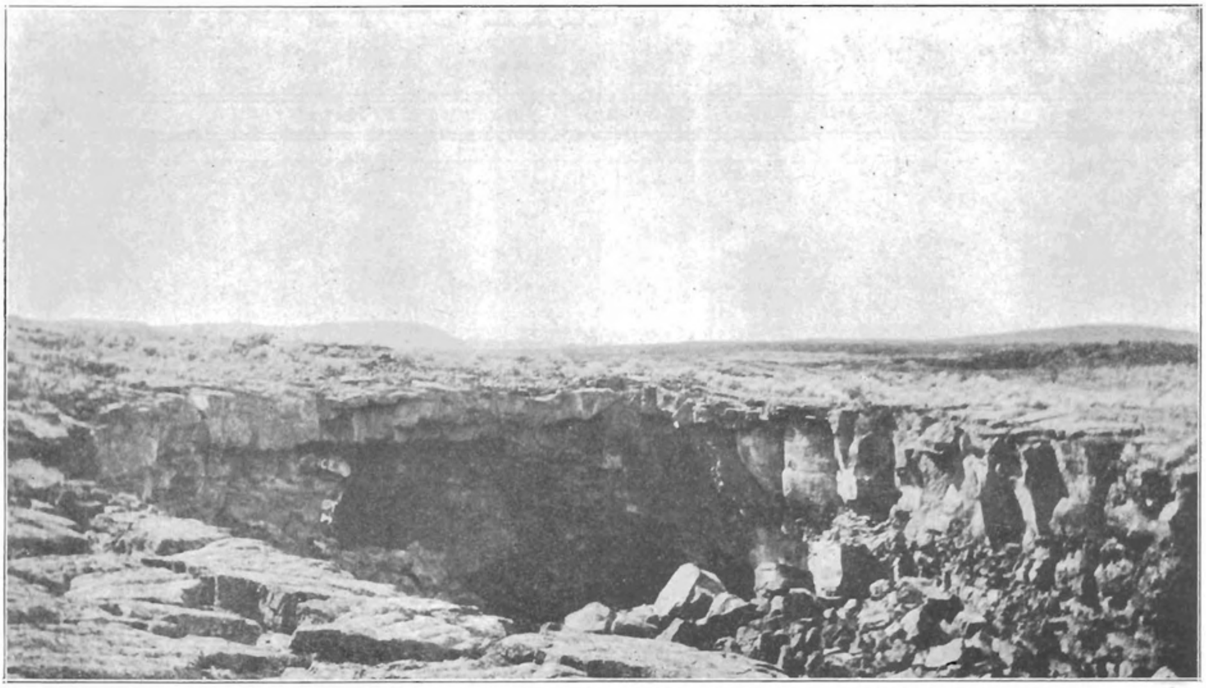
(Second Paper)

By H. G. ROBINSON

In the Volcano Letter for August 28, 1930, this ice cave was described briefly, and an account was given of a series of visits paid to it in the early part of 1930. Since then another trip has been made which resulted in the discovery of several additional facts.

This last visit was made on Sunday, September 7, 1930. The outside temperature was approximately 80° F. The day was clear and hot. In the outermost entrance cave, the ceiling was very damp, and water was constantly dripping. Deep in the cracks which crossed the roof at intervals could still be seen slushy ice crystals. Since there had been no rain for a long while, the water must have come from the melting of those crystals deep in the wall. The floor was still covered with ice, but on top of this ice was a thin film of water which in places measured as deep as half an inch. At the sides of the entrance cave, where the ceiling is very low, formerly there had been thick deposits of clear ice.

It was at once apparent that much melting had taken place at these points, and the ice which remained was no longer clear but looked much like slushy snow. As we approached the ladder we noticed water-cut channels in the ice of the floor, through which small streams of water were running rapidly toward the ladder. They formed a very considerable water-fall just behind and beside the ladder. Right at the foot of the ladder was a depression in the floor ice, worn by the constant stream of visitors usual in the summer time. This depression was filled with



Outer sink and entrance to Shoshone Ice Cave. Photo May 18, 1930 by Bruns.

water. But the floor elsewhere, between this point and the rock pile, was dry.

In view of the amount of water constantly pouring over the edge by the ladder, this indicates rapid freezing conditions in the cave. The floor, previously of clear ice, was now covered with a thin film of ice crystals which sparkled faintly in the flashlight. As we neared the rock pile, a slight film of water was again noticeable. It was not more than a quarter of an inch deep, except in depressions apparently caused by the drip of water from the ceiling, or by melting about some foreign object. Just the other side of the rock pile the drip from above was again noticeable. The stalagmites had in all cases melted away until only slight humps could be distinguished.

Over the rock pile the ice which had been clear enough to enable us to read the newspaper a few months ago was now crocked like old china, forming a mottled pattern all over the surface. It was thinner than before also, for the paper, one which was left behind by accident in January and noticed in April, covered to a depth of about six inches with crystal-clear ice, was now only a few inches below the surface. Nowhere was the ice as slippery as it had been on the previous trip.

The ice wall at the rear was much the same as usual, except that a large part of the wall near the bottom had been dug away, apparently with a pick-ax. Like all other such efforts made in the past, it proved useless, and rather worse than useless, since it revealed no end to the wall and helped to destroy a thing of beauty. We found also that all of the iron stakes driven in at various places to aid us in measurement of the ice thickness had been removed, except those on the right and left floors which were so well concealed as to be unseen by the average sightseers.

There were no ice crystals at all on the ceiling of the entrance cave. At the foot of the ladder the roof was covered with ice which had lost its crystalline form, having apparently melted and refrozen into clear ice drops. Farther back in the cave the percentage of real ice crystals increased, and their presence was noticed much farther back than on any previous visit. It was also noticed that they were much more abundant and extended farther back on the left, or inside, curve of the wall than on the right.

The temperature of the cave at the foot of the ladder was almost exactly freezing. This fact explains the freezing of the water flowing in from the entrance cave, and the reformation of the drops of ice from the crystals on the ceiling. However, the crocked condition of the ice at the rock pile, the original melting of the crystals, and the slushy, snowlike appearance of the ice at the entrance, certainly indicate that considerable thawing had taken place during the summer months.

On this visit a survey of the ground above the cave was attempted by a rough estimate of distances and compass readings. At the point where we believed the underground rock pile to be the ground surface was much disturbed, being composed mainly of loosely piled chunks of lava rock which left many cracks, crevices, and holes leading downward. Though there was a party in the cave at the time, no sound of their voices or other noise could be heard at this place, thus showing that though these cracks are extensive, they do not form any open channel into the cave. Just the same, a network of cracks leading into the cave is almost certain, and the outer loose rock would form, of course. an excellent reservoir for snow, which on being melted by the sun's rays would find its way into the cave below, thus forming the persisent drip at the inner rock pile.

Farther on outside, at the place where the ice wall starts underneath, a sharp V-shaped depression cuts across the surface at right angles to the general direction of the cave. This depression is about 20 feet across and about 50 feet long. It looked as though support had been withdrawn from beneath a crack at right angles to the cave direction, thus causing the two sides to slope in gently toward it. However, no opening could be detected at this point.

On following across country the line of the cave still farther, a very small cave was located. In the eastern wall of this nearest the ice cave were several very small tunnels leading downward and eastward. From these there came drafts of very cold air. By much effort Mr. Bruns, our photographer, wriggled into one of them for some little distance, but saw no ice. However, several other small caves in the vicinity had a little ice in their far recesses. The discovery of these other caves, with their possible connection with the ice cave on the other side of the ice wall, together with the very small opening of the ice cave itself to the exterior, makes one wonder whether the original formation of the ice wall might not be explained by the hour-glass theory advocated by Balch, although the fact that the ice wall is now entirely solid makes the theory of little value in explaining present conditions.

The absence of all ice crystals in the roof in the dead of winter and their appearance later in the spring may be accounted for as a phenomenon of condensation. The cool moisture-laden air of the cave coming in contact with the roof, which has been warmed both by penetration of the sun's rays and by convectional circulation, deposits moisture on the roof where it immediately freezes into crystals. This will of course take place only when the cave air is cooler than the outside air.

As a result of this study, the method by which the ice on the floor is renewed is plain. Its source is ground water from snow and rain, and the presence of the ice wall itself is at least one factor in maintaining a freezing temperature. And yet air currents must play a considerable part, too, since the table of temperatures indicates that the coolest place is always just at the foot of the ladder. From a study of the stake measurements a constant very slow melting may be observed during the interval of study, which is what one would expect.

Though the cave has been observed during the greater part of a year's cycle, the seasonal changes of the local accumulations being roughly recorded, still the phenomenon of the ice wall is not yet explained, and the only conclusion is that detailed and careful study is needed before it can be. Such study might prove to be profitable in opening up new possibilities in refrigeration.

KILAUEA REPORT No. 987

WEEK ENDING DECEMBER 21, 1930

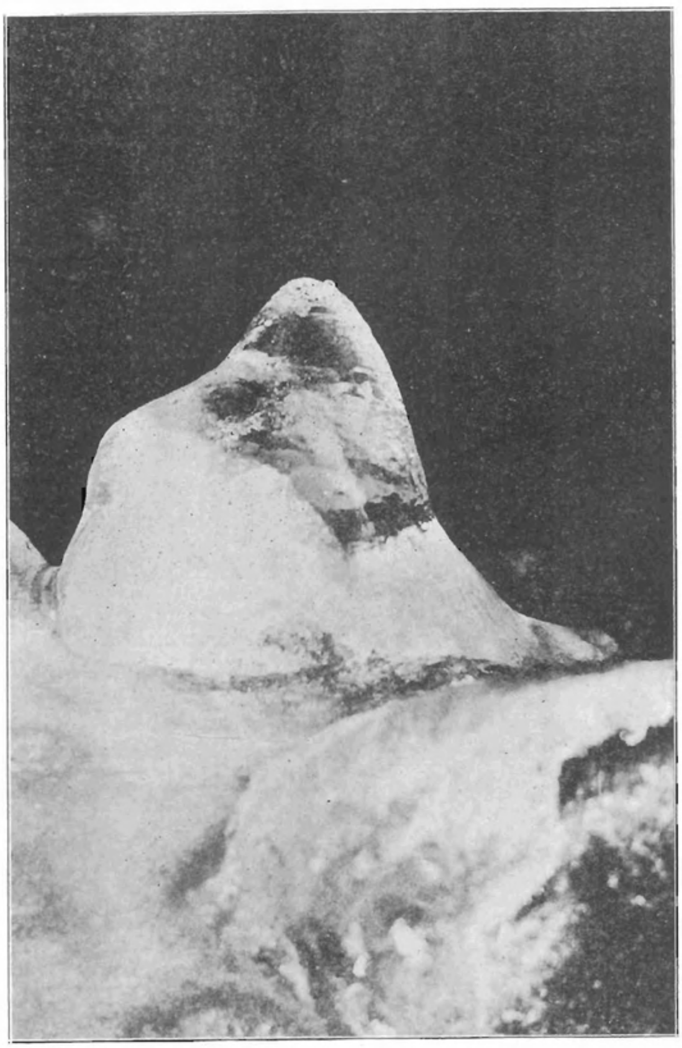
Section of Volcanology, U. S. Geological Survey
T. A. Jaggar, Volcanologist in Charge

The fuming from the new lava fill in Halemaumau has been somewhat less during this past week, but has been constantly noticeable. The fume cloud has been added to by clouds of steam on several rainy days. There has been no further slumping of the surface of the new lava, though a few more fragments from the rim of the spatter cone have collapsed. A feeble earthquake was felt by several persons in the National Park at 4:24 a. m. Saturday, December 20.

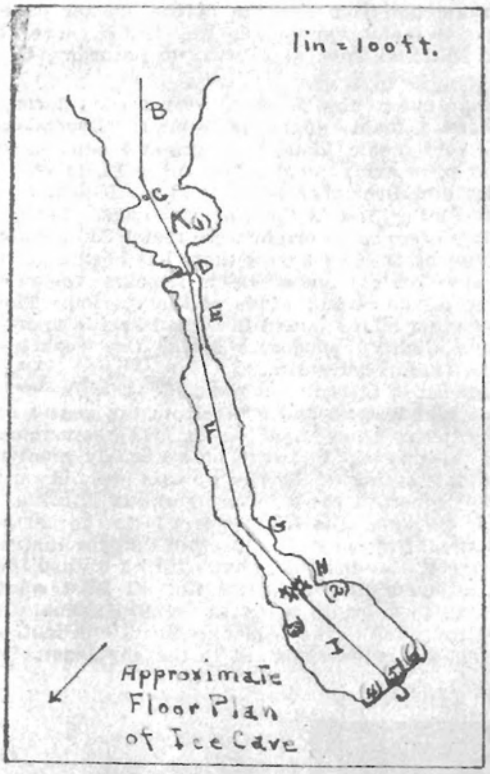
The seismographs at the Observatory recorded 3 very feeble shocks and 1 feeble quake as follows: December 17, 12:21 a. m., very feeble, distance to origin 9 miles; December 18, 8:49 p. m., very feeble; December 19, 11:42 p. m., very feeble; and December 20, 4:24 a. m., feeble, distance to origin 4 miles, felt in the National Park. Thirty-six small tremors of volcanic origin were registered during the week, and during the last 3 days there has been a good deal of tiny spasdomic tremor which appears volcanic but may be due to the strong winds of that period. The non-volcanic swaying of the island indicated by the microseisms has been slight to moderate during the week accompanying the trade-wind storm.

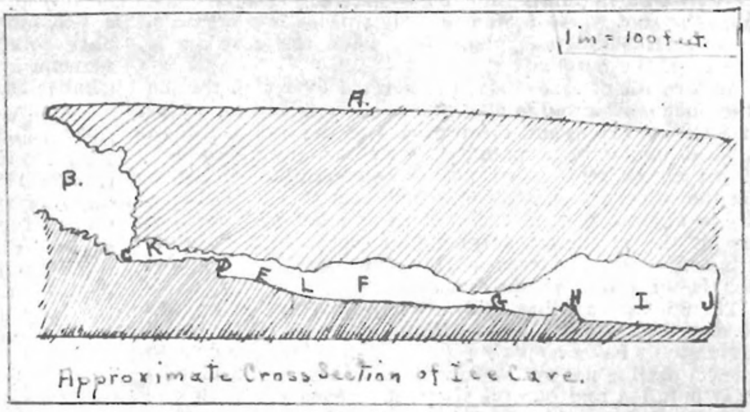
The average tilt of the Kilauea rim under the Observatory has been slight NE, up and away from the center of the crater. During the same time, the rim of Halemaumau has been tilted upward and outward by a slightly greater amount. A notable tilting of the rim upward and outward from the pit accompanied the Kilauea quake of Saturday.

The normal tilting of the Kilauea rim is to the northeast at this season of the year, but the fact that the instrument on the edge of Halemaumau shows tilting toward the southeast at the same time indicates that at least some of the tilt is due to volcanic pressure under Kilauea. If the tilt was entirely due to the seasonal effect, both instruments should show simultaneous tilt to the northeast.



Giant stalagmite of ice two feet high on the rock pile inside of Shoshone Ice Cave. Photo. May 18, 1930, by Bruns.





Key

A - Surface
B - Part of "Crater"
C - Where Ice Begins
D - Abrupt Drop
E - Incline
F - First "Room"
G - Tunnel
H - Rock Pile
I - Second Room
J - Ice Wall
K - Entrance
L - Foot of Slide

Date	Temperatures in Degrees Farenheit.							Amount of Stake Protruding in Inches.					
	Outside	Entrance K	Foot of Ladder D	Foot of Slide L	Tunnel G	Rock Pile H	Ice Wall J	Entrance (1)	Left Floor (2)	Right Floor (3)	Right Wall (4)	Center (5)	Left Wall (6)
Jan. 4	13°	32°	35°	39°	34°	34°	34°	Flush	1¼"	1"	4⅞"	3¾"	1¾"
Feb. 15	50°	28°	30½°	33°	31½°	33¾°	31°	¼"	1¾"	⅞"	2¼"	3¼"	1⅛"
Apr 6	78°	32½°	35°	—	—	34°	33½°	½"	1¾"	1½"	2¾"	Removed	2⅛"
May 18	80°	34°	35°	—	—	—	37°	⅜"	1⅜"	1¼"	Removed	"	2⅜"

Plan and section of Shoshone Ice Cave. Scale reduced here to ⅞ inch to 100 feet. Statistics of earlier visits in 1930. By H. G. Robinson.

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.