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A STUDY OF THE VISCOSITY OF LAVA

By

Harold S. Palmer

Very little is known as to the viscosity of live lava. The typical statement in geologic textbooks is that lavas low in silica may flow like water, but that lavas high in silica are more viscous. Laboratory experiments do not seem likely to yield information on this point because of the difficulty in reproducing natural lavas which are more or less charged with gases which affect the viscosity. It seems that a rough estimate of the viscosity, though inexact, is better than no estimate at all, and in the present paper the attempt is made to compare the known velocity of a certain lava stream with the velocity of a comparable water stream, thus enabling one to compare the viscosities of the two fluids. The velocity of the lava stream was observed in the field. The velocity of the water stream is computed in the office.

Becker* computed that the 1840 flow from Kilauea, which reached the sea at Nanawale flowed at a rate of 22 feet per minute (0.37 feet per second)

* Becker, George F., Some queries on rock differentiation: Am. Jour. Sci., 4th Ser., Vol. 3, No. 13, p. 29, January, 1897.

down a grade of 2 per cent, as it had its source at 1244 feet elevation and advanced 11 miles in two days. He says "Water in a stream of such a cross-section on such a grade would flow at about 6 miles per hour (8.8 feet per second) or about 24 times as fast. Since lava is about 2.5 times as dense as water, these data roughly indicate for the kinetic viscosity 2.5 times 24 or 60 times the viscosity of water." Becker's data are taken from the report by Rev. Titus Coan published by Brigham†. It appears that Becker used the average rate at which the front of the flow advanced which would be slower than the movement of the lava once a channel had been established. The front of a flow advances slowly as a whole, because it does so by making various tongue-like extensions which become blocked so that the lava is turned back and diverted to make new extensions. Furthermore, the advancing flow would have to fill depressions in the terrane before it could go on, and this ponding would delay the advance. Therefore Becker's estimate of the velocity is probably too low, and in consequence his estimate of the viscosity is too high. His estimate is also probably too high, as he used a specific gravity greater than that of live lava.

In 1919 Dr. T. A. Jaggar‡ observed the pahoehoe stream in the main channel or gutter of the Alike Flow to be moving at the rate of 11 miles per hour, or about 16 feet per second. He believes that the channel was from 20 to 40 feet wide and from 15 to 30 feet deep. Recent topographic mapping shows the gradient of the channel to be about 500 feet in $\frac{3}{4}$ mile, or about 12.6 per cent. The rate observed by Dr. Jaggar is compared in the present paper with the rate at which water would flow in a channel of like cross section and gradient.

The velocity of water was computed by use of the Chezy and Kutter formulas, familiar to hydraulic engineers. The Chezy formula is

$$V = c \sqrt{rs},$$

Where V is the mean velocity in feet per second, c is a coefficient depending on the dimensions and roughness of the channel, r is the hydraulic radius, and s is the slope or tangent of the angle of inclination. The coefficient, c, is usually computed by American engineers from the Kutter formula,

$$c = \frac{1.486}{n} \left(41.65 + \frac{0.00281}{s} \right)$$

in which s and r are the same as in the Chezy formula, n is a coefficient expressing the roughness of the channel surfaces, and the various numerical coefficients are those derived empirically from experiments with channels of many types. The gradients involved in the present discussion exceed greatly the gradients used in the basal experiments. Therefore the experimental data are strongly extrapolated, and the computed velocities must be taken as giving little more than the order of magnitude of the velocity of the hypothetical water stream.

† Brigham, William T., Notes on the volcanoes of the Hawaiian Islands: Mem. Boston Soc. Nat. Hist., Vol. I, part iii, pp. 70-74, 1868. Reprinted in Brigham, The volcanoes of Kilauea and Mauna Loa, Mem. B. P. Bishop Museum, Vol. II, No. 4, pp. 50-54, 1909. Also abstracted in Dana, James Dwight, Characteristics of Volcanoes, pp. 61-65, 1890.

‡ Oral communication.

The hydraulic radius is defined as the ratio of the area of the cross-section to the length of its wetted perimeter. As seen by the cross-sections in the right hand part of Figure 1, channels of quite different cross-sections may have the same hydraulic radius. Thus four near the bottom of the diagram have each an hydraulic radius of four feet. If of like roughness and slope they would carry water with the same mean velocity. It may be noted that in very wide streams the hydraulic radius becomes almost equal to the mean depth.

The five curves in Figure 1 show the velocities of streams of water occupying channels with (1), a gradient of 12.6; (2), hydraulic radii of 4, 6, 8, 10, and 12 feet, respectively; and (3), varying degrees of roughness. The dotted line surrounds the region of the graph that includes the probable hydraulic radii and degrees of roughness of the main gutter of the Alika flow. The median velocity in this "probable area" is about 155 feet per second, the range being from 115 to 200 feet per second.

The probability is that Dr. Jaggard observed the velocity of a surface thread near the middle of the channel. Such a thread would have a velocity 5 to 15 per cent greater than the mean velocity of the stream. Therefore the preceding velocities are increased by 10 per cent, making the median 170 feet per second (range 125 to 220 feet per second). These are the velocities which should be compared with the 16 feet per second observed by Dr. Jaggard.

It appears that the lava was flowing about one-eleventh (16/170) as fast as water would have flowed if it had filled the same channel, altho the ratio may have been as great as one-eighth (16/125) or as small as one-fourteenth (16/220).

The rate of flow of the lava is assumed to have been steady, in which case the driving force would have been just enough to overcome the viscosity or internal resistance of the lava, but with no excess of driving force to accelerate the lava. Since the gas-charged fluid lava has a specific gravity of the order of 1.4* the force driving the lava stream would be about 1.4 times as great as the driving force of a comparable water stream with unit specific gravity. If streams of two fluids were alike in all respects except specific gravity, then the driving forces would be in the same ratio as the specific gravities. And if the velocities were the same, the viscosities would be proportional to the specific gravities, that is, to the driving forces.

Since the velocity of a stream is inversely proportional to the viscosity, we may write the equation,

$$\text{Viscosity} = \text{a constant times } \frac{\text{specific gravity}}{\text{velocity}}$$

Substituting 1.4 as a reasonable value for the specific gravity of the Alika lava, 1/11 (or 1/8 or 1/14) for the relative velocity, we find that the viscosity of the lava on this occasion was very likely 15 times the viscosity of water and lay between 11 and 20 times.

There are four sources of error in the computations of the velocity of the hypothetical stream of water. Two refer to the assumptions as to (1) the dimensions of the channel cross-section, and (2) the roughness of the channel walls. A considerable range is allowed for these variables in the graph which is based on computations for 45 combinations of roughness and hydraulic radius. Another source of error lies in the assumption (3) as to the gradient. A number of additional cases were computed assuming gradients one-tenth steeper or less steep than that assumed previously. It was found that such a change in gradient would produce only 4 to 7 per cent change in velocity. Furthermore, it is believed that the gradient assumed is very nearly correct. The fourth source of error comes from (4) extrapolation of the Kutter formula beyond the range of the experimental data on which it is based. Two addi-

* Jaggard, T. A.; Bull. HVO., Vol. IX, No. 2, p. 29, Feb. 1921.

tional sources of error refer to the properties of lava, and are as follows:
 (5) The amount of effervescence and its effect on specific gravity and velocity.
 (6) The amount of solidification on wall of channel and its effect on roughness of channel walls and on hypothetical cross-section.

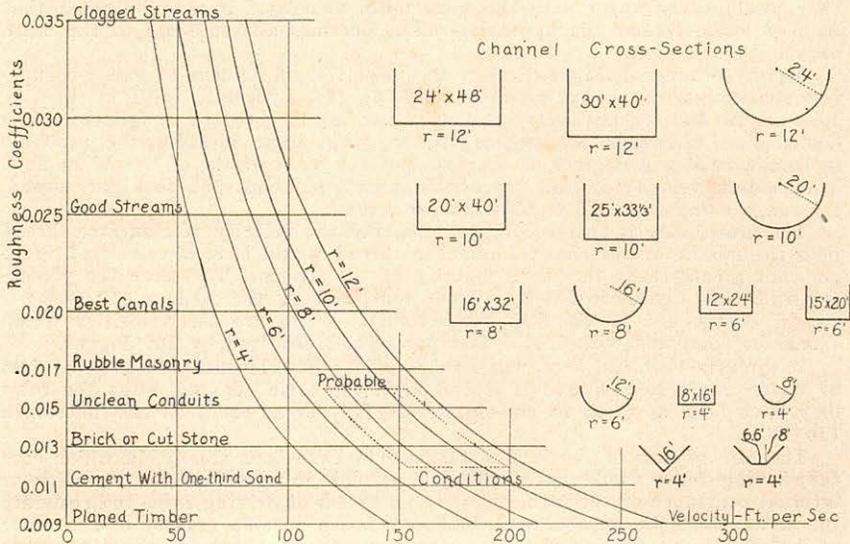


Fig. 1. Channel Cross-Section and Stream Velocities. (Article by H. S. Palmer.)

VOLCANIC CONDITIONS IN JANUARY

Activity of Halemaumau

During this month Halemaumau gave some indication of possible return of lava, with increasing sulphur deposits and rather frequent avalanching. Heavy rains the first days of the month failed to wash away the bright yellow sulphur at the south talus. Blue sulphurous fume does not show at this place as it did formerly: there is only white steam.

For the week ending January 5 there were 16 very feeble local earthquakes. Microseisms were large after January 2, owing to a strong northeast wind. Tilt was moderately eastward.

Fourteen very feeble tremblings were registered during the next week. Microseisms continued strong to January 6, and then diminished to normal. Tilt accumulated moderately westward.

The third week of the month brought about some marked changes: Increase in area of the sulphurous patches; increase in the amount of avalanching, and increase in the number of earthquakes. The combination of these mean chemical and physical disturbances that may portend eruption. On January 15 and 16 there were avalanches loud enough to be heard at the Observatory, and dust from slides was seen frequently. The pit walls were steadily working, and much new debris was added to the talus slopes. There was a total of 29 very feeble local earthquakes, most of them occurring on the 13th, 14th, and 15th. One of the shocks began at 5:07 p. m. on the 14th and lasted over two minutes. Tilting of the ground accumulated very slightly to the east, which may mean an increase of internal lava pressure under Mauna Loa.



Fig. 2. MAUNA LOA LANDSCAPES. August 17, 1915. Looking down on Kilauea, with Halemaumau smoking, from Halealoha, the tank camp, about 7,000 feet elevation, on Kapapala trail, east flank of Mauna Loa. Direction N. 80° E. Photo Wood.



Fig. 3. August 24, 1915. Looking northeast down line of cones along Mauna Loa rift from edge of Mokuaweoweo Crater. Steaming cone in middle distance. Each cone was the source of a lava flow. It was from these that several flows threatened Hilo. Photo Wood.

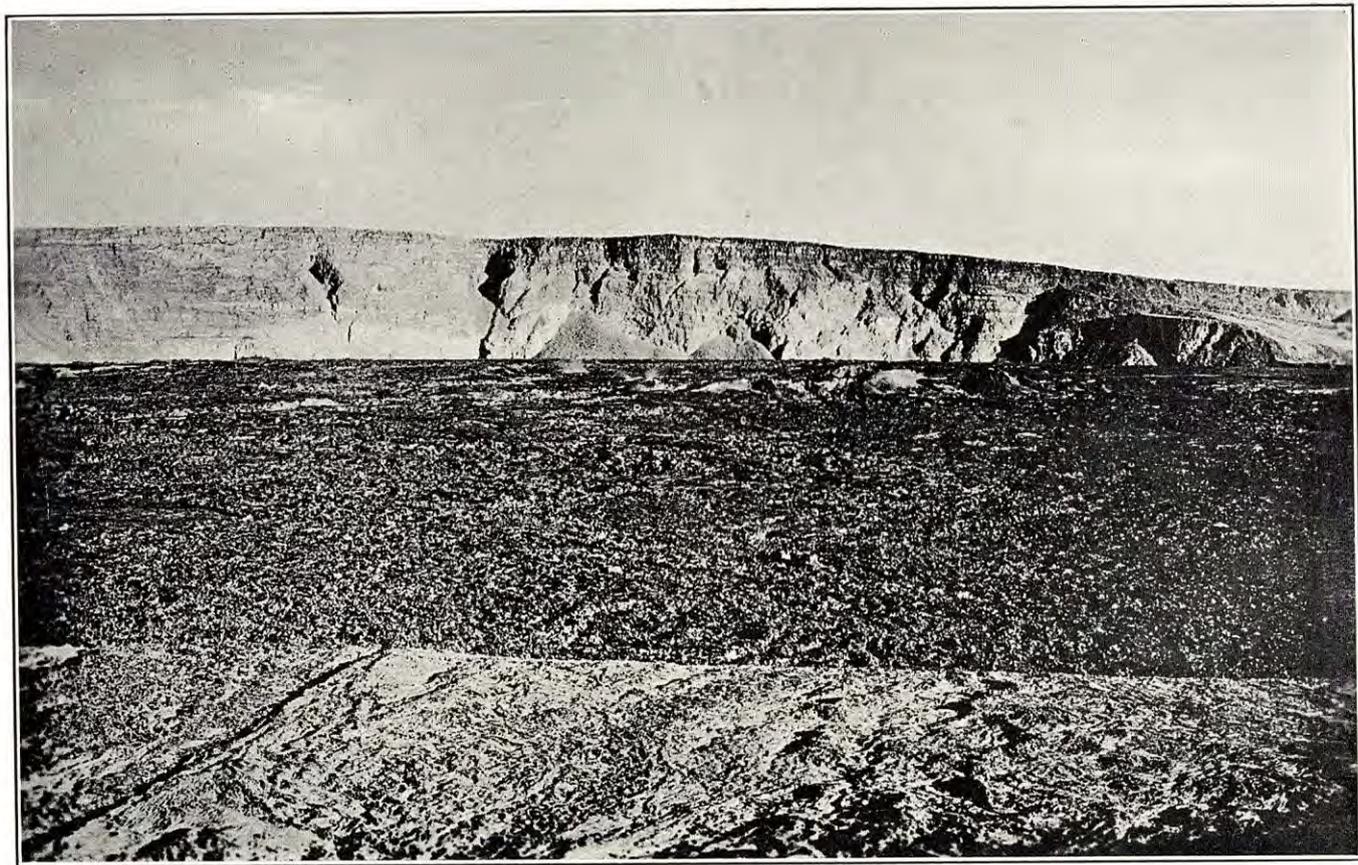


Fig. 4. West wall and bottom of summit crater of Mauna Loa, Mokuaweoweo, August 23, 1915, showing 1903 cones. Panchromatic plate, F filter. Photo Wood.



Fig. 5. Same, looking more to the southwest, showing 1914 cone. Photo Wood.

In the latter part of the month the period of avalanching ceased and the walls became rather quiet once more, although rock falls were occasionally heard when the pit was visited. On January 20 some dust was seen over the pit. The bright yellow sulphur crystals on the south talus remained fixed, though there were heavy rains on the 26th, but the other sulphurous spots became paler.

During the week ending January 26 there were 25 earthquakes recorded, most of which were very feeble. One of these, at 6:49 a. m. January 24, was strongly felt at Kona, and had an indicated distance to origin of 44 miles. A slight earthquake was felt at Volcano House at 6:54 a. m. January 24. There was also a distant earthquake registered, beginning at 2:45 p. m. January 23. Phases of this shock indicated its distance to be about 3,580 miles. Tilt for the week was slightly to the southeast.

The month closed with no new changes in conditions in Halemaumau, and there was little or no avalanching.

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January 5. After several days of northeast storm and rain, the pit shows fixed bright yellow sulphur at the south talus. This area does not emit the SO_2 blue fume that was formerly so noticeable here, mixed with the white vapor. Now there is only the white steam.

The northeast corner of the pit, at the rim, has caved away profoundly, and the talus below has fresh rocks on it. The strong wind has knocked over signs and trig station flags. Steam volume is not unusual. Large areas of white stain are on the north and northeast walls.

January 13. At 1:40 p. m. there was dust from a slide hanging over the pit.

January 15. At 11:43 a. m. an avalanche in the pit was heard at the Observatory, and all about noon dust from slides hung over the pit. At 4 p. m. the north and north-northeast taluses were seen to be topped with fresh debris, and there is a fresh conchoidal break in the north wall. Most of the sliding appeared to have been at the west contact of the big sill.

From 4 to 4:30 p. m. slides occurred from the northeast, north-northeast, north, northwest, and southwest walls. Evidently the walls are uneasy.

The south talus at two places had very bright yellow sulphur spots.

Steam is densest at the upper part of the southwest talus; and is thin at the other places.

The biggest patch of white stain on the walls is under the northeast station. The walls and taluses are dry, and the weather is clear.

January 16. At 2:58:30 p. m. there was a big avalanche roar, and a gray cloud of dust arose, appearing first at the northeast corner of Halemaumau. There were other mild displays of dust before this. This was the noisiest slide and the biggest dust cloud seen for many weeks, though there was a noisy slide, with little dust, yesterday about 11:43 a. m.

The pit was visited at 4:30 p. m. The avalanches had quieted down, but the walls were unsteady, with trickling slides seen and heard repeatedly northeast, north-northeast, north-northwest, northwest, and southwest near the rift cavern. The north corner has a scar of another avalanche, and the north talus is covered with fresh red debris. This was probably the slide that accompanied the earthquake of yesterday afternoon. Today's slide was apparently north-northeast, where there is a fresh wall scar high up.

At the south station the smell of spicy sulphur is strong. This rises from the yellow steaming patch at the south talus.

The walls today are wet and dark red, although rains last night were light in the vicinity of the Observatory. The salts on the rock bank at the base of the southeast wall are entirely washed away, and the white area of the northeast wall is smaller. There are many salts on the ground outside and south of the pit. There are green moss patches and blue green algae halfway

down the south and west walls of the pit. There is much moss and grass and other plants about the steam cracks east of the pit.

About 100 yards south of the pit is a boulder of agglomerate three feet in diameter showing flaky gray ash layers and other pebbly layers, the whole decomposed in place with flakes piled around the rotten heap; this is the largest sample of acid degeneration among the 1924 ejecta yet seen.

January 18. At 4 p. m. there were rock trickles southwest, northwest, and northeast. Dust hung over the pit yesterday occasionally.

The area of the yellow solfatara at the south talus is growing larger. The little area of sulphur at the east margin of the south talus is bright with sulphur crystals. There is much sulphur at two other places along the east edge of the bottom, and a faint yellow stain southwest of the center, about where the July, 1924, cone was. All of this development of sulphur is very new and may portend the return of lava.

The hot line of steam jets up the middle of the southwest talus, with a dry patch in the talus, may turn sulphurous just as the south talus has done and as the bottom of the northwest talus is doing.

The working of the wall today seemed to be near the southwest-northeast rift, both on the southwest and northeast walls.

January 20. A visit to Halemaumau at 6 p. m. showed no change. The weather was calm without wind. There were falls of stones northeast and west. Fresh debris lay on the northern taluses. Some dust was seen over the pit today.

Rocks were heard falling in the pit at 9 p. m.

January 22. During a visit from 3 to 6 p. m. a walk was made around the pit. A few isolated rocks fell. There was dense flocculent steam from the dry patch at the middle of the southwest talus.

The west end of the big sill is against rocks that are very red. The new talus below is very red.

The east sulphur spot is at least 100 feet above the lava floor, and the south sulphur spots are at least 200 feet above the floor.

No new cracking of surface ash was observed anywhere around the pit.

January 23. At 10:30 a. m. there was no change in conditions at the pit. One slide occurred on the southeast side, but was started by boys throwing stones. There was a little sliding northeast.

January 26. At 2 p. m. there was one fall of rocks at the northeast wall. In the upper part of this wall there is a large arch of jointing across all the beds.

Heavy rain for the last two days has wet the walls and made them dark red. The steam of the pit bottom has not increased. The smaller sulphur patches are washed and paler than before. The solfatara of the south talus is still bright yellow; the rain has not washed that away at all.

January 28. From 3 to 4 p. m. nothing new was noted at Halemaumau. A jet of steam was rising from a boulder in the midst of the dry hot patch at the center of the southwest talus. There were no slides of any size.

SEISMOMETRIC RECORD

There were 85 local earthquakes and one teleseism recorded on the Observatory seismographs during the month ended at midnight, January 31, 1927. These and other phenomena are listed below. The time used is Hawaiian Standard (time meridian is $157^{\circ} 30' W.$), which is 10 hours and 30 minutes slower than Greenwich.

The greater number of the very feeble local shocks, counted in the list, make such minute records that the character of the disturbance is not always apparent. Some are true earthquakes; others are perhaps the parts of greater amplitude of a continuous or protracted tremor, which at other times may be too feeble to record; some seem to be records of vibrations set up by avalanches in the pit of Halemaumau.

Abbreviations used below are as follows: vf, very feeble; f, feeble; s, slight; m, moderate; d, instruments dismantled; fl, felt locally; Δ, indicated distance in miles; *, continuous tremor.

Local Earthquakes

January

| | | | | | |
|----|----------------|----|----------------------|----|---------------------|
| 1 | 12:44 a.m. vf. | 14 | 11:28 a.m. vf. | 22 | 3:17 p.m. vf. |
| | 1:17 a.m. vf. | | 5:07-5:09 p.m. vf. * | 23 | 2:28 p.m. vf. |
| 2 | 4:41 p.m. vf. | | 7:42 p.m. vf. | 24 | 4:38 a.m. vf. |
| 3 | 5:49 p.m. vf. | 15 | 5:59 a.m. vf. | | 6:49 a.m. vf. Δ 44 |
| | 7:43 p.m. vf. | | 6:14 a.m. vf. | | 1:23 p.m. vf. |
| | 9:27 p.m. vf. | | 3:37 p.m. vf. | | 1:35 p.m. vf. |
| 4 | 7:16 p.m. vf. | | 3:45 p.m. vf. | | 10:37 p.m. vf. |
| 5 | 6:31 p.m. vf. | | 5:08 p.m. vf. | 25 | 6:54 a.m. s. d. fl. |
| 6 | 4:57 a.m. vf. | | 8:21 p.m. vf. | | 11:15 a.m. vf. |
| | 7:30 a.m. vf. | 16 | 2:59 p.m. vf. | 26 | 3:21 a.m. vf. |
| | 7:00 p.m. vf. | | 4:28 p.m. vf. | | 11:24 a.m. vf. |
| | 7:17 p.m. vf. | 17 | 2:34 a.m. vf. | 27 | 12:01 p.m. vf. |
| 7 | 3:59 a.m. vf. | | 5:08 a.m. vf. | 28 | 2:07 a.m. vf. Δ 22 |
| | 12:45 p.m. vf. | | 10:08 a.m. vf. | | 9:35 a.m. vf. |
| 8 | 10:41 p.m. vf. | 18 | 12:40 p.m. vf. | | 3:46 p.m. vf. |
| 9 | 3:29 a.m. vf. | | 12:51 p.m. vf. | 29 | 2:58 p.m. vf. |
| 10 | 4:09 a.m. vf. | 19 | 12:52 p.m. vf. | | 10:43 p.m. vf. |
| | 2:49 p.m. vf. | | 3:16 p.m. vf. | 30 | 1:11 p.m. vf. |
| | 10:17 p.m. vf. | | 3:21 p.m. vf. | | 9:45 p.m. vf. |
| 11 | 1:57 p.m. vf. | 20 | 1:14 a.m. vf. | 31 | 1:25 p.m. vf. |
| 12 | 8:34 a.m. vf. | | 3:19 a.m. vf. | | 2:09 p.m. vf. Δ 37 |
| | 11:32 a.m. vf. | | 5:13 p.m. vf. | | 11:53 p.m. vf. |
| | 8:41 p.m. vf. | | 5:23 p.m. vf. | | |
| 13 | 1:25 a.m. vf. | 21 | 6:04 p.m. vf. | | |
| | 3:47 a.m. vf. | | 1:12 a.m. vf. | | |
| | 4:39 a.m. vf. | | 6:02 a.m. vf. | | |
| | 5:03 a.m. vf. | | 11:26 a.m. vf. | | |
| | 6:20 a.m. vf. | | 11:30 a.m. vf. | | |
| | 11:04 a.m. vf. | | 11:46 p.m. vf. | | |
| | 11:10 a.m. vf. | | | | |
| | 11:24 a.m. vf. | | | | |
| | 11:52 a.m. vf. | | | | |
| | 4:03 p.m. vf. | | | | |
| | 11:35 p.m. vf. | | | | |

Teleseism

January 23

iP 2:45:03 p.m.

S 2:52:26 p.m.

L 3:01:00 p.m.

Distance 3,580 miles.

Harmonic Tremor

This movement was not recorded during the month.

Microseismic Motion

Microseisms began to increase in amplitude about January 2, reaching a maximum on the 4th, diminishing to normal again by the 6th. They were normal during the rest of the month.

Tilting of the Ground

December 29-January 4.....0.5 second N.

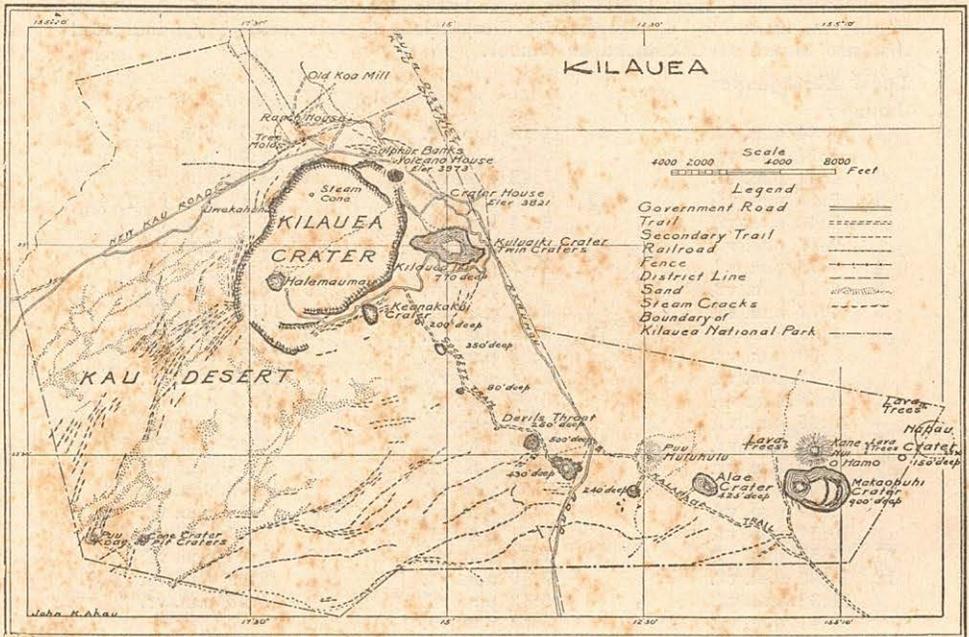
January 5-11.....0.8 " WSW.

" 12-18.....0 " "

" 19-25.....0.3 " W.

" 26-February 2.....0.6 " SE.

T. A. JAGGAR,
Volcanologist.



Black spot shows location of Observatory.

All exchanges, gifts to library, news notes about Pacific volcanic and seismic events, and correspondence should be addressed HAWAIIAN VOLCANO OBSERVATORY, Volcano House, Hawaii.

The Observatory is operated by the U. S. Geological Survey, and its work is supplemented by the Hawaiian Volcano Research Association. The main station is on the northeast rim of Kilauea Crater. Subordinate seismograph stations are operated by the Research Association under the direction of the volcanologist in Kona, Hilo and Hilea.

The Kilauea station operates horizontal pendulums of the Bosch-Omori type and receives time by wireless from the Honolulu Naval Station. Observatory Lat. $19^{\circ} 25' 54.3''$ N.; Long. $155^{\circ} 15' 39.6''$ W.; Elevation cellar 1214.6 meters (3985 feet). The Hilo, Hilea and Kona stations operate horizontal pendulums. Their seismograms are sent to the Observatory.

The Hawaiian Volcano Research Association founded the Observatory in 1911, transferring the plant to the Government in 1919, but continuing cooperation in experimental work by furnishing funds and apparatus and workers as needed by the Government Volcanologist. It is a corporation under the laws of Hawaii, governed by a board of directors, and financed by the subscriptions of its members and patrons. Its aims are identical with those of the Observatory, namely, (1) To keep record of Hawaiian volcanism, (2) To attract volcanologic specialists to Hawaii, and (3) To promote worldwide knowledge of volcanoes and earthquakes and the foundation of more volcano observatories.

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By J. Agostinho, Director of Meteorological Service of the
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NOTE ON THE EARTHQUAKE IN THE AZORES AUGUST 31, 1926

By J. Agostinho

The epicenter of the earthquake was situated in the channel between the islands of Pico and Fayal, some 20 km. to the west of the big volcanic cone of Pico—a mountain 2,274 meters high, which resembles remarkably Fujiyama and whose volcanic activity has only been marked the last four centuries by some lava outbreaks from its slopes. The last occurred in 1720. Earthquakes are frequent in this region, and some submarine eruptions have been signaled very recently.

The earthquake occurred on the 31st August, 1926, at 10 h. 40 m. G. M. T. The zone affected was very small, but the damages in its central part were very important. It is to be remarked that some places on the island of Pico were the seat of great damage, though they were very far from the epicentral zone. This is probably due to the constitution of the soil which changes remarkably from place to place in this island much affected by volcanoes in older times.

Damages in Horta (a small sea-port town, 7,000 inhabitants) were mainly due to bad construction. The number of houses totally destroyed was not very great, but many were so badly cracked that they had to be demolished (10% to 15% of the total). Only nine persons were killed, and nearly 200 were hurt.

Some remarks on the earthquake as felt in Fayal and Pico follow. Duration: Preliminary tremors, one or two seconds; intensity increasing instantly; total duration not greater than five or six seconds. Direction of initial shock: See Figure 7. In Horta the inspection of the ruins shows the evidence of a violent shock coming from the ENE; some evidence, too, of vertical motion. Cracks on the soil: Only a few, very small, diversely directed. Land slides from the cliffs bordering the east coast of the island of Fayal. No changing of level, nor changings in the springs. Noise as of a multitude of motor cars. Shock heavily felt on board ships in harbor. Small waves (two feet high) vanished in a few minutes. No tsunami remarked in the other islands.

The shock was felt also in the following islands: St. Georges (intensity V), Graciosa (intensity III), Terceira (intensity III-IV at 10 h. 41 m. 51 s. G. M. T.), and San Miguel (intensity II, record by Milne seismograph at Ponta Delgada P 10 h. 42 m. 00 s.; M 10 h. 43 m. 24 s.; F 11 h. 04 m. 00 s.).

VOLCANIC CONDITIONS IN FEBRUARY

Activity of Halemaumau

Many slides took place from the walls of Halemaumau during the month. The sulphur patch on the south talus continued to increase in area, though occasional coatings of dust dimmed the coloring. Aside from other slight changes volcanic conditions remained the same.

An avalanche from the northeast wall of the pit on February 1 filled the air with dust for about half an hour. Small slides occurred on following days, and one at 5:20 p. m. February 5 was rather noisy. On this day a large section of the northeast rim was seen to have fallen in.

A distant earthquake was faintly recorded on February 1. Its preliminary wave arrived at 7:36:10 a. m. Hawaiian Time. Eight very feeble local earthquakes were registered during the first week of February. One of these at 11:26 p. m. on the 2nd showed a distance to origin of 45 miles.

There were evidences of big slides in the pit about the middle of the month. Much new debris lay on the northern talus, and dust covered the lava floor. On the 14th considerable dust from slides was seen to rise from the pit, the largest cloud being a red one about 3 p. m.

For the week ending February 16 the count of earthquakes was 12 local and one distant shock. Wind squalls between 5:15 and 7:30 a. m. on the 16th made the instruments in the seismograph cellar vibrate. The distant earthquake was recorded on February 15 and was located by the U. S. Coast and Geodetic Survey as originating at 45° north latitude and 153° east longitude at 1:35:22 Greenwich Time February 16, in the Kurile Islands, 3,230 miles from Honolulu.

Tilt for this week was very slightly west-northwest.

As the month wore on the sulphur spots grew at the bottom of the pit, indicating that lava gas was emerging. Some noisy slides from the walls occurred.

Seismic conditions were very quiet at Kilauea for the week ending February 23. Only eight local earthquakes were recorded, and six of these came on the 21st and 22nd. Tilt accumulated moderately to the south-southwest. On February 21 tilt began to change from southwesterly to southeasterly, and by the 23rd it was nearly due east. With the change of tilt there was an increase in the number of earthquakes, a total of 10 having been registered on the 23rd and 24th.

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February 1. Some slides occurred about 4 p. m. At 5:45 white dust rose in a thin cloud, beginning at the northeast corner and gradually covering the whole pit and remaining above it for 30 minutes or more.

February 2. There was dust over the north corner at 7:30 a. m.

February 3. Dust indicated small avalanches at the pit several times during the day.

February 5. At 4 p. m. there was fresh material on the northeast talus. The sulphur patch on the south talus is growing much larger, and the yellow green sulphur stain is spreading over the talus.

The south-southeast wall is blackened by sulphur over the sulphur steam.

Slides occurred from the northeast corner of the pit at 5:10 and 5:20, and the second was noisy. A large slice is reported to have fallen from the rim.

The steam cracks southwest and west of the pit are purring strongly, as though water were boiling below. This purring is very strong, a real steam pressure, in the hot vents of the Sulphur Bank flat south of the main road north of Kilauea Crater. Does this mean that after the winter rainy season there is liquid water boiling underground, and may it be that the ash seepage and wash of 1924 has made subterranean water reservoirs by sealing the rock, just as ice on top of Mauna Loa and Mauna Kea makes a seal to hold water?

February 6. Some slides occurred in the pit on this day.

February 8. At 3 to 3:30 p. m. there was a light south wind, and the pit was still. The yellow stain continues to grow in area on the south talus. A few rocks fell on the northwest and northeast taluses at long intervals. A slight smell of spicy sulphur was perceptible at the south station.

February 9. There was a rumor that fire had been seen in the pit, but a visit to the pit at 6 p. m. showed that there was nothing new. The weather was wet and foggy.

February 12. At 6 p. m. the black, crater-like area in the sulphur patch of the south talus appeared a little larger. There was a new scar in the middle of the wall over the northeast sill, and new debris on the middle talus under the sill.

February 14. About 3 p. m. there was a strong red dust cloud rising from Halemaumau, and there was dust there at other times.

The pit was visited at 6 p. m., and at the north corner, west of the end of the big sill, there was a prolonged small avalanche falling, making red dust and a roar, with numerous fresh starts from about midway up the wall.

The north and northwest taluses were covered with fresh red debris, and the red dust extended across the bottom of the pit. There had evidently been some big slides.

February 16. At 10 a. m. there was a strong south wind. The pit was very dry, and pink dust was blowing from the desert over the whole of Kilauea. Rocks were sliding a little at the north. The yellow solfatara was dusty. The vapor volume was very thin at all the steam patches.

February 20. At 3 p. m. the sulphur spots were again increasing. A few rocks were falling west and north. The pit was very dry and free from steam.

February 23. In the afternoon there were some noisy avalanches. One was heard from the Observatory at 9 p. m.

SEISMOMETRIC RECORD

There were 46 local earthquakes and two teleseisms recorded on the Observatory seismographs during the month ended at midnight February 28, 1927. These and other phenomena are listed below. The time used is Hawaiian Standard (time meridian is 157° 30' W.), which is 10 hours and 30 minutes slower than Greenwich Time.

The greater number of the very feeble local shocks, counted in the list, make such minute records that the character of the disturbance is not always apparent. Some are true earthquakes; others are perhaps the parts of greater amplitude of a continuous or protracted tremor, which at other times may be too feeble to record; some seem to be records of vibrations set up by avalanches in the pit of Halemaumau.

Abbreviations used below are as follows: vf, very feeble; f, feeble; s, slight; m, moderate; d, instruments dismantled; fl, felt locally; Δ, indicated distance in miles.

Local Earthquakes

| | | | | | |
|----------|-----------------------------------|---------------|----------------|-------------------------------|--------------------------------|
| February | | 7:08 p.m. vf. | 22 | 6:48 a.m. vf. | |
| 1 | 3:55 a.m. vf. | 12 | 10:02 a.m. vf. | 6:04 p.m. vf. Δ ¹² | |
| 2 | 3:44 a.m. vf. | | 11:45 p.m. vf. | 23 | 11:25 a.m. vf. |
| | 7:06 a.m. vf. | 14 | 3:03 p.m. vf. | | 7:33 p.m. vf. |
| | 10:02 a.m. vf. | | 5:48 p.m. vf. | | 8:38 p.m. vf. |
| | 11:26 p.m. f. Δ ⁴⁵ fl. | 15 | 11:14 a.m. vf. | | 9:32 p.m. vf. Δ ¹³ |
| 3 | 5:12 a.m. vf. | | 2:05 p.m. vf. | | 10:05 p.m. vf. |
| 4 | 12:48 p.m. vf. | | 8:45 p.m. vf. | | 10:07 p.m. vf. |
| | 6:08 p.m. vf. | 16 | 2:57 a.m. vf. | | 10:08 p.m. vf. Δ ³⁵ |
| 6 | 2:11 a.m. vf. | 17 | 6:16 a.m. vf. | 24 | 3:58 p.m. vf. |
| | 1:42 p.m. vf. | 18 | 3:53 p.m. vf. | | 5:05 p.m. vf. |
| | 5:52 p.m. vf. | 21 | 5:26 p.m. vf. | | 5:09 p.m. vf. |
| 9 | 1:40 p.m. vf. | | 6:37 p.m. vf. | 26 | 6:09 p.m. vf. |
| | 1:45 p.m. vf. | | 6:50 p.m. vf. | 27 | 10:16 p.m. vf. |
| 10 | 11:48 a.m. vf. | | 7:23 p.m. vf. | 28 | 11:27 a.m. vf. |
| | 2:03 p.m. vf. | | | | |
| 11 | 5:19 a.m. vf. | | | | |

Teleseisms

February 1

eP 7:36:10 a. m.

S ? 7:44:35 a. m.

S ? 7:49:54 a. m.

L 7:52:14 a. m.

Later information gives Solomon Islands as origin.

February 15

L ? 3:30:00 p. m.

Very faint record.

Harmonic Tremor

This type of movement was not recorded during the month.

Microseismic Motion

Microseisms were stronger than normal on February 9, 10, and 11, thereafter diminishing to normal by February 14. On February 16 high wind was the cause of almost continuous irregular tremors without, however, having the effect of increasing the amplitude of microseisms.

Tilting of the Ground

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

| | | |
|-----------------------|-------|-----------------|
| January 26-February 2 | ..... | 0.6 second SE. |
| February 3-9 | | 0.6 second SSW. |
| “ 10-16 | | 1.0 second WSW. |
| “ 17-23 | | 0.8 second SSW. |
| “ 24-March 1 | | 1.3 seconds E. |

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Azores Islands

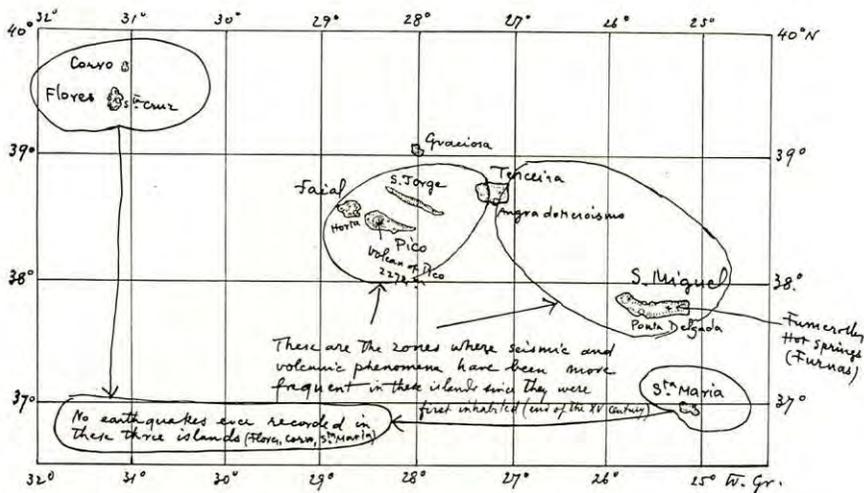


Figure 6. Sketch map of Azores, showing the two active zones in the middle ellipses, and the non-seismic islets at each end of the group. By J. Agostinho.

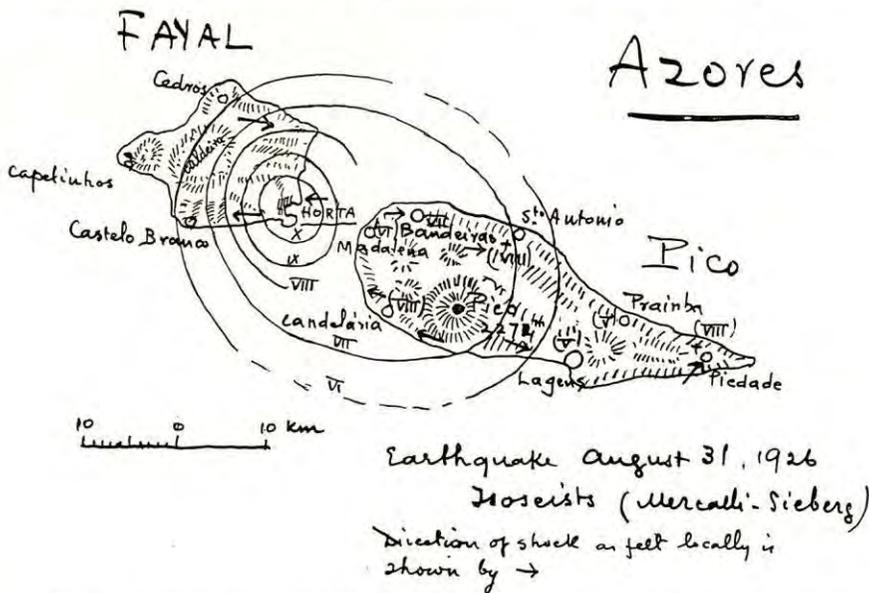


Figure 7. Sketch map of Fayal and Pico, showing isoseists of the earthquake of August 31, 1926. By J. Agostinho.



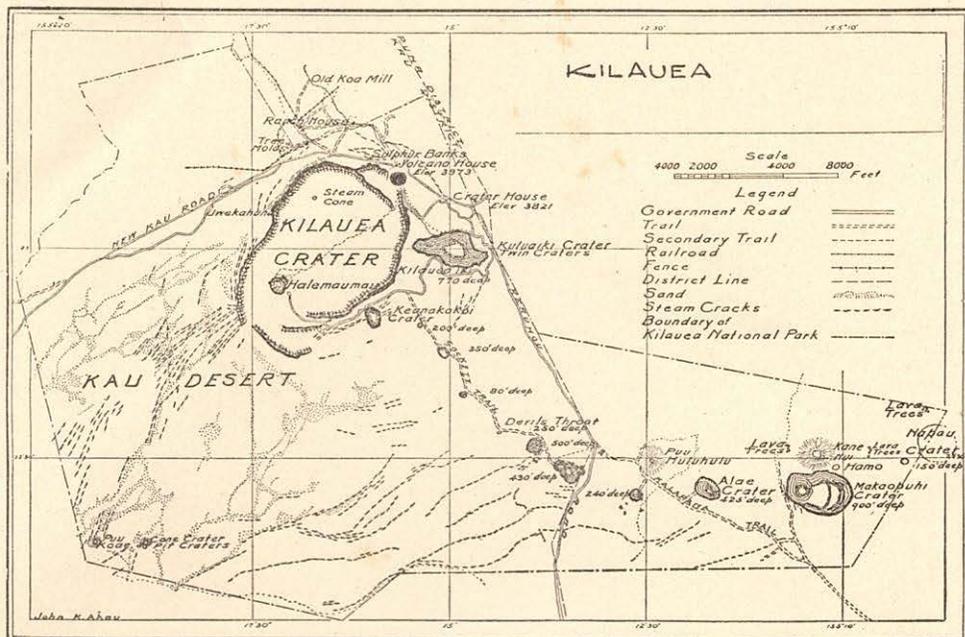
Figure 8. Damaged stucco building, Horta, August 31, 1926. Photo Agostinho.



Figure 9. Rua do Mercado after the earthquake, in Horta. Photo Agostinho.



Figure 10. Damage in Flamengos, a small village 4 km. to the west of Horta, where was maximum destruction. Photo Agostinho.



Black spot shows location of Observatory.

All exchanges, gifts to library, news notes about Pacific volcanic and seismic events, and correspondence should be addressed HAWAIIAN VOLCANO OBSERVATORY, Volcano House, Hawaii.

The Observatory is operated by the U. S. Geological Survey, and its work is supplemented by the Hawaiian Volcano Research Association. The main station is on the northeast rim of Kilauea Crater. Subordinate seismograph stations are operated by the Research Association under the direction of the volcanologist in Kona, Hilo and Hilea.

The Kilauea station operates horizontal pendulums of the Bosch-Omori type and receives time by wireless from the Honolulu Naval Station. Observatory Lat. $19^{\circ} 25' 54.3''$ N.; Long. $155^{\circ} 15' 39.6''$ W.; Elevation cellar 1214.6 meters (3985 feet). The Hilo, Hilea and Kona stations operate horizontal pendulums. Their seismograms are sent to the Observatory.

The Hawaiian Volcano Research Association founded the Observatory in 1911, transferring the plant to the Government in 1919, but continuing cooperation in experimental work by furnishing funds and apparatus and workers as needed by the Government Volcanologist. It is a corporation under the laws of Hawaii, governed by a board of directors, and financed by the subscriptions of its members and patrons. Its aims are identical with those of the Observatory, namely, (1) To keep record of Hawaiian volcanism, (2) To attract volcanologic specialists to Hawaii, and (3) To promote worldwide knowledge of volcanoes and earthquakes and the foundation of more volcano observatories.

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TEMPERATURES OF VOLCANO BORINGS

By T. A. Jaggar

Drilling wells 5 to 20 meters deep in the basaltic lavas of Kilauea Crater was begun in April, 1922. The work was financed by Mr. John Brooks Henderson and the Hawaiian Volcano Research Association. The temperatures at 20 meters depth were 96° C., 65° C. and 36° C. in different places. The gradients were erratic. At a boring in the Sulphur Bank on the upper rim of Kilauea the temperature was 96° from top to bottom and the hole was charged with sulphurous steam. In a second rim bore-hole the three-meter intervals of depth gave 36°, 39°, 37°, 37°, 37°, 36°. Under the Kilauea floor the temperatures at three-meter intervals of depth were 35°, 45°, 54°, 58°, 65°, 64° and 69°.

The Kilauea Crater floor apparently showed a gradient, and all the wells were hot at three meters depth. In 1926 a new project was begun, having in view boring holes three meters deep and 5 centimeters diameter with com-

pressed air drill. These holes were located 300 meters apart at the corners of equilateral triangles over a surveyed net. (See Fig. 12.) Every hole is capped with a metal pipe and cover. This permits taking the temperatures of all the holes at stated intervals and determining isothermal lines for the crater floor and margins. The object of the work is to provide a mechanism for taking rock temperatures apart from the temperatures of vapor cracks. It establishes a method for discovering the true temperature of volcano ground.

True temperature may differ from apparent temperature owing to distributed solfataric cracks which yield hot gases at higher temperature than the average temperature of the rock. Using an artificial hole, of standard size and depth, for a standard method of exposure of thermometer, yields comparative data of quantitative value. With such appliances the ground may be tested as to effect of seasonal air temperature, of underground water, and of porosity, lithology, etc. Thus a basis is laid for repeated temperature measurement in the same district, determining ground isothermals at different stages of volcanic activity. Incidentally, the holes explore surface oxidation of minerals, gas heating, gas composition, and moisture and underground structure, according to their depth.

There have now been drilled 34 bore holes in all, and the use of the air-hammer drill has been continued in 1927. Temperatures appear to be highest along the eastern margin of the fill of Kilauea Crater, apart from hot solfataric cracks in or adjacent to Halemaumau pit. It is probable that the wall-crack of the larger crater, or contact belt between the lava fill and the peripheral wall, is sufficiently open to permit hot gases to rise from greater depths than elsewhere. Some of the holes drilled three meters deep in solid lava show so little rise of temperature at their bottoms that it is essential to seal them and keep them free from rain drip in order to measure the temperature critically. Others are very hot, probably because they cut steam cracks. It is therefore apparent that isothermal lines in plan are more likely to be guided by cracked zones than by any symmetrical system of temperatures in the solid rock.

The following exhibit of centigrade temperatures in the bottom of five holes three meters deep in the lava floor of 1894 flows, east of the center of Kilauea Crater, shows the variety of temperatures encountered. The holes are numbered in accordance with a survey of points to be drilled, 132 in all on Kilauea floor, 300 meters apart, as shown in Fig. 12.

TEMPERATURES OF SUMPS ABOUT THREE METERS DEEP

| No. | Air | Hole | Difference |
|-----|-----|-------|------------|
| 81 | 19° | 20 ° | + 1 ° |
| 83 | 22° | 23 ° | + 1 ° |
| 88 | 16° | 17.5° | + 1.5° |
| 100 | 20° | 25 ° | + 5 ° |
| 101 | 21° | 84 ° | +63 ° |

That a depth of three meters is within the atmospheric temperature effect was shown by the following:

| | |
|---------|--------------------------------|
| No. 100 | gave one day air 22°, hole 30° |
| | do 22°, hole 27° |
| | do 18°, hole 24° |
| No. 100 | do 19°, hole 78° |
| | do 25°, hole 90° |

This hole No. 101 appears to cut a lateral duct or crack carrying hot vapor. Readings with resistance thermometer gave:

| | |
|-----------------|------|
| At depth 44 cm. | 89° |
| do 123 cm. | 106° |
| do 189 cm. | 86° |
| do 219 cm. | 66° |

Readings with a mercurial thermometer on another day gave:

| | |
|------------------|-----|
| At depth 123 cm. | 90° |
| do 219 cm. | 90° |

Thus on three different days this hole gave readings near the bottom of 66°, 78° and 90°, respectively, and one of these days a point half-way down was at 106°.

On two days it gave a reading of 90° 123 cm. down, and on one of these days the bottom 300 cm. down was at 78°, and on the other it was at 90°.

These results agree with observations in certain caverns of the Kilauea floor, which sometimes are only warm, and at other times are very hot and full of steam. As the mountain is porous, it is quite possible that changes of air pressure and of wind direction bring about these differences.

Temperature measurements of other bore-holes follow*:

| No. | Air | Hole | Difference |
|-----|-----|------|------------|
| 44 | 21° | 21° | 0° |
| 45 | 22° | 45° | 23° |
| 46 | 24° | 60° | 36° |
| 46a | 22° | 64° | 42° |
| 61 | 25° | 25° | 0° |
| 62 | 24° | 24° | 0° |
| 63 | 22° | 22° | 0° |
| 66 | 28° | 44° | 16° |
| 67 | 26° | 59° | 33° |
| 84 | 23° | 23° | 0° |

Hole No. 46a, which shows the greatest difference in the above table, is uncapped and only 1.27 meters deep. The other holes are capped and about three meters deep. The reason No. 46a was not completed to the uniform depth is that drills could not be made to go deeper; and therefore hole No. 46 was bored at a near-by point.

Drilling in lava rock layers with parting planes every few feet necessarily encounters openings between the separate lava flows. The opening may be a steam or air chamber. Therefore the vertical temperature gradient obtained by measuring the bottom temperature at intervals while the hole is being drilled is likely to be quite different from the gradient of the finished hole. The finished hole permits convectional adjustment of the vapors, and also is likely to be influenced by the wind in the lateral ducts as pointed out above.

The surveyed net will afford basis for a thermometric survey of the temperatures of natural floor cracks as well as of the artificial drill holes. It will be seen from the above preliminary results that measuring the rock temperature of a pile of lava flows is far from simple. It is evident that the time element is important, and it will be necessary to equip some of the holes with self-recording thermographs.

VOLCANIC CONDITIONS IN MARCH

Activity of Halemaumau

There was little decided change in conditions at the volcano during the month. Wet weather was prevalent, increasing the size of vapor clouds, and the three yellow sulphur spots on the south talus continued to increase in size. Many slides occurred from the walls. Stripping of the northwest wall by slides at the beginning of the month showed intense oxidation beneath the former surface. At this part there was excessive heat and blue sulphurous fume in 1923 and earlier.

* These measurements were made on March 1, 1928, and are here inserted, taking advantage of the fact that publication of this Bulletin is tardy.

There were five local earthquakes and one teleseism registered during the week ending March 9. All were very feeble. The distant shock was faintly recorded for three-quarters of an hour, beginning at 11:08 p. m., and according to newspaper reports originated in Japan. Tilt for the week accumulated slightly to the south.

There were 14 very feeble earthquakes for the next week. One of these showed phases indicating its origin to be 20 miles distant. There were also records of blasts of dynamite used in road construction in the vicinity of the volcano.

On March 19 there were several dusty slides at Halemaumau, and the next day some large slides occurred from the northeast corner, probably caused by the earthquake that occurred just before 5 a. m. described in the next paragraph.

The large earthquake of March 20 was the heaviest that has been recorded on Hawaii for a year. It is an interesting coincidence that a year ago, on March 19, 1926, there occurred at 10:33 p. m. an earthquake of like intensity and practically the same characteristics as the one here described. This is perhaps no more than a mere coincidence, yet it must be remembered that these dates are very near the vernal equinox. The shock as recorded at the Observatory had its initial movement at the instant of one of the time breaks on the seismogram (see Fig. 14). This was at 4:52 a. m. Thus unfortunately the needles were not on the paper to record the direction of the first movement, from which it might have been possible to deduce the direction to the epicenter. The instruments were both dismantled after the first few seconds, so that the various phases of the shock were not recorded. It has therefore been impossible to estimate distance to the origin. Various reports show that this earthquake was felt with about equal intensity throughout the islands of the Hawaiian group. Vague press reports suggest that it may have been recorded as a teleseism on some of the seismographs at observatories on the mainland. This may have well been the case, as the shock was apparently heavy and deep-seated, in contrast to the usual type of local volcanic earthquakes recorded at this station, which are likely to be felt or recorded only a short distance from their origins. There was no damage done beyond the shaking from shelves of bottles and small merchandise in one or two of the stores in Hilo.

Sixteen other earthquakes occurred during the week ending March 23, all very feeble. Tilt accumulated slightly to the southeast.

On March 26 the crack on the southeast side of the pit, about 70 feet back of the rim, was noticed to be quite free from steam. Formerly steam was so abundant as to be disagreeable to persons using the trail which crosses the crack. This change would seem to indicate that internal lava pressure has raised the great block on the pit side and closed the crack to some extent.

For the week ending March 30 twenty-two local earthquakes were registered. These were all very feeble, imperceptible shocks. There were also two periods of almost continuous tremor resembling the harmonic tremor which accompanies lava eruptions. Tilt accumulated moderately to the south-southwest.

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March 1. At 4 p. m. Halemaumau showed new reddening of the whole northwest wall where a large shell of wall has fallen, carrying away the bench (or part of it) that extended from the top of the northeast sill westward. New red debris lay below. The whole wall is red west of this point, showing that small falls have stripped it, revealing intense oxidation beneath, where the fume was in 1923.

There have been big falls, for the whole floor across the south wall was red with dust; also the middle talus of the northeast wall has fresh debris.

Yellowing of the south solfataras continues.

March 6. At 11 a. m. Halemaumau had dense curling steam jets from the southwest talus and elsewhere. Yellow sulphur persists at the sulphur spots.



Fig. 11. October 30, 1924. Halemaumau pit from the Observatory, showing condensation of atmospheric moisture over the pit due to convection. Photo Finch.

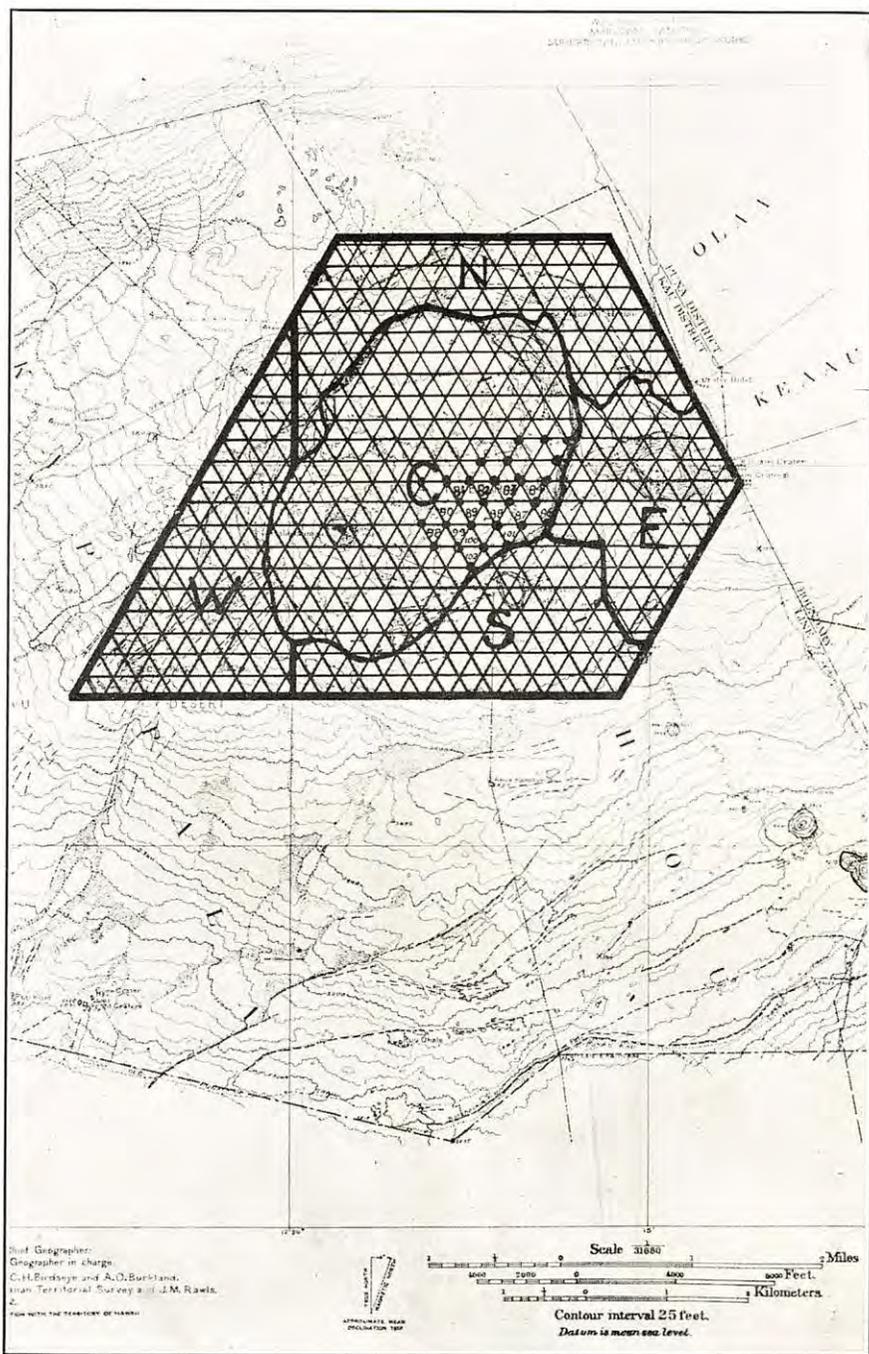


Fig. 12. Map showing surveyed bore-hole net of Kilauea Crater. Black dots represent holes bored.



Fig. 13. April 6, 1926. Compressor, air drill, and special tripod set up at hole No. 90, east-central floor of Kilauea Crater. Shows method of drilling shallow holes for measuring temperature. (See Bulletin March, 1926, p. 15.) Photo Finch.

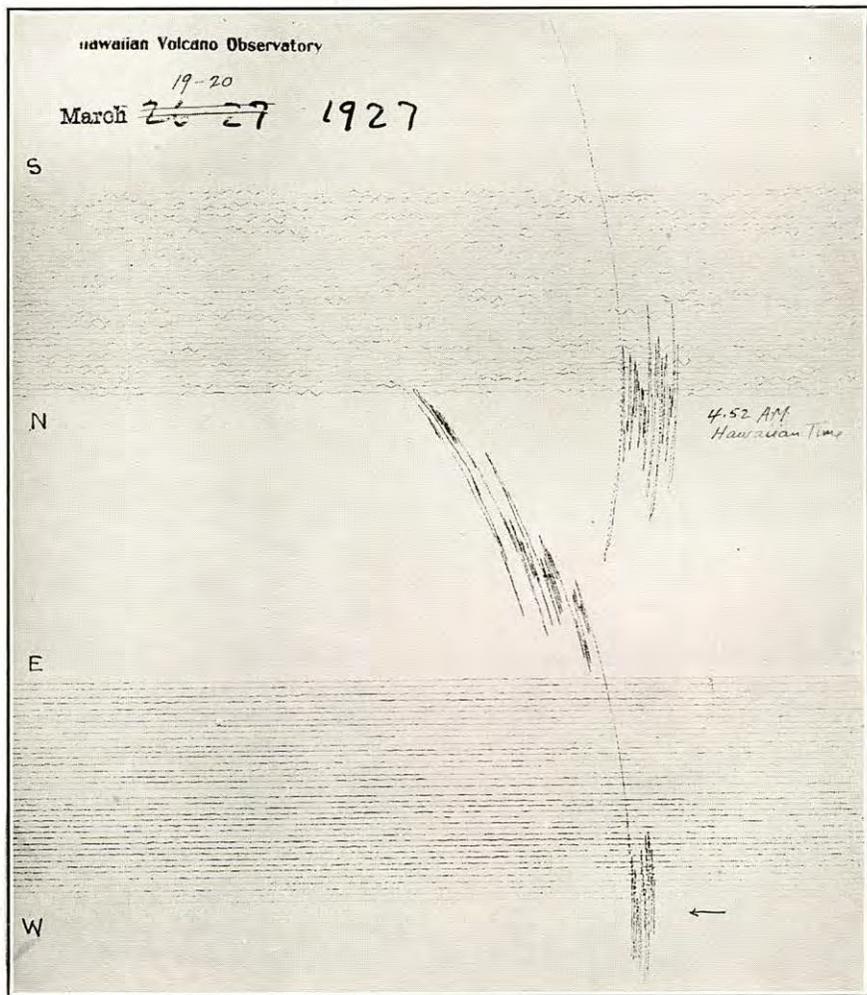


Fig. 14. Seismogram on modified Bosch-Omori instrument of the Hawaiian Volcano Observatory March 19-20, 1927. Shows part of twelve-hour record ending with the shock. Photo print directly from seismogram.

One considerable avalanche fell from the middle of the north wall. There were other small falls.

March 9. At 1:50 p. m. there was a noisy slide on the northwest side of the pit, making dust. This was heard from Uwekahuna Bluff.

March 19. Numerous dusty slides occurred during the afternoon.

March 20. At 10 a. m. there were evidences of large slides at the northeast corner of Halemaumau, and there are additional big boulders on the bottom. White deposits are on the northwest debris slope, and fresh slides have occurred there.

March 22. At 4 p. m. slides were falling at the middle of the northeast sill. No other changes were noted.

March 26. At 10 a. m. the northeast talus appeared elongated downward out onto the floor, and new big boulders lie beside the big one that made a track down the north-northeast talus some months ago. North of the east station there is a big notch in the upper rim that appears fresh. This break in the rim is where a lot of tangential cracks, extending southward, emerge into the pit. The points of the slabs have been caving.

March 27. At 10 a. m. conditions at the pit were much as before, but the cracks at the southeast tourist stand, near the edge of the pit, are so cool that no steam shows, and one can hold his hand in them. The wind is southeast. This development is not sudden: it has been growing doubtless. Perhaps the cracks are hotter with a northeast wind.

March 30. At 11 a. m. the cracks at the southeast trail were still the same, nowhere near the temperature they were in January, 1925 (169° F.). They seem about 105° F. There is no visible vapor at the trail crossing.

Some slides occurred northeast and north. There is new red debris under the north corner.

The three sulphur spots, 200 feet up the center of the south talus, 200 feet up the east side of the south talus, and near the bottom of the east side of the south talus, are becoming alike in size, all big and yellow, in spite of much recent rain. The lower one makes blue fume with the abundant steam rising from it. The other two make soft white steam. There is no blue fume now at the center one, though a year ago, before the yellow sulphur appeared there, much blue fume was there. Apparently blue fume is not the sulphur maker.

SEISMOMETRIC RECORD

There were 63 local earthquakes and one teleseism recorded on the Observatory seismographs during the month ended at midnight March 31, 1927. These and other phenomena are listed below. The time used is Hawaiian Standard (time meridian is 157° 30' W.), which is 10 hours and 30 minutes slower than Greenwich Time.

The greater number of the very feeble local shocks, counted in the list, make such minute records that the character of the disturbance is not always apparent. Some are true earthquakes; others are perhaps the parts of greater amplitude of a continuous or protracted tremor, which at other times may be too feeble to record; some seem to be records of vibrations set up by avalanches in the pit of Halemaumau.

During this month road construction has been in progress within a few miles of the Observatory. The blasting done during this work has added still another cause for very feeble tremors which appear on the seismograms. Such small tremors as were known to have been caused by blasts have not been tabulated below as earthquakes. It is probable, however, that a few of the tabulated tremors are due to this cause when the blasts were not noted and definite correlation determined.

Abbreviations used below are as follows: vf, very feeble; f, feeble; s, slight; m, moderate; d, instruments dismantled; fl, felt locally; Δ , indicated distance in miles; *, continuous tremor.

Local Earthquakes

March

| | | | | | |
|----|--------------------------|----|---------------------|----|----------------------|
| 1 | 12:43 a.m. vf. | 17 | 12:51 p.m. vf. | 25 | 10:24 a.m. vf. |
| 4 | 8:31 a.m. vf. | | 4:05 p.m. vf. | | 11:15 a.m. vf. |
| 5 | 7:15 a.m. vf. | | 8:33 p.m. vf. | 26 | 11:38 a.m. vf. |
| | 4:35 p.m. vf. | | 11:23 p.m. vf. | | 12:05 p.m. vf. |
| 6 | 11:08 p.m. vf. | | 11:25 p.m. vf. | | 12:11 p.m. vf. |
| 8 | 9:18 a.m. vf. | | 11:29 p.m. vf. | | 1:19 p.m. vf. |
| | 9:32 a.m. vf. | 19 | 10:29 a.m. vf. | | 1:27-1:48 p.m. vf. * |
| 9 | 9:00 a.m. vf. | | 11:58 p.m. vf. | 28 | 5:31 a.m. vf. |
| | 1:10 p.m. vf. | 20 | 4:52 a.m. m. fl. d. | | 6:24 a.m. vf. |
| | 1:40 p.m. vf. | 21 | 7:36 a.m. vf. | | 9:01-9:41 a.m. vf. * |
| | 1:46 p.m. vf. | | 4:00 p.m. vf. | | 10:19 a.m. vf. |
| 10 | 5:27 p.m. vf. | 22 | 4:06 p.m. vf. | | 10:50 a.m. vf. |
| | 5:41 p.m. vf. | | 5:12 p.m. vf. | | 1:52 p.m. vf. |
| 11 | 11:15 a.m. vf. | | 5:15 p.m. vf. | | 2:06 p.m. vf. |
| 12 | 5:15 a.m. vf. | | 8:31 p.m. vf. | 29 | 9:25 a.m. vf. |
| | 9:27 a.m. vf. | | 9:16 p.m. vf. | | 4:16 p.m. vf. |
| | 8:50 p.m. f. Δ 20 | 24 | 2:00 a.m. vf. | 30 | 9:10 a.m. vf. |
| 13 | 8:15 a.m. vf. | | 9:29 a.m. vf. | | 2:22 p.m. vf. |
| 15 | 3:28 p.m. vf. | | 11:29 a.m. vf. | 31 | 4:18 a.m. vf. |
| | 7:36 p.m. vf. | | 11:31 a.m. vf. | | 11:29 a.m. vf. |
| 16 | 12:29 a.m. vf. | | 11:42 a.m. vf. | | 8:52 p.m. vf. |

Teleseism

March 6

| | | |
|-----|---------------|--|
| P ? | 11:08 p.m. | Feeble record, no distance estimate made. Probably is the same shock as that described by the press in the Tajima region, Japan. |
| S ? | 11:18:20 p.m. | |
| L | 11:25 p.m. | |
| M | 11:28 p.m. | |

Harmonic Tremor

True harmonic tremor, such as is usually associated with volcanic activity, was perhaps absent during the month. The two spells of continuous tremor which occurred on March 26 and 28, as noted in the tabulation above, had all the appearance of the true harmonic tremor except that there was at the time no volcanic activity to which they might be considered an accompaniment.

Microseismic Motion

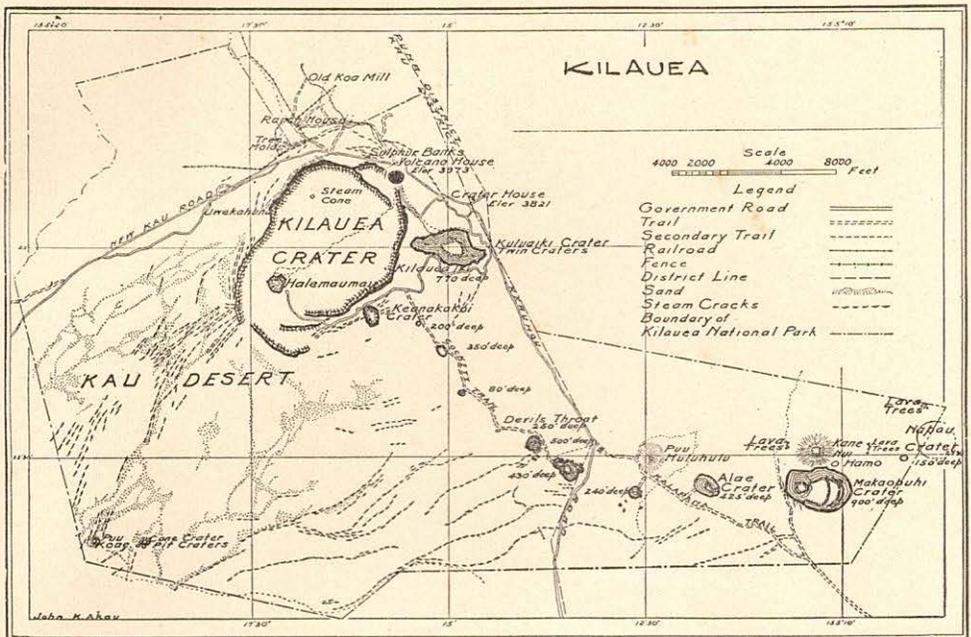
Microseisms were slightly stronger than normal on March 29.

Tilting of the Ground

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

| | | |
|---------------------|-------|-----------------|
| February 24-March 1 | ..... | 1.3 seconds E. |
| March 2-8 | ..... | 1.0 second SSW. |
| “ 9-15 | ..... | 0.2 second SW. |
| “ 16-22 | ..... | 0.6 second SW. |
| “ 23-29 | ..... | 1.8 seconds SW. |
| “ 30-April 5 | | 1.4 seconds SW. |

T. A. JAGGAR,
Volcanologist.



Black spot shows location of Observatory.

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OF THE
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THE OPPORTUNITY FOR SCIENTIFIC RESEARCH IN THE NATIONAL
PARKS OF AMERICA

By T. A. Jaggar

Address delivered April 18, 1927, at Volcano House, Hawaii, to the delegates of the First Pan-Pacific Conference on Education, Rehabilitation, Reclamation and Recreation.

The Geographical Opportunity

National Parks have become creations of government in many countries, and their use by the people is primarily for studying nature and recreation in the wilds. Accordingly, men of science are taking an increasing interest in these sanctuaries of wild life and of human antiquities. Being national, they have the advantage of permanency. Museums have developed in these places,

in order to preserve indoors specimens of those things which admit of collection and exhibition, and even outdoors there is being developed in American National Parks what are called "trailside museums," so that travelers under competent guidance may be shown, while they are walking or riding to places of interest, the birds and flowers and minerals and fossils that are characteristic of those wonderful places. Therefore, the purpose of National Park museums is to extend both education and recreation in the service of large numbers of travelers, and when it comes to research or investigation of the wonders in question, what has hitherto been done has been the work of scientific bureaus of the government or private research establishments.

My interest in this subject is limited to my own field of geology. Much might be told you of the opportunity the National Parks present for the study of other branches of natural history. Moreover, there are many divisions of geology, but I am interested in an opportunity which our parks now have that is not being fostered as it should be. It so happens that at Kilauea we have been delving into one of the most elementary topics of geology; namely, the recording from year to year of the changes in the life of the earth, considering the globe as a living being. In Hawaii there is a rare opportunity for this, because the volcanoes here are continually breathing with the earth, and also forming new skin on the surface of the earth when the mighty lava flows pour forth. It seemed worth while 25 years ago, when 30,000 people were suddenly killed by the volcanoes Pelée and Soufriere in the West Indies, to find out what happened during the months and years preceding such a catastrophe, in order to learn whether the earth, like any other living being, does not exhibit symptoms of the coming trouble.

It is the purpose of the Hawaiian Volcano Observatory to study just such symptoms, and the results of 15 years of work here have developed increasing enthusiasm in the workers, for they have learned of tides and cycles, of tremor, temperature change, rising and falling of the ground, tilting of the ground, earthquakes, and outpourings of lava, which are all related to each other and to the live movements of the crust of the earth. It is this observatory method which seems to me lacking among possible researches that can be extended in geology, so as to include such processes as the lifting-up of the mountains, the breaking-down of the lands under the action of the weather, and the settling of the rubbish in hollows, which geologists call sedimentation. There are no places on the face of the earth so fertile in possibilities for this kind of study as the National Parks.

The application of the observatory method to earth processes promises exceptionally good results in the National Parks of the United States because of the great variety of natural laboratories scattered from the arctic to the tropics. In Mount McKinley National Park there is the highest mountain mass in North America, standing at the end of a graded series of mountains which extends in a marvelous, smoothly curved line out to little volcanic isles in the Aleutian chain. Along that line lies Katmai National Monument, scene of one of the biggest and most extraordinary volcanic eruptions of this century. At Rainier National Park there is a combination of a warm volcano and mighty glaciers. At Glacier National Park there are wonderful overthrust faults, more glaciers, and a typical development of Rocky Mountain uplift. At Crater Lake and Lassen National Parks there are continental volcanoes still partially active, typical of many score such cones that extend the length of the Cascade Range and of the Andes. In the Yellowstone there is the greatest geyser district of the world, adjacent to an earthquake district in Montana which was recently in motion. At Hot Springs National Park there is a development of hot waters in the midst of a region remote from the big mountains, close by the vast accumulations of sediment of the Mississippi flood plain, and possibly in some way connected with the scene of the huge earthquake that shattered the Mississippi valley in 1811. Lastly, there is Hawaii National Park, where

already research by the observatory method has begun, and where observation of the making of new rock is in progress. We treat the earth as though it were a mighty engineer constructing new lands just as our human engineers construct breakwaters and dams and concrete roads. And if you can imagine a scientific mongoose, along the road between here and Hilo, establishing an experiment station to find out why his habitat is invaded by floods of new concrete and stone, and then setting up measurements in order to discover where the concrete comes from and how it gets there, you will have an apt picture of the little volcanologists seated on the flank of Mauna Loa volcano.

There is thus a geographical opportunity elsewhere unequaled which the National Parks offer for the study of mountain erosion, of shore lines and sea bottoms, of rivers and glaciers, of uplift and shifting of the lands at times of earthquake, and of outpourings of slag from the inside of the earth to make new lands such as were created in great volume in the primitive days of the globe, when it was crusting over and congealing from an earlier ball of fire.

The proposed observatories group themselves naturally into four categories, those concerned, respectively, with (1) the making of new rock, (2) the uplift of the land, (3) the rotting of the mountains, and (4) the settling of the rubbish.

The Making of New Rock

The national reservations suitable for observatories of this process are primarily Hawaii, Katmai, Lassen, and the Yellowstone. In Hawaii, Lassen, and Katmai new lava has appeared within the last 15 years. In Hawaii it has come forth at a dozen times and places. At Lassen in 1915 it appeared only as a sluggish paste rising like hot iron in the summit crater. At Katmai it appeared similarly as cracked domes of very siliceous slag inside the crater. About two hundred years ago the Lassen country produced a lava flow of clinker quite like what the Hawaiians call aa. These outpourings, whether liquid or paste, are accompanied by burning gas, and the study of this gas is precious for geophysies, because it shows us the chemical composition of the inside of the earth. If the spectroscope is applied to these outgivings of the earth, it will be possible to make direct comparison of the chemistry of the inside of the earth with the chemistry of the sun. Another kind of rock was made by all these volcanoes when they threw up sand and gravel and ash which accumulated in layers and valley fillings that some day will be compressed and hardened into such rocks as geologists call agglomerates and tuffs. Already the Geological Survey is at work establishing observatories at these places, and the significant results of the work to date are concerned with microscopic movements of the land unsuspected when the work was begun.

We have learned in Hawaii that Kilauea rises and falls by several feet in the course of 15 years, even at the solid ground outside of the crater where the Volcano House is built. We have learned that whenever the gushing lava returns to the pit, the Observatory ground, two miles away, starts a continuous trembling. We have learned that when cracks open near the pit and sulphurous gas comes out, these cracks grow hotter and hotter until the red-hot lava appears. And lastly, we have found out that a sensitive pendulum shows a tilting of the ground away from the center of the island when the lava is rising, even before it appears as an eruption. And when the lava after an eruption goes down, the ground tilts enormously toward the center where it is retreating. Along with all this earthquakes occur, and we are coming to think that much of volcanism is an underground process, with much more of this lava flowing into cracks and crevices deep in the under-earth than ever appears at the surface. This seems a connecting link between volcanism and such process as happened in California when the big earthquakes occurred at San Francisco and Santa Barbara. This leads us directly to the second of the processes that ought to be observed with more observatories.

The Uplift of the Land

There are vague generalities about "tectonic" forces that geologists refer to when mountain-making is the topic, but they do not go and dwell in a tunnel inside the Rockies and set up instruments that they stay with for a lifetime. Yet is not the oscillation of Mount McKinley or Pikes Peak an index of the heartbeats of a continent? If the continent lifts, the surface tilts; if the continent shifts, the surface trembles; if lava rises, the waters heat; and if all these things are in progress, then our peak is higher and crooked at the end of five years. And all these things can be measured.

The Great Northern Railway is building the longest tunnel in America through the middle of the Cascade Range in Washington, between two of the greatest volcanoes in the United States, Rainier and Baker. It will be 7.78 miles long, it will pass 2,000 feet underneath the top of the range, and it will cost over \$12,000,000. President Ralph Budd has asked the Volcanologic Section of the government to draw estimates for details of operation of an underground observatory adjacent to this tunnel. These have been furnished, and propose that a staff of physicists and computers shall permanently live near the tunnel, that a side passage shall be excavated leading to a large underground laboratory electrically ventilated, heated, and lighted, and that the best instruments obtainable shall be installed for the study of level changes, earthquakes, tremors, underground temperature changes, earth tides and gravity changes, and earth currents. More than all, such a station should become an **institute of standards** for such work.

It is such stations as this that the National Parks are fitted for. There is Rainier Park, close by this place and in the Cascade Range. On the other side of Rainier, at Lassen Park, Mr. Finch, formerly of the Kilauea Observatory, is now running his little seismograph station in the snows of Lassen Volcano. But there is needed for the study of the uplift of the Alaskan Range, or the Cascades, or the Rockies, the establishment by government of a new type of experiment station, a mountain observatory, not for forest fires or weather or stars or sunshine, but literally for the "natural history" of mountains.

Rivers flow off, landslides fall, springs heat or chill, and the earth shakes or tilts, according as the mountains lift or lower. Considering the numbers of people who dwell in the hills, or flock to the hills, surely science should lift up her eyes unto the hills, that help may come to mankind.

The Rotting of the Mountains

Mountains are suggested for geophysical work because the processes there are fast. The heaving up of the Mount St. Elias Range in Alaska in 1899 was so fast in September that the tremendous earthquake motions of Yakutat Bay shoved up the solid rock shoreline 47 feet, where the Harriman expedition had made photographs the previous spring. This was measured fact, not guesswork.

Herein lies the romance of Science for Alaska, the islands of the west all unexplored, the tremendous glaciers making in places a real glacial period, the eternally frozen ground, the gigantic eruptions of the Valley of Ten Thousand Smokes, the rifted and shattered fjords of the southeast, and the earthquake messages that come out of the vasty deeps off the coast, described by the Coast Survey seismologist recently in the following words: "In the deeps off the Aleutian Islands we find the origins of probably more world-shaking earthquakes than in any other part of the world."

But this uplifting means another thing; namely, that the tops and sides of the mountains are rotting down all the time, falling by millions of tons, sliding to the oceans, being scoured by the glaciers, being washed out and crumbled by the rains and snows and hot springs. The inside of the Alaskan mountains is hot, it is full of dissolving waters, a chemical laboratory.

And not only Alaska; word has just come from Queensland that whole farms have been sliding in many acres, with washouts and cracks and slips in the Nambour district. Fissures and creepings are reported everywhere. Whole banana fields have moved, with sudden rumblings, and hillsides have come down, tipping up the houses, and a mile of roadway is reported entirely gone. All of this happened January 26, three months ago.

In this the National Parks can supply other work for our mountain observatory to do. Science must get standards for measurement of such processes as this rotting and sliding of the hills. At the time of the Katmai convulsion, call it what you will, one of the tremendous things that the eruption turned loose was a **flowing of the land**, the Mageik landslide, which broke down a mountainside and covered a great acreage of country. These things are sudden accelerations of otherwise slow processes. But not too slow to measure. Here in Hawaii we had the same thing, the "mud flow" at Pahala, 20 miles from this Volcano House, in 1868.

What is needed is the study of strategic places, with stakes and soil borings and surveyed measurements, and a working out of how fast the rock decays, how fast the water undermines, how fast the soil slips, and how fast and where do the rivers combine to carry off the products.

The Settling of the Rubbish

Most people think of the Mississippi or the Amazon as a lot of water flowing down hill. In fact it is nothing of the sort. It is chiefly a lot of mountain rubbish **preventing** the water from flowing down hill. Every time you read of an awful flood in India or China drowning hundreds of thousands of children of men, some of this preventing is being done.

A river basin is a place that is not understood. Engineers spend millions to prevent the preventing. They try to keep navigation open—which the mountain rubbish is preventing. They try to keep the water out of the towns and in the channel—which the mountain rubbish is preventing. They try to make bridges stand up the way the railway people did at Hilo a few years ago—which the mountain rubbish under the bridge piers prevented, by gently flowing into the bay.

Mr. John R. Freeman in 1922 proposed to Congress the establishment of a National Hydraulic Laboratory, for the conduct of research, experiments, and scientific studies in connection with the problems of river hydraulics; for this he asked \$200,000. In the hearing he made the following pregnant statement:

"The greater part of our recent program in science and in the arts has been made by taking problems from outdoors into the laboratory, then coming back out of doors with the result, and working the theoretical and the practical side by side."

Mr. Freeman presented drawings illustrating the laboratory, quoted the Dresden River training laboratory and the hydraulic laboratories of the universities, and came to the conclusion that there ought to be a big national laboratory right at Washington on the Potomac. The design was the product of ten years' work.

The project was opposed by the U. S. Army Engineers and the Mississippi River Commission, and Congress turned it down. The argument of the Mississippi Commission was that "the river is so gigantic in all its elements that a practicable model would be too small to duplicate the regimen of the river." The Commission has kept scientific men on the river for 43 years in "nature's own laboratory, the river itself."

What the National Parks could do in studying the great process of sedimentation, which affects 70 millions of people in the Mississippi Valley alone, would be to combine the physical studies of the mountain observatory with geophysical studies at River Observatories in those parks which are suitable. Neither the river engineers nor the physicist experimenters in hydrostatics can say the last word on rivers.

Rivers are not all water. They are repositories of mountain rubbish, fillings, plains, slime flats from nature's stamp-mill, and they need the experimental geologist. All the limestones, slates, sandstones, oil shales, and conglomerates of geology have been built by rivers that flowed into Mediterranean seas. The great lack of sound knowledge today is the lack of measurement of quantities, coarsenesses, materials, areas, bulks moved over river basins after the streams get the stuff that is uplifted, rotting, and creeping in the hills. This measurement should be done for pure science alone, not for the engineers. Only so can the **natural history** of our continent be learned.

In conclusion, then, I would submit particularly to the Pacific specialists of this Conference on Reclamation and Education, the splendid opportunity that the permanent National Parks have for permanent observatories of geological process.

And to the Park Service of the United States I would recommend specifically that a physical geologist be attached to the service to coordinate plans for a Geophysical Observatory system in the parks, a system of experiment stations for study of all the earth laws by means of resident scientists, not mapping ancient formations, but measuring month to month the building of volcanoes and mountains, the breakdown of the hills to make soils and sea-bottoms, the making of rock, the uplift of the land, the rotting of hills and the settling of the rubbish.

VOLCANIC CONDITIONS IN APRIL

Activity of Halemaumau

There were no visible indications during the month of any change in the magma that underlies the volcano. The usual activity of slides and avalanches, steaming, formation of sulphur spots, and minute quaking of the ground took place.

For the week ending April 6 the number of earthquakes was 16. All were very feeble local shocks with the possible exception of one which occurred at 8:44 a. m. April 1, which may be part of a faint record of a distant disturbance. Tilt accumulated moderately to the southwest.

On April 10 slides were heard from the northeast wall of the pit. At 5:15 p. m. dust from an avalanche was seen to rise. A slight tremor registered on the seismographs seemed to be simultaneous with this avalanche. The sulphur and salts so conspicuous on the south and east taluses were dimmed by heavy rains.

There were 17 very feeble local earthquakes recorded during the week ending April 13. Tilt was very slight to the east.

On April 20 there was new debris on several taluses, and a lump of red rock at the core of the west boss had fallen away. Small slides were still occurring there at 11 a. m.

During the week ending April 20 the earthquakes numbered 14. None of these was perceptible. Tilt was slightly south-southwest.

A noisy rock slide on the northwest side of the pit was heard at 8:45 a. m. April 27. There were also other slides, including one at 10 a. m. April 30 at the north corner which made dust and which left a large scar on the north wall.

Nineteen very feeble local earthquakes were registered for the week ending April 27. Tilt accumulated moderately east-northeast. On April 30, 2:33 p. m., there was a shock perceptible to persons in Hilo and at the volcano. It was followed by several very feeble after-shocks.

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April 3. No change in conditions at Halemaumau was noted.

April 6. A few rocks were sliding during a visit in the morning.

April 9. Nothing new was noticed except increased red dust on the north talus.



Fig. 15. April 19, 1927. Official party at opening of Uwekahuna Observatory and Museum, presented by the Hawaiian Volcano Research Association. Right to left: Director Mather, Secretary Work, Dr. Jaggar and Governor Farrington. Photo Honolulu Advertiser.



Fig. 16. Uwekahuna Museum in July, 1927. Photo Tai Sing Loo.

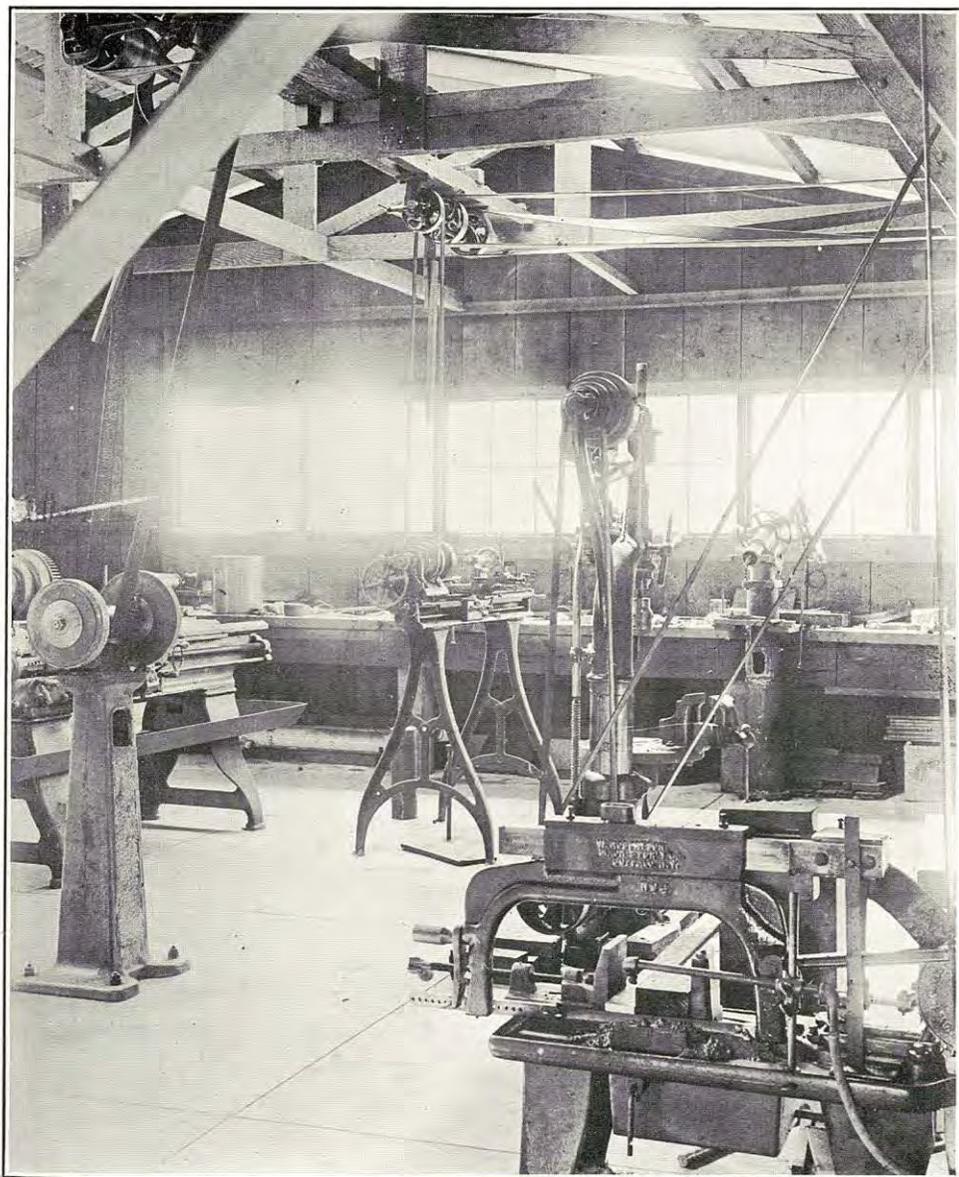


Fig. 17. Machine shop at the Observatory, built by the Hawaiian Volcano Research Association. Here are made the new seismographs and other instruments of the Section of Volcanology of the United States Geological Survey. Photo Wilson.



Fig. 18. Interior of Uwekahuna Museum and projection room; summer of 1927. Photo Wilson.



Fig. 19. Terrace of Uwekahuna Observatory on summit of west bluff of Kilauea Crater, showing Halemaumau pit on the right. Photo Wilson.

April 10. At 10:30 a. m. some light slides occurred at the northeast wall. Heavy rain last night has washed away part of the sulphur south and east.

At 5:15 p. m. a considerable slide sent up a distinct dust cloud at the pit.

April 20. At 11 a. m. the taluses showed fresh debris at the north, west-northwest, and south-southwest sides of the pit. The sulphur patches have been partly washed away by rain recently, and the walls of the pit are quite wet and dark red from wetting. The large sulphur patch at the south talus is still bright yellow, with a dark area in its center.

Small slides were observed twice at the north side of the west boss. The lump of red rock which formerly protruded from the top of the west boss has fallen, and the first slide seen today was from that place. The northeast talus has light colored grey debris, but this did not fall since the rain.

There was a third slide from the west boss at 11:15 a. m. All of these slides were very small, so that dust on the wall could be detected with difficulty. Just north of the peak of the northwest talus is an upright buff-colored streaking from either wash or dust slides.

Steam escapes at the east sulphur patch, at the usual places in the south, southwest, and northwest taluses, a little between the north and north-northeast taluses, a little from the top of the big sill near its east end, and there are the usual small steam jets at the edges of the debris on the floor of the pit.

Salt coatings on the pit walls are conspicuous north of the southwest talus, on the wall between the south and south-southwest taluses, in small amounts with streaks on the southeast rock bank, and along the top of the northeast sill. As a whole the salt staining is not very strong.

The cracks where the trail crosses them back of the southeast rim are even cooler than two weeks ago, although the wind is now northeast. Evidently the cooling was not due to the direction of the wind. They are only faintly warm and are without visible vapor except at places 50 or 60 yards south of the trail.

April 23. At 8:45 a. m. rocks were heard falling on the south side, and at 9:09 a. m. more were falling on the east. A circuit of the pit was made, but no interesting change in conditions was noticed.

April 25. At 8:55 the cracks back of the southeast rim were steaming very slightly. There have been a few more slides at the west boss. A few rock falls on the northwest side were heard, but on the whole the pit was quiet.

April 27. At 8:45 a. m. rocks were falling from the northeast wall. Sulphur patches have been washed by rains. At 9 a. m. rocks fell at the northwest.

April 28. Large dust clouds over the Kau Desert, caused by strong winds, were seen during the middle of the day.

April 29. At 8:30 a. m. the pit was very quiet with a few rock falls on the north and southwest sides. Fresh white-stained rocks on the south talus indicate that slides have occurred there.

April 30. There was dust from an avalanche over the north rim of the pit at 10 a. m. At noon more dust was seen here and in the desert.

SEISMOMETRIC RECORD

There were 68 local earthquakes and one teleseism recorded on the Observatory seismographs during the month ended at midnight April 30, 1927. These and other phenomena are listed below. The time used is Hawaiian Standard (time meridian is $157^{\circ} 30' W.$), which is 10 hours and 30 minutes slower than Greenwich Time.

The greater number of the very feeble local shocks, counted in the list, make such minute records that the character of the disturbance is not always apparent. Some are true earthquakes; others are perhaps the parts of greater amplitude of a continuous or protracted tremor, which at other times may be too feeble to record; some seem to be records of vibrations set up by avalanches in the pit of Halemaumau.

Abbreviations used below are as follows: vf, very feeble; f, feeble; s, slight; m, moderate; d, instruments dismantled; fl, felt locally; Δ, indicated distance in miles; *, continuous tremor.

Local Earthquakes

April

| | | | | | |
|----|-------------------------------|----|----------------------|----|----------------------------------|
| 1 | 10:49 a.m. vf. | 11 | 1:39 a.m. vf. | 23 | 11:57 a.m. vf. |
| | 11:04 a.m. vf. | | 10:09 a.m. vf. | | 12:33 p.m. vf. |
| | 12:11 p.m. vf. | | 2:37 p.m. vf. | | 3:27 p.m. vf. |
| | 4:47 p.m. vf. | 12 | 8:26 p.m. vf. | | 4:59 p.m. vf. |
| 2 | 1:39 a.m. vf. | 13 | 12:37 p.m. vf. | | 7:11 p.m. vf. |
| | 2:04 p.m. vf. | | 10:29 p.m. vf. | | 7:45 p.m. vf. |
| 3 | 5:30 a.m. vf. | 14 | 12:30 p.m. vf. | 24 | 12:59 a.m. vf. |
| 4 | 9:08 a.m. vf. | | 1:05 p.m. vf. | | 6:12 a.m. vf. |
| | 2:50 p.m. vf. | | 2:18 p.m. vf. | | 6:32 a.m. vf. |
| 6 | 1:08 a.m. vf. | 16 | 6:44-6:48 p.m. vf. * | | 1:30 p.m. vf. |
| | 12:19 p.m. vf. | | 6:59 p.m. vf. | | 6:41 p.m. vf. |
| | 10:07 p.m. vf. | 17 | 11:08 p.m. vf. | | 8:07 p.m. vf. |
| 7 | 1:03 a.m. vf. | 18 | 2:00 p.m. vf. | 25 | 1:40 a.m. vf. Δ ¹² |
| | 6:18 a.m. vf. | | 7:57 p.m. vf. | 26 | 3:12 a.m. vf. |
| | 11:44 a.m. vf. | 19 | 12:19 a.m. vf. | 28 | 5:25 p.m. vf. |
| | 3:01 p.m. vf. | | 9:45 a.m. vf. | 29 | 10:44 p.m. vf. |
| | 9:02-9:08 p.m. vf. * | 20 | 5:19 a.m. vf. | 30 | 3:53 a.m. vf. |
| 8 | 3:02 a.m. vf. | | 7:27 a.m. vf. | | 2:33 p.m. s. Δ ⁴⁰ fl. |
| | 2:09 p.m. vf. Δ ¹⁴ | 21 | 8:56 a.m. vf. | | 5:12 p.m. vf. |
| 10 | 7:25 a.m. vf. | | 8:58 a.m. vf. | | 6:26 p.m. vf. |
| | 3:15 p.m. vf. | | 9:02 a.m. vf. | | 6:58 p.m. vf. |
| | 5:13 p.m. vf. | | 9:16 a.m. vf. | | 7:03-7:07 p.m. vf. * |
| | 5:17 p.m. vf. | 22 | 4:27 p.m. vf. | | |

Teleseism

April 1

P ? 8:44 a.m. Very faint record without distinguishable phases.

Harmonic Tremor

This type of tremor was absent during the month.

Microseismic Motion

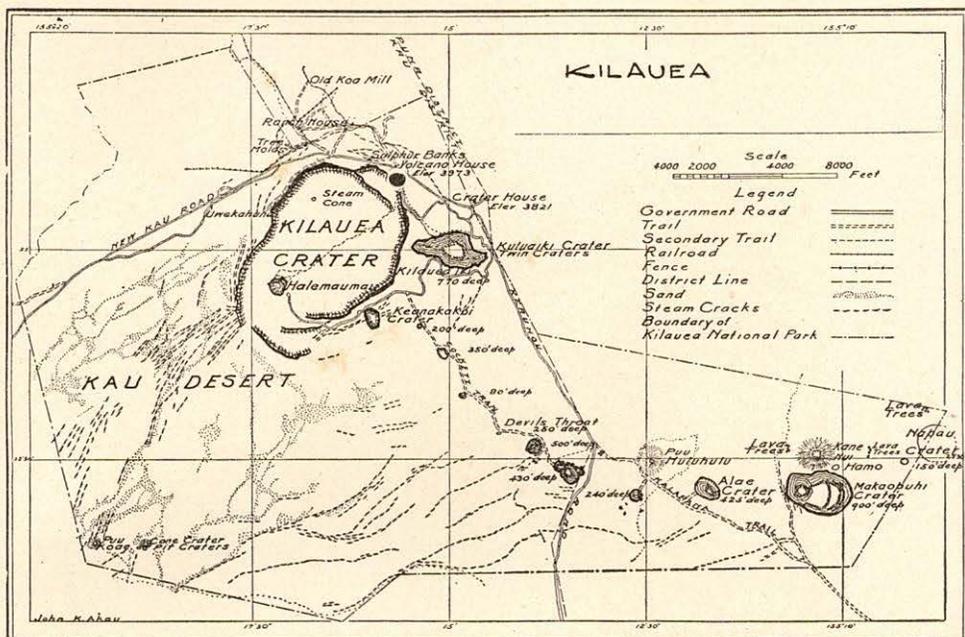
Microseisms were unusually large on April 25 and 26.

Tilting of the Ground

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

| | |
|-----------------------|-----------------|
| March 30-April 5..... | 1.4 seconds SW. |
| April 6-12..... | 0.4 second SE. |
| “ 13-19..... | 1.0 second SSW. |
| “ 20-26..... | 0.7 second ENE. |
| “ 27-May 3..... | 0.2 second SE. |

T. A. JAGGAR,
Volcanologist.



Black spot shows location of Observatory.

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VOLCANIC CONDITIONS IN MAY

Activity of Halemaumau

There were numerous slides and rather frequent avalanches in Halemaumau pit during the month. One large avalanche on May 23 may be considered significant inasmuch as it occurred on the southwest wall in the vicinity of the northeast-southwest rift line. Solfataras on the southwest talus appeared to increase. Conditions as a whole seemed normal.

Earthquakes increased in the first part of the month, 36 having been registered in the week ending May 11. This is the largest number recorded in a single week since the middle of September, 1926. Tilt during the week accumulated very slightly to the northeast.

A considerable drop in the number of earthquakes came in the next week, only 13 having been registered. These were all very feeble with the exception of one feeble shock at 7:01 a. m. on the 13th, which had an indicated distance to origin of 17 miles. Tilt accumulated very slightly to the west.

Slides at the pit seemed somewhat continuous during the week ending May 25, but they could not have been affected in any way by earthquakes, only 11 having been registered. These were all the characteristic very feeble tremors of this district. In addition to the local shocks is the record of a distant

earthquake on May 22 at 12:15:32 p. m. Hawaiian Time. Phases of this earthquake lasted nearly an hour before dying out completely. It had a vaguely indicated distance to origin of 6,120 miles. A determination made by the U. S. Coast Geodetic Survey located it at 35° north latitude and 92° east longitude, at 22:32:48 Greenwich Civil Time.

Thirteen very feeble local earthquakes were registered during the last week of the month. Tilt accumulated very slightly to the north.

On May 15 operation of the Hilea seismograph was temporarily discontinued, until a better instrument becomes available.

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May 2. At 9 a. m. there was a large scar made by sealing at the north corner of the pit, and fresh debris lay on the talus below. This slide came from just above the west horn of the big northeast sill. Slides have also occurred from the east end of the sill.

A new boulder was seen on the floor at the foot of the north-northeast talus.

May 3. The salt coatings have increased on the lower part of the south wall. Some rock falls were heard, and several rocks just under the northeast rim of the pit appear ready to fall. The rim itself is overhanging at this point.

A circuit of the pit was made. On the north-northeast side the odor of spicy sulphur was noticed with the wind in the southeast.

At 4:50 p. m. dust from a slide overhung the pit.

May 4. Dust hung over the pit at 2:53 p. m. At 4:15 a peculiar haze was noticed, probably dust from numerous small slides.

May 5. There were continuous falls of rocks on the north side of the pit early in the morning, making the hazy dust noticed yesterday. There is new debris on the north talus and in the depression between the north and northwest taluses. New boulders lie on the north-northeast talus, and new black dirt is strewn down the east wall and talus.

May 7. At 8:30 a. m. there were dribbling rock falls north, and the north and east taluses have more new debris. Men standing on the north rim may be causing the rock falls by dropping stones over the edge. Judging from sounds the material on the face of that wall must be very loose.

Hot, dry spots on the southwest talus are conspicuous in the rain.

May 9. With a high wind there was much dust in the desert during the day. At 11 a. m. a few rock falls were heard on the north and south walls, and the former was very dusty.

May 11. Several slides were noticed during a visit from 8:30 to 10:30 a. m., including one large one on the southeast side. White salts were conspicuous on the south and southwest walls.

May 18. At 9:30 the pit was quiet, with just a few occasional rock falls. The usual vapor vents were steaming moderately.

May 23. At 9:30 a. m. there was a large slide at the southwest rift tunnel. Sulphur spots appear more noticeable on the floor and near the foot of the southwest talus. The pit was very quiet at 10 a. m.

May 27. The pit was very quiet at 3:25 p. m., and no changes were noted.

May 31. The north wall is reddish from peeling. Slides were heard south and northwest. The northwest talus has a coating of new debris.

SEISMOMETRIC RECORD

There were 82 local earthquakes and one teleseism recorded on the Observatory seismographs during the month ended at midnight May 31, 1927. These and other phenomena are listed below. The time used is Hawaiian Standard (time meridian is 157° 30' W.), which is 10 hours and 30 minutes slower than Greenwich Time.

The greater number of the very feeble local shocks, counted in the list, make such minute records that the character of the disturbance is not always

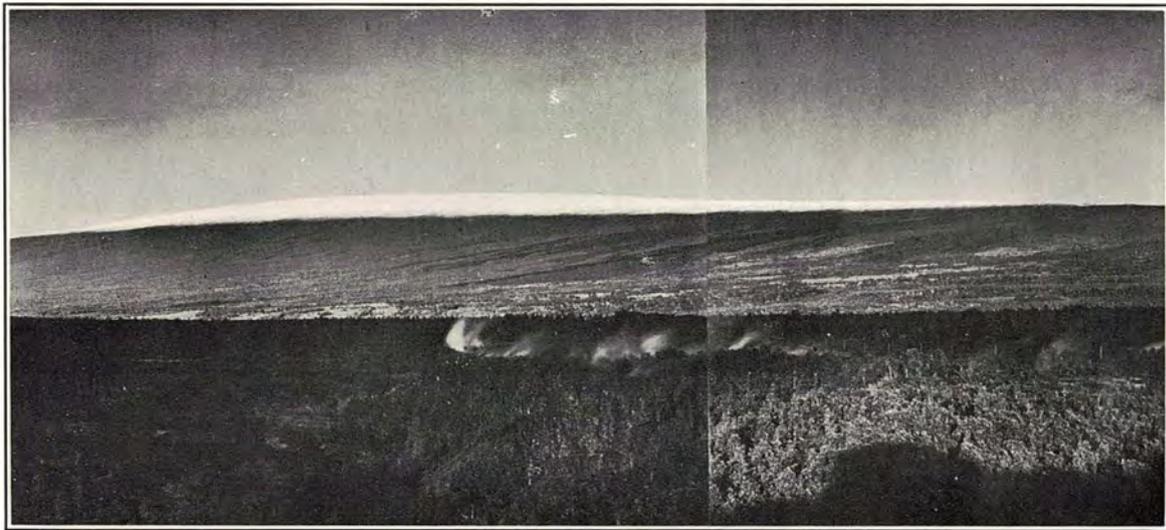


Fig. 20. Mauna Loa from Observatory, showing Kilauea Crater in foreground, the mountain covered with winter snow down as far as Puu Ulaula on the right. Lava flows from the rift seen below the snow. Photo Wood.



Fig. 21. May 29, 1927. Shore wash of the new 1926 flow at Hoopuloa, showing development of beaches and sea walls from winter storms. In the distance is the barrier beach that cut off Hoopuloa Cove, looking north. Photo Godfrey.

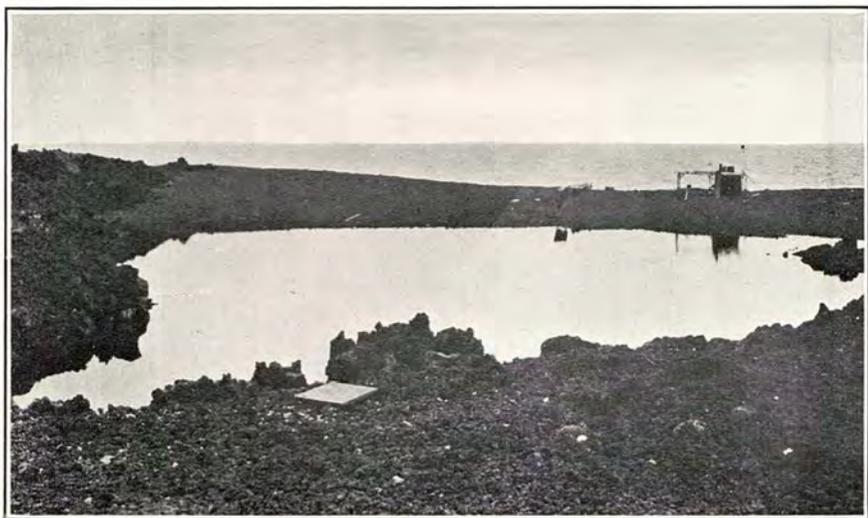


Fig. 22. May 29, 1927. Hoopuloa Cove, looking west, cut off by barrier beach. Fisherman's hut is on the new beach ridge. Compare Fig. 76, Bulletin June, 1926, and Fig. 97, Bulletin December, 1926. Photo Godfrey.

apparent. Some are true earthquakes; others are perhaps the parts of greater amplitude of a continuous or protracted tremor, which at other times may be too feeble to record; some seem to be records of vibrations set up by avalanches in the pit of Halemaumau.

Abbreviations used below are as follows: vf, very feeble; f, feeble; s, slight; m, moderate; d, instruments dismantled; fl, felt locally; Δ, indicated distance in miles; *, continuous tremor.

Local Earthquakes

May

| | | | |
|---|----------------|-------------------------|-------------------|
| 1 | 3:44 a.m. vf. | 12:38 p.m. vf. | 10:23 p.m. vf. |
| | 8:58 a.m. vf. | 1:15 p.m. vf. | 11:45 p.m. vf. |
| | 6:49 p.m. vf. | 2:00 p.m. vf. | 18 2:44 a.m. vf |
| 2 | 7:35 a.m. vf. | 8 9:04 a.m. vf. | 10:55 a.m. vf. |
| | 8:34 a.m. vf. | 10:11 a.m. vf. Δ36 | 6:45 p.m. vf. |
| | 11:05 a.m. vf. | 12:18 p.m. vf. | 20 5:54 a.m. vf. |
| 3 | 2:08 a.m. vf. | 12:55 p.m. vf. | 7:18 a.m. vf. |
| | 4:37 p.m. vf. | 9:34 p.m. vf. | 9:44 a.m. vf. |
| | 4:39 p.m. vf. | 9 4:15 a.m. vf. | 10:03 a.m. vf. |
| 4 | 3:59 a.m. vf. | 8:07 a.m. vf. | 4:34 p.m. vf. |
| | 8:46 a.m. vf. | 11:23 a.m. vf. | 21 12:43 a.m. vf. |
| | 12:40 p.m. vf. | 5:08 p.m. vf. | 23 5:30 p.m. vf. |
| | 1:58 p.m. vf. | 10 6:26 a.m. vf. | 25 2:58 a.m. vf. |
| | 2:07 p.m. vf. | 11:12 a.m. vf. | 6:17 a.m. vf. |
| | 2:10 p.m. vf. | 3:06 p.m. vf. | 26 9:10 a.m. vf. |
| | 2:34 p.m. vf. | 4:14 p.m. vf. | 12:42 p.m. vf. |
| | 3:42 p.m. vf. | 11 1:12 a.m. vf. | 2:38 p.m. vf. |
| 5 | 12:40 a.m. vf. | 5:35 a.m. vf. | 6:53 p.m. vf. |
| | 8:31 a.m. vf. | 12 1:44 p.m. vf. | 7:42 p.m. vf. |
| | 3:19 p.m. vf. | 2:52 p.m. vf. | 27 2:55 a.m. vf. |
| | 11:41 p.m. vf. | 13 7:01 a.m. f. Δ17 fl. | 4:31 p.m. vf. |
| 6 | 2:20 p.m. vf. | 11:33 a.m. vf. | 5:45 p.m. vf. |
| 7 | 2:02 a.m. vf. | 3:10 p.m. vf. | 28 6:37 a.m. vf. |
| | 6:16 a.m. vf. | 9:01 p.m. vf. Δ31 | 29 10:03 a.m. vf. |
| | 7:14 a.m. vf. | 15 8:10 p.m. vf. | 30 6:49 a.m. vf. |
| | 9:34 a.m. vf. | 16 8:28 p.m. vf. | 31 2:00 p.m. vf. |
| | 10:08 a.m. vf. | 8:45 p.m. vf. | |
| | 10:41 a.m. vf. | 8:48 p.m. vf. | |

Teleseism

May 22

| | | |
|-----|---------------|---------------------------------|
| iP | 12:15:32 p.m. | Estimated distance 6,120 miles. |
| SE | 12:26:17 p.m. | |
| SN | 12:26:30 p.m. | |
| Sr | 12:32:06 p.m. | |
| L ? | 12:44:50 p.m. | |

Harmonic Tremor

This type of tremor was absent during the month.

Microseismic Motion

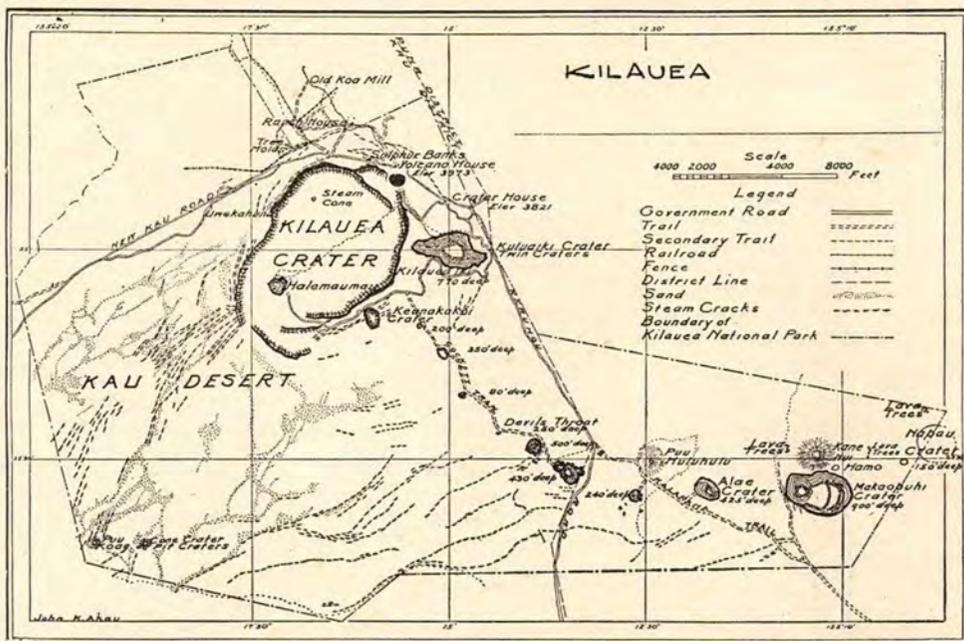
Microseisms were slightly stronger than normal on the 15th.

Tilting of the Ground

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

| | | |
|----------------|-------|-----------------|
| April 27-May 3 | ..... | 0.2 second SE. |
| May 4-10 | ..... | 0.3 second NNE. |
| " 11-17 | ..... | 0.2 second W. |
| " 18-24 | ..... | 0.2 second W. |
| " 25-31 | ..... | 0.3 second NNW. |

R. M. WILSON,
Topographic Engineer.



Black spot shows location of Observatory.

All exchanges, gifts to library, news notes about Pacific volcanic and seismic events, and correspondence should be addressed HAWAIIAN VOLCANO OBSERVATORY, Volcano House, Hawaii.

The Observatory is operated by the U. S. Geological Survey, and its work is supplemented by the Hawaiian Volcano Research Association. The main station is on the northeast rim of Kilauea Crater. Subordinate seismograph stations are operated by the Research Association under the direction of the volcanologist in Kona, Hilo and Hilea.

The Kilauea station operates horizontal pendulums of the Bosch-Omori type and receives time by wireless from the Honolulu Naval Station. Observatory Lat. $19^{\circ} 25' 54.3''$ N.; Long. $155^{\circ} 15' 39.6''$ W.; Elevation cellar 1214.6 meters (3985 feet). The Hilo, Hilea and Kona stations operate horizontal pendulums. Their seismograms are sent to the Observatory.

The Hawaiian Volcano Research Association founded the Observatory in 1911, transferring the plant to the Government in 1919, but continuing cooperation in experimental work by furnishing funds and apparatus and workers as needed by the Government Volcanologist. It is a corporation under the laws of Hawaii, governed by a board of directors, and financed by the subscriptions of its members and patrons. Its aims are identical with those of the Observatory, namely, (1) To keep record of Hawaiian volcanism, (2) To attract volcanologic specialists to Hawaii, and (3) To promote worldwide knowledge of volcanoes and earthquakes and the foundation of more volcano observatories.

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MAP AND STATION DATA

U. S. COAST AND GEODETIC SURVEY CO-OPERATION

By R. M. Wilson

Through the co-operation of the U. S. Coast and Geodetic Survey there has been recently completed on the Island of Hawaii a considerable amount of geodetic work that is of particular interest to the Hawaiian Volcano Observatory. These operations were in progress during the months of October, November and December, 1926, and were ended during the month of January, 1927. Tentative plans for future work have been made, which may be accomplished in the not too distant future if the continued interest of the Coast Survey and other organizations can be counted upon. This work of the last few months is here outlined, and a description of proposed future work is added.

Precise Leveling.

Accurate elevations at the summit of Mauna Loa are of interest for two primary reasons. The topographic branch of the U. S. Geological Survey has need of such elevations for the control of its topographic mapping. Through

the Section of Volcanology, the Geological Survey is interested in these elevations in order to have a check on possible vertical movements of the surface of the mountain due to volcanic or seismic causes. It has been shown that such changes of elevation exist in the vicinity of Kilauea, and Mauna Loa is certainly not less interesting than Kilauea from the volcanological viewpoint. At one of the meetings of the Pan-Pacific Scientific Congress in 1920 a suggestion was made that several lines be run to the summit, radially, from different sides of the mountain, in order to check accurately and discover by subsequent re-runnings possible vertical movements or tumescence. The one line run as a beginning, if it can be re-run after a period of years, will show whether there is information of value to be gained by this means. Several radial lines, all to be re-run periodically, would, of course, give more complete data, but the expense of such a program would be prohibitive. The movements to be detected are probably small; therefore, the most accurate type of work is necessary. If in future runnings discrepancies are developed, it will be necessary to know what faith may be placed in the accuracy of the work before it is possible to say whether these discrepancies are actual movements of the ground or are merely errors in the surveys. For this reason the recent work was done by the most precise of modern methods. The Coast and Geodetic Survey sent Lieutenant Lansing G. Simmons, a man with experience, to take charge of the work and to conduct it in accordance with the high standards of that organization. The Coast and Geodetic Survey paid his salary throughout. Other expenses and party salaries were borne by the Geological Survey; the part of the work lying between Hilo and the Volcano House was paid out of the appropriations of the Topographic Branch, while the Section of Volcanology carried the expenses of the work from the Volcano House to the summit of Mauna Loa.

It will be of interest here to describe briefly the instruments and methods used in this class of leveling. Detailed field instructions are given in Special Publication No. 18 of the Coast and Geodetic Survey. The instrument itself is the heavy and stable prism level that is standard for precise work. It is specially constructed to withstand temperature changes without change of its adjustments. It has two eyepieces; one is the eyepiece of the telescope through which the readings on the rod are taken with the right eye. The left eye can watch at the same time the level bubble in the second eyepiece, through a prism and mirror system. Thus it is possible to make certain that the instrument is exactly leveled at the instant that a rod reading is taken. The reticule has in it three horizontal cross hairs, much like an engineer's transit equipped to read stadia.

The rods are of one piece, about three and a half meters long, made of wood, but with an inlay of invar metal upon which the graduations are painted. This invar metal strip is fastened to the shoe of the rod, but is held loosely throughout its length by the wooden body of the rod. The wood may expand and contract with temperature and moisture, but the invar strip remains practically unchanged in length under all field conditions. The rods are graduated to centimeters, but readings are estimated to millimeters. The rod is read where each of the three cross hairs in the instrument appears across the graduations. The mean of these three readings is then used as the value to compute the elevations through the line. The differences obtained by subtracting the first reading from the second, and the second from the third, should be the same, since the cross wires are equally spaced. Thus the comparison of these differences constitutes a check against errors in reading the rod. Also, these differences give the stadia distance from the instrument to the rod for each sight, which is used in keeping equal the fore- and back-sight distances in running the line. The rods have flat steel shoes, which rest upon iron pins that are driven into the ground for each turning point.

In running the line two rodmen are used, so that the man at the instrument need not wait for the rear rodman to walk ahead to the fore-sight position. One rodman is getting himself prepared to show his rod for the fore-sight,

while the other man is giving the back-sight. Thus the two rodmen alternate in position as the work progresses, each holding his own turning point. In addition to the two rodmen, the working party also includes a recorder and umbrella man. The recorder sets down the readings called out by the instrument man, and checks them against error; the umbrella man keeps the instrument shaded from the sun at all times. The line is double run by sections, each few kilometers of progress is immediately checked by another running of equal precision backward over the same ground. Forward and backward runnings over each section must check within the limit expressed by the product of 4 mm. into the square-root of the length of the section in kilometers. If the two runnings fail to agree within this limit, further runnings must be made until agreement is secured. The resulting mean difference of elevation over each section is used in forwarding elevations along the line. In all running, fore- and back-sight distances are equalized for each section. Permanent bronze bench marks are established about every three kilometers, of which the descriptions and elevations are published.

Lieutenant Simmons arrived in Hilo October 4, 1926, where he engaged local men for his field party. K. Simeona, selected as recorder, had been in topographic parties for several years, and was with Mr. Wingate during the Geological Survey mapping of the summit region of Mauna Loa. The other men selected—Horace Mizuno, Dean Stroup, Sam Punohu, Masamori Gushiken, and Francis Kwoek—were for the most part inexperienced in survey work. They served as rodmen, umbrella man, cook, and general utility man. Lieutenant Simmons ran the instrument himself.

The route chosen for the work was along the main road from Hilo, via Olaa, Mountainview, and Glenwood, past the Hawaiian Volcano Observatory and the Volcano House to the Kilauea Military Recreation Camp. Here the line left the main road and went in past the Keauhou Ranch, thence up the well known Mauna Loa trail, past Red Hill, to the northern end of Mokuaweoweo Crater. The line then went around the west rim of the crater to the triangulation station at the top of Mauna Loa. The work was not run continuously in this order, however, as it was thought best to do the higher portion as soon as possible in order to avoid winter weather at the summit. Lieutenant Simmons spent a few days in Hilo organizing and training his party, at the same time connecting up some of the old established marks. On October 13 he moved his party up to Keauhou Ranch, with supplies and camp equipment. The next day a pack train and saddle horses hired of Mr. A. M. Brown, owner of the ranch, moved him up to the rest house at Red Hill. From the 17th to the 21st the party ran levels from a point a few miles above the rest house down past the rest house a few miles. On the 23rd, the pack train went up to Red Hill with additional supplies, and the next day moved the party into headquarters at "Hotel de Jaggar." This is a small caved-in lava tube at the northern end of the Crater of Mokuaweoweo and on the summit plateau of the mountain. The pack train returned to Keauhou Ranch on the 25th. From the 25th to the 31st of October the line was carried from the summit down past "Hotel de Jaggar" to the point at which work was started on the 17th. The mules took supplies up to the party on October 29-30. The pack train again went up the mountain on November 2, taking more supplies, which were left at the rest house. The next day the horses were taken to "Hotel de Jaggar," bringing Simmons and his party back to the rest house at Red Hill. The writer went up with this trip of the horses, riding to the top, but walking back, since on the return trip the animals were loaded. The party and its equipment were left at the rest house, and the horses continued down the mountain to Keauhou Ranch, arriving there about 9:30 p. m., November 3. The "Hotel de Jaggar" gave the men a certain amount of shelter, but only limited comfort. Fuel had to be packed up from below; water was to be had by breaking the ice in the crevices of the rocks. The kitchen and commissary were established in the depression where the lava tube had caved in, and was covered by a tarpaulin. Blankets were unrolled

in the tube itself, opening off from the "kitchen," a place with so little head room that what comfort there was had to be crawled for on hands and knees. Upon his return to the more commodious rest house, Lieutenant Simmons spent a few days computing and check-running over some weak sections. The horses went up on November 8, and the next day the party moved down to a camp at the stone wall corner which marks the north angle of Kapapala Ranch lands. Here they were below timber line, at about 6,500 feet in elevation. Work was picked up where it had been left off a few miles below the rest house, and so continued on down the trail. They made their final pack train move down from this last camp on November 17, and established themselves at the Naval Recreation Camp. This was made their headquarters for the rest of the running down the trail, and also for the time the work was being carried down the main road to Hilo. The line reached the Volcano House on November 26, and was tied in at Hilo on December 13. Some spur running was done in Hilo on December 16 and 17 to connect with old bench marks, completing the work.

Precise levels are ordinarily run along railroad tracks, or at least along highways having fairly flat and even grades. This work over a mountain trail, with such a steep grade, is very much slower than under usual conditions. It is possible to gain only about nine feet in elevation, on the average, per setup of the instrument. Counting both the forward and backward running, it was necessary to set up the instrument about 2,200 times between the Volcano House and the summit of Mauna Loa, a distance of about 30 miles. On a railroad track this number of setups would carry the double run line over a distance of about 145 miles.

Final results of the work have not yet been computed. The preliminary values of certain elevations here discussed are based upon the elevation of a bench mark in Hilo, as determined by the U. S. Geological Survey in 1912. These preliminary elevations are, therefore, subject to slight change through change in datum, and because of the correction for rod constants not yet applied. Of particular interest is the comparison of the new work with the levelings done in 1912 and in 1921 over the main road between Hilo and Volcano House. This is best seen in the following tabular form. The first column contains the values resulting from the double run line of 1912. The second column gives the results of the single run line and island net adjustment of 1921, and the third column shows the preliminary elevations of this recent precise line. They are all three founded on the same datum at Hilo, and their divergence either represents error in running, or actual change of elevation of the ground. The large systematic divergence is almost certainly due to the latter cause, and is the same sort of ground movement that has been discovered to a still greater degree close around and within the Crater of Kilauea.

| Values of 1912 | 1921 | 1926-27 | Miles From End of Pier 1, Hilo |
|----------------|----------|----------|--------------------------------|
| 6.183 | ..... | 6.183 | 3.1 |
| 359.643 | 359.643 | 359.599 | 10.9 |
| 764.701 | 764.828 | 764.831 | 14.1 |
| 1266.435 | 1266.673 | 1266.682 | 17.2 |
| 2002.342 | 2002.749 | 2002.768 | 20.4 |
| 3821.036 | 3821.840 | 3820.751 | 31.3 |
| 3973.090 | 3974.107 | 3972.526 | 32.5 |

Similar movements to these shown at Kilauea are probably also taking place at the top of Mauna Loa, and it is to be expected that subsequent re-runnings of this precise line to the summit will disclose their nature.

The value 3972.526 is the new preliminary elevation in feet above mean sea level for the bronze tablet in the old monument across the road from the Volcano House. On the same datum, the line gives 10,035 for the elevation at the rest house and 13,653 for the summit of Mauna Loa. The old triangula-

tion station near the summit is 13,651—a remarkable agreement with the old vertical angle elevation determined by W. D. Alexander for the Hawaiian Government Survey, which was 13,650. Since stadia distances were read along the line, and as the line in general follows the regular route of travel, there results from the work a good determination of distances from Hilo. Thus from the end of Pier 1 to the Volcano House is 32.5 miles; to the rest house at Red Hill, 49.2 miles, and to Mauna Loa summit, 62.8 miles.

Gravity

From about the middle of September to the middle of December, 1926, the simultaneous World Longitude Net was being measured. The U. S. Coast and Geodetic Survey was participating in this work, with a party on Oahu, completely equipped with radio receiving sets, a modern astronomic meridian telescope, and gravity apparatus. When the World Longitude work was completed, these men were sent to the Island of Hawaii, at the request of the Hawaiian Volcano Observatory, to determine the force of gravity at Hilo, Kilauea, and Mauna Loa summit. The Coast and Geodetic Survey paid for the work entirely out of their own appropriations.

Complete and detailed instructions for the measurement of the force of gravity may be found in U. S. Coast and Geodetic Survey Special Publication No. 69. The force of gravity is measured by carefully timing the swings of a special pendulum. The length of a pendulum and the force of gravity acting upon it are the two factors that determine its rate of vibration. Thus if the length of a pendulum is not changed, its rate of vibration will change only with change of the force of gravity, and the amount of change of gravity may be computed from the change in rate. The special pendulums used in gravity measurements are very carefully timed at a standard station where the value of gravity has been well determined, and they are thus calibrated. In the field, at a station where gravity is to be determined, it is therefore only necessary to determine how much faster or slower the pendulum swings at the new station than it did at the calibrating station. This will determine how much greater or less the force of gravity is at the new station than at the calibrating station.

The pendulums are very carefully handled and transported, as the slightest change in their shape due to being bent or dented would change their mathematical length and spoil the calibration. Also, dirt or corrosion adhering to them would affect their calibrated length; for this reason they are handled with tongs, and are never touched with the fingers. The pendulums are made of invar metal so that they will change the smallest possible amount with temperature changes. When observations are in progress, they are swung in a metal case from which air is exhausted to form a partial vacuum. Owing to this reduced air friction and the perfection of the knife edges upon which they swing, when they are started to swing through a small arc the motion will continue for more than twelve hours without further impulse.

The measurement of the force of gravity, therefore, becomes a problem in accurate timing. The variations of gravity are small, and this timing must be done with the utmost accuracy in order to detect these variations. The pendulums are of such size as to make one swing in one-half second, nearly. The problem is to determine this period as precisely as possible, and it is done to within less than a millionth of a second. The pendulum is allowed to swing for about twelve hours undisturbed, accurate time being taken at the start and finish. If the duration of this swinging may be determined to within a tenth of a second or better, this error of one-tenth of a second will be divided among the number of single half-second swings the pendulum has made in the twelve hours. Thus the error in the computed time of such a single swing of the pendulum becomes only about a millionth of a second or less.

Before the use of radio for time signals, the best precise method of measuring time was by astronomic observations. The passage of stars across the meridian gives a measure of time that is free from errors of any clock or

chronometer rate. But this involves the setting up of an astronomic meridian transit, and introduces a chance of failure due to cloudy weather. The precision with which modern radio time signals are being sent out, and the development of receiving apparatus that makes it possible to record automatically the signals on a chronograph, has now made this the more convenient method. The beats of the gravity pendulum are recorded on the chronograph also at the start and finish of its swing. Thus if radio signals may be received every twelve hours, and the starting and finishing of the swings are made at the time these signals are received, a very accurate determination of the duration of the swinging may be had.

Lieutenants E. S. Brown and W. H. Bainbridge of the Coast and Geodetic Survey completed their World Longitude work on Oahu and came to the Island of Hawaii on December 15, 1926. They came with their equipment to Kilauea, selecting as their first station a site in the grounds of the Hawaiian Volcano Observatory. The building for the new machine shop had just been completed, but was still empty. The gravity apparatus was set up in this building, with the pendulum box set directly on the concrete floor, thus avoiding the necessity of building a special pier for it. Correct time was obtained by means of a short-wave wireless receiver, which was able to tune in and to record automatically signals from NKF, the U. S. Naval Radio Station at Bellevue, near Washington, D. C. The signals were received at 4:30 p. m., Hawaiian Standard Time, on the 71-meter wave length. This afternoon signal, coming for most of the distance through night hours, was easily received. At 4:30 a. m., the timing of the beats of the expiring pendulum was carried over to the beats of the pendulum freshly started, without the use of radio signals.

Observations commenced on the afternoon of December 17, at the Kilauea station, and ended on the afternoon of the 23rd. There were twelve swingings of twelve hours each. Failure to receive the time signals on the afternoon of the 18th lessened the accuracy of two of these swingings.

The observers were in some doubt as to whether radio reception would be as good on the summit of Mauna Loa as at Kilauea, and they considered taking the astronomic transit with them when they occupied the summit station. The lack of difficulty with the radio at Kilauea, however, made them decide to try radio at the Mauna Loa station also, and so avoid the transportation of the delicate and expensive transit up over the rough mountain trail. When the observations were completed at Kilauea, the apparatus was packed up, and on December 29, 1926, the start up the mountain was made. Horses and mules were hired of Mr. A. M. Brown, of Keaou Ranch. The summit was reached the next day, and the horses, in charge of the ranchmen, returned, leaving Lieutenants Brown and Bainbridge camped in the "Hotel de Jaggar," where Simmons and his party had camped. The instruments were set up here, and nine twelve-hour swingings of the pendulums made. Some difficulty was experienced on account of the low night temperature at this altitude. The cover of the pendulum box, fitted on at the time of higher temperature in the afternoon, showed a tendency to contract as the colder night hours came on. The cover thus contracting allowed air to leak into the box, and the desired partial vacuum could not be maintained. This trouble was so serious that one or two night swingings were lost and the completion of the work was jeopardized. A small tent, improvised from a tarpaulin, was erected over and around the pendulum box, and the observers kept candles burning within this enclosure. By this means the box was protected from the low night temperatures, and the work was brought to a successful termination.

When the end of the observations was in sight, Bainbridge came down the mountain on foot, reaching Keaou Ranch at about 4:30 p. m., January 5, 1927, a hard thirty-mile hike. He notified the ranch that they were ready to have the equipment moved down, and the horses were sent up the next day. Meanwhile Lieutenant Brown by himself completed the observations and prepared the equipment for the pack-train trip down the mountain. The whole outfit arrived at the ranch without mishap late on January 7.

A few days were employed in office work, repacking of equipment, and recuperation. The instruments were moved to Hilo and set up on a ledge under the main building of the U. S. Naval Radio Station. Here the observers had the kind co-operation of the Radio Station in the matter of equipment, lodging, and general assistance. The observations were begun on the afternoon of January 12, and six twelve-hour swings were made.

The preliminary values of the force of gravity determined at these three stations are given in the following tabulation. These values are subject to various corrections which have not yet been made, such as for degree of vacuum and temperature within the pendulum box, flexure of pendulum supports, possible change of calibration of the pendulums, chronometer and time signal errors. When these corrections are applied, the final "observed value" will result. The corrections for the elevation of the stations, for near and distant topography, and for isostatic compensation will then be computed and applied, and the values will be ready to compare with the theoretical values. It is this comparison with values for a theoretical perfect earth that gives rise to the discrepancies called anomalies, which in turn give indications of local crustal densities. These preliminary values are given in terms of the force in dynes acting upon a unit mass of one gram at the station in question. The latitude, longitude, and elevation in meters of each station is also given.

| Station | Mean Date | Dynes | Latitude | Longitude | Elevation |
|-----------------|---------------|---------|-----------|------------|-----------|
| Hilo | Jan. 14, 1927 | 978.878 | 19° 44.0' | 155° 03.1' | 5 m. |
| Kilauea | Dec. 20, 1926 | 978.667 | 19° 25.9' | 155° 15.7' | 1,211 m. |
| Mauna Loa | Jan. 2, 1927 | 978.091 | 19° 29.8' | 155° 34.8' | 3,970 m. |

There were also three gravity stations occupied by the Coast and Geodetic Survey on the Island of Hawaii in 1892. These were on the top, the side, and the base of Mauna Kea much as the recently observed three stations are on the top, side, and base of Mauna Loa. The full description of the work and results at these old stations may be found in the U. S. Coast and Geodetic Survey report for 1893, Appendix No. 12. It will be interesting here to set down a summary of the results that were then obtained. The observed values of gravity as given in this report were founded on the value 980.100 for the base station at Washington. The more recent value at Washington is 980.112. Therefore, the old figures must be changed due to this change of base, and also owing to some other minor corrections, in order to make them comparable to like values at the new stations. This has been done before placing the figures in the following tabulation. Latitudes and longitudes as given in the old report have also been corrected due to a change in horizontal datum, so that these co-ordinates are in harmony with those given for the new work.

| Station | Mean Date | Dynes | Latitude | Longitude | Elevation |
|----------------|---------------|---------|-----------|------------|-----------|
| Kawaihae | July 5, 1892 | 978.812 | 20° 02.1' | 155° 51.6' | 2 m. |
| Kalaieha | July 15, 1892 | 978.499 | 19° 42.2' | 155° 29.9' | 2,030 m. |
| Mauna Kea..... | July 24, 1892 | 978.069 | 19° 48.9' | 155° 30.8' | 3,981 m. |

A brief computation was made in the old report, making use of these figures to arrive at the mean density of the earth. Rock specimens selected as representative of the structure of the mountain mass of Mauna Kea were examined and their mean density taken to be 2.90. The gravity observations at the different elevations yielded the information that the mean density of the earth should be 1.77 times as great as the density of the mountain. This resulted in the value 5.13 for the mean density of the earth. The more modern use of gravity observations is the reverse of this problem. Many observations by different methods have now given a better value for the earth's mean density, which is accepted and used in conjunction with gravity observations to discover the value of local crustal densities.

Tide Observations

During July, 1926, Mr. Jaggar was in Washington, and at that time arranged with the U. S. Coast and Geodetic Survey to establish a tide gauge at Hilo. The instruments and equipment for this station arrived about the time that Lieutenants Brown and Bainbridge finished their gravity observations in Hilo. They were instructed to install this tide gauge in accordance with the specifications for standard stations of the Coast Survey. This was done with funds furnished by the Coast Survey.

Specifications for installing such a gauge, and the instructions for operation, may be found in U. S. Coast and Geodetic Survey Special Publication No. 26. Briefly, the gauge is an instrument which records on a continuous sheet of paper the height of tide at all times. The paper is moved forward by clock work at the rate of one inch per hour, sufficient paper being contained in each blank roll to last for one month. A pencil, which moves at right angles to the motion of the paper, is operated by means of a wire leading to a float which rises and falls with the rise and fall of tide. This moving pencil thus traces a curve representing the height of water plotted against time. By a proper reducing mechanism, the motion of the pencil is only one-sixth the motion of the float, so that the curve is not unduly large. From this curve the heights and times of all high and low waters are tabulated. Tabulations are also made showing the height of water hour by hour. From these tabulations, the Coast Survey is able to calculate the constants which are necessary in predicting the tide at future dates and in constructing the tide tables in current use by mariners. These tabulations also furnish data from which to determine the elevation of mean sea level, which is the reference datum for land elevations and is the starting point for spirit level lines.

The Hawaiian Volcano Observatory is interested in the data furnished by this tide gauge for other reasons. As has been stated before, vertical motions and changes of elevations exist in the vicinity of Kilauea. The whole Island of Hawaii is subject to volcanic changes, and such risings and fallings may well exist along its shore line. An example of such a movement, which happened suddenly, was the subsidence in 1924 of the fault block in Puna, where a section of land and shore line settled about 14 feet (see Bulletin of the Hawaiian Volcano Observatory, Vol. XII, No. 4, April, 1924). Such movements may be slow and of such extent that no stationary datum remains at hand from which to measure them. Thus, referring land elevations to sea level remains the only means at hand for their detection. In order to facilitate this part of the observations, it has been arranged that the tide gauge records from Honolulu shall be sent to the Observatory for comparison with the Hilo records. Day-by-day comparisons will be made, which will in effect be simultaneous readings on the sea for elevation at Honolulu and Hilo. Each day will give a value for the difference of elevation, as indicated by the ocean water level, between the zero mark of the Honolulu gauge and the zero mark of the Hilo gauge. Tide conditions, the difference of latitude of the two stations, wind effects, difficulty of reading definitely the elevation of rough ocean waters, will, of course, cause this observed value to fluctuate, but in the long run its mean should tend to be free of these errors. If no relative motion exists between Honolulu and Hilo, it is probable that this difference of elevation will remain the same in its average year by year. If motion does exist, its nature will perhaps be discovered by a change in this computed difference. Aside from comparison with the Honolulu records, a rise or fall of the Hilo shore line would manifest itself in the change of elevation of Hilo bench marks as computed year by year from the Hilo records alone.

Another feature of the tidal observations of equal value to the Observatory is the study of tidal waves or seismic sea waves. Many tidal waves exist that are too small to be noticed by any means save a tide gauge. The study of tidal waves in connection with local and distant earthquakes can be expected to yield information of much value, not only to science, but to humanity



Fig. 23. August, 1923. Cones and pits on southwest rift of Mauna Loa. Photo Finch.



Fig. 24. Looking down southwest rift of Mauna Loa from about 9,500 feet elevation. Photo Emerson.

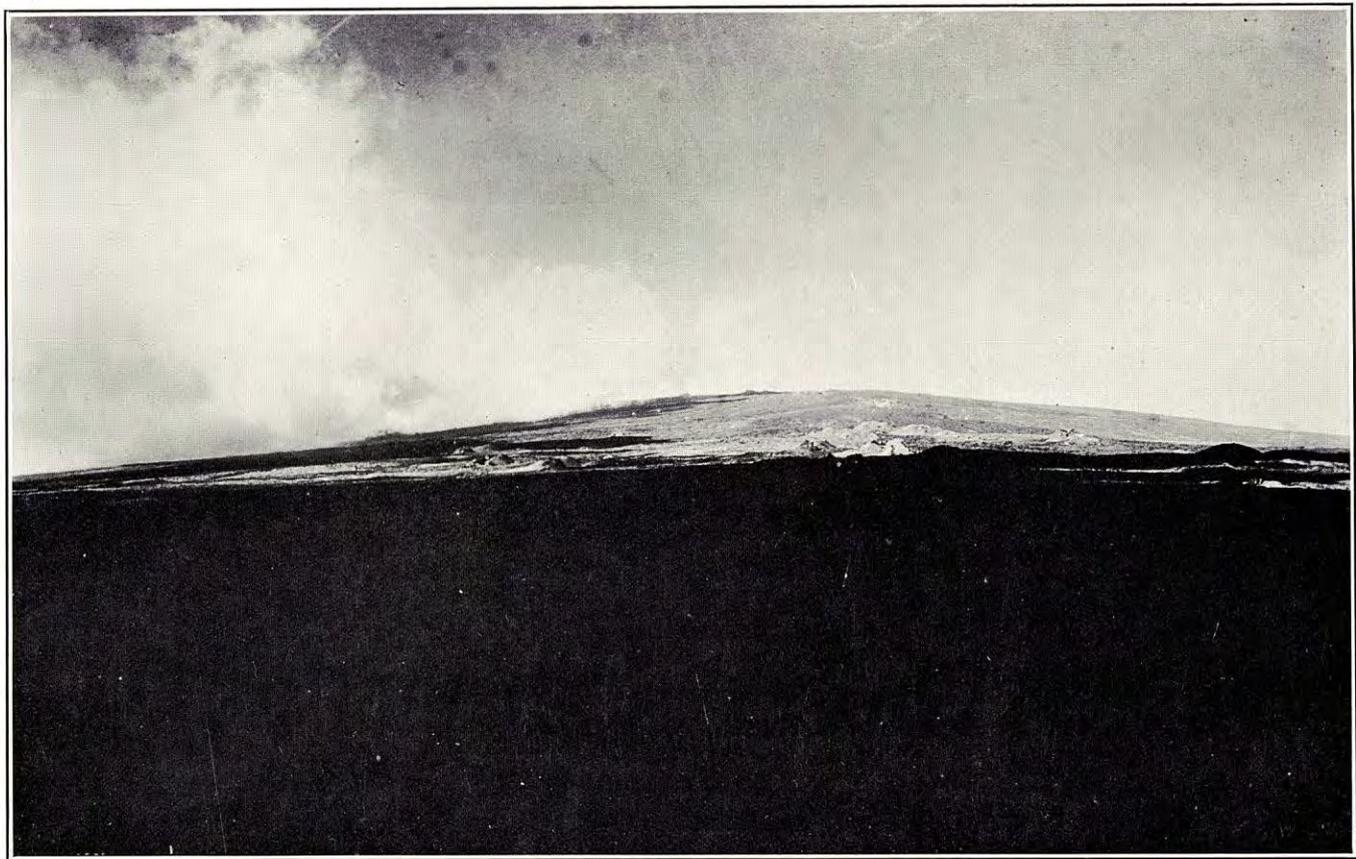


Fig. 25. Looking toward Mauna Loa summit from about 8,500 feet elevation on southwest rift. White spot in middle ridge marks sulphur banks. Photo Emerson.

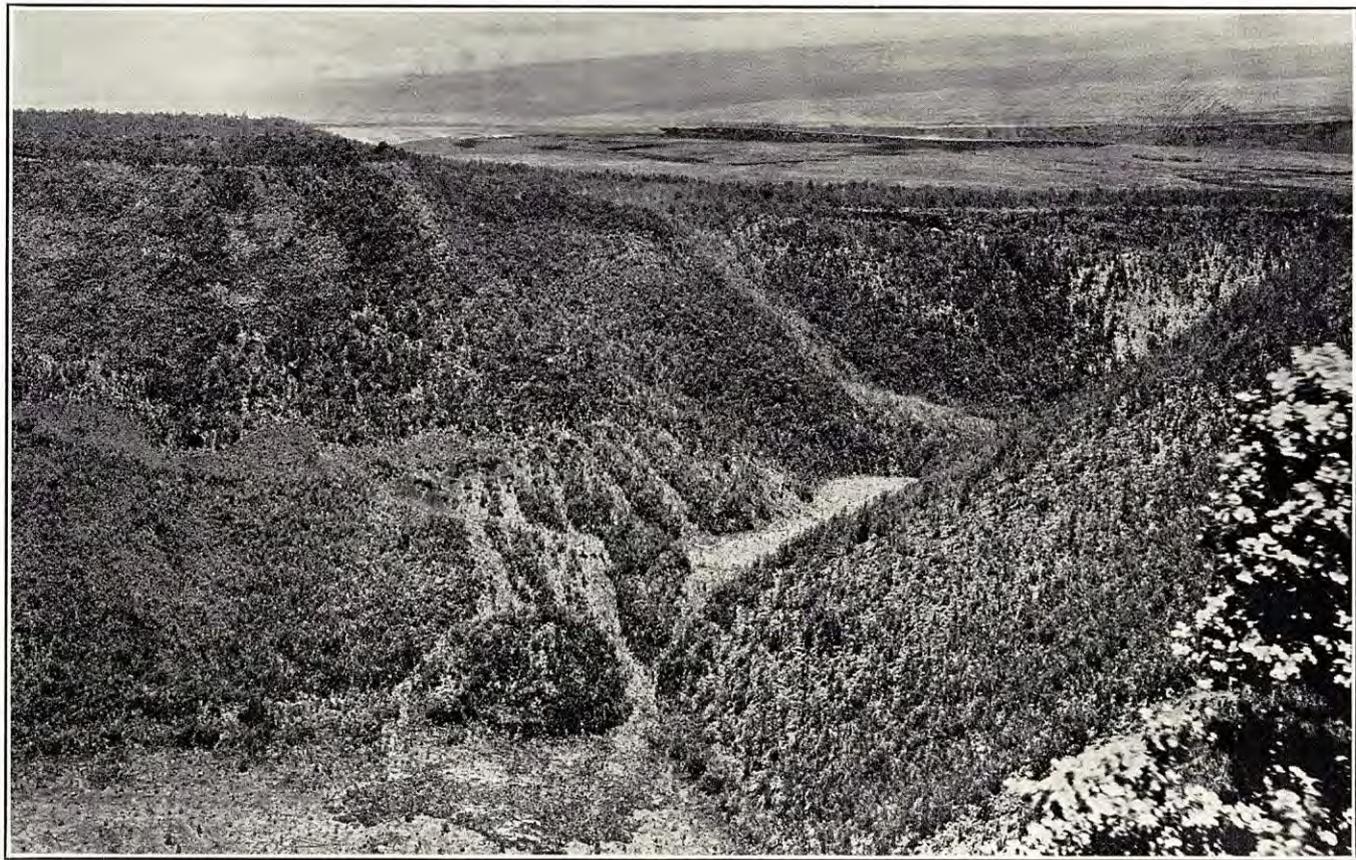


Fig. 26. August, 1927. Looking across Kilauea Iki and Kilauea craters. Showing old aa lava flow in Kilauea Iki, orifice of Halemaumau in the distance, and Mauna Loa hidden by clouds in the background. Photo Wilson.

as well. A tidal wave visited Hawaii and caused considerable damage on February 3, 1923. (Monthly Bulletin of the Hawaiian Volcano Observatory, Vol. XI, No. 2, February, 1923.) It was caused by a large earthquake, which made its record within a few minutes on the seismographs of the Observatory. Thus there was seismic warning of the danger some hours in advance. Warning was given so that such preparation as the time allowed might be made. Mr. R. H. Finch, in an article published in the "Proceedings of the Second Pan-Pacific Scientific Congress," Sydney, Australia, 1923, describes this tidal wave, and others that have come to the notice of the Hawaiian Volcano Observatory. The title of his paper, "On the Prediction of Tidal Waves," represents a subject that may well be studied to advantage.

It will be interesting to know the regions in which the occurrence of earthquakes is likely to produce tidal waves. Experience will tell what earthquake intensities are dangerous from this point of view. Observations will show the rates of travel of seismic sea waves over various depths of oceans, so that predictions may be accurately made. The use of a tide gauge makes possible the accurate study of many tidal waves so small as otherwise to escape notice, yet which yield information of great value in predicting the larger and more dangerous tidal waves.

Future Co-operation

Volcanic action causes horizontal movements in the vicinity of Kilauea that can be measured by triangulation. These movements, considered with the changes of elevation that are detected by means of level lines, give valuable information as to the mechanism of the volcano. In the immediate vicinity of Kilauea the leveling and triangulation has been done and repeated from time to time by the Observatory staff. The movements so discovered along the local fault lines may easily have their counterpart in movements along the major rift lines of the island. The precise level line to the summit of Mauna Loa may be used to check vertical changes along the northeast rift line of that mountain. But to check motion throughout the whole region, triangulation would be much more efficient. This use of triangulation is well known in California, where measurements are being made along the active fault lines. ("Earth Movements in California," by William Bowie, U. S. Coast and Geodetic Survey Special Publication No. 106.)

The Island of Hawaii was first triangulated about 40 years ago by the Hawaiian Government Survey. If stations enough were occupied in a new survey to form a large-figure net over the island, using old stations wherever possible, and intersecting or otherwise tying in other old stations, there would be several purposes served. First, if the accumulated motion of 40 years along any of the rift lines has occurred in such magnitude as to rise above the size of the probable errors of the surveys, it would be discovered and its nature shown. Second, such a survey made with present-day accuracy would make possible the discovery of still smaller earth displacements in the future, at such time as accurate resurveys may be made. Third, this accurate large-figure net would be a strong framework upon which the old triangulation, at present unadjusted, might be adjusted and strengthened. Fourth, many old stations, as well as new ones, would be recovered and permanently marked, thereby making them of real value in the cadastral surveys.

Simple triangulation would serve to discover relative motion among points on the island. But such a net should also be well founded on geodetic datum, with astronomic latitude, longitude, and azimuth stations, with at least one accurately measured base and with connecting figures to the other islands of the Hawaiian group. This work is to be done on Oahu during the coming season by Lieutenants Simmons and Bainbridge. It is hoped that the same work may be done on the Island of Hawaii as soon as possible. The completion by the Topographic Branch of the Geological Survey of accurate contour maps of the island will now make reconnaissance and figure-planning a comparatively simple matter.

The tide gauge should certainly be continued for some years to come. To determine mean sea level, the reference datum used by engineers in general, requires the averaged results of observations over a long period of time. A tide gauge run of several years is necessary for an accurate determination. Each year will give added information as to shore line elevation and depression. The more tidal waves that can be studied, the more surely will accurate prediction be possible, looking toward the avoidance of damage from this cause at the seaports in the future.

VOLCANIC CONDITIONS IN JUNE

Activity of Halemaumau

Kilauea Volcano lay dormant throughout the month. Conditions in Halemaumau pit showed little change. There was the usual peeling of the walls, termed slides when occurring in small amounts, and as avalanches when debris fell in large quantities. A slight movement of the ground around the rim, shown by fresh cracks, appeared indicative of changing pressure in the invisible lava.

Only six earthquakes were registered during the week ending June 8. Five were the ordinary very feeble local shocks, and the other, on June 2, was a faint record of a distant earthquake, phases of which indicated an origin 5,500 miles away.

About 1:30 a. m., June 8, parts of the island were disturbed by a shock that had the effect of a swaying earthquake and was said by some to be accompanied by a heavy booming sound, like an explosion. Checking with the time is a record on the seismogram of a very feeble earthquake, with indicated distance to origin of 14 miles, which could not possibly have been felt. Adding to the mystery is the report by the Kilauea Volcano House night watchman that he saw a glow, seemingly passing to the south, bright enough to illuminate the flower gardens. The light preceded the shock by a few minutes. A plausible explanation may be that a meteor fell and exploded, thereby causing concussion, as only concussion could have made the recorded shock perceptible.

Eleven very feeble local earthquakes was the count for the week ending June 15. In addition there were traces of minute spasmodic tremor on June 14. The normal microseisms were unusually feeble during the week.

During the next week the walls of the pit appeared to take on significant activity, with slides at the rift tunnel on the southwest side and cracking of the ground along the east rim.

Earthquakes for the week ending June 22 numbered 15, none of which was of sufficient intensity to be perceptible, but one, on June 19, showed 11 miles distance to origin. There was feeble trace of a teleseism at 8:40 p. m., June 16. Microseismic motion was very weak.

Active working of the walls continued in the next and last week of the month, and new surface ground movement was noticed back of the north and northeast rims of the pit. Seismic motion was extraordinarily slight, there being only nine very feeble local earthquakes recorded during the week ending June 29.

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June 1. 10:45 a. m. Fog and rain at the pit, and a pretty rainbow extends to the floor. The walls are very quiet, only a rock or two heard falling. New debris lies on the east, north, and south-southwest taluses, and the wall under the west boss looks more broken. A streak of dark gray dirt, perhaps colored by wetness, runs from the niche just above the west end of the north sill and crosses it.

June 2. Steam was dense this morning over the north and northeast walls of the pit, due to the wet atmosphere.

June 4. A visit to the pit at 8:30 a. m. showed it to be very quiet, but full of coloring from the rains wetting the walls.

June 6. The sulphur patch at the southeast rock bank seems to have increased.

June 8. About 1:30 a. m. the watchman at the hotel saw a light thought to have been made by a falling meteor, followed a few minutes later by a shock felt by many persons in the volcano district.

A visit to the pit at 10:45 a. m. showed little change. A few rocks fell on the north side, making dust. Where a section of that wall has broken away is shown the round end of an old pahoehoe tongue about 600 feet below the pit rim. Dustiness of the south wall indicates recent sliding there. Steam vents are less active. Dry spots on the southwest talus are conspicuous.

June 10. At 10 a. m. the pit was very quiet and dry, and there was very little steaming. A few stones were heard rolling on the north and northeast sides. The dry spots on the southwest talus continue to be conspicuous. The large one up the center of the talus steams, but those near the foot do not, but evidently are very hot. The coating of white salts has increased on the lower wall east of the southwest rift tunnel. At 10:23 there was a noisy fall of stone at the southwest. Dust from a slide on the northeast side was seen at 1 p. m. from the Observatory.

June 13. Conditions at the pit appeared quiet at 10 a. m. Yesterday's rains have made wet spots in the pit, most noticeable around the northwest talus. They are steaming. There is a greenish tint to the wall at the west end of the north sill, and the north talus is well sprinkled with red debris. The wall above is very red. One slide was heard on the northeast side.

June 15. Steam vents at the pit were working moderately at 8:45 a. m., the largest jet being on the northwest talus. More slides have occurred at the north corner. Peculiar dark streaks lie at the top of the north talus, probably due to wetness.

June 17. At 10 a. m. no change was noted in the steaming or the solfataras. Some stones were heard rolling at the north side. At noon dust clouds stirred up by the strong wind were seen from the Observatory to be high and thick over the desert, giving a smoky appearance.

June 19. Solfataras appeared brighter at 3:30 p. m. There have been additional slides at the north.

June 21. From the Observatory much dust from slides was seen over the northeast rim of the pit around 9:30 a. m.

June 22. A visit at 8:50 a. m. disclosed new gray debris lying at the foot of the wall between the northeast and north-northeast talus slopes. Slides have been less frequent on the north wall, and white salts are forming there. Slides were noted north, west, and southwest during this visit.

On this day cracks back of the east rim were seen to have widened perceptibly.

June 23. A high wind blew, and dust clouds obscured the desert all day.

June 24. Steaming was only very slight at all the vents, only one of which was active on the lava floor, at the center. There was a dusty slide north at 10 a. m.

June 25. A count on this day showed seven sizable steam jets in the pit, as follows: Center of northwest talus, top of north-northeast talus, three on south-southeast talus (one of which has a large sulphur patch), small one at southeast rock bank, with sulphur, and the one at the sulphur patch on the south talus. None of these works with any vigor.

A circuit of the pit showed several new fractures in the ground back of the northeast rim, containing much heat. New cracks were also seen back of the north rim.

June 26. A large slide southwest was reported occurring at 3 p. m.

June 27. Some stones fell from the north wall at 11:25 a. m. Dark wet streaks were seen around the northwest talus, which were steaming.

June 28. Dust from a slide at the north corner rose at 3:05 p. m.

June 29. Steam vents were more active on the southwest talus, and there was new red dirt on the south-southwest talus and below the walls around the north talus. The pit was quiet, only two falls occurring during a visit about 2 p. m. The odor of spicy sulphur was reported at the southeast station at 10:40 a. m.

June 30. A large dust cloud from a slide northeast arose from the pit at 9:45 a. m.

SEISMOMETRIC RECORD

There were 45 local earthquakes and two teleseisms recorded on the Observatory seismographs during the month ended at midnight June 30, 1927. These and other phenomena are listed below. The time used is Hawaiian Standard (time meridian is 157° 30' W.), which is 10 hours and 30 minutes slower than Greenwich Time.

The greater number of the very feeble local shocks counted in the list make such minute records that the character of the disturbance is not always apparent. Some are true earthquakes; others are perhaps the parts of greater amplitude of a continuous or protracted tremor, which at other times may be too feeble to record; some seem to be records of vibrations set up by avalanches in the pit of Halemaumau.

Abbreviations used below are as follows: vf, very feeble; f, feeble; s, slight; m, moderate; d, instruments dismantled, fl, felt locally; Δ , indicated distance in miles.

Local Earthquakes

| | | | | | |
|------|----------------|----|---------------------------|----|----------------|
| June | | | | | |
| 1 | 6:30 a.m. vf. | 14 | 7:23 a.m. vf. | 22 | 7:18 a.m. vf. |
| 2 | 11:50 p.m. vf. | | 4:33 p.m. vf. | 24 | 5:54 a.m. vf. |
| 3 | 7:44 p.m. vf. | | 5:46 p.m. vf. | | 10:45 a.m. vf. |
| 4 | 9:05 a.m. vf. | 15 | 10:58 a.m. vf. | | 3:14 p.m. vf. |
| 6 | 4:32 a.m. vf. | 16 | 9:00 a.m. vf. | | 6:20 p.m. vf. |
| 8 | 1:29 a.m. vf. | 17 | 4:43 p.m. vf. | 25 | 4:59 a.m. vf. |
| | 1:36 p.m. vf. | | 5:02 p.m. vf. | | 11:27 a.m. vf. |
| 10 | 3:11 a.m. vf. | | 5:27 p.m. vf. | | 11:31 a.m. vf. |
| | 9:37 a.m. vf. | | 5:29 p.m. vf. | 26 | 2:32 p.m. vf. |
| 11 | 2:13 a.m. vf. | | 11:12 p.m. vf. | | 6:56 p.m. vf. |
| | 9:08 a.m. vf. | 18 | 3:32 p.m. vf. | 29 | 11:07 p.m. vf. |
| 13 | 5:43 a.m. vf. | 19 | 7:11 a.m. vf. Δ 11 | 30 | 9:59 a.m. vf. |
| | 11:35 a.m. vf. | 20 | 4:36 p.m. vf. | | 1:40 p.m. vf. |
| | 1:04 p.m. vf. | | 5:48 p.m. vf. | | 3:40 p.m. vf. |
| | | 21 | 6:09 p.m. vf. | | |
| | | | 6:10 p.m. vf. | | |
| | | | 7:02 p.m. vf. Δ 25 | | |

Teleseisms

June 2

eP 8:52:44 p.m.

S 9:02:57 p.m.

Distance approximately 5,520 miles.

June 16

M 8:04 p.m.

Record very faint and no phases could be distinguished.

Harmonic Tremor

This type of movement was not recorded during the month.

Microseismic Motion

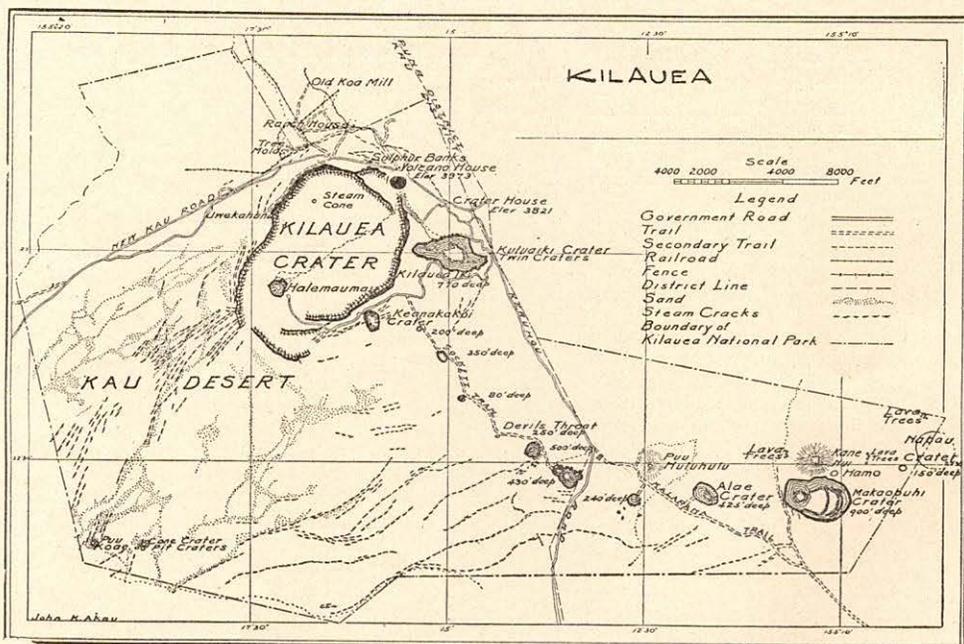
Microseisms were normal throughout the month.

Tilting of the Ground

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

| | | | |
|------------------|-----|--------|------|
| June 1-7..... | 0.5 | second | NW. |
| “ 8-14..... | 0.6 | “ | WSW. |
| “ 15-21..... | 1.2 | “ | NNE. |
| “ 22-28..... | 0.7 | “ | NNW. |
| “ 29-July-5..... | 0.3 | “ | NE. |

R. M. WILSON,
Topographic Engineer.



Black spot shows location of Observatory.

All exchanges, gifts to library, news notes about Pacific volcanic and seismic events, and correspondence should be addressed HAWAIIAN VOLCANO OBSERVATORY, Volcano House, Hawaii.

The Observatory is operated by the U. S. Geological Survey, and its work is supplemented by the Hawaiian Volcano Research Association. The main station is on the northeast rim of Kilauea Crater. Subordinate seismograph stations are operated by the Research Association under the direction of the volcanologist in Kona and Hilo.

The Kilauea station operates horizontal pendulums of the Bosch-Omori type and receives time by wireless from the Honolulu Naval Station. Observatory Lat. $19^{\circ} 25' 54.3''$ N.; Long. $155^{\circ} 15' 39.6''$ W.; Elevation cellar 1214.6 meters (3985 feet). The Hilo, Hilea and Kona stations operate horizontal pendulums. Their seismograms are sent to the Observatory.

The Hawaiian Volcano Research Association founded the Observatory in 1911, transferring the plant to the Government in 1919, but continuing cooperation in experimental work by furnishing funds and apparatus and workers as needed by the Government Volcanologist. It is a corporation under the laws of Hawaii, governed by a board of directors, and financed by the subscriptions of its members and patrons. Its aims are identical with those of the Observatory, namely, (1) To keep record of Hawaiian volcanism, (2) To attract volcanologic specialists to Hawaii, and (3) To promote worldwide knowledge of volcanoes and earthquakes and the foundation of more volcano observatories.

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VOLCANIC CONDITIONS IN JULY

Activity of Halemaumau

The volcano came suddenly to life shortly before 1 a. m., July 7, with a quiet display of lava in Halemaumau pit. This was the first visible lava activity since a similar eruption in July, 1924. Observatory officials believe that these minor lava displays will become more and more frequent until there is once again a lake of live lava constantly within the pit.

The lava gave little indication of its coming. There were a few signs which might have been considered significant, but which were not recognized as such at the time. There was moderate northerly and easterly ground tilting for several days preceding the eruption, which appeared normal for the time of the year. The constant widening of cracks along the east rim of the pit seemed, after the outbreak, to be positive indication of increase of pressure under the crater floor, causing the rim blocks to separate. The main Kilauea rift line trends northeast-southwest, and avalanches prevalent from the north-

east and southwest walls of the pit could have been considered significant, but were not because they represent a normal volcanic condition. Reference to the Journal shows that there was much activity of these walls during the first few days of the month and before the lava made its appearance.

Fume rising from the pit, reflecting the glow, was the first sign that the lava had returned, and on visiting the pit observers found four beautiful fountains, which were building a considerable lake. The fountains were in a line tending to trend northeast-southwest. The northernmost fountain was issuing from a vent below the lake level. It was thought by some to be in the same relative position as "Old Faithful," active over a decade ago. At about the center of the pit was a small double fountain, back from the west edge of the lake, which later surrounded it. Next in line was a fountain which had already built a cone, and for that reason was thought to have been the first to come into action. The southernmost fountain was some distance up the south-southwest debris slope. The positions of these fountains show in Fig 29. After about 24 hours, three of the fountains went out of action, leaving only the southernmost still working, and this one ceased on July 20. Observatory officials estimate that the lava in this eruption decreased the depth of the pit by about 80 feet, most of this occurring on the first day; and surveys show that the new floor covers an area equal to about 30 acres. The cone built by the south fountain rises about 50 feet above the surrounding talus, but is partially buried by fallen debris.

During the lava activity the pit walls were rather quiet, with little sliding, but with the cessation of flowing lava large slides became very prevalent. On July 24 slides from the northeast wall were constant, and all day the air above the pit was heavy with dust. The avalanching apparently came from a natural inward slumping of the walls due to decreasing pressure within the volcano, a condition resembling the great subsidence of 1924.

Perceptible earthquakes at 11:31 a. m., July 29, and 2:14 a. m., July 31, together with the very active avalanching, gave rise to rumors of renewed volcanic activity, but the lava did not reappear.

SUMMARY OF THE JULY, 1927, ERUPTION OF KILAUEA

By R. M. Wilson

The eruption came just before 1 a. m., July 7, and was almost wholly unheralded. Upon looking back there seem to be some events that might have been interpreted as having significance in announcing the coming of an eruption. The most likely symptom was the widening of old cracks and the development of new ones on the main crater floor near and parallel to the northeast rim of the pit. The marked opening of the cracks was first noticed on June 22, and progress of the movement was noted in the Volcano Letters covering the two weeks preceding the eruption. There seemed to be more heat than usual issuing from some of them. The development of cracks became so pronounced that by the first of July the northeast rim of the pit seemed unstable, and it was thought wise to warn visitors away from this dangerous part. At the time, this movement was taken to be a natural result of the slow undermining that had been going on for months in the form of avalanching. Much of the sloughing down had been from the north wall, and had eaten back so far as to leave the northeast wall almost convex, thereby taking from it the arch-like support of the natural concave form. Perhaps related to these movements is the fact that on July 3 or 4 some rocks were loosened from the roof of the small cavern called "Pele's Bath," and fell to the floor. This cavern is within a few hundred feet of the edge of the pit.

Members of the Observatory staff were at work nearly all day at the edge of the pit on July 6, the day before the lava outbreak, taking photographs and measuring the width of the cracks, yet nothing unusual beyond the facts above mentioned was noticed. The air was exceptionally clear,

without a trace of blue haze. The clear atmosphere was particularly noticed in considering the conditions for photography. It was observed, however, that steaming at the usual vents was somewhat increased in volume, but not by any such amount as to cause more than passing comment, especially as this is always the effect produced by damp weather. This day was clear and dry, however.

The statements made by many people who said that they had seen various indications, more or less vague in nature, or had had hunches of the coming eruption, can for the most part be set aside as worthless. Their prophecies were not recorded before the event, and it is easy to prophesy after the event occurs. An interesting recorded prophecy is that made by the guide, Alec Lancaster, as far back as 1924. According to a letter written not long after the lava left the pit in 1924, and now on file in the office of the Hawaii National Park, Alec made the statement that it would be three years before the lava would return, and he set the time as July, 1927. This was a very fortunate long-distance guess. A few days before the eruption, there was a report of a slight blue haze in the pit, but this was not seen by any of the regular observers. At midnight of July 6 one of the National Park employees stated that he had looked toward the pit and had seen or heard nothing unusual.

Of real significance is the statement of Mr. Paul S. Loomis, of Honolulu, who was staying at the Kilauea Summer Camp. Mr. Loomis writes as follows:

"On the night of July 6th, Mrs. Loomis and the writer drove over in our Chevrolet to the pit at about 9:30 p. m. We parked our car at the usual place and walked over to the pit. We noticed a good deal more steam and sort of smoke rising from within the pit than usual. As the wind blew this steamy smoke in our faces, we noticed a different smell than on our previous trips. We also heard a rumbling sound ensuing forth from the pit. These noises were not the same as when we had heard landslides before. The sound is hard to describe, but seemed to the writer something like cannons shooting off in the distance. Mrs. Loomis remarked at that time about the unusual noises, but, of course, not realizing this was the forerunner of an eruption.

"The writer was awakened by the lady living in the adjoining cottage at the Kilauea Summer Camp at about 3:05 a. m. Not being able to sleep, she noticed the red glow in the sky and awakened me. The earthquake occurred while I was getting dressed, which was probably around 3:21 a. m. I took a machineful immediately over to the pit."

Up to the hour before the outbreak, the seismographs were recording nothing more than the usual very feeble local earthquakes without any variation in frequency or intensity from the general average maintained for the six or eight preceding months. There was no sign of change in microseismic motion, nor of abnormal tilting of the ground. Harmonic tremor was absent until just before the appearance of the lava, except for a very feeble trace beginning at 10:55 p. m., July 6, and lasting 17 minutes.

Thus there was nothing observed that had definitely pointed to an imminent eruption, nor was there even anything that had been enough unusual so that an imminent eruption was suspected.

The first day of the outbreak was by far the most spectacular, and the first hour of flow produced roughly 50 per cent of all the lava poured out during the eruption. The succeeding days were merely a continuation of mild activity and lava outflowing from the southwest cone.

The seismological accompaniment to the eruption was remarkably apathetic. There seemed to be no seismic prelude, unless the short, 17-minute period of harmonic tremor, above mentioned, may so be considered. There was but one perceptible earthquake, at 3:21 a. m., July 7, and only 24 hours of harmonic tremor as evidence of the eruption. In other respects, the seismographs showed neither increase nor decrease in frequency or intensity of the usual very feeble local movements. Tilt during the two weeks preceding the eruption had accumulated moderately to the north. On July 8 the trend of

tilt changed rather abruptly to the northwest, which direction was maintained throughout the days of activity and for some time thereafter. The amount of tilt was at all times moderate, and was not enough different from normal to have attracted notice were it not for the eruption itself. Measurements of the cracks around the northeast rim during and after the eruption failed to show definite widening.

The description of the eruption, given hereafter in journal form, is a compilation of notes supplied by a number of observers. R. M. Wilson and R. B. Hodges of the Observatory staff have to thank Mr. R. I. Baldwin of the National Park Service, Professor Paul Kirkpatrick, Mr. P. S. Loomis, and many others for their kind assistance in this respect.

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July 1. An avalanche on the northeast side was observed at 8:45 a. m. from the Uwekahuna Museum. The odor of spicy sulphur was noticeable at 9:05 a. m. on the east side of Halemaumau pit. The cracks in the ground at the 14-ton boulder have widened to such extent that the signs attracting visitors to the boulder were removed.

The pit was quiet, and steaming was slight. New gray debris was seen on the northeast talus at 11:55 a. m.

July 3. Dust from slides filled the pit in the late afternoon. An avalanche from the northeast wall was seen at 2 p. m.

R. B. Hodges, of the Observatory staff, and Dr. G. H. Dieke, physicist of the University of Leyden, made a trip to Mauna Iki, the Kau Desert flow of 1920 from Halemaumau. The many hot spots of this big pahoehoe lava mound are still noticeable by their rusty appearance, and are too warm to sit upon. A favorite stunt of hikers is to toast bread upon them, or to scorch post cards. Paper thrust into the steam vents ignited almost immediately, but green sticks would only scorch.

July 5. A visit to the pit at 9:15 a. m. showed evidences of slides at the southwest rift tunnels, and rocks could be heard trickling there. Large gray streaks, showing the courses of rock falls, were on the south-southwest talus, three of them reaching to the foot. Cracks at the southeast rim have widened slightly. The north wall has fresh scars from slides. A ledge at the southeast rim has settled so as to move the rocks considerably, and the northeast wall has been avalanching. The crack at the 14-ton boulder has widened so as to allow the trail crossing it to be swallowed up, and there are many small fresh surface cracks nearby. The great blocks of the rim on the northeast side also show movement. A small new crack has formed in the ground at the south rim.

July 6. The pit seemed very quiet at 8:40 a. m. Steaming has increased slightly, especially at the vents on floor.

Thinking that the steadiness in the widening of the cracks may prove interesting, 15 points for routine measurements were marked and measured along the east rim.

July 7. Lava came into the pit a few minutes before 1 a. m. The exact time is not known, but the various reports do not greatly differ. The night watchman at the Volcano House was making his rounds at the hotel when he noticed a glow at the pit that grew brighter as he watched. This was probably about 12:50 a. m. He awakened people at the hotel, and Mr. James Tsuchiya spread the news of the eruption in the immediate neighborhood. At the Kilauea Military Camp the glow was noticed a few minutes before 1 a. m., and occupants of some of the summer cottages observed it about the same time. As nearly as it may be estimated, the glow must have first begun to show at about 12:45 a. m. Cars soon began to hurry to the pit, the first ones probably getting there between 1:30 and 1:40 a. m. There were but few clouds in the sky to reflect the glow, yet at the Volcano House there was

light enough from the volcano to read small print; and the crashing noise of the fountaining lava could be plainly heard.

Within the pit there were three large fountains of lava, and a smaller double one, all spouting energetically into the air jets of bright incandescent lava. The three larger fountains were about 125 feet in height, as judged by comparison with the depth of the pit, and by noting the time of fall of some of the shreds of lava from the tops of the fountains. The thundering noise of the fountains, which made it necessary for the observers to speak loudly to one another, gave evidence of the volume of material that was being thrown out by these jets to fall so heavily back again. Back from the edge of the pit there was little wind, but at the edge there came occasional vigorous convection whirlwinds, bringing with them suffocating sulphurous fumes, which made everyone retreat in haste. For the most part, however, the fume clouds rose from the southwest side of the crater. The spectators standing at the southeast station, at the end of the trail from the auto parking space, were thus afforded a clear view in comfort most of the time. The intense heat was pleasing in the cold morning air.

Even within this hour since the beginning of the eruption, enough new lava had come from these fountains to completely cover the old floor of 1924 lava, and the molten lake was in contact with the talus slopes all the way around the bottom of the pit, an area of about 25 acres, estimated about 30 feet deep. The four fountains were nearly in line (see Fig. 29), suggesting vents from a rift running across the northeast-southwest diameter of the pit, which is very nearly the line of the 1920 rift cracks. The southwest fountain was part way up by the south-southwest talus slope, at an elevation of about 120 feet above the lake level, and just under the 1920 rift tunnels. A river, 15 to 20 feet wide, ran from it down to the lake. The next fountain, 600 feet farther northeast, was lower down near the bottom of the big southwest talus, about over the position of the old buried 1924 cone. This vent was about 30 feet higher in elevation than the lake level. Two rivers, 10 to 15 feet wide, were feeding the lake from this fountain. There seemed to be more spatter thrown out here than around the others, and a cone had already started to form, so that perhaps this was the vent where action first started. The small twin fountains were in action about 200 feet east of the one last described. They were just at the edge of the lake, at the foot of the southwest talus. Then, some 800 feet to the northeast, was the third large fountain, which was near the foot of the north-northeast talus. Its source was below the lake level, so that its gushings came up through the surface of the lake. The fact that its convulsions caused visible waves to cross to the other sides of the lake gave evidence as to the depth and fluidity of the impounded lava. The lake showed the usual cracked surface, with occasional minor bubbings, and seemed to be slowly rising equally in level over its whole area.

During the early morning hours the lake continued to slowly rise, but not at any such rate as during the first hour or two. The sky began to cloud over, and about 3:30 rain commenced to fall.

Inspection of the seismograph records showed that harmonic tremor began at 12:32 a. m., possibly representing the time of outbreak of the lava, though the time already stated above seems more probable from the data supplied by those who first saw it. At 3:21 a. m. there was a moderate earthquake, felt not only locally, but generally all over the island. Its indicated distance was 35 miles from the Observatory. The shock awakened the people at the Kilauea Summer Camp, who had slept through two hours and a half of the eruption, so that while they were the nearest to the pit, they were the last of those in the volcano district to arrive at the scene. The harmonic tremor continued all day. In other respects the seismograph records were of normal character.

The coming of daylight showed heavy clouds of fume and steam above the pit, emphasized by the drizzling rain and foggiess of the weather. There

seemed to be very little avalanching, probably no more than normal. The customary steam vents on the walls and taluses seemed to be in no more than normal action. New Pele's Hair could be found around the edge of the pit, formed by the fountaining lava. The convection whirls also sucked up small pieces of very light frothy spatter, which could also be found around the rim of the pit. With daylight the wind began to blow, and the spectators found the mist, sand, and fume carried by the wind increasingly uncomfortable.

There was little change in activity till afternoon. Surveys were made about 3 p. m., showing the lake elevation to be 2,480 feet above sea level, using as datum the most recently determined elevation for the tablet at the southeast station (near the "Halemaumau" sign) as 3,651 feet. The lake was apparently no longer rising, and activity seemed slightly diminished. At about 5 p. m. the small twin fountains died out, leaving a pair of small spatter cones standing at the edge of the lake. Toes of lava continued to push out around the lake shores. There were several small avalanches during the afternoon. Little rain fell in the afternoon, but the weather continued cloudy and windy.

It is estimated that there were 40 or 50 spectators at Halemaumau within an hour after the outbreak. In the evening, when people had assembled from greater distances, there were probably a thousand people present. The estimate of the Superintendent of Hawaii National Park is 1,800 individual visitors during the day, but many of these people made several separate trips to the pit.

July 8. The seismograph records show the harmonic tremor to have faded out at about 1:25 a. m. It reappeared at occasional intervals for a few minutes at a time during the day. Observers at the pit until 1:30 a. m. reported that the three fountains, now more properly called cones, were still very active, but had begun to show signs of weakening. The first new arrivals on the scene in the morning at daybreak found only the southwest cone still active; the other two having died out during the early morning hours. The southwest cone seemed to be as active as ever, throwing large splashes toward the north, and supplying a voluminous stream of lava.

The lake had subsided, the hardened crust collapsing about 15 feet over the whole area, leaving a shore line bench all around the perimeter at the high level mark of yesterday. This bench, due to collapse, was much like that left in 1921 in the bay of the main crater just south of the pit road. The lava from the southwest cone was running out on top of this collapsed lake surface, beginning to form a delta. There was still some liquid lava beneath the crust, however, as it would occasionally ooze out of the surface cracks, and all of the cracks glowed visibly bright red in daylight. The large cone, and the two small twin cones at the foot of the southwest talus, were standing as their last gush of lava had left them, the spatter around the larger one showing that its life had ended supplying only one stream of lava instead of its original two streams. There was no glow visible in the throats of these cones. The northeast vent left no cone. It was below the lake level, and the lava in the lake probably flowed over and effaced its surface evidences. Only a sector of spatter on the neighboring talus served to show its position.

Surveys made about 9 a. m. gave the same general elevation for the shore-line bench that had been secured for the lake elevation during the afternoon of the day before (2,480 feet), showing that there had been practically no further rise in the lake since that time. The elevation of the summit of the active southwest cone was 2,602 feet, and the summit of the large cone at the foot of the southwest talus was 2,543 feet. Points located in position around the perimeter of the new lava made possible the computation of the area covered by the lake, cones, and spatter, 30 acres being the result. Referring to the photograph taken on the morning of the 7th (Fig 29): From A to B is 1,760 feet in distance, and N. 53° E. in bearing. From C to D is 1,420 feet, and S. 33° E.



Fig. 27. July 6, 1927. Southwest wall of Halemau mau, showing mouth of Kau Desert tunnel through which lava drained in 1920 to form Mauna Iki, and (lower center) streaks made by tumbling boulders on talus slope. Photo Wilson.

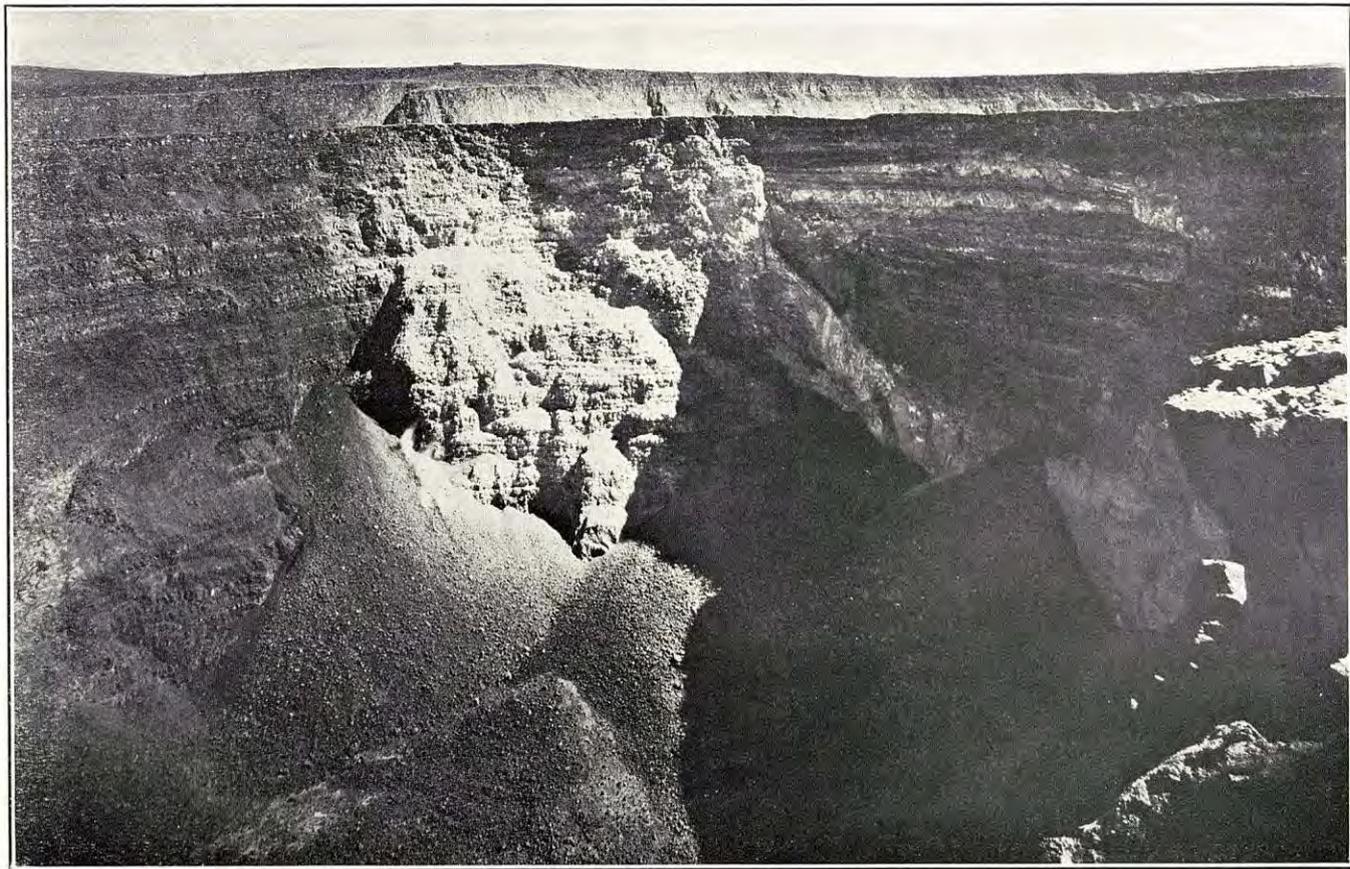


Fig. 28. July 6, 1927. North wall of Halemaumau, showing great northeast sill and Uwekahuna Observatory and Museum on crater rim in the background. Photo Wilson.



Fig. 29. July 7, 1927; 5 a. m. Floor of Halemaumau, showing row of four fountains and lake. Photo Wilson.

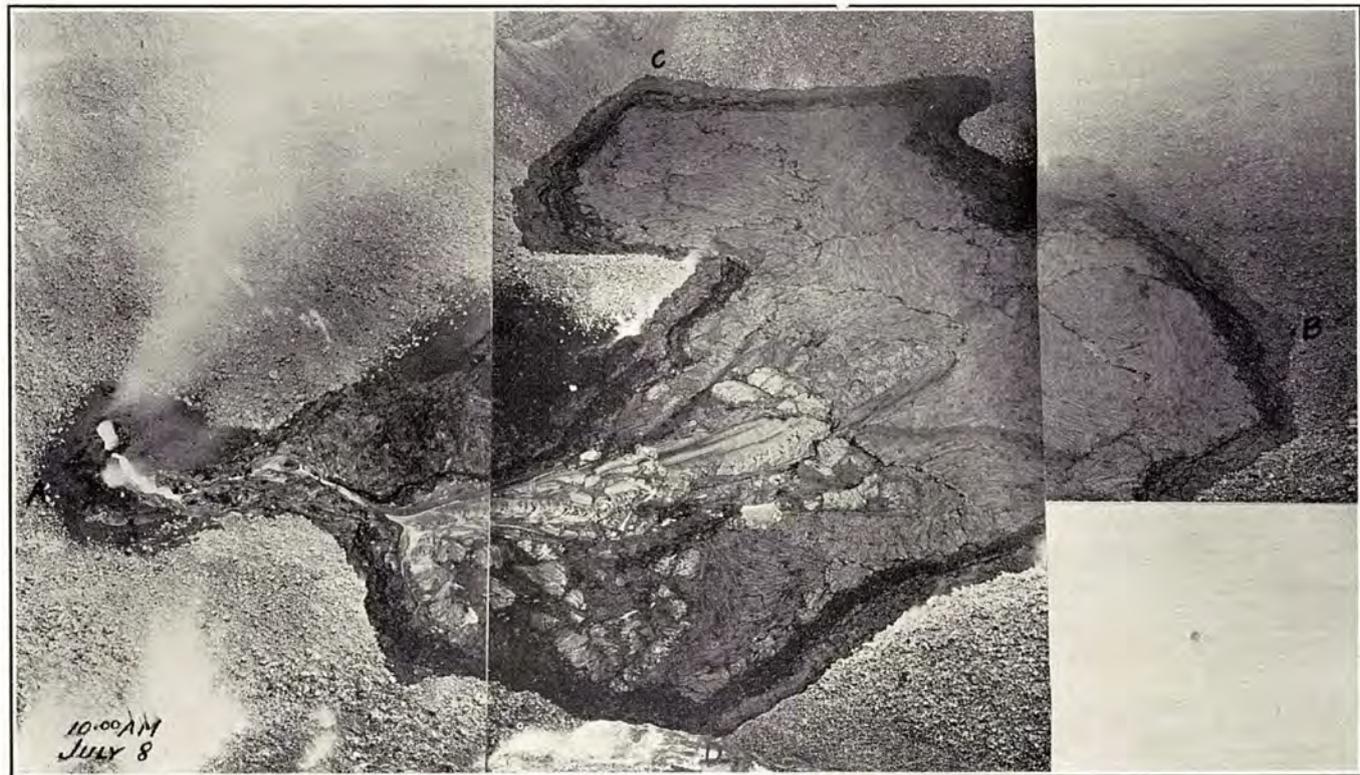


Fig. 30. July 8, 1927; 10 a. m. Halemauau bottom, showing river of lava from southwest cone and dead center cones. Photo Wilson.

The stream from the cone began to build a roof, sometimes caving in and sometimes choking up. The stream, by this action, separated and formed two channels during the afternoon. Action continued about the same during the afternoon and evening, and was much less spectacular than the day before. Fume in the pit was thin. Perhaps the high activity just following the outbreak represents the release of pressure on the lava column when the lava finally forced its way through; and the resulting effervescence was due to this release of pressure.

The number of individuals visiting the pit during the day was 775, according to the National Park records. The afternoon was partly clear, but the wind was strong.

It is reported that on this day rocks fell from the roof of the Thurston Lava Tube in two places.

July 9. At 9 a. m. the activity seemed about the same as on the night before; the southwest cone was still active and was built up a little higher, and the view of molten lava was somewhat more obscured by increased roofing over the channel from the cone to the growing delta. Fume was strong. The red cracks in the collapsed lake were somewhat dimmed, but the flow action on the slopes of the delta continued to be interesting, as the supply of lava from the cone continued steadily. In the evening the cone had nearly capped itself over, but the small opening in the top still gave a view of the lava surging and churning within. The flowing lava came from the cone in a eased-over opening well down on the side. Occasionally the cap of the cone would be blown off, or would collapse, and at times in the evening a pale blue flame could be seen coming from the opening. The delta covered about one-third of the collapsed lake.

The weather during the day was increasingly rainy; the rainfall recorded from 8 a. m., July 8, to 8 a. m., July 9, was 0.8 inch, and from 8 a. m., July 9, to 8 a. m., July 10, was 2.0 inches. The official count of individual visitors during the day was 675.

July 10. Conditions at daybreak were essentially the same as on the evening before. The delta continued to build up and cover more area. The river from the cone was open much of the time, showing the flow of fluid lava for a short distance. Occasional avalanches were noted, but not more frequently than in normal times. The cracks around the northeast rim showed no widening. Fume was moderate, obstructing the view of details on the far wall of the pit.

July 11. Inspection of the pit in the morning disclosed the fact that during the night there had been more than usual outpouring of lava. The area of the delta was considerably enlarged, so that now about two-thirds of the old, collapsed lake was covered. A small section of the river from the cone was still open, and the flowing lava could be seen; aside from this the only visible activity was the slow pushing out of lava toes at the bottom edge of the delta. Sulphur deposits began to appear at the edge of the new floor behind the two small cones. The steam vents seemed to be no more than normally active; the eruption apparently has had little effect on the usual steaming places on the higher parts of the taluses and walls.

During the afternoon the cone occasionally built a cupola over its top which would as often fall in. A loud purring sound could be heard. There were few avalanches noted, and no debris had as yet rolled out onto the new floor.

July 12. The lava activity during the day was much the same as on the day before; the delta continuing to build itself out, the cone capping and falling apart again, and the lava river showing itself from time to time as a rapid flow close up under the cone when the roof of the channel would cave in and expose it. Lava was flowing sluggishly in wide, crusted channels near the top part of the delta. There was very little glow visible from the Vofeano House in the evening.

July 13. The southwest cone still remained active, and sluggish movement was still visible on the delta. Several photographs taken show the fume to have been so thin as to hardly interfere at all with details of the pictures. Only a thin plume of smoke was rising from the top of the cone. The delta was by this time covering the greater part of the lake, excepting the northwest bay. (See Fig. 31.) During the afternoon almost continual small sliding and rolling of rocks from the walls was noticed.

July 14. The flow of lava from the cone seemed neither to have decreased nor increased. When the cap of the cone collapsed, or was blown off, the lava could still be seen tossing within, and occasional red-hot shreds would be thrown out. The delta continued to grow, though more in depth than in area. Patches on the side of the active cone show reds and yellows due to oxidation.

July 15. There was practically no change from the action exhibited during the last two or three days. Sluggish flow on the delta continued, and the lava continued to boil up within the cone. In the sluggish flows on the side of the delta, occasional blocks of cool crust would up-end and sink into the pasty red mass beneath. The flows on the delta had increased its thickness to such a degree that one of the small twin cones was practically buried.

July 16. There was no change on this day in the continued sluggish action of lava coming from the cone. One observer, W. H. Vaughan, who had spent a great deal of his time at the edge of the pit, said that the activity shown by the cone was somewhat periodic in nature. The lava seemed to gush forth in greater quantities about once in every four hours. Also, the lava within the cone seemed to boil more energetically at about five-minute intervals.

Surveys made about 10 a. m. show that the active cone had added considerably to its height since it was last measured on July 8. Its elevation by this later survey at the top of its pointed cap was 2,643 feet above mean sea level, a gain of 41 feet.

July 17. The flow of lava from the cone seemed somewhat weaker on this day, and there was but little activity visible in the pit. Occasional toes of lava were pushing out around the edges of a very sluggish flow on the delta. The cone was fuming constantly. At 10 a. m. a very strong wind was blowing, and dust clouds in the desert were heavy.

July 18. The sluggishness of the flow was more apparent. An avalanche from the east wall scattered debris on the new floor of Halemaumau. It was possible from the southwest rim to look down into the throat of the southwest cone and see there that the lava was still tossing and boiling.

July 19. During the night an increased flow of lava from the still active southwest cone sent a stream over the talus slope above the extinct cone at the bottom of the southwest talus, and connected this area of new lava with the northwest bay. This was the last addition to the area of new lava. At 10 p. m. the cone was reported still active, but weak.

July 20. During the forenoon there was only a slight amount of fume coming from the southwest cone. At 3 p. m., looking down into its throat from the southwest rim, there was no longer any active lava visible. The throat of the cone was no longer even red hot, and there was but the very faintest trace of fume issuing from its mouth. There was no sign of any other activity on the lava floor.

July 21. There was no activity whatever at the southwest cone or on the pit bottom. The eruption has definitely ceased, though considerable glow was visible at night in the cracks of the floor.

July 22. At 1:45 p. m. the odor of spicy sulphur was noticeable at the approach to the pit from the southeast. Falls of rocks from the north and west walls were heard.

A large area of the new lava floor has collapsed on the south side. Steam vents in the pit appear about the same as before the eruption, excepting three new locations on the floor: at the cone at foot of southwest talus, at the edge

of the floor at foot of northwest talus, and in the same position at the foot of the north talus. The latter has a sulphur patch.

The dirt at the southeast rim shows some evidences of ground movement.

July 23. At 3 p. m. there was a large avalanche from the northeast wall. Small avalanches were also observed during the afternoon.

July 24. There was constant avalanching all day from the northeast wall, and the air all around the pit was filled with dust. A considerable tongue of debris has overlapped the new floor, extending at its widest part just opposite the depression between the northeast and north-northeast taluses. The sulphur patch at the edge of the east talus is buried by fallen material.

July 25. The activity of the northern walls has diminished, and at 10:30 a. m. there were only occasional rock slides. The taluses and intervening depressions are considerably built up. Two boulders low down on the north-northeast talus, which were landmarks, have been buried. Many small new cracks were seen back of the north-northeast rim, and old ones showed widening.

July 26. A new vapor jet on the northeast talus was noticed at 1:45 p. m.

July 27. A visit at 3:10 p. m. showed that the north wall of the pit had been avalanching, and there was new debris on the north-northeast talus. The yellow stain on the southeast rock bank has gone. The sulphur patch at the foot of the east talus has reappeared. Avalanches in the evening were reported.

July 29. The northeast and east walls had many fresh scars at 11:20 a. m., and new debris lay below. The odor of spiey sulphur was noticed at the north-east rim. A few rocks fell from the south wall at 11:25 a. m. The steam vents were quite active.

From 3:20 to 3:30 p. m. noisy slides were seen from the Uwekahuna Observatory, and there was much dust.

July 30. At 3:45 p. m. dust from a slide northeast was observed.

SEISMOMETRIC RECORD

There were 72 local earthquakes and three teleseisms recorded on the Observatory seismographs during the month ended at midnight July 31, 1927. These and other phenomena are listed below. The time used is Hawaiian Standard (time meridian is 157° 30' W.), which is 10 hours and 30 minutes slower than Greenwich Time.

Lava appeared in the pit on July 7 for the first time in three years. Eruptions of Mauna Loa and Halemaumau are customarily accompanied by seismic disturbances. In this case, however, the seismic disturbance due to the eruption seems to be remarkably slight. The earthquake at 3:21 a. m. on the 7th, coming about two hours after the outbreak of lava, has perhaps some connection with the eruption, although the indicated distance is 35 miles. The harmonic tremor noted below is the usual accompaniment to an outbreak of lava, but in this case either stopped or became too feeble to record after the first two days of the eruption, even though lava continued to flow into the pit for a number of days longer. The group of perceptible earthquakes near the end of the month may have had some connection with the end of the eruption, perhaps representing collapse upon the retirement of the lava.

The greater number of the very feeble local shocks counted in the list make such minute records that the character of the disturbance is not always apparent. Some are true earthquakes; others are perhaps the parts of greater amplitude of a continuous or protracted tremor, which at other times may be too feeble to record; some seem to be records of vibrations set up by avalanches in the pit of Halemaumau.

Abbreviations used below are as follows: vf, very feeble; f, feeble; s, slight; m, moderate; d, instruments dismantled, fl, felt locally; Δ, indicated distance in miles; *, continuous tremor.

Local Earthquakes

July

| | | | | | |
|----|------------------------------|----|----------------|----|-------------------------------|
| 1 | 12:28 a.m. vf. | 13 | 9:30 a.m. vf. | 24 | 6:03 a.m. vf. |
| 2 | 4:23 p.m. vf. | | 12:50 p.m. vf. | | 6:05 a.m. s. fl. |
| 3 | 5:18 p.m. vf. | | 1:49 p.m. vf. | | 11:56 a.m. vf. |
| 5 | 12:01 a.m. vf. | | 2:05 p.m. vf. | | 3:45 p.m. vf. |
| 6 | 5:03 a.m. vf. | | 2:07 p.m. vf. | 25 | 1:44 a.m. vf. |
| | 5:48 a.m. vf. | 14 | 6:34 a.m. vf. | | 2:07 a.m. s. Δ 25 fl. |
| | 7:54 a.m. vf. | | 7:04 a.m. vf. | | 2:18 a.m. vf. |
| | 2:45 p.m. vf. | | 7:08 a.m. vf. | | 6:13 a.m. s. Δ 28 fl. |
| | 2:46 p.m. vf. | 15 | 12:10 a.m. vf. | | 11:28 a.m. vf. |
| | 7:54 p.m. vf. | | 2:15 a.m. vf. | | 11:56 a.m. f. |
| | 10:55-11:12 p.m. vf. * | | 5:36 a.m. vf. | | 12:01 p.m. vf. |
| | 11:46 p.m. vf. Δ 55 | 16 | 11:36 a.m. vf. | | 6:29 p.m. vf. |
| 7 | 3:21 a.m. m. Δ 35 fl. | 17 | 5:01 a.m. vf. | | 7:42 p.m. vf. |
| | 4:04 a.m. vf. | 18 | 12:14 a.m. vf. | 26 | 1:29 a.m. f. |
| | 5:49 a.m. vf. | | 2:45 a.m. vf. | | 4:10 p.m. vf. |
| 8 | 11:35 a.m. vf. | | 1:36 p.m. vf. | 28 | 6:33 a.m. vf. |
| 9 | 6:46 p.m. vf. | 19 | 3:06 p.m. vf. | | 12:09 p.m. vf. |
| 10 | 8:29-8:33 a.m. vf. * | | 6:20 p.m. vf. | | 3:07 p.m. vf. |
| | 10:35-10:38 p.m. vf. * | 20 | 4:22 p.m. vf. | 29 | 5:19 a.m. vf. |
| 11 | 11:57 a.m.-12:02 p.m. vf. * | | 4:23 p.m. vf. | | 11:31 a.m. s. Δ 39 fl. |
| | 1:39 p.m. vf. | 21 | 3:29 p.m. vf. | 31 | 2:14 a.m. f. Δ 16 fl. |
| 12 | 5:40-5:43 a.m. vf. * | 22 | 4:31 p.m. vf. | | 2:20 a.m. vf. |
| | 5:48 a.m. vf. | 23 | 5:17 a.m. vf. | | |
| | 5:56 a.m. vf. | | 1:17 p.m. vf. | | |
| | 6:15 a.m. vf. | | | | |
| | 5:00 p.m. vf. | | | | |

Teleseisms

July 3

L ? 12:15 a.m. Very feeble record.

July 14

L ? 1:35 p.m. Very feeble record.

July 28

L ? 5:55 a.m. Very feeble record.

Harmonic Tremor

Continuous harmonic tremor began rather definitely at 12:32 a. m. on July 7. It continued without a break, although with very feeble intensity, until the early morning of July 8. By 1:25 a. m. on the 8th it had begun to fade out to such an extent that it was recorded only at intervals during the rest of the day. On the 9th no harmonic tremor appeared on the records. The continuous tremors noted in the table above on the 10th, 11th, and 12th were perhaps temporary recurrences of harmonic tremor of sufficient intensity to be recorded.

Microseismic Motion

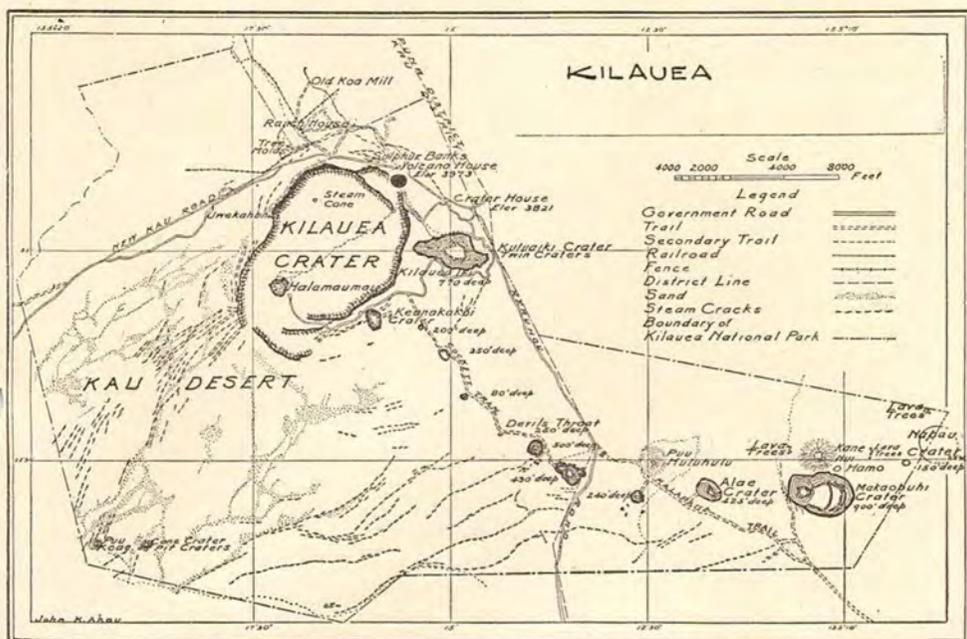
Microseisms were normal throughout the month.

Tilting of the Ground

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

| | | | |
|---------------------|-----|--------|------|
| June 29-July 5..... | 0.3 | second | NE. |
| July 6-12..... | 4.0 | " | NNW. |
| " 13-19..... | 0.7 | " | NNW. |
| " 20-26..... | 0.4 | " | WNW. |
| " 27-August 2..... | 0.6 | " | NW. |

R. M. WILSON,
Topographic Engineer.



Black spot shows location of Observatory.

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The Kilauea station operates horizontal pendulums of the Bosch-Omori type and receives time by wireless from the Honolulu Naval Station. Observatory Lat. $19^{\circ} 25' 54.3''$ N.; Long. $155^{\circ} 15' 39.6''$ W.; Elevation cellar 1214.6 meters (3985 feet). The Hilo, Hilea and Kona stations operate horizontal pendulums. Their seismograms are sent to the Observatory.

The Hawaiian Volcano Research Association founded the Observatory in 1911, transferring the plant to the Government in 1919, but continuing cooperation in experimental work by furnishing funds and apparatus and workers as needed by the Government Volcanologist. It is a corporation under the laws of Hawaii, governed by a board of directors, and financed by the subscriptions of its members and patrons. Its aims are identical with those of the Observatory, namely, (1) To keep record of Hawaiian volcanism, (2) To attract volcanologic specialists to Hawaii, and (3) To promote worldwide knowledge of volcanoes and earthquakes and the foundation of more volcano observatories.

MONTHLY BULLETIN
OF THE
Hawaiian Volcano Observatory
(U. S. GEOLOGICAL SURVEY)

Published by the
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No. 8

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VOLCANIC CONDITIONS IN AUGUST

Activity of Halemaumau

Volcanic conditions were very much the same as during the months preceding the July eruption. The pit was closely watched for any return of lava, but the flow was not renewed. Avalanching was frequent all around the sides of the pit, but mostly from the north and northeast walls. They may have been due to a release of tension following the subsidence of pressure under the crater floor. Perhaps the largest was one from the north wall which accompanied an earthquake about 9:42 a. m., August 3. There was another, but lighter, perceptible earthquake at 9:40 p. m., August 1.

Within the pit were a few spots, in cracks of the floor, which glowed during the first part of the month. The southwest cone, which contributed to most of the activity in July, neither fumed nor steamed, but remained wholly quiet. Occasional slides would pile up debris around its flanks, and it is only a question of time when the cone will be totally buried. The middle cone steamed infrequently, and white and yellow stains formed around it. The stains extended also along the cracks in the new floor.

From time to time, depending on the air currents, the odor of spicy sulphur was perceptible at points near the rim of the pit, having come from sulphur spots on the talus slopes.

Cracks along the east rim of the pit, which showed steady movement prior to the July eruption, were measured occasionally, but they showed little change.

JOURNAL, AUGUST, 1927

August 1. At 1 p. m. dust from a slide on the northeast side of the pit was seen from the Observatory.

August 2. At 4 p. m. a cloud of dust rose from the northeast rim of the pit.

August 3. A circuit of the pit was made, and several rock falls were noted, mostly from the north and northeast walls. The most notable slide was caused by a perceptible earthquake at 9:45 a. m. During the early afternoon much dust from sliding debris northeast was seen, probably caused mostly by men dropping stones over the rim.

The earthquake started a rumor in Hilo that the volcano was again active.

August 5. At 10:20 a. m. there was a large avalanche and dust cloud at the northeast. At 11:15 a. m. a visit to the pit found it comparatively quiet, though there were several new scars.

August 7. There was dust from a slide northeast at 8 a. m.

August 9. The pit was very quiet at 10:30 a. m. Fresh scars showed on the north and northeast walls, also white stains on the lava floor at the foot of the southwest talus. The east and southeast walls have been peeling. The odor of spicy sulphur was strong at the north rim. The north station has been carried away by an avalanche. A circuit of the pit was made.

August 10. The wind was very strong, but a few stones were heard falling on the northeast side, and dust was seen there during a visit about 9:40 a. m. The center of that wall is dark colored, perhaps from wetness. About 2 p. m. there was dust from slides northeast.

August 12. Around 10:30 a. m. rocks were heard falling east, north, and northwest; new dirt lay on the north-northeast talus, and there were new scars north and northeast.

August 15. The pit was visited from 10:10 to 10:30 a. m., but no new changes were noted. A few rocks fell west, and white stains seemed to be forming on the north and northeast walls and increasing on the lava floor at the southwest talus. Steaming was the same.

August 17. The pit was quiet at 10:20 a. m., and very little steam was issuing. Slides from the northeast talus have overlapped the new lava floor considerably.

August 18. A circuit of the pit was made from 10 a. m. to noon. The odor of spicy sulphur was noticeable at the fourteen-ton boulder on the east rim and at the north rim. A few slides were noted.

August 23. The only changes in the pit seen at 10 a. m. were increase of salt coatings on the north and northeast walls, indicating little sliding there; and more yellow and white stains on the floor. Steaming was very slight. The crack at the southeast rim station has widened.

August 24. At 9 a. m. the pit was quiet, with no change except increase of steaming due to wet weather.

August 27. A visit about 11 a. m. during a strong northeast wind, found a few new scars on the north and northeast walls and an increase of white stains on the floor, especially along its east edge. Steaming was very moderate.

August 28. An earthquake about 9:10 a. m. was of sufficient intensity to shake windows at the Observatory, but otherwise was not noticeable. A visit to the pit at 2:30 p. m. showed broken white-stained rocks on the northern taluses. At 3:10 p. m. a large avalanche dust cloud rose from the northeast corner. Two just before were reported by observers on Uwekahuna bluff.

August 29. At 11:40 a. m. all the north and east area of the pit was filled with dust.

August 30. Slides were occurring northeast about 9:40 a. m. The southeast ledge is partly gone. The west wall is streaked full length from a slide.

August 31. Cracks have widened at the northeast rim. Few slides today.

SEISMOMETRIC RECORD

There were 75 local earthquakes and three teleseisms recorded on the Observatory seismographs during the month ended at midnight August 31, 1927. These and other phenomena are listed below. The time used is Hawaiian Standard (time meridian is 157° 30' W.), which is 10 hours and 30 minutes slower than Greenwich Time.

The greater number of the very feeble local shocks counted in the list make such minute records that the character of the disturbance is not always apparent. Some are true earthquakes; others are perhaps the parts of greater amplitude of a continuous or protracted tremor, which at other times may be too feeble to record; some seem to be records of vibrations set up by avalanches in the pit of Halemauau.

Abbreviations used below are as follows: vf, very feeble; f, feeble; s, slight; m, moderate; d, instruments dismantled, fl, felt locally; Δ, indicated distance in miles; *, continuous tremor.

Local Earthquakes

| August | August | August |
|-------------------------|-------------------|------------------------|
| 1 8:40 p.m. f. Δ 15 fl. | 15 7:00 p.m. vf. | 21 9:31 a.m. vf. |
| 2 2:34 a.m. vf. | 16 4:30 a.m. vf. | 22 11:02 a.m. vf. Δ 3. |
| 2:36 a.m. vf. | 17 8:20 a.m. vf. | 23 9:22 p.m. f. Δ 25. |
| 2:38 a.m. vf. | 9:18 a.m. vf. | 24 1:53 p.m. vf. |
| 2:40 a.m. vf. | 9:27 a.m. vf. | 25 12:12 a.m. vf. |
| 2:41 a.m. vf. | 11:04 a.m. vf. | 1:04 a.m. vf. |
| 9:37 a.m. vf. | 12:56 p.m. vf. | 26 1:14 p.m. vf. |
| 4:30 p.m. vf. | 1:49 p.m. vf. | 2:27 p.m. vf. |
| 3 9:42 a.m. m. d. fl. | 3:07 p.m. vf. | 27 2:07 a.m. vf. |
| 9:57 a.m. vf. | 3:21 p.m. vf. | 6:06 a.m. vf. |
| 8:32 p.m. vf. | 18 12:10 p.m. vf. | 11:02 a.m. vf. |
| 4 6:16 a.m. vf. | 5:41 p.m. vf. | 11:36 a.m. vf. |
| 6:19-6:23 a.m. vf. * | 7:53 p.m. vf. | 3:10 p.m. vf. |
| 6:28 p.m. vf. | 10:07 p.m. vf. | 28 5:32 a.m. vf. |
| 8:44 p.m. vf. | 19 11:37 p.m. vf. | 8:10 a.m. f. Δ 2. |
| 5 10:01 a.m. vf. | 20 5:09 p.m. vf. | 29 7:13 p.m. vf. |
| 10:20 a.m. vf. | 6:19 p.m. vf. | 8:02 p.m. vf. |
| 2:29 p.m. vf. | 6:27 p.m. vf. | 30 12:46 a.m. vf. |
| 6 4:09 a.m. vf. | 6:31 p.m. vf. | 2:18 p.m. vf. |
| 9:20 p.m. vf. | 6:36 p.m. vf. | 31 5:38 a.m. vf. |
| 8 10:48 a.m. vf. | 6:38 p.m. vf. | 1:20 p.m. vf. |
| 10 12:35 p.m. vf. | 6:42 p.m. vf. | 3:25 p.m. vf. |
| 2:36 p.m. vf. | 6:45 p.m. vf. | 7:02 p.m. vf. |
| 9:57 p.m. vf. | 6:46 p.m. vf. | 7:08 p.m. vf. |
| 12 11:25 a.m. vf. | 6:51 p.m. vf. | |
| 13 2:03 p.m. vf. | | |

Teleseisms

August 5

L ? 11:43 a.m. Very feeble record.

August 9

L ? 3:17 a.m. Feeble record, doubtfully indicating distance of 4,250 miles.

August 10

L ? 1:45 a.m. Very feeble record.

Harmonic Tremor

This type of tremor was absent throughout the month.

Microseismic Motion

Microseisms were normal throughout the month.

Tilting of the Ground

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

| | | | | |
|--------|-------------|-----|--------|------|
| July | 27-August 2 | 0.6 | second | NW. |
| August | 3- 9 | 0.3 | " | W. |
| | 10-16 | 0.6 | " | NNW. |
| | 17-23 | 0.5 | " | SE. |
| | 24-30 | 0.3 | " | NE. |

R. M. WILSON,
Topographic Engineer.



Fig. 31. July 13, 1927; 9:40 a. m. Same view, showing how lava river crusted over and how delta enlarges. Photo Wilson.

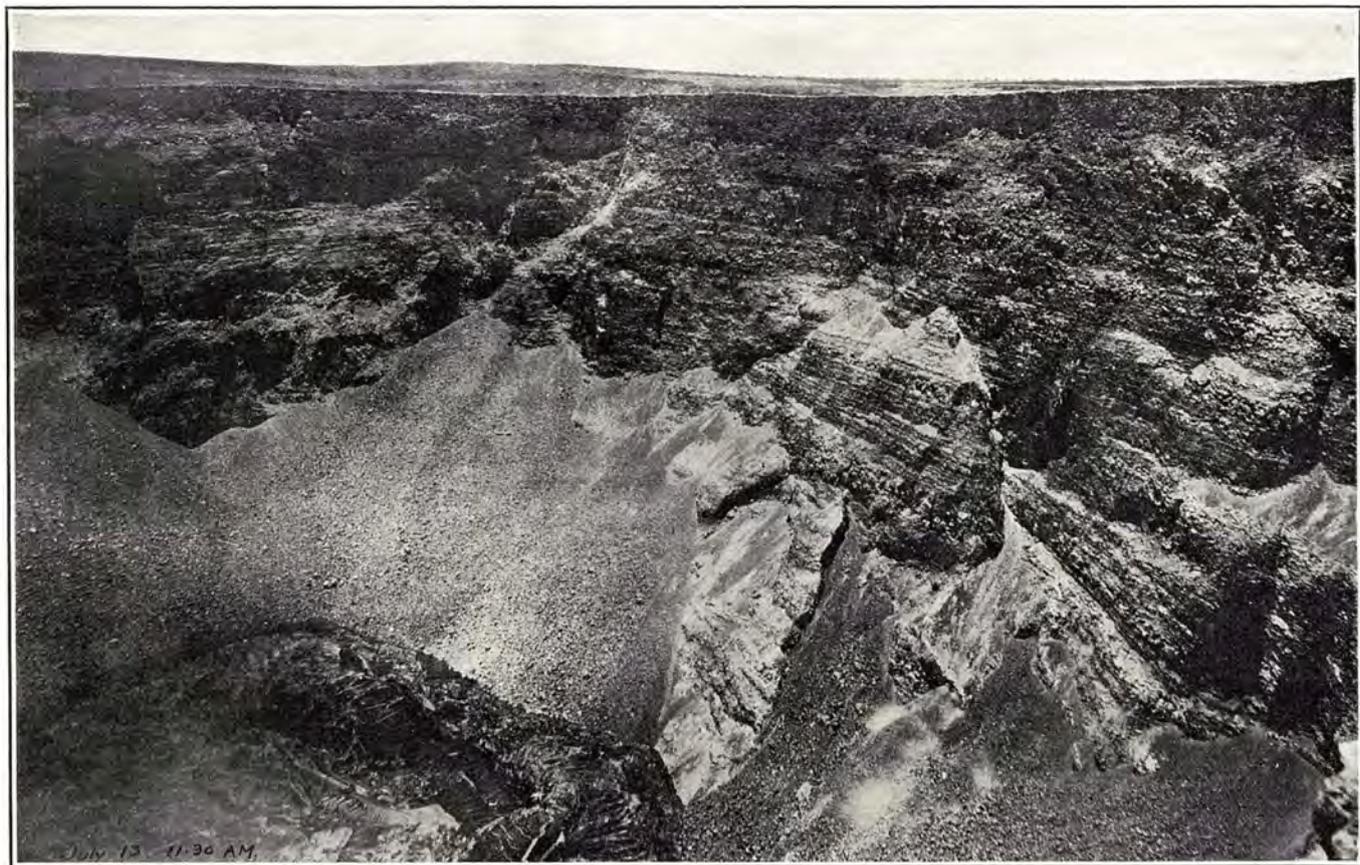


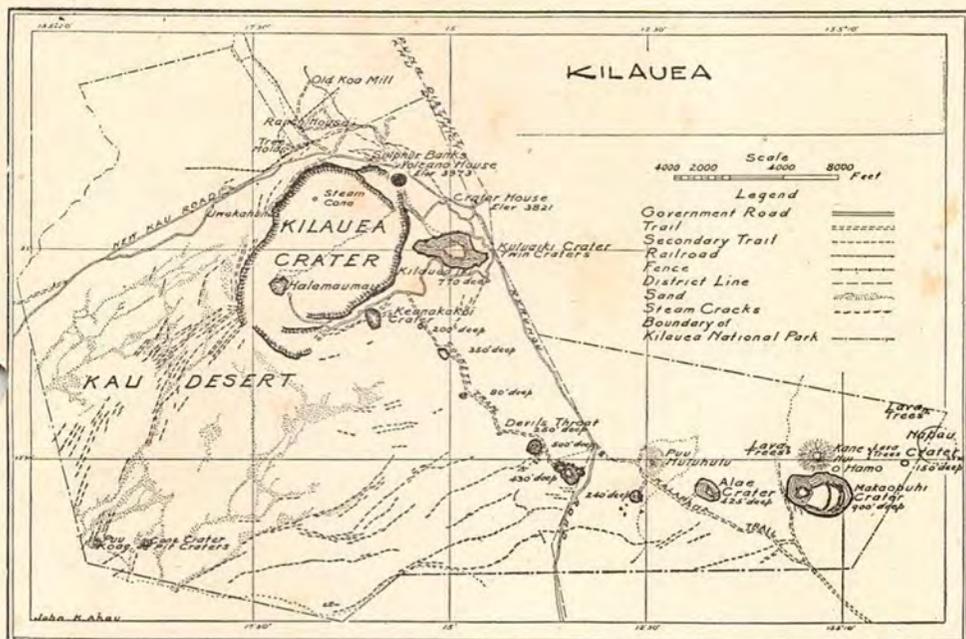
Fig. 32. July 13, 1927. Halemauau, looking northeast. Showing ripples and patterns in live lava lake. Kilauca Iki in left center distance. Photo Wilson.



Fig. 33. July 16, 1927. Telephoto view of active cone in Halemaumau. Shows plainly how lava river after flowing under crust merges with lake, also how top of cone gets smaller due to fountaining action within. Compare with Figs. 30 and 31. Photo Wilson.



Fig. 34. July 15, 1927. View of lake pattern taken at 7 p.m. Photo Wilson.



Black spot shows location of Observatory.

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HONOLULU, HAWAII, SEPTEMBER, 1927

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VOLCANIC CONDITIONS IN SEPTEMBER

Activity of Halemaumau

During the month there was a great deal of avalanching from the walls of Halemaumau pit. Perhaps the period of the equinox had such effect on volcanic conditions as to increase sympathetic activity of the walls. As usual, slides were most frequent from the northeast side, but on September 9 a tremendous avalanche took place at the center of the southwest wall, close to the rift tunnels. Preceding this avalanche there was steady sliding and undermining of the wall. All this suggested motion on the northeast-southwest Kilauea rift line.

A very notable change in the rim contour took place on September 19 when the big southeast ledge, at the tourist outlook, fell in. The crack separating the ledge showed steady movement for many days previously, both by measurement and by sound. Spasmodic trickling of dirt at the crack and the "tick" of sub-surface rocks adjusting themselves to the settling of the ledge, could be heard.

Earthquakes were infrequent at the first of the month, only six very feeble shocks being recorded for the week ending September 7, but increased as the

month grew on, diminishing again near the close. During the second week there were 19 very feeble earthquakes; the third week had 28; and the fourth week had 10 very feeble shocks, one feeble, and one slight, making 12 in all recorded. In addition there was minute volcanic tremor on the 2nd, 3rd, 4th, 5th, 14th, and 30th, very similar to the harmonic tremor that always accompanies lava activity.

The seismographs registered the usual tilting of the ground.

JOURNAL, SEPTEMBER, 1927

September 1. A very large avalanche dust cloud covered the whole north-eastern orifice of the pit at 2:20 p. m.

September 2. From 11:30 to 12:00 in the forenoon the pit was fairly quiet, with a few rocks rolling occasionally from the north and west walls. There was very slight steaming. Recent slides have built up the northeast talus considerably. The crack separating the southeast ledge has widened so as to allow the "Danger" sign, propped in it, to turn. There are small surface cracks near, and the dirt is very loose. The northeast wall is freshly peeled in two places.

The pit was full of dust from slides at 3:45 p. m.

September 3. There was active sliding from the northeast wall in the morning.

September 4. A large avalanche dust cloud from the north wall was reported seen about 6:45 a. m.

September 5. At 10 a. m. new black debris lay on the north-northeast talus, new gray debris on the south talus, and red on the north talus. Some rocks were heard falling northeast.

The new small cracks at the southeast ledge are more pronounced.

September 7. The roar of a large avalanche was reported heard from the Uwekahuna Observatory at 3:10 p. m., but fog prevented seeing the location.

September 9. At 9 a. m. extremely large dust cloud rose from the north side of the pit. A visit at 11 a. m. showed that the avalanche occurred from midway the wall just west of the southwest rift tunnels, leaving an immense scar. Scars were also seen on the northern walls.

September 10. Stones were heard rolling northeast and southwest at 10:40 a. m. Gray debris from yesterday's avalanche has partly buried the southwest cone.

September 12. A circuit of the pit was made from 10:30 to 12 in the forenoon. At 10:43 an avalanche occurred from the northwest wall.

There have been recent slides from the tip of the west horn of the north sill. A big boulder that was suspended just under the northeast rim has fallen, and the crack through the north-northeast fault cliff has widened. A slide occurred northwest at 11:47 a. m. The lower southwest wall has some heavy white salts coatings.

Loud avalanches were reported occurring around 9:30 a. m. from the north wall.

September 13. From the Uwekahuna Observatory several large avalanches from the north wall were noted in the middle of the afternoon.

September 14. New scars showed on the north and northwest walls during an early morning trip to the pit. Rocks were heard settling in the southeast crack. At 1:45 p. m. a dust cloud rose from the north corner.

September 15. There was a dust cloud north at 7:35 a. m. At 10:20 a. m. stones were heard falling northwest, and that talus has new dark debris on its upper slope. Steam vents appear less active than ever before.

September 16. At the Uwekahuna Observatory in the afternoon avalanches were heard from the north wall at 3 and 5 o'clock.

September 17. Active avalanching continues, and all taluses have new debris. Measurements show that the southeast crack has widened half a foot in a week.

September 19. At 1:20 p. m. dust was observed rising from the east side of the pit, and a loud avalanche was reported heard about this time from the Uwekahuna Observatory.

September 20. A visit at 9:20 a. m. showed that the big southeast ledge has fallen into the pit, carrying away a large strip of the near-by rim. The seismogram of yesterday shows record of an avalanche tremor that may have been recorded when the ledge gave way. The pit walls are wet and reddish, but the scar left by the fallen ledge shows dry and grayish.

The east wall has a new scar, and surface cracks have widened there.

September 21. At 9 a. m. the pit was quiet, with one or two rocks falling northwest. The walls are quite wet, but steaming is slight at all vents.

A long avalanche roar was heard from the Observatory at 5:20 p. m., but fog prevented visibility.

September 22. Many new scars were seen all around the pit at 9:20 a. m., as though slides had been very general. Scars were particularly conspicuous on the east-northeast wall. A few stones were heard falling during this visit.

September 24. A few rocks fell at 8:50 a. m. from the northwest wall. The dry weather has dimmed the bright colors of the pit walls and diminished the steaming. New debris was noted on the northern taluses.

September 26. The pit seemed quiet at 9:10 a. m., but a strong wind would obscure any sounds. Steam was observed only in the usual places. The east wall has fresh scars. New notches have appeared in the northeast rim, and there is new debris on the taluses below them. An avalanche dust cloud from the north wall was seen at 1:10 p. m.

September 28. A visit at 8:30 a. m. showed that the upper north wall had been sliding, with the talus below coated a deep red. The walls are full of colorings. Scars appear on the northeast wall, also on the southwest. The north-northeast talus is streaked with new red and black debris. The steam vents are more active with wet weather. At 10:20 a. m. there was a dusty slide northeast.

September 29. At 3 p. m. thin dust rose from a slide northeast.

SEISMOMETRIC RECORD

There were 103 local earthquakes recorded on the Observatory seismographs during the month ended at midnight September 30, 1927. These and other phenomena are listed below. The time used is Hawaiian Standard (time meridian is 157° 30' W.), which is 10 hours and 30 minutes slower than Greenwich Time.

The greater number of the very feeble local shocks counted in the list make such minute records that the character of the disturbance is not always apparent. Some are true earthquakes; others are perhaps the parts of greater amplitude of a continuous or protracted tremor, which at other times may be too feeble to record; some seem to be records of vibrations set up by avalanches in the pit of Halemaumau.

Abbreviations used below are as follows: vf, very feeble; f, feeble; s, slight; m, moderate; d, instruments dismantled; fl, felt locally; Δ , indicated distance in miles; *, continuous tremor.

Local Earthquakes

September

| | |
|---|----------------|
| 1 | 4:22 a.m. vf. |
| | 4:59 a.m. vf. |
| | 9:05 a.m. vf. |
| | 10:00 a.m. vf. |
| | 10:57 a.m. vf. |
| | 11:54 a.m. vf. |
| | 1:37 p.m. vf. |
| | 2:17 p.m. vf. |
| | 2:34 p.m. vf. |
| | 3:29 p.m. vf. |
| 2 | 8:27 a.m. vf. |
| | 9:32 a.m. vf. |
| | 10:31 a.m. vf. |
| | 11:24 a.m. vf. |
| | 1:20 p.m. vf. |
| | 2:11 p.m. vf. |
| | 3:04 p.m. vf. |
| | 3:32 p.m. vf. |
| 3 | 4:04 p.m. vf. |
| | 4:06 p.m. vf. |
| | 4:09 p.m. vf. |
| 4 | 6:58 a.m. vf. |
| | 7:07 a.m. vf. |
| | 11:45 a.m. vf. |
| | 11:47 a.m. vf. |
| 5 | 2:01 p.m. vf. |
| 6 | 8:30 a.m. vf. |
| | 9:55 a.m. vf. |
| | 9:57 a.m. vf. |
| | 11:15 a.m. vf. |
| | 1:19 p.m. vf. |
| | 2:25 p.m. vf. |
| 7 | 9:29 a.m. vf. |
| | 1:38 p.m. vf. |

September

| | |
|----|----------------------|
| 8 | 12:49 p.m. vf. |
| 9 | 4:24 a.m. vf. |
| | 9:00 a.m. vf. |
| | 10:30 a.m. vf. |
| | 12:45 p.m. vf. |
| 10 | 5:45 a.m. vf. |
| | 2:16 p.m. vf. |
| 11 | 10:46 a.m. vf. |
| 12 | 12:19 p.m. vf. |
| | 3:01 p.m. vf. |
| | 9:18 p.m. vf. |
| | 9:38 p.m. vf. |
| 13 | 3:39 a.m. vf. |
| | 4:41 a.m. vf. |
| | 6:01 a.m. vf. |
| | 3:48 p.m. vf. |
| 14 | 1:05 a.m. vf. |
| | 9:18 a.m. vf. |
| | 11:30 a.m. vf. |
| | 5:00-5:04 p.m. vf. * |
| | 5:37 p.m. vf. |
| | 9:10 p.m. vf. |
| 15 | 4:49 a.m. vf. |
| | 5:42 a.m. vf. |
| | 7:33 a.m. vf. |
| | 7:34 a.m. vf. |
| | 7:47 a.m. vf. |
| | 12:16 p.m. vf. |
| | 2:46 p.m. vf. |
| 16 | 7:26 a.m. vf. |
| | 3:31 p.m. vf. |
| | 4:44 p.m. vf. |
| | 5:57 p.m. vf. |
| 17 | 6:11 a.m. vf. |
| | 12:18 p.m. vf. |

September

| | |
|----|-------------------------------|
| 18 | 12:53 a.m. vf. |
| | 2:48 a.m. vf. |
| | 10:04 a.m. vf. |
| 19 | 8:50 a.m. vf. |
| | 1:17 p.m. vf. |
| | 1:25 p.m. vf. |
| | 1:32 p.m. vf. |
| 20 | 4:42 a.m. vf. |
| | 12:50 p.m. vf. |
| 21 | 5:45 a.m. vf. |
| 22 | 1:49 p.m. vf. |
| | 2:21 p.m. vf. |
| 23 | 10:02 a.m. vf. |
| 24 | 2:55 p.m. vf. |
| 25 | 6:09 a.m. vf. |
| 27 | 3:03 p.m. f. Δ 28. |
| | 4:11 p.m. s. Δ 14. fl. |
| | 11:31 p.m. vf. |
| 28 | 1:09 a.m. vf. |
| | 1:28 p.m. vf. |
| | 1:30 p.m. vf. |
| | 1:38 p.m. vf. |
| 30 | 6:09 a.m. vf. |
| | 11:47 a.m. vf. |
| | 2:56 p.m. vf. |
| | 2:59 p.m. vf. |
| | 3:32 p.m. vf. |
| | 4:59 p.m. vf. |
| | 7:28 p.m. vf. |
| | 7:59 p.m. vf. |
| | 8:21 p.m. vf. |
| | 8:30 p.m. vf. |
| | 8:42 p.m. vf. |
| | 9:02 p.m. vf. |

Harmonic Tremor

On September 30 there was a short spell of harmonic tremor from 9:30 p. m. to 10:50 p. m.

Microseismic Motion

Microseisms were stronger than normal on the 26th, 27th, and 28th.

Tilting of the Ground

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

| | | | |
|-----------|----------------|-----|-----------|
| August | 31-September 6 | 0.2 | second S. |
| September | 7-13 | 0.7 | “ NE. |
| | 14-20 | 1.1 | “ S. |
| | 21-27 | 0.8 | “ NE. |
| | 28-October 4 | 0.7 | “ NE. |

R. M. WILSON,
Topographic Engineer.



Fig. 35. July 9, 1927. Time exposure of activity of Halemau mau, showing river and delta of live lava. The active cone fumes, but all other vapor is steam. Photo Tai Sing Loo.



Fig. 36. July 11, 1927. View of Halemaumau interior made with wide-angle lens. Photo Wilson.

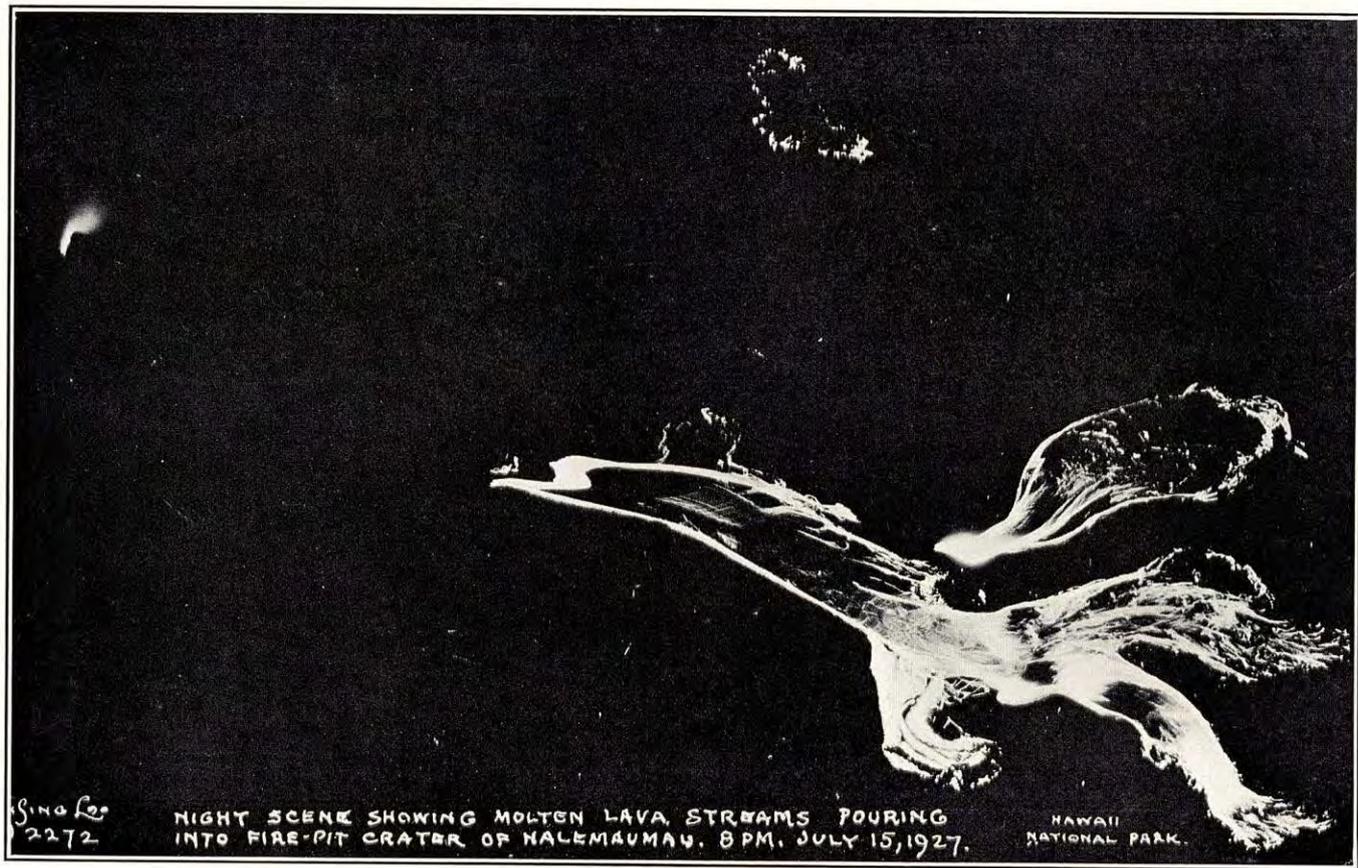
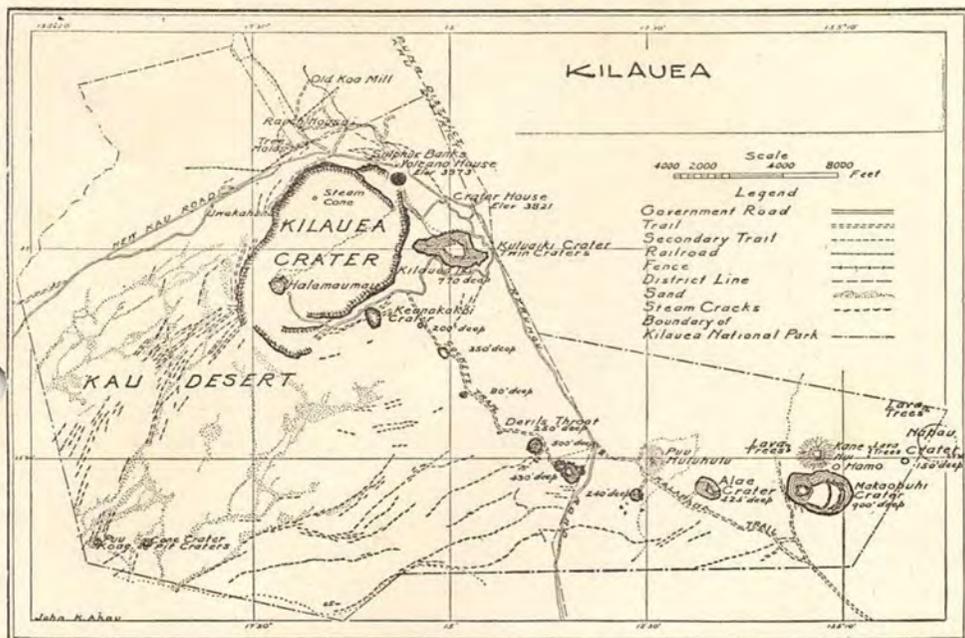


Fig. 37. July 15, 1927. Night view of activity showing (left) vent of active cone nearly closed and movements of the lava delta. Exposure of several minutes. Photo Tai Sing Loo.



Fig. 38. July 9, 1927. View showing lava river and delta patterns. Photo Tai Sing Loo.



Black spot shows location of Observatory.

All exchanges, gifts to library, news notes about Pacific volcanic and seismic events, and correspondence should be addressed HAWAIIAN VOLCANO OBSERVATORY, Volcano House, Hawaii.

The Observatory is operated by the U. S. Geological Survey, and its work is supplemented by the Hawaiian Volcano Research Association. The main station is on the northeast rim of Kilauea Crater. Subordinate seismograph stations are operated by the Research Association under the direction of the volcanologist in Kona and Hilo.

The Kilauea station operates horizontal pendulums of the Bosch-Omori type and receives time by wireless from the Honolulu Naval Station. Observatory Lat. $19^{\circ} 25' 54.3''$ N.; Long. $155^{\circ} 15' 39.6''$ W.; Elevation cellar 1214.6 meters (3985 feet). The Hilo, Hilea and Kona stations operate horizontal pendulums. Their seismograms are sent to the Observatory.

The Hawaiian Volcano Research Association founded the Observatory in 1911, transferring the plant to the Government in 1919, but continuing cooperation in experimental work by furnishing funds and apparatus and workers as needed by the Government Volcanologist. It is a corporation under the laws of Hawaii, governed by a board of directors, and financed by the subscriptions of its members and patrons. Its aims are identical with those of the Observatory, namely, (1) To keep record of Hawaiian volcanism, (2) To attract volcanologic specialists to Hawaii, and (3) To promote worldwide knowledge of volcanoes and earthquakes and the foundation of more volcano observatories.

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HONOLULU, HAWAII, OCTOBER, 1927

No. 10

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GRAVITY ANOMALIES ON HAWAII

In the number of this publication issued for June, 1927, the establishing of three new gravity stations on the island of Hawaii was described. Data obtained at three old stations established by the Hawaiian Government Survey in 1892 are also reviewed there. The new data have now been computed by the Coast and Geodetic Survey, and the results from both old and new stations are given in the following table. To avoid repetition, this table does not give the latitude, longitude, and elevation of these stations, as that information was given in the Bulletin just mentioned. The stations can easily be identified by name. Data from two stations on the island of Oahu have been added for comparison; they are called Honolulu and Niu, their elevations being six and two meters above sea level. The first was established in 1892 and the second in 1926.

The table gives two values of theoretical gravity at sea level for the latitude of each station. One is from the 1901 formula of Helmert, the other is computed from the 1912 formula of Bowie. The correction for elevation at each station is given. The correction for the effect of near and distant topography is shown, computed on the basis of complete isostatic adjustment of the earth's crust at a depth of 113.7 kilometers; the mean solid surface density is assumed as 2.67, and ocean water density as 1.027. The application of these two corrections to the theoretical sea level values of gravity gives the computed values which represent the intensity of gravity to be expected at the stations, presuming no local subsurface irregularities. In the column headed "Observed Gravity" there is given the results of actual measurements at the stations. Comparison of what is expected at a station and what is actually observed usually shows a difference; these differences are the anomalies of gravity, and are positive when the observed value is greater than the computed or expected. The anomalies are thus indications of local irregularity of crustal density or of imperfect isostatic adjustment; or are caused by errors of observation or by the use of inexact formulas in computing the theoretical sea level value and the corrections thereto. Local densities and conditions of isostatic adjustment are known to be the major causes of the anomalies, and will become more completely the causes as future improvements of formulas and field methods are effected. The table gives three anomalies for each station; one resulting from the use of the Helmert formula, another from the 1912 formula of Bowie, and the third using Bowie's formula but not taking into account the correction for topography and compensation. The last is the "Free Air" anomaly, and is largely of theoretical interest. The isostatic anomaly based upon Bowie's formula perhaps represents the more up-to-date conception and is in form for practical application.

For details in the methods of computing the anomalies, and their use in geodetic and geologic investigations, reference may be made to Special Publications Nos. 10, 12, 40, and 99 of the U. S. Coast and Geodetic Survey, or to the book, "Isostasy," by William Bowie.

No application of these new figures has yet been made toward the determination of the densities of Mauna Loa, Mauna Kea, or Kilauea, though studies in this direction should prove of exceptional interest. Additional useful information will soon be available when the results of the observations made by Dr. F. A. Vening Meinesz are computed and published. His measurements made at sea will give the values of gravity over the submerged base of the Hawaiian Ridge, and will also furnish an additional value at Honolulu.

PRINCIPAL FACTS FOR GRAVITY STATIONS IN HAWAIIAN ISLANDS

| Name of Station | Theoretical Gravity | | Corrections for | | Computed Gravity | | Observed Gravity | Anomalies | | |
|------------------------|---------------------|---------|-----------------|--------------------|------------------|---------|------------------|-----------|-------------------|----------|
| | Helmert | Bowie | Elev. | Topog. and Compen. | Helmert | Bowie | | Helmert | Isostatic (Bowie) | Free Air |
| Honolulu..... | 978.711 | 978.719 | -0.002 | +0.162 | 978.871 | 978.879 | 978.946 | +0.075 | +0.067 | +0.229 |
| Mauna Kea (Waiau)... | 978.623 | 978.631 | -1.229 | +0.469 | 977.863 | 977.871 | 978.069 | +0.206 | +0.198 | +0.667 |
| Kalaieha..... | 978.617 | 978.625 | -0.626 | ..... | ..... | ..... | 978.499 | ..... | ..... | ..... |
| Kawaihae..... | 978.636 | 978.644 | -0.001 | +0.138 | 978.773 | 978.781 | 978.812 | +0.039 | +0.031 | +0.169 |
| Kilauea..... | 978.601 | 978.609 | -0.374 | +0.256 | 978.483 | 978.491 | 978.668 | +0.185 | +0.177 | +0.431 |
| Jaggar (Mauna Loa)... | 978.605 | 978.613 | -1.225 | +0.483 | 977.863 | 977.871 | 978.091 | +0.228 | +0.220 | +0.703 |
| Hilo..... | 978.619 | 978.627 | -0.002 | +0.168 | 978.785 | 978.793 | 978.878 | +0.093 | +0.085 | +0.253 |
| Niu (World Long. sta.) | 978.710 | 978.718 | -0.001 | +0.162 | 978.871 | 978.879 | 978.953 | +0.082 | +0.074 | +0.236 |

VOLCANIC CONDITIONS IN OCTOBER

Activity of Halemaumau

Slides and avalanches from the walls of Halemaumau pit continued to be the only visible activity of the volcano, except changes in the sulphur patches and the white and yellow staining. There was little variety in the steaming. The outstanding event of the month was the recording of an earthquake in Alaska, described hereafter.

During the first part of the month the slides seemed mostly to be confined to rather steady working of the northwest and southeast walls. They were somewhat different from the customary intermittent slides from the north and northeast walls, in that they were often so small as not to be visible, but yet were continuous, making a low and slightly hissing or purring sound. Occasionally as rocks were disturbed the sound would grow louder. The northwest talus became very much streaked with fine material. The slides ate a hole into the wall at the top of the southeast talus.

The steady, fine slides ceased the second week of the month, and there was again the normal, intermittent sliding and occasional avalanching. Yellow stains increased on the smallest cone of the July eruption, and solfataras grew conspicuous on the south and east talus slopes. New sulphur crystals formed at the base of the south talus. About the middle of the month slides at the south corner began to be prevalent, making a large, red scar visible from the Uwekahuna Observatory.

Cracks along the east rim of the pit were measured from time to time, but showed little movement. Some small new cracks were seen in the dirt back of the south rim station.

Tilting of the ground during the month was mostly to the north and east.

The seismographs at the Hawaiian Volcano Observatory began to record the Alaskan earthquake at 5:37:40 a. m. October 24, and continued for more than an hour and a half. Because of confusion of preliminary phases and the amplitude of the long waves, the epicenter of the shock was at first thought to be located too near to be on land, perhaps in the Aleutian deep or under the ocean off the Californian or Mexican coast. Warning was therefore given of a possible tidal wave, which would be the result of a heavy shock under the ocean bed. When the time was past that the tidal wave was expected, it was known that the earthquake must have been on land. Press reports soon began to come in, stating that southeastern Alaska had felt the shock, where damage was done to windows and telegraph cables. By computing from records of several stations, the Jesuit Seismological Association located the epicenter on land in the basin of the Alsek River, about 100 kilometers east of Yakutat.

Upon receiving warning of a possible tidal wave, several business establishments along the waterfront in Hilo made considerable preparation to safeguard their belongings, having in mind the disastrous tidal wave of 1922, and sampans moved out to anchorage in deep water. Many stores and garages moved their goods to the second floor, and dredging operations in the harbor were suspended.

An interesting phase in the record of this earthquake is the manner in which a local shock was superimposed on the L wave of the distant shock, shown in Fig. 42.

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October 1. About 9:50 a. m. there was a faint, yet steady, sound of dirt sliding under the southeast rim, growing louder as rocks took to tumbling.

Rocks fell from the north wall at 10 o'clock, also southwest at 10:35. The north talus is sprinkled with white-stained rocks. New scars show on the northern walls, especially at the northeast.

The walls appear very restless. There was over an hour of steady tremor on the seismogram last night. Many boulders have rolled out onto the lava floor. There is little steaming anywhere in the pit.



Fig. 39. July, 1924. Showing activity somewhat similar to that of July, 1927.
This cone was afterwards buried under the great talus shown in Figure 40.
Photo Tai Sing Loo.

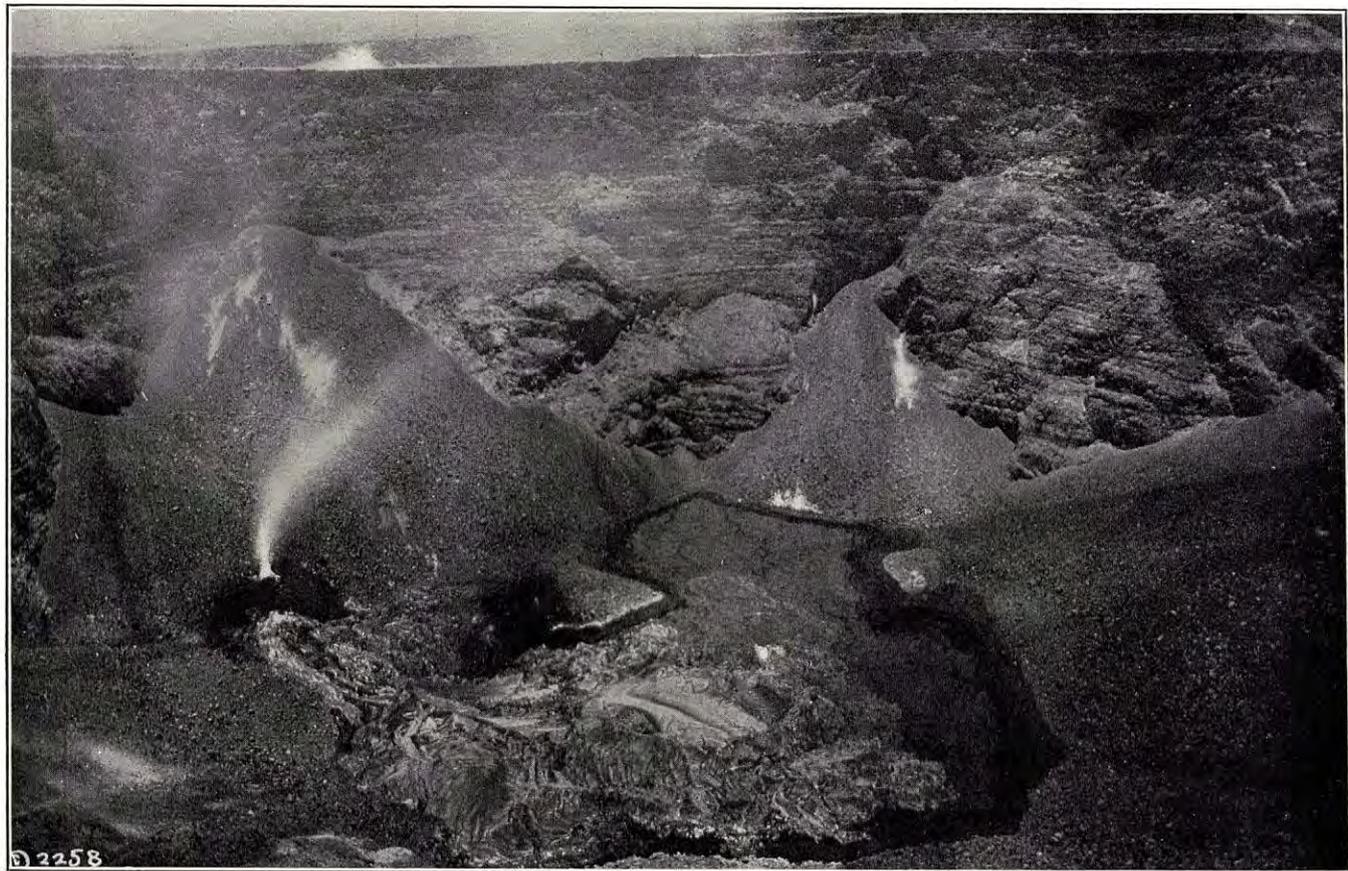


Fig. 40. July 11, 1927. View of Halemaumau showing fountaining of the active cone. Photo Tai Sing Loo.

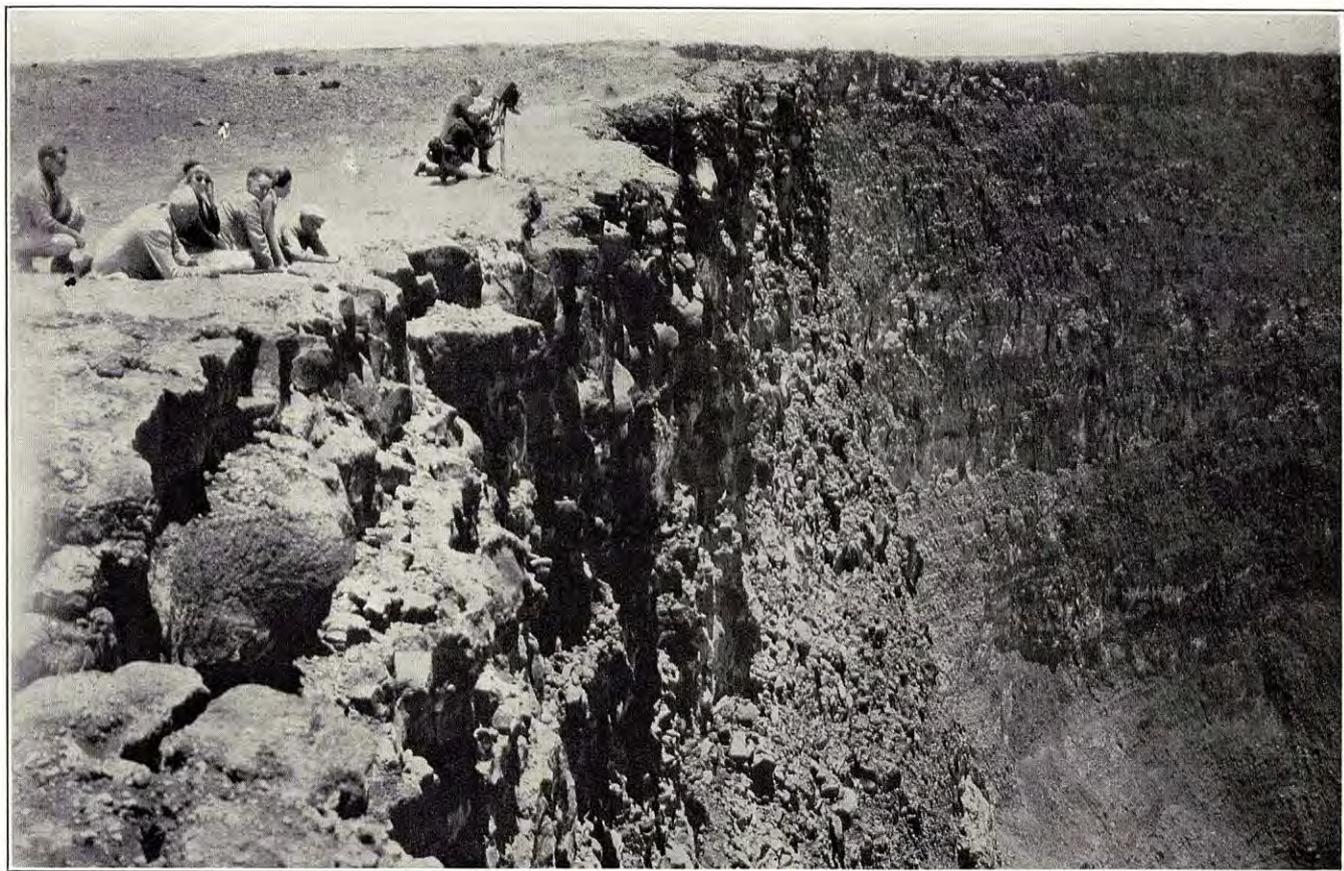


Fig. 41. July, 1927. Group of spectators watching activity, and members of the Observatory staff at work with cameras.
Photo Tai Sing Loo.

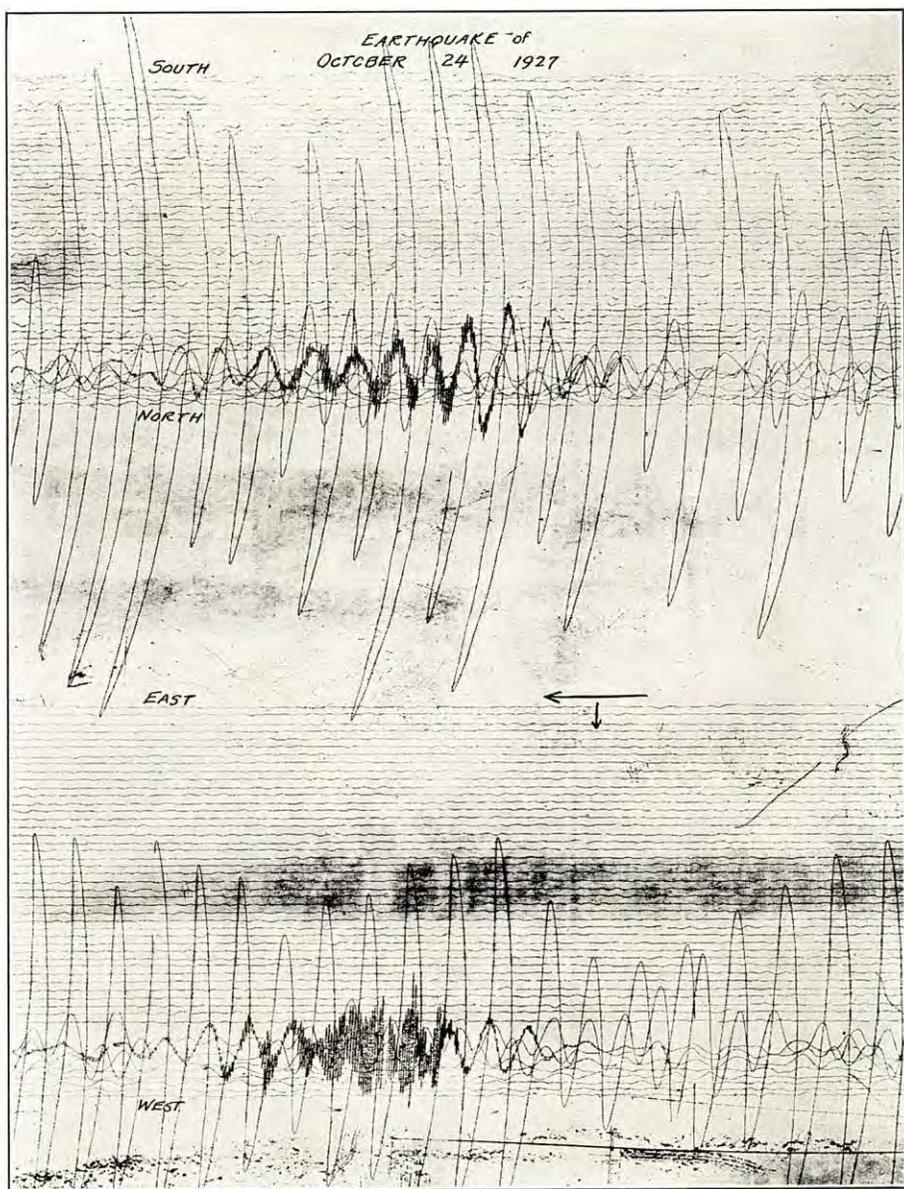


Fig. 42. Part of seismogram of October 23-24, 1927, showing how a local earthquake was superimposed on a teleseism. Bosch-Omori instruments; lines read from right to left, and begin at the top; drum turns once in 15 minutes. The time break in the middle of the local shock is 6:20 a. m., October 24.

October 3. At 2:45 p. m. the pit was quiet, but dirt from slides was seen northeast and northwest. A wide streak of fine material lay the full length of the northwest talus. At 3:03 came a slide of rocks from the north wall, and at 3:16 sluggish slides occurred at the west. From a point on the north-northeast rim the small southeast slides can be seen making a hole in the wall at the top of the talus.

October 5. From 8:30 to 9 a. m. the southeast wall was still working, and slides were observed on the other sides. Steam was escaping from the smaller cone in irregular puffs.

At 10:27 a. m. a large dust cloud from an avalanche rose from the north corner of the pit and hung in the air for many minutes before dissolving. A disturbance was recorded by the seismograph at this time.

October 10. At 9:30 a few rock falls were heard on the northwest side. The talus slopes are dark with the wetting of recent rains, but there is not much steaming. A bright red scar shows near the top of the south wall. A patch of bright yellow sulphur has formed at the north edge of the south talus. Yellow stains on the lava floor are quite pronounced.

October 12. There is much fine material deposited at the foot of the southeast wall. The south talus is streaked with wet steaming spots. Fine material lies also at the foot of the west wall, and slides could be heard there at 9:40 a. m. The east wall has been sliding.

Yellow stains are conspicuous on the small cone, but there is no steam. Solfataras are visible at the foot of the east cone.

October 17. The pit was visited from 10 to 10:50 a. m., and a few slides were observed. The north and northeast walls have new white salt coatings. Wet streaks are conspicuous on the northwest and southeast taluses, though no rain has fallen for a few days.

October 19. From 3 to 4:30 p. m. the pit was mostly quiet, with one slide at the south corner heard. A slide was reported in that corner as making a new scar and showing dust.

There is fresh yellow sulphur at the base of the southeast talus, next where the ledge touches the floor.

Small recent cracks were seen in the dirt near the south station, back from the rim.

About noon two dust whirls were seen on the central floor of Kilauea.

October 24. At 11 a. m. the pit was quiet and dry. A fresh avalanche streak showed on the west wall. There was a little steam at the middle cone of the floor. Steam is now feeble at the wet places in the south talus, where before the July eruption there was very dense steam.

October 26. The pit at 10:10 a. m., in bright dry weather, shows little steam. The densest steam jet is on the north side of the northwest talus, and there is a little steam and sulphur stain at north cone vent of floor. A fresh avalanche streak shows from top to bottom of wall over the southwest talus, and there is fresh wall surface from recent falls above the northwest talus. The sulphur stain is increasing at the bottom of the southeast wall, and fresh fragments lie on the top of the south-southwest talus.

One small trickle of rocks was heard about 10:20 a. m.

October 29. Northeast wind; dry and sunny weather at 2 p. m. Much rain last night, but it has not increased steam in the pit. Slight steam jets appear in the upper parts of the north, west and south taluses. There is increase of yellow stain at north cone vent on floor, which steams. Only one jet of steam was seen for an instant at the middle cone. Slight rock trickles were heard north.

October 31. Dust from numerous northern avalanches was observed morning and afternoon.

SEISMOMETRIC RECORD

There were 76 local earthquakes and one teleseism recorded by the Observatory seismographs during the month ended at midnight October 31, 1927. These

and other phenomena are listed below. The time used is Hawaiian Standard (time meridian is 157° 30' W.), which is 10 hours and 30 minutes slower than Greenwich Time.

The greater number of the very feeble local shocks counted in the list make such minute records that the character of the disturbance is not always apparent. Some are true earthquakes; others are perhaps the parts of greater amplitude of a continuous or protracted tremor, which at other times may be too feeble to record; some seem to be records of vibrations set up by avalanches in the pit of Halemaumau.

Abbreviations used below are as follows: vf, very feeble; f, feeble; s, slight; m, moderate; d, instruments dismantled; fl, felt locally; Δ , indicated distance in miles:

Local Earthquakes

October

| | | | | |
|-------------------|----|----------------|----|-------------------------------|
| 9:46 a.m. vf. | 11 | 3:28 p.m. vf. | 20 | 8:54 a.m. vf. |
| 6:09 p.m. vf. | | 6:17 p.m. vf. | | 10:05 a.m. vf. |
| 2 7:34 a.m. vf. | | 7:42 p.m. vf. | | 1:30 p.m. vf. |
| 8:02 a.m. vf. | | 11:20 p.m. vf. | | 2:49 p.m. vf. |
| 3:04 p.m. vf. | 12 | 1:00 a.m. vf. | | 3:30 p.m. vf. |
| 4:29 p.m. vf. | | 1:39 a.m. vf. | | 6:57 p.m. vf. |
| 3 6:56 a.m. vf. | | 2:04 a.m. vf. | 21 | 2:03 a.m. vf. |
| 4 12:47 a.m. vf. | | 10:09 a.m. vf. | | 7:02 a.m. vf. |
| 12:28 p.m. vf. | | 10:41 a.m. vf. | | 2:32 p.m. vf. |
| 5 10:25 a.m. vf. | | 2:38 p.m. vf. | | 3:10 p.m. vf. |
| 6 12:31 p.m. vf. | | 5:41 p.m. vf. | | 5:45 p.m. vf. |
| 3:46 p.m. vf. | 13 | 6:59 a.m. vf. | | 8:37 p.m. vf. |
| 7 2:33 p.m. vf. | | 11:21 a.m. vf. | 22 | 1:35 a.m. vf. |
| 3:17 p.m. vf. | | 12:01 p.m. vf. | | 1:40 a.m. vf. |
| 10:24 p.m. vf. | | 4:10 p.m. vf. | | 2:10 a.m. vf. |
| 11:57 p.m. vf. | 14 | 3:06 a.m. vf. | | 12:44 p.m. vf. |
| 8 5:02 p.m. vf. | 15 | 1:54 a.m. vf. | 24 | 6:20 a.m. f. |
| 9 7:05 p.m. vf. | | 6:15 a.m. vf. | | 6:28 a.m. vf. |
| 8:06 p.m. vf. | | 4:19 p.m. vf. | | 3:04 p.m. vf. |
| 10 10:57 a.m. vf. | | 5:35 p.m. vf. | 26 | 5:59 a.m. vf. |
| 10:45 p.m. vf. | | 10:40 p.m. vf. | 28 | 2:38 a.m. f, Δ 48, fl. |
| 11 8:54 a.m. vf. | 16 | 6:06 p.m. vf. | | 6:22 p.m. vf. |
| 11:04 a.m. vf. | 17 | 12:56 a.m. vf. | 30 | 2:08 a.m. vf, Δ 25. |
| 11:26 a.m. vf. | | 4:30 p.m. vf. | | 5:44 p.m. vf. |
| 12:16 p.m. vf. | 19 | 12:10 a.m. vf. | 31 | 9:21 a.m. vf. |

Teleseism

October 24

eP 5:37:40 a.m.
 SN 5:43:50 a.m.
 SE 5:43:56 a.m.
 Sr ? 5:46:43 a.m.
 Sr ? 5:46:55 a.m.
 L ? 5:49:00 a.m.

The maximum amplitude of this earthquake as here recorded was considerable, but the preliminary phase was small and not easy to distinguish from microseisms. The feeble local earthquake noted in the above list at 6:20 a. m. was superimposed upon the record of the teleseism. The indicated distance is 2,730 miles.

Harmonic Tremor

This type of tremor was absent throughout the month.

Microseismic Motion

Microseisms were normal throughout the month.

Tilting of the Ground

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

| | | | |
|-----------------------------|-----|--------|------|
| September 28-October 4..... | 0.7 | second | NE. |
| October 5-11..... | 0.6 | " | NNE. |
| " 12-18..... | 0.6 | " | NNW. |
| " 19-25..... | 0.7 | " | ENE. |
| " 26-November 1..... | 0.7 | " | SSW. |

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MAP AND STATION DATA

THE HILO SEISMOGRAPH STATION

After some preliminary reconnaissance in Hilo for a place in which to establish a seismograph station, a site was chosen at the Brothers' School, a little above the main part of town on Waianuenue Street. A small single component seismograph constructed at the Volcano Observatory was installed and was started on September 8, 1921. The records from it were found very useful as an aid in locating the epicenters of island earthquakes when taken in conjunction with the records of the Volcano Observatory and of the Kona station. The instrument was located under one of the main recitation buildings of the school, and was subject to disturbances when classes changed in the room above. This caused the seismogram lines during the daytime to be rather badly jumbled, but did not otherwise detract from the efficiency of the records. The instrument was run almost continuously, at first in charge of Brother Matthias, then after April, 1924, in charge of Brother J. B. Albert.

Data from the station had proved so interesting that it was decided to install a larger instrument with two components in a part of the school grounds that would not be so subject to local disturbances.

During August, 1927, work on the new installation was commenced. The new site is in the south corner of the school grounds, which is distant from the highways and school buildings and is, therefore, free from local disturbances. An excavation was made so that the walls of the building and the pier for the instruments could be firmly founded upon solid rock. The instrument cellar so made is of reinforced concrete with walls and roof six inches thick, all cast at one time so as to make the construction monolithic. The inside dimensions are eight by nine feet. The ceiling is ten feet above the floor at the front side of the building and eight and one-half feet at the back. The floor is about eight feet below the outside ground level. A narrow flight of steps, partly inside and partly outside of the concrete structure, lead down through a door two and one-half feet wide and five feet eight inches high. The upper steps are covered by a wooden vestibule, entered from ground level by another door. The heavy construction and the box-like shape give the structure extreme rigidity.

The very considerable excavation was accomplished by boys of the Brothers' School, and Brother Albert also arranged with county officials for gravel to be delivered on the job for use in making the concrete. Brother Albert and Brother Leo did most of the carpenter work to finish off the details and fittings of the building. For these free contributions of labor and material the Brothers and pupils of the school and the County of Hawaii have the most sincere thanks of the Observatory.

Mr. B. F. Rush was employed to assist in the design and to oversee construction. Lumber for forms, Portland cement, and the labor of mixing and placing the concrete were secured from the Hawaiian Dredging Company. S. Oda was employed to build the forms. Thanks are also due to these firms for the reasonable prices charged and the helpful services given. The cost of the building, paid from U. S. Geological Survey funds, was \$383.

The new instruments were set up and started on September 15, Brother Albert remaining in charge of the new installation. The Hawaiian type seismograph used is the second of this design built at the machine shop of the Hawaiian Volcano Observatory, and is the same one that was on exhibit at the Territorial Fair in Honolulu last year. The first of these instruments was sent to Kodiak, Alaska, and was installed there last summer by Dr. Jaggard. The instrument has been described elsewhere, but a brief outline of its general design may again be given here. It is a two-component instrument, both components recording on smoked paper on the same drum. The inertia masses are about 71.5 kg. in weight, and the computed static magnification is 130. The masses are slung as horizontal pendulums by short piano-wire links, and have been adjusted to seven seconds period. They are critically damped by oil damping. The recording drum is 28.4 cm. in diameter, 30.5 cm. long, and is revolved by an escapement clock mechanism so that the paper speed is 30 mm. per minute. The constants as here stated are somewhat different from the values given in Volcano Letter No. 142, where this installation was first described. The changes are due to more accurate tests made after that publication was issued, and to readjustments of the instrument. The two pendulums are suspended one in the south, and one in the east corner of the room, being fastened directly to the concrete of the structure itself at points of its maximum strength. The axes of the two components are oriented true north-and-south and east-and-west.

Some difficulty was encountered during the first few weeks of operation of the station due to excessive dampness. There was very little ventilation provided at first, in order to avoid possible air currents. Slight ventilation, however, was found necessary in order to carry off this dampness and prevent the condensation of moisture on the upper parts of the walls and ceiling.

The airline distance of this station from the Hawaiian Volcano Observatory is about 23 miles. This furnishes an excellent base with which to plot distance intersections for the epicenters of such local earthquakes as may record themselves at both stations. During the last two weeks of September the records were mainly experimental while the various adjustments to the instrument were being made. There were 13 local earthquakes recorded in October, and an excellent record of the Alaskan earthquake of October 24 was secured. Nine of the local earthquakes were also recorded at the Volcano Observatory, so that most of them could be determined in position. During November the new station recorded 12 local earthquakes and three teleseisms. The records so far have shown themselves to be exceptionally free from local disturbances and pen wanderings due to changes of temperature. Temperature within the building is remarkably even due to the thick walls and the fact that the building itself is shaded during most of the day from the direct rays of the sun. Microseisms are recorded at most times, which attests the sensitivity of the instrument.

VOLCANIC CONDITIONS IN NOVEMBER

Activity of Halemaumau

The activity of Halemaumau during the month was confined to slightly changing conditions within the pit. There were the usual slides and avalanches as parts of the walls crumbled and fell, sometimes making considerable noise and sending up clouds of dust. These are always closely watched in order to ascertain any changes in volcanic conditions portrayed by working of the walls. An analysis of wall activity seems to indicate that the slides vary in frequency and intensity with the increase and decrease of pressure of the magma within Kilauea Volcano. The walls appear to be more quiet when there is a rise in the invisible lava column; when the "tide" recedes, avalanches are frequent because with the lowering of the pit bottom there is an inward slumping of the walls, and are probably accentuated because of "stretching" and loosening accomplished when there is pressure deep underneath. There is also wall activity following a soaking rain, when the drying-out process loosens the wall material. An attempt is made to correlate the quiet and active periods of the walls with the variations in ground tilt as measured by the seismographs in the cellar of the Observatory on the northeast crater rim (see map on last page).

There are a great many steam vents in the lava floor of the crater and on the floor and walls of Halemaumau pit. The activity of these varies with conditions of the atmosphere. Often in very dry weather there is little vapor to be seen, while in protracted wet spells the steam is so thick as to hide all the details in the pit.

A total of 191 local earthquakes and three teleseisms were recorded at the Hawaiian Volcano Observatory during the month. The greatest number of shocks recorded in one day was 29 on November 5. All are fully listed in the Seismometric Record. The tide gauge at Hilo recorded a small tidal wave made by the distant earthquake of November 4, and a disturbance of the water level was noticed by workmen on the breakwater about 9 a. m.

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November 2. Rainy and misty weather. The pit at 2 p. m. was a very brilliant red with iron oxides, and the new lava floor is blue black, with the central and northern cones giving off vapor. Vapor on the taluses was increased by virtue of the damp weather. A trickle of rock was heard at the SW.

The west wall and talus slopes show much more red oxide color toward the bottom than toward the top of the wall. This is true all around, but the west wall is the reddest.

November 5. At 3 to 3:30 p. m. the pit was quiet and the weather clear and dry. Extraordinarily little steam; only small patches of visible vapor at NW., SW., and S. taluses and the north cone. White steam shows at a hole NE. of central cone. There is slight sulphur stain at the wet steam vent in S. talus 200 feet above the floor. Slight rock trickles heard S. and N.

November 7. A considerable avalanche in NE. corner of pit at 1:15 p. m. was shown by dust rising.

November 8. Dust from slides N. and NE. at 8:30 a. m. hung in the air for more than 15 minutes.

November 9. The pit was quiet at noon, and vapping was slight. There was new talus material NE., N., and SSW. A considerable notch in NE. wall has developed during the past summer.

November 11. At 2:40 p. m. rocks were sliding S. That wall is streaked with dust from slides, and the NE. corner is scarred, one place just below the rim. All walls are dry and dusty, and the floor thickly coated.

Rather continuous rock trickles S. were occurring at 2:50 p. m.

The trail crossing crack at 14-ton boulder has dangerously sunk, but the crack itself has not widened.

A slide at S. corner at 3:10 p. m. sent boulders tumbling the full length of the S. talus. There have been many slides here.

The middle and northern cone vents steam steadily, and the S. cone steams in puffs, perhaps accentuated by the dust of the slide.

November 13. The pit was quiet at 11 a. m., but the floor was covered with tan-colored dust, thickest at the base of SSW. talus under the two tunnels. Nine tropic birds were flying around the lower of the two tunnels as though nesting there. Difficult to see where is the scar left by the recent avalanches. Appears to be either under S. station or a widening of the big avalanche of September 9 at the SW.

The sulphur patches SE. and E. are both still yellow, unmasked by dust.

At 9:40 p. m. and a few minutes later noisy avalanches were heard.

November 16. At 2 p. m. the pit was the same, the bottom was dusty and very dry, and a small trickle of rocks was heard at the S. wall. The upper south wall is cracked west of south station for 50 feet, and is ready to fall. Very fresh cracks in dirt. Slides occurred NW.

November 19. At 4:15 p. m. the weather was clear, with light NE. wind. Recent rains have washed away most of the floor dust of Halemaumau. Fresh brown debris lies on the NE. talus. Rocks were heard falling once or twice at the north. The pit is dry, with a little steam at the usual places.

During the forenoon much dust was blowing at the SW. rim of Kilauea Crater.

November 23. At 11:20 a. m. there were no marked changes in the pit. A little steam rose next the hole in the middle floor cone. The NE. talus had fresh dark red debris from a wall scar of same color above.

The cracks formerly steaming around the automobile terminus seem to steam much less at present.

The recent floor dust still shows in sunlight, but it has clustered in puddles of dried mud.

November 27. At 11 a. m. the pit was steaming from walls in several places owing to rain falling, as well as many places on bottom and taluses. There are small falls of rock making dust visible from a distance these days. Most of these are slowing stripping the N. and NE. walls.

November 29. A tall cumulus cloud remained over Mokuaweoweo, on Mauna Loa, a large part of the day, and later there was a persistent possible fume cloud.

November 30. No change seen in Halemaumau at 9 a. m. There is still avalanche dust on the south side of the floor. Avalanches at the north make dust occasionally, but no falls were heard at the time of visit.

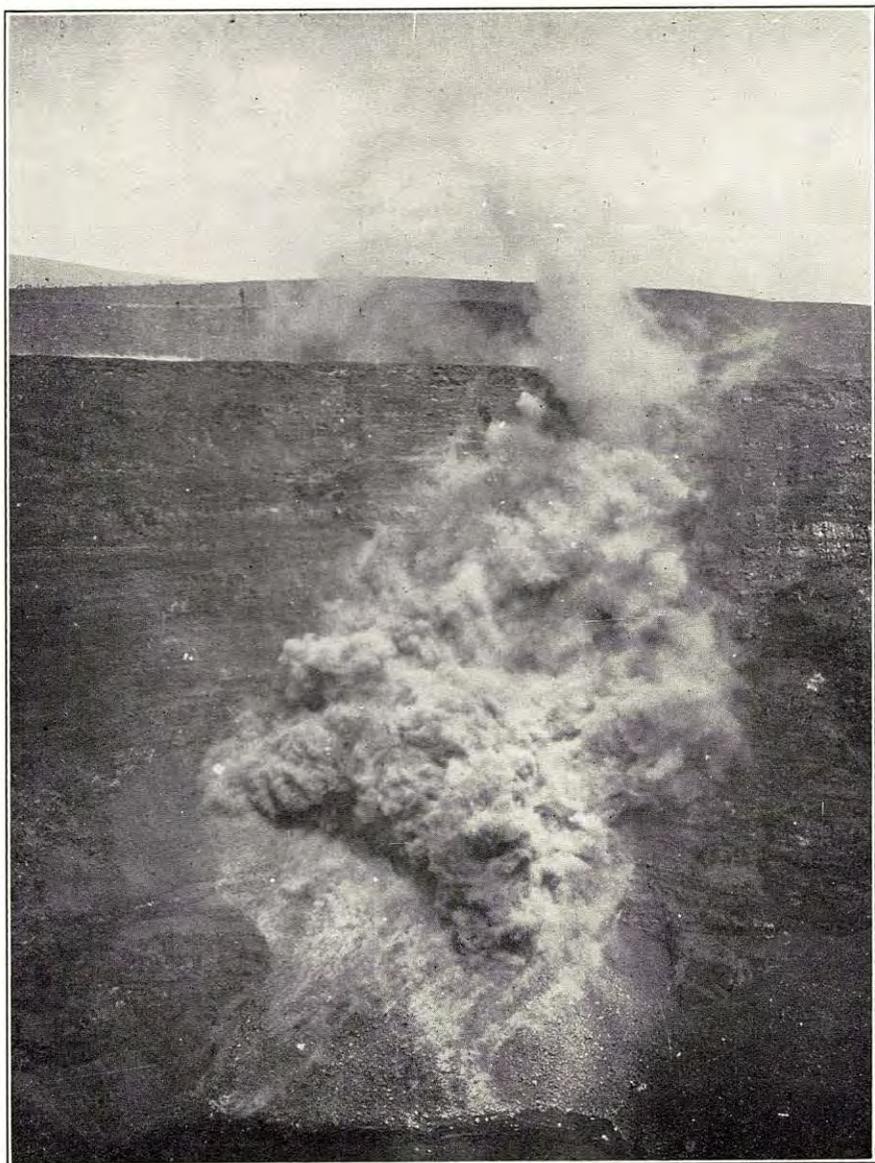


Figure 43. October 5, 1927. Avalanche from north wall of Halemaumau at 10:27 a. m. Photo Evans.



Figure 44. New seismograph station at Hilo. Building constructed in June, and the instruments installed in September. Brother J. B. Albert in charge. Photo Wilson.



Figure 45. Interior of Hilo station showing one of the horizontal pendulums and the recording mechanism. Photo Wilson.

SEISMOMETRIC RECORD

There were 191 local earthquakes and three teleseisms recorded on the Observatory seismographs during the month ended at midnight November 30, 1927. These and other phenomena are listed below. The time used is Hawaiian Standard (time meridian is 157° 30' W.), which is 10 hours and 30 minutes slower than Greenwich Time.

The greater number of the very feeble local shocks counted in the list make such minute records that the character of the disturbance is not always apparent. Some are true earthquakes; others are perhaps the parts of greater amplitude of a continuous or protracted tremor, which at other times may be too feeble to record; some seem to be records of vibrations set up by avalanches in the pit of Halemaumau.

Abbreviations used below are as follows: vf, very feeble; f, feeble; s, slight; m, moderate; d, instruments dismantled; fl, felt locally; Δ, indicated distance in miles; *, continuous tremor:

Local Earthquakes

November

| | | | | | |
|---|--------------------|----|------------------|----------------------|----------------|
| 1 | 3:16 a.m. f. Δ19. | 5 | 12:20 a.m. vf. | 12:43 p.m. vf. | |
| | 4:52 a.m. vf. | | 3:10 a.m. vf. | 7:28 p.m. vf. | |
| | 7:31 a.m. vf. | | 6:05 a.m. vf. | 10:04 p.m. vf. | |
| 2 | 2:04 a.m. vf. | | 8:31 a.m. vf. | 10:40 p.m. vf. | |
| | 11:20 a.m. vf. | | 10:47 a.m. vf. | 10:43 p.m. vf. | |
| | 11:49 a.m. vf. | | 1:37 p.m. vf. | 11:47 p.m. vf. | |
| | 1:04 p.m. vf. | | 1:41 p.m. vf. | 11 | 6:00 a.m. vf. |
| | 1:09 p.m. vf. Δ16. | | 1:53 p.m. vf. | 6:05 a.m. vf. | |
| | 1:19 p.m. vf. | | 2:06 p.m. vf. | 6:07 a.m. vf. | |
| | 1:27 p.m. vf. | | 4:08 p.m. vf. | 6:09 a.m. vf. | |
| | 2:57 p.m. vf. | | 4:21 p.m. vf. | 6:10 a.m. f. Δ14 fl. | |
| | 10:12 p.m. vf. | | 4:53 p.m. vf. | 6:41 a.m. vf. | |
| 3 | 12:15 a.m. vf. | | 5:05 p.m. vf. | 6:44 a.m. vf. Δ16. | |
| | 2:38 a.m. vf. | | 5:37 p.m. vf. | 8:59 a.m. vf. | |
| | 3:37 a.m. vf. | | 5:40 p.m. vf. | 9:01 a.m. vf. | |
| | 4:53 a.m. vf. | | 5:47 p.m. vf. | 10:59 a.m. vf. | |
| | 5:30 a.m. vf. | | 5:54 p.m. vf. | 12 | 12:22 a.m. vf. |
| | 7:10 a.m. vf. | | 6:09 p.m. vf. | 12:24 a.m. vf. | |
| | 7:19 a.m. vf. | | 6:23 p.m. vf. | 1:12 a.m. vf. | |
| | 7:59 a.m. vf. | | 6:56 p.m. vf. | 9:15 a.m. vf. | |
| | 8:29 a.m. vf. | | 6:59 p.m. vf. | 12:18 p.m. vf. | |
| | 10:34 a.m. vf. | | 7:30 p.m. vf. | 3:12 p.m. vf. | |
| | 12:32 p.m. vf. | | 7:51 p.m. vf. | 4:03 p.m. vf. | |
| | 1:48 p.m. vf. | | 8:22 p.m. vf. | 13 | 9:48 p.m. vf. |
| | 4:30 p.m. vf. | | 8:28 p.m. vf. | 14 | 1:40 a.m. vf. |
| | 6:15 p.m. vf. | | 8:57 p.m. vf. | 5:05 a.m. vf. | |
| 4 | 1:55 a.m. vf. | | 9:02 p.m. vf. | 6:50 a.m. vf. | |
| | 2:02 a.m. vf. | | 9:20 p.m. vf. | 11:09 a.m. vf. | |
| | 2:22 a.m. vf. | | 9:38 p.m. vf. | 11:49 a.m. vf. | |
| | 3:19 a.m. vf. | 7 | 7:23 a.m. vf. Δ5 | 1:39 p.m. vf. Δ25. | |
| | 4:04 a.m. vf. | | 9:13 a.m. vf. | 1:48 p.m. vf. | |
| | 9:21 a.m. vf. | | 2:21 p.m. vf. | 1:50 p.m. vf. | |
| | 10:57 a.m. vf. | | 8:12 p.m. vf. | 4:17 p.m. vf. | |
| | 11:00 a.m. vf. | 8 | 2:54 p.m. vf. | 6:41 p.m. vf. | |
| | 3:01 p.m. vf. | | 5:05 p.m. vf. | 15 | 7:30 a.m. vf. |
| | 5:37 p.m. vf. | 9 | 5:52 a.m. vf. | 1:16 p.m. vf. | |
| | 6:05 p.m. vf. | 10 | 12:56 a.m. vf. | 4:04 p.m. vf. | |

| | | | | | |
|----|----------------|----|---------------------------|----|----------------|
| | 5:48 p.m. vf. | 17 | 2:06 a.m. vf. | | 5:36 a.m. vf. |
| | 10:22 p.m. vf. | | 4:50-4:55 a.m. vf * | | 9:12 a.m. vf. |
| 16 | 1:00 a.m. vf. | | 5:02-5:07 a.m. vf * | 22 | 11:57 p.m. vf. |
| | 1:01 a.m. vf. | | 6:05 a.m. vf. | 23 | 11:12 a.m. vf. |
| | 1:02 a.m. vf. | | 11:20 a.m. vf. | | 2:58 p.m. vf. |
| | 1:05 a.m. vf. | | 5:10 p.m. vf. | 25 | 5:50 a.m. vf. |
| | 1:08 a.m. vf. | 18 | 11:36 a.m. vf. | | 9:36 a.m. vf. |
| | 1:10 a.m. vf. | | 3:55-4:00 p.m. vf * | | 12:44 p.m. vf. |
| | 1:13 a.m. vf. | | 5:46 p.m. vf. | | 11:16 p.m. vf. |
| | 1:14 a.m. vf. | | 6:46 p.m. vf. | 26 | 6:52 a.m. vf. |
| | 1:16 a.m. vf. | | 8:31 p.m. vf. | 27 | 8:49 a.m. vf. |
| | 1:17 a.m. vf. | 19 | 1:14 a.m. vf. | | 9:01 a.m. vf. |
| | 1:20 a.m. vf. | | 6:02 a.m. vf. | | 10:26 a.m. vf. |
| | 1:21 a.m. vf. | | 7:01 a.m. vf. | | 1:24 p.m. vf. |
| | 1:22 a.m. vf. | | 7:06 a.m. vf. | 28 | 11:44 a.m. vf. |
| | 1:24 a.m. vf. | | 7:11 a.m. vf. | | 12:57 p.m. vf. |
| | 1:25 a.m. vf. | | 7:16 a.m. vf. | | 3:09 p.m. vf. |
| | 1:26 a.m. vf. | | 7:26 a.m. vf. | | 3:40 p.m. vf. |
| | 1:27 a.m. vf. | | 7:31 a.m. vf. | 29 | 12:17 a.m. vf. |
| | 1:28 a.m. vf. | | 11:29 a.m. vf. | | 3:45 p.m. vf. |
| | 1:30 a.m. vf. | | 12:11-12:13 p.m. vf. * | 30 | 12:55 a.m. vf. |
| | 1:35 a.m. vf. | | 6:59 p.m. vf. | | 3:13 a.m. vf. |
| | 1:50 a.m. vf. | 20 | 6:19 a.m. vf. | | 7:49 a.m. vf. |
| | 6:29 a.m. vf. | | 7:12 a.m. vf. | | 10:21 a.m. vf. |
| | 12:14 p.m. vf. | | 5:50 a.m. vf. | | 4:03 p.m. vf. |
| | 5:25 p.m. vf. | | 6:10 a.m. vf. | | 11:37 p.m. vf. |
| | 9:54 p.m. vf. | 21 | 2:37 a.m. vf. Δ 8. | | |

Teleseisms

November 4

- eP 3:27:45 a.m. This teleseism caused a small tidal wave in Hilo,
 ? 3:30:00 a.m. detectable only on the tide gauge. Indicated dis-
 S 3:33:28 a.m. tance to origin is 2,440 miles. The time at origin
 Sr 3:35:53 a.m. is 3:20:32 a. m. Hawaiian Time.
 L 3:37:50 a.m.

November 14

- eP 10:06:37 p.m. No other phases recognizable. Very feeble record.

November 18

- S or L 8:46 p.m. Very feeble record.

Harmonic Tremor

This type of tremor was absent throughout the month.

Microseismic Motion

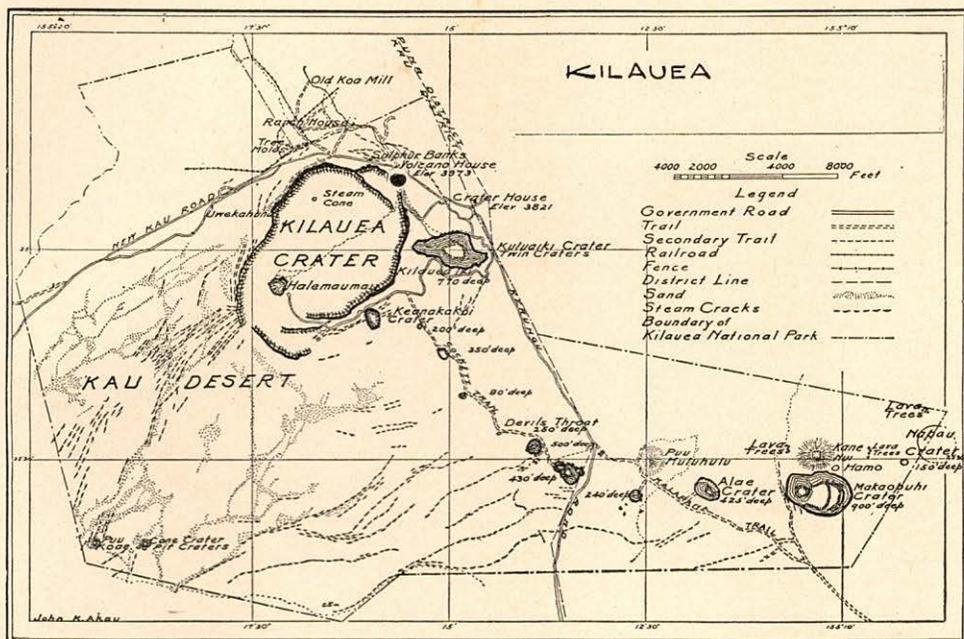
Microseisms were stronger than normal on November 15 and 16.

Tilting of the Ground

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

| | | |
|----------------------------|------------|--------|
| October 26-November 1..... | 0.7 second | SSW. |
| November 2-8..... | 0.6 | " SSE. |
| " 9-15..... | 1.1 | " NE. |
| " 16-22..... | 0.9 | " NE. |
| " 23-29..... | 0.7 | " SE. |

T. A. JAGGAR,
 Volcanologist.



Black spot shows location of Observatory.

All exchanges, gifts to library, news notes about Pacific volcanic and seismic events, and correspondence should be addressed HAWAIIAN VOLCANO OBSERVATORY, Volcano House, Hawaii.

The Observatory is operated by the U. S. Geological Survey, and its work is supplemented by the Hawaiian Volcano Research Association. The main station is on the northeast rim of Kilauea Crater. Subordinate seismograph stations are operated by the Research Association under the direction of the volcanologist in Kona and Hilo.

The Kilauea station operates horizontal pendulums of the Bosch-Omori type and receives time by wireless from the Honolulu Naval Station. Observatory Lat. $19^{\circ} 25' 54.3''$ N.; Long. $155^{\circ} 15' 39.6''$ W.; Elevation cellar 1214.6 meters (3985 feet). The Hilo and Kona stations operate horizontal pendulums. Their seismograms are sent to the Observatory.

The Hawaiian Volcano Research Association founded the Observatory in 1911, transferring the plant to the Government in 1919, but continuing cooperation in experimental work by furnishing funds and apparatus and workers as needed by the Government Volcanologist. It is a corporation under the laws of Hawaii, governed by a board of directors, and financed by the subscriptions of its members and patrons. Its aims are identical with those of the Observatory, namely, (1) To keep record of Hawaiian volcanism, (2) To attract volcanologic specialists to Hawaii, and (3) To promote worldwide knowledge of volcanoes and earthquakes and the foundation of more volcano observatories.

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By R. M. Wilson

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REVIEW OF LOCAL SEISMIC FEATURES FOR THE YEAR

The year 1927 was a comparatively quiet one considered from the point of view of seismic and volcanic activity. There was throughout the year the usual run of very feeble tremors, with occasional stronger shocks which made themselves felt. While there were very few spectacular features, yet times of repose of the volcanoes, and times of relatively low seismic activity, are nevertheless phases which must be studied. It is during these quiet phases that search must be made for symptoms which may foretell coming activity.

The number of local earthquakes recorded during the year was 1,149. The 19 teleseisms recorded have been omitted from this count and will also be omitted from the following discussion as this review is to concern purely local conditions. Of the local earthquakes, 1,121 were of the very feeble class. Sixteen were feeble, 9 were slight, and 3 were moderate; 17 of these were reported as perceptible. As is noted in the explanatory paragraphs of the Seismometric

Records of the Monthly Bulletins, the very feeble tremors recorded are difficult to classify as to cause. They are of interest more for their numbers and their grouping into swarms. The terms denoting intensity represent approximately the following equivalents in millimeters per second per second of maximum acceleration: Very feeble, 2.5; feeble, 5.0; slight, 10.0; moderate, 25.0.

It must be here noted that these earthquakes are local not only in their origin, but also in their effects. Even the heavier volcanic shocks are usually shallow and not far-reaching, and are not often recorded away from the island. They must not be confused with the deep-seated tectonic earthquakes which sometimes shake the whole earth; such shocks seldom originate in Hawaii.

The instruments at the Observatory upon which these disturbances are recorded are horizontal pendulums of the Bosch-Omori type somewhat altered in detail to fit the need of local conditions. There are two components, north-south and east-west, with inertia masses of 100 kg., both recording on smoked paper on the same drum. The static magnification used is 116, and the instruments are run with their free periods adjusted to seven seconds; they are oil damped to aperiodicity. Reports from this station of the heavier local earthquakes frequently speak of the instruments being dismantled. This term leads to some confusion in the minds of those not acquainted with seismograph construction. When the instruments are so dismantled it does not in any sense mean that they are damaged. The coupling link between the boom of the heavy mass and the magnifying lever is so arranged that earthquakes of dangerous intensity will cause this coupling link to become disengaged, thereby saving the instrument from damage. It is the throwing off of this coupling link, replaceable in a few seconds, which is referred to as "dismantling."

Deductions from a general review of the year's earthquakes are facilitated by considering the grouping and frequency of the shocks. The frequency curve here submitted (Figure 47) is made by plotting overlapping three-day means, so that the number indicated by the curve for any particular day represents the average number of shocks per day for the three-day group of which that day is the middle. To plot the numbers for each day as they occur would result in a jagged curve which would be difficult to read, so that this slight smoothing is advisable. The numbers of earthquakes have been used regardless of their intensity. An earthquake above the grade of very feeble does not, therefore, affect the curve more than would a very feeble tremor. In order to show when these more intense shocks occurred, they are represented by dots above the curve; the size of dot roughly represents relative intensity.

The crests of this curve exhibit a possible periodicity which may correspond with certain phases of the moon. Ocean tides are caused by luni-solar attraction, and smaller tides in the solid crust of the earth are known to exist from the same cause. The connection, therefore, between earthquake frequency and the phases of the moon is understandable, and has been discussed quite fully by H. O. Wood in the Second Report of the Hawaiian Volcano Observatory, published in 1917. The dates of the quarter phases of the moon during 1927 have been indicated for comparison with these crests of earthquake frequencies in the curve given here.

The outstanding seismic features of the year are few. The heavy earthquake of March 20 has been described in the Bulletin of that month. The series of seven perceptible shocks, with two others nearly large enough to be felt, during the last week of July and the first few days of August, represents a noticeable feature and suggests collapse upon the retirement of the lava column. The harmonic tremor that occurred during the July eruption of lava was mentioned in the Seismometric Record for July, and was referred to in the description of the eruption. A very unusual and remarkable swarm of spasmodic tremors came on December 3 and 4. This swarm was so clearly of volcanic origin that surface manifestations of activity were momentarily expected, but apparently no such visible action occurred. Other high peaks in the numbers of tremors during November and December perhaps represent similar swarms,

though their records do not so clearly show them to be spasmodic tremors of true volcanic type.

The southwest storm which began on December 25 undoubtedly had some seismic effect either through the barometric changes and high winds which accompanied it, or through the heavy precipitation which occurred at that time. A peculiar feature occurred on June 8, when a visible flash of light and a concussion as if from an explosion were reported from widely separated points on the island. A small tremor was recorded at the same time on the Observatory seismographs. It is suspected that these phenomena represented the fall of a meteorite, though no traces of it have yet been found.

Tilting of the ground as recorded by the slow and persistent wandering of the recording pens of the seismograph has been found through past years at the Observatory to be well worth observation. Such tilting away from the pit of Halemaumau has in general been correlated with rising of the lava column, while tilting towards the pit has usually come with retirement of the lava or at times of general collapse. The tilt at the Observatory appears to have a normal annual range of about 10 seconds of arc towards the pit (southwest) during the first half of the year, and a recovery during the second half. This normal movement and some other shorter period variations may not be strictly due to volcanic causes. General temperature changes either of the instrument room, of the ground upon which the Observatory stands, or of the face of the cliff near the Observatory may produce tilting effect and so account in part for this annual change, though experiments show that it certainly is not a purely local movement. Volcanic conditions are known to produce tilt also, and these volcanic tilt effects are superimposed upon the tilts produced by other causes.

The diagram here shown (Figure 48) indicates the change of tilt during 1927. The method of illustrating it is the same as used by Knott to show diurnal tiltings. Suppose a wand to be placed upright at a place on the earth's surface, with its upper end bearing upon a sheet of paper supported free of local earth movements. Tilting movements of the ground at that place would then cause the upper end of the wand to trace a curve on the paper according to direction and amount of the tilt. The wand may be supposed long enough to produce the necessary magnification. The diagram represents the wandering of the tip of such an imaginary upright pointer which would be caused by the ground tiltings at the Observatory. The progress of the line in the diagram represents the direction of tilting for that particular time, and the amount of motion is represented by the space between the marked dates. This is a smoothed curve, resulting from the use of overlapping seven-day means.

It is of interest to note how clearly the time of the July eruption stands out on this curve. A definite change of direction begins with the beginning of the eruption and ends about the time lava ceased to flow; the curve then takes up the course it was following before the eruption. Another interesting feature is the very rapid surge of tilt toward the south during the last part of December.

The scale of the diagram is indicated in seconds of arc of tilt. This has been arrived at through the mathematics of the seismograph, and has been approximately verified by test. The amount of tilting involved is evidently so small as to be detected only by very sensitive instruments or by accurate spirit leveling.

Avalanching in the pit of Halemaumau is not a seismic phenomenon, but the close correlation between avalanching and earth tremors, either as cause or effect, makes it interesting to mention here. Spells of avalanching may perhaps be caused by inward tilting of the walls of the pit, which should be in some way correlated with ground tilting at the Observatory. The times of major spells of avalanching during the year have been roughly indicated on the earthquake frequency diagram. Avalanches are as a rule hard to photograph, as the larger and more interesting ones come unexpectedly and do not last long enough to allow preparation of cameras. Dr. S. A. Barrett, Director of

the Milwaukee Public Museum, was especially fortunate in this regard in, by chance, getting an excellent motion picture of the big avalanche of September 9. A copy of this film which he supplied to the Observatory has since been shown regularly at the Uwekahuna lecture room.

Shortly before the July eruption, it was noticed that the rim cracks around the pit had suddenly widened. Some of these cracks were marked, and routine measurements of their width have been made at intervals since that time. The sudden and definite widening first noted was about June 22. Previous measurements had not been made, so the amount of movement at that time is not known, but it was of the order of several inches, and the disturbed region was about 1,200 feet of the southeast rim of the pit. There seemed to be no definite widening during the July eruption. A noticeable movement occurred about July 24 near the SE. station at the "Halemaumau sign." The cracks at the same place widened again during the last few days of August, and the small section of rim carrying the SE. station fell in on September 19. Most of the cracks measured show an even and gradual widening amounting to one or two-tenths of a foot during the six months. During the latter half of December a movement of three or four-tenths of a foot has occurred in the cracks near the 14-ton boulder at the east side of the pit.

THE UWEKAHUNA SEISMOGRAPH

When the Uwekahuna Observatory and Lecture Room was planned, provision was made for an exhibition seismograph. A small alcove at the back of the room was built, with a large concrete pier founded upon solid rock and separated structurally from other parts of the building. In October, 1926, when Dr. Jagger was in Japan, he arranged for the purchase of a three-component Japanese seismograph of modern design to occupy this alcove. The instrument was made by Akashi & Company of Tokyo.

The seismograph is of a standard Japanese design, except that for the horizontal components Dr. Jagger specified wire suspension for the inertia masses instead of the cup and pivot arrangement. The three components have inertia masses of about 6.4 kg., and the static magnification is adjustable to any desired value between 10 and 50. The horizontal components are now being operated at the higher value. The vertical motion component is mounted on the same base plate with the two horizontal components. All three units record on the same drum, using smoked paper, with the paper traveling 50 mm. per minute. Fresh paper is placed on the drum once every 24 hours. Damping is electromagnetic. The instrument is quite compact, the whole base plate measuring only 70 by 80 centimeters. It was mounted to conform with the orientation of the building so that the two horizontal pendulums hang approximately south 38° west and south 52° east, respectively, from their supports. This installation is 0.9 mile north-northwest of the center of the pit of Halemaumau, and is therefore nearer to the pit by 1.7 miles than is the Hawaiian Volcano Observatory. For this reason its records of avalanche tremors have tended to be of greater amplitude than the same disturbances recorded on the more distant instruments at the Volcano Observatory. It is probable that comparative study of the records of the two stations will be an aid in deciding which of the many very feeble local tremors now registered are due merely to superficial disturbances in the pit.

The instrument so far has given good results, although it is not operating under conditions tending towards its best efficiency. Disturbances of car loads of people coming for lectures and of crowds of people moving about within the building make irregularities in the records. The room has a considerable daily range of temperature, which has a disturbing effect on the recording position of the pens, particularly in the case of the vertical component.

Any loss in efficiency of operation is more than compensated, however, in having this modern instrument available for the inspection of visitors. Lec-

tures are made much more interesting by the presence of a seismograph in actual operation, to show more clearly the relation of seismology to the mechanism of the volcano.

VOLCANIC CONDITIONS IN DECEMBER

Activity of Halemaumau

There were numerous slides throughout the month which increased in the period between December 17 and 28, when there was a heavy storm from the south and southwest. Loud avalanches were frequently heard as the month drew to a close. The stripping of the walls disclosed dykes northeast and southwest hitherto unnoticed. The avalanches and slides seem to have been occasioned by a lowering of the pit bottom, as suggested by the tilting of the ground, allowing the walls to tip inward; and by the excessive soaking from rains. The east rim cracks by measurement showed widening during the month, which seems to check with the lowering of the lava column and the inward-tipping of the walls.

The amount of rainfall is interesting, being the greatest in recent years. It is tabulated below by days. Note that December 25 had 7.80 inches.

| Day | Amount | Day | Amount |
|---------|--------|------------|--------|
| 1..... | .16 | 17..... | .45 |
| 2..... | .17 | 18..... | .15 |
| 3..... | .01 | 19..... | .67 |
| 4..... | Trace | 20..... | .31 |
| 5..... | .00 | 21..... | 1.85 |
| 6..... | .13 | 22..... | 3.00 |
| 7..... | 4.00 | 23..... | .95 |
| 8..... | .08 | 24..... | 2.00 |
| 9..... | .01 | 25..... | 7.80 |
| 10..... | 1.68 | 26..... | 4.50 |
| 11..... | 2.40 | 27..... | 7.45 |
| 12..... | .43 | 28..... | .85 |
| 13..... | 1.40 | 29..... | .19 |
| 14..... | 1.18 | 30..... | .12 |
| 15..... | .98 | 31..... | .08 |
| 16..... | .15 | | |
| | | Total..... | 43.15 |

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December 6. Rocks were heard falling from the north wall at 11:27 and 11:35 a. m. At 11:41 a small slide NE. made a little dust.

A vertical cleft was noticed in the wall at the W. end of the N. sill. Fresh red scars on the N. wall indicate slides have occurred there. The pit was extremely quiet and dry.

December 7. At 10 a. m. the pit was wet from rains and full of color. The center cone steams profusely, and other steam vents have also increased their activity.

December 10. There was nothing noticeably new at Halemaumau at 2 p. m. One small slide of rock was heard at the north. Three places that have fresh broken surfaces all the way to the top of the walls are NW., NE., and over the SW. rift. The northwest niche is broken away by this stripping of the wall above the NW. talus. The p'ace is under the NW. station, next to the Postal Rift cavern. At the NE. stripped wall there is a curved red fill in cross-section, against a dyke of cracked rock east of it.

December 13. A slide was heard at 3:55 p. m.

December 14. The pit was quiet at 11:40 a. m., and the air was calm. The walls were a brilliant red after rain. Note five dykes up NE. wall and four SW. Also a net of reticulate intrusions in NE. wall over E. end of N. sill. The sill, which formerly would remain hot and dry after rain, is now dark with moisture, but there is a large dry patch at the top of its E. end and another in the wall above. Also there is a dry patch on the N. side of the W. boss. The extremely brilliant brick red of the walls, marking intense oxidation of the lava flows of the last century, is very striking.

The wall steams around the edge cracks on top S., SW., W., NW., and NE., and the lower wall NE., E., S., SW., and NW. The taluses S., SW., and NW. steam the most. The lava floor shows dry places about the edge of the eastern collapsed area. It steams at the three cone vents.

Rock falls were heard every 5 or 10 minutes NE., N., and S. No other noise was heard in perfectly still air.

December 17. Nothing new at the pit at 2 p. m., and no slides heard. The talus slopes appear undisturbed after much recent rain. Nothing appears freshly fallen or freshly broken.

December 28. First visit to Halemaumau for 10 days owing to heavy Kona (southwest) rain and wind storm. The pit is nearly full of steam, but a glimpse was had of the bottom with hundreds of steam tails blowing from the west.

Almost incessant slides occurred from all sides, some roaring avalanches NE., and SW. This was at first thought caused by washing out of talus and undermining by the storm, but seismographs show that excessive tilt S. and SE. has begun, and it looks as though lowering of the lava column under Halemaumau might be beginning. This must be watched.

Avalanche roars from the pit were reported.

December 29. Prolonged roar of an avalanche was heard at 8:15 a. m. Numerous avalanche roars have been heard lately. Today, just as yesterday, the rocks are falling. The pit is clear and walls wet and red except one place above W. end of N. sill. This place appears to be dry because avalanches have stripped it, which is proved by the large patch of dry fragment on the talus below. Big slides were observed NW. and N., and small ones NE. x W., and S. The material is so wet it makes no considerable dust clouds.

The Uwekahuna seismogram shows many tremors last night, larger proportionately to its magnification than the same (avalanche) tremors registered at H. V. O.

Cracks east and southeast were measured with large wooden calipers at points established in July by means of white paint spots on crack walls and numbered in white paint. The southeast cracks showed little change, but east the big cracks near the 14-ton boulder of 1924 had increasingly widened as one proceeded north. Widening was two to three inches in the month.

At this time (3 p. m.) there was rain drizzle from the southwest, and the pit had more vapor than during forenoon. Avalanche roars continue from time to time. The bottom appears unchanged.

December 31. At 10:02 a. m. there were two large avalanches at the same time, one N. and one SE., and a simultaneous earthquake shows on the seismogram. The avalanches have become less continuous and less strong, but more or less sliding still takes place. The roaring and the appearance of dust at the pit are much commented on by visitors. The Uwekahuna seismograph records many avalanche tremors.

The weather is improving while the wind still remains southerly.

SEISMOMETRIC RECORD

There were 243 local earthquakes and one teleseism recorded on the Observatory seismographs during the month ended at midnight December 31, 1927. These and other phenomena are listed below. The time used is Hawaiian Standard (time meridian is 157° 30' W.), which is 10 hours and 30 minutes slower than Greenwich Time.

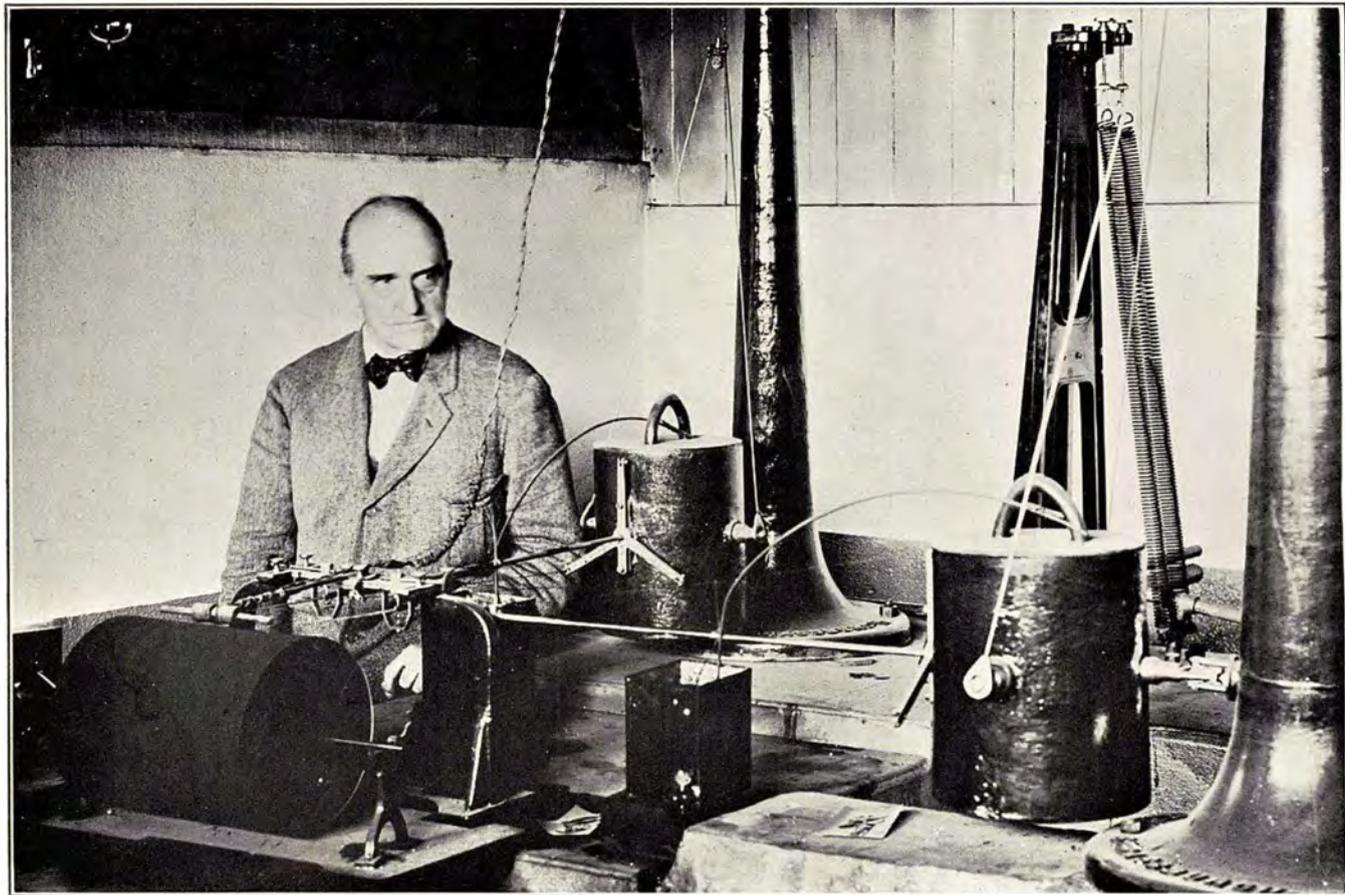


Figure 46. Dr. T. A. Jaggar and the Bosch-Omori seismograph as now in use at the Hawaiian Volcano Observatory.

Photo Wilson.

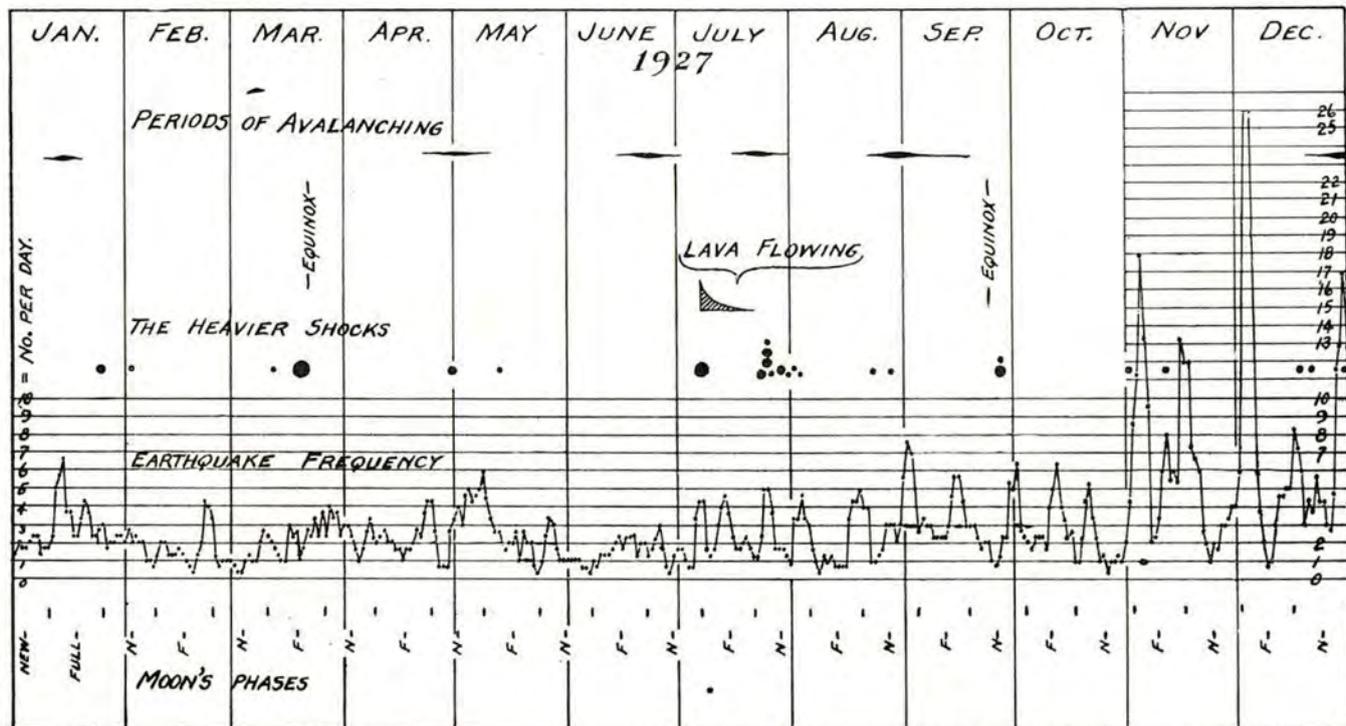


Figure 47. Diagram showing frequency of earthquakes during 1927.

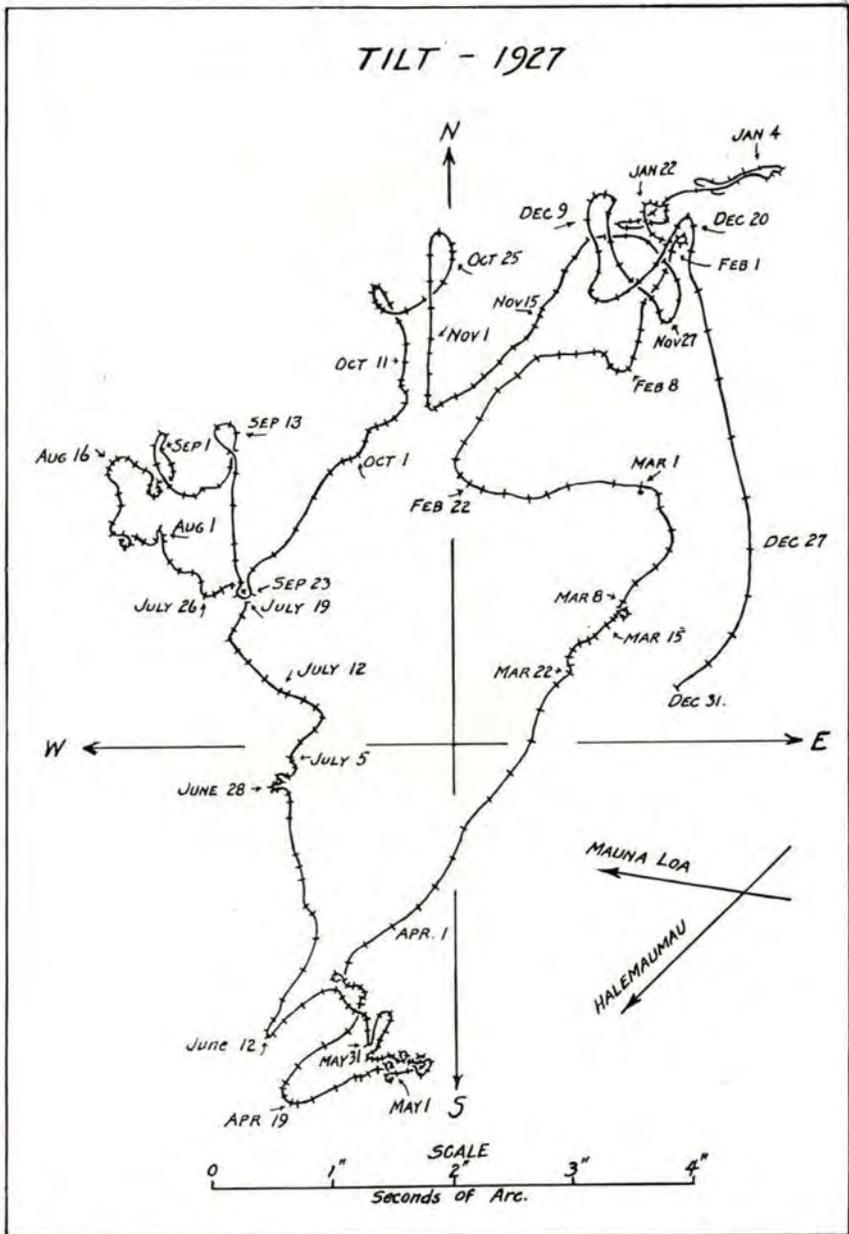


Figure 48. Diagram to show direction and amount of tilt in 1927.

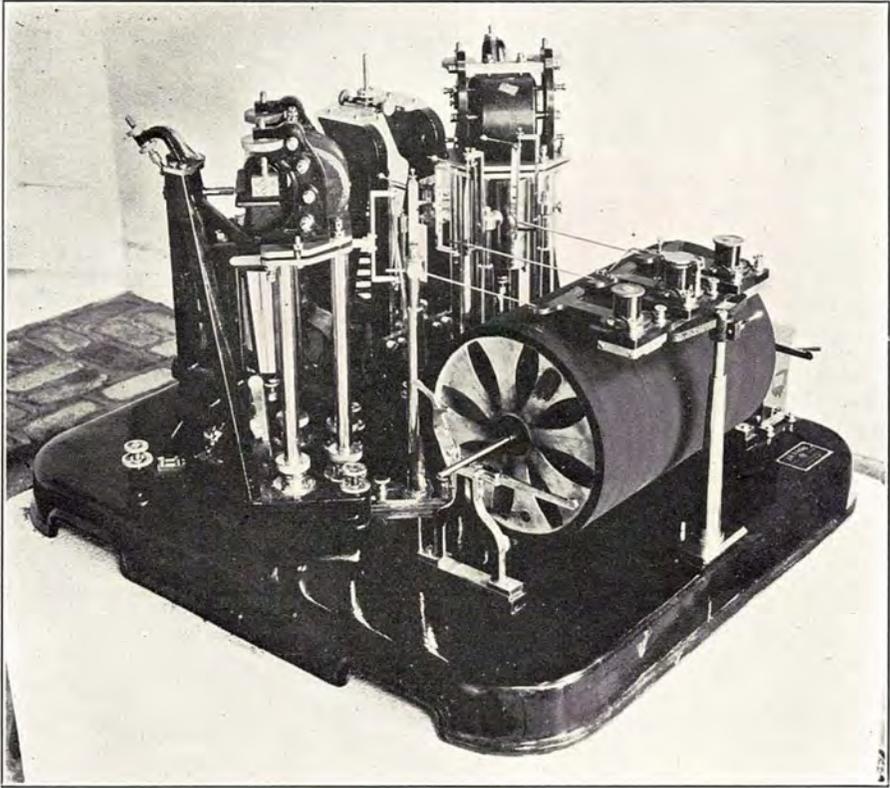


Figure 49. The three-component seismograph at the Uwekahuna Observatory.
Photo Wilson.

The large number of very feeble shocks listed here below on December 3, 4, and 5 represent a series of spasmodic tremors so definitely of volcanic origin that eruption of one of the volcanoes seemed both imminent and certain. Very close watch was kept of both Kilauea and Mauna Loa, telephone messages were sent to South Point and to Kona requesting people to watch Mauna Loa, but no sign of activity was anywhere visible.

The greater number of the very feeble local shocks counted in the list make such minute records that the character of the disturbance is not always apparent. Some are true earthquakes; others are perhaps the parts of greater amplitude of a continuous or protracted tremor, which at other times may be too feeble to record; some seem to be records of vibrations set up by avalanches in the pit of Halemaumau.

Abbreviations used below are as follows: vf, very feeble; f, feeble; s, slight; m, moderate; d, instruments dismantled; fl, felt locally; Δ , indicated distance in miles; *, continuous tremor.

Local Earthquakes

| | | |
|--------------------------------|------------------|-------------------------------|
| December | 6:10 p.m. vf. | December |
| 1 9:42 a.m. vf. | 6:23 p.m. vf. | 12:54 p.m. vf. |
| 10:00 a.m. vf. | 6:28 p.m. vf. | 5 1:31 a.m. vf. |
| 10:09 a.m. s, Δ 12, fl. | 6:33 p.m. vf. | 1:35 a.m. vf. |
| 12:34 p.m. vf. | 6:41 p.m. vf. | 2:10 a.m. vf. |
| 2 9:08 a.m. vf. | 6:45 p.m. vf. | 2:23 a.m. vf. |
| 9:53 a.m. vf. | 7:00 a.m. vf. | 2:24 a.m. vf. |
| 11:57 a.m. vf. | 6:56 p.m. vf. | 2:27 a.m. vf. |
| 1:15 p.m. vf. | 7:02 p.m. vf. | 11:21 a.m. vf. |
| 3:55 p.m. vf. | 7:12 p.m. vf. | 11:41 a.m. vf. |
| 7:45 p.m. vf. | 7:24 p.m. vf. | 6 7:37 a.m. s. Δ 2 fl. |
| 7:48 p.m. vf. | 7:49 p.m. vf. | 7:41 a.m. vf. |
| 10:47 p.m. vf. | 8:14 p.m. vf. | 8:37 a.m. vf. |
| 3 5:58 a.m. vf. | 8:48 p.m. vf. | 9:03 a.m. vf. |
| 5:59 a.m. vf. | 9:19 p.m. vf. | 8:13 p.m. vf. |
| 6:03 a.m. vf. | 9:39 p.m. vf. | 7 12:06 p.m. vf. |
| 6:49 a.m. vf. | 10:30 p.m. vf. | 12:07 p.m. vf. |
| 7:28 a.m. vf. | 11:27 p.m. vf. | 12:25 p.m. vf. |
| 7:51 a.m. vf. | 11:51 p.m. vf. | 1:42 p.m. vf. |
| 8:29 a.m. vf. | 4 12:21 a.m. vf. | 5:02 p.m. vf. |
| 8:55 a.m. vf. | 1:09 a.m. vf. | 8 6:11 a.m. vf. Δ 28. |
| 9:10 a.m. vf. | 2:01 a.m. vf. | 10 4:13 a.m. vf. Δ 37. |
| 11:01 a.m. vf. | 3:05 a.m. vf. | 11 1:39 p.m. vf. |
| 12:19 p.m. vf. | 3:43 a.m. vf. | 10:47 p.m. vf. |
| 12:20 p.m. vf. | 4:58 a.m. vf. | 12 12:59 a.m. vf. |
| 1:50 p.m. vf. | 6:16 a.m. vf. | 5:33 p.m. vf. |
| 2:03 p.m. vf. | 7:47 a.m. vf. | 5:41 p.m. vf. |
| 2:21 p.m. vf. | 8:15 a.m. vf. | 5:49 p.m. vf. |
| 2:51 p.m. vf. | 8:56 a.m. vf. | 6:19 p.m. vf. |
| 3:29 p.m. vf. | 9:32 a.m. vf. | 10:25 p.m. vf. |
| 3:41 p.m. vf. | 10:57 a.m. vf. | 13 11:25 a.m. vf. |
| 4:16 p.m. vf. | 12:58 p.m. vf. | 12:30 p.m. vf. |
| 4:42 p.m. vf. | 1:24 p.m. vf. | 12:33 p.m. vf. |
| 4:44 p.m. vf. | 3:00 p.m. vf. | 2:46 p.m. vf. |
| 4:56 p.m. vf. | 3:22 p.m. vf. | 3:52 p.m. vf. |
| 5:11 p.m. vf. | 3:33 p.m. vf. | 4:50 p.m. vf. |
| 5:44 p.m. vf. | 4:15 p.m. vf. | 14 12:22 p.m. vf. |
| 5:45 p.m. vf. | 7:00 p.m. vf. | 12:56 p.m. vf. |
| 5:55 p.m. vf. | 7:26 p.m. vf. | 15 2:07 a.m. vf. Δ 17. |
| 6:01 p.m. vf. | 9:18 p.m. vf. | 5:33 a.m. vf. |
| 6:02 p.m. vf. | 11:02 p.m. vf. | 11:26 a.m. vf. |

| | | | | |
|----|--------------------------------|----------|--------------------------------|--------------------------------|
| | 12:43 p.m. vf. | December | | 7:22 a.m. vf. |
| | 2:22 p.m. vf. | | 3:46 p.m. vf. | 7:57 a.m. vf. |
| | 3:35 p.m. vf. | | 4:25 p.m. vf. | 8:01 a.m. vf. |
| | 6:10 p.m. vf. Δ^{22} . | | 5:57 p.m. vf. | 8:13 a.m. vf. |
| 16 | 1:41 p.m. vf. | 23 | 11:02 a.m. vf. | 8:29 a.m. vf. |
| | 1:43 p.m. vf. | | 12:16 p.m. vf. | 9:56 a.m. vf. |
| | 2:20 p.m. vf. | | 1:51 p.m. vf. | 9:58 a.m. vf. |
| | 4:45 p.m. vf. | | 3:39 p.m. vf. | 10:28 a.m. vf. |
| | 4:46 p.m. vf. | | 4:21 p.m. vf. | 1:52 p.m. vf. |
| | 4:49 p.m. vf. | 24 | 12:07 a.m. vf. | 4:16 p.m. vf. |
| 17 | 8:01 a.m. vf. | | 3:28 p.m. vf. | 6:50 p.m. vf. |
| | 8:03 a.m. vf. | | 4:15 p.m. vf. | 11:59 p.m. vf. |
| | 8:05 a.m. vf. | | 11:49 p.m. vf. | 30 4:01 a.m. vf. |
| | 8:07 a.m. vf. | 25 | 9:47 a.m. vf. | 5:34 a.m. vf. |
| | 12:14 p.m. vf. | | 10:15 a.m. vf. | 6:55 a.m. vf. |
| | 1:44 p.m. vf. Δ^8 . | | 11:45 a.m. vf. | 9:26 a.m. vf. |
| | 2:57 p.m. vf. | | 10:44 p.m. vf. Δ^{28} . | 4:56 p.m. vf. |
| | 2:58 p.m. vf. | 26 | 6:20 p.m. vf. Δ^{23} . | 9:56 p.m. f. |
| | 5:04 p.m. vf. | 27 | 3:30 a.m. vf. | 10:37 p.m. vf. |
| | 5:05 p.m. vf. | | 6:07 a.m. vf. | 31 12:02 a.m. vf. |
| | 5:06 p.m. vf. | | 5:37 p.m. vf. | 12:08 a.m. vf. |
| | 5:15 p.m. vf. | 28 | 7:06 a.m. vf. | 12:43 a.m. vf. |
| | 5:19 p.m. vf. | | 7:21 a.m. vf. | 1:23 a.m. vf. |
| 18 | 2:26 a.m. vf. Δ^{25} . | | 9:01 a.m. vf. | 2:38 a.m. vf. |
| | 11:14 a.m. vf. | | 9:31 a.m. vf. | 2:53 a.m. vf. |
| | 3:09 p.m. vf. Δ^2 . | | 3:19 p.m. vf. | 3:29 a.m. vf. Δ^{33} . |
| | 3:57 p.m. f. Δ^2 fl. | | 3:21 p.m. vf. | 4:03 a.m. vf. |
| 19 | 4:57 p.m. vf. | | 3:41 p.m. vf. | 6:29 a.m. vf. |
| | 5:07 p.m. vf. | | 6:37 p.m. vf. | 6:54 a.m. vf. |
| 20 | 6:25 a.m. vf. | | 7:26 p.m. vf. | 7:27 a.m. vf. |
| | 4:38 p.m. vf. | | 9:35 p.m. vf. | 7:50 a.m. vf. |
| | 4:44 p.m. vf. | 29 | 1:48 a.m. vf. | 8:59 a.m. vf. |
| 21 | 8:57 a.m. f. Δ^{14} . | | 1:53 a.m. vf. | 9:07 a.m. vf. |
| | 11:22 a.m. vf. | | 2:19 a.m. vf. | 9:28 a.m. vf. |
| | 1:38-2:03 p.m. vf. * | | 2:33 a.m. vf. | 10:01 a.m. vf. Δ^{36} . |
| | 4:19 p.m. vf. | | 2:56 a.m. vf. | 10:15 a.m. vf. Δ^{16} . |
| | 4:20 p.m. vf. | | 3:02 a.m. vf. | 2:16 p.m. vf. |
| | 4:40 p.m. vf. | | 4:11 a.m. vf. | 2:51 p.m. vf. |
| | 5:37 p.m. vf. | | 4:17 a.m. vf. | 5:53 p.m. vf. |
| | 6:22 p.m. vf. | | 4:43 a.m. vf. | 6:38 p.m. vf. |
| 22 | 10:45 a.m. vf. Δ^{22} . | | 6:07 a.m. vf. | 10:43 p.m. vf. |

Teleseism

December 28

| | | |
|----|--------------|---------------------------------|
| eP | 7:59:12 a.m. | Indicated distance 3,440 miles. |
| S | 8:06:23 a.m. | |
| L | 8:10 a.m. | |

Harmonic Tremor

This type of tremor was absent throughout the month.

Microseismic Motion

Microseisms began to increase above normal December 25, reaching maximum amplitude on the 27th. They continued moderately strong during the rest of the month. This increase of amplitude was probably caused by the southwest storm, which was in progress on the 25th, with heavy wind and rain. The wind diminished to normal within a few days; the microseisms continuing strong after the wind had diminished locally.

Tilting of the Ground

By weeks this movement was as follows, expressed as angular change and direction of motion of the plumb line:

| | | | | | |
|----------|-------------|---|-----|---------|------|
| November | 30-December | 6 | 1.1 | seconds | NNW. |
| December | 7-13 | | 0.9 | second | S. |
| " | 14-20 | | 1.1 | seconds | NE. |
| " | 21-27 | | 2.7 | " | SSE. |
| " | 28-January | 3 | 2.2 | " | SW. |

T. A. JAGGAR,
Volcanologist.

