**PREFACE**

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

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

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

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

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

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

The Volcano Letter publications are also available in print:

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

April 2023

# THE VOLCANO LETTER

No. 431—Monthly, Department of the Interior, National Park Service, January, 1936

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

## HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JANUARY, 1936

The top crater and well smoking at 12,000 feet.—December 27, 1935.

**VOLCANOLOGY**

As was anticipated, the operations carried out during the last week of December, 1935, by the bombing of certain selected localities upon the mountain-flank, thus venting the heavily gas-charged lava flowing within roofed tunnels, hastened the conclusion of the Mauna Loa eruption. While the actual bombing took place on December 27 with immediately recognizable results in the form of gushing of aa lava from the channel in the lower flow December 30 to January 2—the forward movement entirely ceased upon the latter date. The most marked features of the period subsequent to the bombing—in addition to the gushing referred to—comprised lateral overflow to northward of the main stream at an elevation of 5,750 feet: and sudden spillings from the medial channel at the front itself. These ranged in width from 50 to 200 feet—and pushed forward at speeds varying between 75 and 1400 feet per hour. The last forward movement ceased during the early morning of January 2 at Long. 155° 21′ west: Lat. 19° 42′ north, at a point 600 feet inside the Forest Reservation Fence. At this spot, a finger of pahoehoe, 50 feet wide, pushed slowly forward and then ceased to move. The great Mauna Loa lava flow had definitely ended.

It cannot be claimed, however, that the eruption has come to a close. During the entire month there has been continued emission of smoke and fume at the rift cone northeast of the summit crater at the 12,000 foot level. As long as this continues there is, undoubtedly, moving lava within deep cracks and the mountain is still in actual eruption.

Routine observation reports of this section during the month were as follows:

January 3 to 5. Fume with vapor at the cone which was heavily encrusted with sulphur. Fume and smoke rising from the cooling flows in various places.

January 10 to 11. A wide band of brown fume-changing on January 11 to a thin, upright column.

January 14. Faint fume visible from Observatory, and again on January 17, rising in a thin dark column in definite puffs, brown in color. Marked increase in fume density on January 18.

January 19. A report from a party of five observers visiting the cone on this date, stated: "Glossy black Pele's tears (droplets of lava spatter) were found on the ground near the trail. The conelet was climbed at the S end of the new crater in the large lava hill. Dark smoke puffed up from the shaft at the bottom of the crater with a purring noise, and spells of greatly increased pressure occurred, when it came with a roar. When the wind veered, the sulphur gas was unbearable. Within the cone there was yellow sulphur and greenish coatings. On the outer flanks the sulphur was brilliantly yellow, especially at the S. The outer lava was warm and brittle."

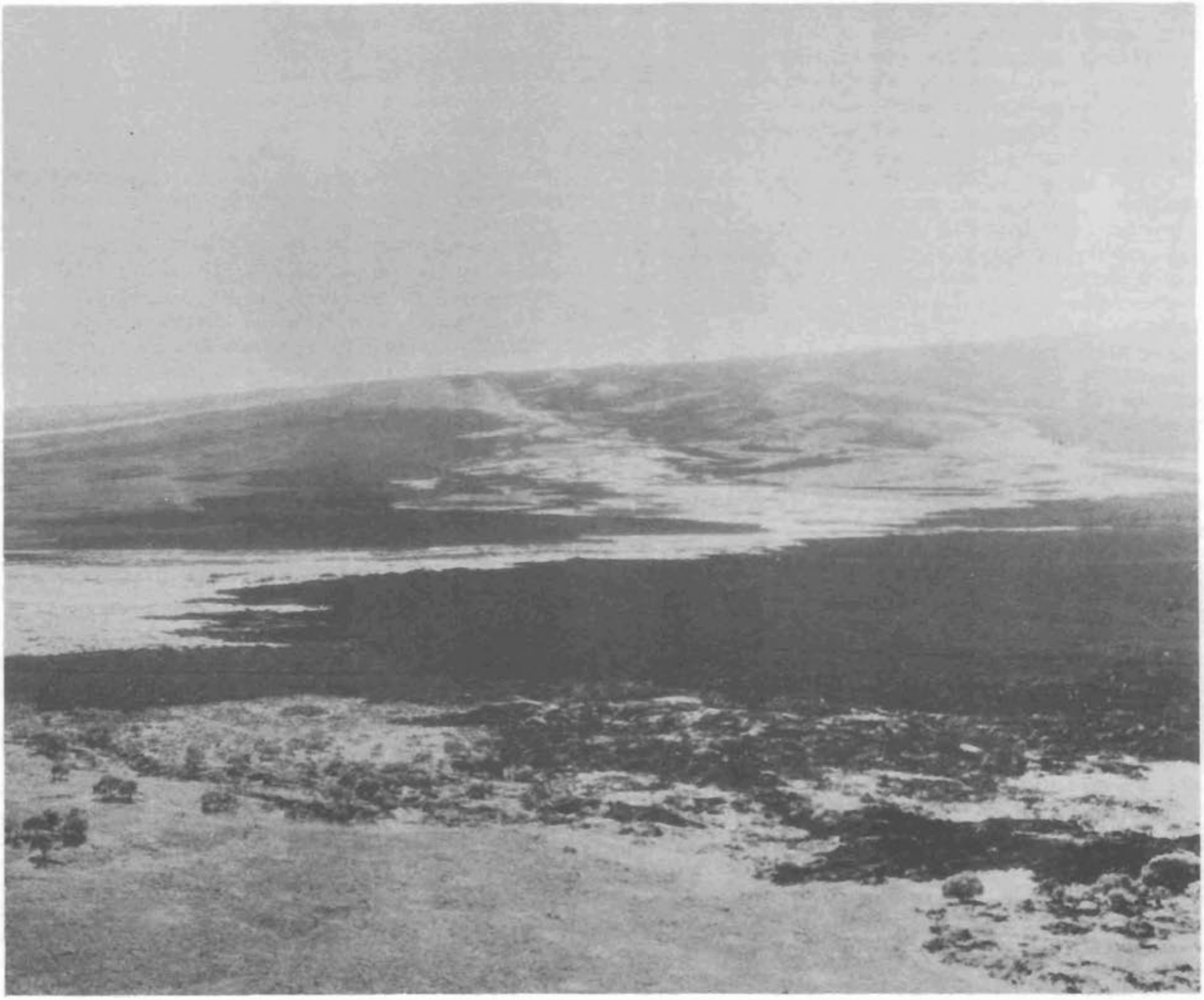
January 26. Fume from the upper rift continues unabated, making a brown cloud—and hangs in the upper atmosphere in thin wisps of bluish-white color.

January 30. The Mauna Loa activity is not yet finished. The rift cone continues to send up jets of sulphur fume showing bluish under overhanging clouds. The mountain above 9,700 feet is heavily covered with snow.

**KILAUEA OBSERVATIONS**

Halemaumau on January 1 showed no sign of fresh slides. Blue fume rose at the yellow solfatara NW. On January 2 and 4 slope gravel was in motion WNW and at the north wall. Unusually dense fume was rising on January 7 at 3:30 pm and avalanche dust was observed on January 9. A slide occurred at the west wall at 9:32 am January 16 and fume from the SE edge of the floor was rising on January 18. In calm weather on January 21, blue fume, mostly from the yellow solfatara NW, filled the pit, producing an odor of spicy sulphur. With a moderate NE wind on January 24-25 the fume was inconspicuous. Earlier west wall sliding, 10 am January 30, developed into a large slide at 11:05 am—followed by another at 11:25 am between the northwest talus and the yellow solfatara. At noon on this date there was an eastern slide and freshly fallen rocks thereafter lay upon the southeast floor.

The lava stream is seen flowing diagonally at upper right.—Dec. 28, 1935.



The target source on the mountain slope.—December 29, 1935

**Crack Measurements**

Measurements of the 32 places marked on concentric cracks around Halemaumau, resulted as follows:

Week ending January 4. 11 opened. 3 closed. Aggregate opening for the week 9.5 mm.

Week ending January 11. 15 opened. None closed. Aggregate opening for week, 13.5 mm.

Week ending January 18. 7 opened. 6 closed. Aggregate opening for week 6.0 mm.

Week ending January 25. 11 opened. 1 closed. Aggregate opening for week 11.5 mm.

Week ending February 1. 7 opened. 4 closed. Aggregate opening for week 6.0 mm.

**Seismic Observations**

During the month of December, there was a total of 196 minutes of tremor and 15 earthquakes were recorded. Of these latter, ten were very feeble, two were feeble, one was slight and two were distant. Local seismicity was 14.5.

The epicenters of local earthquakes were determined as follows:

December 2, at 7:55 am, very feeble, located 13 miles W of the Volcano Observatory and 6 miles S of Puu Ulaula, 19° 26.8' N; 155° 28.0' W.

December 4, at 9:14 pm, feeble, located 1.1 miles deep under Kilauea Crater 0.4 mile E of Pit seismograph station, 19° 24.4' N; 155° 16.7' W.

December 10, at 6:19 pm, very feeble, probable location under Kilauea SW rift 14 miles SW of Pit seismograph station.

December 13, at 9:31 am, very feeble, located 1.6 miles deep and 0.4 mile E of Pit seismograph station. 19° 24.3'N; 155° 16.7' W.

**Seismic Observations**

During the month of January, 138 seisms were recorded of which, 111 were tremors and 27 were very feeble earthquakes.

The very feeble shocks were:

| | | | | |
|---|---|---|---|---|
| Dec. 30 | 1.04 am | Estimated distance | | 12 miles |
| Jan. 2 | 2.47 pm | " | S | 25 " |
| Jan. 3 | 7.34 am | " | " | Uncertain |
| Jan. 3 | 9.41 am | " | " | 20 miles |
| Jan. 4 | 11.44 am | " | " | 14 " |
| Jan. 5 | 10.27 am | " | " | 2 " |
| Jan. 6 | 6.00 am | " | " | 2 " |
| Jan. 7 | 8.06 am | " | " | 2 " |
| Jan. 7 | 11.08 am | " | " | 2 " |
| Jan. 8 | 4.32 am | " | " | 25 " |
| Jan. 11 | 2.14 pm | " | " | 2 " |
| Jan. 12 | 7.54 pm | " | " | 20 " |
| Jan. 15 | 9.59 pm | " | " | 2 " |
| Jan. 16 | 10.15 am | " | " | 6 " |
| Jan. 16 | 1.14 pm | " | " | 3.5 " |
| Jan. 16 | 11.43 pm | " | " | 2.4 " |
| Jan. 17 | 1.11 pm | " | " | 49 " |
| Jan. 18 | 1.45 am | " | " | 62 " |
| Jan. 19 | 11.31 pm | " | " | 24 " |
| Jan. 22 | 5.27 pm | " | " | 20 " |
| Jan. 23 | 5.15 pm | " | " | 2.7 " |

An analysis of these distances shows that shocks recorded at distances up to six miles from the Observatory were under—or adjacent to Kilauea Crater. All others, with the exception of those on January 17-18, being Mauna Loa earthquakes. The increase in recorded shocks from Mauna Loa during the week ending January 5 is indicative of increased friction within the mountain as the internal lava became blocked. Mauna Loa distances for the 1935 vents approximate 19 miles. It is noteworthy that no larger shocks occurred during the month to point to the sealing of the rift and the end of the eruption. Local seismic indices (1), microseismic motion (2), and tilting of the ground at the Observatory for the month (3) were

| Week ending | (1) | (2) | (3) |
|---|---|---|---|
| Jan. 5 | 7.75 | Strong | Slight SW |
| Jan. 12 | 8.75 | Moderate | Moderate E |
| Jan. 19 | 7.50 | Strong to Moderate | Slight SE |
| Jan. 26 | 10.00 | Moderate to Light | Slight SW |
| Feb. 2 | 7.25 | Light to Strong | Slight WNW |

The increase of microseismic motion during the week ending February 2 was coincident with marked barometric depression and unusual cyclonic storm.

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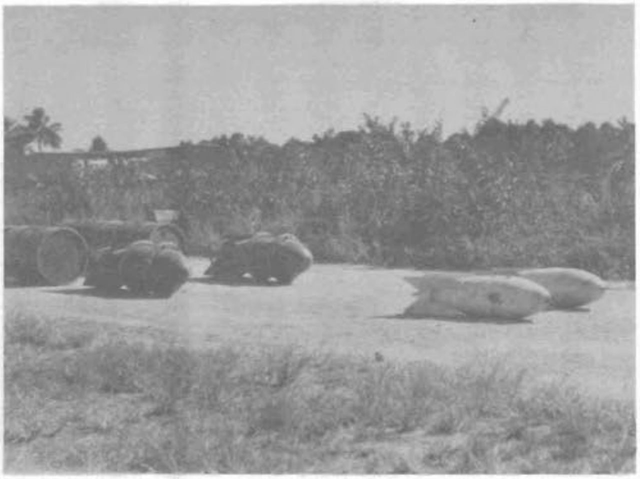
**THE BOMBING OPERATION AT MAUNA LOA**

A brief account of the actual bombing operation—an event that has aroused widespread interest in many parts of the world, will be of interest here. As was stated in the December issue of the Volcano Letter, there was nothing in the earlier phases of the flowing of Mauna Loa lavas to cause apprehension of damage other than to certain sections of pasture lands belonging to ranches situated at relatively high altitudes. Much of the elevated terrain at the junction of the slopes of Mauna Loa and Mauna Kea consists of lava covered land, rocky and sterile, intermingled with grassy pasture areas, not of particularly great agricultural value. As long as the flows were confined—in the main—to this area, they would spread slowly across it and would be harmless. This condition was maintained until the solstice on December 21 when a sudden change took place with the commencement of the draining of a large lake which had accumulated in the saddle between the two mountains. Upon the following day, the pahoehoe lava passed Puu Huluhulu and flowed eastward for more than a mile with a front 200 feet wide, tending to change to aa. The front of this flow almost immediately commenced to pour into a pronounced valley leading directly towards Hilo on the sea coast—and it was speedily apparent that a serious crisis might be developing.

It is of value at this point to recall the three distinct centers of activity: (1) the smoking rift crack at elevation 11,500 feet, beneath which the internal lava was boiling in a pit; (2) the source vent on the north flank of the mountain (some 6 miles north of the upper rift crack) from which the Humuula flow was being fed, and (3) the new activity caused by the draining of the Huluhulu lake. This presented an onward moving mass of clinkery paste carrying huge bowlders upon its surface—consistently fed by glowing torrents that tended to crust over and form roofs—thus creating tunnels from the source downwards and forming a pipe leading down the side of the mountain. Through this tunnel, the slaggy melt was moving—impelled both by gravity and by hot gases expanding within it. Even though there might be breaks, or windows in the roofs of such tunnel

Bomb dropped into flowing channel, throwing molten lava high into the air. The picture shows the wide expanse of Pahoehoe lava in foreground.
—Photo by Maehara, December 27, 1935.



TNT bombs, bomb pointers, gasoline for planes.—Photo by Maehara

systems—these would merely act as flues through which oxygen would be sucked—to unite with the gases and maintain the temperature of the flowing mass. It was through such a tunnel as this that the main stream was now advancing at the rate of more than a mile a day travelling upon a down grade of 157 feet to the mile.

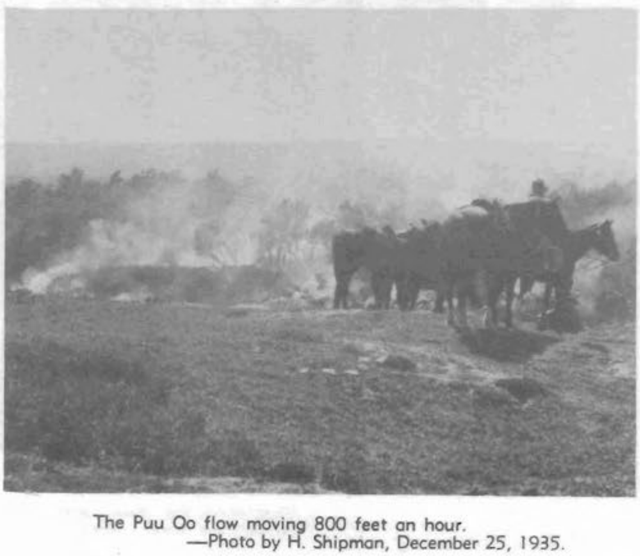
It was abundantly obvious that a continuance of this flow would constitute a danger, not only to the sources of Hilo's water supply—but also the city itself. Even discounting the probability of an acceleration of the rate of travel as the flow reached a steeper grade to the eastward, the front would be in the Kaumana road of Hilo by January 9th, and would have an almost unobstructed path down towards the city upon the seashore. When it is remembered that the flow was spreading out upon flat places to a breadth of 2000 feet it will be seen that the situation had become serious and presented a marked change from the conditions prevailing prior to December 21. It must be remembered also that there were other indications of danger other than those more apparent upon the surface. The structure of the mountain itself beneath the upper layer of surface rock, particularly under the lower levels, is honeycombed with tunnels and tubes of earlier lava flows. That the lava was making its way under the ground through such passages, was evident from the cannon-like detonations that were constantly occurring—hundreds of feet in advance of the main flow. These were due to the penetration of live lava into such tunnels, igniting mixtures of gas and air and shattering the old rock surface.

Under such conditions therefore, it had become imperative to take action, and the volcanologist sought assistance from the United States Army with a view to bombing the source at the 8500 foot level, and by thus breaking up the stability of the flow tunnels to spread and divert the flowing throughout this region.

On December 23, the matter was taken up through Major Hugh Gilchrist, Commander of the Kilauea Military Camp—and an urgent appeal was forwarded by airplane to Colonel Daniel Van Voorhis, Department Chief of Staff at Fort Shafter in Honolulu. The response was immediate. Upon the same day, an army amphibian, carrying a pilot, an engineering officer and a bombing officer was dispatched from headquarters under orders to fly over the area and to report upon return to Colonel Delos C. Emmons, Department Air Officer, upon December 24. Colonel Emmons accompanied by Lieut. Col. Virgil L. Peterson, Commander of the 3rd Engineers flew over the lava flows—and the U.S.A.T. Royal C. Frank was ordered to proceed immediately to Hilo with a supply of 600 lb. TNT high-explosive bombs. It had been decided that the occasion was of considerable urgency and that all possible cooperation should be accorded by the Army. Several reconnaissance flights were made upon this day—accompanied by the volcanologist—the course of the various flows was carefully mapped and a large number of vertical photographs taken in order that the targets might be indicated in the precise localities where bombing would be likely to be of the greatest value. The general situation at this time was that the main easterly flow was twenty miles in length with its front within five miles of the Hilo water supply—and only fifteen miles from the city itself. If it followed the natural contour of the ground it would undoubtedly reach Hilo.

Fourteen army planes arrived from Honolulu during the day and all arrangements were made for the operation, twenty officers and twenty-seven enlisted men being detailed to carry out the details involved. The ships were ten bombardment aircraft, two amphibians and two observation planes. Officer personnel comprised Lt. Col. Duncan, Maj. Lucas V. Bean, Maj. Roscoe C. Winston; Capts. Maurice C. Bisson, Joseph J. Ladd, Lewis R. Parker, Clarence P. Kane, Ford J. Lauer, Charles F. Born, Walter A. Fernander; 1st. Lieuts. Byram A. Bunch, William C. Beard, Charles E. Fisher, William C. Capp, David N. Crickette, Dale E. Altman, N. F. Coddington, Christian H. Clark; 2nd Lieuts. John C. Armstrong and Travis Hatherington. To these gentlemen fell the honor of being participants in the first experiment of its kind in the history of science.

It was decided by Col. Emmons that, owing to their dangerous cargo, the planes would not fly over Hilo, but would head out to sea until the proper altitude had been reached—and then circle in towards the mountain, passing over the sparsely populated Puna section on their way to the saddle land. Arrived over their targets and from a position at least three thousand feet above them—the bombs would be dropped. Arrangements were made for the posting of guards to divert traffic and spectators were warned to keep away from the vicinity. All was now in readiness and, favored by magnificently clear weather, the planes took off early on the morning of December 27. Taking off from the Hilo airport at intervals of ten minutes, seven Keystone bombers were employed, each carrying a pair of 600 lb. TNT bombs and two 300 lb. sighting bombs. The volcanologist, from his chosen post of observation upon Puu Oo Hill, had an uninterrupted view of the entire operation which was spectacular and impressive. Amid the thunder of shattering explosions, masses of rock and sheets of glowing lava were hurled in all directions, many of the great bombs, dropped from planes travelling at high speed, plunging directly into open channels through which molten lava was flowing, while others crashed upon the roofs of tunnels, blowing them open and releasing the melt imprisoned within, causing it to gush upwards and commence spreading immediately.



The Puu Oo flow moving 800 feet an hour.
—Photo by H. Shipman, December 25, 1935.

From the airport, at which interested crowds had gathered, the roar of the explosions could not be heard, but gigantic columns of black smoke, rising one after the other, were clearly seen, the great plumes drifting steadily off upon the prevailing trade-wind. The undertaking was continued until six tons of bombs had been dropped—and was entirely successful, the violent release of gas, of lava, and of hydrostatic pressure at the source, robbing the lower flow of its substance and heat. During the following night, there was greatly increased glare as seen from Hilo—this being occasioned by the draining of the tunnels and overflowing of clogged canals.

On December 28, fresh incandescent streaming was observed about the vent and channel. Thirty-three hours after the conclusion of the bombing, the front of the flow, fifteen miles away down the lava stream in Puu Oo ranch, stopped moving entirely for a half-day. At the lower front there was only side and frontal spilling of viscous channel lava and the total forward motion was approximately 1000 feet, dwindling to 500 feet on December 29. In the pooled pahoehoe lava of the divide at Humuula—fresh puddles of glistening slag were observed welling up through cracks. During the next two days there was slight gushing of aa lava from the channel in the lower flow, but by early morning of January 2 all motion at the front had definitely come to an end and the former crisis had ceased to exist.

Thus, terminated the first experiment of its kind in attempting to curb one of the most destructive forces of nature—and thus also was afforded a happy exemplification of the results that may be obtained by the cooperation of one branch of science with another. It is entirely permissible through the medium of this publication, publicly to acknowledge the high appreciation of the extremely courteous and valuable help rendered by the Army Air Service upon this occasion and to express profound admiration of the almost miraculous accuracy with which the task was performed. That it has aroused world-wide interest is gratifying, for it is obvious that further research along similar lines may prove of incalculable value to those who live in active volcano lands and are at all times under the shadow of possible menace.

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**NATIVE SUPERSTITION**

It may not be out of place as a matter of general interest, to comment upon the reaction of the older generation of native Hawaiians to the bombing of Mauna Loa. For countless generations, belief in Pele—the Polynesian goddess of fire, played an important part in the lives of the Hawaiian people.

Legendary lore is filled with stories of the doings of this mythical deity who lived in turn within the craters of the various islands, forsaking them in succession until she finally established her habitat in the depths of Halemaumau, the firepit of Kilauea—and under Mauna Loa. Indubitably, very many of the older natives still cling to their belief that the fiery floods pouring down the mountain are the visible effect of some insult offered to the dangerous goddess, and many are the efforts made upon such occasions to propitiate her in order that her anger may be stayed. The island of Hawaii, upon which these two great active volcanoes are situated, abounds in legends of Pele, and it cannot be gainsaid that many startling rumors of her appearance in human form in various places upon the mountain sides have been closely followed by lava outbreaks, although this has by no means been a natural corollary.

It was certain that many objections would be raised by older Hawaiians to any project of bombing Mauna Loa lava flows. They maintained that the goddess had her own reasons for being out on the mountain in the midst of her fiery torrents, and predicted dire catastrophe if her plans should be hampered by the unbelieving white man. They recalled an ancient legend of Pele and her bitter enemy, Kamapuaa—who, after many centuries of warfare during which the latter fought Pele's fires with water, endeavoring to drown her—came to an agreement under whose terms the goddess agreed never to destroy lands upon the northern side of the Wailuku river which runs through Hilo—if her enemy would undertake to protect the lands on the southern side from floods. Confident that this agreement would be kept—the Hawaiians predicted that any attempt to bomb the flows would anger the goddess who would immediately vent her wrath upon the city and cause widespread destruction. This feeling was widely shared and considerable strength was given to it by the fact

Illustrating the thick, pasty consistency of the Pahoehoe lava flowing through the forest.—Photo by Maehara, December 21, 1935.

The front dead —January 4, 1936.

that the flows did not immediately stop after the bombing operations. On the morning of December 28—considerable native excitement was caused by an aged Hawaiian who declared that he had seen an immense image of the goddess, with bulging eyes and streaming hair hovering over the flow region.

Perhaps the most interesting, and amusing, reaction was the declaration of an aged native, Keala Nuionaahienaena Kaha Kanianikaipo, more familiarly known as Ben Amina, who described how he, personally, had stopped the flow by direct supplication to the goddess. This gentleman claims direct descent from the goddess herself and his story—as told to the Hilo Tribune-Herald on January 8, six days after all movement of the flows had ceased, is well worth quoting.

"It was like this," he said. "I heard from my friends that the Army planes were going to throw bombs on Mauna Loa on December 27th to stop the flow. I shook my head because I knew Pele's life would be endangered by these bombs. I knew she would become angry and seek vengeance upon us. I was ready to do anything to stop this mad experiment, but my family prevented me. The bombing took place but the lava flow still continued. I was feeling desperate because I knew Pele too well. So, on December 31 at 4:30 p.m. I went up the road with four witnesses, Joe Pacheco, John Medeiros, Tony Reach, and William Rocha, all of Hilo, and gave the Hawaiian prayer which would melt Pele's heart. They were with me all the time I prayed to the fire-goddess.

"I faced the mountain and the huge column of smoke, raising my hand and beseeching Pele to hear my prayer. Then I called to her that I was her descendant who wanted to save my friends and the people of the island from this awful fate. I told her she had had a wonderful Christmas on Mauna Loa and that she was now celebrating New Year's Eve in her home of fire. I begged her to stop the flow on New Year's morning—beseeching her 'Pau, pau, pau (stop, stop, stop.) ' "

He stated that he sat in front of his home all night, keeping a close watch upon the mountain, and praying to Pele throughout the vigil. "At one o'clock in the morning," he said, "just an hour after the New Year was heralded, the mountain grew dark and no light could be seen. Pele had answered my prayer and I am grateful."

Hilo at large heard the news that the flow had stopped, on New Year's Day. Amid the general feeling of relieved tension, old Ben sat and chuckled, convinced that he was the one who stopped it.

Such beliefs may appear strange to those who are familiar with the development and progressiveness of these islands. But they are founded upon centuries of faith in a vast assemblage of gods and goddesses and they do not die out easily.

The man in foreground points with his stick to a place where an explosion from beneath the ground has disrupted the surface. Such explosions were frequent in advance of the flows; were violent and dangerous.
—Photo by Jaggar, January 4, 1936.

ISLAND OF HAWAII
N
S
W
E
156°
155°
20°
19°
Upolu Pt.
AIR PORT
Hoea
Hawi
Honoipu
Kauhola Pt.
Kohala
Niulii
Mahukona Harbor
NORTH KOHALA
Waimanu
Waipio
Kukuihaele Ldg.
Mt. Kohala 4676 ft.
Ka Lae o Mala
Honokaa Ldg.
Honokaa
Paauhau Ldg.
Kaiwaihae
Paauilo
Kukaiau
Kamuela
Parker Ranch
Puako Bay
Waimea Hotel
SOUTH KOHALA
HAMAKUA
Ookala
Laupahoehoe
Waima Pt.
Papaaloa
Ninole
Honohina
NORTH HILO
Hakalau
Hakalau Bay
Kiholo
Lae Mano
Papiha Pt.
1859
1801
MAUNA KEA 13,825 feet
Honomu
Pepeekeo
Alia Pt
Puuanahulu
Puuwawaa
Onomea
Paukaa
Papaikou
Hilo Bay
Keahole Pt.
Huehue
NORTH KONA
MT. HUALALAI 8,269 feet
HILO
Leleiwi Pt.
Puu Oo
AIR PORT
Kaiwi Pt.
Keahuolu Pt.
KONA INN
KAILUA
1843
1881
SOUTH HILO
Keaau
Holualoa
1899
Keaau
Olaa
Kaloli Pt.
Kahaluu
Keauhou
1935
1852
Kurtistown
Mountain View
Keikiwaha Pt.
Kealakekua
Cape Kumukahi
Kapoho
Mokuaweoweo Crater (Active 1933)
Cook's Monument
Kealakekua Bay
Napoopoo
SOUTH KONA
Glenwood
PUNA
Pahoa
Kapoho Pt.
Pohoiki
Volcano House
MAUNA LOA 13,675 feet
Honaunau
CITY OF REFUGE
KILAUEA CRATER
Opihikao
Kealia
HAWAII NATIONAL PARK
Hookena
Kaimu
Waipuku Pt.
Kalahiki Beach
1926
Kalapana
KAU
Kauluoa Pt.
1920
KAU DESERT
Ka Lae Kupapau
Ka Lae a Puki
Kapapala Ranch
1823
Keauhou
Keana Pt.
Alika
1919
KAU FOREST RESERVE
Pahala
Papalehau Pt.
1926
Hoopuloa
1868
Mahuka Bay
Milolii
Palima Pt.
Punaluu
Lae o Puuo
LEGEND
Hanamalo Pt.
Roads
Honuapo
Waiohinu
Honuapo Bay
Trails
1907
Naalehu
Districts
1907
Lae o Kauna
Kahilipali Pt.
1887
1868
0
10
20
Lae o Kamilo
Kaalualu
MILES
Kailikii
Waiahukini
Ka Lae

# THE VOLCANO LETTER

**No. 432—Monthly, Dept. of the Interior, National Park Service, February, 1936**

**Hawaii National Park**
**Edward G. Wingate, Superintendent**

**Hawaiian Volcano Observatory**
**T. A. Jaggar, Volcanologist**

## HAWAIIAN VOLCANO OBSERVATORY REPORT FOR FEBRUARY, 1936

### VOLCANOLOGY

**Conditions at Kilauea**

The month at the Halemaumau Pit of Kilauea produced no notable changes. Conditions were extremely quiet. A moderately heavy slide occurred about February 13, piling fresh debris upon the floor and leaving a scar upon the NE wall. On February 16, the SE wall showed the mark of a slide and rocks were dribbling from the West and NE walls. Some cracks on the floor appeared to be widening. On February 18, rocks were falling from the N wall which appeared dry. Small slides from this wall and the NE wall occurred upon the following day.

**Mauna Loa Observations**

Fume was still rising in puffs from the rift source at 12,000 feet as the month of February drew to a close. As long as this puffing continues it cannot be said that the eruption has ended since it is obviously due to continuance of lava action within the pit from which it comes. From the eastward, or Hilo side, this fume is not often now discernible as it is blown southwestward by the prevalent tradewind. Occasionally however—in still air—more particularly about the time of sundown it may be seen rising as a thin column by observers near the city.

The Observatory upon the rim of the Kilauea Crater, being situated many miles to the south-south-east, is more favorably located and, provided the mountain is unobscured by cloud, the fume may generally be seen. On February 6, it was visible at noon, and on the 9th, it stood as a large yellowish milky cloud about 900 feet above its base. At the base, it was more dense and appeared to be puffing steadily. The mountain was covered with snow at this time and the cold would have condensed water vapor—but there was more sulphur smoke than steam in this cloud. At 5 pm on February 6, an opalescent fume cirrus was left by this cloud in the upper atmosphere: it lay in a sheet to the west of the zenith, bluish in color and with rainbow hues on its edges. On February 10, light fume was visible in the morning, both from Kilauea and from Hilo. A southerly wind on February 14 made brown fume visible all day: a tall, slender brown column was seen at 7 am on February 15, and milky fume against the western sun was reported by a Hilo observer on the following day.

On February 18 the smoking rift cone was visited by Seismologist H. H. Waesche of the Kilauea Station. He reported that, accompanied by D. McClellan he reached the NE cinder cone after crossing lava of the present eruption. "This was found to be black shelly pahoehoe with aa on its outer edges and gave off almost no heat when crossing over it. In fact, in many places, unmelted snow was lying upon its surface. The cone itself was from 50 to 75 feet in height—composed of black cinders and ash—and was about 750 feet in length—with a width, at its base, of approximately 150 feet. No fuming or steaming areas were found in or upon it—but considerable heat, accompanied by the familiar foundry-like odor emanated from the interior. Upon the SE slope and towards the SW end of the cone were areas of sulphur deposits associated with white salts. Two openings in the NW flank—one about the center of the cone's length—and the other towards the SW end had served as outlets for lava flows which had streamed away northwards.

"The SW cone was next visited from its northern side—more of the 1935 lava being crossed in order to reach it. This lava also was black and more or less shelly pahoehoe with occasional patches of aa. It was warm in places but for the main part was cool enough for snow to remain unmelted. Immediately to the NW of both cones there was much pumice and fine cinders—mixed with the rounded glassy droplets known as Pele's Tears and with pieces of irregularly shaped lava glass from one-half to three-quarters of an inch in diameter.

"Immediately adjacent to the SW cone and to the northeast of it was a large spatter cone some 75 feet in height and 100 feet in diameter at its base. From an orifice at its summit a large volume of fume was steadily pouring. With a moderate NE wind it was possible to approach from the northern side. No pulsation in the fuming process was observed—neither was there any marked force in the volume either from the spatter cone or from a cinder cone further to the SW which also fumed steadily. It was possible to reach the brink of the throat of the cinder cone by use of a handkerchief held over the nose. This cone was between 75 and 100 feet high and about 250 in diameter in the direction of the rift. Although in climbing the

Looking NE along former lava stream which originally flowed from SW cone along base of NE cone, February 18, 1936.

cone progress was made over a large snowbank, the cinders underfoot were distinctly warm. The fume clouds were bluish-white in color and the strong odor of $H^2SO^3$ was strong and unpleasant even through the folds of the protecting handkerchief upon which yellow sulphur stains were left where they had been deposited by fume associated with air breathed through the material.

Opening in NW rim of NE cone through which lava stream flowed during activity, February 18, 1936.

"Along the base of the cone and more particularly to the SW, large areas of sulphur were forming and fume was rising from these places and from numerous spots of a similar nature though of smaller size along the flanks of the cone. Where new lava lay beneath such areas it had become soft and of a rotten texture. The largest sulphur deposit was at the SW end of the cone where the latter was superimposed upon the rift, which lay open towards the SW and was emitting steam. There was no sound of internal noises and no vibrations were felt. We crossed the rift to the SW of the cone and made our way back to the trail, passing through moderate fume strongly impregnated with sulphur."

**SEISMOLOGY**

During the month of February there were 12 seisms of which two were feeble earthquakes, nine were classified as very feeble, and one was a record of a distant shock. These produced a total of 89 minutes of tremor. Their distribution was as follows:

- Feb. 4. 2 miles deep: 0.7 miles S of pit seismograph: feeble. A Kilauea earthquake.
- Feb. 5. 21 miles deep: 5.0 miles NW of Puukoli. North slope of Mauna Loa: feeble, but reported felt in Hilo and at Kilauea Military camp.
- Feb. 12. 4.6 miles deep: 1.5 miles SW of pit seismograph: SW rift zone of Kilauea: very feeble.
- Feb. 12. 5.0 miles deep: 0.8 miles WNW of pit seismograph: vicinity of Kilauea Rift Cones: very feeble.
- Feb. 13. 1.9 miles deep: 0.2 miles N by E of KoKoolau Crater: very feeble.
- Feb. 21. 3.5 miles deep: 3.5 miles E of Kilauea Iki Crater: very feeble.
- Feb. 27. 2.8 miles deep: 0.5 mile N of Pauahi Crater in Kilauea SE rift zone: very feeble.
- Mar. 1. Very feeble—located probably in Kilauea SW rift zone about 1.0 mile SW of Halemaumau.

The epicenters of the above local disturbances were determined from the seismograms of instruments operated at stations of the Hawaiian Volcano Observatory. Kilauea earthquakes were located by means of the main station located at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant earthquakes were determined with aid of seismograms from stations at Hilo and Kealakekua. The depth of focus is given wherever possible.

16 minutes of harmonic tremor began recording at 10:19 am on February 13. On February 26, two spells of harmonic tremor were recorded. The first commenced at 2:41 pm and lasted 6 minutes, and the second, lasting 13 minutes, began at 3:08 pm.

The preliminary waves of a distant earthquake began recording at 2:29 am on February 15. Its estimated distance from the Volcano Observatory was 5735 miles.

Microseismic motion was strong February 3 to 9 and on February 29. It was normal February 10 to 12, 15, 19 to 28, and March 1, and light on February 13, 14 and 16 to 18, all dates inclusive.

**TILTING OF THE GROUND**

The following table shows tilt by weeks from seismograms at the Volcano Observatory, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope locations towards or away from the Pit.

| | | | | Stations |
|---|---|---|---|---|
| Week | Observatory | Halemaumau | Clinoscope | Pit |
| Ending | | West | Southeast | Resultant |
| Feb. 9 | 1.31"S.44°W | 8.20"N.34°E | 8.62"S. 7°W | 8.56" * |
| Feb. 16 | 1.46"S.57°W | 2.09"S. 76°W | 5.38"N.57°E | 2.41" * |
| Feb. 23 | 0.87"S.29°W | 3.87"N.43°W | 3.01"S. 81°E | 4.29" * |
| Mar. 1 | 0.80"S.45°E | 3.58"S. 70°W | 7.94"N. | 2.89" † |

*—from. †—toward.

The total accumulated tilt at the Observatory for the year ending March 1, was 0.37"S and 0.40"W.

**RETROSPECT**

Now that the outbreak of Mauna Loa is ended, it may be interesting to look back a few years and compare the precise predictions then made, with what actually happened in 1935. Such retrospection will, at least, show the value of consistent study and uninterrupted compilation and maintenance of record, since—in just the same way as a small

View of Spatter cone and SW cinder cone as seen looking to SW from the NE cone, February 18, 1936.

acorn may develop into a mighty oak, so the true picture of what is likely to occur in connection with individual volcanoes—can only be gained by taking most careful note, through many years, not only of major happenings, but of even the most infinitesimal and, to the layman, seemingly unimportant movements far below the surface of the ground. It is a truism that the most important part of the work of volcanology is the correct interpretation, not of the outward manifestations of an eruption—but of the calm periods when the earth seems to be in a complaisant mood. For it is during such periods that vigilance is most necessary in order that no least movement may be overlooked. The faintest stirring of the calm evening air may be the precursor of the cyclone: the most minute tremor beneath the ground may be the forerunner of increasingly greater movements that may end in a disastrous earthquake, or an eruption with accompanying lava flow.

Spatter cone and SW cone as seen from N, February 18, 1936.

Inhabitants of volcanic lands may be subjected to four different classes of disaster. These are: 1. Explosion and volcanic blast: (2) Lava flow: (3) Earthquake, and (4) Tidal wave. All of these four have happened in Hawaii. There was a great explosive eruption of Kilauea in 1924: Lava flows from Mauna Loa in 1881 threatening Hilo, in 1926, destroying Hoopuloa—and a large number of other flows in very recent years: earthquakes, notably in Kau in 1868, in Puna in 1923 and at Puuwaawaa in 1929: tidal waves in Puna in 1868, and at Hilo in 1877 and again in 1923. As each of these is represented by damage in this century—the topic is a live one.

Speaking before the Hilo Chamber of Commerce on June 9, 1931, Dr. T. A. Jaggar, Director of the Hawaiian Volcano Observatory, called attention to the possibility of disaster to Hilo and urged that precautionary action and organization be taken and established. He said, in part:

"Hilo is peculiar among cities in the world in that it is squarely in a volcanic belt, but happens to have been largely spared until now. So far as strong earthquake is concerned this is equally true of Honolulu, for both of these places are liable to a terrific earthquake, when everybody will be surprised just as the living generation was surprised at Charleston, Santa Barbara and San Francisco. They will be surprised in Hawaii, because the earthquake interval overlaps several generations, and in Hawaii in the 18th century, before the coming of the white man, earthquakes made no impression upon grass houses.

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

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

**"Just at this point could be applied the project to stop a lava flow** advocated by the late honored L. A. Thurston, **and only at this point.**

"No aa flow in its early and rapid stages could be arrested. **A pahoehoe flow in the later stages of an eruption, by reason of the tunnel mechanism, could be blown up at the source tunnel about the nine thousand foot level, or just below the source cone so as to dam the lava stream with rock and force it to start afresh.** The eruption would continue as before, with the lava starting to flow anew out of the blocked channel over the surface of the country by a slightly changed course. If the previous pahoehoe flow took five months to get down near the Hilo level, the renewed flow 30 miles up the mountain would require as much or more, and the city would be given five months respite. The main source would go out of action in that time, and Hilo would be saved.

"If **the 1855 or the 1881 situations were exactly repeated, this diversion of the flow at the source could be done.** It could not possibly have been done for Hoopuloa or Alika. The 1855 flow lasted 15 months, the 1859 flow ten months, and the flow of 1881, nine months. Such durations are quite possible now—for the tunnel flows on the Kilauea floor in 1919, lasted seven months, and so did the Kau Desert flow in 1920. Contemplation of these possibilities is thoroughly sound economics for this community."

The foregoing predictions were made in 1931. Let us, in the light of them, look at what happened in 1935.

On October 1st of that year exceptional Mauna Loa earthquakes were recorded—followed by smaller ones, and by 50 seismic disturbances per week for the first three weeks of November. Warnings were issued by the Observatory that an outbreak along the northeast rift line of Mauna Loa was imminent. At 1:11 am on November 21, a heavy earthquake occurred under this rift line. The quake of October 1 was located at 17½ miles below the surface: that of November 21 was less than 5 miles down—clearly implying a splitting movement from below upward. At 6:25 pm on November 21, another earthquake—followed immediately by smaller ones, occurred, and the people of Hilo looked up and saw the bright light on the northeast rift line. The great lava flow had commenced.

By mid December, the main flow had definitely swung in the direction of Hilo and was headed for the valley of the Wailuku River. It was being fed through a source tunnel at an elevation of 8,500 feet, forking out into many tubes below around the 6,500 foot level, and the danger not only to the water supply of Hilo but to the city itself, was clearly apparent. It was therefore necessary to blow up the source tunnel in order to secure the result whose possibility had been outlined in the speech of 1931. This was done on December 27, with entire success. The details have been fully covered in the January issue of the Volcano Letter.

It was during the same speech in which these predictions, later so accurately borne out, were made, that Dr. Jaggar touched upon the topic of organization for preparedness, in order that, should disaster occur, suffering might be reduced to a minimum. Alluding to the terrific earthquake in the North Island of New Zealand in February of that year, he said:

"Let us look at what has happened at Napier. Wherever you were, in your car, on the road, standing indoors, standing outdoors, suddenly there comes a tremendous crash like an explosion and down you go. Everything goes down, houses,

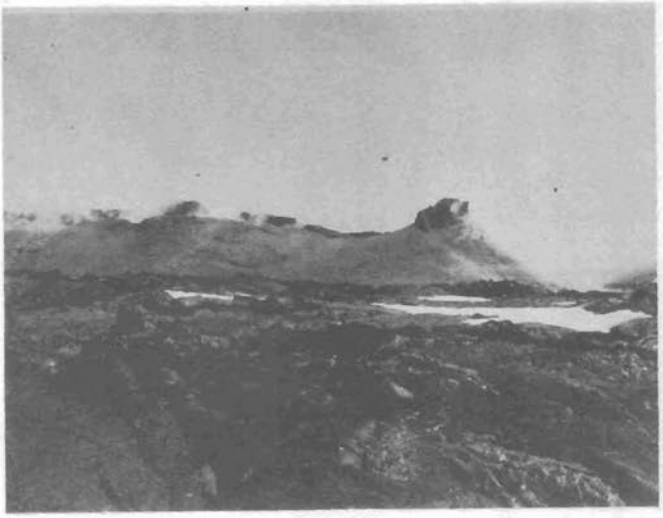
Rift looking SW from SW cone February 18, 1936.

bridges, gulches, cliffs, fires start, road fills crack open, automobiles fall into the cracks, wharves are all down, some of the shipping is grounded, the breakwater has settled out of sight in places. In other words, the enemy has hit Hilo with a Big Bertha. The railway is out of commission, emergency telepones are called for as the wires are all down, the water mains have burst, the sewage is interrupted, the fire engines are pinned in their houses, the roads are interrupted by landslides. More than all, the people are struck dumb with shock, and until a warship arrives, to which this sort of thing is all in the day's work, the population is dependent on whatever leaders happen to be soldiers.

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

"Necessarily the Navy and shipping are of great use, and there were three ships which reached Napier. A small, compact, efficient, relief committee was found to be the first requirement at Napier and the organization of an information bureau to answer inquiries. Within a week when outsiders arrive to bring relief, there is need of quarters to correspond with the destroyed hotel, and there is need of increased wharf facility. Free meals have to be organized with the relief funds. Now there is need for a card record of hospital cases, of which there were 2,200 at Napier. The stoppage of the sewers and the bad water supply made it necessary to get together as many trucks as possible as soon as the road gangs had opened a way to get out of the district, and 5,000 people evacuated from Napier and Hastings to a neighboring town which had not suffered, Palmerston. Palmerston organized itself to receive the transport of refugees. There was an acute clothing shortage, and notices had to be placed in newspapers of other towns instructing the public what to send, for they sent too many groceries and too little clothing. The loss at the central towns was of the order of $15,000,000. Fire insurance was simply not paid, for the situation was just the same as at San Francisco and Tokyo, and companies when they do write

View of fuming SW cone taken from South. Distance about ¼ mile, February, 18, 1936.



SW Cinder cone Mauna Loa eruption of November 1935, as seen from N. February 18, 1936.

risks involving conflagration always reinsure with other companies. Only when earthquake is specified, and fire resulting from earthquake, and when these risks are paid for, can there be any expectation of restoration by insurance. **After the event** in all these cases, San Francisco, Tokyo, and Napier, insurance companies wrote earthquake risks. This is always done without any logic, on the part of the owners seeking insurance, who try to save the horses after the barn is burned down. Then after 45 or 50 years when there is real danger, everybody has forgotten it, insurance has been withdrawn, the building code has been relaxed, and it all happens over again. Such is human nature."

Dealing with the important subject of organization for preparedness Dr. Jaggar said:

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

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

**(1) Discipline and Communication**

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

**(2) Rescue**

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

**(3) Relief**

SW end of cone showing major sulphur forming area, February 18, 1936.

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

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

**(4) Relief Funds**

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

**(5) Refugee Camp**

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

## WHAT MAY BE LEARNED FROM TILT

Tilting of the ground as recorded by the slow and persistent wandering of the recording pens of the seismograph bears an important relation to the whole problem of the movement of lava columns underground and therefore to the problem of forecasting of possible surface outbreaks.

Study of the records made at the Hawaiian Volcano Observatory during many years has shown that tilting away from the pit of Halemaumau has, as a whole, been correlated with rising of the lava column, while tilting towards the pit has usually marked retirement of the lava or has been pronounced 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, however, may not be strictly due to volcanic causes. Changes of temperature in the instrument room itself: of the ground upon which the Observatory stands, or of the face of the cliff near the buildings may produce tilting effect and so account in part for this annual change, though experiments have shown that it certainly is not a purely local movement. Volcanic conditions undoubtedly produce tilt, and these volcanic tilt effects are superimposed upon the tilts produced by other causes.

Quantitative measurements of the uplift and depression of the Kilauea dome have been made upon many occasions by means of precise spirit levels, and horizontal movement detected by a careful retriangulation of a network of stations about the pit also connected by precise levels. Such levels run in 1912, 1920, and 1927 have amply demonstrated the value of spirit levels as a means of detecting even small amounts of vertical displacement. The net of triangulation stations about Kilauea was first established in 1920 and connecting levels were run during the same period. Final adjustment of both surveys by the method of least squares was made by the computing section of the Geological Survey in Washington, D.C.

The resurvey of this net in 1927 and 1928 correlated most satisfactorily in its results with the general breakdown and depression of the Kilauea dome during the seven year period from 1920. Horizontal movement was shown to be a general pull-in of all points towards Halemaumau as a center.

Similar repetitions of surveys have been made upon an extensive scale by the Japanese government in earthquake-stricken provinces, and the area along the San Andreas rift in California has been retriangulated by the U.S. Coast and Geodetic Survey. The results of these measurements, as of those in Hawaii—clearly demonstrate the amount of displacements of the earth's crust which took place during periods of disturbance. Some of these displacements were extremely small and required the most accurate of modern engineering methods to detect: also, the surveys were made after the greatest movement had occurred. But the lesson to be learned is that by applying the same methods at regular intervals it may be possible to predict the likelihood of earthquake—or what more closely concerns us in Hawaii, the rise of the Kilauea or Mauna Loa lava columns.

Rift looking toward SW base of SW cone, February 18, 1936.

The measurements in California or Japan have been concerned partly with earthquakes of tectonic origin, and as these are caused by continued long strain and warping of the earth's crust over a number of years until the breaking point is reached, it follows that periodic surveys of known active fault areas may be of the utmost value, in the prediction of approaching disturbances. Here in Hawaii it would be necessary to correlate such measurements with data from the seismograph or tilt-meter and to continue it through two or more active phases since the actual tilt of the ground from day to day is small and not perceptible except by magnification. However, cumulative tilt is undoubtedly a measurable quantity, and since accumulated tilt away from the Halemaumau pit has been shown generally to precede an active period, it is logical to assume that measurements of the relative change in elevation of established bench-marks together with the measurement of the horizontal angular change between such points would give a more firm basis for prediction.

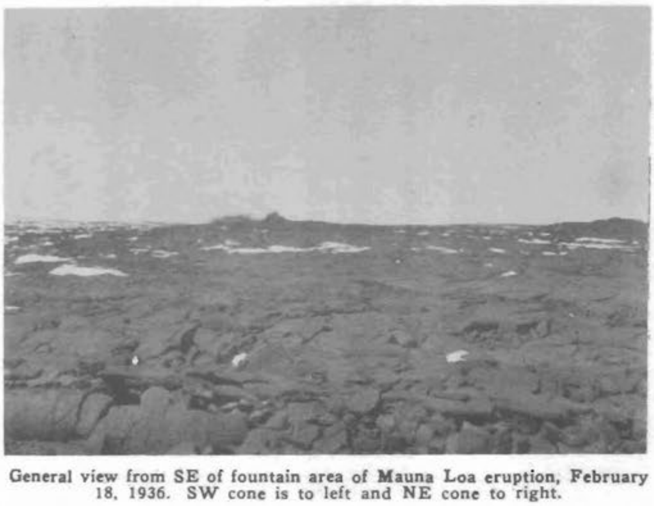
With this end in view, new stations were established about the rim of Halemaumau. One of these adjoins the pit seismograph cellar—the others forming a rough square spanning the crater, and being triangulated for any immediate emergency. Horizontal angles were observed by a repetition with a Berger transit graduated to 20 seconds. Each angle is observed 12 times, six times in a clockwise direction, three settings made with telescope direct, and three reversed, both verniers being read. The angle is then measured in a similar manner but in a counter-clockwise direction, the mean of the 12 readings giving the correct angular value free from instrumental errors. Horizon closures are made the same way. Particular care must be given to the centering of the instruments over their respective marks.

View of SE cone Mauna Loa, February 18, 1936, as seen from S.

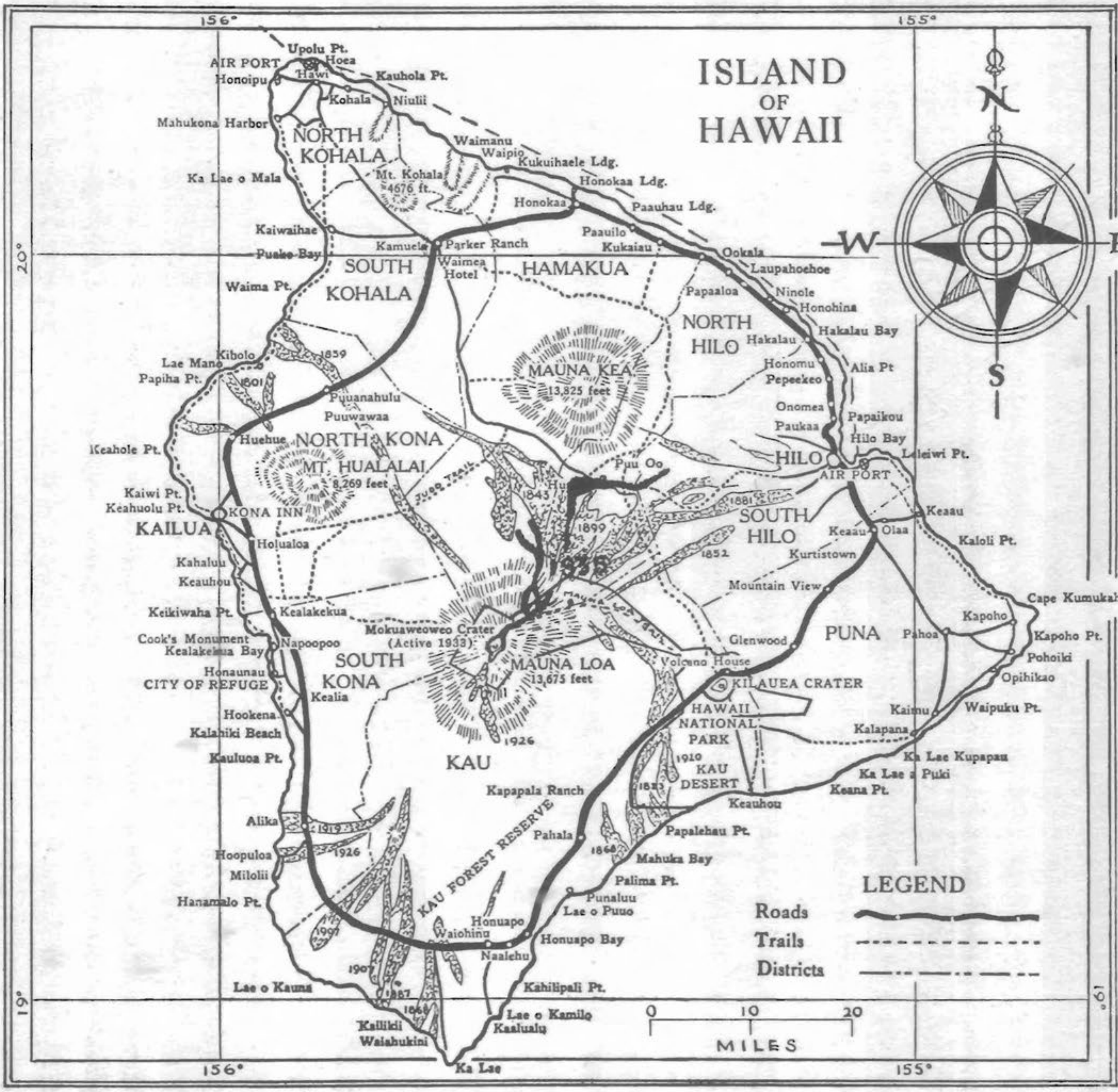
The measurement of rim cracks around Halemaumau has in the past proved of scientific interest, as well as of value to the public in marking off weak or dangerous sections about the pit. This precaution is highly necessary as Halemaumau is the main attraction to all visitors to the Hawaii National Park and is reached directly by automobile from Hilo—the seaport city on the coast at the foot of Kilauea mountain. As one of the world's most stupendous windows into the molten heart of the globe, it attracts thousands of visitors throughout the year, any unusual activity causing an influx of tourists and island people whose safety must be carefully considered.

Measurements of rim cracks however, are not always meticulously accurate, instrumental errors amounting to as much as two or three millimeters having occurred, owing to the uncertainty of exact points of measurement as well as to the inaccessibility of some of these points. Measurements must be made from new points as may become necessary and new methods of measuring must also be devised. Tumescence of the Kilauea dome as the result of rising lava has its effect upon the more deep-seated fractures, the lifting of the lava column upon various occasions causing a widening of the superficial rim cracks with sections breaking off and avalanching into the pit.

But as a part of the complicated, process of volcano study, observation of the tilting of the ground is a highly important factor. E.G.W.



General view from SE of fountain area of Mauna Loa eruption, February 18, 1936. SW cone is to left and NE cone to right.


ISLAND OF HAWAII
N
S
W
E
156°
155°
20°
19°
Upolu Pt.
AIR PORT
Hoea
Hawi
Honoipu
Kauhola Pt.
Kohala
Niulii
Mahukona Harbor
NORTH KOHALA
Mt. Kohala 4676 ft.
Waimanu
Waipio
Kukuihaele Ldg.
Honokaa Ldg.
Ka Lae o Mala
Honokaa
Paauhau Ldg.
Kaiwaihae
Paauilo
Kukaiau
Kamuela
Parker Ranch
Puako Bay
Ookala
Laupahoehoe
SOUTH KOHALA
Waimea Hotel
HAMAKUA
Waima Pt.
Papaaloa
Ninole
Honohina
NORTH HILO
Hakalau
Hakalau Bay
Kibolo
1859
Lae Mano
Papiha Pt.
1801
MAUNA KEA 13,825 feet
Honomu
Pepeekeo
Alia Pt
Puuanahulu
Puuwawaa
Onomea
Papaikou
Paukaa
Hilo Bay
Huehue
NORTH KONA
Keahole Pt.
MT. HUALALAI 8,269 feet
HILO
AIR PORT
Leleiwi Pt.
Puu Oo
1843
1881
Kaiwi Pt.
Keahuolu Pt.
KONA INN
KAILUA
SOUTH HILO
Keaau
Holualoa
1899
Keaau
Olaa
Kaloli Pt.
1852
Kurtistown
Kahaluu
Keauhou
1935
Mountain View
Cape Kumukahi
Keikiwaha Pt.
Kealakekua
Kapoho
Mokuaweoweo Crater (Active 1933)
PUNA
Pahoa
Kapoho Pt.
Cook's Monument
Kealakekua Bay
Napoopoo
Glenwood
Pohoiki
SOUTH KONA
MAUNA LOA 13,675 feet
Volcano House
KILAUEA CRATER
Opihikao
Honaunau
CITY OF REFUGE
Kealia
HAWAII NATIONAL PARK
Hookena
Kalahiki Beach
Kaimu
Waipuku Pt.
Kalapana
1926
Kauluoa Pt.
KAU
1910
Ka Lae Kupapau
KAU DESERT
Ka Lae a Puki
Kapapala Ranch
1823
Keana Pt.
Keauhou
Alika
1919
Papalehau Pt.
Pahala
Hoopuloa
1926
KAU FOREST RESERVE
1868
Mahuka Bay
Milolii
Palima Pt.
Hanamalo Pt.
LEGEND
Punaluu
Lae o Puuo
Roads
Honuapo
1907
Waiohinu
Honuapo Bay
Trails
Naalehu
Districts
1907
Kahilipali Pt.
Lae o Kauna
1887
1868
Lae o Kamilo
Kaalualu
Kaliikii
Waiahukini
0
10
20
MILES
Ka Lae

# THE VOLCANO LETTER

**NO. 433—Monthly, Dept. of the Interior, National Park Service, March, 1936**

**Hawaii National Park**
**Edward G. Wingate, Superintendent**

**Hawaiian Volcano Observatory**
**T. A. Jaggar, Volcanologist**

## HAWAIIAN VOLCANO OBSERVATORY REPORT FOR MARCH, 1936

### VOLCANOLOGY

Activity at Halemaumau during March was marked by increased seismic activity the middle of the month followed by a sudden decrease the latter part. Numbers of slides from rim walls increased as did the size of individual slides. The peak of seismic activity was reached the afternoon of March 12, when three feeble earthquakes within one hour's time shook the Kilauea District. Their location was apparently under the East Rim of the Crater S of Kilauea Iki. The significance of the shocks of the second and third weeks of March and the quiet of the fourth week is probably a sinking of the deep lava under Kilauea as a reaction from similar sinking under Mauna Loa. This period of activity was closed with a feeble earthquake, March 21. Much of the seismic activity of the third week was the result of unusually heavy sliding of Halemaumau walls thus producing a large number of tremors on the Observatory record. Large sections of the NE rim fell into the Pit greatly increasing NE talus accumulations on the edge of the lava floor. A section of the rim bounded on the NE by one of the regularly measured cracks disappeared between March 15 and 22. This was discovered March 22, when making the regular rounds of crack measurements and the SW side of the crack was found to be missing. The distance from the former crack to the previous edge of the Pit was about thirty-five feet. The length of this section may have been two hundred feet. It is interesting to note that this excessive rim sliding is at the NE side of the Pit which is thought to be in the vicinity of the emergence of Crater rifts from the NE. The receding lava column suggested in the review of the earthquakes, may have caused movement in the rift region thus precipitating sections of the Pit walls in this weakened zone. Nearby Crack No. 46 opened considerably. Excepting these two cracks, it was noticed that an abnormal number of other concentric cracks had closed. An analysis of this condition further tends to confirm the supposition that lava was receding below Kilauea and Mauna Loa. Reference to records of 1935, show that heavy sliding occurred during the latter part of March and continued into April and May. At that time the SSW wall of the Pit was in the active center of avalanching. As was true of the same

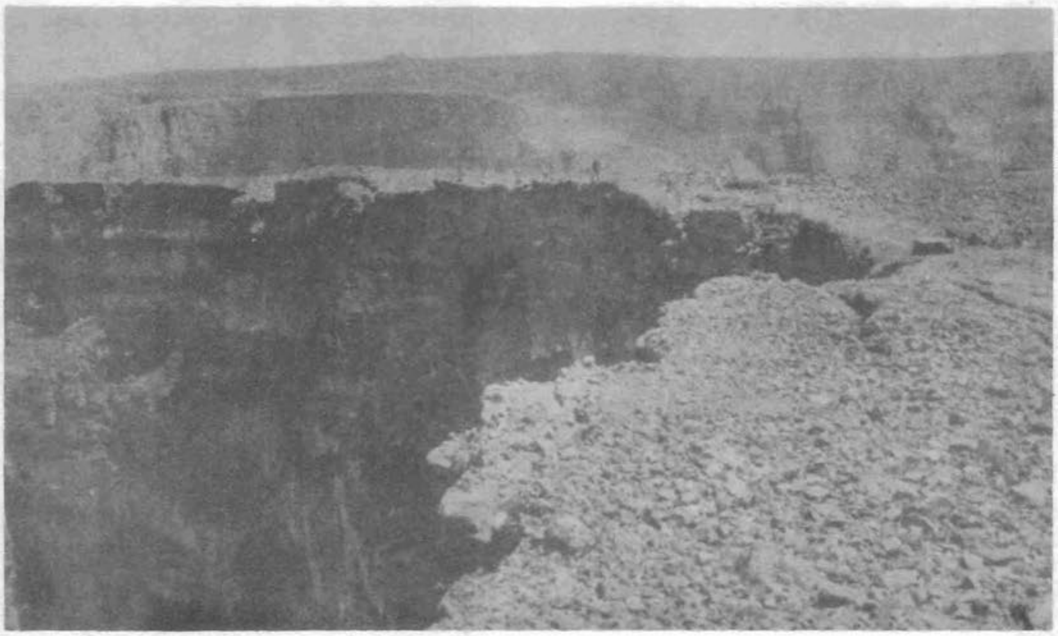


Fig. 1. Section of Rim of Halemaumau showing bay largely formed by the falling of masses of wall rock. Note figure of man for comparison with Fig. 2.

phenomena this past month, last year seismic activity increased in a manner similar to this year because of tremors resulting from heavy rock falls. The 1935 series of slides were to the west of the point of emergence of the Kilauea SW rift at the Pit. The points of greatest avalanching were at opposite ends of the Pit but both were associated by proximity to the main crater rift system. The occurrence of each at approximately the same time of year may be of significance demonstrating possible annual lava movements or pulsations of like nature.

Fume from the yellow solfataras around the edge of the floor of Halemaumau continued emitting bluish fumes with apparently little change throughout the month. Fuming was reported as very light at 9:50 am, March 29. The day was clear and a moderate wind was blowing from the NE.

Fuming of the source cones of the 1935 eruption at 12,000 feet on Mauna Loa has died down considerably as no fume was observed from the Observatory after the first week in March.

The summary of these events in each case tends to show a lowering of the lava column and or pressures under Mauna Loa because of:—

1. Earthquake shocks and high seismicity followed by a sudden drop in seismicity;
2. Slides in Halemaumau from probable lowering of Crater floor;
3. Closing of more than the usual number of cracks and,
4. The disappearance of fume on Mauna Loa as seen from the Observatory.

## KILAUEA OBSERVATIONS

**Slides at Halemaumau**

Slides at Halemaumau have been noted as follows:—

March 7, small slides from N wall at 9:58 and 10:35 am.

March 4, at 9:46 am, small slide from N wall and from fresh dust on floor probable slides from SE and NE wall within last 24 hours.

March 13, fresh scar about 500 feet below NE rim, fresh talus at foot of wall and fresh dust on floor seen at 9:48 am, indicate large slide during preceding night.

March 17, at 10:13 am, slide from NE wall about 200 feet below rim.

March 18, sliding from NE wall noted as follows: loud noise of falling rocks indicating large slide heard at Pit seismograph station at 9:56 am; 10:06 am, small slide; 10:10 am, heavy slide followed by another small one at 10:14 am. A very heavy slide occurred about two-thirds of the way up Pit wall at 3:20 pm. This was followed by a larger one at 3:32 pm, leaving a large apse like embayment at same point as 3:20 slide. Continuous trickle of small rocks interrupted by large sliding bowlders from time to time was observed between 3 and 3:45 pm.

March 19, continuous trickling of rocks from NE wall about 9:30 am.

March 20, much noise and trickling of rocks from NE wall at 9:58 am.

March 22, small slide from NE wall at 9:48 am. Dust cloud over Halemaumau as seen from Observatory at 4:36 pm indicated sliding.

March 23, rocks trickling from NE wall at 9:57 am; noise and trickling of rocks from NW wall 10:05 am; dust clouds at 12:40 pm and 12:51 pm seen from the Observatory indicate moderate slides in the Pit.

March 25, slide from NE wall at 9:40 am.

March 29, small slide from NE wall at 9:50 am.

**Halemaumau Solfataras**

Observations of the sulphurous fumaroles around the edges of the Halemaumau floor, and of the vapor cracks have been as follows:—

March 17, fume very slight, 10:13 am. Weather: light NE wind with rain and high humidity.

March 20, strong fume from yellow solfatara below Tourist Lookout 9:58 am. Lt. SE wind, heavy fog and mist, and high humidity.

March 29, fume very slight at 9:50 am from all solfataras. Weather clear, moderate humidity and wind was moderate NE.

Note:—Weather is an important factor in observations of fume as all the variable factors may influence its appearance so that the same amount of fume may appear different depending upon immediate meteorological conditions. That is to say, that for a given amount of fume, it appears to increase with an increase of humidity which of course increases directly with fog and rainfall. Thus, the greater the percent of moisture in the air, the greater the volume of fume seems to be. The lower the temperature, the greater the fume, and temperature also affects humidity. The lower the temperature the greater the relative humidity. Wind direction and strength will affect air currents in the Pit, thus at times disseminating the fume more or less rapidly as the case might be so that the location of the vent may be protected from the wind one day and not the next. There is always more fume visible on a quiet day than on a windy day. From this it can readily be understood that for comparative results on fume visibility care must be taken to consider weather conditions at the time of observation.

Fig. 2. Detail of condition of rim as shown in Fig. 1, in front of observer illustrating probability of further collapse.

**Measurements of Halemaumau Rim Cracks**

Weekly measurement of 32 marked places on rim cracks around the upper edge of Halemaumau pit resulted as follows:—

| | Opened | Closed | Aggregate Opening |
|---|---|---|---|
| March 7 | 16 | 0 | 21.0 mm. |
| March 14 | 14 | 0 | 54.5 mm. |
| March 22 | 4 | 8 | 6.5 mm. |
| (31 cracks as No. 34 had disappeared) | | | |
| March 28 | 13 | 2 | 14.0 mm. |
| (31 cracks) | | | |

Cracks No. 46 and No. 34 combined, contributed 10.5 mm. of the total amount for March 7, and 47.5 mm. of the total for March 14. As previously stated Crack No. 34 was eliminated by sliding during week preceding March 22.

**Crater Angles**

The horizontal angle measurement across Kilauea Crater and Halemaumau for March 16, taken from the Observatory, compared with similar measurements for February 20, showed closing of the angles in all cases. Between SE and NW Rims of Kilauea there was closing of 4.2". Between the SE and NW Rims of Halemaumau there was closing of 0.8". Accompanying this marked closing of the Crater angles there was much sliding of rock from the walls of Halemaumau.

Fig. 3. Rim Crack #46 at point where weekly measurements are made. This crack has continued opening of 4.5 millimeters per week for the past two months.

**SEISMOLOGY**

**Earthquakes** **Table**

| Week ending | Minutes of tremor | Very feeble earth-quakes | Feeble earth-quakes | Slight earth-quakes | Distant earth-quakes | Local * Seismi-city |
|---|---|---|---|---|---|---|
| Mar. 8 | 31 | 4 | 0 | 0 | 1 | 9.75 |
| " 15 | 22 | 5 | 0 | 3 | 0 | 14.00 |
| " 22 | 52 | 7 | 1 | 0 | 0 | 17.50 |
| " 29 | 26 | 4 | 0 | 0 | 0 | 8.50 |

*—For local seismicity see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station located at the Observatory and the two subsidiary stations located at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant quakes were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and, whenever such determinations were possible, the depth of focus is given.

March 3, at 1:36 am, very feeble, probable location under N rim of Halemaumau, Kilauea Crater.

March 5, at 7:31 am, very feeble, located 1.6 miles deep and 1.8 miles E of Pit Seismograph Station. 19° 24'.4N; 155° 15'.4W.

March 6, at 5:33 pm, very feeble, probable location under SW rim of Halemaumau.

March 9, at 2:15 pm, very feeble, probable location under SE portion of Kilauea Crater.

March 10, at 12:59 pm, very feeble, probable location under E slope of Hualalai volcano.

On the afternoon of March 11, there were three slight earthquakes all of which were sharply felt in the Volcano District by many people. The first one of the series began at 4:15 pm; it was located 1.1 miles deep on the East rim of Kilauea Crater and 0.6 mile S of Kilauea Iki; 19° 24'.5N; 155° 15'.1W. The second shock followed at 4:54 pm, and was located 1.5 miles deep and 0.7 mile S of Kilauea Iki, 0.6 mile E of the E rim of Kilauea Crater; 19° 24'.4N; 155° 15'.0 W. The third shock at 4:55 indicated the same location as the preceding. Very feeble shocks registered on the Observatory seismograph at 4:19 pm and 4:49 pm. They were apparently associated with the disturbances which caused the heavier shocks.

March 21, at 3:50 pm, a feeble earthquake began to record. The probable location was deep under the west slope of Hualalai Volcano.

March 22, 5:44 am, very feeble, located 35 miles under Mokuaweoweo Crater of Mauna Loa. 19° 26'.5N; 155° 35'.8W.

March 23, at 8:19 am, very feeble, probable location, deep under Kilauea Crater.

March 25, at 2:34 am, very feeble, located 3.0 miles deep and 1.2 miles E of Puhimau Crater in SE Kilauea Rift zone. 19° 23'.8N; 155° 14'.0W.

Several spells of harmonic tremor occurred during the month. Sixteen minutes of such continuous tremor began recording on the seismograph at 7:05 am, March 8. Four minutes were recorded beginning at 5:04 am, March 17, and on March 24 at 11:58 pm, an eleven minute spell began, lasting until 12:09 am, March 25. These tremors were similar in every way to those accompanying volcanic outbreaks of Mauna Loa and possibly are caused by lava movements underground.

The surface waves of a distant earthquake began to record at 8:06 pm, March 4.

Microseismic motion of the ground at the Observatory was light March 9 to 11, and 26 to 29, inclusive. It was normal March 2, 4 to 8, 12 to 15, 17 to 19, inclusive and was strong the remaining days of the month. —H.H.W.

**Tilting of the Ground**

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE Rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope locations, towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending March 29, was 3.37"N and 2.88"E.

**Table of Tilt**

| Week ending | Observatory | Halemaumau Clinoscope Stations West | Southeast | Pit resultant |
|---|---|---|---|---|
| Mar. 8 | 2.12"N 77°E | 10.79"N 60°E | 3.58"N 29°W | 2.63"† |
| Mar. 15 | 0.76"N 13°E | 3.73"N 33°E | 1.64"S 64°W | 0.19"† |
| Mar. 22 | 2.84"S 54°W | 24.95"S 37°W | 2.09"S 75°W | 9.35"† |
| Mar. 29 | 0.12"W | 8.75"N 16°W | 7.36"S 89°W | 0.80"§ |

† from § toward.

—H.H.W.

Fig. 4. Cascade of 1934 flow showing conditions prior to the heavy avalanching of 1935.

## A TRIP UP THE 1935 MAUNA LOA FLOW

On the morning of March 1, 1936, Dr. T. A. Jaggar and H. H. Waesche of the Volcano Observatory left Kilauea for an exploration of the Mauna Loa flow of November-December 1935. The objective was to be the source vent at about 8,500 feet elevation on the N slope of Mauna Loa. This locality was of added interest because it was the scene of the bombing operations of December 27. The night was spent in the Forest Reservation west of Puu Huluhulu.

At 8:00 am, March 2, approach to the edge of the flow was made as nearly as possible by car. The weather appeared unfavorable for the expedition as it was raining heavily and there were no signs of a change. To attempt the trip over still warm lava flows would have been dangerous as steam or fog would be created, lowering visibility to a point where travelling would be slow and directions uncertain. This situation caused abandonment of the trip for the day. However, exploration of the pahoehoe in the vicinity about one mile west of Puu Huluhulu was made. From this area, a tongue of pahoehoe, hitherto unnoticed was seen extending about a mile to the west. It had stopped about two miles southwest of Puu Huluhulu and immediately S of the Omaokoili Hills. It was of interest in that this lobe had evidently been stopped by 1843 aa and thus dammed, was prevented from moving farther to the west and consequently caused a filling in of all the low areas of the Humuula Ranch land before finally extending itself eastward and then advancing rapidly toward the upper source of the Hilo water supply. The new pahoehoe, although formed in the third week of December was still warm and in some places quite hot. The hotter spots may have been localities of greater thickness of lava or may have been caused by chemical reactions still progressing, particularly within the remains of buried vegetation. Cooling had contracted the lava so that many cracks had been formed and some were emitting fume or vapor or both which was depositing sulphur and white salts along their surfaces. In some cases the red color indicating selenium was seen. The fuming hot spots seemed to be more common near the edge of the lava bordering the grass lands thus supporting the idea that some of the heat was possibly the result of chemical activity between the lava and covered vegetation. The trace of a former stone wall was crossed. The location of the wall could readily be followed along its former line. In some places this wall had been pushed over by the force of the advancing lava but more often the pahoehoe had frozen on the S side of the wall thus strengthening it so that the lava was either locally diverted or forced to build up to the height of the wall and then cascade over. Where this latter had happened the wall was completely invisible but was marked by a change in the character of the lava along its course. Where the lava had been diverted, the wall was visible on the N but usually buried on the S side. The exploration was continued until the main river channel of the flow was reached about two miles SW of Humuula. It was decided that the frozen surface of this river would make the best path of travel in reaching the source vents and would be so used when the weather permitted. At this point, the river channel was about thirty feet in width and its surface was more or less corrugated as seen in the photograph with the corrugations running in the direction of flowage. As the weather still showed no signs of change, the party returned to the car and back to Waimea Hotel.

The weather seemed very unfavorable again on March 3, so that continuation of the trip was postponed until March 4. On this date however, it was decided to make the hike up the flow even though the weather still was not too favorable. The start was made from an edge of the flow near Puu Huluhulu. The pahoehoe here was the typical billowy type and was comparatively dense so that at no time did it give way under foot as is so often the case with shelly pahoehoe usually encountered near source vents. After walking about a mile the frozen surface of the former meandering lava river was encountered. The river varied in width from a few feet in some places to as much as one hundred and fifty in others. As is true of rivers of water, the lava river was narrower and straighter on steeper grades whereas it meandered and was wider on the more level portions. It had built up more or less natural levees at each side, 5 to 25 feet high, making the flow higher than its surroundings. The pahoehoe on each side of the river was much broken and contorted and in some places the location of the actual river was not identifiable because of the broken condition of the surface of the entire flow. Hiking was comparatively easy. Along the river course there were to be seen interesting peculiarities such as cascades

Fig 5. Talus slopes in Spring of 1935 covering cascade shown in Fig 4.

and as shown in accompanying photograph, the frozen design of a former cascade with a whirlpool at its base. The boundary to the east was either 1935 aa, pahoehoe of the 1899 flow or very old light brown pahoehoe. To the west the river boundary was either 1935 aa or aa of 1843, mostly the latter. The 1935 pahoehoe as seen along the river was either black or bronze in color and billowy as it had been at the start of the hike.

After climbing up grade for about five miles, the slope became steeper. From this point on, the river's course was marked by frequent yawning holes of various shapes and sizes from a few feet to thirty. They connected with a lava tube below. The lava tube was apparently the location of the former very active liquid stream which had fed the front of the flow far below during the height of the activity. Its floor was five to possibly fifteen feet below the surface of the river. Intense heat poured from practically all, making exploration either very difficult or impossible. The holes were the result of the caving-in of weak portions of the tube roof. After hiking about seven miles from the starting point, a place was found where the roof of the tunnel had caved in leaving a pit about fifty feet long and about thirty feet wide. At each end the openings of the tube were seen. The one to the north was too hot to be approached but the one to the south was cool. Camp was made in this cooled portion of the tube. The floor was covered with slabs of material which had fallen from the ceiling. In many places slabby portions of the roof seemed most precariously perched and ready to fall at any minute. Lunch was partaken of and then the hike continued about two miles farther up the flow. A point was reached where the going was difficult as the lava became broken and slabby with many patches of aa. The main source vent was still to be seen between one and two miles farther along. To the SW could be seen fume and steam rising from a distant portion of the 1935 flow. In the immediate vicinity and on up to the main source vent, bluish fume made the air somewhat hazy. It was at this locality that depressions and craterlets showed an interesting variety, showing characteristics of eruptive activity, such as might be caused by bombing and in other cases, collapse seemed to be the cause. In all cases there had been fresh outpourings of smooth pahoehoe as seen in photos No. 1 and 2. No. 2 shows a typical depression and No. 1 shows the downstream flow of pahoehoe which had welled out of the depression. It was at first thought that these might be bomb craters. Later determinations showed this to be incorrect as the locality was not one of those bombed. After abandoning attempted continuation of the exploration for that day because of rain, camp was made in the tunnel at the place previously mentioned. During the night booming sounds with a slight jarring motion of the lava issued from the flow. These were apparently caused by more rapid cooling of the lava at night with consequent shrinkage.

On the morning of March 5, the main lava river was left in favor of a small more easterly arm of pahoehoe which led directly to the lower bombing locality. This locality consisted of a large heap of lava both pahoehoe and aa through which ran a channel, the former path of the main lava stream and the target of the army bombers. The floor of the channel was about thirty feet below the surface and was about fifteen to twenty-five feet in width. Observation of the channel could be made through much elongated openings or windows along its course. Wherever one of these windows was discovered, large amounts of pahoehoe and lava veneer surrounded it apparently having flowed from the vent at a very late period of the eruption. As this region was a part of the bombed area further discussion of its nature will be left to future articles concerning the results and other data related to the unique experiment of bombing a lava flow.

The uneventful hike back to Puu Huluhulu ended a most interesting and profitable trip up the still hot course of the river which fed the main Mauna Loa flow of 1935.

Pahoehoe which had flowed from craterlet of picture below.

**LASSEN VOLCANO — CALIFORNIA**

Attention has been drawn to Lassen Park at this season by the large number of earthquakes recorded in this area. Many of the newspaper reports have been exaggerated and without scientific foundation. Speculation and prediction have been rife and those not familiar with the situation may be led to believe that the volcano is about to burst forth into cataclysmic activity. Under those conditions, an impartial description of the present status of Lassen Peak as a volcano, so far as can be determined from its features and activities, may be of value.

Since the 1917 activity of Lassen Peak, more than thirty constantly active fumaroles have been present on or near the summit. These fumaroles are located in and around the 1915 and 1917 craters and consist of steam issuing from fissures in the dacite. Some $H_2S$ and $SO_2$ gas is present but is usually just barely noticeable. Sulphur deposits are present around some of the vents but there are no evidences of recent sulphur deposition. There are no hot springs, mud pots, or other solfataric features present, and the steam vents may not be noticed by the casual observer, especially on a warm, dry day when the steam is quickly evaporated and dissipated.

Observers in the vicinity of the base of the peak have noticed an unusually large amount of steam coming from these fumaroles this spring. Jets of steam, probably two or three hundred feet high are observed frequently from Manzanita Lake, four miles from the summit. On several occasions clouds, perhaps partly composed of steam, have been seen hovering over the craters on quiet, moonlit evenings. These phenomena have not been unknown in the past, but they are much more frequent this spring.

In an effort to ascertain the cause of this seemingly unusual activity, Park Naturalist Swartzlow and the writer recently climbed to the summit of Lassen Peak. The craters were carefully inspected and special attention was given the fumaroles. So far as could be determined, there are no new steam vents present and the known fumaroles are not emitting excessive amounts of steam. Having inspected the area under various conditions more than 100 times during the past three summers, the writer feels qualified to state that there are no obvious reasons for believing that Lassen Peak or its fumaroles are more than usually active. In fact, on several damp, cold days last season, there was much more steam visible than on the occasion now referred to.

The writer also inspected the hot springs at Bumpa's Hell to see if they were unusually active. They were reported to be excessively violent this year and it was thought that there might be some connection between the recent earthquakes

Showing one of the craterlets.

Cascade and whirlpool in lava river of 1935. Mauna Loa Flow.

and their activity, since they are probably located on a fault which may be active. However, the hot springs, mud pots and fumaroles seemed to be normal in action. Since features of this kind are probably dependent upon surface water, they are naturally more active when the snow is melting rapidly in the spring and early summer than later when the supply of water is small.

The appearance of an unusual amount of steam from the fumaroles this year is probably due to atmospheric conditions. During the past six weeks, the weather has been unusually cold and damp and there has been little wind. Such conditions prevent the rapid evaporation and dissipation of steam and increase its visibility so that the normal quantity appears much greater.

One cannot say that Lassen Peak will not erupt tomorrow because no one can see what is transpiring below the surface and our seismographs are poor indicators of subterranean activity. However, there have been no surface indications that any unusual activity is present or is about to begin.

— By Russell Farmer, Ranger Naturalist.

**HOW TO MAKE A SIMPLE SEISMOGRAPH**

From time to time the Hawaiian Volcano Observatory receives inquiries from students and other interested persons upon the method of construction of a simple earthquake-recording instrument that—while not possessing the refinements and high magnification common to costly apparatus, shall, nevertheless, show practical results for ordinary purposes of daily observation.

Since such inquiries have become increasingly frequent during the past few months and it has been impossible to reply to all of them in full detail—we here present a brief working plan from which, with a little patience and ingenuity, a satisfactory seismograph may be constructed, using only the most simple of materials and avoiding the necessity of outlay upon expensive equipment.

The seismograph in most common use is a horizontal pendulum. Figure 1 shows the hanging part of such a pendulum which anyone can make for himself. There is here shown a clock on the wall which is a good timepiece made by the Howard Company in Boston, Mass. This is fitted with electrical contacts closing the circuit of a four-cell dry battery for about

Lava river of 1935. Mauna Loa Flow.

Looking upstream. 1935 Mauna Loa Flow.

two seconds every minute and about six seconds every hour. It is a weight-driven pendulum regulator with eight-day movement. The electrical contacts on the minute and hour are for marking the time continuously on the smoked paper which covers the drum of the seismograph, so that any hour or minute may be identified on the paper for discovering the time when an earthquake has marked the paper.

On the left is shown a concrete post in a basement room with an upright hollow or groove cast at the bottom where the post rises from a concrete table or pier. It is better to have the cylinder as shown hanging from an isolated post than to hang it from the wall. We have tried both plans for indicative of what the actual ground is doing under the whole country, and therefore is measurable for the particular two directions in which a single horizontal pendulum swings.

The dimensions of the cellar shown in the picture are ten by ten feet, and the general plan of the instruments followed the lines of the Omori seismograph. The concrete post, ten by ten inches square, stands 27 inches high above the pier which is 18 inches high above the floor and two feet square. The cylinder consists of a cast-iron container holding nine circular lead discs, which make the whole weigh 225 pounds. The lead discs are each bored and threaded in the center to take a large screw-eye, so that the container can be handled by one

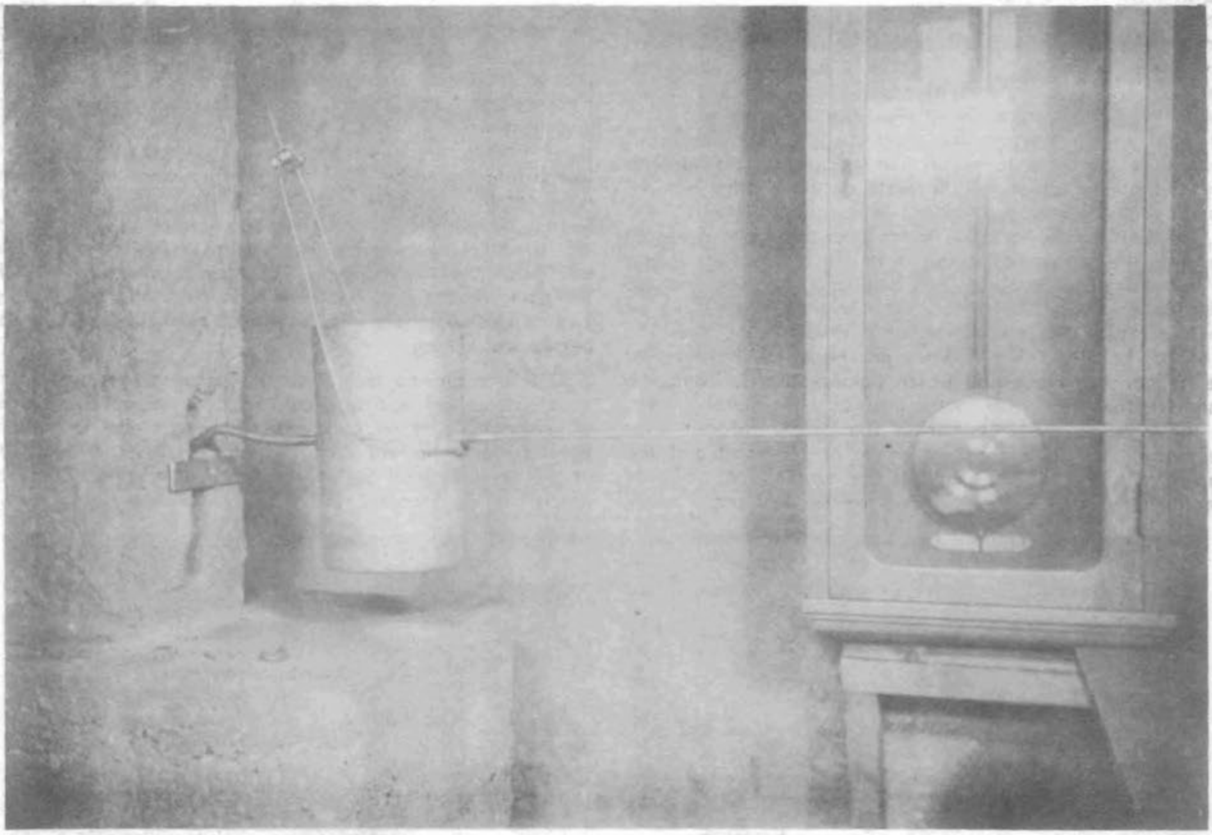


Fig. 1. Showing concrete pier and post—heavy mass suspension and boom and the Howard Clock.

different instruments at the Hawaiian Volcano Observatory. As the hanging cylinder is very sensitive to the slightest tilt given to its supports, walls are not desirable. The upper part of the concrete wall of a cellar on the outside of the building is heated by the sun for some parts of each day. The heating expands the wall and it cools at night, thereby contracting. The seismograph is so sensitive, magnifying earth motion some two hundred times in case of a horizontal displacement, that the distortion of the wall under expansion and contraction will cause the writing pen to swing sidewise an inch or more in the course of a day. This causes the lines to interfere and interlace with each other. A certain amount of normal tilting of the ground is to be expected in the course of each day anywhere, and it is likely to be exceptionally big at an active volcano. Therefore we do not want any tilting due to solar heating of the house. What tilting we get, measured by the swinging apart or the close approach of the lines, should be man by lifting the discs out or putting them in separately.

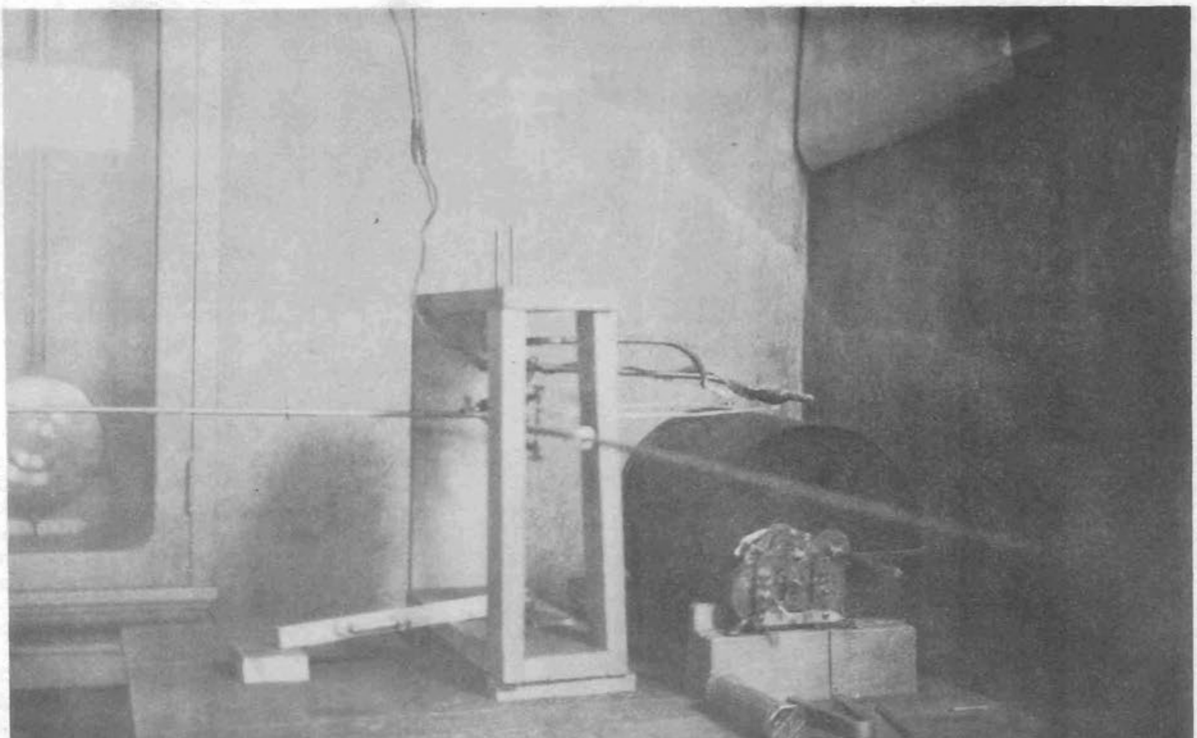
An iron rod, bigger near the post, and smaller at its outer end, passes horizontally through the middle of the heavy mass or cylinder. This protrudes 52 inches from the center of the cylinder. The bit end of the rod is bent and lies in the niche at the base of the post, supported by a short hinge of spring-steel wire. This wire hinge is terminated by metal balls in two slots cut with a hack-saw. One of these slots is in the flat iron strap shown pinned across the niche, the other in the bent end of the rod. The heavy cylinder is supported by a stirrup hanging from a piano wire which is made fast to a simple adjustable bolt in two angle irons pinned to the top of the concrete post. For these attachments to the post it is convenient to use expansion bolts, which are readily put in holes drilled in the concrete. The adjustments of the upper attachment of the piano wire permit of winding it up to lift the mass, and of moving it right and left to bring the outer end of the rod or boom to a medial position.

From all this there results a mass hung like a door with a boom protruding out from it, designed to record those oscillations or tilts of the earth at right angles to the plane of the suspension. The boom is braced by fine steel wires extending from its outer end to the cylinder. If the boom points to the east, the inertia of the mass registers the north-south earthquakes. Another similar pendulum is hung north-south to record the east-west components of the motion. Under each pendulum the system is damped, or prevented from free swaying on its own account, by sheet-aluminum vanes attached to the boom, protruding downward into a metal tank of automobile oil, so that with swinging of the pendulum, the vanes move edgeways in the oil. The little oil tanks, four or five inches square, not shown in the illustration, are supported by a removable stand in front of the pier.

The registering mechanism is shown in Figure 2. The recording drum is built on a steel spindle threaded with ¼-inch worm at the end away from the drive clock. This moves the drum lengthways in a sleeve at the driving end. The drive-clock is a Seth Thomas two-barrel power movement with rotation of spindle once in 30 minutes. The inner sleeve of the drum is set by a screw on the clockwork spindle. The worm end of the drum spindle rests on knife-edge wheels. Glassine paper is wrapped around the drum, pasted at the ends, smoked over a kerosene lamp, and the drum is set in place with the set-screw locking it to the clock. The writing lever-pen from the pendulum has a hinged stainless steel tip which rests on the smoke surface. The lever pens are made of aluminum. They are pivotted about a vertical axis near the end of the booms. The pen tips and the levers have pivots made of standard clock and watch balance staffs. Motion is transmitted from the boom to the lever by light metal T-bars, with the ends of the cross-bar in the boom and the lever respectively. The drum ends are made of ply-wood and the surface of pasteboard. The pen tips are magnetized, lifted to make a gap in the written line on the smoked paper every minute by an electro-magnet connected with the time-piece on the wall. The drum surface moves 30 mm. to the minute. The static magnification of the boom is five and of the writing lever forty, making the total 200. A marker pen attached to the plate supporting the drum and lever system, is made to write a line for a few minutes once a day on the side of the smoked paper, to be used as a datum line for measurement of wandering of the pendulums under tilting of the ground.

The free period of the pendulums is adjusted to seven seconds by moving the upper support of the piano wire in and out from the posts. The pen tips are laid back with a horseshoe magnet when the drum is changed. The change of paper is made once a day and the seismogram removed is passed through a bath of very dilute shellac and denatured alcohol, which fixes the smoke image of the line written by the pens. In the second photograph there is shown the second boom vanishing into the foreground, connected with the second pen by its T-bar impinging on an angle piece in the lever at right angles to the lever. In this way both pens, north-south and east-west, write during the day bands of lines side by side on the same paper. The paper is 12½ by 38 inches. Each line is interrupted by its minute and hour marks, the operator indicates the time of the starting mark by scratching it in the smoke, and simple counting for the succeeding hour marks on the smoke is all that is needed for timing an earthquake autograph that may appear. The light pasting of the ends of the paper on the drum is easily separated by a slender paper-cutter. The seismogram is dated and marked with its location before shellacking.

It will readily be seen from this account that any amateur with mechanical aptitude can build for himself a sensitive seismograph, and he can learn all about the technique of the science if he will consult the back files of the Bulletin of the Seismological Society of America, the headquarters of which are at Stanford University, California.



Feb. 2. Recording end of simple seismograph, showing booms of both north-south and east-west pendulums, pivot connections with writing levers, straight-wound electric magnet for marking time and the driving clock and drum, the latter with smoked paper.

# THE VOLCANO LETTER

No. 434---Monthly, Department of the Interior, National Park Service, April, 1936

Hawaii National Park
Edward G. Wingate, Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar, Volcanologist

## HAWAIIAN VOLCANO OBSERVATORY REPORT FOR APRIL, 1936

### HAWAIIAN VOLCANO OBSERVATORY

A signal honor was conferred upon Director T. A. Jaggar early in the month in the form of an invitation from the Royal Society of London, England, to assist a scientific party it was sending to the island of Montserrat in the British West Indies to study an alarming earthquake crisis in progress there and to make necessary preparations for the protection of the population in the event of a possible volcanic eruption upon that island.

Permission was secured from the Secretary of the Interior and Dr. Jaggar sailed from Hilo on April 11 to connect with a vessel from Honolulu a week later, expecting to be away for at least two months. A complete report of this expedition will be published in a later issue of the Volcano Letter.

While in Honolulu, Dr. Jaggar delivered an illustrated lecture upon the recent eruption of Mauna Loa and the successful bombing experiment. The attendance was so overwhelming that many hundreds of people were unable to obtain admission and

Seismograph Hut southeast of Halemaumau. Thermometer shelter, rain gauge, bench mark, trig station, and in the hut both tilt-meter and two-component seismograph. Shows T. A. Jaggar, volcanologist, and H. H. Waesche, seismologist.

the lecture was accordingly repeated a few days later—also to a capacity crowd.

With Assistant Geologist Waesche absent on annual leave to the Orient, the Observatory was reduced to a skeleton staff and no more than usual routine operations could be carried out. These consisted, in the main, of the care of the seismographs with changing of the records: measurement of rim cracks and tabulation of all changes—and the usual compilation of meteorological data. The weekly reports, reading and study of the seismograms, preparation of other data and all correspondence were handled by Superintendent E. G. Wingate.

Repair and boxing of seismograph parts for transmission to Lassen National Park and the University of Hawaii was attended to during the month.

## MAUNA LOA OBSERVATIONS

With Kilauea remaining quiet, attention was concentrated upon Mauna Loa throughout April. Blue fume rising from the source region of the recent eruption was plainly visible under favorable atmospheric conditions. Towards the latter part of the month, fume was observed in increased volume and density. A Navy aviator reported the source cones as smoking profusely and covered with brilliant sulphur deposits.

On the night of April 28 there were many unconfirmed reports of activity at the source cones—but since the seismographs indicated no activity at this time, it is probable that the reports owed their origin to the reflection of a brush or cane fire upon an overhanging blanket of cloud.

There was, however, some indication of increased activity during the week ending April 26th. This consisted largely of tremors—of which several were noticeable for their duration. Three spells, occurring on April 20, were of 12, 18 and 25 minutes duration respectively.

On April 15, a slight to moderate earthquake occurred at 8:28 a.m. It was felt more or less strongly in the Kilauea section—also at Olaa Village near Hilo, and at Hookena in South Kona on the west side of the island. It was sufficiently strong at the Kilauea Observatory to dismantle the east-west component of the Bosch-Omori seismograph—but no reports of damage were received.

Review of the seismograms from the Hilo, Kona and Kilauea stations indicated the epicenter as east of the summit crater of Mauna Loa and south of the recent eruption source about 15 miles from the Observatory. All other earthquakes occurring during the month were classed as very feeble or feeble.—E.G.W.

## TABLE

**Earthquakes**

| Week Ending | Minutes of Tremor | Very Feeble Earth-quakes | Feeble Earth-quakes | Mod-erate Earth-quakes | Distant Earth-quakes | Local* Seismicity |
|---|---|---|---|---|---|---|
| April 5 | 41 | 5 | 0 | 0 | 2 | 12.75 |
| " 12 | 28 | 3 | 0 | 0 | 0 | 8.50 |
| " 19 | 18 | 7 | 1 | 1 | 1 | 12.00 |
| " 26 | 86 | 6 | 0 | 0 | 1 | 24.50 |
| May 3 | 20 | 3 | 0 | 0 | 0 | 6.50 |

Epicenters of the following local disturbances were determined by means of seismograms from the station operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant quakes were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and, whenever such determinations were possible, the depth of focus is given.

April 1 at 11:13 am, very feeble, probable focus in vicinity of Cone Peak, about 1.6 miles SW of Pit seismograph.

April 4, at 4:24 am, very feeble, located 2.5 miles deep under SE rim of Kilauea Crater and 0.8 mile SW of Keanakakoi Crater. 19° 23.9′ N; 155° 16.4′ W.

April 5, 9:31 pm, very feeble, located 1.1 miles deep and 2.0 miles SE of the Volcano Observatory under S edge of Kilauea Iki. 19° 24.6′ N; 155° 18.4′ W.

April 9, 10:40 am, very feeble, located about 8.0 miles deep off the Hamakua Coast in the vicinity of Pepeekeo. 19° 49.5′ N; 155° 5.5′ W.

April 10, 7:21 am, very feeble, probable location under Kilauea Crater.

April 11, 9:50 pm, very feeble, thought to be located in vicinity of Pahala.

April 13, 6:46 am, very feeble, located 1.6 miles deep and 1.8 miles S of the Observatory under SE rim of Kilauea. 19° 24.4′ N; 155° 15.8′ W.

April 13, 6:59 pm, very feeble, probable location 1.5 miles SW of Pit seismograph in Kilauea SW Rift zone.

April 14, 2:13 am, very feeble, located 1.8 miles deep and 1.0 mile NE of Pit seismograph. 19° 24.8′ N; 155° 16.3′ W.

April 15, 6:03 am, very feeble, located 0.6 mile under Kilauea Crater and 1.4 miles SW of the Observatory. 19° 25.2′ N; 155° 18.7′ W.

At 8:27 am, April 15, a moderate earthquake occurred which was generally felt on the Island of Hawaii. Definite reports were received from Olaa, Hookena and the Hamakua district. It was felt rather strongly in the Volcano district. The east-west component of the Observatory seismograph was dismantled. Its origin was determined to be 18 miles under the SE portion of Kilauea Crater. 19° 24.0′ N; 155° 15′ W.

A feeble earthquake which occurred at 12:30 pm, April 15, was located 8.0 miles deep and 3.8 miles SSE of the Pit seismograph under Pali Kalanaokuaiki.

April 15, 6:47 pm, very feeble, located near the surface of Kilauea Crater floor and 0.7 mile ENE Pit seismograph. 19° 24.6′ N; 155° 16.4′ W.

April 16, 3:38 pm, very feeble, probable location under NE section of Kilauea Crater.

April 17, 7:44 pm, very feeble, located 0.9 mile deep under Kilauea Crater and 0.4 mile N of Keanakakoi Crater. 19° 24.6 N; 155° 16.0′ W.

April 20, 1:24 pm, very feeble, probable location about 1.0 mile SW of Volcano Observatory in Kilauea Crater.

April 23, 1:08 pm, very feeble, probable location 0.9 mile W of Pit seismograph in Kilauea SW Rift zone.

April 25, 3:11 pm, very feeble, located 1.1 miles deep and 2.0 miles SE Pit seismograph in the vicinity of Ahua Kamokukolau. 19° 22.0′ N; 155° 15.7′ W.

April 26, 9:22 am, very feeble, located 8.5 miles deep and 1 mile SE of Makaopuhi in Kilauea SE Rift zone. 19° 21.5′ N; 155° 10′ W.

April 27, 3:47 am, very feeble 8.0 miles deep under ocean floor 5 miles NW of Hoopuloa. Reported felt at Hoopuloa. 19° 15.5′ N; 155° 57.4′ W.

April 29, 8:29 am, very feeble, probably located 2.0 miles SW Pit seismograph in Kilauea SW Rift zone.

May 2, 7:09 am, very feeble, probable origin under Mauna Loa SW Rift about 8.0 miles from summit.

Spells of harmonic tremor began recording at the Observatory as follows: March 30, 4:46 am, for a duration of 17 minutes; April 5, 11:22 pm, 4 minutes, and on April 20, at 5:00 am, 9:30 am, 1:21 pm, 1:26 pm and 6:24 pm for 25, 5, 3, 14, and 11 minutes respectively. This represents the greatest amount of harmonic tremor within the same time limits since the first three days of the Mauna Loa eruption in November, 1935.

Microseismic motion of the ground at the Observatory was

* For local seismicity see Volcano Letter 371.

strong April 6 and 7, it was moderate March 30, April 5, 8, 9, 14, 15, 17, 18 and April 27 to May 3, inclusive. The remainder of the month it was light.

Four teleseisms, or distant earthquakes, were recorded during the month. Preliminary waves began to register at 3:51 pm, March 31, for the first of the series. The origin was 5380 miles from Kilauea. The reported location was 46 miles below the ocean floor, N of the Celebes Island. 2.5° N; 123.5° E. The secondary waves of the second teleseism began recording at about 8:30 pm, April 1. Its location was undetermined. The preliminary tremors of a teleseism began recording at 6:47 pm, April 18. The estimated distance from the Volcano Observatory was 3745 miles. The reported location was in the vicinity of the Solomon Islands. 9° S; 15.6° E. The secondary waves of the last recorded teleseism of the month began at 1:01 pm, April 23. The reported location was in the vicinity of the Aleutian Islands. 50.5° N; 17.8' E, 62 miles deep. H.H.W.

**Tilting of the Ground**

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Hale-

Measuring a crack locality on Halemaumau rim with steel tape over permanent metal studs in the rock.

maumau the algebraic sum of radial tilts for two clinoscope locations towards or away from the Pit.

At the Obseravtory the total accumulated for the year ending May 3 was 4.13″ N and 2.66″ E.

**TABLE OF TILT**

| | | HALEMAUMAU CLINOSCOPE STATIONS | | |
|---|---|---|---|---|
| Week Ending | Observatory | West | Southeast | Pit Resultant |
| April 5 | 0.76″S 70°W | 2.62″N 42°W | 2.66″S 5°E | 3.59″ from |
| April 12 | 0.60″S 47°W | 3.87″S 85°W | 9.72″N 2°E | 3.58″ toward |
| April 19 | 1.50″N 14°E | 1.49″N 48°W | 6.16″N 24°E | 2.04″ toward |
| April 26 | 2.48″S 66°W | 6.38″N 20°W | 5.22″S 55°W | 1.49″ from |
| May 3 | 1.10″ N 66°E | 4.41″N 74°W | 6.54″N 9°W | 1.66″ toward |

H.H.W.

## UNIVERSITY OF HAWAII SUMMER SESSION

The Summer Session of the University of Hawaii this year changes its Volcano School to a program of research only. This is in charge of Dr. Thomas A. Jaggar, Professor of Volcanology in the Graduate Division. As volcanologist in the national park Dr. Jaggar has developed a number of experimental problems during the last twenty-five-years. One is the location underground of earthquake centers, produced by some kind of impact or jolt. Another is the possible gradual change, or sudden change, from time to time, in such gases as those at the Volcano House sulphur bank. Both of these things, if measured and interpreted promptly, and more accurately, may indicate the coming of eruptions. The foretelling of eruptions is one important result of volcano study.

Accordingly in August, two investigators from the Physics Department of the University will start using new instruments at Kilauea. The shops of the Volcano Observatory have been renovated for their use. A University Laboratory has been arranged in a special building. The workers are Assistant Professor Stanley S. Ballard, specialist in spectroscopic work, and Instructor Iwao Miyake, skilled in electrical instruments.

Dr. Ballard will collect the Sulphur Bank gases, and also the gaseous products in Kilauea Crater at certain localities. The collection will be with pumps and tubes specially designed to exclude outside air, which tends to be sucked in when steam condenses in ordinary vacuum tubes. The object is to design field apparatus which will be effective in retaining pure volcanic gas, after collecting such gas not only at solfataras, but even at flame vents in lava where gas is burning. There is no such lava available now, but many experiments may be made in preparation for such active periods as last December. The tubes of gas will be carried back to Honolulu laboratories. There the gas will be carefully subdivided into numerous samples for use in discharge tubes, in partial vacuum, illumined by an electric discharge. These will be photographed for the spectrum of rare gases. This work is done with a large quartz prism spectrograph.

It is planned to make negatives of numerous gases, and if results are satisfactory, to establish a new routine at the Observatory. This will consist in collecting the gases at regular intervals and sending them to Honolulu to see if there is any change. It is also hoped to obtain for the Observatory a small model spectrograph which may perhaps be used in the field for direct recording of gases. The object of all the work is to start a movement for more precise use of the spectroscope in volcanology.

The work of Mr. Miyake is based on experiments started more than a year ago under the direction of Assistant Professor Willard H. Eller at the University of Hawaii. His experiments were designed to record the exact time in fractions of a second of blasting explosions at Moiliili quarry. Then an electrically equipped seismograph was set up at the Physics Laboratory some distance away recording the exact time that the earthquake shock from the explosion reached the University. According to the difference in times of the quarry measurement and the university measurement, the rate of travel of the earth wave could be discovered. Mr. Miyake has been improving the apparatus for doing this kind of exact work electrically.

It is now proposed that he bring his apparatus to the Volcano Observatory where thirty or forty actual seismic disturbances occur every week. The seismologic work of the earthquake investigators at the Observatory has taught how to locate earthquake centers approximately. We need to know exactly how fast and in which direction the earth waves travel for a Mauna Loa earthquake, a Kilauea earthquake and others. It may be possible with simple apparatus buried in the ground to compel an earthquake wave passing a place five miles away to send a wireless message to the Observatory and record its time on an Observatory chronograph. If the same earthquake when it reaches the Observatory makes another record on the same chronograph, the time of travel for the five miles will be known. It is hoped by electrical work of high precision to discover the travel times of different kinds of earthquake waves. The Volcano Observatory is a natural laboratory for this work, because it has many movements of tilting and trembling all the time.

These investigations will continue until the end of September, and Dr. Jaggar and Mr. Waesche will bring to bear the resources of the Observatory records on the two kinds of work. The University of Hawaii has recently published four papers from the Volcano Observatory by Wilson, Jones, Powers and Wentworth on ground movement, seismology, soils and geography of Hawaii. The appointment of Professor Jaggar brings the resources of the Kilauea laboratories and their large accumulation of unstudied records within the orbit of a research university graduate school. This contact of National Park and University to make available the natural resources of the nation to scholarship and education, is along the lines of what other national parks are doing.

## THE INFLUENCE OF VOLCANIC RESEARCH IN HAWAII

The by-products of the popularity of our volcanoes have been the National Park and its improved roads; the Mauna Loa road and camps; the military recreation camp; the Chain of Craters road; the Haleakala road and Park; the Hilo-Volcano road; the Uwekahuna Museum; the projected Hilo-Kona road; increased tourist visitation effects of this on Island business; the coming expansion of the National Park and its road system; the pleasure visitation of Mauna Loa and Kilauea by airplanes; the gradual opening of Mauna Loa to visitation and science; the completion of topographic maps of the whole island; science guiding the police, the ranchers to safety, and the public to sight-seeing, through ten lava crises. All of these things we have seen grow up during the last twenty-five years.

### What Did the Science Do?

It measured continuously the materials and the movements coming forth out of the three active volcanoes Kilauea, Mauna Loa and Hualalai. Having this experience led in part to the **social** benefits enumerated. The latest of these is the **social** contract with a British presidency, another volcanic island, seven thousand miles away.

### Larger Meaning of Measuring the Earth

The following are results of measuring the earth's powers: Boulder Dam, the Panama Canal, the Tennessee Valley Authority, the Mississippi Flood Control, the Great Lakes Drainage Project, the Golden Gate Bridge, Earthquake Insurance, Earthquake-proof construction. Geophysical prospecting for oil. Finding radium, caesium, selenium, tungsten, vanadium, uranium, rhodium, fluorine, helium and nitrogen. Prospecting the soil for its real meanings, a far cry from the days of guano and Chilean nitrate. Developing the air drill, the Diesel tractor, the new explosives for moving mountains. Tying up the earth in roads, pipe lines, telefer wires and aqueducts such as the world never dreamed of. Penetrating fogs. Steering by sea-bottoms. Mapping by airplanes And traversing Antartica by the tools of modern science.

All of this is the work of that man of science called the engineer. He has become utterly **Social.** He has a fine ethics like the physician. This is because his responsibility is for public safety, and for justifying a **measurement** of the earth that he has made for service. It makes him sober, to know that he has the responsibility of serving **socially** a million people in the future.

There is a still larger social aspect to the sciences of the Earth. We hear much of extravagance, of colossal expenditure, and the question "Who is going to pay for it all?" But pay for it in what? If the labor of the nation is doing it, and the result is doing the nation good, why not look back and say "Who has ever paid for the free franchises, free farms, free rights of way, and free public utilities of the American people? Who has ever paid science for improving the earth for man's occupancy? What modern men of science ever work for profit?

Is anyone now asking who will ever pay the great inventors for the extravagance, the colossal expenditure in blood and brain and spirit, of Jesus, Lincoln, Goethals, Walter Reed, Gorgas, Darwin, Faraday, Pasteur or Curie?

Do we realize that one man or woman somewhere and somewhen, produced a future billion dollars, in prospecting the Earth with his brain, for each great engineering and social achievement, among such constructive discoveries as those I have enumerated, like the Boulder Dam or the rare metals? For the Boulder Dam is just as much a discovery as the North Pole, and requires a hundred times more courage and brains.

The bonded debts of the world can never be repaid in coins. Money is the blood of youth and the labor of men. The earth furnishes some raw material and power for blood and labor to use. There is no other wealth than the good-will of men, and the self-sacrificing measurements of progressive learning, in economizing happily the energies of men. The energies of men are banded together to discover moral power and earth power. By moral we mean "MORES," improved human habits. This is the whole of education.

The Earth is yielding much to the chemist. It is not being made to yield enough of its resources to the engineer. Our sea-bottoms are not mapped, our deserts and mountains are almost untouched, our oceans are not working for us, our sunlight is not yet running our cars and planes. We live too much in city laboratories. There is here a gigantic field for the employer of labor.

Science is not yet extricating Society from its foolish city congestions: and sending MEN out in vast employments, to discover THE EARTH, with the new **social** tools of modern physics and engineering. Here is a chance for the benefactors of mankind to rethink social science. T. A. J.

### THE VOLCANIC AREA OF BUFUMBIRA, UGANDA

The following excerpts and paraphrasings from "The Volcanic Area of Bufumbira" by A. D. Combe and W. C. Simmons,

The west tilt cellar on Kilauea crater floor, housing clinoscope pendulum for daily readings.

published in 1933 by the Geological Survey of Uganda, shows many striking similarities to descriptions of Kilauea at various times.

The volcano Nyamlagira is in about 1° 25′ south latitude and about 29° 12′ longitude east of Greenwich in Belgian territory. The summit is 10,026 feet above sea level. It rises gently to a height of about 5,000 feet above its base. The mountain has been built by the piling up of successive lava flows apparently of large volume and in a very fluid state.

The caldera or crater depression is over a mile in diameter and it is surrounded by a vertical wall from 200 to 300 feet high, which is breached on the northwest side by a gap between 500 and 600 yards wide. The main part of the floor of the depression is formed by a flat terrace with a general crescentic outline and possibly 800 yards in width over its widest part. The breach in the caldera wall is on a level with this terrace, and thus one can walk onto it from the slopes of the mountain without climbing down. This terrace is in part bordered by a narrower one from 100 to 150 yards in width and about 100 feet lower. From the lower terrace there is a descent of perhaps 100 feet to an irregular elliptical depression which occupies the greater part of the southern portion of the caldera, the floor of which is covered with ropy and pahoehoe lava. It is on this that the pools of liquid lava are situated. On the south-east side of this depression there is a direct drop from the upper terrace and on the southern side a direct descent into it from the high wall surrounding the caldera as a whole. In the southwest corner of the depression there is a pit from 150 to 200 feet lower with an irregular elliptical outline, vertical sides, and perhaps from 250 to 300 yards across. The floor of this pit is the lowest part of the caldera. The southwest side of the pit is formed by the main wall of the caldera which is there from 400 to 450 feet high, while the west side descends directly from the upper terrace.

At the time of Combe's visit nine centers of activity could be seen. The largest was a pool of boiling lava, perhaps 70 yards in width, from the surface of which jets of lava, probably caused by the escape of juvenile gases, issue at frequent intervals. The rim of the pool has been built up above the level of the adjacent floor. The others have built up small cones from which large volumes of steam and sulphurous gases are given off. Liquid lava was seen in several of these cones. In many places jets of gas and steam issue through the surface of the ropy lava. At the time of his visit small intermittent streams of liquid lava issued from under the solid ropy rock and dropped over the steep wall into the lowest part of the caldera. These did not reach the bottom in a liquid state, but became partly solidified and dropped as lumps of scoria which have formed a large pile along the base of the wall resembling the ash heap of a power plant.

A striking feature of the structure of the volcano is that the wall surrounding the caldera, the terraces and the sides of the lowest depression are formed by a homogeneous lava in horizontal layers. The edges of the layers present a generally jagged surface cut off vertically, which suggests that they have been broken off by subsidence within the caldera. In many places large strips and blocks have broken away from the edges of the terraces. Over the floor of the terraces lines of fumaroles issue from fissures, the gases of which appear to be mainly of steam and sulphurous types, but in one place there was a strong smell of sulphuretted hydrogen. Native sulphur has been deposited adjacent to some of the fumaroles.

It is quite clear that the present-day caldera has been formed by the direct subsidence of the upper part of the volcano. The mode of origin of the flat layers of homogeneous rock, none of which exhibits columnar structure, is not so clear.

No recent flows have been derived from Nyamlagira itself that reach any considerable distance down the mountain side, for the lower slopes are clothed with dense forests.

On the whole the activity of Nyamlagira appears to have been rather quiet, but that violent explosions have taken place is indicated by the large number of bombs and ejected blocks, some of which are as much as two feet in diameter, scattered over the slopes of the mountain and over the upper terrace.

The lavas of Nyamlagira are mainly medium-grained leucite-basanites in which porphyritic crystals of plagioclase, augite, and a brownish olivine are set in a holocrystalline groundmass.

One of the fundamental tenets of science is that like causes produce like results. Nyamlagira is a volcano which, like Kilauea and Mauna Loa, yields chiefly basic, fluid lavas. Consequently the resulting volcano and volcanic structures and topography are much alike.

The matter abstracted above regarding Nyamlagira reads very much like various descriptions of Kilauea written during the nineteenth century.—H. S. Palmer.

## EARTHQUAKES IN UNITED STATES

It is not generally realized how wide has been the range of seismic disturbances in what now comprises the United States of America. Practically every state in the Union has recorded earthquakes within the last hundred and sixty years and Indian tradition constantly refers to such occurrences in earlier times. Students of the geology of the North American continent can point to abundant evidence of many great upheavals that have occurred within comparatively recent geologic time.

Probably the greatest earthquake of modern times in North Amrica was the catastrophic series of shocks that commenced early on the morning of December 16, 1811, and affected an area extending from Cairo, Missouri, along both banks of the Mississippi River through Arkansas to the vicinity of Vicksburg in the south. While the greatest destruction occurred within these limits, the effects were felt over an area of 50,000 square miles while the vibrations were clearly perceived by persons in upper Canada as well as in Detroit, Washington, and Boston. This actually means that the shocks of this great earthquake were felt over a million square miles, half of the area which became the United States of today.

We take the liberty of reviewing a most interesting account of this great disaster by Thomas Ewing Dabney, appearing in a recent issue of the magazine section of the New Orleans Times-Picayune. The gifted pen of the author has conjured up a vivid picture of the occurrence.

"Trees," he says, "began to move on a windless day, then clashed together like flailing clubs. High bluffs leaned forward, poised in fearful dignity, bowed into the river with enormous splashes. Waves of earth rolled over the land; rose higher and higher and burst. Back flowed the Mississippi; waterfalls raced above its surface, cast their roarings into the chaos.

"The shocks began soon after 2:00 a.m. on December 16. The crash of falling chimneys, the groaning and creaking of house timbers and the noise of overthrown furniture drove the inhabitants of New Madrid outdoors. A horrible darkness pressed down from the sky; strange odors released by the breaking earth filled the air. Daybreak came with dreadful rumblings; the ground rose and fell so that one could not stand erect. Forests fought and fell; a welter of sound rose from the tortured rivers."

Throughout that day and the next, the shocks were incessant but steadily decreasing in intensity. There was a savage renewal on January 23, 1812, followed by two weeks that were almost normal. But there was a renewal of the upheaval on February 7 and for many days after that the earth was shaking constantly. The shocks gradually ceased, but for more than twelve months afterwards recurrences kept the people in a state of alarm.

"One observer who attempted a systematic record counted 1,874 shocks between December 16, 1811, and March 15, 1812. This count was made in Louisville, far away from the main disturbance. Unfortunately no record was kept in New Madrid where, as one man said, 'the world seemed to be blowing up with loud explosions.'

"Passengers on the river steamer New Orleans which visited the devastated areas, described the enormous changes which had taken place.

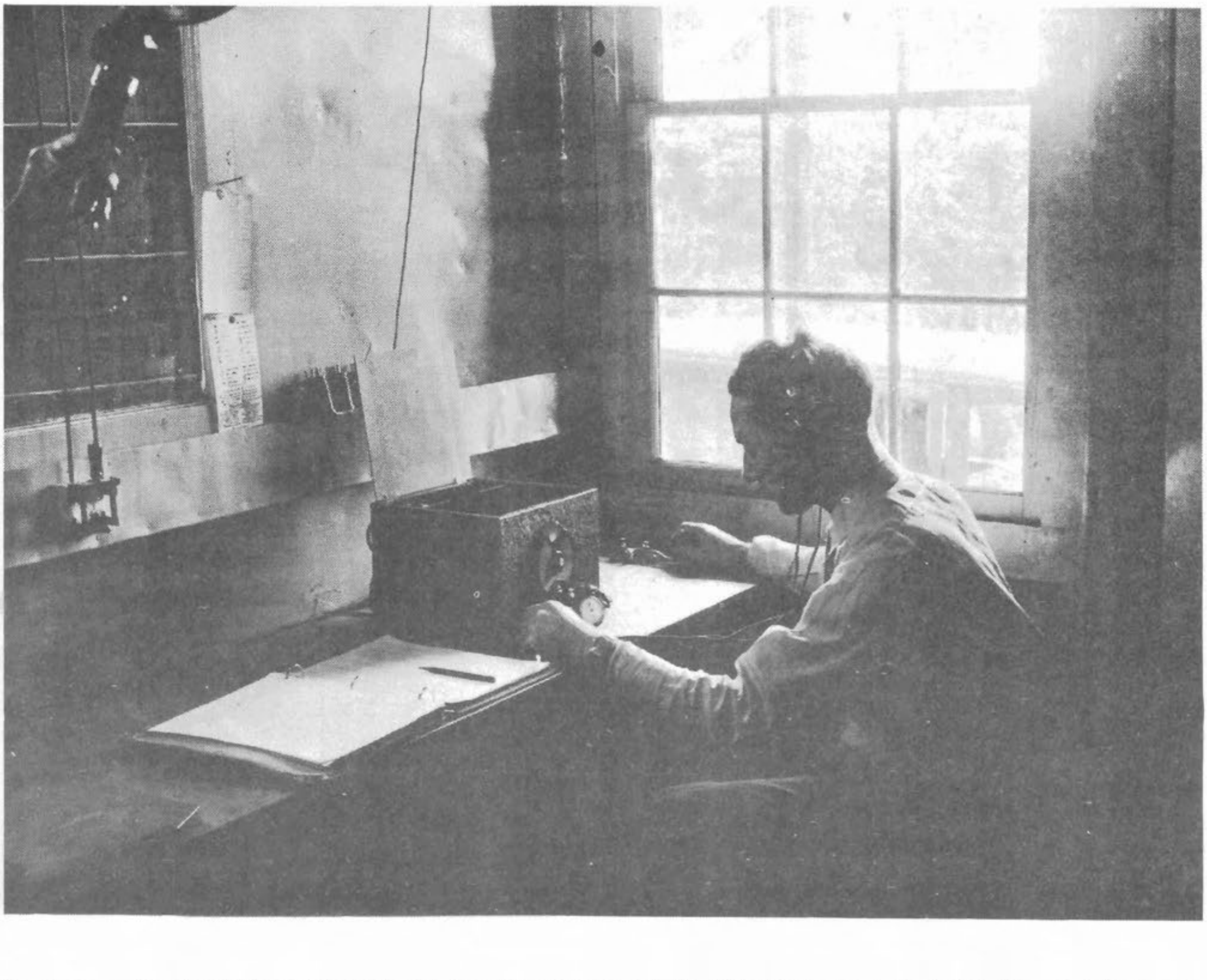
"New Madrid itself, they found, was practically destroyed. Much of the town had been swallowed by the river and the houses on higher ground had collapsed. Further down the river, the prosperous agricultural community of Little Prairie (the Caruthersville of today) had become a desolate waste of sand and water spewed up from the splitting earth. The whole channel of the Mississippi River appeared to be up-tilted so that the water ran backward towards its sources for more than an hour and until the current broke its way through the upthrust material, the river was a crazy thing. One account speaks of a great waterfall six feet high and half a mile wide, apparently formed by the water being violently sucked into some chasm in the river's bottom. The same narrator speaks of another fall of the same character eight miles below New Madrid.

What are now called the "sunken lands' 'of western Tennessee, southwestern Missouri, and northwestern Arkansas covering hundreds of square miles were made in this subsidence to which Reelfoot Lake also owes its origin.

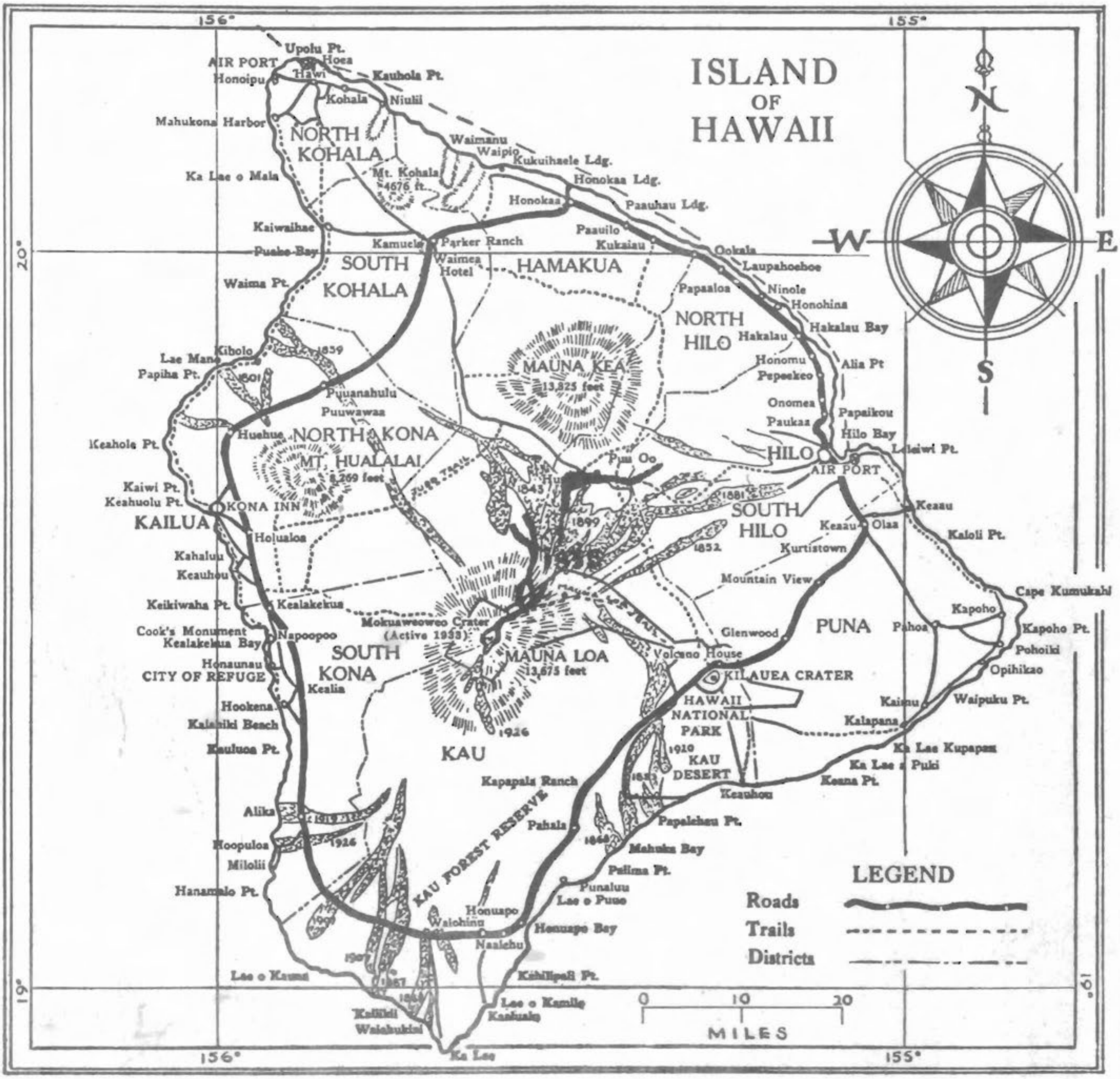
In other sections, land was raised and navigable streams went dry. A fifteen-mile stretch or territory in southeast Missouri, once a part of the flood plain, was raised nearly twenty feet. There was widespread fissuring, due to the opening of the earth after the main wave-motion had swept through the surface strata. Mr. Dabney tells us that some of these openings were several hundred feet long and were so numerous that in some sections men felled trees against the direction of the movement and clung to them to prevent being engulfed. It is worthy of note that while many of these fissures were twenty feet in width, their depth was shallow and reached only to the quicksands underlying the surface alluvium. Through many of these fissures tremendous ejections of sand, water and carbonaceous material took place, burying the fertile land. At one place the skull of the long extinct musk ox was thrown out on the surface and was later placed in the Museum of Natural History in New York.

The loss of life, owing of course, to the scanty population, was astonishingly small. Should such a shock occur in these present days of closely crowded people and tall buildings, most of which are anything but earthquake proof, the loss of life would be almost too appalling to contemplate. Congress passed an act allowing the sufferers from the disaster to locate on an equivalent amount of land in any other part of the public domain open to entry. But after a year of frequent earthquake shocks, the survivors had become so accustomed to them that of the five hundred certificates issued only twenty were located by the original claimants in person.

Mr. Dabney, in his able article, has made a valuable contribution to American literature on this important subject.—deV-N.



Short wave radio set in Volcano Observatory for receiving time signals from Washington and imprinting them on seismograms through a telegraph key.



ISLAND OF HAWAII
LEGEND
Roads
Trails
Districts
N
S
E
W
156°
155°
20°
19°
0
10
20
MILES
NORTH KOHALA
SOUTH KOHALA
HAMAKUA
NORTH HILO
SOUTH HILO
NORTH KONA
SOUTH KONA
KAU
PUNA
MAUNA KEA
13,825 feet
MAUNA LOA
13,675 feet
MT. HUALALAI
8,269 feet
Mt. Kohala
4676 ft.
Mokuaweoweo Crater
(Active 1933)
KILAUEA CRATER
HAWAII NATIONAL PARK
KAU DESERT
KAU FOREST RESERVE
HILO
AIR PORT
KAILUA
KONA INN
CITY OF REFUGE
Upolu Pt.
Hawi
Hoea
Honoipu
Kauhola Pt.
Kohala
Niulii
Mahukona Harbor
Ka Lae o Mala
Waimanu
Waipio
Kukuihaele Ldg.
Honokaa Ldg.
Honokaa
Paauhau Ldg.
Paauilo
Kukaiau
Ookala
Laupahoehoe
Papaaloa
Ninole
Honohina
Hakalau
Hakalau Bay
Honomu
Pepeekeo
Alia Pt
Onomea
Papaikou
Paukaa
Hilo Bay
Leleiwi Pt.
Kawaihae
Puako Bay
Kamuela
Parker Ranch
Waimea Hotel
Waima Pt.
Kiholo
Lae Mano
Papiha Pt.
Puuanahulu
Puuwawaa
Huehue
Keahole Pt.
Kaiwi Pt.
Keahuolu Pt.
Holualoa
Kahaluu
Keauhou
Keikiwaha Pt.
Kealakekua
Cook's Monument
Kealakekua Bay
Napoopoo
Honaunau
Kealia
Hookena
Kalahiki Beach
Kauluoa Pt.
Alika
Hoopuloa
Milolii
Hanamalo Pt.
Lae o Kauna
Kalihiki
Waiahukini
Ka Lae
Lae o Kamilo
Kaaluala
Kahilipali Pt.
Naalehu
Waiohinu
Honuapo
Honuapo Bay
Lae o Puue
Punaluu
Pahala
Palima Pt.
Mahuka Bay
Papalehau Pt.
Kapapala Ranch
Keauhou
Volcano House
Glenwood
Mountain View
Kurtistown
Keaau
Olaa
Kaloli Pt.
Cape Kumukahi
Kapoho
Kapoho Pt.
Pahoa
Pohoiki
Opihikao
Waipuku Pt.
Kaimu
Kalapana
Ka Lae Kupapau
Ka Lae o Puki
Keana Pt.
Puu Oo
1859
1801
1843
1899
1881
1852
1935
1926
1919
1907
1868
1887
1823
1920

# THE VOLCANO LETTER

**No. 435 — Monthly, Department of the Interior, National Park Service, May, 1936**

**Hawaii National Park**
**Edward G. Wingate, Superintendent**

**Hawaiian Volcano Observatory**
**T. A. Jaggar, Volcanologist**

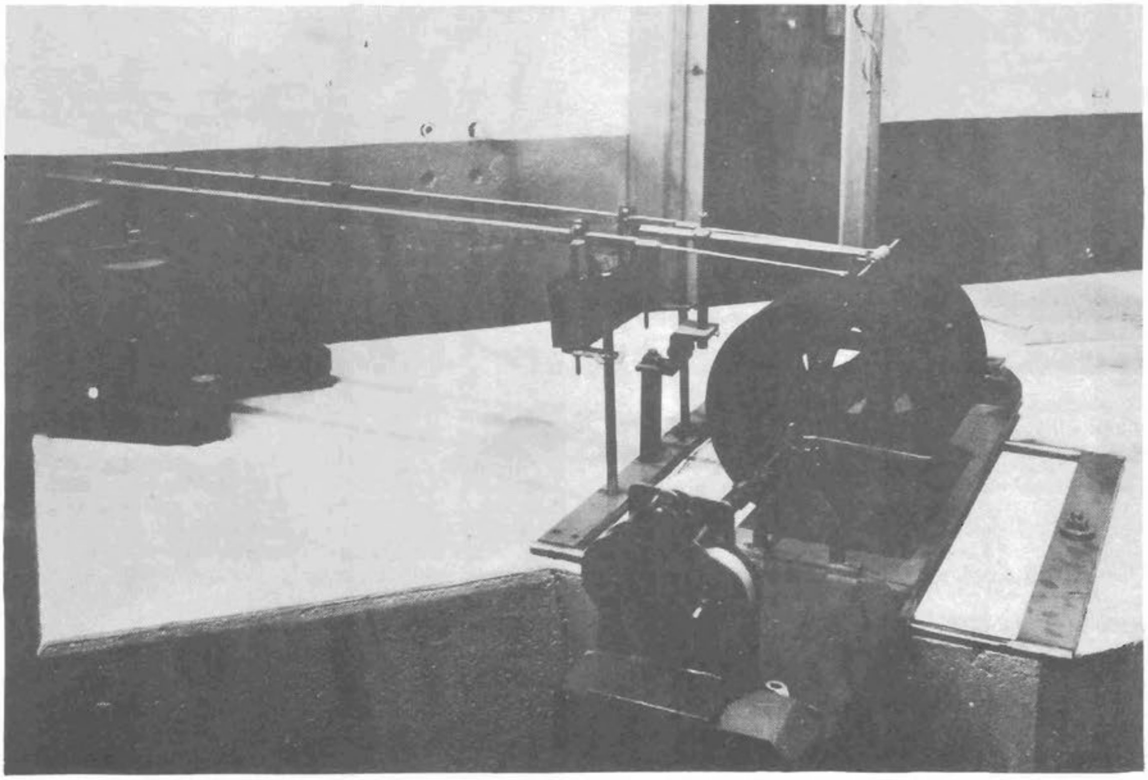
## HAWAIIAN VOLCANO OBSERVATORY REPORT FOR MAY 1936

### HAWAIIAN VOLCANO OBSERVATORY

Routine work at the Volcano Observatory was ably carried on during the month by H. Yasunaka, who at times was assisted by Asao Okuda, carpenter and mechanic, both Volcano Research Association employees. This work consisted of caring for seismographs, changing of records, recording meteorological data, recording tilt at clinescope stations and caring for the Observatory grounds, buildings and equipment.

In the absence of both Volcanologist T. A. Jaggar and Assistant Geologist Waesche, weekly reports were written by Superintendent Wingate. Dr. Jaggar is on an expedition to the island of Montserrat in the West Indies by invitation of the Royal Society of London. He is studying a volcano on that island which has given indications of a possible eruption at an early date. H. H. Waesche was absent on annual leave from the park on a trip to the Orient, but returned to resume his regular duties at the Observatory May 23.

M. S. Seger, Associate Landscape Architect of the National Park Service, accompanied Mr. Waesche on the trip to the Orient. An inspection of Japanese national parks was made, including visits to the volcanic parks of Aso, Unsen and Fuji.



Strong-motion seismograph with low magnification to record those earthquakes that are too big for the other instruments.

Other parks visited were Inland Sea and Nikko. A visit was made to the national park headquarters in the Home Office Building in Tokyo, where members of the administrative staff were met. Dr. Tamura of the Japanese National Parks presented Mr. Waesche with a bomb from the summit of Mt. Fuji. This is a "sister rock" to the one presented to Ambassador Grew, in ceremonies in Tokyo, as a present from the Japanese national parks to those of the United States. The Mt. Rainier rock was part of the exchange of courtesies of this nature between Mt. Rainier National Park and the Japanese National Parks. Sakarajima Volcano was visited. Inspection was made of the seismological institute of Tokyo Imperial University as well as the seismological research department of the same institution. In addition to Japan, China, Manchukuo and Korea were visited.

SEISMOGRAPH ROUTINE I
Checking the clock time against a stop-watch, Uwekahuna Seismograph.

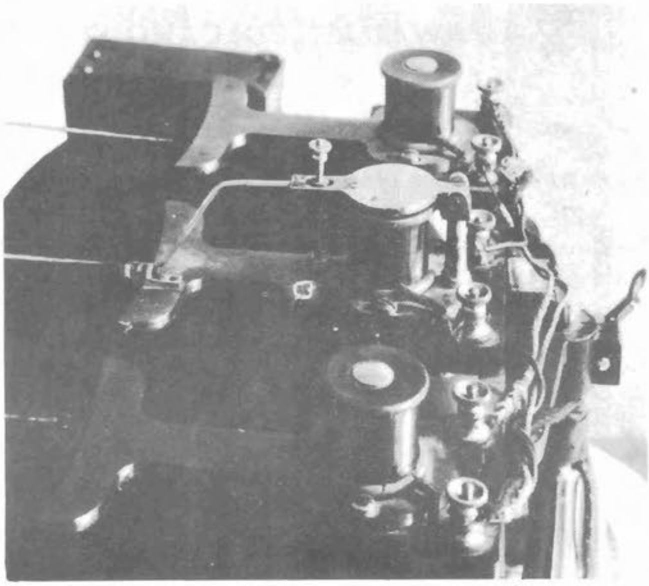
## KILAUEA AND MAUNA LOA OBSERVATIONS

Kilauea and Mauna Loa have both been quiet throughout the month. As late as May 16 fume was reported seen at the rift cones of the 1935 eruption of Mauna Loa. Sulphur deposits around the cones were said to be increasing. No fume has been noticed the latter part of the month. Fuming at the sulphur spots in Halemaumau continues about the same. Slides have been few and small.

Seismic activity has been comparatively moderate. There were feeble earthquakes May 2, 7 and 26, none of which was reported felt. All other disturbances were classed as very feeble or as tremors. Spells of continuous tremor of 5 minutes duration were reported for May 8 and 9. Most of the disturbances for the month originated in the Kilauea area.

Crack measurements showed abnormal opening of No. 46 on the NE rim of Halemaumau near the point where a large section of the rim disappeared into the pit in March.

Addition was made to the Observatory equipment of a Leitz precise level.



SEISMOGRAPH ROUTINE Ia:
The pens for east-west, north-south, and up-down, pendulums. The spools are electro-magnets lifting the pen-tips every minute.

**TABLE**

**Earthquakes**

| Week Ending | Minutes of Tremor | Very Feeble Earth-quakes | Feeble Earth-quakes | Distant Earth-quakes | Local* Seismicity |
|---|---|---|---|---|---|
| May 10 | 19 | 4 | 1 | 0 | 7.75 |
| " 17 | 22 | 3 | 0 | 0 | 7.00 |
| " 24 | 41 | 3 | 0 | 1 | 11.75 |
| " 31 | 39 | 9 | 1 | 1 | 15.25 |

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at the Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant quakes were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and whenever such determinations were possible, the depth of focus is given.

* For local seismicity, see Volcano Letter 371.

May 6, 8:55 pm, very feeble, located 0.6 mile deep in Kilauea Crater, 1.0 mile SW of the Observatory. 19° 25' 2N; 155° 16' 2W.

May 7, 6:51 am, very feeble, located 1.9 miles deep in Kilauea Crater near SE rim. 19° 24' 7N; 155° 15' 9W.

May 7, 8:07 am, feeble, located 0.4 mile deep in approximate center of Kilauea Crater 1.5 miles SW of the Observatory. 19° 24' 9N; 155° 16' 5W.

May 10, 6:57 pm, very feeble, located 1.2 miles deep under W portion of Kilauea Iki. 19° 25' 0N; 155° 15' 1W.

May 14, 4:42 pm, very feeble, located 1.6 miles deep under SE rim of Kilauea Crater and 0.4 mile W of Keanakakoi Crater. 19° 24' 2N; 155° 16' 3W.

May 14, 9:04 pm, very feeble, located 1.2 miles deep and 0.6 mile S of the Twin Craters and 1.2 miles E of Kilauea Crater rim. 19° 25' 4N; 155° 14' 6W.

May 16, 6:35 am, very feeble, probably located under S rim of Kilauea Crater.

May 21, 2:31 pm, very feeble, probably located in Kilauea Crater.

May 21, 2:46 pm, very feeble, located 1.7 miles deep and 0.4 mile N of Keauhou Ranch House. 19° 26' 6N; 155° 16' 9W.

May 25, 10:46 am, very feeble, located 1.1 miles under Waldron Ledge, NE rim of Kilauea Crater. 19° 25' 5N; 155° 15' 5W.

May 26, 11:48 am, feeble, located 1.4 miles deep under Waldron Ledge. Same as preceding quake.

May 28, 3:09 am, very feeble, located 9.0 miles deep in the Hilina-Kapukapu Fault system, 3 miles N of Keauhou Point. 19° 19' 3N; 155° 14' 8W.

May 30, at 6:19 am, very feeble, probably located in NE rift of Mauna Loa.

The preliminary waves of a teleseism began recording at 4:45 pm, May 19, and the indicated distance from the Observatory was 3630 miles. The reported location was in the vicinity of the Solomon Islands 7° 7S; 159° 6E. On May 28, at 8:35 am, the secondary waves of a distant earthquake began to register. The reported location was about 900 miles off the SW coast of Honduras. 9°N; 103° 5W.

Microseismic motion was moderate, May 10, 11, 15, 19; the remainder of the month it was light.

SEISMOGRAPH ROUTINE 2
Removing the drum covered with smoked paper.

**TABLE OF TILT**

| Week Ending | Observatory | Halemaumau Clinoscope Stations West | Southeast | Pit Resultant |
|---|---|---|---|---|
| May 10 | 0" 83 N 27°E | 4" 77 N75°W | 4" 47 N 36° E | 2" 87 from |
| " 17 | 0" 57 N 54°W | 5" 19 S 78° W | 2" 27 N 30°E | 4" 25 from |
| " 24 | 0" 85 N 4°W | 1" 01 S 23°W | 2" 27 N 5°W | 1" 33 toward |
| " 31 | 1" 24 S 82°W | 2" 21 N 58°W | 5" 57 S60°W | 1" 14 from |

H.H.W.

SEISMOGRAPH ROUTINE 3
Installing a fresh drum and pulling over the pen points with a horseshoe magnet.

**Tilting of the Ground**

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending May 31, was 4" 20N and 1" 9E.

## THE METHODS OF THE HAWAIIAN VOLCANO OBSERVATORY

From trying everything experimentally, in 1912, to a routine of measurement in 1936, there was growth of method at Kilauea in the effort to discern what a volcano is doing underground. One of the impressive results of the Observatory approach to volcanoes, is the failure of underground lava to announce its intentions. Newcomers to volcano science always think a hot crack at the edge of a live crater will get hotter when an eruption is impending. They solemnly measure with a thermometer. The eruption comes and goes, and nothing whatever happens to their hot crack.

Or it may be earthquakes. The lava gushes up in the bottom of the pit, and immediately the tremors may become fewer than before. Or the shakes temporarily flare up, if measured very close to the crater, and then die away before the eruption ends.

The idea that a beautiful fever chart would show everything, before the disease breaks out, is a dream doomed to disappointment. Lava is there all the time. It is a substance which suddenly releases thermal and kinetic energy, apparently from great depths. But **how,** chemically and physically, this release proceeds, is still a mystery.

The mere finding out that the lava is there all the time is a real discovery. It is proved by the sudden geysering of gas and red hot froth at the edge of a plug in the pit bottom, when a new eruption begins. By experimental drilling into Kilauea crater we found places growing hotter downward. By watching the walls of the pit when a big cave-in occurred, we found red hot avalanches 600 feet down. And when a thick new flow cools off, we find the under parts stay hot for years.

Comparing the dull times when the lava in the pit was sluggish but liquid, and the dull time now when it is crusted and hard, there is no essential difference in behavior: sulphurous hot gas always rises, the rim cracks move, the earth tremors increase and decrease, and the top of the mountain is a flexible shell that tips inward, or tips outward. Always the ground is **alive,** and very different from the terra firma of Honolulu.

Four things, weather, earthquakes, slow movement, and gas emission are the things we set ourselves to measure after twenty-five years of Observatory work. First, the measured changes of the weather. We must know what weight of rainwater loads the mountain, what pressure and temperature of the air may make changes in the rock, and how wind and storm and sunshine may deceive us in viewing steam or vapor from cracks.

Second comes the locating of earthquakes. This looked like a delightful prospect in 1912. We would find out who felt the quakes most. We would make a nice little instrument for everybody. Then Kona would tell us the December quake there was of Grade 2, Kohala would have Grade 1, Hilo would show Grade 6, and Kilauea would be Grade 8. Ergo, Kilauea was strongest, and Kilauea lava made the shake.

But nothing like that happened. When it came to **feeling,** people in one end of Hilo town felt quakes that nobody noticed in the other end. With a magnifying seismograph in Hilo and at Kilauea, Kilauea got many tremors that did not show at all in Hilo. When a nice little earthquake was felt in Kohala, Kona, Hilo and at Kilauea, all at the same hour, and surely the same shock, nobody felt it more strongly than anybody

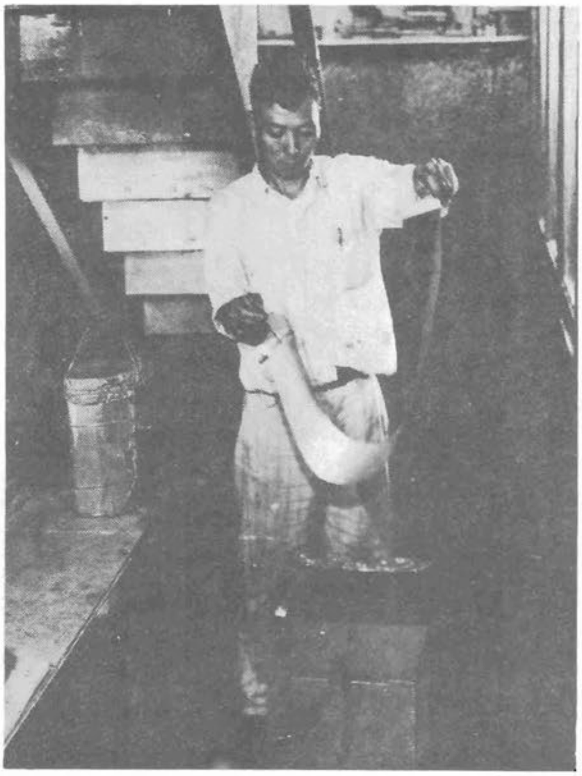
SEISMOGRAPH ROUTINE 4
Carrying case for drum, transported by car to be changed, and the record varnished.

else: it seemed to have been felt equally all over the island. This was most disconcerting. It raised such baffling questions as "What **is** an earthquake, anyway?" And so we were led to phases, and compression, and angle of emergence, and vertical component, and depth of origin. And to the question, what **is** an origin? Is it a snapping open, or a scraping slip, or a closing bump?

The entire science of seismology was painfully reviewed and investigated and experimented with; complicated seismographs were set up and discarded and tried anew; at Kilauea, Hilea, Kona, Puu Waawaa, Waikii, Honokaa, and Hilo. Trials of simplified shock recorders were made. The telephone was used to send the same time-keeping to different stations. Wireless was installed to get the same time-signal to each station. Some instruments were made to write with a beam of light on photographic film. And all of this had a **geographical** motive, to

peared above ground, was done on Mauna Loa in 1935. This was the result of careful studies for two decades by faithful seismologists. But we are still far from knowing exactly what an earthquake is.

The third quest of the Observatory concerns finding out what is the secular strain under which a volcano is laboring. Not only does the ground shake, but it rises and tilts. This involves a long engineering program, again harnessing an island. Kilauea Crater has been proved to move more, through a period of twenty years, than Hilo. The movements up and down were big, before and after the pit exploded in 1924. They were up before, down afterward. The mountain swelled for ten years, then its top was let down suddenly. At the same time the lava was withdrawn, water must have rushed in below, and steam gushed out. Probably the lava flowed out under the ocean.



SEISMOGRAPH ROUTINE 5
Fixing the smoked seismogram with varnish bath.

cover the whole island. The result was a deadlock, for the whole island had to be covered with skilled physicists, an obvious impossibility. The workers were faithful amateurs, but a seismograph properly requires a highly trained scientist.

So the Observatory muddled through, getting a result here and a result there, and an improving list of earth movements. The dream of 1912 faded away. The harnessing of an island with amateurs is still awaiting a suitable instrument. Three stations have been maintained at corners of a triangle. Theoretical seismology has improved, and the routine is shown in the accompanying photographs. The horizontal pendulum three-component seismograph, with smoked-paper records, is still used, and the earth has written thousands of autographs. The locating of a place underground, where an outbreak ap-

All of this story from 1912 to 1926 was told by R. M. Wilson in engineering language, "Ground Surface Movements at Kilauea Volcano," (University of Hawaii Research Publications No. 10, 1935, 56 pp. with maps and charts). The work has been done repeatedly by levelling, tide gauge reading, triangulation, setting up nets of flags, bench marks and towers across the volcano, and by comparing the results of 1897, 1912, 1922, 1927 and other times.

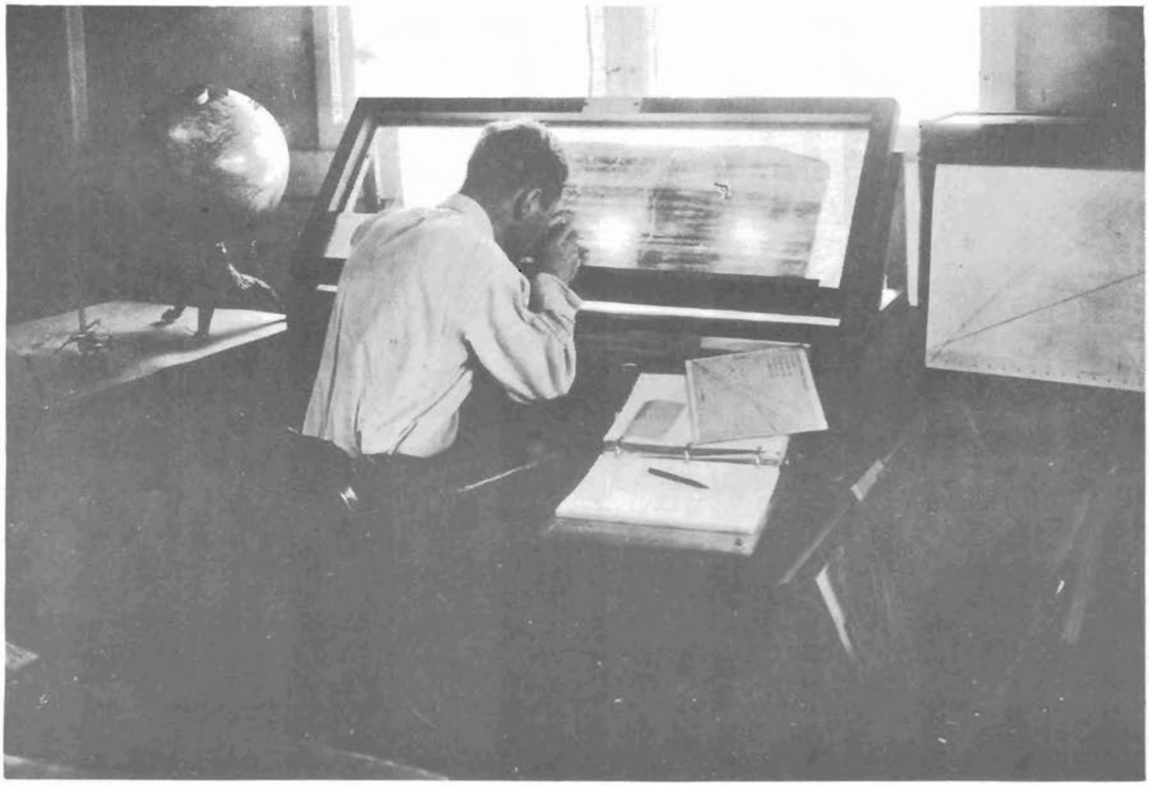
This has been supplemented by the pendulums of the Observatory, writing on smoked paper, from day to day, many years. This writing showed tilting of the ground away from Kilauea very strongly after 1918. And there was strong tilting back again towards the crater in 1924. The Volcano House rose bodily about two feet during the years before 1924. It sank as much after the lava collapsed in 1924. And the edge of the inner pit Halemaumau sank **thirteen feet,** and the walls on opposite sides of the crater **approached each other.** This was proved by measuring horizontal angles with a transit, in the triangulation.

All of these laborious discoveries might have applied equally to the great crater on the summit of Mauna Loa, if men and means had been available, before and after the eruptions of Mauna Loa in 1914, 1916, 1919, 1926, 1933 and 1935. What Wilson began at Kilauea has gradually been added to by the weekly and monthly measurements at the Observatory, with level and transit. This was set in motion by E. G. Wingate, who succeeded Wilson as topographic engineer. Some of our illustrations show the surveying instruments used to line up the changing geometry of the crater.

The fourth and most elusive high ambition of the Hawaiian Volcano Observatory, in its methods of studying the chemistry and physics of the inner earth, deals with the emission of gases, especially hydrogen. To collect new or "juvenile" gas from live lava, to trap and analyze it, to develop a technique that can be applied at any sulphurous volcanic vent or actual flame, is the volcano student's dream. Whenever the mighty fountains play above a gushing rift on Mauna Loa, there are flames. When the gushing stops, there are steam jets and sulphur and selenium and alum. The so-called "solfataric" mild activity (Sulphur Bank) of quiescent volcanoes, is still **in communication by gas ducts** with potentially live lava below. We see such gases on the sun, and both volcano and sun yield free hydrogen. Free hydrogen at high temperature is not to be trapped. No laboratory container will restrain it. At lower temperature it has been trapped at Kilauea, in small percentages. Its oxide, water vapor, appears in large percentages. The lower the water vapor, the higher the hydrogen. This ratio leads to the suspicion that if spectroscopic or other method could find out, what is the Hawaiian gas before it vanishes in flame, we might discover hydrogen to be the prime mover of all volcanism. It is certainly a primary element in all chemistry, and in astro-physics: and water vapor is nothing more than burned hydrogen.

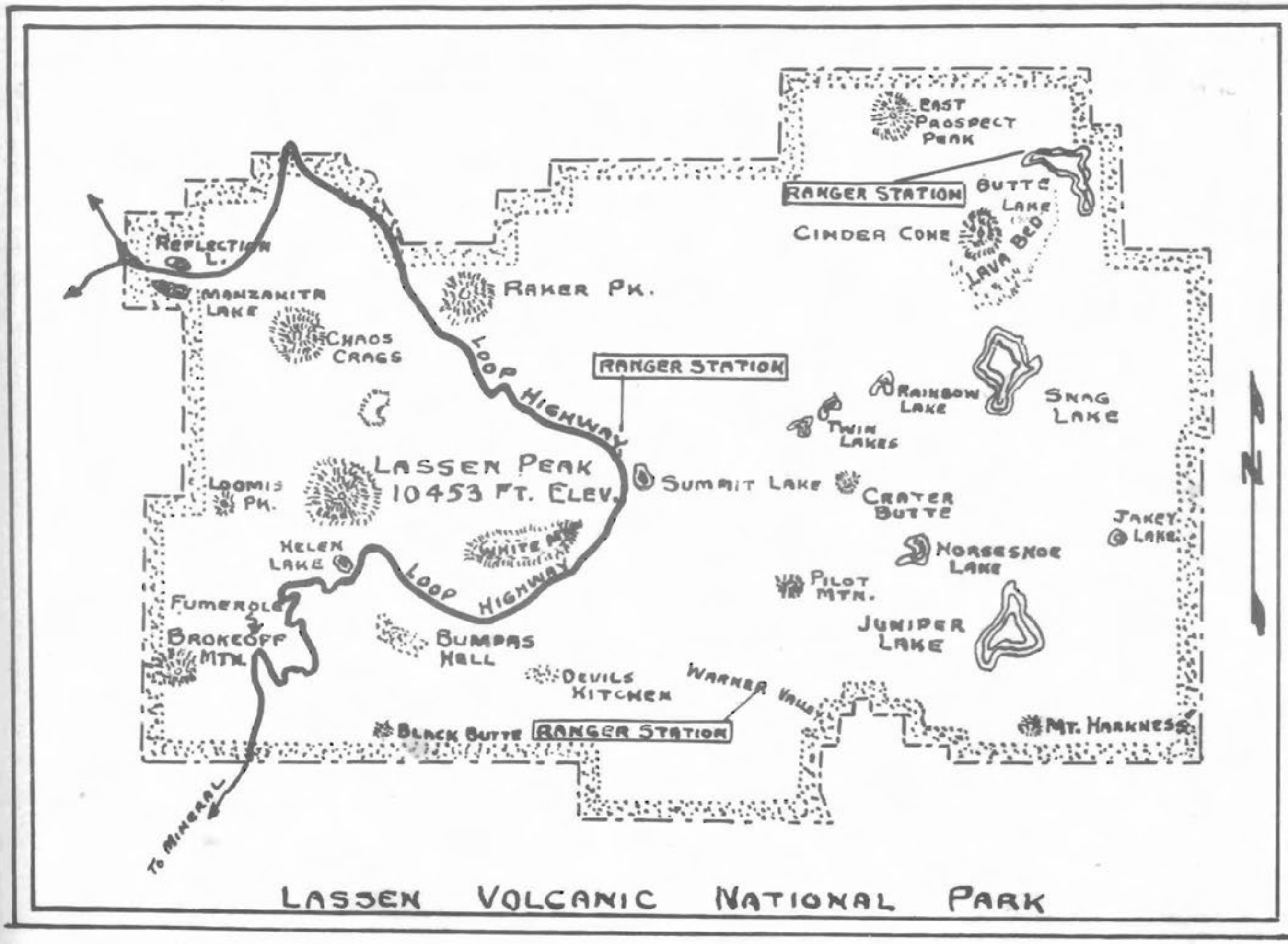
The methods of attacking the gas problem are illustrated in some of the photographs. Vacuum tubes are thrust behind a flame, or into a sulphurous crack, and the tip is melted or broken deliberately. The glass is sealed and the contained gas carried to a laboratory for analysis. This work is now being improved by special researches by the Physics Department of the University of Hawaii; in which the spectroscope will play a part.

The illustrations appearing in this issue of the Volcano Letter show the seismograph routine; other apparatus in regular daily use will be shown in succeeding issues. T. A. J.



SEISMOGRAPH ROUTINE 6

Studying and measuring the seismogram, calculating the epicentral location, and entering in record book.




## EARTHQUAKES IN LASSEN VOLCANIC NATIONAL PARK DURING MAY, 1936

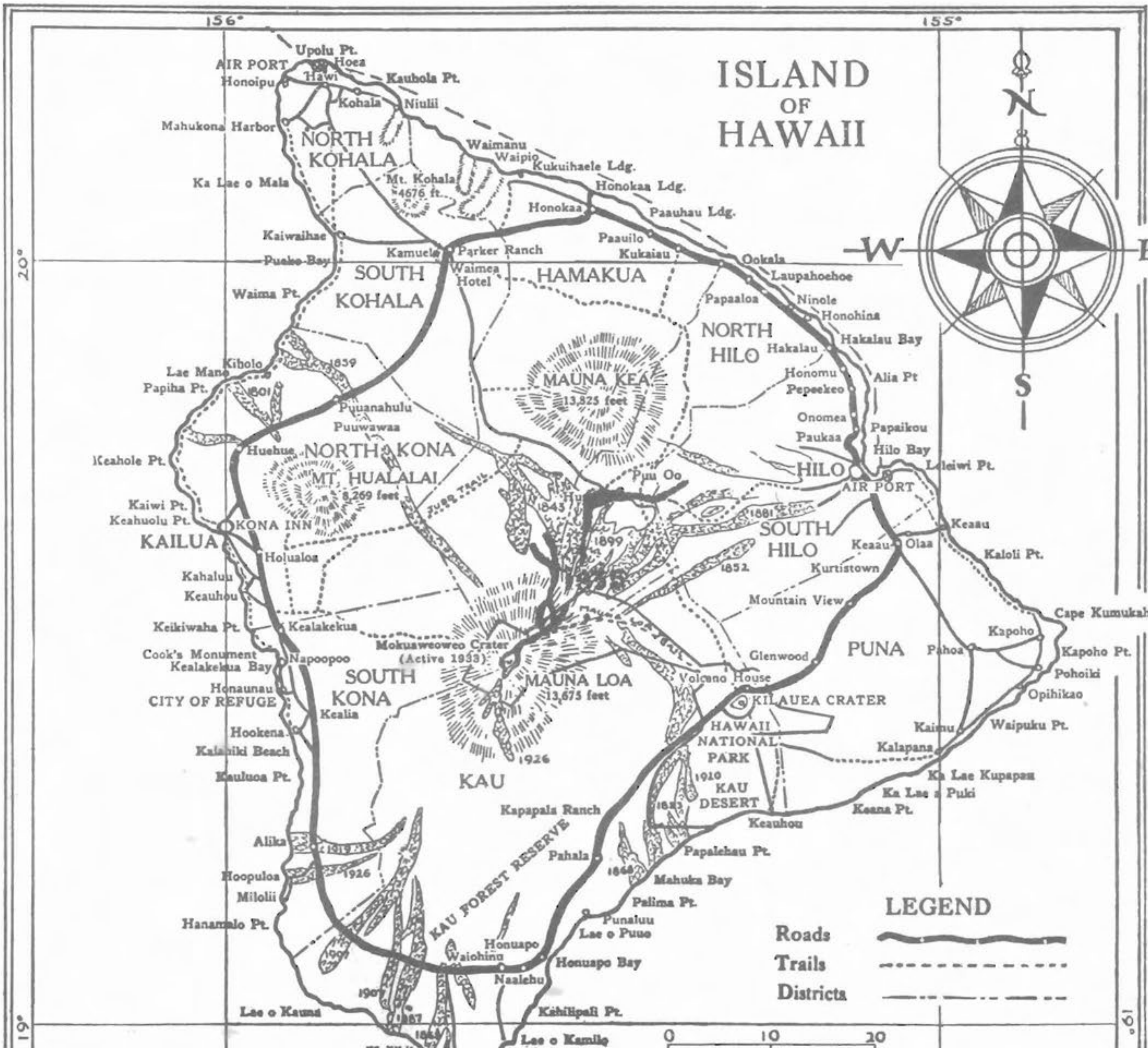
Carl R. Swartzlow
Park Naturalist

More earthquakes occurred in May, 1936, than in any previous month. The shocks were all of low intensity. Only four were of No. 5 intensity, according to the McAdie Scale, and the rest were less severe.

The earthquakes were accompanied by considerable tilt during the periods of greatest activity.

With a few exceptions the epicenters were located within the park boundaries. Most of the shocks did not center under Lassen Peak as many people believed but were located along fault zones in the eastern part of the park. The Warner Valley fault zone was the center of greatest activity, with some minor shocks felt in the Butte Lake District.

The hot spring activity has remained practically normal throughout the month. On April 30, four columns of steam rose from the crater of Lassen Peak to a height of between 200 and 300 feet, but activity on the peak has been normal since that day, although a little abnormal activity was noted in Bumpas' Hell early in the season. Conditions in the Devil's Kitchen in Warner Valley have been normal during the period of observation.


ISLAND OF HAWAII
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NORTH KOHALA
SOUTH KOHALA
HAMAKUA
NORTH HILO
SOUTH HILO
NORTH KONA
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KAU
PUNA
MAUNA KEA 13,825 feet
MT. HUALALAI 8,269 feet
MAUNA LOA 13,675 feet
Mt. Kohala 4676 ft.
Mokuaweoweo Crater (Active 1933)
KILAUEA CRATER
HAWAII NATIONAL PARK
KAU DESERT
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Upolu Pt.
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Keana Pt.
Keauhou
Kapapala Ranch
Papalehau Pt.
Pahala
Mahuka Bay
Palima Pt.
Punaluu
Lae o Puue
Alika
Hoopuloa
Milolii
Hanamalo Pt.
Honuapo
Waiohinu
Honuapo Bay
Naalehu
Lae o Kauna
Kahilipali Pt.
Lae o Kamilo
Kaalualu
Kalihiki
Waiahukini
Ka Lae
1859
1801
1843
1899
1935
1881
1852
1926
1910
1823
1868
1919
1907
1887
156°
155°
20°
19°
0
10
20
MILES
LEGEND
Roads
Trails
Districts

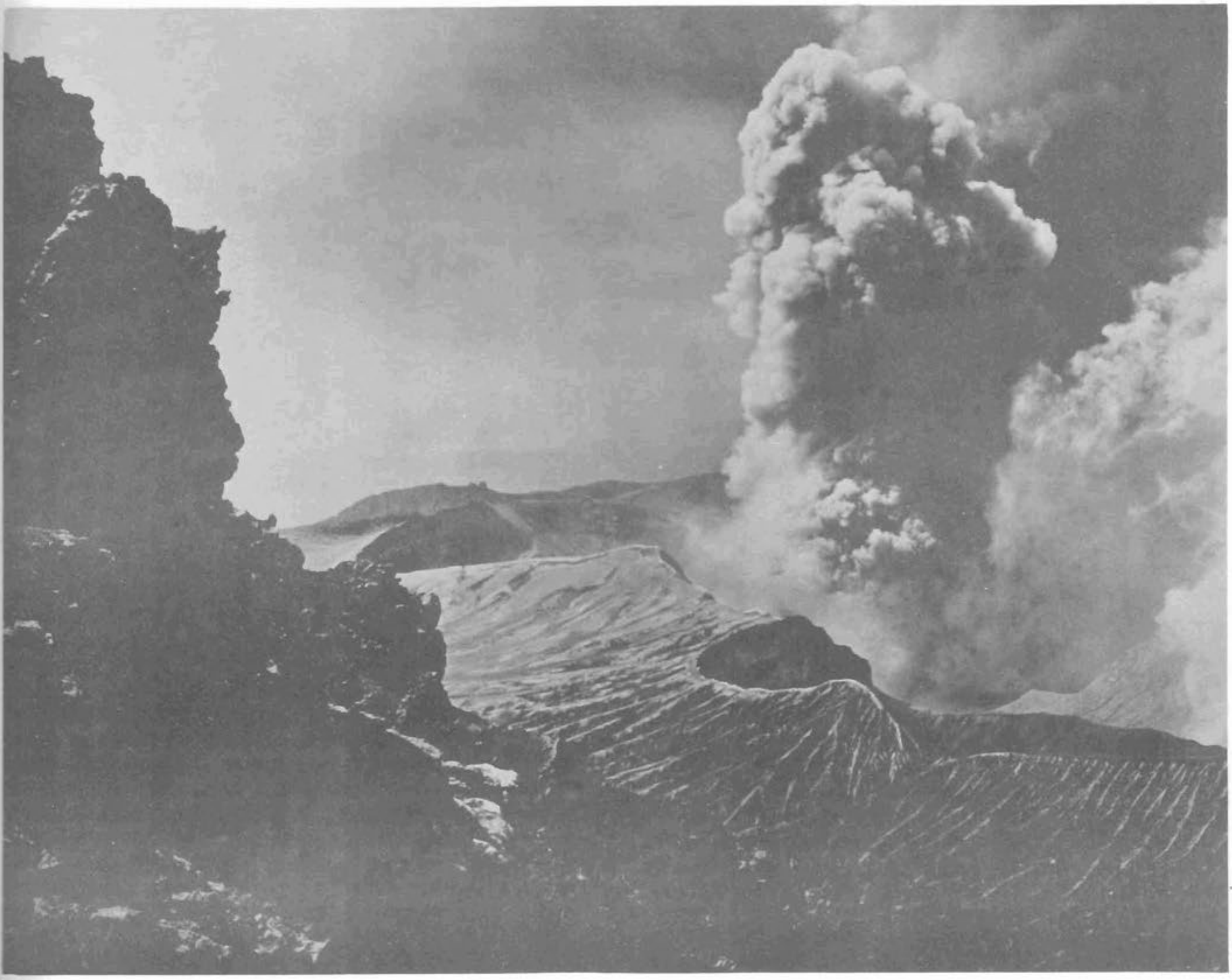
# THE VOLCANO LETTER

**No. 436—Monthly, Department of the Interior, National Park Service, June, 1936**

**Hawaii National Park**
**Edward G. Wingate, Superintendent**

**Hawaiian Volcano Observatory**
**T. A. Jaggar, Volcanologist**

## HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JUNE, 1936



Naka-dake Crater, Pit No. 2, of Mount Aso Volcano, Japan

### REPORT OF VOLCANO OBSERVATORY FOR JUNE, 1936

The normal schedule of routine activities has been carried on at the Volcano Observatory during the month. Regular records have been kept of daily activities and of observations of Mauna Loa and Kilauea. The usual daily trips to the seismograph stations and tilt stations for observations have been made. Daily meteorological records have been kept.

The Volcanologist, Dr. Jaggar, is still absent on a scientific expedition studying conditions at Montserrat for the Royal Society of London.

Mauna Loa and Kilauea have been quiet throughout the month. June 14 ended a week of exceptional quiet at Kilauea, during which no rock slides from the walls of Halemaumau were reported. This is the first time that such has been the case for over a year. Active sliding was again resumed the week of June 28. A party accompanied by Ranger Murray made a trip to the summit of Mauna Loa June 13 to 16. They report that there had been considerable activity in the NE section of Mokuaweoweo, the summit crater, during the November, 1935, eruption. The trail, one-half mile below the crater, was covered by a new lava flow. Fuming, though greatly diminished, was continuing at the source cones at the 1200-foot elevation and deposits of sulphur were reported large around their base. All trails and markers in the NE portion of Mokuaweoweo have been obliterated. The summit rest house was unharmed.

Seismic activity has been moderate and fairly consistent as shown by the numbers of disturbances for the successive weeks of 32, 32, 21 and 32. Of these one was a feeble quake on June 4, 26 were very feeble shocks and the remainder was made up of tremors. Three minutes of continuous tremor began at 11:26 P.M. June 2. On the morning of June 30 at 3:59 twenty-eight minutes of continuous tremors began recording. Most of the disturbances are of Kilauea origin.

Crack measurements around Halemaumau for the month showed very little change except number 46, located on the NE rim, which has consistently opened at an abnormal rate of 4.5 millimeters per week.

Mr. F. Chase of the Department of Geology, Harvard University, visited the Park on June 10-17. He spent considerable time studying at the Observatory and made a trip to the summit of Mauna Loa. He had been two years in Australian gold mining work and was returning to Cambridge to resume his duties there.

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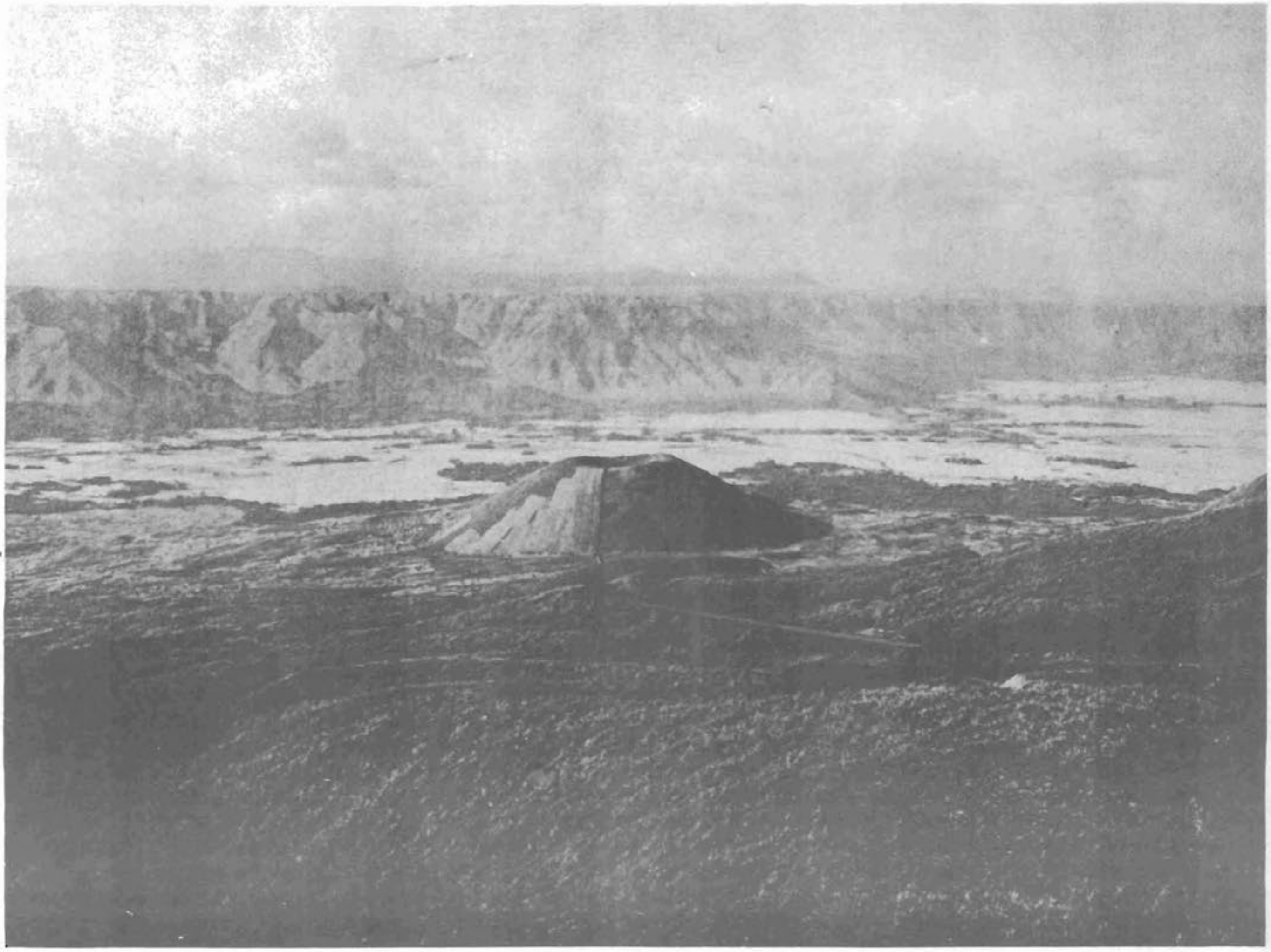
**TABLE**

**Earthquakes**

| Week Ending | Minutes of Tremor | Very Feeble Earth-quakes | Feeble Earth-quakes | Distant Earth-quakes | Local* Seismicity |
|---|---|---|---|---|---|
| June 7 | 25 | 8 | 1 | 1 | 11.25 |
| " 14 | 28 | 4 | 0 | 0 | 9.00 |
| " 21 | 17 | 4 | 0 | 0 | 6.25 |
| " 28 | 23 | 9 | 0 | 0 | 10.25 |



View of Mount Aso Crater, Japan

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant quakes were located with the aid of the seismograms from stations at Hilo and Kealake-

Boiling Mud at Hot Springs, near Beppu, Japan

kua. The disturbances began at the times indicated and whenever possible determinations of depth of focus have been made.

June 1, 6:33 pm, very feeble, probable location in Kilauea Crater.

June 1, 7:53 pm, very feeble, located 2.5 miles SSW of Pit seismograph station in Kau Desert. 19° 22' 3N; 155° 18' 0W.

June 3, 8:13 pm, very feeble, located 1.5 miles deep in Kilauea Crater 1:0 mile SW of the Volcano Observatory. 19° 25' 2N; 155° 16' 1W.

June 4, 1:21 pm, very feeble, located 2.5 miles under SE rim of Kilauea Crater 19° 24' 7N; 155° 15' 8W.

June 4, 3:18 pm, very feeble, located 1.8 miles deep in Kilauea Crater, 1.0 mile SW of the Volcano Observatory. 19° 25' 2N; 155° 16' 1W.

June 4, 3:21 pm, feeble, located 3.0 miles deep in Kilauea SW Rift zone 0.4 mile west of Halemaumau in vicinity of the Rift Cones. 19° 24' 6N; 155° 22' 8W.

June 5, 4:09 pm, very feeble, located 1.2 miles under Pit Seismograph in Kilauea Crater. 19° 24' 3N; 155° 17' 0W.

June 7, 9:53 pm, very feeble, located 0.8 mile deep under SE rim of Kilauea Crater. 19° 24' 5N; 155° 15' 9W.

June 7, 11:28 pm, very feeble, located 1.2 miles under N rim of Kilauea in vicinity of Kilauea Military Camp. 19° 26' 3N; 155° 16' 8W.

June 11, 5:05 pm, very feeble, located 1.4 miles deep in Kilauea Crater 5.0 miles SW of the Volcano Observatory. 19° 25' 6N; 155° 16' 0W.

June 14, 8:31 am, very feeble, probably located in Kilauea SW Rift zone 8 to 9 miles SW of Halemaumau.

June 17, 12:55 am, very feeble, located 1.4 miles S of Pit seismograph and 1.9 miles deep. 19° 23' 2N; 155° 18' 0W.

June 18, 12:03 am, very feeble, located 2.5 miles under W rim of Kilauea Crater 0.7 mile SW of Uwekahuna. 19° 25' 1N; 155° 18' 0W.

June 22, 2:37 am, very feeble, probable location in vicinity of Hilina Pali.

June 23, 7:19 am, very febele, probable location in Kilauea Crater.

June 25, 8:34 pm, very feeble, located 3.7 miles deep and 1.1 miles SW of Puu Ohale. 19° 20' 9N; 155° 17' 7W.

June 25, 8:37 pm, very feeble, located 3.1 miles under NW rim of Kilauea. 19° 25' 9N; 155° 17' 4W.

June 26, 6:57 am, very feeble, located 1.6 miles deep and 0.3 mile S of S rim of Kilauea Iki. 19° 24' 6N; 155° 15' 1W.

June 26, 9:25 am, very feeble, probable location in NE portion of Kilauea Crater.

June 26, 2:54 pm, located 1.6 miles deep and 0.8 mile S of Twin Craters. 19° 24' 4N; 155° 14' 2W.

The surface (L) waves of a distant earthquake began recording at the Observatory at 11:02 pm, June 2. The reported location was off the Coast of British Columbia. 40° 7N; 125° 5W.

Three minutes of continuous tremor registered, starting at 11:26 pm, June 2.

Microseismic motion was moderate, June 2, the remainder of the month it was light.

**Tilting of the Ground**

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending June 28 was 5".08 N and 0".74 W.

H.H.W.

**Crater Angles**

Measurement of horizontal angles across Kilauea Crater from the Observatory June 9, compared with similar measurements March 16 and April 15, showed little change across Halemaumau but indicated opening across the crater from rim to rim in a NW-SE direction. March 16, to April 15, Halemaumau showed opening of 0".11 and April 15, to June 9, it closed 0".52. Across the Crater there was an opening of 0".75, and April 15 to June 9, an opening of 2".18.

**TABLE OF TILT**

| Week Ending | Observatory | Halemaumau Clinoscope Stations West | Southeast | Pit Resultant |
|---|---|---|---|---|
| June 7 | 1".00 S 40°W | 6".59 S 65°W | 7".52 N 10°W | 0".34 toward |
| " 14 | 0".29 N 59°E | 3".10 N 38°W | 6".19 S 9°E | 7".11 from |
| " 21 | 0".75 N 33°E | 4".26 S 40°W | 6".71 N 2°E | 2".22 toward |
| " 28 | 0".92 N 19°E | 5".96 N 79°W | 1".94 S 83°W | 4".69 from |

View of Sakurajima, Kagoshima in Foreground, 1914 Eruption

## NOTES ON JAPANESE VOLCANOLOGY, AND ON SEISMOLOGICAL RESEARCH

H. H. Waesche

Cherry blossoms, temples, and volcanoes are three things that every visitor to Japan becomes conscious of as soon as his ship docks at one of the Empire's many ports. He may not see the cherry blossoms as they are a seasonal exhibit only, and a visit could be made without seeing any of the shrines or temples, but evidence of volcanic activity, either past or present, cannot be overlooked. Volcanoes are a part of the everyday life of all the Japanese. Volcanism is a major motif in their art, it enters into religion, and even in their play at various hot-spring resorts or "spas," as they are called. Fujiyama is known the world over for its grace and symmetry of form. This dormant volcano is exhibited in practically all Japanese arts and being sacred it influences the thought of the entire country. It is probably the typical volcano. Volcanic eruptions, destructive and otherwise, have been a part of the history of Japan from its very beginning. There are many volcanoes which are periodically active, such as Asama, Mihara (Oshima), Aso, and Sakurajima among the more famous, and others at scattered localities from Hokkaido in the North to Kyushu in the South. Anyone interested in volcanology and its related subject, seismology, will find both well represented in their many phases in the "Land of the Rising Sun."

H. Waesche, Assistant Geologist at the Hawaiian Volcano Observatory, and Merel S. Sager, Associate Landscape Architect of the U. S. National Park Service, visited Japan during April and May, 1936. Trips to the volcanic areas of Mt. Fuji, Beppu, Sakurajima, Mt. Aso and Unzen were made during their stay. They also visited the Department of Geology, and the Research Institute of the Tokyo Imperial University. Acknowledgment is made of the many courtesies extended and helpful information given by Dr. S. Tsuboi of the Department of Geology, Dr. M. Ishimoto of the Research Institute, and Drs. Imamura and Matuzawa of the Seismological Institute. The trips to the National Park Areas were made most enjoyable and profitable through the very kind assistance of Dr. T. Tamura, of the Japanese National Park Association, his assistant Mr. Kato, and the local directors of the several parks, as well as local prefectural officers. All contributed toward making the trip one of outstanding value.

The morning of April 17 was spent inspecting Hot Springs in the vicinity of Beppu. This city is one of the most famous of Japan's 1200 spas. It is located on the east coast of the Island of Kyushu bordering the famous Inland Sea. Here in a volcanic area of about twenty square miles are found over a hundred thermal springs and fumaroles exhibiting a variety of characteristics. They are known as "Big Hells" or to the Japanese as jigoku. Associated with many of the hot springs are smaller areas several feet in diameter of boiling mud similar to the "paint pots" seen in Yellowstone. These latter are noisily and continuously agitated by escaping steam. The largest of the hot springs is known as Umijigoku and is thought to be over 400 feet in depth and has a temperature of 195° F. at the surface. The water of one spring visited possessed a bright red color which appeared to be caused by the presence of iron, evidently in the form of ferric oxide. Articles of clothing and other materials dipped in the red water and stained were valued souvenirs by many visitors. The name of this spring was Chinoikejigoku or "blood pond." Most of the fumaroles produced sulphurous odors. No native sulphur deposits were observed, however. A popular novelty along the seacoast at Beppu is the so-called "sand bathing." Hot springs bubble up through the sand beaches where the bathers bury themselves in the sand and take a modified turkish bath.

The next stop after leaving Beppu was made at the city of Kagoshima in the southern part of the Island of Kyushu. This city is located on the shores of Kagoshima Bay. In the Bay and two miles east of the city, towering 3,500 feet above the water, is Sakurajima, one of Japan's mightiest volcanoes. This cone marks the scene of the greatest eruption in the annals of the Island Empire which took place beginning in January, 1914. It is of interest that this eruption was expected, and the local residents being thus warned were prepared, with a consequent loss of life of only 35 people and some millions of dollars in property damage. Warnings concerning the possibility of an explosive eruption were made as early as 1909 following rather violent earthquakes in the vicinity. In 1913 violent eruptions began at Kirishima Volcano some thirty miles to the north of Sakurajima. The last two eruptions there occurred on November 8 and December 9, consequently expectations at Kirishima were high when January 9 arrived, but nothing happened. However, at Sakurajima an outburst of earthquake swarms transferred suspicions to that vent. Four hundred and seventeen earthquakes were recorded at Kagoshima between 4 am January 11 and 10 am January 12, after which the main eruption began. The morning was cloudy so that the activity was not visible until after 10 am when the

Meteorological Observatory on Sokojio Unzen, Japan.

clouds dissipated. At that time a swelling balloon of black smoke in the middle of the mountain was seen rising from the ground where an hour before there had been orange orchards and cultivated, terraced fields. The column of smoke went up some 30,000 feet in the air and then bent eastward, strewing dust all over Central Japan. A smaller column arose on the east flank of the mountain having started ten minutes after the western one with which it later merged. There were booming concussions, flashes of lightning and in the lower part of the cloud, being thrown to great heights were ashes, sand and bombs. At night these latter were seen to be red hot. At 6:29 pm a violent earthquake shook Kagoshima and it was in the destruction caused by this shock to buildings and in landslides that most of the casualties resulted. This shock was recorded on seismographs in Europe. It was followed by lava emissions. Their flow continued several months, filling in new craters, pouring into the sea and on the east side of the Island filling in a strait, changing the Island into a peninsula. This happened the afternoon of February 1. Much pumice was formed and so great was the quantity floating in the bay that boats traveled with difficulty. Fortunately for the City of Kagoshima the eruption was not concentrated at the one western vent pointed in its direction as its fate might have been similar to that of St. Pierre on the Island of Martinique when Mt. Pelee erupted in 1902. The water of the Bay around Sakurajima was warmed considerably and near the lava flows measured as high as 138° F. More than 4,000 acres of lava were poured out above sea level in two months. Ash measured 70 inches in depth near the volcano, a thin film 30 miles away and some even fell in Tokyo 600 miles away on the third day of the activity. Precise geodetic measurements of Sakurajima showed that an elevation on the mountain had risen 10 feet whereas a point submerged in the bay had lowered 10 feet. This would seem to indicate that the volcano had swollen with lava inside while the surrounding land had subsided with the release of pressure and emission of lava.

On April 18 of this year Sakurajima was quiet when visited. In the early morning a moderate cloud of fume or vapor was seen rising from the summit crater. This was obscured by clouds shortly before noon. A boat trip was made to the tip of the most westerly lava flows from Kagoshima. The party landed on a beach composed of pumice. The lava was of a rough fragmental nature, black in color, very similar to the aa of Hawaii. It is said to be a hypersthene-hornblende andesite. The flow at this locality was piled up probably two hundred feet in thickness. Reports said that the eastern flow was 300 feet above sea level in localities formerly covered by 200 feet of water. The upper slopes of the volcano were bare of vegetation, were light reddish in color and seemed composed of soft materials of the nature of ashes and cinders. Sakurajima is of the usual conical shape much like the volcanoes of the Cascade Range of the Northwestern United States. Although not now active in a spectacular way it is an inspiring sight.

Leaving Kagoshima by train, the City of Kumamoto was reached the evening of April 18. The night was spent at the Tsukasa Inn. Early the next morning the party, consisting of Mr. Matsumuro, Director of Aso National Park, Mr. Goto, the Assistant Director, and a Japanese policeman by the name of Jiro Kurageno, left Kumamoto for Mt. Aso Volcano. Mr. Matsumuro left the party after going a few miles out of Kumamoto. The policeman went along as translator, being the only Japanese of the group who could speak English. At Bochu a bus was taken for the point of greatest activity. The bus was a very sumptuous one including swivel chairs as in a railway parlor car. Besides the driver there were two Japanese girls, one who described the places of interest in sing-song Japanese and another who translated it into English. The latter girl's name was Sumi Araki formerly of Honolulu, Hawaii, and spoke excellent English. She is now employed by the Great Aso Motor Bus Company in charge of the other girl employees and as a translator for foreign visitors. The bus used was one which had been especially built the preceding year for the exclusive use of Prince Takamatsu when he was a visitor to Mt. Aso. At the summit Mr. Henry K. Haraguchi, owner of the park concessions, was the party guide. The road from Bochu to the summit was finished five years ago, having been built by the Imperial government, and is now operated by the National Parks Association of Japan. It is about nine miles long and at no point is the grade more than 1:12. At the end of the road, which was about one-half mile from the active crater, there was located a seismograph station. Here there was an instrument of moderate magnification registering on a smoked drum. In the valley below Aso, toward Kumamoto, the Kyoto Imperial University has an observatory where studies of all changes and activities at Aso are being continuously made.

The Aso Volcano is the largest of a chain of vents extending along a zone of crustal weakness from Mt. Kuju to the east to Mt. Unzen to the west. This zone of weakness is supposed to be a continuation westward of the depression zone of the Inland Sea. The mountain proper covers the major part of the two provinces of Higo and Bungo and its base extends 30 miles E-W and 28 miles N-S, including some 700 square miles. It consists of a "somma" which attains a height of 3,200 feet above sea level, topped by an oval crater, 10 miles wide and 15 miles long, the floor of which is sunk an average of about 1,600 feet below the rim of the outer slope. The wall of this caldera is nearly perpendicular with talus accumulated at its base. This huge crater is thought to have originated by depression, as have those of Hawaiian volcanoes, due to the outflow of immense volumes of lava. The caldera is attained from Kumamoto on the west through the Futaye Pass cut into the rim to a depth of over 2,000 feet. Another pass known as the Tateno Break occurs to the south of Futaye Pass. Breaks in the rim walls along fracture zones aided by water erosion are supposed to be responsible for these two gaps. Rising near the center of this huge crater, said to be the largest in the world, are the central cones called the "Five Peaks of Aso." The most important of these is one known as Naka-dake, the scene of current activity. Standing west of Naka-dake is the highest cone, Taka-dake, rising a mile above sea level and around 3,600 feet above the floor of the caldera. Surrounding these central cones are the plains extending to the crater wall which are known as the "atrios." The part to the north of the cones is the Aso valley and to the south is the Nango valley. These atrios, consisting of volcanic ash, sand, lapilli and gravel, form a fertile soil on which lives a population of some fifty thousand people including 11 villages. The stratification of the materials composing the crater floor suggests the existence of a former crater lake, which was later drained through the passes previously mentioned.

Naka-dake possesses a series of five pits composing the summit crater. These are numbered consecutively from north to south and share honors as centers of activity with the number 1 pit having the majority to its credit. Number 3 pit is next in frequency of eruptions. Number 4 pit was active 10 years ago and continued intermittently for several years. In 1926 number 2 pit was described as a small kettle-shaped depression, at times filled with water and never very active. At present this is a large depression and the center of activity. It broke out with an explosive eruption in 1934 which was the largest in 150 years. Bombs and boulders were thrown over three hundred feet in the air and literally peppered the ground for several square miles around the vent. Much ash and cinders were ejected but no lava flows. A huge column of smoke now billows above the vent, rising high in the air and easily visible almost the entire trip from Kumamoto to Bochu. Viewed from the rim of the pit, it is seen to be rushing out with considerable force and is accompanied by loud roaring sounds below. Evidently this cloud of fume is composed principally of steam with considerable sulphur fumes, as shown by the amber color in reflected light and bluish in transmitted light. This pit is now over 3,000 feet long by 1,500 in width and is about 450 feet from the rim to the throat of the funnel-shaped aperture from which issues the huge cloud of vapor. The throat is supposed to be about 35 feet across. Occasionally incandescent material is visible below. Number 1 pit is about 400 feet, number 3 about 250 feet and number 4 about 475 feet in depth. Their floors are dotted with fumaroles and solfataras. Historical records indicate that Naka-dake has erupted between 60 and 70 times. These have always consisted of emissions of mud flows, ashes and fragmental materials but never any trace of a lava flow.

The rocks of Mt. Aso are petrographically classed as andesites and are comparatively basic, many of them containing olivine or angite or both. The olivine-bearing rocks are found in the central cones and are younger than hornblende-bearing rocks found on the outer slope of the crater.

Aso Volcano is without doubt one of the most interesting sights to be seen in Japan today. It is apparently putting on an excellent and impressive performance at all times whether of a violent nature or otherwise. Five hundred thousand visitors annually are reported to look into the awesome depths of the rumbling pit. As is true of Mihara and Asama, Aso seems to be an attractive spot for those Japanese suffering from suicide manias. An average of 200 of these unfortunates is reported to make the leap from the rim of number 2 crater per year.

The next volcanic district as a part of the Japanese itinerary was that of Unzen, also a National Park and a very popular hot springs resort, catering mostly to foreigners. It is located on the Shimabara Peninsula, western coast of the Island of Kyushu and is the western terminus of the volcanic chain of which Mt. Aso is a part. The group of mountains at Unzen consists of a central cone called Fugen-dake and associated peaks of Kunimi, Myoken, Takaiwa and Kinugasa. The whole mound consists of a more acidic type of rock than was found on Mt. Aso.

Within historic times there have been several recorded eruptions at Unzen. One is reported to have started in 1657 A.D. and marks a period of activity lasting for more than 20 years. Others occurred in 1663 and 1664. The most eventful activities started with a series of earthquakes in the winter of 1792. On the morning of February 9 that year, Fugen-dake erupted with loud explosions, throwing heavy smoke clouds, mud and rocks. Lava broke out in the valley of Anasako February 25, overwhelming the village of Semboki. This lasted several months. A heavy earthquake shock on March 11 was followed by over 300 slighter shocks that night and over 100 during each of the next two days. Around April 1 a huge landslide following earthquake shocks occurred on the southeastern part of Mea-yama, a mountain on the seacoast south of Shimabara. About one-sixth of the entire mountain mass slid into the sea, producing severe tidal waves. Two villages were completely buried under the debris. The portion of this huge mass which slid into the sea gave rise to between two and three hundred islets of which many still exist. Today these are called "Ninety-nine Islands" and are partly covered by vegetation. The boat which runs from Misumi to Shimabara affords excellent opportunity to see the scar left by the slide and the islands which resulted. Whether this was really a volcanic explosion or not is a moot question. Casual observation from the boat suggested structural failure rather than volcanic activity. Various phases of diminished activity continued until February, 1793. Eruptions of this nature are of interest in exhibiting, specifically, relationship to a marked degree of volcanic activity and seismic activity. Other than a heavy earthquake in December, 1922, and minor shocks from time to time no further evidence of activity except hot-spring and fumarolic emissions has occurred.

In the recently erupted flat dome of Obiyama, past volcanic activity is indicated by numerous hot springs and fumaroles. This is the famous spa district of Unzen where are located the many hotels for the thousands of visitors who come from all over the world annually. The springs are usually acidic and contain sulphur compounds. Near the vents, siliceous sinter and deposits of sulphur are being built up. The spa is 2,200 feet above sea level. A nine-hole golf course is located at the foot of Mt. Myoken.

An excellent view of the surrounding country may be had from the summit of Kinugasa-yama. This mountain, over 3,000 feet above sea level, is the location for a meteorological station under the control of the Nagasaki Prefecture. Here are housed various instruments such as barometers, anemometers and thermometers. In a separate building is an Omori seismograph and quarters for an attendant. Unzen posseses a charm deserving of its great popularity.

The supreme expression of volcanism in Japan, at least to the popular mind, is the world-famous Mt. Fuji. Rising to a height of over 12,000 feet above sea level, it is usually surrounded by clouds and during most of the year there is a mantle of gleaming snow on the upper portion. Wherever Japanese art has gone, there also has gone Fuji. It is the very symbol of Japan itself and as previously mentioned is held in sacred veneration by the Japanese people. It well deserves this consideration. Its perfect cone is considered the classic type shape for a volcano of the explosive type. When the weather is favorable, Mt. Fuji may be seen from Yokohama, where visitors from North America first land, from Kamakura, parts of Tokyo and from the main line railroad between Yokohama and Kobe.

Mt. Fuji is characterized by a long, gentle slope of similar inclinations on all sides except the southern, where there is an explosion crater. Halfway up the inclination is 17° and at the summit it is 34°. A typical summit crater is found at the top of the mountain which is a funnel-shaped depression, 720 feet deep and 1,970 feet in diameter at the uppermost level.

Mt. Fuji has been active several times within history. In 800 A.D. a lava stream flowed down the Katsura-gawa and eached the Enkyo bridge following a violent eruption. In 864 A.D. two great streams of lava poured down the northern slope. The last major activity occurred in 1707 when a large explosion took place on the southeastern flank, producing the Hoeisan Crater. No lava was emitted but great quantities of bombs were thrown out. This was followed by small explosions in 1708 and 1792. The volcano seems dormant at present although reports mention fumaroles on the east side and on the top, none of which are very active. Numerous spas and hot springs dot the countryside around Fuji, however, of which some of the best known were visited at Myanoshita and in the Hakone District. One of these, visited May 9, 1936, known as the "Big Hell," was emitting quantities of sulphurous vapors, was surrounded by sulphur deposits, and was of comparatively high temperature. At Myanoshita, waters from the hot springs are run into very imposingly appointed baths at the Fujiya Hotel for the use of guests. Dr. Tamura of the National Parks Association presented a bomb from the summit crater of Mt. Fuji to H. H. Waesche. This was a sister rock of the one presented to Mt. Rainier National Park in the United States as an exchange of goodwill between the respective countries. They were both brought down by Mr. Kato, Landscape Architect of the Japanese National Parks. The bomb was oval-shaped and about seven or eight inches in maximum diameter. Like other Fuji rocks it is of an andesitic composition. One of the best views of Fuji is obtained from Nadao Pass to the south, reached by bus from the Fujiya Hotel at Myanoshita.

On May 11 a visit was made to the Tokyo Imperial University. Dr. Tsuboi, the head of the Department of Geology, was host to the party. Activities of the Geology Department were discussed and results exhibited. Geological work was in progress on the Mount Fuji region and much areal mapping had been done. Instruments used for petrographical and mineralogical work were inspected. The department was up to date in all respects and seemed to be carrying on an extensive as well as progressive program of research with emphasis on the geological phases of volcanism, earth movements and structures, petrography and mineralogy. There was a large collection of thin sections of rocks from all parts of Japan. Everything was being carried on with the customary Japanese thoroughness.

Dr. Ishimoto, Director of the Earthquake Research Department, next took charge of the visitors. He has a large, well-equipped department with many seismographs of various types. Most of them were modified Galitzins of the accelerometer type, having a vibration period in some cases as long as 0.7 second. One vertical instrument had a pendulum extending three stories up to the roof of the building with a period of 7.0 seconds. Photoelectric recording was the preferred method, although many instruments utilized very thinly smoked drums. In all cases the drums were rotated by means of synchronous motors. They made in most cases four revolutions per hour. A few seismographs used no timing. Instrument magnification ran from 100 to 500 and on low magnification instruments from 2 to 10. The time marks were recorded on the drums by means of electrical solenoids which jarred the frames, thus widening the pen's trace at that instant and were controlled by master clocks. Tilting of the ground in Tokyo is given considerable attention because of its possible value in earthquake predictions following observed tilts of blocks between fault lines. One very interesting tilt instrument consisted of a long horizontal pipe partially filled with water and buried several feet in the ground. The open end of the pipe was faced with glass where the water level could be seen. Regular daily micrometer measurements of the changes in level of the water were taken and from them tilt calculations made. This seemed to be quite practical for tilt measurements in one plane and had the advantage of being earthquake proof. One laboratory room was used for testing seismographs and accelerometers with a standard rocking machine. Various types of harmonic motion could be produced in this manner with known values, making possible the determination of instrument peculiarities and characteristics. A similar instrument is in the shop at the Hawaiian Volcano Observatory and has been used for tests on instruments now in use. A great deal of attention is given to initial movement determinations. Both vertical and horizontal instruments are used. Models of glass representing the disturbed area are made, with small silk threads showing deformation of the earth near the focus as indicated by interpretation of initial earth movements at a number of localities.* All the instruments at the Earthquake Research Laboratory are located one to two stories below the ground level for better control of variable conditions, such as temperature changes and in order to reach a good rigid sub-stratum. Gravity determinations of localities on the earth's surface is a source of much active research along with the seismological studies.

As guests of Dr. Ishimoto, luncheon was enjoyed at the faculty restaurant in the company of Drs. Tsuboi and Imamura, as well as the host. After luncheon Mr. Sager called at the Architectural Department while H. Waesche accompanied Dr. Imamura to the laboratories of the Seismological Institute, of which he is Director Emeritus. The Institute is an older organization than the Earthquake Research Institute. It was previously under the direction of the late Professor Omori, world-renowned seismologist, and is now directed by Dr. T. Matuzawa. Possibly the work of the two organizations overlaps. The primary interest of the Seismological Institute, though, seems to be the study of the cause and effect of earthquakes with their possible prediction of occurrence in mind. Here they are interested in what happened in Tokyo and Yokohama in 1923 and what can be done to prevent recurrence of such catastrophes. More attention is given to local shocks. The Earthquake Research Institute, on the other hand, is more interested in the theory of wave propagation, physics, and mathematics of seismology. The day was concluded with Drs. Matuzawa and Imamura conducting the remainder of the party through their laboratories. It was noticed that an instrument identical to the one in use at Uwekahuna was in operation. Many old obsolete seismographs were on display as well as various other instruments of a seismological nature. Pictures of earthquake destruction were plentiful. Seismology is taken seriously in Japan—and it should be, with the occurrence of such catastrophes as some of the past earthquakes have caused. These two seismological research institutions are working day and night to learn more about one of Japan's principal problems. Knowledge is not a guarantee of protection but it will go a long way toward making Tokyo a safer place in which to live, and prediction of earthquake activities more reliable.

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* From the Proceedings of the Imperial Academy, Vol. VIII (1932), No. 2, Sur le Mécanisme de la Production des Ondes Sismiques au Foyer: Existence d'une Source Quadruple au Foyer; and Vol. XI (1933), Part 2, la Deformation de la Croûte Terrestre et al Production des Ondes Sismiques au Foyer, par Mishio Ishimoto.

# THE VOLCANO LETTER

**No. 437—Monthly, Department of the Interior, National Park Service, July, 1936**

**Hawaii National Park**
**Edward G. Wingate, Superintendent**

**Hawaiian Volcano Observatory**
**T. A. Jaggar, Volcanologist**

## HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JULY, 1936

### VOLCANOLOGY

A fresh scar was found on July 1 on the west end of the north wall of Pauahi Crater in the Chain of Craters. Other scars representing recent slides were noticed in Makaopuhi, along with an increase of fuming and sulphur stains.

The week ending July 12 was peculiar in that no rock slides were reported from Halemaumau. Fumes continued to issue from the west floor solfatara, and a more intense puff of fume than usual rose over the NW rim of pit July 11, 10:15 am.

Measurement of 32 marked concentric cracks around Halemaumau, showed changes each week from the week before, as follows, with certain notable openings of Crack No. 46, which is about 150 feet back from the ENE rim:

Six days ending July 3, 6 opened, 4 closed, aggregate opening 5.5 mm. Crack 46 opened 4.5 mm.

Eight days July 11, 13 opened, 2 closed, aggregate opening 11.0 mm. Crack 46 opened 5.5 mm.

Week ending July 18, 7 opened, 5 closed, aggregate opening 5.5 mm. Crack 46 opened 4.5 mm. Fresh cracks opened on the ENE rim.

Six days ending July 24, 7 opened, 1 closed, aggregate opening 9.0 mm. Crack 46 opened 6.0 mm.

Eight days ending August 1, 7 opened, 3 closed, aggregate opening 10.5 mm. Crack 46 opened 8.5 mm.

Thus through five weeks the aggregate openings have been 5.5, 11.0, 5.5, 9.0 and 10.5 mm, and crack 46 has opened 4.5, 5.5, 4.5, 6.0 and 10.5 mm, these facts showing progressive increase of yawning open of cracks northeast.

#### Rock Slides in Halemaumau

June 29, new dust on floor and scar on wall 400 feet below Crack No. 29, NE. At 12:45 pm a NE slide made dust cloud visible for 5 minutes.

June 30, 3:50 pm, small slide. Others occurred at 5:35 pm, 6:18 pm, 6:25 pm and 6:30 pm, all NE.

July 2, 8:55 pm, SW wall, 9:10 pm, NE wall.

July 13, two large slides sent up dust 3:20 and 3:24 pm.

July 18, 9:58 am, noise of rocks falling at SE wall.

July 20, avalanche scar NE.

July 21, noon and 3 pm, dust from slides NE, followed by dribbling slides.

July 22, more scars, small slide 9:37 am, a larger one 1:19 pm, and others 3:43 and 4:30 pm.

July 23, slides from NE wall 9:13 am, 9:52, 10:01, 10:07 am. Northeast chasms on the edge were widening.

July 24, dust clouds from slides 8:15 am and 1:24 pm.

There appear to have been increases in sliding northeast, along with the opening of cracks.

All of this means that a portion of the northeast wall of Halemaumau is "working," whether because of movement on the deep rift blocks, or because of lava motion, cannot yet be told.

T.A.J.

### TABLE

**Earthquakes**

| Week Ending | Minutes of Tremor | Very Feeble Earthquakes | Feeble Earthquakes | Slight Earthquakes | Distant Earthquakes | Local* Seismicity |
|---|---|---|---|---|---|---|
| July 5 | 29 | 9 | 2 | 0 | 2 | 20.75 |
| " 12 | 18 | 7 | 0 | 0 | 0 | 8.00 |
| " 19 | 38 | 12 | 0 | 2 | 1 | 22.25 |
| " 26 | 45 | 4 | 0 | 0 | 0 | 13.25 |
| Aug. 2 | 44 | 3 | 0 | 0 | 0 | 18.50 |

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant quakes were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and, whenever possible, determinations of depth of focus have been made.

June 30, 7:28 am, very feeble, located 4.0 miles deep and 0.5 mile SW of Pit Seismograph. 19° 24' 0N; 155° 17 3W.

July 1, 2:31 pm, feeble, located 15.0 miles deep and 3.0 miles SW of Halemaumau in Kilauea SW Rift zone. 19° 22' 3N; 155° 18' 6W.

July 1, 2:32 pm, feeble, same locality as preceding quake and both reported felt in Hilo.

July 2, 12:47 pm, very feeble, probable location in rifts 2.3 miles west of Pauahi Crater.

July 3, 6:27 am, very feeble, located 4.0 miles deep and 1.6 miles S of Pit Seismograph, 1.0 mile west of Ahua Kamokukolau. 19° 22' 9N; 155° 17' 1W.

July 3, 1:25 pm, very feeble, located 1.8 miles deep in Kilauea Crater. 19° 24' 7N; 155° 16' 3W.

July 5, 7:04 pm, very feeble, 1.3 miles deep and 0.7 mile E of Pit Seismograph in Kilauea Crater. 19° 24' 4N; 155° 16' 4W.

July 6, 7:41 pm, very feeble, located 0.9 mile deep in Kilauea Crater, 0.5 mile W of Byron Ledge. 19° 24' 9N; 155° 16' 1W.

July 9, 8:48 am, very feeble, probable location under E portion of Kilauea Crater.

July 12, 6:22 am, very feeble, located 2.0 miles deep in Kilauea Crater. 19° 24' 7N; 155° 16' 3W.

* For local seismicity definition, see Volcano Letter 371.

July 12, 3:46 pm, very feeble, located 15.0 miles deep under N slope of Mauna Kea, 4.0 miles below summit. 19° 52' 6N; 155° 26' 5W.

July 15, 5:16 pm, very feeble, probable location in Kilauea Crater.

July 15, 9:40 pm, very feeble, located 1.7 miles deep and 0.5 mile S of Kilauea Iki. 19° 24' 4N; 155° 14' 9W.

July 15, 11:12 pm, very feeble, located 1.5 miles under SE rim of Kilauea Crater near Keanakakoi Crater. 19° 24' 4N; 155° 16' 2W.

July 15, 11:39 pm, slight, located 1.6 miles deep under S rim of Kilauea Iki. 19° 24' 7N; 155° 14' 9W. Reported felt in the Kilauea Area and in Hilo by several persons.

July 16, 4:14 am, very feeble, located 0.9 mile under Byron Ledge E rim of Kilauea Crater. 19° 25' 1N; 155° 15' 7W.

July 18, 6:21 am, very feeble, located 1.7 miles deep under NE rim of Kilauea Crater. 19° 25' 8N; 155° 16' 0W.

July 18, 8:24 am, slight, located 2.8 miles deep under SE portion of Kilauea Iki. 19° 24' 9N; 155° 14' 8W. Reported felt by several persons at Military Camp and at the Volcano House.

July 18, 12:45 pm, very feeble, probable location SE portion of Kilauea Crater.

July 20, 8:50 am, very feeble, located 1.8 miles deep, 3.3 miles SW of Pit Seismograph and 2.0 miles W of Aloi Crater. 19° 22' 0N; 155° 15' 3W.

July 23, 6:41 pm, very feeble, probable location Mauna Loa NE Rift, about 5.0 miles from Summit Crater.

July 25, 4:41 pm, very feeble, probable location under E slope of Hualalai about 5.0 miles from summit.

July 27, 4:58 pm, very feeble, probable location under Mokuaweoweo, Summit Crater of Mauna Loa.

The preliminary waves of a distant earthquake began recording at 4h 45m 14s HST, June 30. Newspapers reported quake as being 4100 miles NW of Pasadena, California. The distance from the Volcano Observatory was 3190 miles. Reports from the Central Station of the Jesuit Seismological Association gave the location near N portion of Japan Trough off the S end of the Kamchatka Peninsula. 51° 0N; 161' 1E. The preliminary waves of a distant earthquake began recording at 8h 37m 4s, HST, July 5. The estimated distance from Kilauea was 5650 miles. Reported location was the southern extremity of the Philippine Trough, N of Moluccas. 4° 0N; 124° 9E. The preliminary waves of a distant quake began recording at 12h 55m 45s, HST, July 13. Its estimated distance from Kilauea was 6480 miles. Reported location, in Chile Trough off the N coast of Chile.

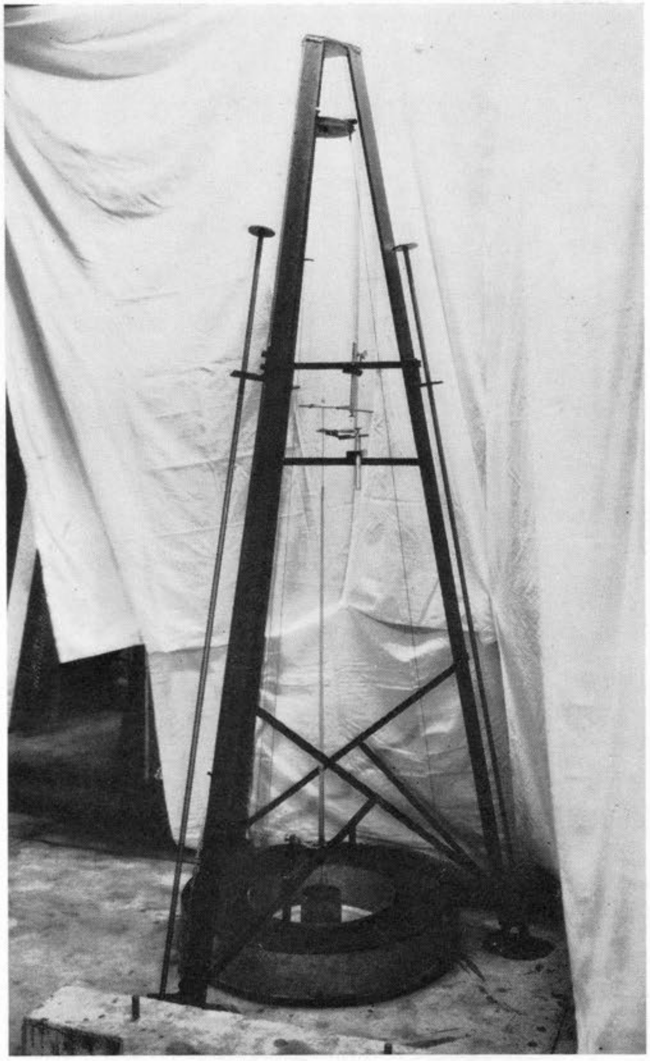
At 3:59 am, June 30, 28 minutes of continuous tremor began registering. At 7:38 pm, July 19, three minutes of continuous tremor began. 24 minutes of tremor began at 11:31 am July 30.

Microseismic motion of the ground at Kilauea was moderate July 15, 17 and 18; the remainder of the month it was light.

**Tilting of the Ground**

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending August 2, was 4" 35N and 1" 81W.



The tiltmeter or clinoscope designed by Wingate and Jaggar, and installed in the three cellars around Halemaumau. A heavy ring weight in oil moves when the ground tilts the tripod. The top of the boom is pointing to a disc marked in directions and distances from a center. The reading of the bottom surface of the disc is made daily with a mirror. The adjusting rods on the tripod bring the boom back to center.

**TABLE OF TILT**

| Week Ending | Observatory | Halemaumau Clinoscope Stations | | |
|---|---|---|---|---|
| | | West | Southeast | Pit Resultant |
| July 5 | 0".76 N 16°W | 5".22 N 83°W | 3".73 N 4°E | 2".15 from |
| " 12 | 0".39 N 15°W | 3".23 S 60°W | 3".92 N 29°W | 0".90 toward |
| " 19 | 0".12 N 3°E | 0".36 N 49°W | 2".43 N 36°E | 0".51 toward |
| " 26 | 0".30 N 28°W | 9".24 N 64°W | 1".20 S | 8".87 from |
| Aug. 2 | 0".86 N 51°E | 3".04 S 86°W | 5".83 N 18°W | 2".54 toward |

H. H. W.

**Crater Angles**

Measurement of horizontal angles across Kilauea Crater from the Observatory, July 24, compared with similar measurements June 9, showed slight closing across Halemaumau and slight opening across the Crater from the SE rim to Uwekahuna on the NW rim. The amount July 6 was a closing across Halemaumau of 0".83 and an opening across the Crater of 0".4. Between July 6 and July 24, the Halemaumau angle opened 0".41 and the Crater angle opened 0".84.

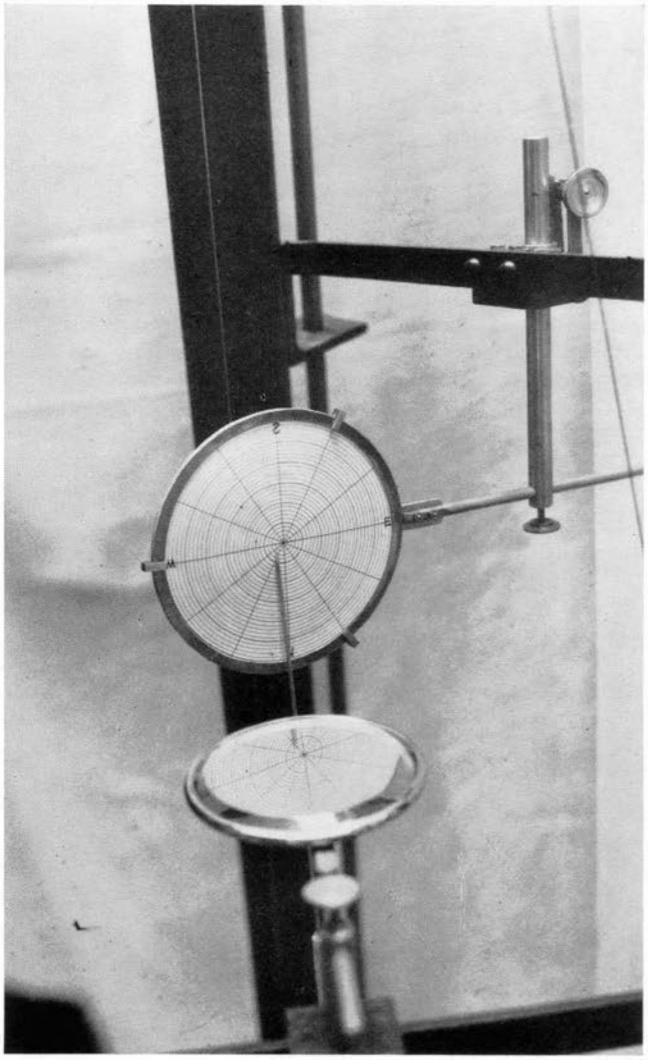
H. H. W.

## MORE ABOUT VOLCANO OBSERVATORY METHODS

**Tilt Measuring Instruments**

We have seen in the May number and in the pictures of the April number, how the Hawaiian Volcano Observatory makes seismograms, measures cracks, receives time signals, collects gases, watches the weather, and surveys the land to prove its rising and falling, swelling and shrinking, and the spreading apart of the cliffs of the Crater.

Here and in Japan, the study of earthquakes has led the workers increasingly to watch the tipping or tilting of a piece of ground. Just what does this mean? It obviously does not mean that the ground was level before. It means that a plumb-bob, hung on a thread and allowed to come to rest, has its thread making a certain definite angle with the surface of the ground at any place. If the ground tilts between January and July, the thread will make another angle, in another direction, when the weight is hung over that same place.



Mirror and dial of Hawaiian Volcano Observatory clinoscopes.

What we need, then, is a weight hanging in one place from a support over a level floor, and a device for measuring the angle that the thread makes with the floor. If the floor were really level, the thread would be at right angles to it with reference to all points of the compass.

But no floor is level. We are not measuring in degrees but in seconds, and a second is one-thirty-six-hundredth part of a degree. A tilt of two seconds would be a disturbing event for the foundation of an astronomical telescope used for measuring the position of the stars. Imagine, then, how an astronomical telescope would fare, when the edge of Kilauea Crater tips eight seconds in two days!

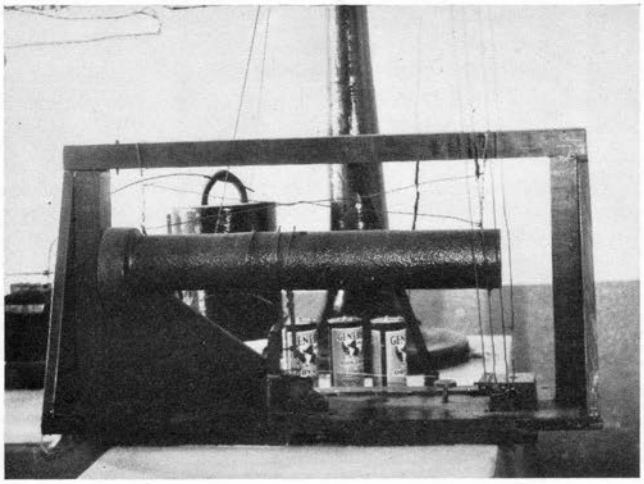
Sometimes these tippings are sudden and are accompanied by earthquakes. This means that the mountain block where our level floor is built has suddenly shifted and our floor is no longer level. At other times the motion is more gradual as though the shell of the mountain were bending like a bow. There are many possibilities. The man of science must think of all these possibilities and select the one that fits best. We had a little seismograph station in February, 1929, at the southeast edge of Halemaumau, the inner pit of Kilauea Crater. The instrument was a pendulum hinged against an upright post like a door with the plane of the hanging at right angles to a radius of the pit. The outer end of the boom attached to the hanging weight wrote a line on smoked paper driven by clockwork. If the ring formed by the upper edge of the pit were lifted, the ground would tilt away and the boom would move away from the pit, and the line on the paper would move with it. On the other hand, if the mountain under the pit should shrink, the pit edge would lower and the door-like weight would swing toward the pit.

The main purpose of such an instrument is to write a zigzag when an earthquake occurs. But its second purpose is to measure tilting of the ground by the position of the line on the moving paper, with reference to a fixed mark on the instrument. It measures tilt in one line of direction only, and that is the line at right angles to the hanging plane.

On February 19, just before midnight, this instrument showed sudden tilting, accompanied by small earthquakes, straight away from the center of the pit, and the moving of the boom away from the pit increased, and kept it up for two hours. Then molten lava gushed up in the bottom of the pit, and the eruption lasted a day and a half. When the eruption ceased, the tilt pendulum moved back towards the center of the pit, and a trembling which it had registered while the lava fountains were operating, rather suddenly ceased.

This splendid demonstration of a relationship between tilt and eruption, the whole pit swelling before the eruption began, and the whole pit sinking when the eruption ended, at once suggested the importance of having two more instruments on other sides of the pit. Thus the idea of a special "Clinoscope" was born.

We proceeded to build the "Clinoscopes" in the Observatory shops. This tilt meter is shown with its parts in the accompanying pictures. It seemed desirable to make it show both direction and angular amount of the change in position of a weight hanging vertically from a single piano wire, so a heavy ring-shaped weight was hung from a seven-foot tripod in a bath of automobile oil, and a magnifying boom or lever was led vertically upward from the space in the middle of the ring. A sharp point at the top of this lever nearly touches a horizontal circular card, which is ruled in points of the compass and in concentric circles. A mirror makes it convenient to read the bottom surface of the card and see where the sharp point lies. By centering it every day, after seeing how far and in what direction it has migrated, we can tell the direction and the amount of tilt of the floor of the cellar where the tripod is placed. The three cellars are at the points of an equilateral triangle around the pit and are built to avoid change



Earthquake Annunciator: Heavy cylinder hangs on wires. Connecting needle magnifies the motion. Tip makes mercury contact and rings bell.

of temperature. Each instrument is read every morning, and the findings are entered in the Observatory records.

The results of running these instruments for some years have not shown that all eruptions in the pit behave on the three sides the way the 1929 eruption behaved on the one side. The principal discovery made with the Clinoscope is that the Kilauea Rift Belt goes across the pit in a straight line and the tipping is right and left with reference to that belt. It is not "all around" with reference to the center of the pit on radial lines. This is very interesting. It means that the circular pit is only a detail of a linear crack. For tilt measurements the crack is the important thing, the blocks on each side of it lifting or tilting away from or towards the crack. We know where the crack crosses, and both the western and northern cellars are on the Mauna Loa side of the crack, while the cellar near the Tourists' Stand is on the ocean side of the crack.

The Clinoscopes are unfortunately not earthquake-proof. This gives us a great deal of trouble because fifty or sixty earthquakes and tremors occur every week. The large earthquakes certainly derange the delicate pivots. Any slightest derangement of a pivot makes the record erroneous where there is such high magnification. We are now redesigning the instruments and hope to make them entirely earthquake-proof, the reading to be done with a microscope without using any pivots. We ought to have a larger number of these instruments around the outer rim and inner floor of Mauna Loa Crater, and also around the rim of the larger Kilauea Crater, and at some distance away on the radiating highways.

**An Earthquake Annunciator**

Three of our pictures show respectively a rough hanging cylinder in a wooden frame, a very sensitive long needle under the cylinder balanced horizontally about a vertical axis, and a common electric bell annunciator showing four numbers just as used in the office of a hotel to show signals from four bedrooms.

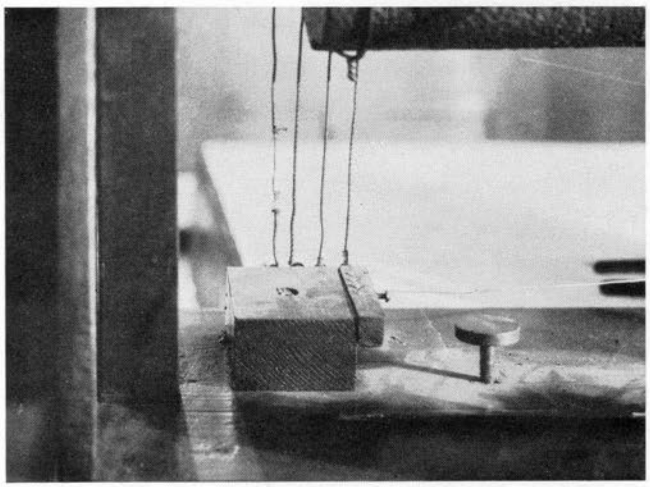
The hanging cylinder is in the seismograph cellar of the Observatory, the annunciator bell is in the seismologist's room above. The object of the device is to notify the seismologist when four different sizes of weak earthquakes occur, all in the class too feeble for him to feel. The bell rings, notifies him that an earthquake is going on, and he may take action accordingly.

The cylinder is a very heavy piece of shafting hung to swing from a beam in an east-west direction. It is appropriately connected with the short arm of an aluminum lever, the long needle. The magnification is about one hundred. This is like the magnification of our sensitive seismographs. The tip of the long arm of the lever, when an earthquake moves the beam back and forth, makes contact electrically with four drops of mercury spaced out in a line, progressively farther from the tip. If the earthquake is big enough to reach number four mercury drop, the number four arrow of the annunciator dial springs sideways and points to the figure four. The same with the other numbers.

This annunciator proved unexpectedly useful during the eruption of Halemaumau Pit, two miles from the Observatory, in September, 1934. The little cone on the floor of the pit became violent with gas explosions every few hours. These explosions were rhythmical. Every time they began, a tremor impulse or shock was sent through the earth to the distant Observatory, and the annunciator bell started ringing with a rhythm exactly accordant with the explosions. Thus a record could be kept by an observer sitting quietly in the Laboratory of the recurrent spasms of explosions at the Pit, two miles away.

**Meteorological Instruments**

There is little to be said about the thermograph, rain gauge, or the maximum and minimum thermometers, except that their showings have been recorded here for twenty-five years. The Observatory has been a volunteer station of the United States Weather Bureau. The wet- and dry-bulb thermometers, which Mr. Waesche is shown swinging in the breeze, attached to an instrument called the Hygrodeik, is for registering the moisture of the air; the relative humidity at the edge of Kilauea Crater is very high owing both to the climate and to the innumerable steam cracks.



Earthquake Annunciator: Tip of needle opposite four mercury cups. These are for four different intensities of earthquake motion.

**Crack Movements at Halemaumau**

This subject has already been illustrated on page three of the April issue, but it is just now an appropriate time to show another picture of a special caliper built for measuring the extremely large cracks on the edge of the pit.

Earthquake Annunciator: Bell and numbers record by arrows earthquake intensities 1, 2, 3 and 4. This notifies the seismologist what the seismographs are doing when he does not feel the quake. Shows also timepiece and mercurial barometer.

For several months, as indicated in the reports, we have had excessive movement at crack number forty-six, which lies some distance back from the northeast edge of the pit and this is merely an extension of a crack emerging at the edge of the pit as in the photograph. A section of the rim bounded by one of the regularly measured cracks, fell in between March 15 and March 22, 1936, and in our March issue we illustrated some of these cracks. The aggregate opening of all cracks on March 14 was more than 54 mm. This is excessive, and these movements of cracks at times have yielded very useful data for the National Park Service. The change will come gradually or suddenly and some portion of the rim of the pit may become dangerous and have to be roped off.

Just before the eruption of February, 1929, described above, there was such a disturbance at the eastern margin of Halemaumau so that the entire Tourists' Stand had to be changed in position and a new station built.

There appears to be a complicated relation between local earthquake, tilting of the ground, rise and fall of the pit rim, and the avalanches which fall from the walls of the pit. The complication concerns the question of whether the avalanching and the cracking make the local earthquakes or whether the local earthquakes make the avalanching and the cracking. Both kinds of relations have been discovered on different occasions.

T. A. J.

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**DES MOINES SEISMOLOGICAL STATION**

Editor's Note: We are privileged this month to publish a brief account of the only earthquake-recording station in America, designed, constructed and operated by a woman. To Mrs. M. M. Seeburger, a talented scientist from whose facile pen comes the article which follows, and to whose patient study and steadfast work seismology is indebted, we tender respectful esteem and cordial appreciation.—Ed.

The establishment of the Des Moines Seismological Station was the outgrowth of a number of years of study of volcanic activity by the writer. Inspired by annual visits to the Lassen Observatory in California, where the Hawaiian-type instruments were in use and the laboratories at Pasadena and Berkeley, where various types of optical instruments were developed and operated, the writer's interest in seismology grew, and plans were made to establish a station in Des Moines with teleseismic instruments sufficiently sensitive and accurate to supply needed records in the midwest area, where stations are far apart.

The instruments were designed and built by the writer, the first component being started in operation December 20, 1934, and the second March 15, 1935. They are modified Bosch-Omori in type, and record on smoked paper, one drum being used for both components. The period is 9 seconds and a magnification of 15 was used until this month, when it was increased to 25. A 24-kilogram heavy mass is used, this being adjustable along the pendulum. A pivot is used for the lower suspension and a fine piano-wire suspension at the top of the upright is adjustable back and forth for change of period and from right to left to correct tilt.

Weather Recording: Swinging wet-bulb and dry-bulb thermometers for relative moisture content of the air.

The magnifying system is a new device, designed to reduce friction, which is the great problem in lever magnification. A steel rod, attached to the end of the boom by a three-way adjusting device, ends in a U-shaped fork, having a needle eye at the end of each tine. The fork moves in the same plane as a clock wheel, mounted on a pinion, working in polished bearings in a frame, the wheel being mounted between the two ends of the fork. A groove is cut in the rim of the wheel. A fine silk thread, knotted at one needle eye, passes around the groove in the wheel, thence through the other needle eye and back to the steel rod, where it is kept at unvarying tension by a tiny weight. A 17 cm. recording arm of .006 aluminum is

Weather Recording: Thermograph, rain gauge, maximum thermometer, minimum thermometer.

riveted to the wheel, ending in a fork with an arbor set in polished bearings. The arbor carries the balanced stylus which has just enough weight to remain on the smoked paper. When a movement occurs the fork with the silk thread turns the wheel, oscillating the recording arm and resulting in the variation from the straight line which records the earthquake's message.

Oil damping is used. Time control is provided by a regulator clock closing a circuit every minute and lifting the stylus by means of an electromagnet. Time is checked twice a day by radio signal.

Records are sent to the United States Coast and Geodetic Survey and the Jesuit Seismological Society. During 1935, the first year of operation, 29 earthquakes were recorded at the Des Moines station, varying in distance from the Nebraska earthquake, March 1, 1935, 250 miles distant, to the December 26 shock near Sumatra, 9,700 miles distant. From January 1 to September 1, 1936, 20 shocks have been recorded.

The Seeburger family home offered a good location for the station, being located on a street undisturbed by heavy traffic. A special room was provided, with no windows, and well insulated to keep temperature as nearly uniform as possible. The cement work and casting of lead cylinders was done by the writer, assisted by her husband, who is city solicitor of Des Moines, and a high school son. The assistance of a machinist and a jeweler was required for some parts of the mechanism. Designing, experimenting, and final construction of the instruments required about a year's work.

## ADVENTURES AND METHODS IN STUDYING WEST INDIAN VOLCANOES

The bombing of Mauna Loa December 27, 1935, was followed by the stoppage of the lava flow before it damaged Hilo. The preparation for this engineering job was twenty-four years of recording and experimenting on Kilauea and on Mauna Loa. The action taken was not suddenly inspired, but was methodically thought out sixteen years earlier. The coming of this particular 1935 eruption of Mauna Loa was published early in 1934 for time, place, possible direction, earthquake accompaniments, preparedness, and method of airplane attack.

The volcano excelled itself in coming to time. Predicting is the test of right interpretation of physical processes. At Hawaiian Volcano Observatory mere descriptions and photographs of eruptions gradually gave place after the first six years of work to systematic measurements of earthquakes, tilts, tremblings, gases, and temperature. The effort was always to see what lava is doing underground. Photographing and describing it above ground during eruptions, and comparing the earth motions during eruptions, gave information of what lava is and how it may be acting underground all the time. Gradually the non-erupting times became very interesting as pointing to the places and depths where lava was working its way upward.

This has all led to the investigation of three main projects which in scientific terms may be described as locating earthquake centers underground, measuring the year to year elevation or sideways motion of the ground, and measuring the ejection of matter, either lava or gas, or both. There is always gas being emitted, but not always lava. Sometimes the lava takes it out in lifting the mountain by swelling inside.

When I had opportunity in the spring of 1936 to visit Montserrat in the West Indies, which had been violently shaken by many earthquakes, I had these principles in mind. There was no observatory on Montserrat, but some good earthquake observers had made lists of shocks, and some agricultural chemists had studied the sulphur banks in the craters.

The West Indian volcanic adventures of the last few years have come on several different islands along a curved line of several hundred miles of active volcanoes. They are like the Hawaiian Islands in being thirty or forty miles apart, and long ages past they poured out black lava. But now they are shoving up stiff lavas which are more crystalline and contain more silica. These masses underground react violently with water, the way Kilauea did in 1924. The result was the terrible eruption of Mont Pelé in 1902, which sent out a downward blast of scalding steam and destroyed 26,000 people in St. Pierre. The day before this the volcano Soufrière in St. Vincent made a similar eruption with similar destruction. Mont Pelé during the next year sent up a stiff plug of siliceous lava from its crater. Soufrière did not do so, but filled its crater with a lake of hot water which gradually cooled off during the decades since. Mont Pelé renewed its eruptions in 1929 after twenty-four years of quiet and again increased its height by thrusting up a central plug.

It was just after this last event, which came to an end in 1932, that Montserrat started making a nauseating smell of sulphurous gases in its crater, which is 146 miles northwest of Mont Pelé. It is the same kind of a crater, with several valleys containing sulphur banks, and boiling springs and steaming chemicals. These are all the products of lava somewhere below and the reaction of its acid gases with the rocks of the island and with water. Immediately thereafter, Montserrat started to shake. About every six months in 1934 and 1935 the swarms of earthquakes increased in number and violence, and most of the churches were shaken down. The morale of the people was upset, for everyone remembered the scalding hot blasts of Mont Pelé.

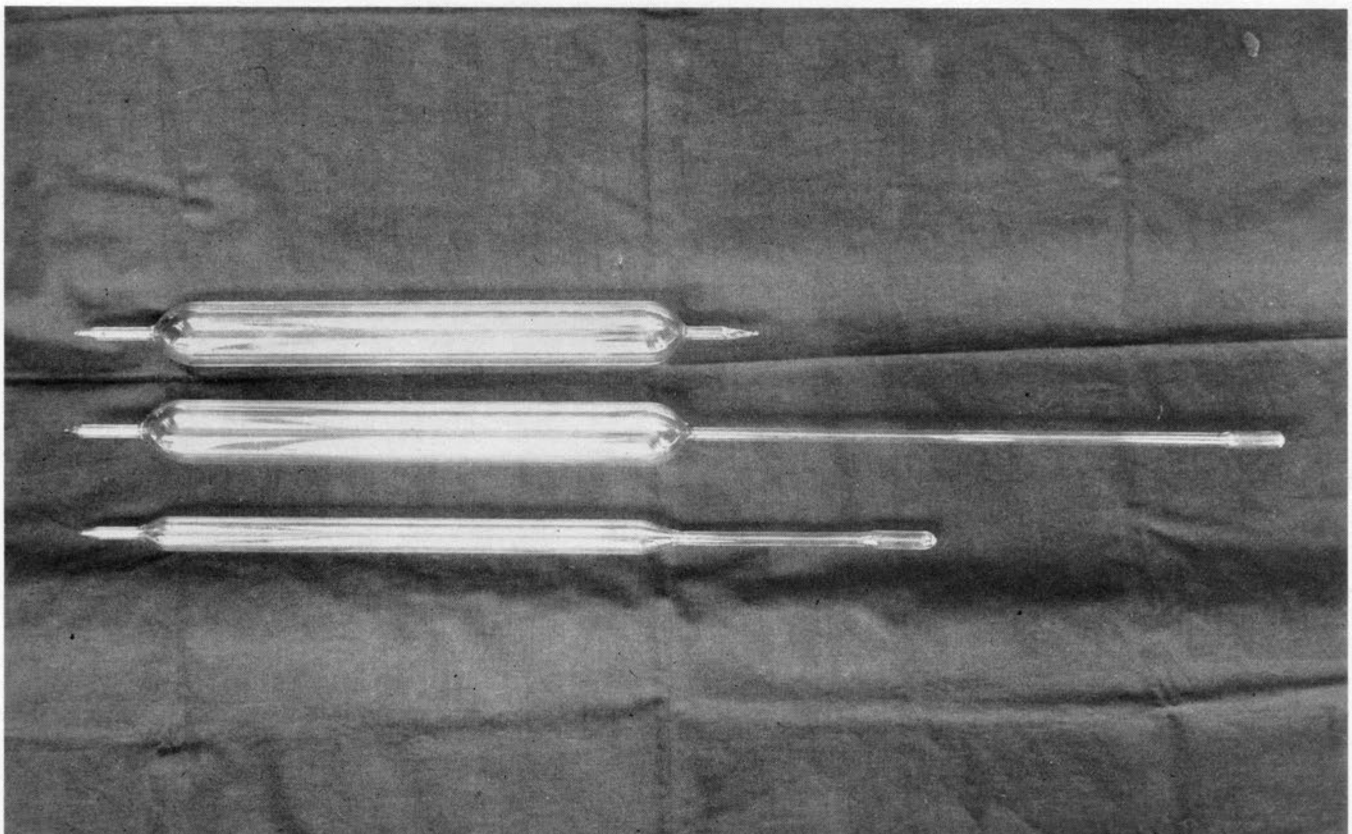
The shift of activity in 1902, 111 miles from St. Vincent to Mont Pelé in 17 hours, and the shift of activity of a different kind, 146 miles from Pelé to Montserrat in a year in 1933, shows that we have to deal with something like the shifts of activity from Kilauea to Mauna Loa, and also such changes from outside eruption to inside heaving, as we had in 1929 when Kilauea stopped erupting and North Kona started shaking. Here are shifts in Hawaii from one place to another, for much shorter distances, than the distances in the West Indies. But the kinds of action are much the same, with due allowance for a different kind of lava.

After making such allowances it is evident we can apply our three methods in the West Indies, if we locate earthquake origins, measure slow motions of the ground, and measure the kinds and temperatures of gases. All of these things are measurable there all the time. The chemistry of the hot solfataras, and there are scores of them in the West Indies, is very interesting and very significant. But before any predicting can be done it is essential to combine the changes in gases and the changes in sequences of earthquakes. This means we must know what the little earthquakes were in numbers and intensity during the quiet time before the crisis developed. For this same time we must know what the gases were and how hot they were before the nauseating and excessive gaseous emission became conspicuous. These are just the facts that we do not possess, in the absence of an observatory. The same thing was true in 1901, the year before Mont Pelé and Soufrière erupted.

What methods, then, should be recommended for understanding any such active volcano? Clearly the measurement must be repeated and continuous. The little earthquakes, the changing elevation of the ground, and the gases, must be measured every week or month or year, and the measurements entered in a record book. Montserrat appears now to have quieted down. What place in those ten or twelve active volcanoes, in those eight or nine islands, along those 350 miles of curved volcanic crack, is now going to do something unusual in 1937 or 1938 or 1939, following upon the shift from Martinique to Montserrat?

There have been many difficulties and disappointments in studying Kilauea and Mauna Loa. There are enormous difficulties and disappointments for the Dutch engineers in studying with airplane and otherwise the many volcanoes that destroy human beings in densely populated Java. But these Hollanders remained manfully at their posts in the jungle amid poisonous reptiles and poisonous gases, and they are getting results. This kind of work of the Geographical Engineer is growing more important, all the world over, because men must know the power and the materials of the earth that is their home.

T. A. J.



Vacuum tube styles for breaking or melting the tip in a gas-hole or volcanic flame: and one tube which has been sealed with gasoline torch.

Use of caliper for measuring large cracks at Halemaumau. The crack is equipped with copper studs and, after setting, the caliper opening is measured with steel tape. An improved caliper is made with arc and clamp.

# THE VOLCANO LETTER

No. 438 monthly | Department of the Interior National Park Service | August 1936

Hawaii National Park
Edward G. Wingate Superintendent

NE PLUS HAUSTAE AUT OBRUTAE URBES

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

## HAWAIIAN VOLCANO OBSERVATORY REPORT FOR AUGUST, 1936

Campfire Lecture. Grand Canyon, Arizona.

### SCIENCE IN THE NATIONAL PARKS

The opening of the Uwekahuna Museum at Kilauea April 18, 1927, was the occasion for an address by the writer to the delegates of the "First Pan-Pacific Conference on Education, Rehabilitation, Reclamation, and Recreation," which met in Hawaii at the call of Secretary of the Interior Dr. Work. Mr. Stephen T. Mather, Director of the Park Service, attended this meeting and the subject of the talk was the geographical opportunity that the Parks offer for experimental studies by measurement of geologic processes (Bulletin Hawaiian Volcano Observatory, April, 1927).

The present address was delivered to the University of Hawaii Summer School at Kilauea, June 20, 1935, in order to outline the growth of educational work in natural science in the National Parks (which has been greatly added to in the last few years), and to show how the several volcanic Parks may add important data to the science of volcanology that is being studied experimentally at Kilauea and Mauna Loa.

It was in 1872 that Yellowstone region was created the first National Park on earth "set apart as a public park or pleasuring ground for the benefit and enjoyment of the people; the preservation from injury of all natural features; and their retention in their natural condition."

The National Park Service as a great organization under the Department of Interior was established August 25, 1916, and owes its original solidity and growth very largely to Stephen T. Mather who was its guiding spirit until January 28, 1929. The idea of creating free nature guides for travellers began at Yosemite in 1919 and this became the Division of Research and Education under Dr. Harold C. Bryant in 1930. A large growth in numbers of Naturalists and Ranger Naturalists attached to the Parks took place during the formative period, and the importance of visual education and photographs* was accented after 1923.

A committee on the educational problems in the Parks made an extended study of the question of developing museums in close proximity to the places where the exhibits came from. There were many places where the actual landscape spread out before the traveller gave life and reality to these exhibits. And there were many other places, like our footprints of the old Hawaiian natives in the Kau desert, where the whole significance of a specimen depends on seeing it in its natural environment. Hence arose the "trailside museum" where a group of fossils or crystals or objects of organic life may be both preserved from harm and seen in their natural relations under advantageous lighting.

The committee on the study of educational problems consisting of Messrs. Merriam, Bryant, Atwood, Bumpus, Kellogg, and Oastler made critical studies of such Parks as the Yellowstone, the Yosemite, Crater Lake, and Lassen; with the assistance of the American Association of Museums, the American Library Association and the Rockefeller Foundation.

From 1924 on, a field school of natural history had been established in the Yosemite. The expenses of the visiting committee of educators were provided after 1928 by the Laura Spelman Rockefeller Memorial which also supplied $118,000 for Yellowstone Museums, near Old Faithful and at Mammoth Hot Springs.

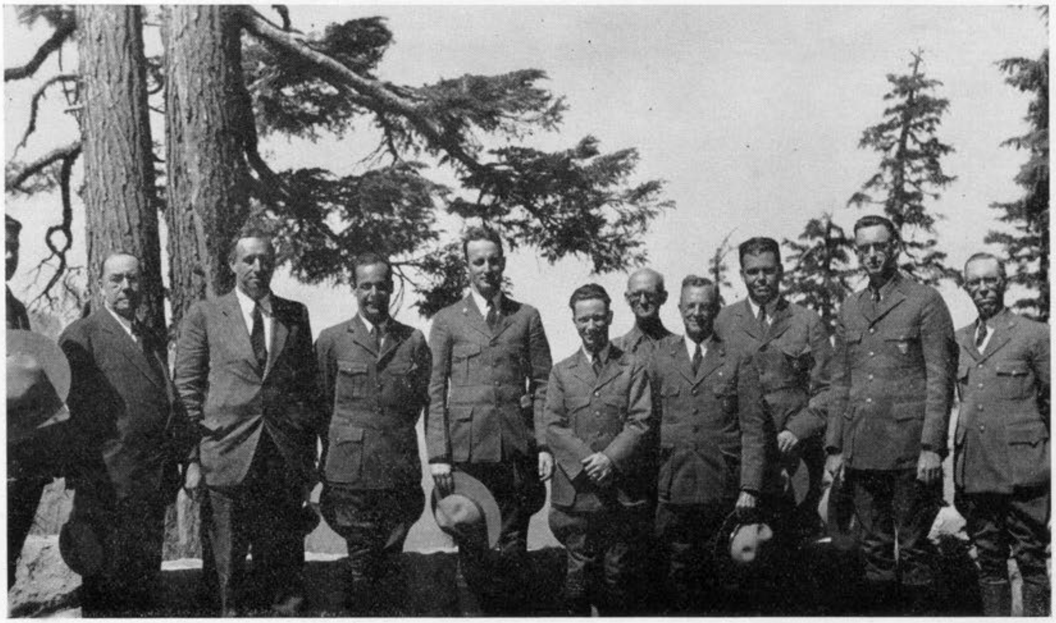
The report of the committee in 1929 pointed out the necessity and the advantage of further research in science as a service to the visiting public, and as service to educators and investigators, "to increase the general and special knowledge of the phenomena represented in the Parks."

In 1928 a trailside museum was built at Yavapai Point in the Grand Canyon. In 1929 the Museum at Yosemite was built. The Loomis Museum was accepted as a gift from private donors at Lassen.

Archeological museums were now springing up in Parks having remains of Cliff Dwellers and Indians, the cooperation of the Smithsonian Institution had been secured, fish culture was in progress, the preservation, feeding and study of animals in their native habitat had become a large branch of the work, and to this the Biological Survey contributed, as did the Bureau of Forestry to the protection of National Park Forests.

In 1930 at Craker Lake a memorial was built to Congressman Sinnott of Oregon. This is a rough stone observation station, inside the rim of the crater, with mounted field glasses, specimens and relief map, all in a commanding position with parapet overlooking the lake. An archeological museum was built at Mesa Verde, and an Indian museum at Acadia (Mount Desert).

At this time several Parks had adopted the practice of conducting automobile caravans from place to place in the care of trained naturalists, and the cooperation in research by government bureaus had become a regular practice. In the cliff dwellings of the southwest, Dr. A. E. Douglas, who had developed the science of interpretation of tree-rings in relation



A Group of Educators and Park Officials at Crater Lake in 1934.

to sun-spot intervals and the climatal changes that affected trees, applied his knowledge to the beam cores of the cliff dwellings, so as to determine their age.

In 1931 lectures and field trips had become the first aim of the Naturalist Branch, a Chief Historian was appointed to cover history and archeology, and Dr. Bumpus succeeded Dr. Merriam as Chairman of the Educational Advisory Board. The Fishing Bridge Museum and Trailside Shrine at Obsidian Cliff were built in Yellowstone Park. At Dinosaur National Monument in Utah an actual fossilized skeleton of a large extinct reptile was excavated in relief by the American Museum of Natural History in its natural site.

Three-year studies of wild life conditions were begun, particularly in the Yellowstone; and for the elk, a cooperative survey was made for the migration routes, the life history and the forage requirements. The Biological Survey, the Forest Service, and the Montana Fish and Game Commission collaborated in this.

In 1932, the native Indians were employed to show their arts and crafts. A ranger-naturalist at the Grand Canyon accompanied privately operated airplane flights. In Acadia a sunrise breakfast caravan was led to the top of Cadillac Mountain, and in the Yellowstone an evening caravan was led to suitable places for stalking game with the camera. Informal campfire talks to five hundred people at a time were held in the Yosemite and the Yellowstone.

The use of the National Parks by university classes was increasing; the principal subjects of investigation being the group relations to each other of plants and animals, and the geology. Graduates of the Yosemite Field School are now serving as ranger-naturalists in other Parks. Thus the Park Service becomes a University for training its own men.

In pure science, cosmic ray investigations have been made in Hawaii and at Mount McKinley. In the Yellowstone, and the Absaroka Mountains to the east of it, university groups of highly trained specialists have investigated the origin of granite, and the geology of the Rocky Mountains.

In 1933 the Emergency Conservation Program was at work in numerous C. C. C. Camps of the National Parks, and the preservation of historic sites was one of the activities of the Educational Board. Sea caravans of motorboats were added as a new feature at Acadia, to study sea-life. Indian pageants were organized, a wayside museum of archeology was built at the Grand Canyon, and a wayside exhibit of the life history of the beaver was established at Yellowstone. In two lookouts there, long-range telescopes were set up. Botanic gardens have been created at Yellowstone and Crater Lake, and a new garden was presented to Yosemite Park.

As examples of the utilization of cooperative research in the National Parks, we have had out here in Hawaii Dr. Meinecke of the Bureau of Plant Industry, and Drs. Day, Shepherd and Allen of the Carnegie Institution. Dr. Wetmore, ornithologist of the Smithsonian has taken a great interest in the Parks and has also been to Hawaii, and the Biological Survey has contributed the work of Drs. Palmer and Murie. Dr. Hommon of the Public Health Service has studied Park problems, and Dr. Hazard of the Bureau of Fisheries. In history Dr. Leland has called in the Council of Learned Societies and a group of leading historians for the numerous battlefields and other places related to the history of the country. So it is with the prehistoric sites where ancient man lived and worked and tilled the soil. The universities of Michigan and California have collaborated in studies of the Teton Range, a National Park in the Rocky Mountains immediately south of the Yellowstone.

**National Park Science in Hawaii**

The foregoing outline sketches the growth of public interest in the many branches of natural and human science that are related to the preservation forever of large tracts of natural wilderness, or smaller ones of historic land.

The tendency of industry is to tear the land to pieces for raw materials, agriculture, transportation or construction and congestion of cities.

The National Park idea has in some measure preserved the natural frontier which our forefathers met in their restless march seeking freedom and wealth. There is still a frontier and a restless march. The tools of the primitive American frontier were the axe, the plow and the rifle. The tools of the new frontier are the airplane, the radio, and the chemical balance. By the ever-widening range of these new tools, which look outward to the universe, and inward to the core of the earth, the frontier of the human spirit today knows no boundary.

Sequoia National Park. General Sherman Tree.
Height, 280 ft.; Diameter, 36½ ft.

The outlook of the Hawaiian Volcano Observatory on its frontier, hewing its way with metaphorical axe and plow and rifle to a visionary palace of science on the top of Mauna Loa Volcano, differs somewhat in its aim of education and research from most of the enumerated activities above outlined.

The word "research" means searching over again, and the historical viewpoint is conspicuous in the attitude of scholarships. How did the elk and buffalo originally live? How did the beaver behave when undisturbed by man? How did the cliff dwellers live? How was that battle fought? How did those mountains grow? How did the dinosaur behave? How does the undisturbed trout breed and meet his enemies? How did the tree rings vary in the seventeenth century? What were the customs of the original Indians? How did the primitive forests grow?

It is a curious and inevitable trait of education and scholarship that the past is more detailed and elaborated than the present and the future, in current methods of research.

In contrast to this, the activities of the present are studied in the chemical laboratory, the growth of living cells in the microscope, the interaction of plants and animals on land and sea; and the effect of planting of gardens and forests and the culture of fish and insects.

The seismologists look inward at the shells of the globe for echoes from distant big earthquakes; and the magneticians and gravity physicists do the same with the compass needle and the pendulum.

The day to day changes, and the statistics of the present are used by laboratory and field science, and the widely distributed National Parks are very valuable for these sciences, whenever a variety of latitudes, elevations or climates affects the process that is being studied. Science goes to the beach when it has to study sea-life, and it goes to the mountain top when it has to study effects of elevation. The Middle Ground, between University and Universe, is apt to be neglected.

On the other hand, the astrophysicists study the universe, and the ultimate atomism of physics, but frankly acknowledge little interest in the earth, the moon and the planets. The earth is chiefly a nuisance, because of the disagreeable optical properties of its atmosphere.

These investigators are studying the light which left distant bodies in space hundreds of thousands or millions of years ago, and so they also are intensely interested in the past. Their observatories have the great advantage of being close to universities, and it is only occasionally that the hardship of an expedition is necessary for such an event as an eclipse. The frontier of the outer universe is the field of their restless march, and their tools are the telescope, the spectroscope, and the electro-magnet.

A part of science, therefore, leaps from the university microscope or electroscope, to the observatory telescope, in studying pinpoints of light. It leaves the study of the earth, the study of the great rough frontier, of the mountains, the rivers, the ice, the sea-bottoms and the volcanoes, to the great rough corporations and their engineers, who handle great rough bodies of labor in tearing up the earth for raw materials and for power.

But what of the earth itself, and its great and small natural processes on the surface, where man dwells, at the present day? And what of the future results of those same processes, many of them quite within the range of man's prediction, that will sweep his cities with hurricane, flood, drought, dust, insect plague, famine, fire, earthquake, blizzard and tidal wave?

The mathematical quantitative study of a point of light under a lens, and the explanation of the past by its aid, is so much more orderly than fighting the battles of the earth frontier; that the pure sciences of the interaction of the atmosphere with the earth, are somewhat left to engineers, and governments, and commerce.

In relation to the looming bulk of those things in the economy of mankind, there is no adequate field science today of the inorganic processes, of oceans, rivers, shorelines, glaciers and earth movements.

The Hawaiian Volcano Observatory has stood for this field science of Experimental Geonomy from the time when it was first proposed in 1909. The object was to keep a diary of active volcanoes, and by patient effort to decipher their habits, to discover the swelling and shrinking of the land, the cycle of outbreaks, the location of centers of small localized earthquakes, and the peculiarities of lava when it pours forth. The island was treated as a working model of process. This followed a resolution of 1907 recommending the foundation of earthquake and volcano observatories, passed by the Geological Society of America.

In the same way the Mississippi might be treated as a model of river process, all the way from Yellowstone and Rocky Mountain National Parks to the delta in the Gulf of Mexico.


Loomis Memorial Mission, Lassen Volcanic National Park.

And the laboratory should be called an observatory, because its function is to observe and record forever.

The result of twenty-five years of work in Hawaii has been to show that the Hawaiian volcanoes are always predicting their own coming events. Sensitive instruments tell what is happening underground. Earth movements and earth chemistry never cease. There are some discovered emanations, in gases and wave movements; there are probably many undiscovered ones which are telling the times and places of future eruptions.

Grand Canyon, Arizona.

There is great importance to comparison with different places. Such different volcanic places are the Yellowstone and the northwestern volcanoes, the hot steam region north of San Francisco, the Aleutian Islands, and Arkansas Hot Springs. How do the undeciphered emanations there differ from the Hawaiian ones? And what difference do they predict for intrusion of lava underground, in contrast to the occasional and relatively rare extrusion, in places like Hawaii and Japan?

And so for the other processes of the earth, the making of new rock, the uplift of the land, the sweep of the waters, the rotting of the mountains, and the settling of the rubbish, we need never leave the National Park System to establish observatories of the behavior of the earth.

Glaciers are to be found in Glacier Park, Rainier and Mount McKinley. Mountains are rotting in different ways in the Great Smokies, the Grand Tetons and Yosemite. Rivers are telling their story in all of these, as well as at Platt, Hot Springs, Yellowstone and Grand Canyon. Volcanoes offer a variety at Lassen, Crater Lake, Rainier, Katmai, Craters of the Moon, Yellowstone and Hawaii. And sea-bottoms in great variety are close to Hawaii, Acadia, Katmai, Sitka and Olympus.

All of these places contain superb opportunity for establishment of permanent geonomical observatories. Here lie the mysteries of possible deciphering of the great powers that dwell in our own earth; which from second to second and minute to minute is being altered as man's habitation by the hot forces within it, and by both the hot and cold forces of its own interaction with water and air.

T. A. J.

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Photographs herewith kindly supplied by Assistant Geologist H. H. Waesche.

**VOLCANOLOGY**

The month of August, at Halemaumau Pit of Kilauea Volcano, produced more slides and a widening of eastern cracks at the edge of the pit. Otherwise nothing of external happenings was conspicuous for the Hawaiian volcanoes during this month. The third week of the month was most active seismically and showed the highest weekly index per month, of local seismicity, since April, the sequence being for the weeks ending:

| | | | |
|---|---|---|---|
| May | 31, | Seismic index | 15.25 |
| June | 7, | " " | 11.25 |
| July | 19, | " " | 22.25 |
| August | 23, | " " | 45.50 |

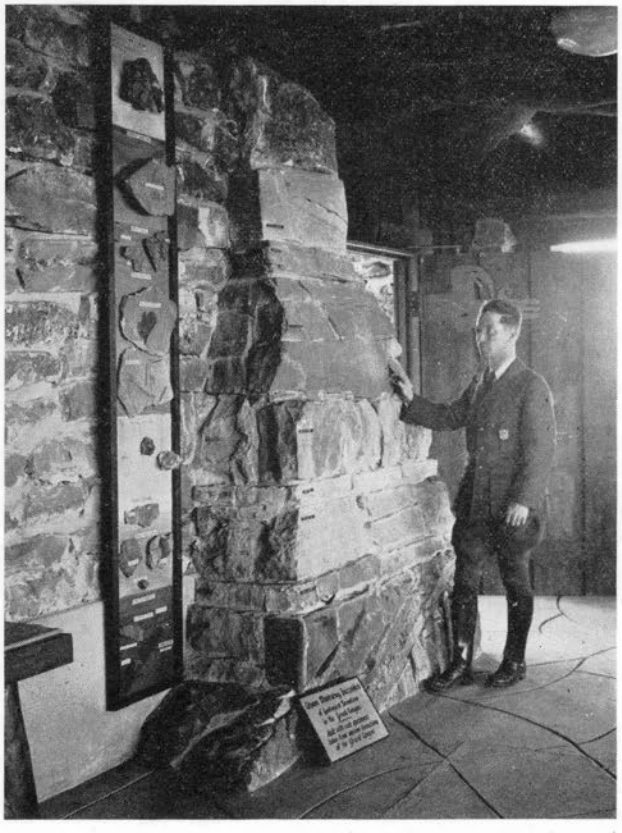
In the main this index is made up of tremors, and this summer these tremors have been greatly affected by slides from the walls of the pit. The total number of slides for the month, however, counted during daily forenoon visits and by dust cloud at other times does not accord with the above table of seismicity maxima:

| | | |
|---|---|---|
| Number of slides | May | 12 |
| | June | 6 |
| | July | 26 |
| | August | 6 |

**Slides at Halemaumau**

Slides from the wall of the pit have been noted as follows:

August 6. Dust on floor of pit seemed to concentrate around the floor crack.



Columnar Sections of Natural Rocks and Fossils of Grand Canyon in Yavapai Museum.

August 9. Moderate slide NE wall 9:25 a.m., apparently from gaping outcrop of Crack No. 29.

August 18. Moderate slides 9:35, 9:42 and 10:42 a.m. NE wall under Crack No. 29. A little farther north some distance back is Crack No. 46, which has been opening. Still farther north Crack No. 34 caved in completely on March 22. This high part of NE wall, between E and NNE taluses, was getting ready to fall.

August 31. Moderate slide 8:03 a.m. under Crack No. 29, sending up thick dust cloud, leaving fresh scar, and thin dust on floor beneath.

August 31. Small slide same place 12:18 p.m.

lava cascades NW. These places are on a diagonal of the pit at right angles to the rift belt.

**Measurement of Halemaumau Rim Cracks**

Weekly measurement of 32 marked places on rim cracks around the upper edge of Halemaumau Pit resulted as follows:

Week ending forenoon of:

August 8, 9 opened, 3 closed, aggregate opening 9.5 mm. Crack No. 46 opened 6.5 mm.

Mountain Lion. North Rim, Grand Canyon, Arizona.

**Halemaumau Solfataras**

There has been no notable change in the places at the edge of the floor, where yellow sulphur and white sulphates are depositing and blue fume rises, varying in visibility with the humidity of the air. The most conspicuous places are under the Tourists' Stand SE, and at the north end of the 1934

August 15, 6 opened, 4 closed, aggregate opening 8.5 mm. Crack No. 46 opened 7.0 mm.

August 22, 11 opened, 2 closed, aggregate opening 14.0 mm. Crack No. 46 opened 7.5 mm.

August 29, 8 opened, 2 closed, aggregate opening 12.0 mm. Crack No. 46 opened 8.0 mm.

T. A. J.

## EARTHQUAKES

**Table**

| Week Ending | Minutes of Tremor | Very Feeble Earth-quakes | Slight Earth-quakes | Distant Earth-quakes | Local* Seismicity |
|---|---|---|---|---|---|
| August 9 | 84 | 5 | 0 | 0 | 23.50 |
| " 16 | 17 | 6 | 0 | 0 | 7.25 |
| " 23 | 140 | 19 | 1 | 1 | 45.50 |
| " 30 | 47 | 7 | 0 | 1 | 15.25 |

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible, determinations of depth of focus have been made.

August 3, 10:36 pm, very feeble, probably located in Kilauea Crater.

August 7, 8:21 pm, very feeble, probably located near Puu Huluhulu, Chain of Craters Rift.

August 8, 7:13 pm, very feeble, probably located about 0.8 mile SW of center of Halemaumau.

August 8, 9:51 pm, very feeble, with location same as preceding quake.

August 10, 3:12 am, very feeble, probably located in SW rift zone of Kilauea, 0.9 mile W of Pit seismograph.

August 13, 12:25 pm, very feeble, probably located in vicinity of Kamakaia Hills about 10 miles SW of the Observatory.

August 16, 7:38 am, very feeble, probably located about 10 miles W of Hilo. Reported felt by several at Waimea Hotel.

August 18, 4:54 pm, very feeble, located 2.2 miles deep in Kilauea SW rift zone near Puu Koae. 19° 21′ 8N; 155° 19′ 3W.

August 18, 10:39 pm, very feeble, located 1.4 miles deep under Byron Ledge, SE portion of Kilauea Crater about half the distance between Keanakakoi and Kilauea Iki Craters. 19° 24′ 5N; 155° 15′ 6W.

August 19, 10:28 am, very feeble, located 1.9 miles deep in west portion of Kilauea Crater. 19° 25′ 2N; 155° 17′ 4W.

August 19, 11:05 am, very feeble, located 0.7 mile deep and 1.2 miles S of Pit Seismograph Station. 19° 23′ 3N; 155° 17′ 0W.

August 20, at 6:23 am, a slight earthquake occurred. It was probably of very shallow origin under SE rim of Kilauea Crater. The shock was not reported felt. 19° 24′ 2N; 155° 16′ 1W.

August 20, 9:41 am, very feeble, probably located under N rim of Kilauea Iki.

August 20, 6:04 pm, very feeble, located 2.4 miles deep in rifts 0.3 mile N of Ahua Kamokukolau. 19° 23′ 2N; 155° 16′ 3W.

August 21, 8:36 pm, very feeble, located 3.3 miles deep in rifts 0.9 mile SE of Ahua Kamokukolau. 19° 21′ 5N; 155° 15′ 4W.

August 24, 1:56 am, very feeble, located 6.2 miles deep in Chain of Craters rift near Devil's Throat. 19° 22′ 8N; 155° 14′ 5W.

August 24, 2:17 am, very feeble, located 2.3 miles deep and 0.3 mile NE of the Observatory. 155° 15′ 5W; 19° 26′ 1N.

There was a marked increase of seismic activity during the week of August 16-23. Many of the locations of the very feeble earthquakes of the month were difficult or impossible to make because of the lack of definite demarkation of phases. In most cases they waxed to maximum amplitude with little change from the initial type of movement. In this respect they resembled enlarged tremors.

At 8:34 pm, August 21, the preliminary waves of a teleseism began recording at 8h 33m 31s pm. Its reported location was in Formosa. 22° 3N; 121° 5E. The distance from Kilauea was 5,265 miles. Another teleseism registered its preliminary waves at the Volcano Observatory beginning at 10h 59m 6s am, August 26. Its estimated distance from Kilauea was 3,155 miles.

Periods of continuous tremor registered as follows: beginning at 9:32 am, August 4, 4 minutes; at 11:16 am, August 9, 30 minutes.

Microseismic motion of the ground at Kilauea was light for the entire month of August.

H. H. W.

## TILTING OF THE GROUND

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending August 30, was 4" 67N and 0" 25E.

H. H. W.

## CRATER ANGLES

Measurement of Horizontal angles across Kilauea Crater from the Observatory, August 18, compared with similar measurements July 24, showed a slight closing both across the Crater and Halemaumau. From July 24 to August 7, there was closing from the SE rim of Kilauea to Uwekahuna of 2″.5 and across Halemaumau from the Pit seismograph to the NW BM, closing of 1″.25. From August 7 to August 18, the Crater angle opened 1″.00 and the Halemaumau angle opened 0″.67.

H. H. W.

* For local Seismicity definition, see Volcano Letter 371.

**TABLE OF TILT**

| Week Ending | Observatory | Halemaumau Clinoscope Stations | | |
|---|---|---|---|---|
| | | West | Southeast | Pit Resultant |
| August 9 | 0″.15 N 4°E | 3″.28 W | 10″.63 S 18°W | 8″.42 from |
| August 16 | 1″.02 N 40°E | 4″.53 S 54°W | 4″.47 N 34°W | 0″.99 from |
| August 23 | 0″.38 N 20°E | 5″.39 N 45°W | 4″.21 S 25°W | 5″.37 from |
| August 30 | 0″.55 N 17°E | 5″.00 N 75°W | 4″.57 N 15°W | 0″.41 from |

NE PLUS HAUSTAE AUT OBRUTAE URBES

# THE VOLCANO LETTER

**No. 439 monthly Department of the Interior National Park Service September 1936**

Hawaii National Park
Edward G. Wingate Superintendent

NE PLUS HAUSTAE AUT OBRUTAE URBES

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

The succession of numbers of this journal in the autumn of 1936 will deal with the sequence of special studies, by the Volcanologist, that led to the bombing operation on Mauna Loa during the great lava flow that reached South Hilo District in December 1935.

The present number describes the summit crater eruption, the like of which is always followed by a flow from the flank.

The October number will print the Annual Address of March 1934 that showed the reasons for expecting that flow within two years at the north: with more illustrations of the 1933 eruption.

The November number will describe the Kilauea eruption of September 1934, with illustrations of that extraordinary cascading eruption of Halemaumau, keeping up the precedent of averaging one eruption a year for the Hawaiian system in the recent eleven-year cycle 1924-1935.

The December number will reprint, by permission, an article from "The Military Engineer", describing concisely the exact facts concerning the 1935 eruption, the bombing, and the stoppage of the flow towards the city of Hilo, with illustrations.

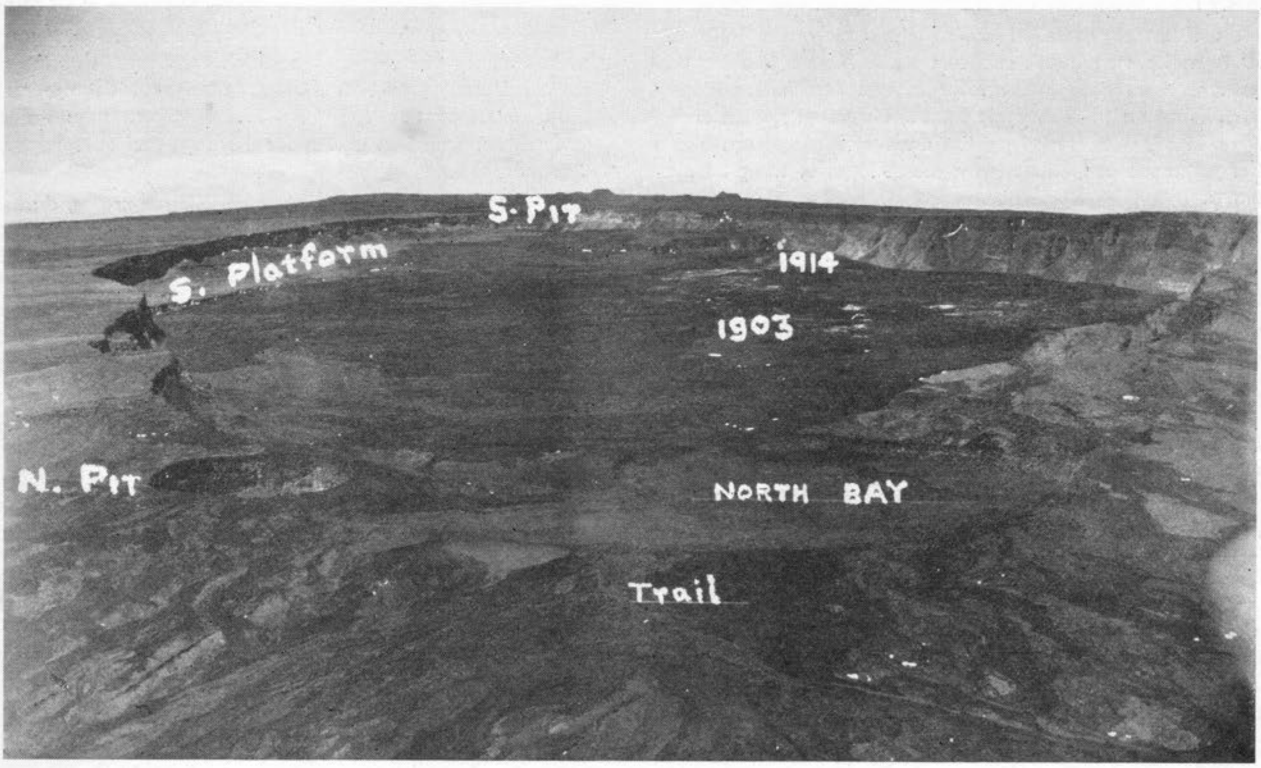



Figure 2. Mokuaweoweo from an airplane January 20, 1925, looking SSW. Condition before the 1933 eruption. Photo by 11th Photo Section, A.C., Wheeler Field, T. H. Elevation 14,600 feet (4450 meters).

## SUMMIT OUTBREAK OF MAUNA LOA DECEMBER, 1933

T. A. Jaggar

### Sequences Preceding 1933

Eruptive cycles of the Hawaiian volcanic system have indicated[1] that a complete eruption of Mauna Loa, and disregarding Kilauea, consists usually of one or more preliminary summit crater eruptions. These lead to one or more concluding lava outflows from an established rift that cuts across the mountain from southwest to northeast, with a slight bend at the summit crater.

The lava outflows so led up to, and occurring some years after the crater outbreak, themselves begin with a summit gushing. This takes place a few days before the establishment of the flank outlet, which may be 6 to 12 miles (10 to 20 kilometers) from the central caldera.

The last complete cycle for Mauna Loa, preceding the one which is the subject of this paper, started in 1914. It began with an eruption of liquid lava, in the large summit sink-crater Mokuaweoweo, making a brilliant display at a fountaining cone, and flooding the crater floor from November 25, 1914. to January 11, 1915, a period of 48 days.

The later flank outflows, down the southwest rift of the mountain, were in 1916 and 1919; these came in May-June and September-November, and lasted respectively 17 days and 56 days.

The completion of a cycle for Mauna Loa may not be judged without taking account of Kilauea. Kilauea frothing lava spurted and subsided in sympathy with the two outbreaks of Mauna Loa 1914 and 1916. After the Hawaiian Observatory had plotted this sympathy, the 1919 outbreak induced us to publish the expectation of sudden subsidence of Kilauea, which was then flooding, as soon as the Mauna Loa outbreak was finished. This was verified and the lowering occurred in Halemaumau pit of Kilauea volcano 600 feet (180 meters) in one morning, November 28, 1919. The lava in the pit immediately recovered and rose nearly to the top in 24 days,[2] a lift of 560 feet (171 meters). Such sympathy appears in the Halemaumau pit only when the crateral pipe has free liquid lava in evidence within it. When it is plugged the sympathetic movements can only manifest themselves by seismic action.

As Kilauea proceeded during the four years following 1919 to make three flank outflows, while Mauna Loa stopped its action, the repose interval for Mauna Loa had evidently arrived. That an 11-year cycle for the Hawaiian system ended in May 1924, was proved by the unusual large steam-blasts and engulfments at Kilauea, with the collapse of the pit Halemaumau.

The platted curve of rise and fall of lava for both volcanoes[3] makes a complete 11-year cycle for the system, between 1913 and 1924.[4]

This brings us to the new cycle for Hawaii, which began with the return of a short-lived inflow of spurting liquid lava on the bottom of the cup of talus in Halemaumau pit, in July, 1924. Just as in the case of the last cycle when Kilauea had resumed vigorous activity in 1914 and was followed by the Mauna Loa eruption of 1916, so this inflow at Kilauea of 1924 was followed by the gushing of Mauna Loa in April, 1926. This began its outbreak at the south pit of the summit caldera Mokuaweoweo, then spread down the southern flank and the lava emerged at about 8,000 feet elevation, to pour into the sea at the village Hoopuloa. The eruption lasted 25 days.[5]

This eruption of Mauna Loa was followed by small gushings in the bottom of Halemaumau pit, each adding a layer 60 or more feet (about 18 meters) deep, in July 1927, January 1928 (thin), February 1929, July 1929, November 1930, and December 1931.

## The Outbreak of Mauna Loa, 1933

The earthquakes associated with this eruption have been described by Jones in Journal Washington Academy of Sciences Vol. 24, No. 10, October 15, 1934. A cluster of notable shocks in October, 1933, felt strongly at Kapapala Ranch on the east side of the mountain, led to an investigation of the summit crater by E. G. Wingate and A. E. Jones, Nov. 1-2, 1933. The main crater showed puffing vapor from the 1914 cone[6] on the floor, fume was dense from the sunken area around it, and the western walls of the crater were dusty with fresh avalanche scars. There was nothing remarkable about sulphur fumes or vapors elsewhere. Later events proved that the dense fume and puffing vapor near the 1914 cone in the southern part of the main bowl of the big crater heralded at just that place the coming eruption of December 2.

The summit crater of Mauna Loa was split along the upper end of the southwest rift (see map of Hawaii November Volcano Letter 1935, and later), where frothy lava gushed up, at 5:43 a.m. December 2, 1933. The rift opened along a belt about two miles (three km.) long in the southwest part of the crater, trending south 27° west from the inner basin. The cracks crossed the south inner platform, extended up the cliff to the outside country, and then on to the south for a half mile (one km.), about 500 feet (150 meters) west of the lip of the South Pit. The breakage was then offset 500 feet (150 meters) to the east, a crack emerging from the west corner of this pit and continuing across the upland to the southwest, so that cascades of lava were poured both into the South Pit of the main crater, and into the next pit to the south, Lua Hohonu.[7] The gushings of these outside cracks were short-lived, and the main activity of the eruption which continued, was inside the main Mokuaweoweo basin, about 500 feet (150 meters) east of the cone of 1914. Here a line of gigantic fountains was formed, continued in action for 16 days and stopped gushing December 18.

The physical measurements at Kilauea crater, during the activity of Mauna Loa, were of considerable interest. Halemaumau pit had its bottom sealed with the lava plug of December-January, 1931-32, so that no liquid lava, to rise or fall, was observable at the time of the Mauna Loa eruptions of the last cycle. The weekly measurement of marked rim cracks around Halemaumau, and precise levellings during the week ended December 17, comparing Halemaumau rim with the southern gravel spit, and the readings of horizontal angles across the pit from the Observatory, measured twice during the month, revealed no unusual ground surface displacements.

The tremors, tilts both at the Observatory and Halemaumau, and the total local seismicity, showed striking changes accordant with the period of the Mauna Loa eruption.

The number of minutes of tremor for the week preceding the eruption, as measured at the Kilauea observatory, was 56, whereas for the week ending December 3, the day after the outbreak, the number was 1393. For the next two weeks, the weekly frequency of tremors dropped off to 345 and 580. Thereafter the figures were low and normal, the numbers of tremors per week being 20 and 34 for the last two weeks of December. It thus appears that the number of tremor spasms, or minutes of tremor, increased suddenly from figures counted in tens, to figures counted in hundreds, for the three weeks of the eruption.

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[1] The Hawaiian Volcanic Cycle. Volcano Letter No. 325, March 19, 1931. Volcanic Cycles and Sun Spots. Volcano Letter No. 326, March 26, 1931. The Peak of the Volcanic Cycle. Volcano Letter No. 330, April 23, 1931. Beginning of the Volcanic Cycle. Volcano Letter No. 332, May 7, 1931. When the Pit Lava Sinks. Volcano Letter No. 324, March 12, 1931. Copies of the references in this paper may usually be obtained by addressing the Hawaiian Volcano Observatory.

[2] Bulletin Hawaiian Observatory, Vol. VII, No. 11, November 1919, pages 166 and 169. Page 166 is from the press report issued before the collapse.

[3] Lava Tide, Seasonal Tilt and the Volcanic Cycle, by Jaggar, Finch and Emerson. Monthly Weather Review, March 1924, Fig. 4. Tilt Records for Thirteen Years at the Hawaiian Volcano Observatory, by Jaggar and Finch. Bulletin Seismological Society of America, March 1929, Fig. 3, page 41.

[4] The Eruption Cycles in Hawaii, by T. A. Jaggar. Thrum's Annual, Honolulu, 1932, pages 83 to 93, chart on page 84.

[5] Bulletin Hawaiian Volcano Observatory, April 1926, with illustrations in May to December numbers, 1926. See also Volcano Letter, Nos. 68 to 72, April 15 to May 13, 1926.

[6] Effects in Mokuaweoweo of the Eruption of 1914, by H. O. Wood. Amer. Jour. Sci., May 1916.

[7] Geology of Kau District, Hawaii, by Stearns, Clark and Meinzer, Water Supply Paper 616, U. S. Geol. Surv., 1930, maps.

It is customary at the Hawaiian Volcano Observatory to compute local seismicity in terms of minutes of "tremor", feeble, slight, moderate and strong correspond to I, II, III, IV, of the Rossi-Forel scale. The local seismicity index for any

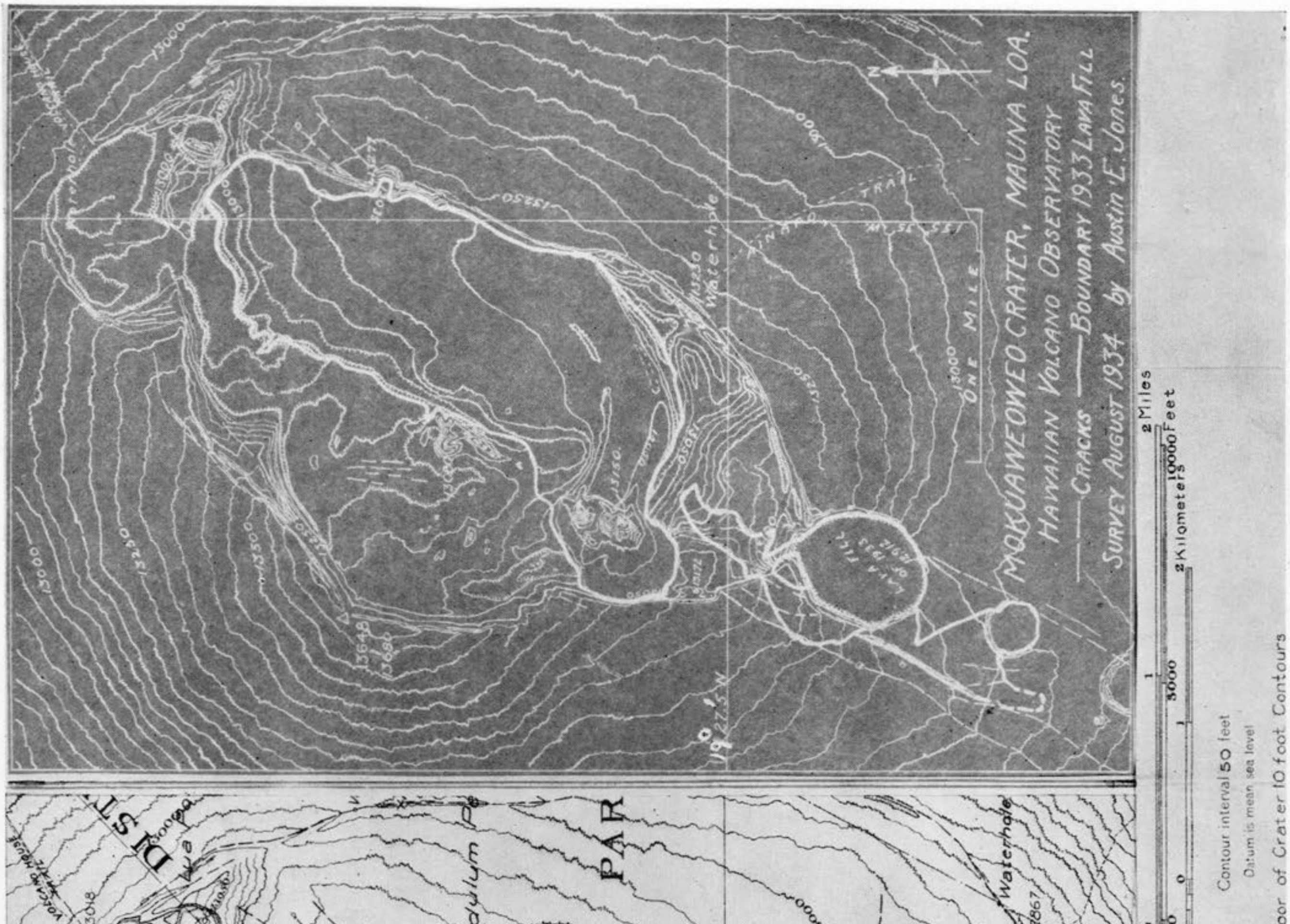



Figure 1. Maps of Mokuaweoweo before and after 1933 eruption.

unfelt or "very feeble" earthquakes, slightly felt or "feeble", felt or "slight", generally felt or "moderate", and "strong" representing earthquakes that are alarming. The grades

week is obtained by adding together the frequency numbers of arbitrary weights, corresponding each to one unit of each type of earthquake. The tremor unit is ¼, the very feeble shock is

½; feeble is 1, slight is 2, moderate is 3, and strong is 4. When a tremor lasts less than a minute it is evaluated as a single tremor unit; when it is continuous the unit is the minute of

mau pit, outward away from the pit, or inward toward the pit, measured on the radial lines from the center of the pit, and disregarding other directions of tilting, yielded interesting re-

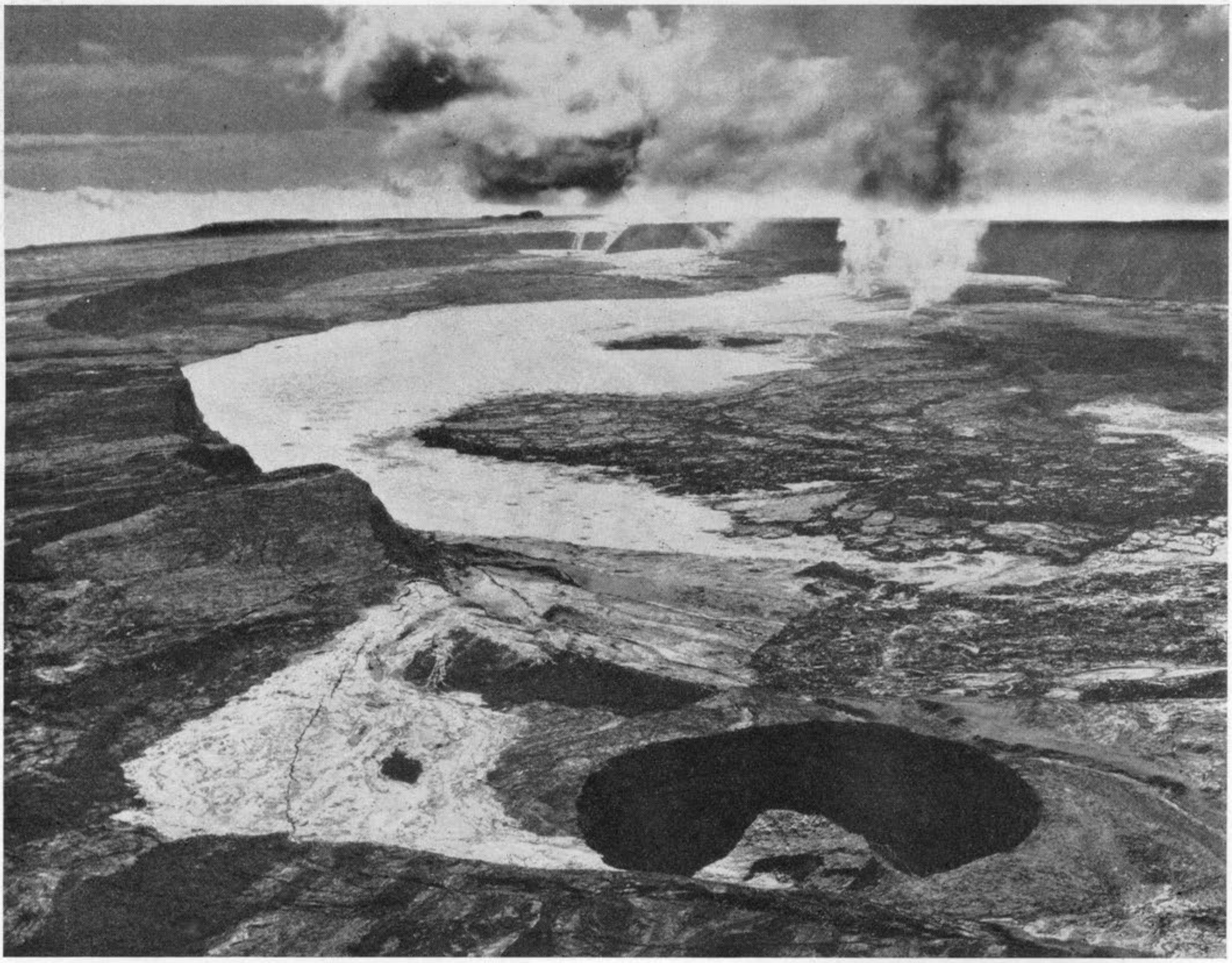


Figure 3. Mokuaweoweo eruption from 14,250 feet, 11 a.m. December 2, 1933, looking SW. North Pit in foreground, old lava gleaming to left of it. By permission Fleet Air Base, Pearl Harbor, U.S.N.

duration. If a week produced one of each of the six types the local seismic index, or summation of the weights would be 10¾. It will readily be seen that continuous tremor, measured in minutes, is a factor which greatly raises local seismicity values.

These values in 1933 were as follows, the eruption starting December 2:

| | Seismicity |
|---|---|
| Week ending November 26 | 15.50 |
| Week ending December 3 | 360.00 |
| Week ending December 10 | 86.00 |
| Week ending December 17 | 170.00 |
| Week ending December 24 | 6.50 |
| Week ending December 31 | 12.50 |

Tilting of the ground, measured at the Observatory on the northeast rim of Kilauea crater, was strong and northerly or easterly (away from the crater), before and after the Mauna Loa eruption, weaker and westerly during the eruption. The total tilt of the three clinoscope[8] cellars around Halemaumau pit, outward away from the pit, or inward toward the pit, measured on the radial lines from the center of the pit, and disregarding other directions of tilting, yielded interesting results. The aggregate tiliting at the pit had been notably inward for many months before the Mauna Loa eruption. The week of the outbreak it was strongly outward as though the Kilauea floor were swelling upward. After the outbreak it was **more** strongly inward, as though the sinking of the Kilauea floor followed the sinking back of lava under Mauna Loa. This sequence, for the lava fill, is just what happened at Kilauea, when the live lava in Halemaumau was visible during the Mauna Loa eruptions of 1914, 1916 and 1919; and the Mauna Loa crater is 22 miles (35 km.) away WNW.

[8] Volcano Letter, Nos. 382 and 392.

**Maps of Mokuaweoweo Crater**

In Figure 1 maps are shown of Mokuaweoweo crater before and after the 1933 eruption. The first is by E. G. Wingate, as mapped in the summer of 1926, after the eruption of that year. Contour intervals are 50 feet (15.24 m.) outside the crater, 10 feet (3.05 m.) within the crater floor. The lowest point of the main bowl showed elevation 12,934 feet (3942 m.) before the eruption, 13,035 feet (3973 m.) after the filling of 1933. The bottom of the South Pit showed elevation 12,835 feet (3912 m.) before the eruption, 12,912 feet

(3936 m.) after the filling. The eastern side of both bowls had been depressions before the eruption, but the fills made them relatively flat or level. The heavy outlines on the second map, a survey of August 1934 by A. E. Jones, indicate the two areas of fresh lava north and south. The northern area was fed by the north-south line of big cones approximately 100 feet (30 m.) high that built themselves up on a crack immediately east of the cone of 1914. This source made big floods of lava over the entire eastern side of the main bowl north of the southern lunate platform. These floods also filled the depression adjacent to the 1914 cone and made a new fill against the high western wall of the crater for a third of a mile (one-half kilometer).

The southern area of 1933 outbreak includes the two pits and the cracked upland west of them. A big fountain formed a cone at the foot of the bluff just north of the South Pit and sent a cascade for many hours into that pit. It is this cascade which produced and lies northeast of the small island mapped in the southern area of lava, shown on the northern side of the South Pit. The surface area of the southern lava tract is one square kilometer (0.39 sq. mi.) and of the northern tract three square kilometers (1.16 sq. mi.). The total volume produced in this eruption was of the order of 68 million cubic meters (2400 million cu. ft.).

1 sq. km. = 1 million sq. meters.

Max. thickness in pits southern area = 24 meters.

Mean thickness in south area = 8 meters—thin at the west.

Max. thickness in north area = 31 meters.

Mean thickness in north area = 20 meters counting the cones and west fill.

Area south = 1,000,000 sq. meters.
x 8 = 8,000,000 cu. meters.

Area north = 3,000,000 sq. meters.
x 20 = 60,000,000 cu. meters.

Add N & S = 68,000,000 cu. meters.

**Progress of the Eruption**

The estimated time of outbreak, 5:43 a.m., December 2, 1933, is that shown by the beginning of continuous volcanic tremor at the Kilauea seismographs. At 7:00 a.m. December 2 two dense white columns of vapor were rising, and by 9:00 a.m. there were three jets, the northern the largest and highest, the two southern ones each double. After the first two hours the white vapor columns became bluish and sulphurous, and these when seen in transmitted light were absinthe red. Filamentous glassy lava, or Pele's hair, fell in small amounts at Hookena 22 miles (35 km.) to leeward, west-southwest. There is reason to think that the division of the fume columns in three corresponded to the opening of three principal gashes on the rift belt. These are respectively the southern gash connecting the two outlying pits, the gash immediately west of the South Pit, and the gash inside the big crater offset still farther to the west and extended to the north. By 7:30 p.m. December 2, when the glow of the fountains at the base of each fume column could be seen, the glowing columns were three in number. The northern one was triple and very brilliant, representing three gigantic fountains east of the 1914 cone within the big crater. The second one was bright and stood over the big fountain at the southwestern border of the big crater, building a cone which vomited up a cascade that streamed down into the South Pit. The southern glow column was faint, and represented the last gushings of the southern gash after fourteen hours of action. The region near the southern pits went entirely out of action by the end of the first twenty-four hours.

Figure 2 shows a lengthwise view of Mokuaweoweo taken before the eruption from an army plane in 1925 at elevation 14,600 feet (4430 meters), looking from the region of the northeast rift towards the southwest rift cones in the distance.

The whole bowl of the caldera is exhibited for comparison with Figure 3, which shows the activity of the first forenoon of 1933 eruption. The line of fountains crosses the southern part of the large cauldron, cuts the northwest cliff-block of South Pit, and extends into the upland beyond, sending cascades of incandescent lava into the South Pit and the pit farther south. The three fume patches represent three principal fountaining areas, the first and largest just east of 1914 cone; the others north and west of South Pit, the floor of which has a new lava fill. Vast floods of pahoehoe in the picture are filling the depression near the cone of 1914, and also the basin of the east side of the main crater.

On the first day, December 2, there were about 35 fountains in the main basin, and 20 each at the two other localities. The basin fountains concentrated to a smaller number about built-up cones. These basin vents poured lava both east and west, but the eastern flows became the great feature. The western ones obliterated the pit of 1914, and made a fill against the western cliff of the south lunate platform. The South Pit outside of the main basin received a fill about 21 meters deep (70 feet) at the base of the cascade through the gap. The main flow area covered about 3 square kilometers (1.16 square miles) the second day, and the southern pits had received a quarter as much. The southernmost upland fissure made big fountains the first day, the lava cascading strongly into South Pit, and feebly into Lua Hohonu.

In the main crater there was liquid flooding of silvery sheets of lava the first day, but on the second day there were crusted floor flows, and flocculent skins appeared on the scarlet torrents of the main streams. On this day the outside southwestern cracks were steaming only. The flow lava of the crater was pahoehoe, but the cones were heaped with basaltic pumice, and Pele's hair lay on the ground to leeward. Milky-blue fume cirrus lay in belts across the sky during the next few days. There was glow over the crater at night, and a fume column by day. December 4 the southwest wall fountain stopped. December 5 the two central fountain groups were within throne-like conical heapings more than 100 feet (30 meters) high.

Figure 4 is a remarkable picture of lava-flow pattern. It shows a half-mile (0.6 kilometer) of the spouting rift inside Mokuaweoweo. It is the forenoon of December 3, when the fountains along the crack, about eighteen in the photograph, had built pumice cones. The jets were 100 to 400 feet (30 to 120 meters) high, and show indistinctly as light patches, for the camera was directed downward. The 1914 cone was smoking violently but still intact behind the second of the two larger fume columns. The left-hand or southern end of this particular fault-block rift crack, one of the echelon of cracks that erupted, is drowned under its own flood. This lake of lava spread to the western crater wall, in a local basin that had been left in 1914. The erupting crack is itself faulted down in the foreground, bounded by a higher block in the background west, and so building crescent half-cones on the step, and the lava flows away from the rise.

This last feature is highly significant of an age-long trend in the active rifts of Hawaii. They are breaking down in steps away from the summit. The same step-down to the east appeared in the 1926 eruption 3 kilometers (2 miles) south of here. The larger fault blocks of both Kilauea and Mauna Loa are sliding toward the southeastern bay of the island for the Kau district, and toward Kealakekua Bay for the Kona district. Something similar is going on in a northern embayment of Mauna Loa, on the Mauna Kea side. Probably dikes underground form three hard ribs on the southwestern, northeastern and northwestern rifts, and between these, the weight of the flanks of the dome breaks it on slipping planes.

The foreground of the photograph shows the great rivers of golden pahoehoe which filled the eastern half of Mokuaweoweo with 30 meters' depth (100 feet) of new lava. The two main fume columns are over the two persistent fountaining heaps, destined to build up cones 80 to 100 feet (25 to 30 meters) high and to envelop the 1914 cone as shown on maps, Figure 1.

The peculiar flocculent pattern of the surface of the liquid rivers is occasioned by the forming and rending of skins of solidification. Each of these skin belts may be traced to its fountain source, the wider ones to the bigger cups, and the contact of skin against skin produces lines longitudinally like the medial moraines of a glacier. Each skin belt tends to wrinkle in festoons of ropes, with convexity down-stream, so that the lines are occasioned by the meeting of the curtains at the frictional drag, where each festooned crescent flows more slowly at the sides. The writer had opportunity to inspect this scene from an airplane, and this was the first time in the history of Mauna Loa when its summit eruption was repeatedly so inspected, by regular passenger planes. By this method far more could be determined in a few minutes, concerning the progress of the eruption, exploring from an airport 65 km. (40 miles) away, than through days and weeks of camping trips, wherein only a small part of the field could be seen at one time.

The flows within Mokuaweoweo proper continued to spread against the east wall; the eastern part of the cliff on the north side of the south lunate platform became obliterated (See Figure 2). Airplanes carried visitors day after day to watch the fan-like rush of lava pouring eastward from the two cone-filled gashes in the crater. The fountains of the northern gash, by December 12, had dwindled to two small ones. December 13 there was only one fountain, with occasional jets from other vents. The fume and glow as seen from Kilauea continued until December 17, becoming faint. The last fountain died down at 2 a.m., December 18, revived slightly after daylight, and thereafter went out of action. The Mokuaweoweo crater area remained very hot and fumy with many jarrings and rumblings.

A party visiting the crater January 6 to 7, 1934, found that the new lava was somewhat broken up in places near the fronts of the flows. There was much heat about the new cones, rumbles and sharp cracking noises were heard during the night, coming at intervals of three or four minutes, and a few sharp earthquake shocks were felt.

During the mapping expedition, July 30 to August 3, 1934, the new summit resthouse of the national park was occupied by Mr. A. E. Jones and his men, and gave much protection against the cold. The temperature was 32° F. at sunset, and 20° F. at daylight. There were occasional sounds of falling rocks, much of the new shell-lava broke easily and was dangerous to walk on, the lava near the vents was hot enough to be uncomfortable, and sulphurous fume was locally strong.

The results of mapping show the new lava field in the eastern half of the main Mokuaweoweo bowl to be over three kilometers (nearly two miles) long, and something more than one kilometer (0.6 mile) wide, with a thickness of 30 meters (100 feet). The source cones are 30 meters (100 feet) high; the lower basins of the crater are now at the north and at the southeast. The new lava heap is an elongate dome, highest at the southwest in a ridge athwart the crater sink, with its longer axis northeast-southwest.

# Hawaiian Volcano Observatory Report for September 1936

## VOLCANOLOGY

During the month of September the number of slides from the ENE wall of Halemaumau Pit at Kilauea Volcano increased. Eighteen were reported as compared with six for August.

The following tabulation shows the relation for the month between local seismicity, number of reported slides, and aggregate opening in millimeters of the measured cracks:

| Week | Seismicity | Number of slides | Aggregate crack openings |
|---|---|---|---|
| First | 7.00 | 0 | 10.5 mm. |
| Second | 12.50 | 3 | 13.5 mm. |
| Third | 24.75 | 6 | 17.5 mm. |
| Fourth | 20.25 | 5 | 14.5 mm. |
| Fifth | 27.75 | 4 | 28.0 mm. |

It is evident that these phenomena as a whole increased during this month that ended with the fortnight that followed the equinox. The crack opening was much larger than August, but not the seismicity.

### Slides at Halemaumau

The NE rim of Halemaumau had been roped off, owing to the menace of crack opening and of slides, and the latter from the wall of the pit have been noted as follows:

September 7, Rocks were heard dribbling down the NE wall 9:12 a.m.

September 9, Moderate slide from E rim, near Crack No. 31, 9:50 a.m.

September 9, Rocks dribbling NE 9:58 a.m.

September 14, Large fresh scar over dust on floor, 150 feet below rim, under Crack No. 29. Rocks there were still in motion during forenoon visit.

September 15, Slide under NE rim 10:50 a.m.

September 16, Dribbling rocks NE 1:40 p.m.

September 19, Rocks in motion NE 9:30 to 11:00 a.m. Central part of NE talus had been increased with debris falls from fresh scar above.

September 25, Big noisy slide ENE at 9:42 a.m., and a new scar had appeared 100 feet below ENE rim near Crack No. 29. Rocks dribbled down wall throughout forenoon visit.

September 26, Small slide E wall 10:04 a.m.

September 26, Another at same place 10:24 a.m.

September 29, Small rocks fell WNW wall 9:40 a.m., and a larger slide had left a scar there 300 feet below rim.

October 1, Large dust cloud arose ENE rim, 2:20 p.m.

October 3, Small slide NE rim 11:00 a.m.

### Halemaumau Solfataras

September 19 fume was rising from SE and NW Solfataras at edge of floor. This was not unusual.

### Measurement of Halemaumau Rim Cracks

After the middle of the month, all along the ENE rim, the opening of cracks shown by the measurements was supplemented by breaks in the surface soil. At the NE flag the slumped slabs under the rim had moved down. By the end of the month the cracks ENE had widened and broken the soil extensively, with marked increase in rate of opening since the September equinox.

Weekly measurements of 32 marked places on rim cracks around the upper edge of Halemaumau Pit resulted as follows:

Week ending forenoon of:

September 5, 7 opened, 6 closed, aggregate opening 10.5 mm. Crack No. 46 opened 9.0 mm.

September 19, 6 opened, 0 closed, aggregate opening 7.5 mm. Crack No. 46 opened 11.0 mm., and Crack No. 31 opened 3.5 mm. Crack No. 31 is east, No. 46 northeast.

September 26, 3 opened, 4 closed, aggregate opening 14.5 mm. No. 46 opened 13.0 mm., No. 31, 3.5 mm.

October 3, 12 opened, 1 closed, aggregate opening 28.0 mm. No. 46 opened 17.0 mm., No. 31, 6.0 mm.

—T. A. J.

**EARTHQUAKES**

**Table**

| Week Ending | Minutes of Tremor | Very Feeble Earthquakes | Feeble Earthquakes | Slight Earthquakes | Distant Earthquakes | Local* Seismicity |
|---|---|---|---|---|---|---|
| Sept. 6 | 20 | 4 | 0 | 0 | 0 | 7.00 |
| Sept. 13 | 40 | 3 | 0 | 1 | 0 | 12.50 |
| Sept. 20 | 91 | 4 | 0 | 0 | 0 | 24.75 |
| Sept. 27 | 73 | 4 | 0 | 0 | 1 | 20.25 |
| Oct. 4 | 87 | 10 | 1 | 0 | 1 | 27.75 |

* For local seismicity definition, see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible, determinations of depth of focus have been made.

September 4, 6:06 am, very feeble, probable location under NE portion of Kilauea Crater.

September 4, 8:03 am, very feeble, probable location in Kilauea Crater about midway from the Pit to the Observatory.

September 4, 9:38 pm, very feeble, located 18 miles deep near the old Halfway House 13.0 miles SW of the Observatory. 19° 20' 5N; 155° 26' 0W.

September 6, 6:25 am, very feeble, probable location under NE rim of Kilauea Crater, 0.5 mile west of the Observatory.

September 7, 4:18 am, very feeble, located 0.8 mile deep, under NE edge of Kilauea Crater floor. 19° 25' 4N; 155° 15' 7W.

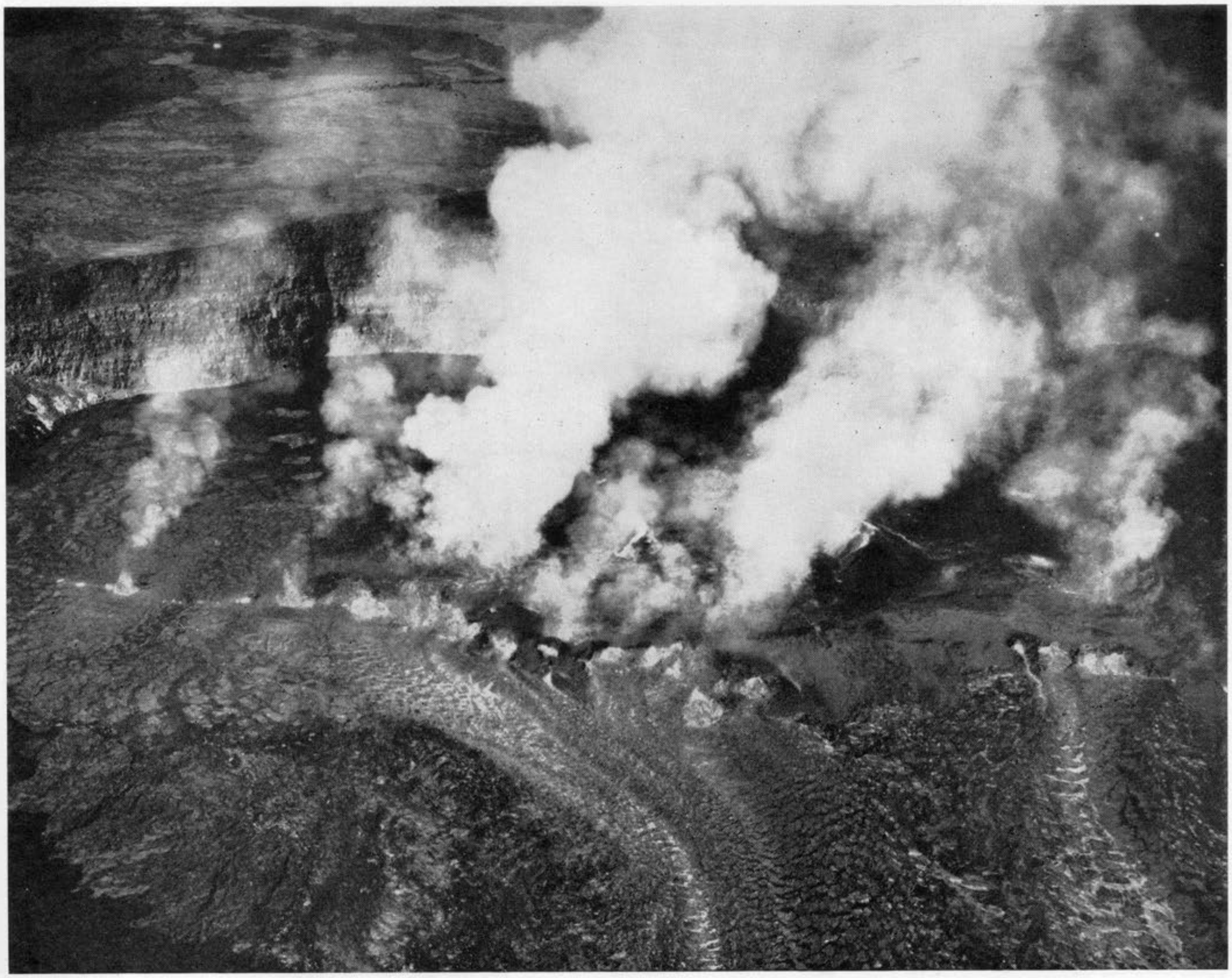


Figure 4. Line of main fountains inside Mokuaweoweo looking west, the second day December 3. The cone of 1914 is seen back of fume column. Lava-pattern, west cliff and outside Mauna Loa slope. From elevation 14,500 feet. By permission Fleet Air Base, U. S. Navy, Pearl Harbor.

September 8, 7:17 pm, very feeble, located 13.0 miles deep and 4.0 miles S of Makaopuhi Crater in the Hilina-Kapukapu Fault. 19° 18' 8N; 155° 10' 6W.

September 9, 5:46 pm, a slight shock felt by a few in Volcano district. Located 2.3 miles deep and 1.3 miles SE of the Pit Seismograph Station. 19° 23' 4N; 155° 16' 1W.

September 14, 3:39 pm, very feeble, located 4.0 miles deep and 2.0 miles NE of east entrance to Hawaii National Park. 19° 26' 6N; 155° 12' 9W.

September 15, 12:07 pm, very feeble, located 1.2 miles under NE portion of Halemaumau. 19° 24' 7N; 155° 17' 0W.

September 17, 1:37 am, very feeble, probably located under NE rim of Halemaumau.

September 20, 2:44 am, very feeble, located under SE rim of Kilauea Crater near Keanakakoi Crater. 19° 24' 4N; 155° 16' 2W.

September 21, 3:56 am, very feeble, located 5.5 miles deep under that portion of Kilauea Crater immediately to the east of Halemaumau and 0.4 miles N of Pit Seismograph. 19° 24' 6N; 155° 16' 9W.

September 23, 1:11 pm, very feeble, located 4.0 miles deep and 3.3 miles N of Uwekahuna. 19° 28' 2N; 155° 17' 4W.

September 24, 1:25 pm, very feeble, probably located in SE portion of Kilauea Crater.

September 28, 2:06 am, feeble, located 2.2 miles deep and 3.6 miles E of the Pit seismograph. 19° 24' 1N; 155° 13' 6W.

September 28, 3:08 am, very feeble, located 3.7 miles deep and 2.1 miles N by E of the Volcano Observatory. 19° 27' 6N; 155° 15' 1W.

September 29, 4.12 am, very feeble, probably located in NE rift of Mauna Loa near Puu Ulaula.

October 4, 12:02 pm, very feeble, probably located 1.0 mile NE of Kilauea Crater.

The surface (L) waves of a telesism began recording 2h 37m 41s, HST, September 25. Reported location was approximately 300 miles off W Coast of Southern Oregon, 2140 miles from Kilauea. 42° 5N; 131° 4W. Registration of the preliminary waves of another distant earthquake began at 11h 26m 25s, HST, October 4. It was 5340 miles SW by W of the Island of Hawaii and the reported location was the northern border of the Banda Sea east of Celebes Island. 3° N; 126° 4E.

Periods of continuous tremor registered as follows:

September 20, 3:49 am, 6 minutes and October 1, 12:33 pm, 4 minutes.

Microseismic motion of the ground at Kilauea was moderate September 16, 17 and 18, the remainder of the month it was light.

H. H. W.

**CRATER ANGLES**

Measurement of horizontal angles across Kilauea Crater from the Observatory on September 23, showed slight opening across Halemaumau and slight closing across the Crater as compared with similar measurements August 18. From Kilauea SE rim to Uwekahuna the angle closed 1".92 August 18-September 1; September 1 to September 11 an opening of 2".67; September 11 to September 23, an opening of 1".25; total closing 0".6. From the Pit seismograph to the NW Pit station there was a closing of 1".00, August 18-September 1; September 1 to September 11, a closing of 1".83 and September 11 to 23, an opening of 3".33. Total opening 1".50.

H. H. W.

**SPIRIT LEVELLING**

Spirit levelling across Halemaumau from the Spit SE edge of Kilauea Crater to the NW Pit BM showed a lowering of the NW Pit BM with reference to Spit of 5.5 centimeters between February 10 and September 3, 1936.

H. H. W.

**TILTING OF THE GROUND**

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending August 30, was 4."23 N and 1".1 E.

**TABLE OF TILT**

| Week Ending | Observatory | Halemaumau Clinoscope Stations | | |
|---|---|---|---|---|
| | | West | Southeast | Pit Resultant |
| September 6 | 0".23 W | 4".71 N 58°W | 4".34 N 31°W | 0".65 toward |
| September 13 | 1".00 N 72°E | 4".02 S 79°W | 4".28 N 19°W | 0".12 from |
| September 20 | 0".00 | 1".04 N 10°W | 3".30 S 31°W | 1".30 from |
| September 27 | 0".50 N 71°E | 5".18 N 77°W | 3".82 N 31°W | 1".67 from |
| October 4 | 0".95 N 65°E | 2".59 S 60°W | 2".92 N 6°W | 0".76 from |

H. H. W.

# THE VOLCANO LETTER

**No. 440 monthly Department of the Interior National Park Service October 1936**

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

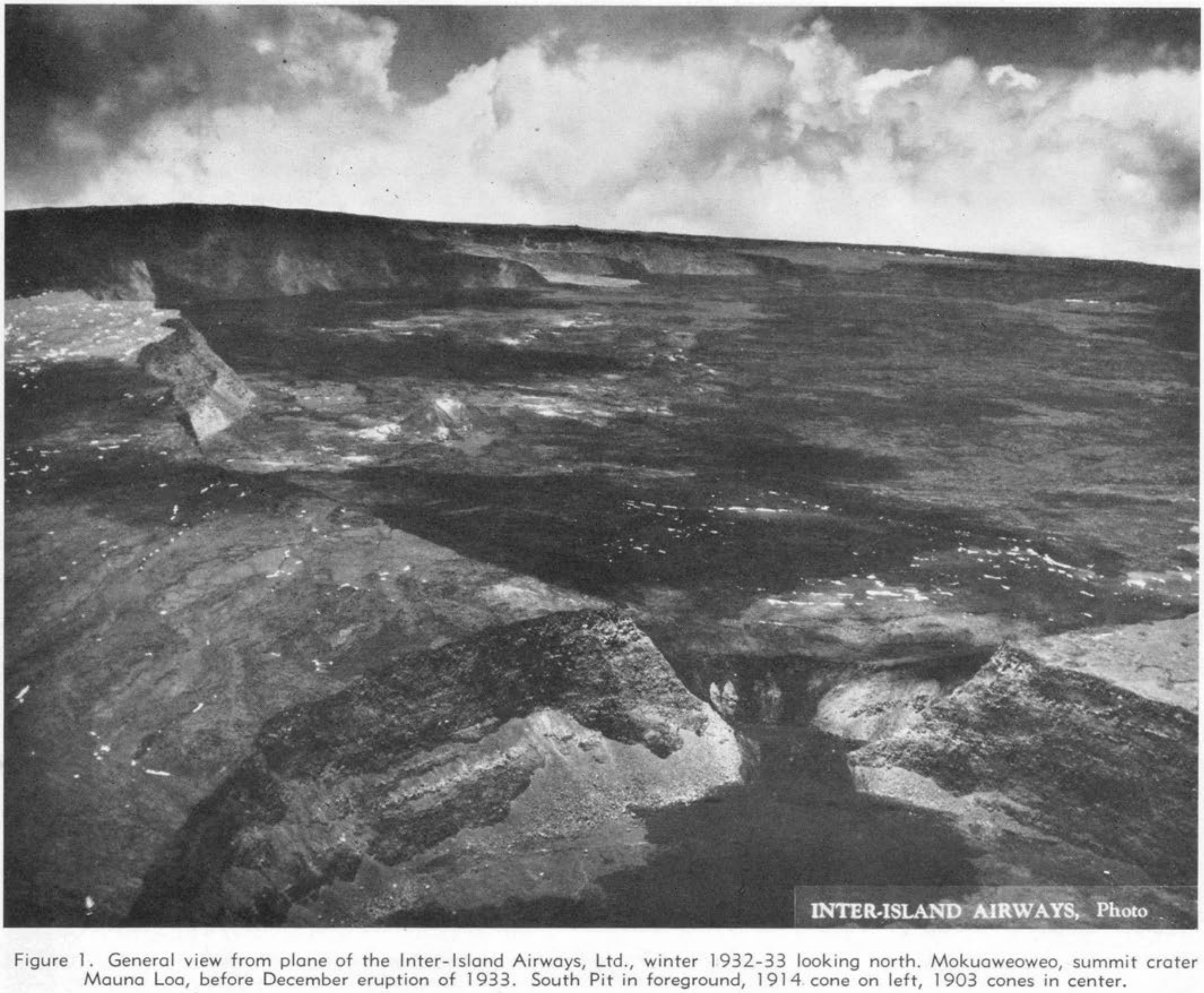



Figure 1. General view from plane of the Inter-Island Airways, Ltd., winter 1932-33 looking north. Mokuaweoweo, summit crater Mauna Loa, before December eruption of 1933. South Pit in foreground, 1914 cone on left, 1903 cones in center.

## THE COMING LAVA FLOW

### The Most Serious Responsibility in Our History

T. A. Jaggar

Annual Address, March 26, 1934, Hawaiian Volcano Research Association*

Mauna Loa at its summit crater has recently made a spectacular lava gushing December 2-18, 1933. This 17 days of summit activity should be followed by an outflow over somebody's land within a period of from 16 to 37 months.

This expectancy is the serious responsibility which rests on the shoulders of the Hawaiian Volcano Research Association. The words are not "the most serious lava flow in history." They are "serious responsibility." It is serious if we take our 22 years of volcano observing seriously, because we are called upon to make good, to make the forecast as careful as possible, and to advise the community soberly and preparedly.

* In sequence of dates to preceding and following Volcano Letters.

There is no call for fear. There is every appeal for an intellectual and practical victory over nature. Prediction and resulting preparation are what exhibit science at her best.

**What are the Facts about the Past of Mauna Loa?**

There are listed 23 summit crater eruptions of Mauna Loa, in 90 years, between 1843 and 1933. This is without counting some small summit effusions which may have gone unrecorded.

Between 1832 and 1899 there were nine NORTHERN and EASTERN flank outflows, with one source as low as 8500 feet elevation on this 14,000-foot mountain, namely 1852.

Between 1868 and 1926 there were eight SOUTHERN and WESTERN flows, with one source as low as 3500 feet elevation in 1868, and one below sea-level in 1877.

The districts invaded by Mauna Loa have been NORTH KONA, SOUTH KONA, KAU, SOUTH HILO, NORTH HILO INLAND, HAMAKUA INLAND, and even SOUTH KOHALA was touched by the prehistoric but recent Keamuku flow west of Humuula. The very voluminous 1843 flow at the same place might well have found its way to South Kohala. Puna and North Kohala are the only districts of the Island not visited by fiery lavas from Mauna Loa sources, and Puna has been abundantly invaded by flows from Kilauea volcano.

**What are the Intervals between Crater Eruptions and Outflows?**

There are two classes of Mauna Loa eruptions, those at or near the summit crater lasting days, weeks or months, and followed by a major lava flow, usually some years later; and secondly, those at or near the summit, but not necessarily in the crater, often making small preliminary flows on the upper rifts, always lasting only a few minutes, hours or days, and then followed immediately by an outflow from a vent farther down the mountain. This second class is the SOME YEARS LATER group of the first class.

In other words, all great lava flows are preceded immediately by high-level gushing, and some are preceded by a summit crater eruption a few years before which announces that a flow is coming; but this preliminary summit crater outbreak may announce that a GROUP OF SUCCESSIVE OUTFLOWS is coming.

In like manner, all eruptions exclusively in the summit crater, like our recent display of December, 1933, are followed eventually in a few years by one or more low-level outflows with their immediately accompanying summit gushings; but it is possible for such summit crater eruptions of the preliminary class to follow one another in a GROUP OF SUCCESSIVE SUMMIT CRATER ERUPTIONS, before the mountain breaks to emit an outflow lower down.

Applying these facts of history to December, 1933, for discovering what is to follow, we may expect either one or more additional summit crater extrusions, or one or more lava flow eruptions.

**Eruptions wholly at the summit Crater**

| Year | Duration | Interval | Next Succeeding Outflow |
|---|---|---|---|
| 1832 | 3 weeks | 10½ years | 1843 |
| 1849 | 3 weeks | 2 years | 1851 |
| 1865-66 | 4 months | 2 years | 1868 |
| 1870 | 2 weeks | 7 years | 1877 |
| 1872 | 2 months | 5 years | 1877 |
| 1873 | 10 months | 4 years | 1877 |
| 1874 | 10 months | 3 years | 1877 |
| 1875 | 2 months | 2 years | 1877 |
| 1876 | 1 week | 1 year | 1877 |
| 1880 (May) | 6 days | 6 months | 1880 (Nov.) |
| 1892 | 3 days | 7 years | 1899 |
| 1896 | 15 days | 3 years | 1899 |
| 1903 | 9 weeks | 4 years | 1907 |
| 1914 | 6 weeks | 2 years | 1916 |
| 1933 | 17 days | | |

**Flank Outflow Eruptions with Near-Summit Beginnings**

| Year | Duration | Interval Between Near-Summit Start and Outflow | Elevation of Flow Source |
|---|---|---|---|
| 1843 | 3 months | 7 days | 10,000 feet |
| 1851 | 4 days | minutes? | 13,000 feet |
| 1852 | 4 months | 3 days | 8,500 feet |
| 1855 | 16 months | hours? | 11,000 feet |
| 1859 | 10 months | minutes? | 11,000 feet |
| 1868 | 4 days | 10 days | 3,500 feet |
| 1877 | few days | 10 days | 30 fathoms submarine |
| 1880 (Nov.) | 9 months | 5 days | 10,500 feet |
| 1887 | 10 days | 2 days | 6,250 feet |
| 1899 | 26 days | 5 days | 10,800 feet |
| 1907 | 14 days | 4 hours | 6,500 feet |
| 1916 | 17 days | 3 days | 7,300 feet |
| 1919 | 40 days | 3 days | 7,600 feet |
| 1926 | 1 day | minutes? | 13,000 feet |
| 1926 | 19 days | 3 days | 8,000 feet |

**Summary of Frequency for Mauna Loa Eruptions**

There were 30 summit or near-summit events on Mauna Loa between 1832 and 1933, within the period of 101 years. As all the lava outflows begin with a near-summit outburst, this number includes all the Mauna Loa eruptions recorded in the white man's occupancy of Hawaii.

There was probably an average of just as many Mauna Loa eruptions in the eighteenth century and the first quarter of the nineteenth, but the icy wastes of the high mountains were too remote to interest Hawaiians. Lava flows lower down were taken as a matter of course and were not recorded. White explorers like Captain Cook and Vancouver did not usually happen to arrive at eruptive dates. Captain Cook apparently never heard of Kilauea and records Mauna Loa as extinct.

**What are the Average Intervals for Mauna Loa?**

The average is one outbreak in three and a third years near the Mauna Loa summit. There are 14 flows between 1843 and 1926, in the period of 83 years, averaging one outflow from the flank of Mauna Loa, as perceived by man, either above sea-level or close to sea-level under water, every six years. It must be remembered that commonest interval is by no means identical with average interval. Reviewing:

Intervals, SUMMIT AVERAGE, 3⅓ YEARS.

Intervals, FLOW AVERAGE 6 YEARS.

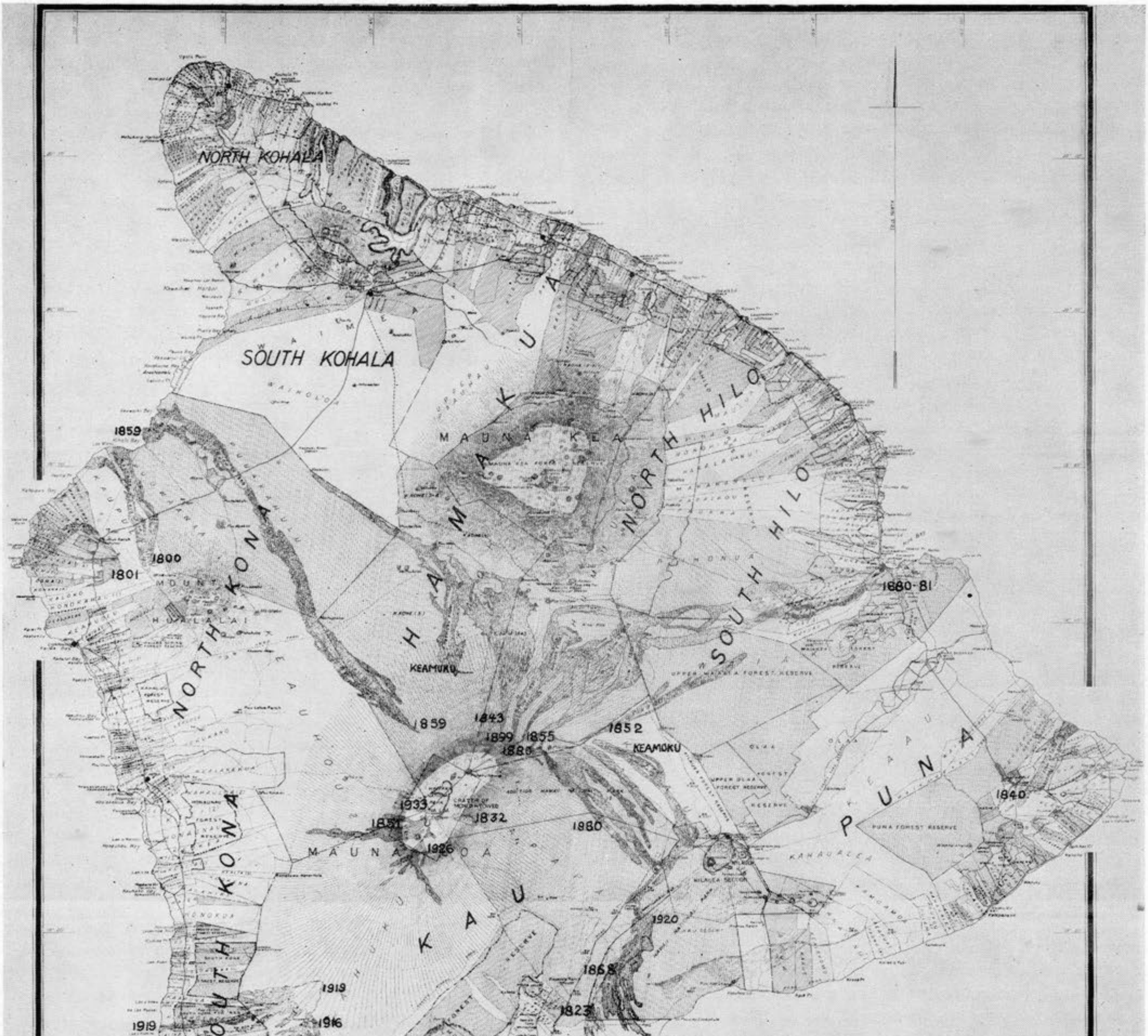
There were probably several submarine outflows under deep water, not perceptible to man, but indicated by extraordinary crater collapses, like those at Kilauea in 1790, 1894 and 1924. The reason for thinking this is that observed outflows close above sea-level caused similar collapses, as in 1823, 1840 and 1868. The submarine outflow in Kealakekua Bay in 1877, made very slight impression on mankind, but as it drained Mauna Loa of lava after seven years of summit activity, it may have been one of the greatest lava flows of history, down that cold, dark, wet slope, tipping away steeply 12,000 feet off Kona. The crater collapses of Mauna Loa have gone unnoticed, as nobody lives there. There is plenty of room in this globe for it to do colossally big things without informing mankind, until such time as it occurs to man to distribute and live in numerous observatories of the earth.

The frequency and continuity of lava activity at Kilauea have been even greater than on Mauna Loa, and there have been contributions within 200 years from Hualalai and Haleakala volcanoes, but this discussion is concerned only with Mauna Loa.

**How the Lava Breaks the Dome**

With summit eruptions of Mauna Loa every 3⅓ years, and outflows every 6 years, it appears to be nearly twice as easy for the lava and gas to squirt through the summit vents, as to break the flank of the great dome. We have to think of the expanding gas-charged paste swelling the mountain all the time through hundreds of thousands of years, dammed back by its own accumulations which have built the mountain. An eruption is determined by the yielding of the heap to a never-ending force.

The breaking of the flank ranges from 180 feet below sea-level, to elevations on Kilauea mountain 700 feet (1840), on Hualalai mountain 1500 feet (1801), and on Mauna Loa slopes approximately 3,000, 8,000, 10,000, 11,000, and 13,000 feet above sea-level for the statistics of only one century.



**What Class was the Recent Eruption in?**

The outbreak in Mokuaweoweo crater of Mauna Loa volcano in December, 1933, was not in the Class II of the second list, where the outflow follows the summit gushing by a few hours or days. No outflow has appeared. Therefore, the flow is yet to come, and when it comes it will begin at the top.

This concentrates interest in the first list where the summit eruptions lasted from three days to ten months, and were followed each by one or several flows of the second list, after repose intervals of from six months to ten and a half years.

By analogy the 1933 outbreak lasted 17 days; other eruptions of one to three weeks at the summit were those of 1832, 1849, 1870, 1876, 1880 and 1896. Imagining 1933 to be like one of these, let us see what happened:

**Samples of Eruptions like the 1933 Outbreak**

After 1832, June, at the summit, the interval was 10½ years to January, 1843. The 1843 flow poured for more than six weeks, largely pahoehoe as mapped today, filling the Mauna Loa-Mauna Kea saddle, flowing north and northwest 14 miles, starting at an elevation of 10,000 feet.

After 1849, May, at the summit, the interval was two years and two months to August, 1851. The 1851 flow poured only four days, pahoehoe lava above and aa lava below. It went towards Honaunau, very high up on Mauna Loa, moving due west eight and a half miles, starting from the southern pits of Mokuaweoweo at an elevation of 13,000 feet.

After 1870, January, at the summit, "steam and smoke," introducing seven years of summit activities, the interval was seven years to February, 1877. The other summit gushings lasted two months in 1872, 10 months in 1873, 10 months in 1874, two months in 1875, one week in 1876 and 10 days in 1877 just before the outflow. What was seen of the 1877 flow lasted only half a day. It was frothy lumps of hot pahoehoe under the sea in Kealakekua Bay in 30 fathoms of water a half mile off Keei. The pieces bubbled up and floated while hot and were collected. No one knows how far the flow went under the sea, nor how long it may have pushed onward under its water-chilled skin.

After 1876, February, the interval was one year to the Kona submarine flow February, 1877.

After 1880, May, the interval was six months to the flow of November 5, 1880. The 1880-1881 flow poured for nine months in several branches, aa at first, pahoehoe afterwards. A first aa flow went to Ohaikea in Kapapala, 11½ miles, after four days of preliminary upland flowing. Then aa flows went towards Mauna Kea and towards Hilo. Always the vent lavas were pahoehoe, changing to aa a short distance away by stirring. Finally the source pahoehoe overrode the previous flows and pushed its way to Hilo town. The length of the flow was 30 miles. It stopped in August, 1881, in the outskirts of Waiakea, one mile from the city center (August 10). The source was on the northeast rift of Mauna Loa at an elevation of 10,500 feet. The lower extremity of the flow is about 100 feet above sea-level.

After 1896, April, the interval was 3 years 2 months to July 1, 1899. The 1899 flow poured ten to fifteen miles northeast for 26 days, starting at elevation 10,800 feet on the northeast rifts of Mauna Loa. It headed for the upper Wailuku drainage back of Hilo, but did not reach it. It was aa at first over most of its course, but pahoehoe as mapped, in a final stream, eight miles long. One account states that an early branch headed towards Kau, as in the case of 1880.

**Is the Present Time like 1870-1877?**

The 1870-1872 time was critical for comparison with 1933, if it should happen that 1933 is the prelude to a new shift of flow sources, from the southern vents of the last thirty years, to northern vents in the near future.

Seismic happenings now in 1934, and the location of earthquakes under the mountain at the north in 1933, point to activity under the northeast rift of Mauna Loa. The progressive higher elevations of flow sources in 1868, 1887, 1907, 1916, 1919, 1926 and 1933, all on the southwest rift, point strongly to the probability that the cracking open of vents will cross the summit to the northern rifts. For the 1933 eruption, though mostly in Mokuaweoweo ,crater, began along southern cracks, just outside the crater and where the 1926 eruption left off.

If we make this expected shift a basis for comparison with the 1870's, there may come numerous summit crater eruptions for some years. Thereafter the northern flank will split open. Compound eruptions, involving numerous vents, for Mauna Loa, have occurred not only in the seventies, but also in the fifties, the eighties, the nineties and after 1914. Something similar is to be expected at present, as the combination 1926-1933 is already compound, and not yet finished. There is an eleven-year cycle following the profound crisis of 1924, which has been discussed elsewhere (Thrum's Annual 1932) for the Kilauea-Mauna Loa volcanic system.

**How can we use Average Intervals?**

The average interval, between summit eruption and outflow, for these six selected occasions that resembled 1933 in duration, was 4.1 years. The average interval for all the summit eruptions of the first list was 3.8 years. The range between longest and shortest intervals for all was from one-half year to ten and a half years. If we leave out the exceptionally long intervals of 1832, 1870 and 1892, we get an average interval of 2.6 years, and a range from one-half year to five years. The Mauna Loa average for all flows, and the probability of a cycle, ending in 1935, make two years after 1933 a probable limit of time within which the next event should come.

The National Park rangers right now report increasing fumes of sulphur at the summit crater vents of last December. Earthquakes have almost ceased under the southern half of Mauna Loa, where until recently they were most abundant. The suggestion of a coming flow on the Hilo side is inescapable. Let us summarize the probabilities:

**Summary of the Expectations**

1. A lava flow from Mauna Loa, or else another summit eruption, is expected within two years.

2. If it is a lava flow, the history of sixty-six years indicates sealing of the southwest rift, and coming outbreak at the north.

3. The resulting flow may push in any direction between North Kona and Kilauea. A likely direction is towards Hilo.

4. The change from Kau flows to Hilo flows is likely to be accompanied by a severe earthquake. This is what happened when the change was from Hilo flows to Kau flows in the terrific earthquake of 1868.

5. Severe earthquakes on the northern Mauna Loa rifts have already begun, at Hualalai, in the autumn of 1929.

6. Opening of the northeast rift of Mauna Loa after its repose and solidification for thirty-five years may make a world-shaking earthquake, for the whole east side of the island Hawaii, just before the outflow starts. The earthquake of 1868 was felt all the way to the island Kauai, and strongly felt.

**Responsibility for the Protection of Property**

To point out these probabilities is not to set dates for the events. To fail to point them out would be to suppress truth.

Hilo knows all these things, is completely organized to meet them, and has been instructed about the relief committees of Napier, Long Beach and Sakurajima. A statement of the Mauna Loa problem for the Hilo Chamber of Commerce appeared in Volcano Letter No. 338.

New Zealand, California and Japan have taught us lessons in earthquake insurance. With us the local government, the National Park administration, the National Guard, the American Legion, the Coast Guard, the Navy and the Army all know what they will be called upon to do. On December 11, 1933, the superintendent of Hawaii National Park called a meeting of an emergency committee of these organizations in Hilo to discuss Mauna Loa, and it was done quietly and efficiently. Honolulu is also organized.

The Volcano Observatory at Kilauea was founded in 1911 under the Whitney Fund of the Massachusetts Institute of Technology, with these words: "To be conducted with a view to the protection of human life and property."

That charge was accepted by the Hawaiian Volcano Research Association. A fire department, which in dry weather with high winds did not take special precautions, would neglect its duty.

This address definitely announces that volcano dwellers in Hawaii should now take precautions, for **Mauna Loa has definitely mobilized and declared war.**

**What Precautions Can Be Taken?**

The answer is as follows:

1. The northeast slope of Mauna Loa must be made accessible. The roadway proposed should be built at once, no matter how roughly. It should extend from the top of the mountain to Kilauea.

2. The Hawaiian Volcano Research Association should increase from 180 to 1000 members and patrons. Government funds for the Observatory have been cut 83 per cent since 1932. Twenty thousand dollars are needed when the lava flow comes, which might be this summer, if 1880 is repeated.

3. The staff is now two scientists, and not even a typist. With a suitable staff, the Hawaiian Volcano Observatory can resume its scientific publication, which amounted to 3500 pages prior to 1932. It can keep the community properly informed. It can organize more volunteer observers to report small earth movements. It can patrol Mauna Loa with more expeditions. It can man an observatory on Mauna Loa when the rough road is built. It can organize preliminary plans for volunteer assistance by airplane services and other public relief, and prepare special maps. It can improve everything it is doing now in concentrating on Mauna Loa, if it has the requisite man-power. You cannot make war without money and men. The patrolling of an area as large as Mauna Loa is not a small job.

4. The actual details of how a northern Mauna Loa flow will lap up Hilo's water supply, as it has done it in the past, is set forth on page 3, Volcano Letter 338, under the title "Preparedness against Disaster."

Figure 2. Similar view to Figure 1, during eruption December 3, 1933, from altitude 14,500 feet, airplane photograph by permission Fleet Air Base, Pearl Harbor, T. H. Note offset in active rift cracks, new floor of South Pit, new and old cascades, and in upper left corner the trace of rim of ancient caldera.

5. Japan has had her Earthquake Investigation Committee, and does not hush up anything. The most important precaution to be taken we may copy from Japan. It is to face the situation, and not cry about bad advertising, and cry of wolf, and fear of scaring tourists. Tourists come from Los Angeles and Santa Barbara and San Francisco, and they know the game, and that Hawaii is not more dangerous than their own homeland.

6. A foreseen Mauna Loa flow can be made the best advertisement Hawaii has ever had. The headlines will read "Hawaii meets lava flow with complete preparation." "First time in history when mankind has been prepared." "Everybody in Hawaii rejoices and goes to the flow." "Everyone in Hawaii a member of Volcano Association." "Hawaiian lava flow scares nobody."

The introduction said: "There is every appeal for an intellectual and practical victory over Nature."

If every firm, engineer, officer, doctor, teacher and homemaker, if every business man will turn to and join the association now, if those who can't afford it will take an interest and get behind the Observatory at Kilauea, if every educated person will help and not kick, then this Territory can laugh at the fiery fountains and make them an asset. They may gush and bubble as inflammably as they choose, and we shall rub our hands with glee. Our engineers and aviators and bombers will rejoice at the opportunity to show their prowess. And finally, a program of generalship will be laid down, with advice from all experts, which can be carried out as an object lesson to the world. The Volcano Observatory cannot do it, but we can unite and do it, using the motto of volcanology, "Be always ready, and never hysterical."

## Hawaiian Volcano Observatory Report for October 1936

### VOLCANOLOGY

The month of October at Halemaumau Pit of Kilauea Volcano produced the culmination of the landsliding and crack opening which has been disturbing the NE edge of Halemaumau for two years. This took the form of a large avalanche on October 22. The records of crack opening and wall sliding increased to a maximum at this time, but the local seismicity, while greater because of the many tremors generated by the slides did not vary directly with the figures for sliding and crack opening. The following is the abridged table of these movements:

| Week | Seismicity | Number of Slides | Aggregate Crack Openings |
|---|---|---|---|
| First | 8.00 | 13 | 42.5 |
| Second | 17.50 | 12 | 93.0 |
| Third | 39.00 | 50+ | Infinite |
| Fourth | 20.25 | 16 | 26.0 |

For the first week slides increased to 13 from 4 the week before and crack opening to 42.5 from 28. For this same week seismicity decreased from 27.75 to 8.00. It should be remembered that the number of slides is merely the record for a short period of observation, not a quantitative expression of the measurable number, which is uncountable with any present apparatus. The word "infinite" for the third week in crack opening means that the big avalanche carried away the cracks.

**Sequence of Events by Weeks**

The first week produced many slides from the E and NE walls and along with this went excessive opening of ENE rim cracks.

The second week increased the cracking open of the rim and the sliding of the NE walls, while fresh cracks in the soil opened in many places. It is evident from the map of the pit outline, that the breaking down of this wall was eliminating one of the straight parts of the circular outline of the pit. This straight part was a nearly vertical cliff between the peaks of the E and NNE talus cones. The form of stability that will result for the pit will extend the circular curve in plan, and make the inner slope more a funnel and less a cliff.

The third week produced the large avalanche at 5:54 a.m. October 22, along with many other slides. This extended peeling of the wall for months has removed a length of 1500 feet along the rim ENE, to a maximum distance back near Crack No. 46 of more than 100 feet. Following the collapse of the former Crack No. 34 in March 1936, there were now obliterated Cracks Nos. 29, 30, 31, 32 and 46. This reduced our marked crack locations from 32 to 27.

The beginning of this yawning open of the cracks can be traced to measurements two years ago when Halemaumau erupted in September 1934. A marked increase of the gaping open, however, began in October 1935 just when the premonitory earthquakes were heralding the coming November outbreak of Mauna Loa.

The many slides kept a dust cloud over Halemaumau for most of the week. The result was a very large new talus cone halfway up the wall, over the middle of the white ledge known as the Canoe Sill. The new break is adjacent to the dykes of the Rift Belt on their eastern side. The whole of this part of the wall has fallen to form the heap, overlapping the 1934 floor about a third of the distance to the center of the pit, and covering the ENE floor cracks, the depression that lay along the wall, and part of the 1934 lake-basin. Crack No. 46 lay N 57° E from the pit center, and this direction is along the line of the former cracks across the bottom that were mapped after the eruption of 1931-32. (See mapping, Volcano Letter 394). The limit of destruction of the rim was slightly beyond No. 46, and movement on the deep rift possibly stimulated this landslide.

During the fourth week smaller slides ENE continued, the surface cracks in the ground had opened to the Volcano House Trail, so that on November 1 this area had to be roped off, and the trail was established farther back. The new breakage of the ground is southward from the great avalanche of October 22. The opening of measured cracks was now near the E corner of the pit.

**Slides at Halemaumau**

Slides from the wall of the pit have been noted as follows, but these are only a part of what actually occurred:

October 6, 9:40 a.m., moderate NE near Crack No. 29; fresh scar near No. 31.

October 6, 3:00 p.m., numerous avalanches.

October 7, 7:56 a.m., small rock sliding NE near Crack No. 31.

October 8, 9:11 a.m., rocks moving under Crack No. 29: scar 150 feet below it, new rocks and dust on floor.

October 9, 12:30 p.m., avalanche dust arose.

October 10, 10:15 a.m., moderate slide below Crack No. 34 NE.

October 10, 12:50 p.m., moderate avalanche and dust cloud NE.

October 11, forenoon, rocks sliding, east talus enlarged, more rocks and dust on floor, and fresh mark under Crack No. 31 perhaps due to earthquake of 4:05 a.m. Much cracking of soil ENE.

October 11, 1:30 to 1:45 p.m., numerous slides S of Crack No. 46.

October 11, 4:15 p.m., slide under Crack No. 31.

October 12, 2:00 p.m., dust from slide E.

October 12, 3:50 p.m., dust from slide E.

October 15, 9:05 a.m., dust from large slide E: changes in walls E and NE.

October 15, 10:00 a.m., small slide in motion.

October 16, 9:44 a.m., noisy NE slide: new scar 200 feet below edge there.

October 17, 10:25 a.m., big avalanche NE: heavy sliding during forenoon measurement with continuous dribbling of rocks down wall.

October 17, 11:55 a.m., big avalanche NE.

October 18, 9:20 a.m., moderate slide E, starting 300 feet below edge.

October 19, 9:20 to 9:49 a.m., thirteen slides NE; of these one at 9:20 was moderate, those at 9:30 and 9:40 were noisy and started 150 to 400 feet below edge under Cracks Nos. 29 and 31.

October 20, 4:19 a.m., loud roar of slide.

October 20, 2:00 to 3:40 p.m., continuous dribble of rocks NE half-way down.

October 20, 2:40 p.m., moderate slide.

October 22, 5:54 a.m., the great avalanche.

October 22, 8:30 a.m. to 2:45 p.m., 18 slides listed, the larger ones at 8:55, 11:20, 11:30 a.m., and 2:05 p.m.

October 22, 5:00 p.m., large cloud of dust lasting 20 minutes.

October 23, 8:30 a.m. to afternoon, continuous rock falls, with occasional moderate slides. Slides diminished between 5:00 and 6:00 p.m.

October 26, 9:20 a.m., moderate slide ENE.

October 26, 9:24, 9:47, 9:49, 9:57, 10:00, 10:04, 10:09 and so on, showing intervals for this period between small or moderate slides.

October 27, 9:23 a.m., slide making dust cloud, followed by dribbling of rocks.

October 27, 10:00 a.m., moderate slide: followed by smaller ones 10:03, 10:11, 10:15 a.m., etc.

October 28, 9:33 a.m., slide making thick dust cloud.

October 31, 10:20 a.m., large slide near dyke NE.

November 1, 12:50 p.m., dust over pit: this period showed some tendency to increase of slides just after the noon hour.

**Halemaumau Solfataras**

Fume from the sulphurous vents from the floor was conspicuous during forenoon crack measurements October 17, but nothing during this period of avalanching indicated anything unusual about the fuming of the solfataric vents.

**Measurement of Halemaumau Rim Cracks**

Weekly measurement of the 32 marked rim crack localities, reduced to 27 after October 22, around the upper edge of Halemaumau Pit resulted as follows:

Week ending forenoon of:

October 10, 9 opened, 4 closed, aggregate opening 42.5 mm. No. 46 opened 24.0 mm. No. 31 opened 14.0 mm.

October 17, 7 opened, 2 closed, aggregate opening 93.0 mm. No. 46 opened 47.0 mm., No. 25 2.0 mm., No. 31 43.0 mm.

October 24, five cracks had gone. Of the remainder many of them not on the avalanching sector; 8 opened, 3 closed, aggregate opening 12.0 mm.

October 31, 8 opened, 3 closed, aggregate opening 26.0 mm. Cracks at E corner of pit partly opened, while others closed as the rim blocks tilted: No. 24 close to the rim closed 1.0 mm., No. 25 a little farther back opened 11.5 mm.; No. 28 in the same region closed 1.0 mm.; No. 45 farther north opened 7.0 mm.

T. A. J.

## TOPOGRAPHIC DATA

**Crater Angles**

Measurement of horizontal angles across Kilauea Crater from the Observatory on October 20, showed slight opening across the Crater and closing across Halemaumau as compared with similar measurements September 23. From Kilauea SE rim to Uwekahuna there was an opening of 0".5, September 23 to October 6 and an opening of 0".41, October 6 to October 20. Total opening—0".91. From the Pit Seismograph to the NW Pit Station there was an opening of 0".33, September 23 to October 6 and closing of 1".17 October 6 to 20. Total closing —0".84.

**Spirit Leveling**

Spirit levelling across Halemaumau from the Spit SE edge of Kilauea Crater to the NW Pit BM showed a lowering of the NW Pit BM with reference to the Spit of 6.4 centimeters between September 3 and October 23. H.H.W.

## SEISMOLOGICAL DATA

**EARTHQUAKES**

**Table**

| Week Ending | Minutes of Tremor | Very Feeble Earthquakes | Feeble Earthquakes | Slight Earthquakes | Distant Earthquakes | Local* Seismicity |
|---|---|---|---|---|---|---|
| Oct. 11 | 26 | 3 | 0 | 0 | 0 | 8.00 |
| Oct. 18 | 50 | 15 | 1 | 0 | 0 | 17.50 |
| Oct. 25 | 134 | 7 | 0 | 1 | 1 | 39.00 |
| Nov. 1 | 67 | 7 | 0 | 0 | 1 | 20.25 |

* For local seismicity definition, see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began recording at the times indicated and whenever possible, determinations of depth of focus have been made.

October 11, 4:05 am, very feeble, accompanying rock slide in Halemaumau.

October 11, 5:39 pm, very feeble, located 3.3 miles deep and 0.7 mile NW of Pit Seismograph Station. NW rim of Halemaumau. 19° 24′ 8N; 155° 17′ 3W.

October 12, 4:44 pm, very feeble, located 1.0 mile deep in Kilauea Crater, 0.6 mile SW of Volcano Observatory. 19° 25′ 6N; 155° 16′ 1W.

October 12, 4:59 pm, very feeble, of shallow focus SE portion of Kilauea Crater in immediate vicinity of Pit Seismograph.

October 14, 2:45 am, very feeble, 0.9 mile deep under fissures immediately W of Keanakakoi Crater. 19° 24′ 1N; 155° 16′ 3W.

October 15, 1:15 am, feeble, 2.3 miles deep under N rim of Kilauea Crater. 19° 26′ 1N; 155° 16′ 7W.

October 15, 8:15 am, very feeble, 3.5 miles deep and 1.0 mile SE of the Twin Craters. 19° 24′ 5N; 155° 13′ 7W.

October 15, 9:02 am, very feeble, 0.9 mile deep under fissures immediately W of Keanakakoi Crater. 19° 24′ 1N; 155° 16′ 3W.

October 15, 9:03 am, very feeble, probably located under Waldron Ledge E rim of Kilauea Crater.

October 15, 5:48 pm, very feeble, 1.1 miles deep under fissures 0.5 mile N of Puu Ohale. 19° 21′ 8N; 155° 17′ 3W. This quake was succeeded by one October 16, at 12:10 am and another at 6:41 am, both of latter very feeble and all three of same location.

October 16, 10:18 am, very feeble, 1.0 mile deep in E portion of Kilauea Crater adjacent to Kilauea Iki. 19° 24′ 9N; 155° 15′ 8W.

October 17, 5:17 pm, very feeble, 1.8 miles deep near Stone Corral, Kilauea Crater. 19° 24′ 8N; 155° 16′ 2W.

October 18, 7:15 pm, very feeble, 2.0 miles deep near center of Kilauea Crater, 1.2 miles SW of the Observatory. 19° 25′ 1N; 155° 16′ 4W.

October 19, 8:52 pm, very feeble, 1.4 miles deep under E rim of Kilauea Iki. 19° 25' 0N; 155° 14' 8W.

October 20, 4:19 am, very feeble, accompanying slide from NE rim and by roaring sound from Halemaumau heard on NE rim of Kilauea Crater.

October 21, 8:18 am, very feeble, 3.4 miles deep NW rim of Kilauea Crater 0.6 mile NE of Uwekahuna. 19° 25' 6N; 155° 17' 0W.

October 21, 5:53 am, very feeble, 5.0 miles deep near center of Kilauea Crater. 19° 25' 1N; 155° 16' 4W.

On October 22, at 5:54 am a slight earthquake occurred simultaneously with a large avalanche from the E and NE wall of Halemaumau. Lack of definite preliminary phases prevented exact location but a review of the seismograms from Halemaumau and Uwekahuna showed it to be of Kilauea origin and was possibly caused by the fall of the unusually large mass of material.

October 22, 8:55 am, very feeble, accompanying slide in Halemaumau.

October 29, 7:36 pm and 7:37 pm, very feeble, probably caused by slides in Halemaumau.

October 31, 6:11 am, very feeble, probably located in fissure zone immediately west of Keaankakoi Crater.

The preliminary waves of a distant earthquake began recording at 8h 02m 09s pm HST, October 22. It was located 2835 miles from Kilauea and was reported by radio to have occurred in Alaska. The preliminary waves of a teleseism began to register at 8h 18m 40.0s am HST, October 29. It occurred 3960 miles from Kilauea and reports indicated the location as the Marianas Trough south of the Island of Guam.

A period of harmonic tremor lasting twenty-two minutes began at 2:56 pm October 19.

Microseismic motion of the ground at Kilauea was strong October 25, moderate October 7, 11, 12, 13, 15, 16, 17, 21, 24, 26, 27, 29 and November 1, and was light the remainder of the month.

## TILTING OF THE GROUND

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending November 1, was 4" 0N.

**Table of Tilt**

| Week Ending | Observatory |
|---|---|
| October 11 | 0".00 |
| October 18 | 0".35 S 15°E |
| October 25 | 0".89 N 78°E |
| November 1 | 0".38 S 77°E |

Halemaumau Clinoscope Stations

| | West | Southeast | Pit Resultant |
|---|---|---|---|
| Oct. 11 | 1".85 N 60°W | 3".05 N 33°W | 1".43 toward |
| Oct. 18 | 2".24 S 89°W | 4".86 S 88°W | 0".03 toward |
| Oct. 25 | 7".12 N 62°W | 8".81 N 18°W | 2".47 toward |
| Nov. 1 | 3".34 N 31°W | 17".50 S 72°W | 4".17 toward |

H.H.W.

# THE VOLCANO LETTER

**No. 441 monthly   Department of the Interior   National Park Service   November 1936**

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist


Figure 1. "The line of people is like a concourse of fire worshippers. At the bottom is a pool of blood-red molten slag." Halemaumau September 6, 1934, 5 p.m. Photo, 11th Photo Section, A.C., Wheeler Field, T. H.

## ERUPTION OF KILAUEA VOLCANO SEPTEMBER 1934

T. A. Jaggar

This will show first the dramatic aspects of such an eruption and its effect on people living in Hawaii. Then there will be presented the scientific data describing the phases of the eruption. Here are two broadcasts by the Honolulu Advertiser, the first September 10, for the Hawaiian Islands, from Hawaii National Park: the second September 11, in a thunderstorm on the actual edge of Halemaumau pit, a national broadcast that was heard distinctly by listeners from Canada to Mexico, along with the detonations of the lava bursts on the floor of the pit 800 feet below. The eruption had started in the very early morning of September 6.

**"September 10, Volcano House.** Tonight in presence of the fire-pit, with the glowing lava again gushing and pounding and shaking the seismographs, I am asked to tell you something of the scientific meaning of it.

"We have established here a very small observatory. The University is helping and has made some experiments with the blasts at Moiliili quarry. The Bishop Museum is studying all the Polynesian islands. The plantations are trying to find more water underground, and want to prevent their soils from washing into the sea. The engineers were baffled by the ocean at Mala, when they found that steamers cannot tie up to the wharf.

"These volcano changes, and shakings, and the building of coral islands, and the movements of the waters, are forces either useful or antagonistic to ourselves. We use gasoline from the earth which fifty years ago was hardly dreamed of for anything but cleaning gloves. The earth is full of secrets like this new force of petroleum. Six miles from Kilauea in the Kau Desert, we can light a stick at a crack. Here is a mysterious volcanic force from the ground, where continuously for fourteen years just past, we could have boiled water for making steam at those cracks.

We know a lava-flow is coming out of Mauna Loa. Where and when? The answer is written on that big, round, formidable mountain, with its cracks and caverns and sulphur and fume.

"We feel sure that a lava flow of 1924 lies under the sea east of Hawaii. Nobody has yet tried to discover it by sounding. A clever exploration there, with sonic sounding, wire sounding, bottom sampling, experiments, would make one of the great mappings of science, and would set a new standard.

"There is a job for fifty trained men for fifty years in unravelling the tangles of sea and land that beset us right here in Hawaii. This science of the earth will take men away from the cities. That is what the science of forestry is doing in the great public works program. That is what the Tennessee power plant is doing. That is what Boulder Dam is doing.

"It is astonishing that people with power, people who can employ labor, people with imagination, people who want to make a name or honor a name, cannot see the vision of the earth, and all the wonders it will yield. They see visions of the stars, but they do not see visions of the earth.

"Here in the light of the fiery lava which has risen thirty miles through the crust of the earth, which makes earthquakes for our seismographs twenty miles underground, which pours out under the sea or spouts up colossally on top of Mauna Loa, ought we not to be reminded of earth power?

"An Institute of Earth Research at Hilo could make a name for its donor that would live forever if it discovered the source of that rock heat at Mauna Iki, and the use of the powers of the living earth.

**"September 11, crater's edge.** Smooth miles in a noiseless car through hibiscus and stately tree ferns and summer habitations of men. No trace of volcanoes or brimstone in all that Hawaiian loveliness. And then in a flash you come upon a smoking fire-hole.

"A thousand people at the active crater Kilauea in Hawaii are standing here, on the edge of a vast circular pit three quarters of a mile across. The line of motionless white faces, all turned towards the setting sun, is like a concourse of fire worshippers. Sulphur of the volcano is in their nostrils. All are looking down, over a ring of precipice 800 feet high.

"At the bottom is a pool of blood-red molten slag. Through it come bursting fountains, making slow surges outward of fiery melt. Away from the fountains radiate zigzag bright lines. They are brilliant orange color, they are cracks eternally splitting the dark crust.

"Between them is a pattern of watered silk, in the black satiny robe that clothes Pele' the fire goddess. This magnificent garment lies over a bowl of the earth's glowing substance, molten, glassy, basaltic foam.

"Before the outbreak, a week ago, there was a hard lava floor, black or rusty, with a conelet at one side. The conelet is nearly drowned. The whole floor was the top of a taper cork, over converging slopes of debris. The live lava beneath lifted the cork and tipped it, escaping violently at one side of the neck of the bottle crater. Along with it, it lifted an upright slab of the wall four hundred feet high, and the glowing stuff squirted up the crack behind the slab.

"The eruption was the result. It was a quiet, instantaneous and unexpected gushing, in the dark before dawn, September 6. The evening before, nothing. The week before, nothing. The month before, nothing. People woke up, rubbed their eyes at three a.m., saw a brilliant glow and a vast cloud at the big inner pit two miles away. No one is frightened. Everybody cheers in Hawaii. Pele' has come back!

"It was all arranged as though the tourist stand, on the southeast side of the fire-pit, had been laid out by Pele' herself. In twenty minutes people were standing there, within a thousand feet of the near side of the lava lake, and just where the President's car stood a month and a half ago. There was no danger, the air was clear, the tremendous fire fountains and cataracts were all on the opposite side, and so were the whirlwinds. The best photographs were all made right there.

"The most spectacular and unusual feature of this lava rising was what happened at the wall slab, an immense cascade of incandescent liquid rock. Ribbon cataracts four hundred feet high, about twenty-five of them side by side, along a horizontal crack nine hundred feet long, fell from half-way up the wall of the pit. The liquid coalesced into a Niagara of fire at the side of talus. These cascades stopped flowing about three hours after the beginning of the eruption.

"A short distance to the north, at the edge of the glowing lake, were brilliant jets squirting up as though from hose nozzles, and criss-crossing against another slide-rock slope. These were more noisy, with deep rumble, than any of the other phenomena of the eruption. This rumble is due to gases rushing and shakng the whole volcano.

"Still farther around out in the lake was a tremendous fountain, shooting up three hundred feet in huge ropy flings, which slopped down onto the surface of the lake. The lake itself was indescribably beautiful, a vast labyrinth of glowing cobweb pattern ever changing radial and concentric to the central fountain group. The fire surf pounds on the shore, and the shore itself changes in the course of a few days of activity. A beach rampart forms. Then as the lake rises, slabs of crust pile up higher and higher on this rampart. It is like an ocean barrier beach of big flakes of stone, only the sea is made of fireworks.

"The deep shaking was such that all our seismographic instruments were vibrating violently, in unison with the trembling of the fire goddess.

"One of these machines is an annunciator, which rings a bell in the room above. When on the second day of the eruption, the big fountain started banging away like a big gun, this bell would ring in the Observatory building. Every detonation two miles away completely announced itself, as though Pele' were pressing the button.

"The whirlwinds were set going by the very hot rush of gas on the side of the pit away from the people. A strong trade wind threw this into cyclonic motion. Fragments of pumice, red hot, were falling on the west floor of Kilauea the first day. Some of them were a foot long. The whirls merged together and swept up the gravel on the ground as though with a giant's broom. I walked through this region on the first morning, in the light of the glowing pit, in order to read the tilt-meter in our cellar on the west side. My assistant picked up a pumice fragment with enough glow inside to light his cigarette. Now and then we had to crouch down to keep from being blown over. The gas and flying sand were trying, but the mighty yellow clouds shooting up above us, full of light fragments that floated down, made a marvellous spectacle. And the great billows of cloud rolled away to leeward for fifty miles in a straight battalion of brownish volutes, tinged with pink by the rising sun. Pele' had declared war!

"What does it all mean to science? Do you say? Eight eruptions in ten years have laid new layers of lava on the bottom of Halemaumau pit in Kilauea crater. The layers average about sixty feet each. The pit is now about 800 feet deep.

"We have three active volcanoes in Hawaii, Kilauea, Mauna Loa and Hualalai. Mauna Loa had an outflow to the sea and destroyed a village in 1926. It erupted gloriously at its summit crater last December, and the travellers visited it in airplanes. We had a steam-blast eruption from Kilauea in 1924, and probably a mighty lava-flow poured out under the ocean to the east, where the water is 18,000 feet deep. We had a great trembling and shaking, thousands of earthquakes in a few weeks, from the volcano Hualalai on the west side of Hawaii in 1929. Add these things to Kilauea and you get eleven events in ten years. Who shall say that the Goddess is dead?

"A lava flow is soon coming from Mauna Loa. The scientific observatory of Hawaii National Park has been accumulating records for twenty-two years. Hawaii is the most perfect natural laboratory in the world. Here new land is being made, wind and weather act upon it, ocean and rivers sweep down the rubbish, and under all the crust of the globe is lifted. The Observatory will measure everything for a century to come. The measurement of the living earth and its breathing is just as important to your state as to Hawaii. Volcanoes in the past erupted in the Carolinas, Virginia, Pennsylvania, New Jersey, New York—your Palisades are a mass of Hawaiian lava—and in Connecticut, Massachusetts and Nova Scotia. But here in Hawaii you can take the pulse and breath and temperature of new rock when it is a-borning, and when it is making earthquakes. All over the globe there is need for more explorers for the study of the living earth.

"And now, listen to the Fire Goddess Pele' herself in the throes of her birth-pangs, listen to the pounding of liquid lava, to the bursts of earth puffing, to the surging of the waves of molten rock on the shore, all carried to you on the wings of radio, 180,000 miles a second—"

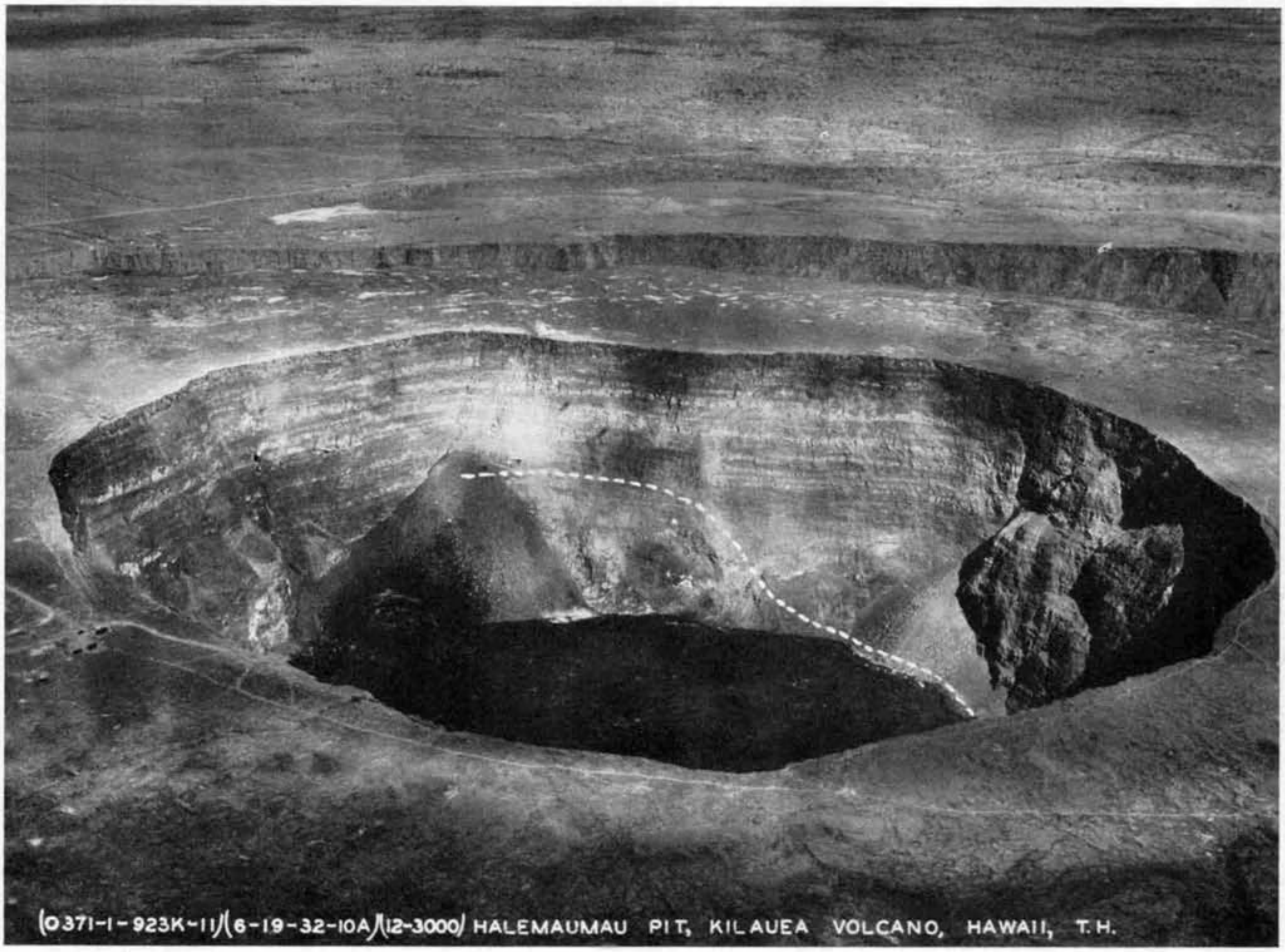



Figure 2. Halemaumau looking west from airplane June 19, 1932. Dotted line shows where the plug of 1931-32 lava lifted a wall slab to open the vent of 1934. Photo, 11th Photo Section, A.C., Luke Field, T. H.

**ERUPTION OF KILAUEA VOLCANO, 1934**

T. A. Jaggar

The seismic events in Hawaii that accompanied the outbreak of Mauna Loa in 1933 were reviewed by A. E. Jones in Journal Washington Academy Sciences for October 15, 1934, and those associated with the 1934 eruption of Kilauea in the number of October 15, 1935. In an earlier communication the writer has described and illustrated the 1933 eruption of Mauna Loa.

In Halemaumau pit there were slides before and after noon September 5, 1934, and the seimograph in a cellar near the southeast rim of the pit registered southwesterly tilt on the afternoon of this day. This was the first conspicuous premonitory symptom of the gushing up of lava in the bottom of the pit about 2:44 a.m. September 6.

Tremor spasms recorded seismometrically began at 1:07 a.m. and occured at intervals of a few minutes. Shocks close to the pit accompanied the outbreak, a feeble one at 2:44 a.m. caving away of the rim portions, and the leaving of a remnant buttress below. The vertical crack behind such a buttress is often not at all in evidence, and is frequently covered by talus.

Figure 3. Halemaumau 4:30 a.m., September 6, 1934. Looking northwest, "twenty-five ribbon cataracts four hundred feet high, and brilliant jets squirting up below." Photo Maehara.

being followed by the continuous tremor which is characteristic of the rush of gas that accompanies fountaining. At the same time the bright glow of inpouring lava appeared, and clouds of fume arose. The fountaining places began at the edge of the lava floor at the bottom of Halemaumau on the north, northwest and west sides. The gush of gas bringing with it lava foam emerged through talus slopes at the first two places. The third was altogether different, and unique in the experience of the Observatory.

This was the gushing up of lava along an extensive fissure, forming a vertical crack back of a western buttress of the wall. The lava squirted up in 25 jets along a horizontal line half way up the wall of the pit. The frothy lava so ejected cascaded down the wall in ribbon cataracts. They poured over the large west talus between 3 a.m. and 6 a.m., and then went out of action. Ten main vents persisted until 6 a.m. along the cascade crack, the cascades being from 300 to 400 feet high, and there were two or three subordinate cascades, on an extension of the crack which opened on the northern side of the buttress. This buttress was in the nature of a fault slab, with the live dike fissure behind it. The wall of a pit of this kind is made up of several such imbricating fault blocks, produced by the

The two photographs shown in Figures 3 and 4 are pubished by permission of K. Maehara for the night scene, and of the Eleventh Photo Section, Air Corps, Wheeler Field, U.S. Army, Territory of Hawaii, for the daylight view, which was made from an airplane. Both pictures were made from the southeastern side of the pit, the night scene about 4 a.m. September 6, while the cascades were in action, the daytime view at 9:30 a.m. September 7, the second day of the eruption, after the big western fountains had entirely ceased action. The two views show the contrast between the liquid flood of the first few hours of one of these pit eruptions, and the chilling around the borders which rapidly takes place afterward. The extraordinary feature of these photographs is the great western cascade. The upright fracture along the middle of the wall slope was 900 feet long and extended under the large west talus so that some of the fountains gushed through the talus along a horizontal belt, others poured over the rock buttress where there is an old intrusive body of irregular form, and still others cascaded out of the crack on the north side of the buttress, and it will be seen that the crack behind resisted the splitting effect for a quarter of its length. The most violent fountains were those at the northwest side of the pit shown at the right of the night photograph. These were several hundred feet high, like jets from hose nozzles, covering the northwest wall and talus with pumiceous lava. The fragments of pumice were ejected several hundred feet above the rim of the pit the early morning of September 6, and fell in light spongy fragments as much as a foot long over the floor of Kilauea crater to the southwest. There was not much Pele's hair, but coarser needles of basaltic glass were common.

**Phases of the Eruption**

This eruption of Kilauea may be divided into four phases: (1) the large liquid pool of September 6; (2) the small lake heap and overflows which developed September 7 to 20; (3) border trickle flows from the wall-crack dike September 20 to 30 and (4) the period of subsidences, with detonations and intrusion from September 22 to October 8. These phases were more illuminating in revealing new explanations of some habits of Hawaiian lava, than anything which has happened here for many years.

**Phase One: The Large Liquid Pool**

This is the phase illustrated by the night photograph, and its decline is shown by the picture of September 7. Sulphurous fume of absinthe red color in transmitted light boiled up several thousand feet during the first 12 hours. The reflected fountain light was yellow-green to orange. The noise was a rumbling, and a rushing of gas, while hundreds of whirlwinds swept clouds of surface dust west and southwest of Halemaumau, and the odor was that of sulphur dioxide.

At 4 a.m. September 6 there were 30 jet fountains, and by 8 a.m. the new pool had covered the former floor 60 feet deep. Its area was 90 acres and its volume nine million cubic yards. Only the top of the 1933 border cone was still emergent. At noon the north fountains had dwindled, the northwestern ones were very violent, and the lava lake was covered with a bright-line pattern and black silky skins. A bench and rampart of crusts developed around the lake, wider at the talus slopes where the submerged slope was flatter. Between 3 and 4 p.m. the violent northwest fountaining stopped rather suddenly, and only thin blue fume was left rising from the north central fountains within the lake area itself.

Shrinkage of the lake now started in, so that by September 9 there was an inner lake 1100 feet in diameter surrounded by a floor which had shrunk and lowered beneath the border rampart 10 to 20 feet. The remnant lake was concentrating about the fountains at the NNE side of the floor. On all sides there was a slump scarp at the inner border of the rampart. The lake September 10 measured 1000 feet east-west by 400 feet north-south and became defined as an oval plateau on top of a terraced heap surrounded by a rim, over which went overflows. (See map). Within the lake spatter banks formed behind the two bigger fountains, showing that the lake was shallow, and that only the fountains were over source wells.

**Phase Two: Small Lake Heap and Overflow**

As early as September 7, temporary tremor increase rang the seismometric annunciator bell at the Observatory two miles

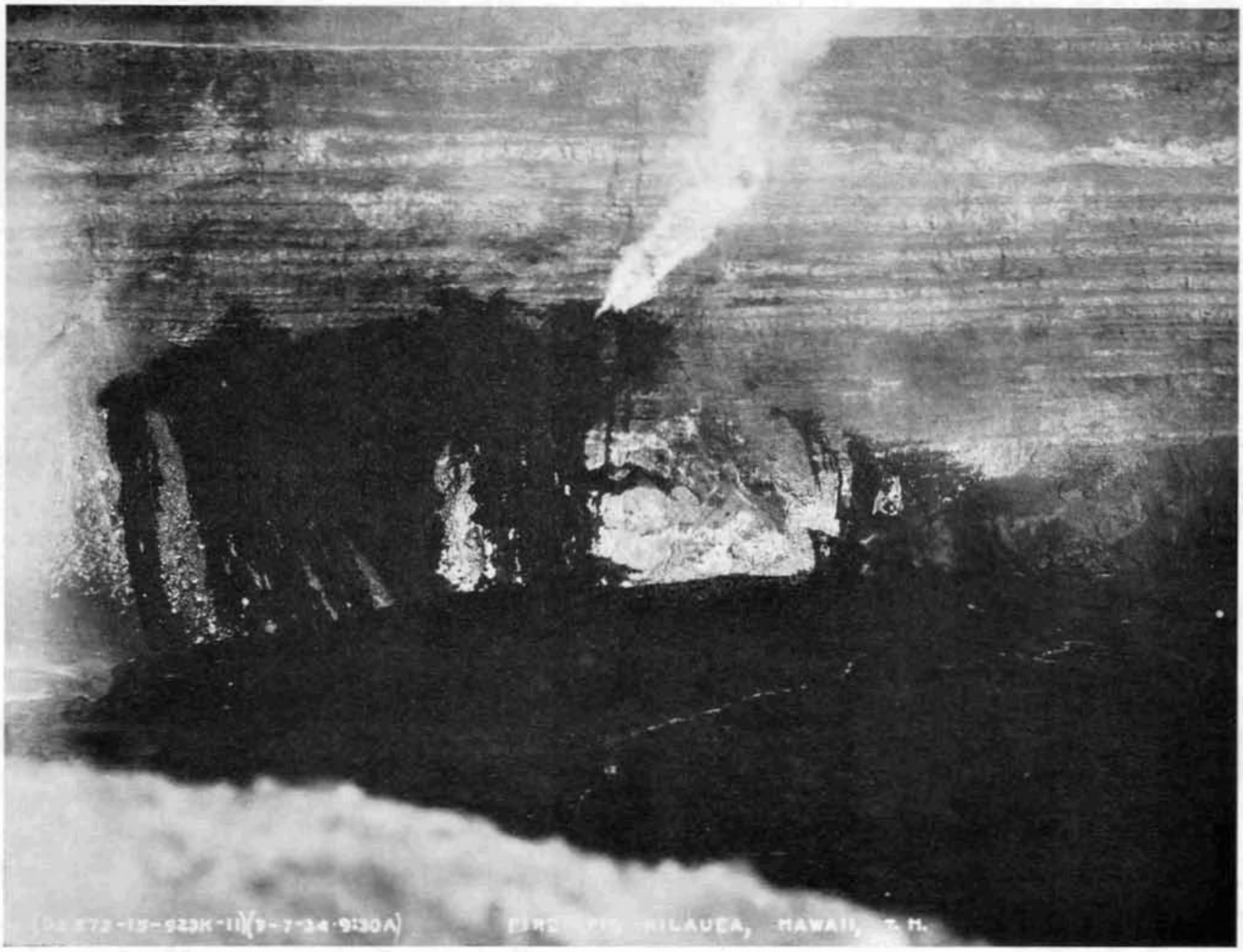



Figure 4. Halemaumau 9:30 a.m., September 7, 1934. Compare with Figures 2 and 3. Looking northwest. 11th Photo Section, A.C. Wheeler Field, T. H.

away. This meant that the larger fountain was making blast-like detonations, flinging up lava froth 300 feet, and emitting brown puffs. These detonations from the fountain wells increased as the vents clogged. September 15 there were five principal fountains, and a line of shoals across the lake. The reduced lake began to develop an interior topography, with a cone and crater around the large western fountain and nine other fountaining vents amid six islands and a peninsula.

By September 20 the floor measured 2700 by 2200 feet, and the lake oval was a detail within it at the north measuring 744 by 390 feet. The lake pool was on a heap 38 feet above the floor, and the highest grotto heap piled by the fountains stood 136 feet above the pre-eruption floor immediately under it. The average 1932 floor level was 2796 feet above sea-level, while the average 1934 new level was 2874 feet.

Overflows built up the new lake heap and 10 cracks developed in the outer floor radial to the lake, indicating that the lake heap was over a laccolithic swelling. Within the lake the streaming was from west fountains to east fountains, and sometimes the latter exhibited inward cascading downward. Evidently a convectional circulation was being established. Finally the sinkhole well tended to explode with detonations. Overflows were numerous from the lake so that it was being built up on a slag heap.

**Phase Three: Lava Trickle up the Wall Crack**

A new feature appeared September 20 around the extreme edges of the floor in the shape of a welling up of red lava, between the talus and the cake of 1934 fill, which constituted the floor. This was the first time any glowing lava had appeared from a source away from the fountaining wells. They began along the talus edges, but eventually extended to places where the floor made contact with the rock wall of the pit. In no case did they cascade over the slump scarp inward, but the lava rose as a dike between the floor cake and the containing funnel. The band of border extrusion was 20 feet wide in places, and it gradaully extended to all sides of the floor with the exception of the north edge that was closest to the lake. The marginal extrusion was always simultaneous with extra pressure at the lake, accompanied by overflow. It was evident that intrusive action was going on under the floor. Transit surveys in the course of the eruptive period showed that the outer floor rose, and the lake area gradually lost its relief.

**Phase Four: Subsidence with Detonations**

Detonation spells from both east and west wells, which had built cones within the lake, recurred from time to time during September 22. This usually happened when the east fountain had been transformed into a sinkhole grotto at the level of the lake, big bursts of gas and flame came up, and downpouring would last from 10 to 20 minutes. Then the pot would resume ordinary fountaining with outward flowing streams. During the detonation spells, tremor increased at the seismographs. By September 23 the west fountain had become a pool in a raised craterlet, from which a cascade poured into the lake. This craterlet also made noisy explosions, and four avalanches were noticed at the north wall of the pit close by.

About 2 p.m. September 23 the lake drained away through the eastern sinkhole leaving a saucer 20 feet deep, and then the liquid poured in again. These drainages increased in duration until October 1. Their violence also increased, they lasted from half an hour to two hours, and the intervals between them were notably about six hours. The detonations were finally heard three miles away.

It now appeared that the whole floor was swelling by intrusion, and a concentric ridge around the edge of the floor replaced the former slump scarp. Apparently the pulsations of lowering the lake basin were occasioned by inflow of the liquid under the shell of floor crust. The floor was lifted and the lake area went down. Gradually they were brought to a common level. The explosions were due to clogging of the gases in the increasingly viscous lava of the wells, and to the confinement of a small shaft. Failing to overflow the wells became gun-barrels. With each detonation an umbrella-shaped fling of stiff lava would shoot up, sometimes 400 feet, the roofs of the grottos would be blown to pieces, and fragments would clatter down all over the surrounding surfaces. Toward the end the explosive spells would be followed by complete quiet for a half hour. Then the liquid would quietly recover in the wells and restore the lake to a period of four or five hours of quiet streaming.

The detail of a sinking spell was as follows: At 9 a.m. the west fountain cone was cascading over its flank; at 11 a.m. the lake saucer was 25 feet deep, with shoals on its bottom, and both east and west wells were cannonading vertically, long squirts of viscous melt were sent up 200 feet or more, the intervals between detonations or hisses were from 5 to 10 seconds. The lava pooled in the wells and came back with quiet fountaining just after noon. The explosions gradually lessened, a fan-shaped flow on the lake bed from the west fountain encountered an expanding puddle from the east fountain in mid-lake, and the entire body of new liquid overrode the foundered crusts that formed the floor of the lake.

September 28 and 29, and again on October 1 occurred the last overflows of the lake margin. The extraordinary intrusion ridge at the edge of the floor at the foot of the east talus had become 25 feet high, crevassed along its crest, and the floor on the inner side of this ridge, which had been 15 feet below the slump scarp around the margins, was now 25 feet above it. The actual lift of the floor therefore, above its slumped position of three weeks before was of the order of 40 feet.

The lake area was gradually converted into several ponds. By October 3 three quarters of the lake basin had become a slag heap, with the northern pool a depression in its flank 300 feet long. There were evidently tunnels leading from the cone pots to the lakes. Several pots had developed and these became smoke holes. October 5 the lake area had collapsed, blowing noise was audible and some streaming was still visible. Thudding noise was heard in the western part of the swelling floor, and prolonged slides at the north wall of the pit showed that slumping of the lake area was in progress. The eruption ended October 8 and subsequent shrinkage caused numerous slides from the pit walls.

**Level Changes**

From time to time the Observatory runs levels from a bench mark on the gravel spit south of Kilauea crater as a base, so as to close a circuit around the rim of Halemaumau pit. After the eruption, October 17-25, A. E. Jones ran such a leveling circuit to discover changes since July 2, 1934. Treating "Spit" bench mark as stationary, results showed a stretch of the north rim of Halemaumau 1800 feet long to show positive elevation to a maximum of 1.28 feet; along 1000 feet of the rim on each side of the elevated tract, negative elevation to a maximum of 0.5 foot occurred northwest and northeast of Halemaumau. The remainder of the rim showed diminishing depression southward to a line of no change 400 feet SSE from the pit.

It should be observed that the north tilt cellar near the pit rim was much less disturbed by the eruption than the two other cellars southeast and west, as though the north were comparatively rigid ground. The rift belt of the mountain crosses the pit from southwest to northeast. The bench mark "Spit" lies within an old graben fault block on the side of downthrow relative to the north side of the rift belt. It seems likely that the evacuation of magma produced by the eruption undermined this fault block, that the northern country remained relatively stable, and that what is really represented by the level change

Figure 5. Halemaumau from Observatory September 6, 1934. Heavy fume column over lava fountains. Photo Jaggar.

is a lowering of the bench mark, rather than an elevation of the northern pit rim.

## Hawaiian Volcano Observatory Report for November 1936

### VOLCANOLOGY

The month of November at Halemaumau Pit of Kilauea Volcano continued the slides from the walls which have been so conspicuous of late.

The following is the abridged table of movements:

| Week Ending | Seismicity | Number of Slides | Aggregate Crack Opening |
|---|---|---|---|
| November 8 | 15.50 | 20 | 518.5 mm. |
| November 15 | 19.75 | 14 | 20.0 mm. |
| November 22 | 11.75 | 14 | 5.5 mm. |
| November 29 | 7.50 | 16 | 0.5 mm. |

**Sequence of Events by Weeks**

The first week slides and cracking of the NE rim continued with more debris added to the talus slopes, and much breaking of rim ground. Crack No. 34, a chasm close to the cliff edge, opened 501 mm.; this accounting for the excessive value above.

The second week kept up these processes, with a marked tendency to continuous dribbling of rocks down the E and NE walls about the noon hour.

The NE surveying station monument, the third week, was left unstable at the extreme edge of pit, undermined by slides.

The fourth week showed a change of habit, with much lower seismicity, much **closing** of cracks, so as to make the lowest record of weekly crack opening since September 20, 1935, and uplift instead of sinking for the levelling measurements of Kilauea floor at Halemaumau pit rim. The slides extended their operations to the north wall of the pit.

**Slides at Halemaumau**

Slides from the wall of the pit have been noted as follows, but these are only a part of what actually occurred:

November 2, 10:00 am., continuous sliding NE wall 12 to 1:30 p.m., dust from slides until 3:00 p.m., continuing slides N and NE.

November 3, 9:42 and 9:53 a.m., small slides.

November 5, 9:00, 9:40, 10:15 a.m., moderate slides. 9:55 a.m., small slide. 11:53 a.m., 12:55 p.m., slides. 2:20 p.m., 3:36 p.m., large slides NE station. 1:30, 5:00 p.m., continuous sliding. 3:18 p.m., earthquake rang No. 1 Annunciator Bell, dust cloud at pit NE. 3:46 p.m., No. 1 Bell again, dust continues. Below Crack No. 34, 200 feet, a dark spot in the wall was caving away.

November 6, 9:22, 9:30 a.m., moderate slides NE.

November 10, 9:02 a.m., a large slide had left a scar, and small rocks dribbled down the wall E, sending up light dust. 9:37 a.m., moderate slide NE, 100 feet below Crack No. 34. 9:51 a.m., large slide ENE.

November 11, 9:54 a.m., small slide sending up light dust E. The Volcano House trail near the pit ENE had now lost 100 feet of length by caving in, a new notch here indented the edge of the pit, and fresh cracks farther back had started to open.

November 12, 10 to 11 a.m., rocks falling continuously from E wall.

November 13, 8:50 a.m., rocks dribbling down wall. 11:55 a.m., 12:40 p.m., moderate slides send up dust.

November 14, 10:15 a.m., moderate slide E. 11:16 a.m., big noisy slide E.

November 15, 9:24 a.m., 9:55 a.m., moderate slides ENE with small slides in interim.

November 16, 9:45 a.m., moderate slide NE. 9:50 a.m., larger slide ENE, preceded for 15 minutes by dribbling stones. Slides during day undermining NNE wall and removing 100 feet of edge east of NE station.

November 17, 9:56 a.m., rocks dribbling at new scar NNE.

November 19, 10:12 a.m., rocks dribbling NNE.

November 21, 9:25 a.m., dust NE wall. 9:46 a.m., continuous small sliding ENE. 9:54 a.m., 10:17 a.m., moderate slides NE and ENE.

November 24, 9:00 a.m., NE dust cloud. 9:45, 9:47 a.m., small slides ENE. 9:50 a.m., large dust cloud. 10:15 a.m., moderate slide ENE and dust cloud under NE station. 10:22 a.m., large slide there leaving scar. 10:30 a.m., 10:45 a.m., large dust clouds N. 11:15 a.m., large dust cloud ENE. 2:50 p.m., dust cloud NE station. 4:00 p.m., moderate slide 400 feet west of NE station. 4:10 p.m., large slide same place. 3:00 to 4:00 p.m., continuous falling of rocks there, which ceased after the large slide.

November 25, 10:55 a.m., noise of moderate slide heard, followed by continuous dribble on wall 300 feet W of NE station.

November 27, 11:15 a.m., dust from slide NE.

**Halemaumau Solfataras**

Fume of bluish color continued to rise at the edge of floor of pit NW and SE. On November 13 it appeared dense at 8:50 a.m., and thinner at 9:40 a.m. It was reported "not conspicuous" the third week.

On November 19 a fresh slide was reported to have left a scar in the SE corner of Hiiaka Crater in the Chain of Craters east of Kilauea.

**Measurement of Halemaumau Rim Cracks**

Weekly measurement of 27 marked rim-crack localities, reduced to 26 the third week, resulted as follows. Some time before November 21 possibly during the earthquake of November 16, sliding carried away the southern ledge of Crack No. 34.

Week ending forenoon of:

November 7, 11 opened, 1 closed, aggregate opening 518.5 mm.

November 14, 9 opened, 2 closed, aggregate opening 20.0 mm.

November 21, 9 opened, 1 closed, aggregate opening 5.5 mm.

November 28, 6 opened, 8 closed, aggregate opening 0.5 mm.

Crack No. 34 on November 7 was found yawning excessively and collapsed in the middle of the month. It is a chasm over the NE extension of the Kau Desert rift which crosses Halemaumau. Omitting it the general opening November 7 was 17.5 mm.; No. 17 opened 2.5, No. 25 8.0, and No. 45 2.0 mm. No. 17 is SSE, the others E (See map of pit, rim figures).

On November 14, the opening of cracks was in gradations to a maximum of 9.0 mm. at No. 28, where the edge had broken back the most. No. 34 NE opened only 2.0 mm., in contrast to November 17, when it opened 510 mm.

November 21, the destruction of No. 34 over the deep rift made the sixth marked crack on the rim destroyed within a month. The rift belt crosses the pit (see map) from SW Pit Station to NE Pit Station.

## SEISMOLOGICAL DATA

### EARTHQUAKES

**Table**

| Week Ending | Minutes of Tremor | Very Feeble Earth-quakes | Feeble Earth-quakes | Slight Earth-quakes | Distant† Earth-quakes | Local* Seismicity |
|---|---|---|---|---|---|---|
| Nov. 8 | 22 | 15 | 1 | 0 | 2 | 15.50 |
| Nov. 15 | 65 | 7 | 0 | 0 | 2 | 19.75 |
| Nov. 22 | 21 | 8 | 0 | 1 | 0 | 11.75 |
| Nov. 29 | 12 | 9 | 0 | 0 | 1 | 7.50 |

† Includes teleseisms or those shocks over 5000 kilometers distant.

* For local seismicity definition, see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began recording at the times indicated and whenever possible, determinations of depth of focus have been made.

November 3, 5:28 pm, very feeble, located in fissure zone 0.5 mile NE of Ahua Kamokukolau and 2.4 miles deep. 19° 23' 1N; 155° 17' 2W.

November 5, 3:18 pm, very feeble, in Kilauea SW Rift Zone near the Kamakaia Hills and 16.0 miles deep. 19° 19' 5N; 155° 21' 0W.

November 5, 11:26 pm, very feeble, probable location, Mauna Loa NE rift about 18 miles SW of Hilo.

November 7, 1:43 pm, very feeble, 1.8 miles deep and 0.6 mile N of Kalanaokuaiki Pali. 19° 21' 7N; 155° 15' 3W.

November 7, 2:19 pm, very feeble, 3.3 miles deep, 2.0 miles S of Halemaumau and 1.4 miles W of Ahua Kamokukolau. 19° 22' 8N; 155° 17' 4W.

November 7, 3:47 pm, feeble, located 4.8 miles deep and 0.6 mile E of Keanakakoi Crater. 19° 24' 3N; 155° 15' 4W.

November 12, 4:25 am, very feeble, located near center of Kilauea and of shallow depth.

November 16, 1:44 am, very feeble, located 1.0 mile NW of Kilauea Military Camp and 4.0 miles deep. 19° 27' 1N; 155° 17' 0W.

November 16, 4:42 am, very feeble, located 4.2 miles deep in vicinity of Kilauea Military Camp. 19° 26' 3N; 155° 16' 2W.

November 16, 8:33 am, very feeble, 1.0 mile deep under NE edge of Kilauea Crater. 19° 26' 0N; 155° 16' 2W.

November 16, 8:36 am, very feeble, 0.9 mile deep under western portion of Kilauea Iki. 19° 25' 1N; 155° 15' 2W.

November 16, 10:14 am, very feeble, 5.0 miles deep in Kilauea Crater adjacent E edge of Halemaumau. 19° 24' 7N; 155° 16' 9W.

November 16, at 1:08 pm a slight to moderate earthquake registered on all the Observatory seismographs. It was located immediately to the SE of Kilauea Iki Crater, 1.4 miles E of Byron Ledge E rim of Kilauea Crater. Reports indicated that it was felt slightly by many people in Hilo. The shock was felt by a few in the Kilauea Area and very strongly in the vicinity of Puu Koae on the Kau Desert SW of Kilauea Crater. 19° 24' 8N; 155° 14' 4W.

November 16, 5:11 pm, very feeble, 4.8 miles deep near juncture of Pali Lele o Kalihipao and Kalanaokuaiki Pali. 19° 21' 1N; 155° 16' 0W.

November 16, 5:52 pm, very feeble, 0.4 mile N of N edge of Kilauea Iki, 3.5 miles deep. 19° 25' 5N; 155° 14' 9W.

November 16, 7:36 pm, very feeble, located 3.4 miles deep under E portion of Kilauea Iki. 19° 24' 9N; 155° 14' 7W.

November 18, 1:51 pm, very feeble, located 9.0 miles deep and 5.0 miles E of Mauna Loa Summit Crater.

November 23, 5:48 am, very feeble, probably located in the vicinity of Ahua Kamokukolau, 2.0 miles SE of Halemaumau.

November 25, 1:02 pm, very feeble, probable location under center portion of Kilauea Crater.

November 27, 9:39 am, very feeble, probably located under SE rim of Kilauea Crater.

November 28, 10:06 am, very feeble, probably located in fissure zone 1.3 miles SE of Ahua Kamokukolau.

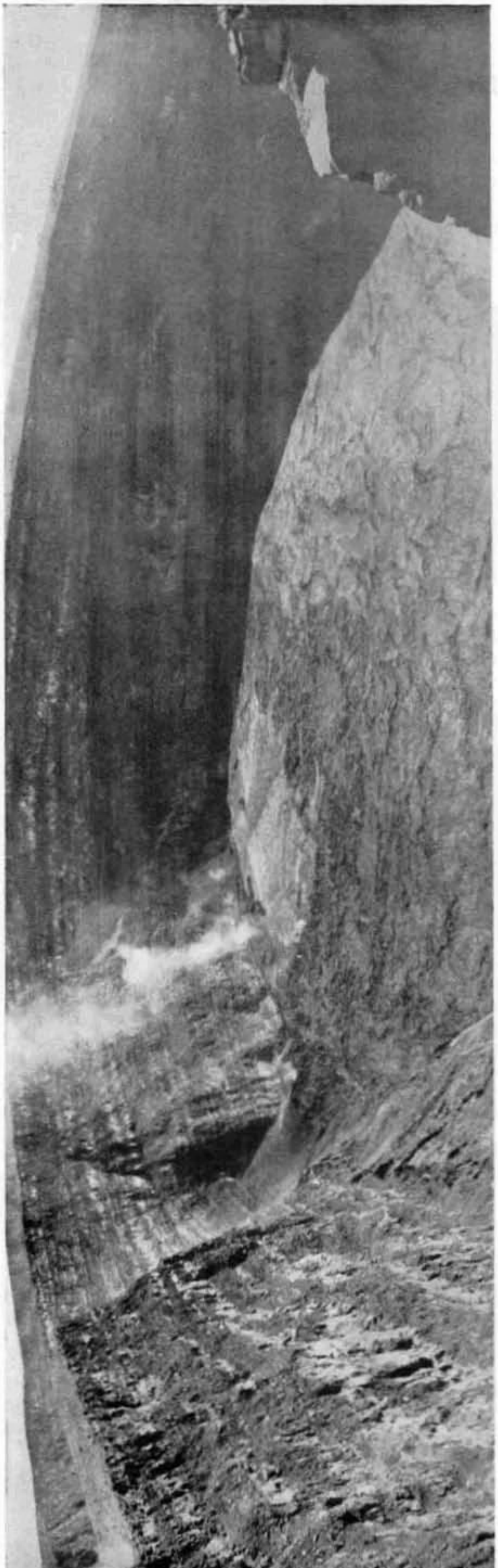


Figure 6. Halemaumau looking NE September 13, 1934, when the inner lake had formed at the top of a heap. Photo Jaggar.

The following very feeble earthquakes occurred simultaneously with, and are probably associated with rock slides from the E, NE or N walls of Halemaumau. November 5, at 2:03, 2:20, 2:28, 3:36, 4:40, 4:41 and 4:49 pm.

November 14, at 11:13 and 11:17 am.

November 24, at 2:13 and 4:08 pm.

Periods of continuous (harmonic) tremor registered during the month as follows: beginning at 5:41 am November 5, six (6) minutes; 6:54 pm, November 13, twenty-eight (28) minutes.

Microseismic motion of the ground at Kilauea was light November 4, 13 and 28; strong November 8, 9, 14 to 21 inclusive and 24; the remainder of the month it was moderate.

Teleseisms or Distant Earthquakes began registering on the Observatory seismograph as follows: November 2, the preliminary (P) waves at 4h 36m 39s H.S.T., thought to be located near Guam, 3485 miles from Kilauea. November 2, (P) waves at 10h 25m 48s H.S.T., 3850 miles from Kilauea, reported location off the coast of Honshu west edge of Japan Trough 38° N; 142° E (U.S.C.G.S.). November 12, (P) waves at 9h 43m 51s H.S.T., 3905 miles from Kilauea. November 13, (P) waves at 2h 10m 11s H.S.T., 3305 miles from Kilauea, reported location near Kamchatka Peninsula N of Japan Trough 57° N; 164° E (U.S.C.G.S.). November 25, (P) waves at 10h 10m 50s H.S.T., 2200 miles distant from the Volcano Observatory. November 28, Secondary waves (transverse) at 8h 21m 45s probably associated with news reports of disturbances in Alaska.

H. H. W.

## TILTING OF THE GROUND

The following table shows tilt by weeks from seismograms at the Volcano Observatory NE rim of Kilauea Crater and at Halemaumau, the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending November 29, was 4" 85N and 3" 66W.

**Table of Tilt**

| Week Ending | Observatory | Halemaumau West Station |
|---|---|---|
| November 8 | 1"90 N 30°E | 1".82 S 35°W |
| November 15 | 1".18 S 70°W | 2".59 N 38°W |
| November 22 | 0".50 N 12°W | 5".78 N 88°W |
| November 29 | 0".33 S 61°W | 5".22 S 52°W |

| Week Ending | Halemaumau Southeast Station | Halemaumau Resultant |
|---|---|---|
| November 8 | 4".92 N 17°W | 3".'50 toward |
| November 15 | 1".20 S 69°E | 1".86 from |
| November 22 | 6".67 N 16°W | 0".35 toward |
| November 29 | 5".12 N 19°W | 3".39 toward |

### Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory November 23, showed closing across the Crater and slight opening across Halemaumau as compared with similar measurements October 20. From Kilauea SE rim to Uwekahuna there was closing 2".75, October 20 to November 2; closing of 0".66, November 2 to 13 and opening of 1".00, November 13 to 23. Total Closing 2".42. From the Pit Seismograph to the NW Pit B.M. there was opening 0".25, October 25 to November 2; closing of 0".58, November 2 to November 13 and opening of 0".67, November 13 to November 23. Total opening 0".34.

### Spirit Levelling

Spirit levelling across Halemaumau from the Spit, SE edge of Kilauea Crater to the NW Pit B.M. showed elevation of the NW Pit B.M. with reference to the Spit of 6.4 centimeters. This is the first indication of elevation since before the 1934 eruption of Kilauea.

H. H. W.

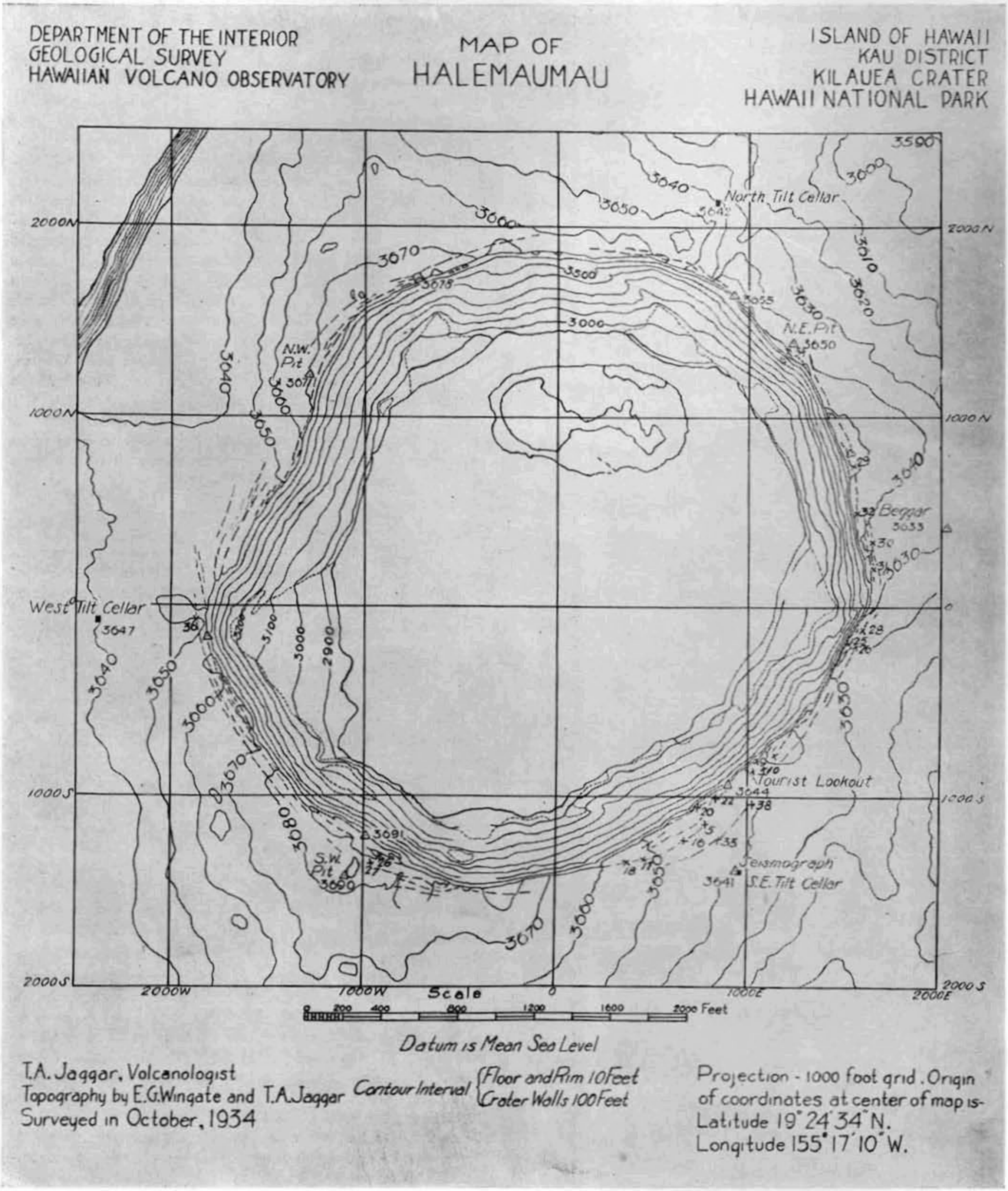
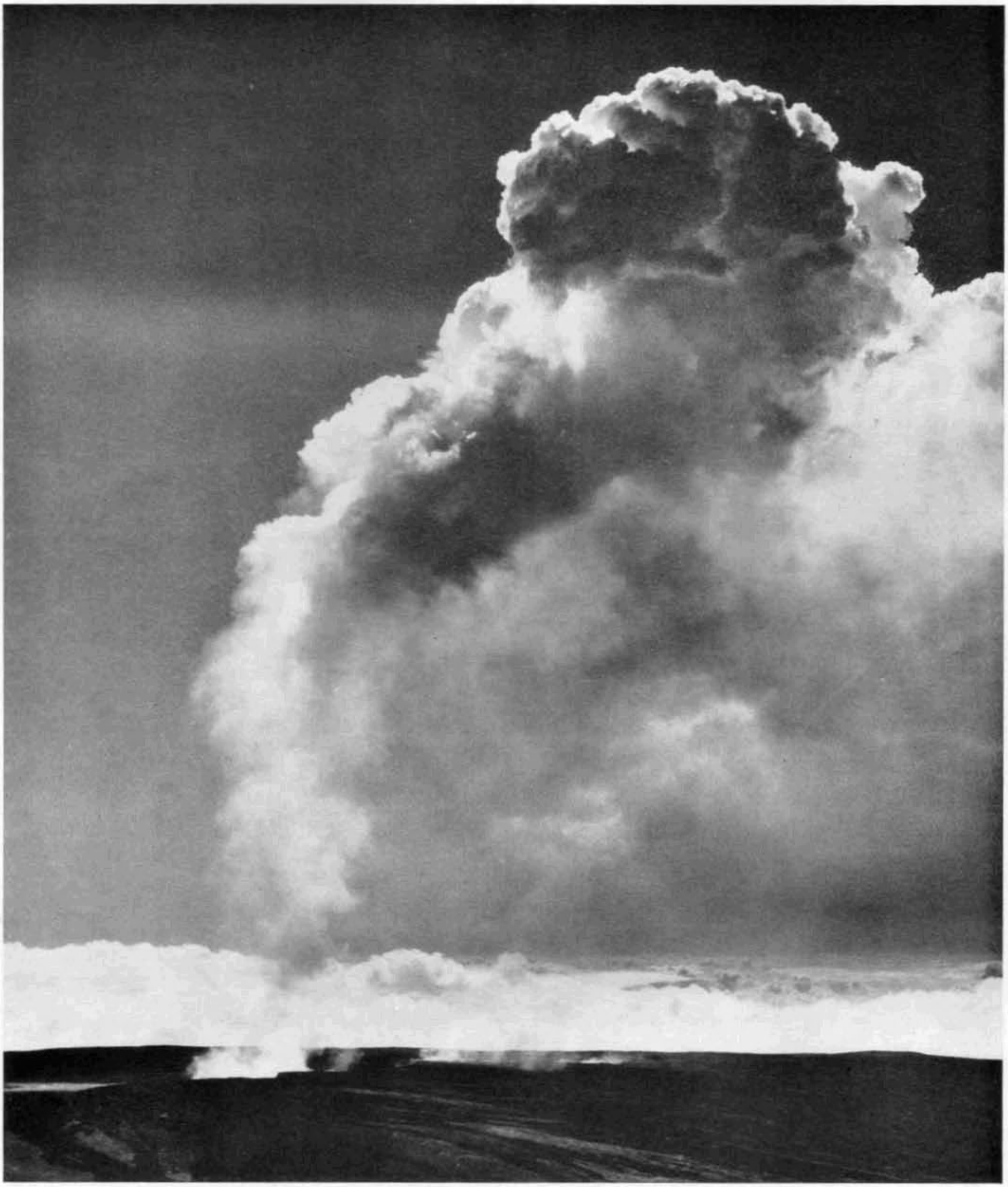



Figure 7. Map of Halemaumau October, 1934. Compare Volcano Letter No. 395 for map before 1934 eruption.



A remarkable photograph taken from an airplane above Makuaweoweo Crater, Mauna Loa, at an elevation of 14,500 feet. Thin fume rising from lava fountains playing within the crater, merges into dense white cumulus of atmospheric moisture above. By permission Fleet Air Base, Pearl Harbor, T. H.

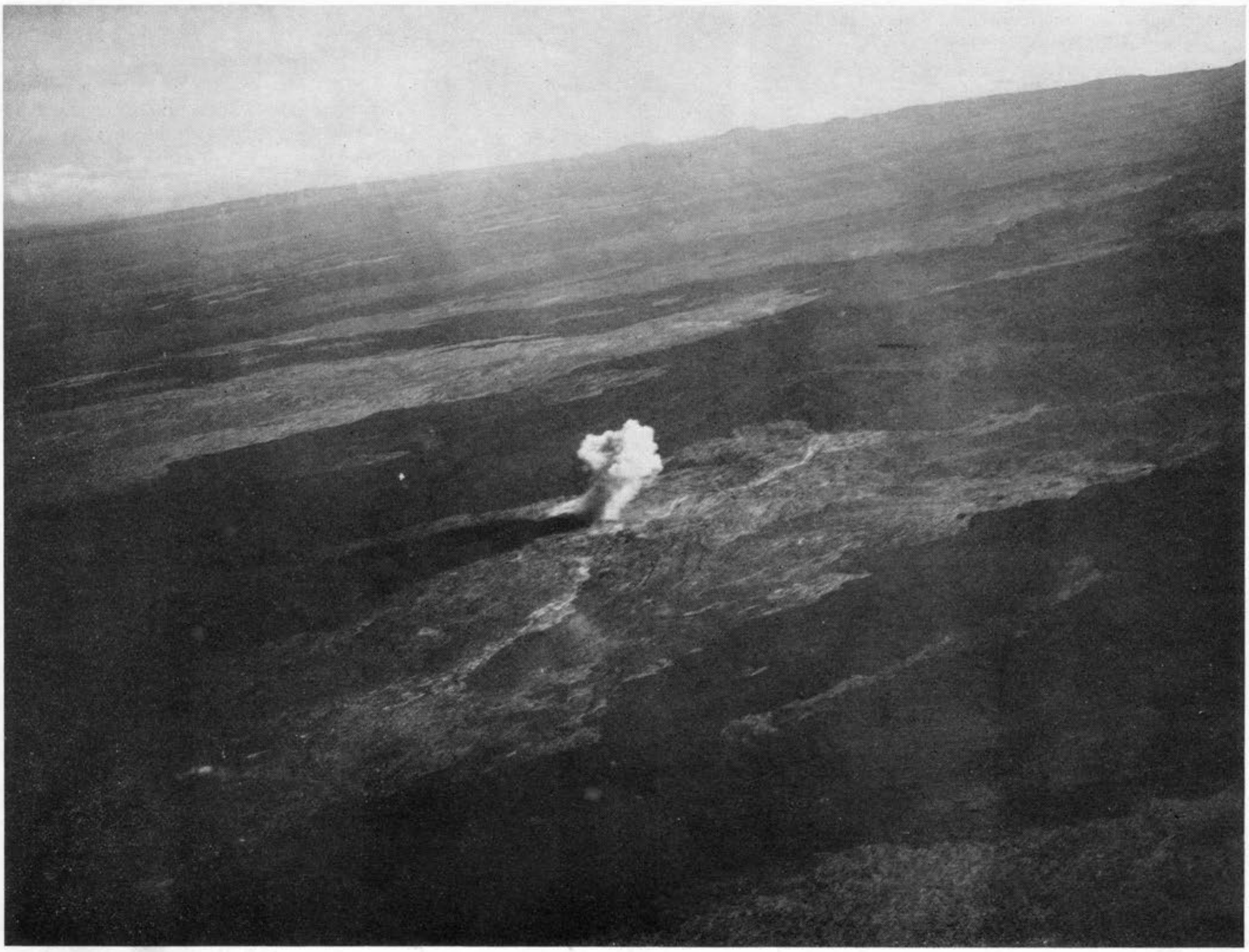
NE PLUS HAUSTAE AUT OBRUTAE URBES

# THE VOLCANO LETTER

**No. 442 monthly** **Department of the Interior** **National Park Service** **December 1936**

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

The mountainside and a channel hit. Photo, 11th Photo Section, U.S.A.

**THE BOMBING OF MAUNA LOA, 1935***

T. A. Jaggar

Summit crater lava eruptions of Mauna Loa are always followed eventually by a breaking open of the mountain flank and emission of lava there. Mauna Loa crater filled with 100 feet of fresh lava December 2-18, 1933, and on March 26, 1934, the following statements were published: (1) A lava flow is expected within two years; (2) It should come at the north; (3) A likely direction is toward Hilo; (4) Several earthquakes, or one severe earthquake, may happen at Hilo.

Eight earthquakes came, one about every three months, close to equinox and solstice, some of them alarming shocks in Hilo. They occurred throughout the two years, and this relieved the city from any single cataclysm.

The lava flows came on the north side of the mountain, November 21, 1935. The near-summit gushing of fume, from the new rift which ejected the lava, continued into March. The

* Reprinted from the July-August 1936 issue of The Military Engineer, The Mills Building, Washington, D. C.

prolonged flow, which developed a vitreous cover, moved crookedly north, then, on December 22, bent east toward Hilo after pooling in the saddle between Mauna Loa and Mauna Kea. It was about 15 miles long including its meanders, and had 20 miles more to go to reach Hilo.

**Expectancy and Policy for Emergencies**

Apart from earthquake probability, above noted, the Hawaiian Volcano Observatory has experimented with preparation for emergencies for many years. The work is based on statistics and has been useful in many eruptions. Hilo is organized through its police and Red Cross systems, and these have the collaboration of the National Guard and the American Legion. A Conference of the Associated Engineers of Hawaii on January 16, 1918, was advised of the exact facts concerning Hawaiian volcanic blasts and lava flows, earthquakes and tidal waves. A Conference of the Chamber of Commerce, June 9, 1931, was advised of the Napier, New Zealand, unpreparedness. Organizations for discipline, communication, rescue, relief, funds, refugees, and rebuilding were considered.

Hilo understands that it is committed to future lava flows. The Volcanologist in the 1931 address stated: "A vitreous lava, flowing under crust in tunnels, but doing damage on lower mountain slopes, could be blown up at the source tunnel about the 9,000-foot level. This would open the tunnel, dam the lava stream with rocks, and force it to flow anew out of the blocked tunnel and channel over the surface of the upper country by a changed course. If the previous flow took 5 months to get near Hilo, the renewed flow 30 miles up the mountain would require as much, and the city would be given 5 months' respite."

**The Crisis of December 22, 1935**

The map shows the relation of the 1935 flow areas to earlier flows of definite years. The expectancy of a north flow was based on the succession of south flank outflows from 1868 to 1926, moving progressively up the mountain along the southwestern rift belt. The belt crosses the summit. Each flow on cooling seals the rift at its orifices. The next flow after 1933 was expected across the summit, and it so happened.

The expectation that 1935 would be the year was based on average intervals and past history. The expectation of northern earthquakes was based on a southward crossing of the summit in 1868 and southern earthquakes therewith. If there were a northward crossing of the summit now, northern earthquakes might be expected to accompany the rupture of the north rift. The likelihood of advance towards Hilo was based on the precedents of 1852, 1855, and 1881.

Without recounting all the detail of the 1935 eruption, it may be said that the first rapid flows, between November 21 and November 26, from a near-summit source, swept 8 miles northward and stopped. The loss of gas, heat, and energy of emission was very rapid the first day. The clinker slag cools from below upward, releases fixed gases that react exothermally to heat the top surface, and the stirring crystallizes the melt so that solidification is by crystalline frosting or sprouting. The Hawaiian name of this clinker lava is **aa** (pronounced ah-ah). The sprouts break up into boulders during viscous flow.

Beginning November 27, an entirely new flow vent appeared. This was 4,000 feet below the summit and 10 miles northeast from the top of Mauna Loa. An ancient tunnel or fissure was opened underground to drain the central well. From this orifice a new clinker-lava stream poured north toward Mauna Kea, between the 1899 and 1843 flows. The near-summit vent of the first outbreak clogged itself, and became noisy with gas bursts and viscous blobs. Then its lava subsided into the shaft, clouds of yellow smoke puffed up, and sulphur was deposited on the conelet. This upper vent was at about 12,000 feet elevation. The new lower vent was at 9,000 feet.

It was this lower flow that turned towards Hilo on December 22. Before that date there was doubt. The lava pooled in the saddle. It might have drained westward into waste lands, but the 1843 flow blocked it and it turned eastward a mile a day into valuable pastures, steeply sloping into the well-watered drainage of Wailuku River. This is part of the Hilo water supply. By December 26 it had flowed 5 miles of the 20 that would put it into Hilo.

During the month the lava had changed its character from clinker lava to vitreous, or glassy-skinned, lava. This the Hawaiians call **pahoehoe** (pah-hoy-hoy). It is exactly the same chemically as clinker lava, but is totally different physically. With less of stirred "sugaring," the glass may rise to the top of basaltic melt. It forms a gas-tight skin. The gas-making slag then pours onward under a heat-insulating crust of thickening membranes. This is the "ropy lava" of geology. It is silvery, smooth and vesicular, and unlike the clinker type, it cools and solidifies from the surface downward. The skins, ever reforming over bulbous toes which push down the hill, confine the heat and create a mechanism of tunnels. There is a single tunnel near the source, and there are distributary tunnels at the fronts. It is this vitreous-coated lava which may hold its heat and push forward for 40 miles. It is in sensitive equilibrium isothermally to its own evolution of self-heating gas bubbles, to the chill of the air, to the pressure on its pipe walls, and to the source pressure, which is both hydrostatic and effervescent—that is, the lava from inside the mountain is really a glassy foam.

The point of all this is that if the single source tunnel is broken open, a pressure-temperature adjustment of gas-in-slag is destroyed. Not only does this let the higher fluid escape and rob the lower distributary frontal tunnels, but also it lets loose the gas and heat, and solidifies the fluid **back into the source vent.** A lava filled shaft, after a month of violent release, is no longer a resistless mountain-breaker. The weight of the mountain and the cooling have reasserted themselves as dominant.

**The Army Called In**

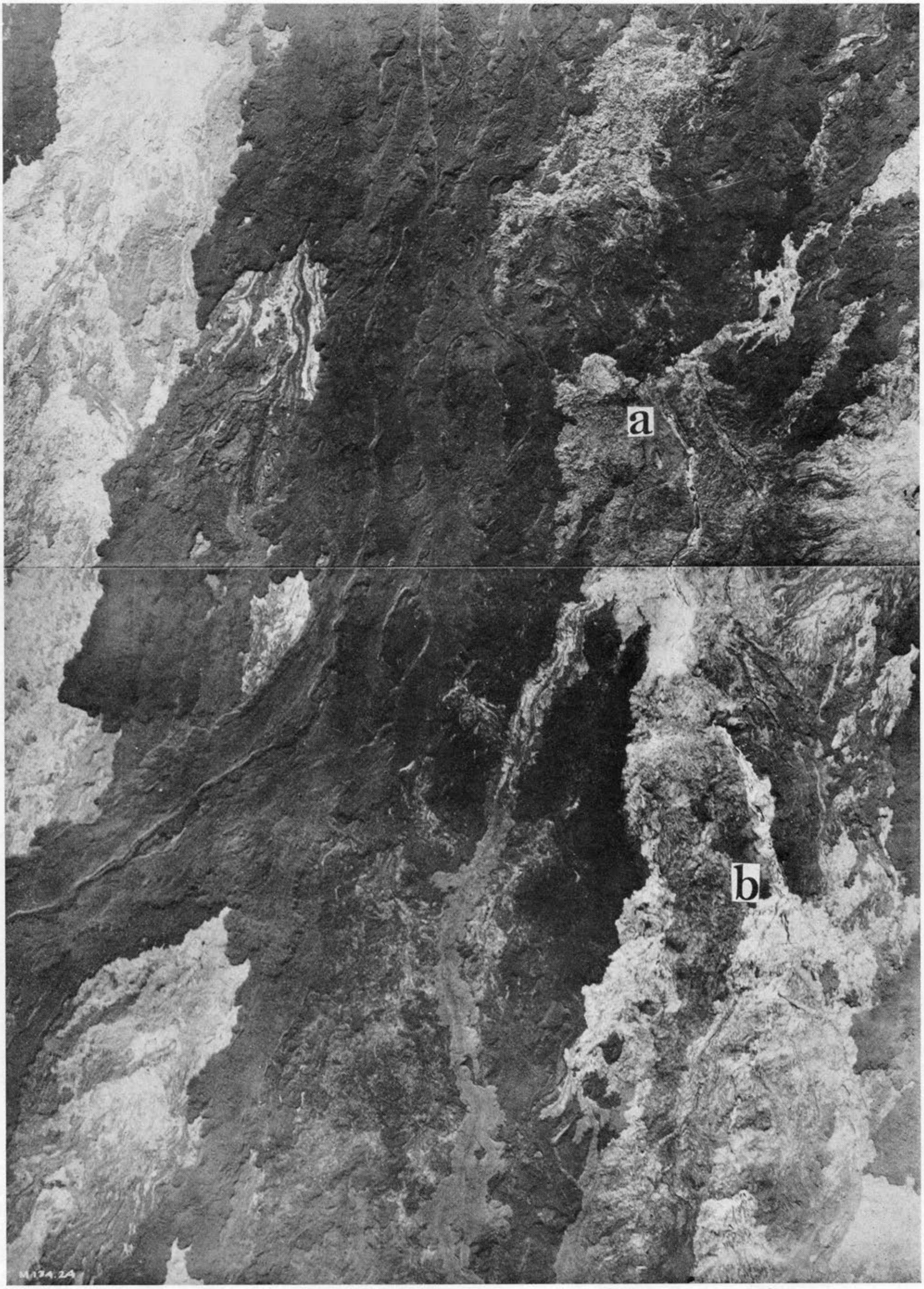
Monday morning, December 23, the Volcanologist, Dr. T. A. Jaggar, consulted Maj. Hugh C. Gilchrist, commanding Kilauea Military Camp. Before that time bombing would have been dangerous, for it might have diverted the flow **toward** Hilo, but now the flow was definitely headed thither. Major Gilchrist sent a radio at once to the Chief of Staff, Col. Daniel Van Voorhis. The Commanding General, Hawaiian Department, sent a plane from Honolulu with three officers of the bombing squadron that afternoon to inspect the lava flow area. At noon the next day a conference was held in Hilo with Col. Delos C. Emmons, Department Air Officer; Lieut. Col. V. L. Peterson, Department Engineer; Capt. J. J. Ladd, bombing officer; Lieut. J. W. Cox, Third Engineers; Lieut. B. J. Webster; Major Gilchrist; Mr. Stanley Elmore, President of Hilo Chamber of Commerce; Superintendent E. G. Wingate of Hawaii National Park; and the Volcanologist.

Col. Delos C. Emmons, Air Officer of the Hawaiian Department, reported that he and Lieut. Col. Virgil L. Peterson, Corps of Engineers, examined the lava flow from the air December 24 and held the conference above recorded with the Volcanologist, and with other officials. They jointly reported:

**a.** That lava flow actually threatened the headwaters of Wailuku River, which provides water to Hilo. There also seemed to be a possibility that this flow might endanger the city of Hilo with its valuable harbor.

**b.** That public opinion demanded that something be done to divert or stop this lava flow.

**c.** We recommend that twenty 600-pound bombs be dropped in an effort to divert the lava flow.




Vertical airplane photo of Target a, the uppermost channel, and Target b, a mile downstream.
Photo, 11th Photo Section, U.S.A.

Dr. Jaggar stated that there was a strong probability that properly directed bombs would help the situation materially; that there was always the possibility in the future of a more serious eruption which might destroy Hilo unless preventive steps were taken, and that it should be found out now whether or not aerial bombs would stop or divert a lava flow. The Secretary of War, during a recent visit, had expressed great interest in the aerial bombing of a lava flow, and Dr. Jaggar had been assured that, if an emergency arose, the Department Commander would assist in protecting life and property threatened by lava.

Aa and pahoehoe lavas of 1935. Jaggar photo.

**The Conduct of Operations**

It was decided, after the Volcanologist had outlined the problem, to conduct the operation December 27. The Army Transport **Royal T. Frank** brought twenty 600-pound TNT bombs; and as many 300-pound pointer bombs were brought by the planes and were charged in Hilo with black powder and sand.

On December 26, the Volcanologist accompanied a group of Bombing Squadron officers over the target in a Douglas amphibian plane in order to point out the area to be bombed. They, in turn, took up other officers later in the day, so that all should be acquainted with the terrain. The Volcanologist recommended that the uppermost channel of the actual flow be bombarded at elevation approximately 8,500 feet on the north flank of Mauna Loa. The channel about a mile down the lava stream was indicated as a second target. This was to be demolished in the event that the upper target had been successfully hit, so that if any liquid still trickled through the tunnel, it would encounter a second obstacle. Both parts of the channel were crusted over, but glimpses of the liquid lava appeared in open parts of the tube where the crust had caved in. By demolishing the tunnel roof, the operation would block the tube with debris, force the liquid within to overflow, cool it and release gas, and thereby rob the tube system farther down the mountain where the front of the flow was being fed with lava through this tunnel.

Special Orders Number 304, December 26, 1935, sent twenty officers and thirty-seven men, including sixteen sergeants and corporals, by air from Luke Field, Honolulu, to the island of Hawaii, in command of Lieut. Col. Asa N. Duncan, Air Corps. They represented the 23d and 72d Bombardment Squadrons, a Signal Corps operator of Headquarters Detachment, four men from Wheeler Field, including photographers of the 11th Photo Section, and one each from the 4th and 50th Observation Squadrons.

The departure for Hilo from Honolulu was at 8:30 a.m., December 26, in ten bombing planes, two observation planes, and two amphibians. Upon arrival at Hilo, work was begun immediately in locating the targets with the aid of the Volcanologist. The Ordnance Department sent two civilian employees to supervise fusing and loading of bombs.

Colonel Duncan's report shows that, in the operation of December 27, the first bombing plane took off at 8:45 a.m. from Hilo and was followed by four others at twenty-minute intervals. Each plane was loaded with two 600-pound demolition bombs, armed with 0.1 second delayed-action fuse, and two 300-pound practice bombs for sighting shots. The bombs were dropped from an altitude of 12,000 feet, approximately 3,500 feet above the target. Two photographic airplanes accompanied the bombers and carried cameras for still and moving pictures. The first mission showed that individual bombing produced good results, so that the salvo method, using five planes in formation, was not used.

**Observation of the Bombing**

Colonel Duncan and staff at Hilo Airport maintained short-wave radio communication with the airplanes; and telephone communication with Dr. Jaggar, the Volcanologist, who had established a station at Puu Oo ranch high up on Mauna Kea mountainside, to observe the bombing. Twenty demolition bombs were dropped between 9:30 a.m. and 3:00 p.m.

From the high post of the Volcanologist at Puu Oo ranch house, elevation 6,300 feet, the front of the flow was seen to be pushing through the valley 4 miles away in the foreground; Hilo airport was discernible with field glasses 23 miles away to the east; and the lava source targets were in full view up the mountain southwest, 12 miles in a bee line. The planes were moaning overhead all day long, and the bombers climbed high, poised, pitched forward, and a gray ball of smoke and dust boiled up from the upper lava channel.

The hits were noted at 9:43 a.m., there was a flash, 60 seconds interval, then a deep boom; at 9:49, a flash and a weak smoke column; at 10:15, a high column and noise after one minute; at 10:18, a soft column and the detonation; at 10:28, a high puff, interval, and booming; at 10:32, the same; and, at 10:59, a double puff, as though two bombs hit together. All the early shots were at the extreme upper tip of the gleaming silvery lava field, narrowing to a point at the source.

After 11 a.m. the lower target, the lava channel a mile below the source, was evidently the goal. One bomb exploded

The great bend of the flow towards Hilo, pahoehoe lava: a tunnel lies underneath. Jaggar photo.

with very deep penetration and heavy concussion in the depths of the incandescent stream, and great sheets of glowing melt shot hundreds of feet into the air, orange red, glistening, and spreading like a fan. When this was seen the Volcanologist knew that the single channel of the upper tunnel could not stand such punishment without damming itself, freezing, and spilling over. That tunnel lay at the bottom of a trench 10 feet wide and 40 feet deep in places; and a 600-pound bomb crater might be blasted 20 feet wide and 5 feet deep in hard rock; hitting a trench of the size noted, it could hardly fail to wreck it. Hitting it in five places directly along the upper mile of its course (the 25 per cent of direct hits reported by Colonel Duncan) might be counted on to block the channels and leave the lower tube system to empty itself and collapse.

Other bombings were observed until 2:37 p.m. and notes were made of the soft black powder explosions, in contrast to the heavy puffs and thunder claps of the demolition shells.

**The Stoppage of the Flow**

The evening of December 28 all motion at the front stopped temporarily. This was a totally new phenomenon, for the preceding week had shown the front making a mile a day; and the front lay on an increasingly steep slope, averaging 157 feet to the mile for the 7 miles of eastward flow from the lake of lava in the saddle.

The bombing thus smashed and dammed the source tunnel, released lava there, and beginning at the noon hour of the


The lava heaps of the flow source; a direct hit near upper source channel target a: and a collapsed tunnel near foreground showing a glowing stream inside. Photo, 11th Photo Section, U.S.A.

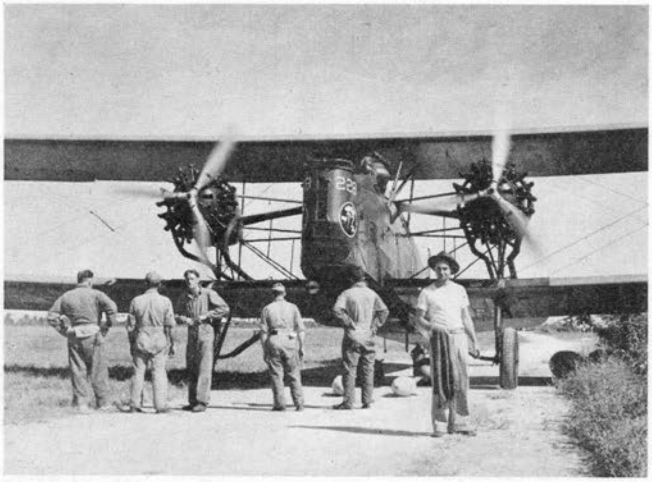
Meanwhile the front of the flow pushed ahead, passing successive tree markers which had been photographed. All day photographs were taken to show the changing progress. At 11:15 a.m. the front of the flow piled itself 30 feet high, entered woods, and sent up clouds of black dust and flames, while explosions of carbon gas made noisy detonations in old caverns. That night, December 27, the flow was more brilliant than ever, for oxygen had been admitted to the tunnel system by its collapse. Up at the bombed area, ten or twelve glow spots were visible where liquid lava was welling up bomb holes. A side branch of smooth lava made out from the main flow below the saddle.

bombing date, the speed of frontal motion was:

| | |
|---|---|
| 12:00 noon December 27 | 800 feet per hour |
| 4:00 p.m. December 27 | 150 feet per hour |
| 10:30 a.m. December 28 | 44 feet per hour |
| 6:00 p.m. December 28 | 0 feet per hour |

The release of liquid lava at the source tunnel was confirmed as follows: December 26 the Volcanologist flew over and could see no liquid on the surface. During the bombing, December 27, the pilots could see liquid in short stretches of collapsed tunnel roof. Next day air inspection showed a rapid glowing stream at the source itself, on the surface of the lava field. On December 31 all motion on the surface had ceased at the source.

This last fact was an unexpected development and was not the end of the eruption. But it was the end of the outflow. The inside eruption was manifest by clouds of sulphurous vapor from internal lava effervescing in the near-summit crater, showing that the well beneath was still charged with liquid;



A bombing plane with the bombs beneath. Maehara photo.

and this continued until March, 1936. An earthquake crisis in that month definitely ended the eruptive period.

That the bombing would end the source outflow was theoretically probable. The direct hits were sufficient in number to blast open the roofed channel and release to the air the vitreous froth called basaltic lava. The equilibrium of self-heating was destroyed and the slag, after spilling over for two days, stiffened, slowed down, and solidified into the source vent. Pilots who flew over on the second and third days after the shelling reported that the released liquid stream at the source had stopped.

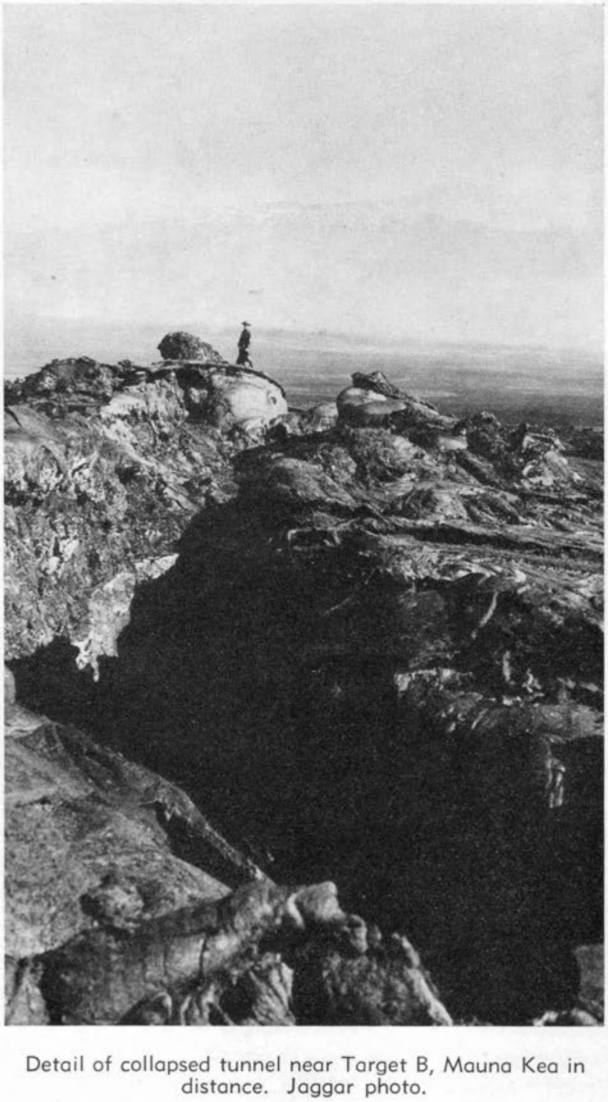
The remainder of the activity of frontal flowing towards Hilo was a spilling of remnant lava from the tunnels and streamways. This was partly over the sides of the lava fields, partly lengthening of the front. There was a notable sudden gushing out of clinker lava at the front on December 30 for 1,000 feet. The final tongues became narrower, and one of these slightly passed the Forest Reserve fence east of Puu Oo ranch January 1 at 11 a.m. The last motion of the tip of this finger, only 100 yards wide, was at 2 a.m., January 2. The position of this final front was in the drainage basin, 8 miles east of the saddle, and 12 miles short of the Kaumana Road in Hilo. The total movement forward after the bombing was 1 mile in 6 days. If the flow rate of the Christmas season had continued, the front would have been in Hilo on January 9.

The following is quoted from a report of the operation: "After the bombing was completed, a reconnaissance was made of the shelled area. It was found that five bombs hit the stream itself, three in the flowing lava of the first target (source stream), and two directly above the tube of molten lava of the second target (one mile downhill). One of these caved in the tunnel and the other failed to penetrate. Three other craters were within 5 feet of the stream, the explosion throwing debris into the red lava. Two others were within 20 feet of the target. From the sensing of the pilots, seven other bombs fell within 50 feet of the stream. Those who witnessed the bombing declare that the execution of the mission was superb; that the bombs had been placed exactly where they should have been; and that this aerial bombing of a lava flow made history for science in performing a great geological experiment which was a success. From a military viewpoint of the bombing, Colonel Emmons says: 'Very valuable tactical training was received as a result of this mission, well worth the cost. Excellent co-operation was received from the Quartermaster Depot, the Ordnance Depot, and the commanding officer, Kilauea Military Camp'."

Hilo Chamber of Commerce furnishes the following minimum approximation of values, apart from life, good-will and natural assets like the harbor:

| | |
|---|---|
| Sewers | $ 1,200,000 |
| Streets | 2,125,000 |
| Schools and churches | 2,883,804 |
| Water supply | 1,000,000 |
| Piers, breakwater, dredging | 7,500,000 |
| Taxable land | 10,387,824 |
| Taxable improvements | 12,408,300 |
| Territorial property | 2,224,395 |
| Federal property | 350,000 |
| Personal property, growing crops, etc. | 11,000,000 |
| | $51,079,323 |

Supposing that the flying, transportation, ammunition, and payroll cost $25,000, the operation of December 27 appears to have been more than justified. An experiment pouring



Detail of collapsed tunnel near Target B, Mauna Kea in distance. Jaggar photo.

liquid clay on a scale model of Hawaii showed that this flow would have extended itself down Wailuku Canyon so as completely to fill Hilo breakwater and wipe out the second harbor of the Territory. Just such a flow in 1859 extended the land at Kiholo. As there will be more flows on the Hilo side, the bombing experiment has furnished a new weapon to civilization.

The Volcano Observatory at Kilauea was founded in 1911 by the Whitney Fund of the Massachusetts Institute of Technology with the words: "To be conducted with a view to protection of human life and property." That responsibility was accepted by the Hawaiian Volcano Research Association and the National Park Service. The 1934 address announced that "Mauna Loa has definitely mobilized and declared war, there is every appeal for an intellectual and practical victory over Nature, and a program can be laid down whereby our engineers and aviators and bombers will rejoice at the opportunity to show their prowess." All honor to the Army for an excellent peace-time achievement.

# Hawaiian Volcano Observatory Report for December 1936

## VOLCANOLOGY

The coming of December, and the elapse of a year since the last outbreak of the Mauna Loa-Kilauea system, are both reasons for expecting return of lava to Halemaumau. The winter solstice has produced more eruptions here than any other season. And the average of intervals has been one year. But nothing happened in December 1936 except a sudden quietness the last week of the month. This may mean uplift under Kilauea crater, following the slumping that caused the October avalanches.

All the movements were fewer than in November, as shown (see Volcano Letter 441) by the following tabulation, that indicates by weeks the local seismicity, the counted number of slides in Halemaumau pit when it was under routine observation, the amount of aggregate opening of marked rim cracks at Halemaumau by weeks, and the seimograph count of local tremors and quakes:

| Week Ending | Seismicity | Slides | Cracks | Quakes |
|---|---|---|---|---|
| December 6 | 5.00 | 1 | 6.0 mm. | 12 |
| December 13 | 8.75 | 0 | 6.0 mm. | 13 |
| December 20 | 7.75 | 2 | 5.0 mm. | 25 |
| December 27 | 12.75 | 1 | 2.5 mm. | 33 |
| January 3 | 0.50 | 0 | 0.0 mm. | 2 |

### Sequence of Events by Weeks

The first week the pit was generally quiet, and the second week showed no slides at all, and remarkable constancy.

The third week slightly increased seismic motion and dust from a few slides. The shocks were mostly from Kilauea.

The fourth week tremors increased, and fume from the NW floor solfatara was notable.

The new year opened with unparalleled quiet, no slides, very slight crack movements, and seismic activity confined to two tremors in seven days.

### Slides at Halemaumau

Slides from the wall of the Pit have been noted as follows, mostly from a distance, or at type periods of visitation:

December 6, 4:10 p.m., small dust clouds east edge.

December 17, 11:00 a.m., dust at NE wall, and scar from a recent slide there.

December 27, 4:00 p.m., dribbling of small rocks down NE wall.

### Measurement of Halemaumau Rim Cracks

Weekly measurement of 26 rim crack locations resulted as follows:

Week ending forenoon of:

December 5, 10 opened, 0 closed, aggregate opening 6.0 mm.

December 12, 7 opened, 4 closed, aggregate opening 6.0 mm.

December 19, 11 opened, 4 closed, aggregate opening 5.0 mm.

December 26, 7 opened, 2 closed, aggregate opening 2.5 mm.

January 3, 4 opened, 2 closed, aggregate change 0.0 mm.

It is of interest as showing consistency among the subjects selected for measurement after years of experience at the Observatory, that crack widening, numbers of quakes, intensity of quakes, and number of slides all dwindled simultaneously the last week. This shows Halemaumau to be an index vent for all Hawaii, as some of the usual earthquakes originate under other parts of the Island, and those regions also were quiet the last week of the year. It would seem also, with seismicity suddenly lowering along with crater values, that all the island seismicity is clearly volcanic. T. A. J.

## SEISMOLOGICAL DATA

### EARTHQUAKES

| Week Ending | Minutes of Tremor | Very Feeble Earthquakes | Distant† Earthquakes | Local* Seismicity |
|---|---|---|---|---|
| December 6 | 14 | 3 | 0 | 5.00 |
| December 13 | 31 | 2 | 1 | 8.75 |
| December 20 | 19 | 6 | 0 | 7.75 |
| December 27 | 47 | 2 | 1 | 12.75 |
| January 3 | 2 | 0 | 1 | 0.50 |

† Includes teleseisms or those shocks over 5000 kilometers distant.

* For local seismicity definition see Volcano Letter 371.

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory on the Island of Hawaii. Kilauea earthquakes were located by means of the main seismograph station at the Observatory and the two subsidiary stations at Uwekahuna Museum and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from stations at Hilo and Kealakekua. The disturbances began recording at the times indicated and whenever possible, determinations of depths of focus have been made.

December 3, 11:17 pm, very feeble, located under SE rim of Kilauea Crater adjacent to Keanakakoi Crater and 1.5 miles deep. 19° 24' 4N; 155° 16' 2W.

December 4, 12:11 am, very feeble, located under N rim of Kilauea Crater 0.3 mile SW of Kilauea Military Camp and 2.0 miles deep. 19° 26' 1N; 155° 16' 7W.

December 11, 7:20 pm, very feeble, probably located under SE portion of Kilauea Crater.

December 16, 3:05 am, very feeble, located 0.7 mile NW of Ahua Kamukokulau S of Kilauea Crater and 0.8 mile deep. 19° 23' 4N; 155° 16' 6W.

December 16, 10:20 am, very feeble, located 1.1 miles SE of Pit Seismograph and 5.0 miles deep. 19° 23' 6N; 155° 16' 4W.

December 17, 5:52 pm, very feeble, located deep under SE slope of Mauna Loa. 19° 19' 0N; 155° 33' 2W. Reported felt at Hookena.

December 18, 3:22 pm, very feeble, probably located in SE portion of Kilauea Crater.

December 19, 5:56 am, very feeble, of Kilauea origin.

December 27, 12:06 am, very feeble, located deep under Kilauea SW Rift 5.0 miles SW of the Volcano Observatory. 19° 22' 0N; 155° 14' 5W.

Periods of continuous (harmonic) tremor registered on the Observatory seismograph as follows: beginning at 12:04 pm, December 1, six (6) minutes; 9:11 pm, December 13, twenty-one (21) minutes and 4:24 pm, December 26, seventeen (17) minutes.

Microseismic motion of the ground at Kilauea was light December 2, 3, and 5; moderate November 30 and December 1, 4, 6, 7 and strong the remainder of the month.

Registration of Distant Earthquakes at the Observatory was as follows: December 13, the preliminary waves at 11h 10m 37s am, HST, with 3020 miles as the distance of focus from Kilauea; probable location in the Kamchatka Peninsula as reported by newspapers. At 8h 50m 37s am, HST, December 21, the surface waves of a teleseism began recording. Its distance was undetermined. At 4h 27m 40s am, HST, December 29, the preliminary waves of a teleseism began recording. Its location was 3550 miles from Kilauea.

## TILTING OF THE GROUND

The following tables show tilt by weeks as recorded by the Observatory seismograph, NE rim of Kilauea Crater and at Halemaumau the algebraic sum of radial tilts for two clinoscope stations towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending January 3, 1937, was 3.60″ N and 0.24″ W.

**Table of Tilt**

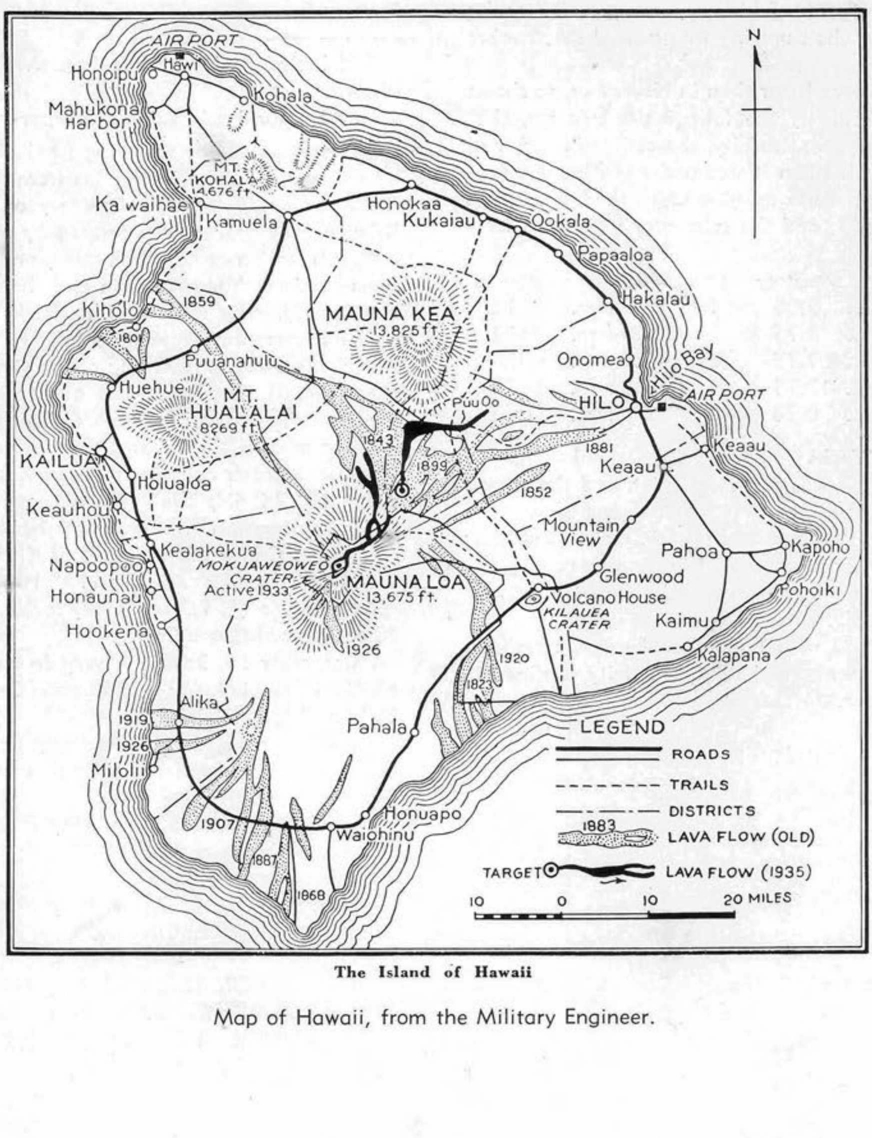
| Week Ending | Observatory | Halemaumau West Station |
|---|---|---|
| December 6 | 0.62″ S 78° E | 3.19″ N 57° W |
| December 13 | 1.10″ N 43° E | 2.15″ S 65° W |
| December 20 | 0.74″ N 38° W | 9.86″ W |
| December 27 | 1.05″ S 33° W | 3.75″ S 61° W |
| January 3 | 1.18″ S 02° E | 5.13″ N 64° W |

| Week Ending | Halemaumau Southeast Station | Halemaumau Resultant |
|---|---|---|
| December 6 | 3.79″ N 11° E | 0.26″ from |
| December 13 | 1.46″ N 34° W | 0.63″ from |
| December 20 | 2.20″ N 61° W | 7.75″ from |
| December 27 | 3.11″ S 21° W | 5.05″ from |
| January 3 | 5.61″ S 81° W | 2.04″ from |

**Crater Angles**

Measurement of Horizontal Angles across Kilauea Crater from the Observatory, December 26, showed a closing of the Halemaumau value and an opening of the crater value compared with similar measurements made November 23. From Kilauea SE rim to Uwekahuna there was opening 0.42″ November 23 to December 11 and closing of 0.08″ December 11 to December 26. Total opening 0.34″. From the Pit Seismograph to the NW Pit B.M. there was a closing of 0.84″ November 23 to December 11 and closing of 1.16″ December 11 to 26. Total closing 2.00″.

H. H. W.




The Island of Hawaii

Map of Hawaii, from the Military Engineer.