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

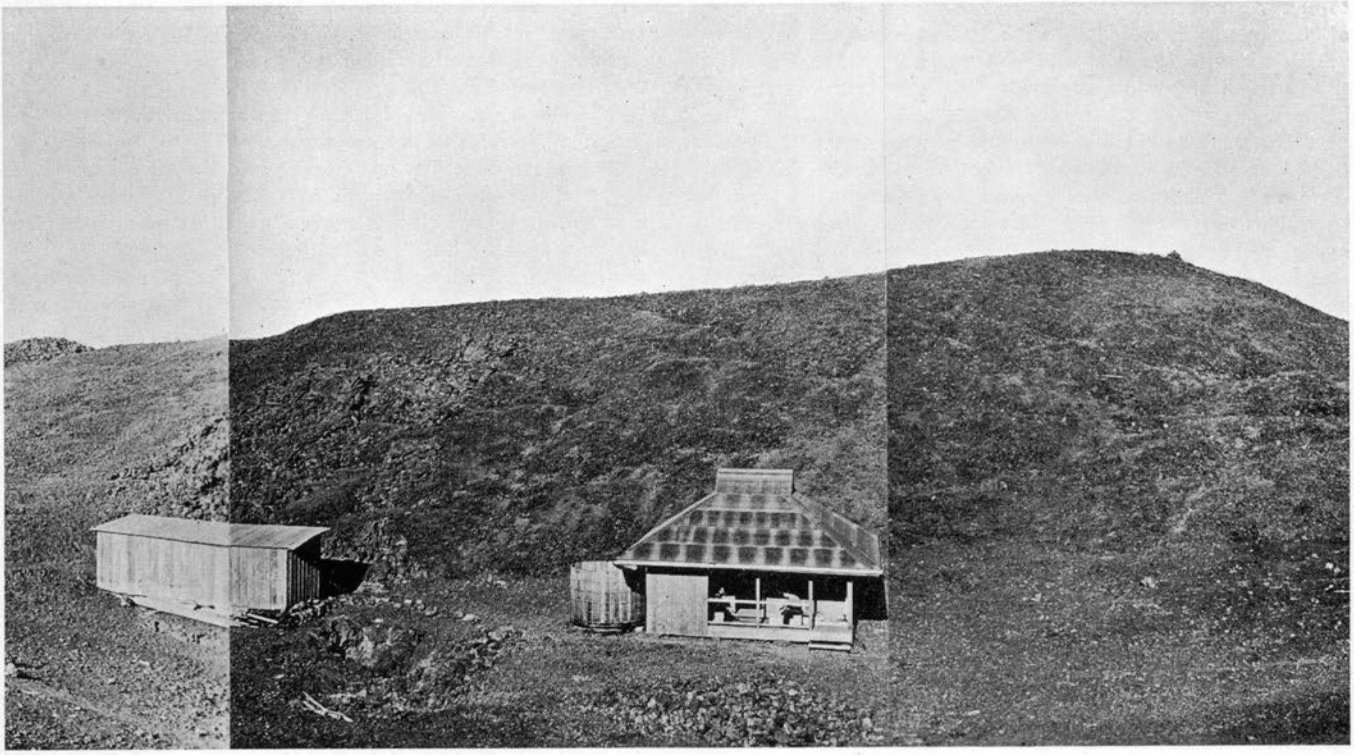
April 2023

THE VOLCANO LETTER

No. 443 monthly **Department of the Interior** **National Park Service** **January 1937**

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Red Hill, at 10,000 Feet Northeast Rift of Mauna Loa, with Resthouse and Stable

PROTECTION OF HILO FROM COMING LAVA FLOWS*

By T. A. Jaggar

Observatory Plans 1936

The following paragraphs are from the special report of December, 1936, from the Volcanologist to the Superintendent of Hawaii National Park. They concern, not a new and sudden alarm, but a serious project for safeguarding the industries of Hawaii from the lava flows of Mauna Loa. It has long been the intention of the Hawaiian Volcano Research Association to make Mauna Loa its principal center of study, and the time has come to do this.

"It is just one year since the Mauna Loa Flow of 1935, which seriously threatened Hilo, and ceased flowing in sequence upon artificial bombing. The law of cycle recurrence on Mauna Loa for 101 years is one crater outbreak every three and a third years, and one lava flow every six years. The north rift is open and smoking, and the next outbreak may threaten Hilo again, by analogy with nineteenth century sequences.

"The National Park with CCC labor has finished nine and nine-tenths miles of truck roadway up Mauna Loa east slope, going WNW from Bird Park. The resources of volcano research should be brought to bear on the engineering problem of protecting Hilo with the planning aided by 1935 experience. In like manner the 1933 crater eruption of Mauna Loa furnished data for forecasting the 1935 outflow of lava.

"There are four issues involved, namely: more Park land on Mauna Loa, an embankment to deflect lava flows near the source, other embankments lower down, and a survey of the rift land. Discussion of the project has the approval of the park superintendent, and is on the initiative of the Hawaiian Volcano Research Association.

"The embankment proposed is entirely distinct from the

* Address delivered at Annual Meeting of Chamber of Commerce of Hilo, Hawaii, January 19, 1937.

bombing method. The latter is a last resort measure, intended for lava flows of the tunnel-flowing variety called 'pahoehoe,' which appear in late stages of an eruption. The embankment-deflection is for the early and most dangerous liquid stage of an eruption, lava called 'aa,' which we saw naturally deflected November 22, 1935, by old lava banks. There is abundant loose rock on Mauna Loa for construction. There is no question but that an artificial embankment aligned downhill oblique to flowing slag would deflect it. A lava flow fills as a liquid. It does not push as a solid.

"The source belt, a mile wide, is a series of definite cracks trending N 70 deg. E from the summit crater for eleven miles. The distance to Hilo in the same direction is 35 miles. The divide between Puu Kipu, and Puu Ulaula called 'Red Hill,' is the parting line between old Hilo flows and southward flows, and the line trends N 85 deg. E.

"An embankment from Red Hill N 20 deg. W, five miles long, would steer any flows such as 1855, 1880, and 1899 to safety. An embankment north and south, with Puu Huluhulu of Humuula in its middle, about a half mile in each direction, would hold the flow pool steered into the Humuula lands by the Red Hill embankment, and send it west from the saddle between Mauna Loa and Mauna Kea.

"The short Puu Huluhulu embankment would be about 20 feet high; and the Red Hill embankment, oblique to the flows down a steep slope, need be only about 15 feet high.

"With reference to a line survey of the proposed embankments, and an aerial photographic mosaic of the entire northeast flow belt from the rift to Hilo, General Drum has expressed approval of the project.

"There the matter stands at the end of 1936. The volcanologist recommends that the establishment of Observatory volcanologic work on Mauna Loa at Red Hill shall be the main purpose of 1937 plans of the Hawaiian Volcano Observatory. The founding of Mauna Loa seismological measurement, and rift patrol, appear essential to the safety of the community."

Motive of the Work Proposed

From a small village threatened by numerous lava flows, with upper land destroyed by two of them, and the main water source invaded by three of them, Hilo has grown to a city, a port, and an airport.

These things have been improved at great expense from time to time, and the population has grown from a few hundred to 20,000 people. The harbor dredging and breakwater, the airport, wharfs and real estate will all be improved much more, and the adjacent plantations in health, labor, insect control, transport, agronomy, water supply, and milling are models of scientific advance in aggressiveness and in defense against evils. Hilo is their harbor.

The shadow of the lava menace is just as removable as the shadow of malaria, tuberculosis or yellow fever, the noxious mosquitoes, the leaf hopper, or the plague fleas and rats. It merely never occurred to anyone to remove it.

There is just one way to do this, and that is to face the exact facts, and then act with decision and unanimity at this present time of Government employment of labor. Remove the lava shadow, and watch Hilo go ahead by leaps and bounds.

Expectable Intervals and Flow Sources

Using the data of the 1934 article (Volcano Letter, October, 1936) for the history of Mauna Loa flows, the average of Mauna Loa eruptions is one summit outbreak every three and a third years between 1832 and 1933, and one flank outflow every six years.

There were six Mauna Loa eruptions between 1914 and 1935, making present average three and a half years. There were four flank flows, making outflow average 5.5 years. Thus the twentieth century holds up the general average.

The succession of newly opened vents since 1868 was from elevation 3,500 feet that year at the southern end of the Mauna Loa rift, progressively up the rift to 13,000 feet in 1926, 13,150 feet inside the crater in 1933; and 12,000 feet in 1935, on the northern extension of the rift down the Hilo slope.

This was approximately five miles north of the 1933 eruption, and if the next flank outflow comes out five miles farther north, the place will be a half-mile above Red Hill, close to the source of the 1881 flow, which entered the city of Hilo.

It should not be understood that the next eruption of Mauna Loa will be a flank outflow. Furthermore it may not come in three and a half years; that figure is merely an average. It may come in the summit crater or on some other flank, as alternations between the two sides of the mountain are common.

We know, however, that fume and steam are rising, that the ground is hot, and that sulphur is depositing at the line of source cracks of 1935. That means that the north rift of Mauna Loa in the Hilo direction is open and ready for action which was not the case between 1900 and 1926, when all the outflows were from the south rift.

Eruptions Now Expectable

On the basis, then, of the same historical data that the Hawaiian Volcano Observatory collected for the argument of 1934, we can state that a succession of eruptions is expectable now from the Hilo rift, some of them making outflows down the northeastern flank of the mountain, at intervals averaging three and a half years for all eruptions.

A change began with the great series of bad northern earthquakes of 1929, whereby the northern rifts were opened and the southern ones were closed.

The historical flow sources of the northern rifts may be thought of as lying in a semicircle around the north side of Mauna Loa all the way from Huehue to Nanawale, making a set of radial fractures from the summit of Mauna Loa northwest, north, northeast and east, the northwestern one being the Hualalai rift, and the eastern one the Kilauea rift.

The Huehue Flow at the west poured into the sea from elevation 2,000 feet in 1801, and the Nanawale Flow at the east poured into the sea from elevation 650 feet in 1840. Note what low sources are possible.

It is fortunate for Hilo that the northeast rift bends eastward at elevation 8,000 feet; and we have no historic record of a flow source, of Hilo flows, lower than 8,424 feet, at the head of the 1852 flow. But there were many pre-historic ones that formed the entire south side of Hilo bay, when the ancient shore line extended from Waiakea Kai to Olaa Mill. The range of speeds of sudden aa flows has been 1 to 20 miles a day.

The Lava Cycles of the Nineteenth Century

There is good evidence in recent history for eleven year cycles, 1903-1913, 1914-1924, 1925-1935. These include both Mauna Loa and Kilauea, each with at least two eruptions Mauna Loa; Kilauea pit variously spouting, fluctuating, or rising, and the lava as a whole effervescing strongly and sinking at the end of the cycle.

The cycle is terminated by a very quiet year or years. The quiet years were 1913, 1925, and 1936; we are now approaching the end of the 1936 lull. The distinctive character of this 1936-1937 repose period, leading to an assumed 1936-1946 cycle, is that it is the first repose period following Kau flows and leading to Hilo flows, since 1840.

Leaving aside theories about cycles for 1840, as structural resistance to breaking is the real control, the significant feature of that year, with reference to the structure of the island, was that it made an outflow into the ocean from the eastern Kilauea rift, and it followed southern outflows from both Kilauea and Mauna Loa of 1823 and 1832. A characteristic of 1840 was that it was followed in the next cycle by two northern outflows of Mauna Loa, 1843 and 1852, both beginning just where our 1935 eruption began.

Disregarding intervals, as structural sequence is more important and comparing 1924 with 1840, we had the eastern Kilauea rift erupting 1922 to 1924, following after southern outflows from both Mauna Loa and Kilauea, respectively, 1916, 1919, and 1920. This was very much like the sequence 1823 to 1840.

The parallel is made still more remarkable by the fact that the 1916-1924 sequence of southern and eastern outflows for the whole island has been followed in 1935 by an outbreak at the north in the same place as the eruption of 1843 from Mauna Loa, with the flow in very nearly the same volume and filling the saddle between Mauna Kea and Mauna Loa in just the same way.

This parallelism to the first half of the nineteenth century leads one to suspect that the unrecorded period of Mauna Loa activity preceding 1932 produced flows in Kau just as did the twentieth century period preceding 1935.

We know that the middle of the nineteenth century, beginning with 1843 and continuing to 1881, produced a tremendous volume of flows to the north from Mauna Loa, those of 1852, 1855, and 1881 ending progressively closer and closer to Hilo; 1855 and 1881 might have been successfully bombed.

Add to these 1935, straight down the Wailuku River valley, which if it had not been bombed might have filled Hilo harbor, and we find indication that the threat to Hilo is increasing. We now in 1937 find ourselves with the island structure broken wide open for a succession of lava flows historically similar to the series 1852-1881.

Early Series

That series was 1849 at the summit crater; 1851 west of the summit for 10 miles towards Kona; 1852 from the northeast end of the Hilo rift for 15 miles in 20 days straight toward the city, ending 11 miles from the Federal building.

1855 started at the northeast rift farther west than 1852, and travelled 25 miles for 15 months in a curved course to the Wailuku drainage, ending seven miles from the city.

1859 started at elevation 11,000 feet northwest of Mauna Loa summit, and travelled for seven months 38 miles into the sea at Kiholo Bay. There it filled the northeastern half of the bay making new land two miles along shore and a mile out to sea. Its first gushing of aa reached the sea in seven days at Wainanalii.

The next north flow was 1881 starting in the northeast rift and travelling 29 miles for nine months towards Hilo, with a side branch at first to Kapapala that flowed ten miles in a day. It stopped one mile from the city center.

The Fortification of a Harbor

The first flows are always very liquid aa. They travel far in a few days, and are the most dangerous to property if they get into industrial lands. For such flows bombing would be wasteful and useless.

It was this kind of flowing which destroyed Bosco tre Case on Vesuvius in 1906, and also Mascali, a large town of 7,000 inhabitants, on the railroad east of Etna in 1928. In either of these cases it would have been possible to fortify the town, if suitable earthworks oblique to the course of an expected lava flow had been erected in advance, at a site selected to divert such a flow into a valley leading to agricultural or forest lands.

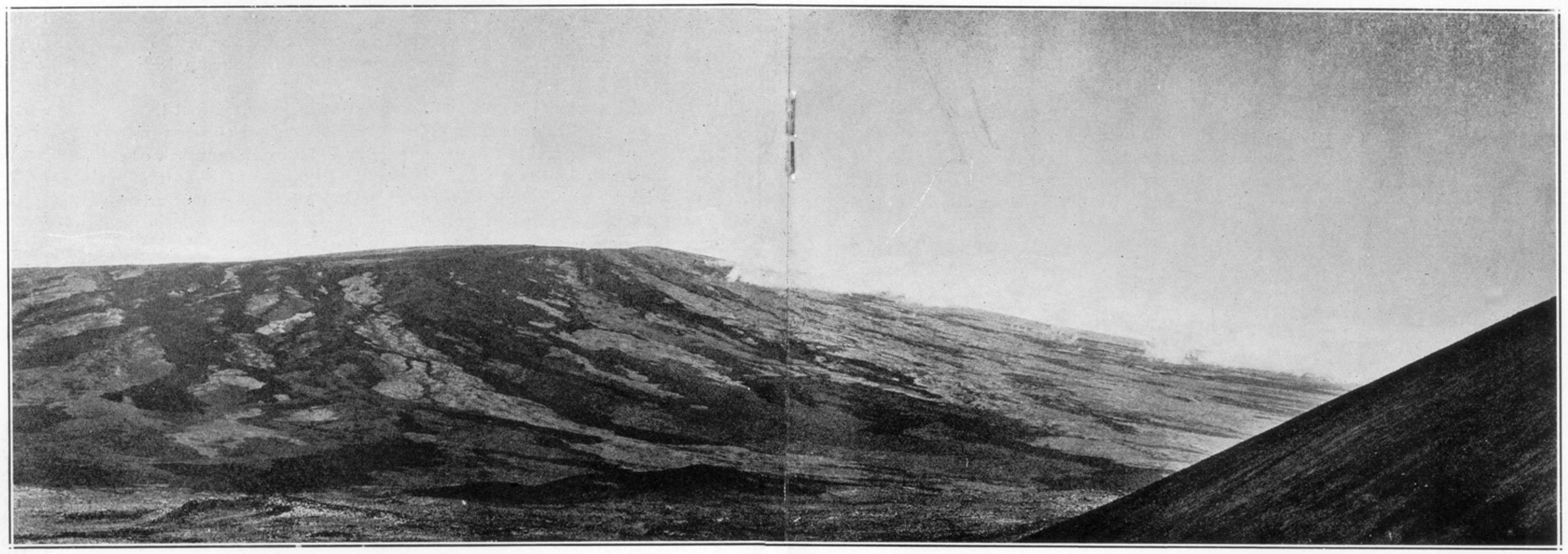
Rapid Lava Flow Pouring Into Ocean Destroying Hoopuloa Village in 1926

In neither of these cases was any harbor involved. A harbor is a national asset, it usually lies where a valley emerges on the ocean, and if a mass of new rock, a mile seaward and miles long, fills a developed port, the calamity cannot be reckoned in money. A harbor is vastly more valuable as a natural feature than all the millions spent on houses, roads, sewers, and public utilities.

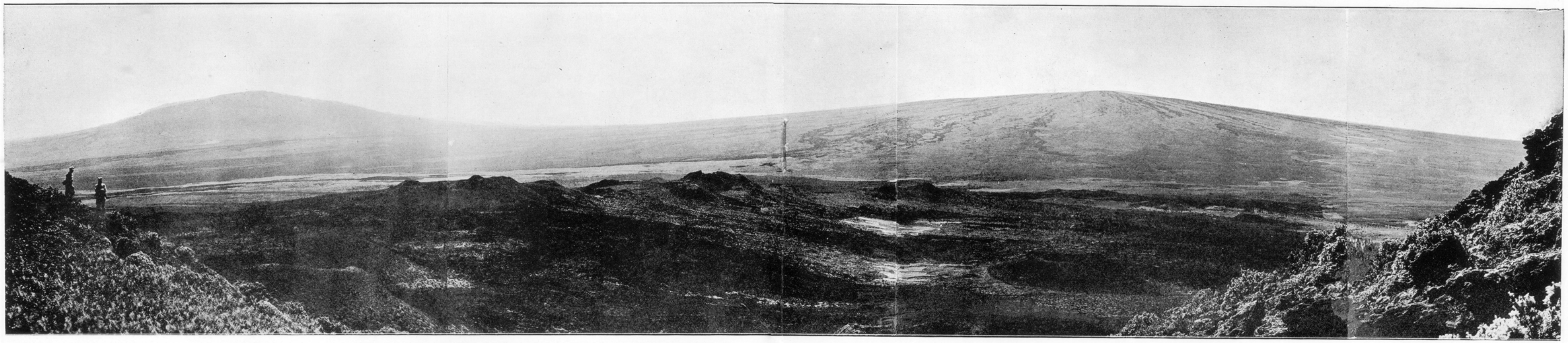
The Situation of Hilo

Hilo lies at the meeting place of three valleys all straight below the dangerous end of the Red Hill rift of Mauna Loa. These we may call the Wailuku Valley, the Kaumana Valley, and the Waiakea Valley. The first is the contact of lava flows against Mauna Kea drainage. The other two are seepage remnants of buried valleys on the east slope of Mauna Loa.

All three would lead a new rapid lava flow straight into the harbor. The distance is only 20 miles from the nearest possible lava source, Puu Kipu at Helipo Camp. Puu Kipu is right in the line of the east bend of the live rift. An existing heavy aa flow from it in the forest extends half way to Hilo.



North Face of Mauna Loa Volcano, Showing Net of Lava Flows Mutually Deflected; the Area of the Red Hill and Humuula Barriers



Mauna Loa (right) from Hualalai, Showing the Hualalai Rift Belt Line of Cones in Foreground: Behind Them aa Lava of 1859 (dark), and Pahoehoe Lava (light).

A new flow on its north side would sweep about 24 miles to Waiakea Fishpond, and at the rate of the 1859 flow would reach the sea in five days.

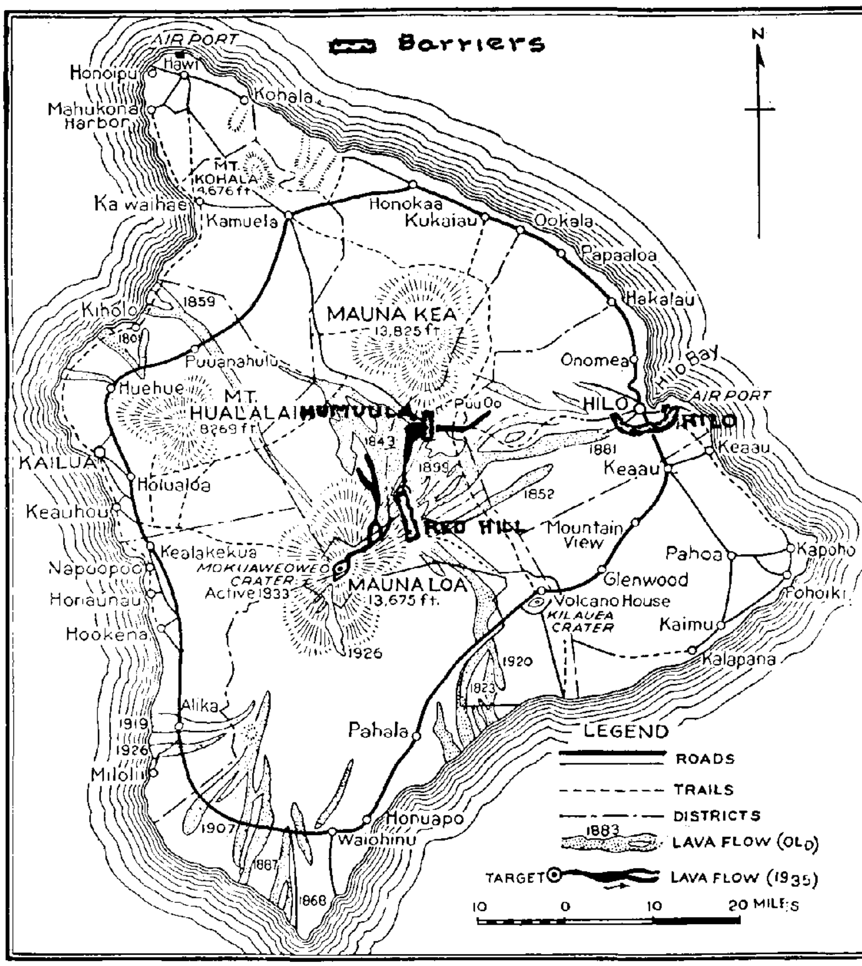
A flow from the 1852 source at the same rate would travel 26 miles, take six days, follow the southeast side of the 1881 flow and Alenaio stream, and enter the sea at Mooheau Park.

A flow from an old cone at elevation 8,750 feet 2¾ miles north of Red Hill, at the same rate, would flow 27 miles between the 1881 and 1855 flows, reach the Wailuku River by Kahoama stream and the gorge above Waiale Falls, pass Piihonua and reach the railway bridge over the Wailuku River in something like six days.

All these distances are shorter than the 1859 flow, which travelled 38 miles in seven days from a point 11,000 feet up.

There are three elements in the Hilo problem. One is to steer lava flows with obstacles, near their sources, into safe places like Humuula while they are liquid. The second is to build an obstacle at the Humuula pass that will protect Hilo's water supply. The third is to build a final protection for the harbor in Hilo itself in case of (1) an unexpected low vent or orifice in the mountain; (2) a vent too far east for the obstacles constructed; (3) the failure of all upper obstacles.

The first two obstacles have been mentioned in the preamble. One is the Red Hill embankment, which, along with natural features, will extend about five miles N 20 deg. W from near Red Hill, will steer such flows at 1855, 1881 and 1899 to Humuula, will be about 15 feet high down a relatively steep slope, and may take 300 men two years to finish.



Map of Hawaii 1937, Showing Proposed Barriers Exaggerated

If the 1859 flow had come out at Puu Kipu with the same energy, it probably would have done the 24 miles to Hilo Bay in four days and piled up the material of its remaining 14 miles of first gushing in Hilo breakwaster. The breakwater would probably hold it and tongues of aa like the Laupahoehoe flat would spread out in a leaf delta to the north of Hilo harbor, after the harbor was transformed into the same kind of land as Keaukaha.

Defense of Hilo

The foregoing is a legitimate picture of what we have to fortify against. Fortification in war consists of two elements, protection and obstacle. Lava flows are the enemy. Protection will shield Hilo from a lava flow when it comes. Obstacle will prevent the lava flow from coming to close quarters if possible.

This is partially prepared for by the CCC camp at Hawaii National Park, which has built 9 9/10 miles of truck roadway up Mauna Loa, and has about eight miles more to go to reach Red Hill. The work of laying a 15-foot bank down natural grade, with double track for dump trucks on top, and using loose aa blocks, without much grading and almost no cutting, taking advantage of natural spurs, is simpler than building a road. It will be necessary to extend the present road as a rough track as fast as possible to Red Hill. A volcano observatory will be established there this year.

At Puu Huluhulu, the forested hill in front of Humuula sheep station, a bank 20 feet high will be built north against Mauna Kea about a half mile long. A similar one will be built south against Mauna Loa for the same distance until its top is at grade. These, with the hill, will be at a height where a lava pool in the saddle will spill west over the top of the 1843 flow. The Red Hill bank will steer flows near the 1935 and 1843 flows. Such flows will pool in the saddle and spill west. The combined obstacles will protect the projected Kaumana-Kona road, the water supply of Wailuku River, and stave off 80% of expectable flows, including a low northern or Humuula vent. This steers flows to Keamuku, not to Puuwaawaa.

The Puu Huluhulu bank is prepared for by the improvement in the Humuula road made by the Pohakuloa CCC camp, and by the camp itself as a nucleus for labor, and as a shelter for laborers. The work will take a year, with perhaps 200 men.

The Hilo Causeway, or Lava Guard

At first it was thought that to construct a fortress against lava attack in Hilo would be impossible. So it would be if we threw up earthworks in a wide circle around the outer city limits. But a study of the topographic map has revealed a strategic line for a Hilo Causeway, or Lava Guard Embankment, which will not be excessively expensive, and may be used (1) as a parkway drive, (2) for possible impounding of water, (3) as a cross-connection for existing roads and (4) as a possible start for the Kaumana-Kona driveway.

As no lava flow on a slope is likely to be more than 12 feet high here, this embankment will average 18 feet in height, being higher where it has to cross low ground. It will start at Wailuku valley above Piihonua over the head of Waiale Falls, with a culvert or arch for the river. This is above the big Mauna Kea tributaries, so that it will not get maximum floods. The culvert construction will have to provide a steel gate capable of closing the arch to small dimensions in case of lava flow.

The line will start about South 70 deg. East for a mile from the river and then run east; the grade downhill to Lanikaula Street is 200 feet to the mile, and obliquely crosses all the valleys. The bank will cross only the Kaumana and Volcano roads, and will make a smooth curve northeast before reaching the railway near the quarries. It will then cross the railway fork, may be lowered to 15 feet, and carry far enough on the Keaukaha spur to guard the harbor as far as Keokea Point.

The roads and railways will pass under bridges in the embankment, and there also the uphill face of the causeway will hold rolling steel gates inclined at the natural slope of the bank. These will be kept rolled to one side. Remember that the lands outside the guard are protected by the upper two obstacles.

The total length of the Lava Guard will be seven miles to the top of the Keaukaha spur. The fundamental object of the guard is to protect Hilo and Hilo harbor, the second harbor of the Territory. If everything fails in the upper obstacles, if the water of one or the other valleys were buried, Hilo could still find water. But if a quick flow comes into Hilo itself and the harbor, there will be no motive left to find any water. There will be no Hilo. Remember what we watched as the 1926 flow swallowed Hoopuloa.

The Lava Guard will require heavy quarrying on the uphill side of the bank, the places being chosen to create a channel across obstacles.

I estimate roughly the Hilo job will occupy two years, and give work to 600 men.

The costs for the three jobs may be:

Red Hill	$300,000
Humuula	100,000
Hilo	400,000
Total	$800,000

If any of these embankments has a lava flow piled up against it, it will be more an obstacle than ever, strengthened for its work.

The Hilo Causeway will be the Hindenburg Line, the final protection. It should be begun first and it is most important. It is near labor and a base of supplies and subsistence. On that account it is much easier than the Red Hill job. The first thing to do is to run the line surveys. The second is for all organizations to pull together to get all three jobs done, for they completely interlock.

The Parallel With Kiholo Bay

In 1800 the Kaupulehu Flow poured from Hualalai into the south end of Kiholo Bay. It filled three miles of shoreline, and out to sea one mile. In 1859 the flow from Mauna Loa poured into the north end of Kiholo Bay. It filled the harbor a mile out, along two miles of shoreline.

The Puuwaawaa valley may well have been like the Hilo valleys centuries ago, ending in a deep indentation. Here were only 60 years of the nineteenth century, and the harbor that on the west side of the island corresponds exactly to Hilo, had five miles of length filled one mile wide.

From Mauna Loa Kiholo was protected by Puuwaawaa hill, Hualalai Mountain, and Puu Anahulu. The 1859 flow was not stopped at all by Puu Anahulu flats. The whole South Kohala shore as far as Puako is a filling of Mauna Loa flows. The early 18th century filled west. Seventy-five per cent of present-day flows are to the east.

Hilo has no hills whatever between it and the most dangerous present active rifts of Mauna Loa. It is on a valley which Mauna Loa is perfectly certain to fill up in time. It is 34 per cent nearer to the active vents than Kiholo is to the 1859 source. It has been attacked five times in 83 years, mostly when it was a small village. Last year it was attacked in its urban maturity, and it was saved by bombing pahoehoe. The next flow may be of different kind, when nothing will save Hilo but fortification.

The lava surface equal to the Kiholo fill would be five square miles. This would fill Hilo harbor from a point a mile north of Wainaku across to a place in the sea a half-mile north of Keaukaha. There would be no city, no Iron Works, no Canec, no Waiakea, no railway yards, no airport, no wharves, no electric works, no telephone center.

The city is worth $51,000,000; the harbor possibly $500,000,000 to the Territory, to commerce, and to the Nation. There are only two real harbors on Hawaii Island, Kealakekua and Hilo.

The river would find a new channel in one of the northern gulches. The people would sit on the Halai Hills and watch another layer added north from Reeds Bay and Onekahakaha, both of which are Mauna Loa lava flows. The Oil Tanks would blow up, the sugar in Kuhio wharf would be buried, and the lumber mills would burn, just as we watched the Hoopuloa wharf burn.

If a foreign Hobson were going to scuttle Merrimac hulks in the breakwater entrance, we would ask the Government to line up a blockading fleet. That is exactly what we are called upon to do against Mauna Loa. You have created an intelligence service, the Observatory. It is making its report soberly and conservatively. This is not alarmist sensationalism.

Conclusion

The thing I would suggest that the Hilo Chamber of Commerce do, is to have a meeting, for discussion of this question, with representative engineers, business men and the supervisors. At that meeting may be decided whether or how to approach the Governor.

I would suggest having representatives of the National Park, the Army, Navy, Parker Ranch, Shipman Ranch, and the Bishop Estate; with the Land Commissioner to represent the Governor. I have discussed the matter with Mr. Whitehouse, and with several of these administrators of Mauna Loa lands, and also General Drum, and the presidents of the Hawaiian Volcano Research Association and the University. The protection of Hilo needs no argument, and these gentlemen have great respect for Mauna Loa.

The things to do are:

1. Extend the Mauna Loa road.
2. Equip a Red Hill Observatory and patrol.
3. Acquire the upper Mauna Loa waste lands.
4. Design and start the Hilo Lava-guard Causeway.
5. Design and start the Humuula Obstacle.
6. Design and start the Red Hill Embankment.

For all of these the appeal, started by myself as volcanologist of Hawaii National Park and the Hawaiian Volcano Research Association, for which I take full responsibility, should probably proceed through the Hilo Chamber to the Governor, who will take whatever action seems wise.

If we do these things you can sleep in Hilo and feel jubilant for your future and your business. Read the pathetic letters of Mrs. Severance to Miss Gordon-Cumming in 1881, when the flow was in Hilo, if you want to know the depression of it (book called "Fire Fountains," Gordon-Cumming). Or see the volcano film of Etna at the National Park museum. And after the embankments are built we still have bombing in reserve for the slow smooth flows.

More than all else, you will set an example to the world. Italy, Japan, the Philippines, Java and Central America will all watch Hilo. Hilo has not said "Manana" (tomorrow), nor "Shikata ga nai" (it can't be helped). The trails of the Hawaiians go straight to the goal with the motto "Eternal is the life of the land in righteousness." Righteousness means straightness. Let us perpetuate the life of the land in Hilo.

Hawaiian Volcano Observatory Report for January 1937

VOLCANOLOGY

The month of January indicated continuance of the quiet conditions which had begun rather suddenly the last week of December. The winter proved exceptionally rainy, with much stormy weather and high winds, occasioning deep ground swells that broke on the rocky cliffs of the island. As a result microseismic motion has been strong, and appears to vary with the impact of waves on the shore.

Observation of Mauna Loa

On January 2 a party from the Observatory, S. Sato and A. Okuda, accompanied soldiers from the Red Hill Resthouse up the Mauna Loa trail, encountering fresh snow from a point a mile and a half above the house. The old steam crack east of the trail was making vapor with snow close to its edge. The 1935 cones at about 12,000 feet elevation showed sulphur coatings that were too hot to hold the snow, and both vapor and blue fume were noted there. After exposure to snow glare from seven to ten hours, some of the party were snowblinded, and had to be led down the trail on the return. This experience of snowblindness has been repeated by other parties on Mauna Kea, where a new trail built by Civil Conservation Relief Workers has induced many to go skiing.

From the Observatory at Kilauea the 1935 cone on Mauna Loa, 18 miles away, was seen to make visible fume the hour before noon on January 6.

Observations of Kilauea

The following tabulation for January shows somewhat higher values for the Kilauea Volcano Observatory data than in the week ending January 3, but mostly lower values than December. There are indicated by weeks the local seismicity, the counted number of slides in Halemaumau pit when it happened to be observed, the amount at Halemaumau of aggregate opening of marked rim cracks by weeks and the Observatory count of local seismographic tremors and quakes:

Week Ending	Seismicity	Slides	Cracks	Quakes
January 10	7.25	3	2.5 mm.	11
" 17	2.75	4	3.0 mm.	9
" 24	3.00	3	6.0 mm.	8
" 31	7.00	0	3.0 mm.	14

Sequence of Events by Weeks

The first week produced two felt earthquakes and some sliding from the Halemaumau wall.

The second week had lower seismicity and small slides continued.

The third week produced occasional dust from slides and no change in the seismicity.

The fourth week of heavy rains filled the pit with large clouds of water vapor, surmounted by cauliflower clouds caused by convectional displacement, and the nucleation due to fume issuing from vents on the floor of the pit. There were some felt earthquakes, and southerly tilt was strong.

Slides at Halemaumau

Slides from the wall of the pit have been noted as follows, either from a distance or at typical times of visitation:

January 6, 12:45 p.m., dust rose from a small slide NE, while blue fume was seen at E and W Solfataras.

January 7, 9:30 a.m., small rocks dribbled down west wall, and at 1:30 p.m. dust arose NE.

January 8, at 2:18 p.m., a moderate slide fell from NNW wall.

January 15, 9:33 a.m., a small slide fell N.

January 17, 12:03, 12:27, and 12:35, dust clouds from slides arose NW; all were small.

January 22, 12:45 p.m., dust arose N rim.

January 23, A scar on the west wall indicated new sliding, and small rocks were in process of dribbling down there.

The last week was too stormy for observation of slides.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 26 rim crack locations resulted in aggregate movement as follows: week ending forenoon of

January 8, 5 opened, 2 closed, opening 2.5 mm.
" 15, 7 opened, 4 closed, opening 3.0 mm.
" 22, 6 opened, 1 closed, opening 6.0 mm.
" 29, 9 opened, 4 closed, opening 3.0 mm.

T. A. J.

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory, January 21, showed an opening of the Halemaumau value and an opening of the Crater value compared with similar measurements made December 26, 1936. From Kilauea SE rim to Uwekahuna there was closing of 0.17", December 26 to January 8 and opening of 0.84", January 8 to January 21. Total opening, 0.67". From the Pit Seismograph to the NW Pit B.M. there was an opening of 0.17", December 26 to January 8, and an opening of 0.83", January 8 to January 21. Total opening, 1.00".

H. H. W.

Spirit Levelling

A recheck of levels run in Kilauea Crater after February, 1936, indicates that values reported for elevation changes are erroneous. Improper corrections and poor instrumental adjustments have been responsible for the discrepancies. Proper corrections will be made and results reported in a later edition of the Volcano Letter.

H. H. W.

Note: Seismological Data for January, 1937, will appear in February issue.

THE VOLCANO LETTER

No. 444 monthly **Department of the Interior** **National Park Service** **February 1937**

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

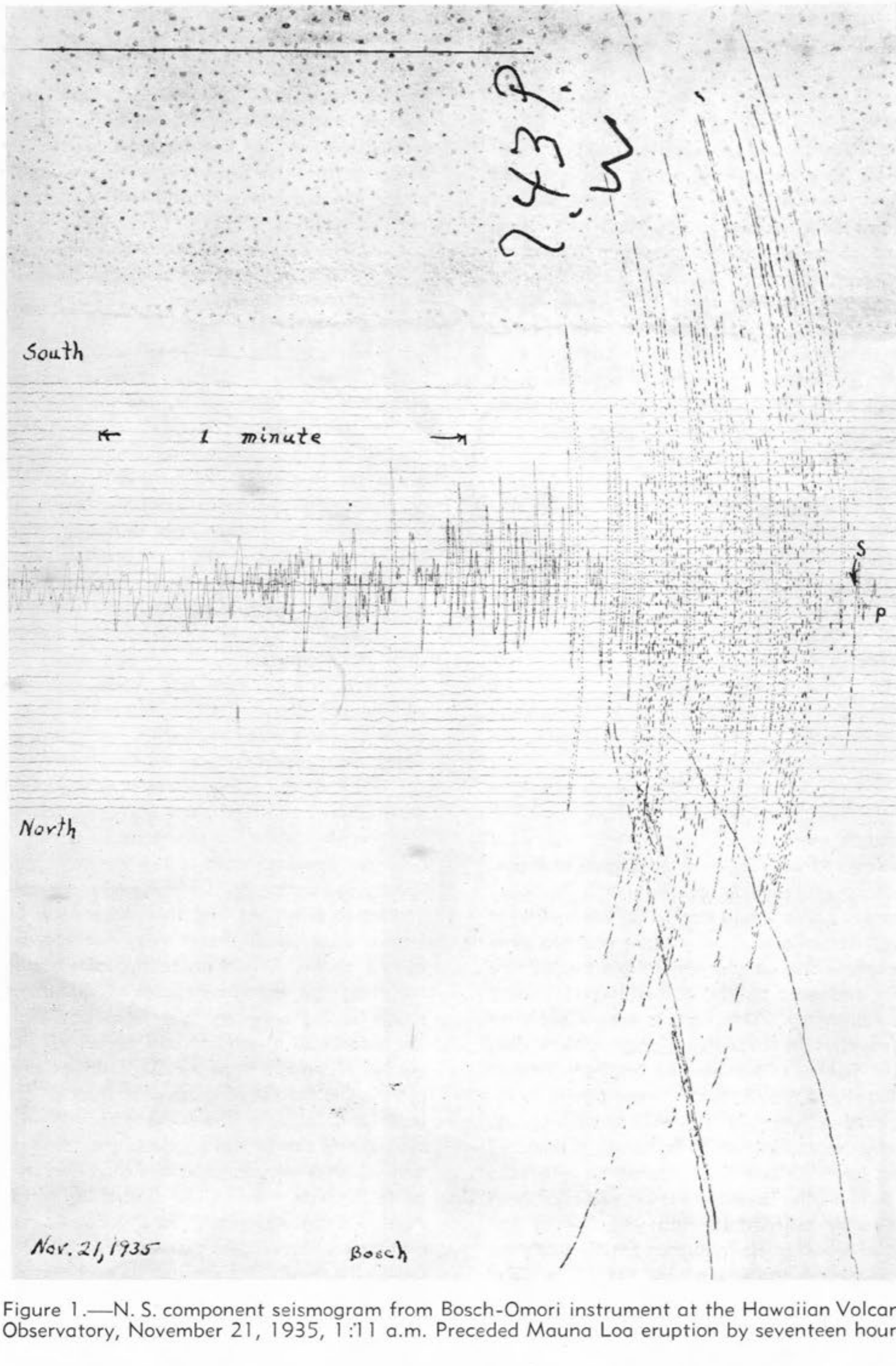


Figure 1.—N. S. component seismogram from Bosch-Omori instrument at the Hawaiian Volcano Observatory, November 21, 1935, 1:11 a.m. Preceded Mauna Loa eruption by seventeen hours.

EARTHQUAKES*

By Hugh H. Waesche, Asst. Geologist, H.N.P.,
Hawaiian Volcano Observatory

A very commonplace phrase or question in Hawaii is, "Did you feel the earthquake last night?" Sometimes there was one, more often imagination has played someone a trick and there was none. We are all earthquake conscious here on this island, and justifiably so, as fairly frequent earthquake shocks are as much a part of the region as are the volcanoes of Hawaii National Park, the City of Refuge at Honaunau or the Black Sands of Kalapana. Hawaii being volcanic, is at the same time an active earthquake center. This condition is true of other parts of the world. It has been discovered that earthquakes occur most commonly in two zones or belts on the earth's surface. One of these zones starts at the southern tip of South America and runs northward following the course of the Andes, passes through Central America, continues through Mexico and the U. S., following the Rocky Mountains, Sierra Nevada and Cascade Ranges to Alaska from where it follows the Aleutian Chain to Japan, passes on to Java and Sumatra of the Dutch East Indies and finally swings back eastward across the South Pacific. The other belt runs diagonally across this one and includes the Caribbean, the Mediterranean Sea, the Caucasus and Himalaya Mountains and the East Indies. It is interesting to note that these two zones also roughly indicate regions of volcanic activity. However, from that relation it must not be inferred that the one is the cause of the other. It would be better to think that both earthquakes and volcanoes are the resulting effects of disturbances or movements in zones of evident crustal weakness. Earthquakes can and do occur in these regions without volcanic activity. Volcanoes can and do erupt without being accompanied by major earthquakes although they usually occur simultaneously with local earthquake shocks, or are preceded by the latter. In Hawaii we often have earthquakes of various intensities without any sign of activity. They are usually located near features of structural importance such as under one of the five volcanic masses of the island or rifts associated with them. How these locations are determined will be described later.

The exact cause of earthquakes is still open to question but is always an interesting point. When a person feels the so-called ground under him shaking violently or possibly rocking like a ship at sea he wants to know what is causing the disturbance. This is a natural reaction and the early Greeks and Romans of the Mediterranean areas who were quite familiar with both volcanoes and earthquakes asked that question just as do their successors. They were contented though with a much more simple, and to them, logical explanation. Some of these explanations, connected with gigantic underground explosions, wind blowing through tunnels in the earth and the caving-in of subterranean caves would not fit in too well with modern concepts along those lines. Today three possible general causes are suspected. The first and generally accepted one is the most important and goes by the rather high sounding name of elastic rebound theory. This type is associated with the making of new fractures in the earth's crust or remaking of old ones such as the making of earthquake cracks in Hawaii in 1868 or a split along the Mauna Loa Northeast rift in 1935. In spite of the name of this theory, it is simple to understand. Most everyone has had the experience of breaking a piece of kindling wood over his knee. When the wood partially breaks with a snap there is a jar in the hand and knee. This jar is in reality a small hand-made earthquake and was felt by the rebound of the pieces of wood to their former position as they snapped back from the bent position across the knee. The bending is the elastic part of the theory name and the snapping back of the wood is the rebound. The same thing happens in most natural earthquakes, large or small, depending on the strength and snap of the material concerned. Stresses tend to build up on either side of a rift or crack in the earth's crust and so continue accumulating until like in the case of the stick of wood—it gives and the ends snap back into position and then everybody says "Oh! did you feel the earthquake?" and the telephone starts ringing at the Volcano Observatory. The second type of earthquake is spoken of as volcanic. Many of these occur around any active volcano and their originating cause is somewhat doubtful. They may be of the same origin as the first-mentioned group, caused by lava and gas pressure changes on the rocks composing the volcano. Explosive volcanic activity likewise results in earthquake movements. Another possibility would be the sudden stopping of a lava column with the same general effect as the jar in a hydraulic ram or the stopping of a weight in a pile driver. Rapidly flowing lava or gas produces earth vibration just as water flowing from the end of a hose nozzle will vibrate one's hand. In any event, although volcanic earthquakes as we all know here, can be quite strong locally, they are seldom felt at a great distance. This is characteristic of such disturbances. An exception was in the case of the great shock in Hawaii in 1868 which was classed as one of world-shaking variety. The elastic rebound type of earthquake first discussed is given the credit for causing practically all major disturbances. Typical examples of this great class are the Charleston earthquake of 1886, the Yakutat Bay earthquake of 1898 when a good-sized mountain range raised itself forty-two feet, the San Francisco earthquake of 1906 where in places the ground slipped as much as twenty feet sideways along the San Andreas rift, and the Tokyo earthquake of 1923 which practically destroyed Yokohama and Tokyo. Most any of the great world-shaking earthquakes one might mention belong to this class. A third and very minor cause of earthquakes is still listed in most textbooks. This theory is concerned with the caving-in of underground openings or caverns. The strong shocks of the New Madrid, Missouri region in 1812 were thought by some to have originated in this fashion. Subsidence of the ground certainly did occur but it would be hard to conceive of underground spaces of sufficient size to produce such disturbances.

From time to time one reads in the newspapers that an earthquake occurred at such and such a place and that its distance was a number of miles from some given locality. Sometimes these reports are based on someone reporting having felt the shock at the point where it occurred or on the basis of its destruction but more often the detection of the quake and its location is based on instrumental evidence. That is, scattered over the world at more or less strategic points are instruments known as seismographs which make a record of the earthquake at that locality. At first this all seems a little mystic until one knows more about the activity generated in the earth's crust by the shock. When an earthquake occurs, waves are set up radiating out from the center of disturbance in all directions much as the waves go out from where a stone or fly strikes the surface of a pond of still water. In the case of the earthquake, three different kinds of waves are started simultaneously. The fastest of these goes through the earth and vibrates back and forth in the same direction in which it moves. A second and slower wave follows the same path as the first type and vibrates crossways to the direction in which it moves just as do the waves on a tight clothesline which is struck sideways. A third and the slowest type of wave follows the earth's surface and makes the biggest movement of all. It, too, vibrates crossways. By means of experiments and mathematical calculations the respective speeds of these types of waves are known and it is this knowledge that makes distances from the earthquake to

* Radio talk, KHBC, Hilo, Hawaii, February 23, 1937.

seismograph stations determinable. Since the first group or longitudinal waves and the second group or transverse waves start together but travel at different speeds they must arrive at some other point at different times with the longitudinal waves arriving first. Tables have been made which show directly the distance a shock is from a station for any given time difference in time of arrivals of these waves. That means that it is only necessary to have some method of detecting and recording the wave movements and then for one experienced to identify the specified waves on the record which must have some time control. The first-mentioned wave travels moderate distances at about seven miles per second. However, as the distance increases the rate also increases. The waves that weight is connected properly to some device which will trace the record of the earthquake on a piece of paper then we have a seismograph. Since earth motions even of strong quakes seldom exceed, at most, a quarter of an inch the motion must be magnified so that the waves may be large enough on the record to study. This is accomplished by either of three methods, first, by mechanical levers, second, by electrical magnification and, third, by light beams as levers. Usually in the most sensitive instruments a combination of the last two is used for distant quakes. At the Volcano Observatory, mechanical levers are used, with magnification of the actual earth movement of about one hundred. Two common methods of registering are used. The first uses a sheet of paper which has been

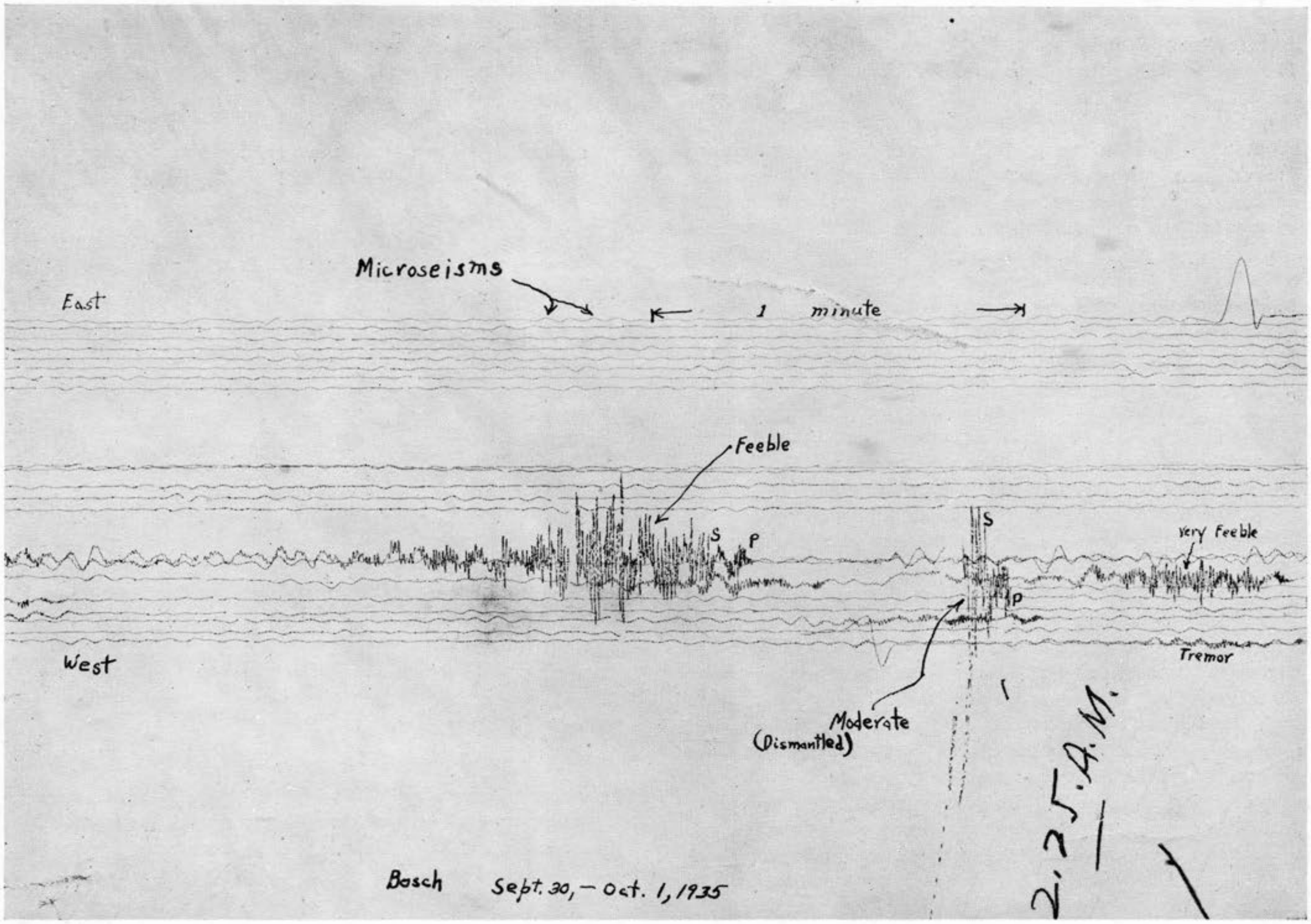


Figure 2.—East-West component of part of earthquake series of September 30-October 1, 1935. Observatory Bosch-Omori instrument, static magnification 115.

travel around the surface travel at a constant rate of about two and a half miles per second regardless of distance.

Now to return to the seismograph which is the instrument that records the earth's movements, we find a comparatively simple apparatus which nevertheless must be well constructed for proper results. It is a well-known fact that if a heavy object is at rest a lot of extra force is necessary to move it. When a fast-moving car stops suddenly the people are thrown forward, when the car starts the passengers are jerked backward. This is the same property and is known as inertia. No doubt you have all heard that word applied to some people with reason—and for the same reason. Anyhow, it is this property which makes the seismograph work. In these instruments a weight is suspended from a support which is attached solidly to the earth much as is the pendulum in a clock only in this case the earth swings in an earthquake and the weight stays still. Now, if the smoked with a kerosene flame, revolving on a drum at a known constant speed and in which a very light steel point attached to the pendulum through the levers draws a line. When nothing happens this mark is straight but zigzags when an earthquake occurs. The other type of recording uses a sheet of photographic paper and a beam of light takes the place of the steel pen of the first type. Magnification in the second type sometimes is as high as one thousand. The movement of the ground in Hawaiian earthquakes ranges between about one one-thousandth of an inch and a tenth of an inch. Remember the one of June 28, 1935, which knocked down a few chimneys and cracked several walls in Hilo? The ground movement at the Volcano Observatory was only slightly more than a tenth of an inch and the earthquake was centered as close to the Park as it was to Hilo. Yes, when mother earth moves even a little bit —and does it rapidly—you are going to know it. That earthquake was probably the first official herald of the Mauna Loa eruption in November.

A completely equipped seismograph station has three separate pendulums or instruments. They are usually so arranged that one records only earth movements north and south, another only east and west and the third, up and down. The advantage to this arrangement is that under favorable conditions an earthquake can be located from the one station. This is possible because the first longitudinal wave to arrive will move the pen east or west, another north or south and the third up or down on the record exactly proportional to the direction and intensity. The best recent example was the case of the earthquake of November 21, 1935 (Figure 1) which occurred at one-eleven a.m. and was pretty strongly felt all over the island. At the Observatory the east-west pen moved east one-half millimeter; the north-south pen moved south three millimeters. That meant the earthquake was a little south of east of us, or a little north of west. The time space between the first waves and the second waves showed it to be about nineteen miles away. Inspection of the up-down record showed that the ground had gone down at the Observatory, meaning that the wave was contracting and therefore the earthquake was nineteen miles, slightly north of west from the Observatory right on the Mauna Loa northeast rift about five miles below the summit. Seventeen hours later Mauna Loa was pouring streams of lava from around that spot. But don't be misled—they do not all come out that well.

The Volcano Observatory operates other stations than the one mentioned. It has one at Kealakekua, one at Hilo, one on the southeast edge of Halemaumau and one at Uwekahuna Museum at the Park Naturalist's headquarters. In locating the general run of shocks all of these stations are used. Distances are determined from each and laid off as circles on a map. Lines are drawn connecting the circle intersections and the point where these lines cross shows the earthquake center. But that is not all—by a little descriptive geometry the earthquake is ferreted up to the surface and the distance it was under ground is determined. Preceding the Mauna Loa eruption, the heavy shocks of September-October, 1935 (Figures 2, 3 and 4), ranged as deep as twenty-five miles. The shock of November 21 was not over five miles deep and those which occurred with the outbreak were so shallow that depths could not be determined. By no means are all the earthquakes which occur on this island located. Roughly, forty per cent are located within reason and half of this number are located with comparative accuracy and the large remainder are located only in a general sort of way as a Kilauea shock, a Mauna Loa shock a Hualalai shock, and so on. There is good reason for this deficiency. A large per cent of the shocks do not oblige by having nicely defined wave groups; many are close to only one station so cannot be checked on the others, because they are too weak to record that far away. Sometimes clockworks which rotate drums get stuck, time marks interfere and portions of the quake are lost and if the earthquake is strong and close by, dismantles the instrument before it can make a clear record—and some earthquakes just go by the name of "Maud" and both stubbornly and impudently defy you to locate them, but it makes a reasonably exciting chase at that.

At the Observatory some five different sizes of shocks are recognized as earthquakes. These are very feeble, feeble, slight, moderate and strong. By far the greatest per cent of them are very feeble with feeble a poor second. Both of these are only instrumental and are only felt where they are some distance from the instrument and near an observer. Slight earthquakes are usually felt by many people slightly near their origin. Moderate earthquakes are generally felt all over the island and produce visible effects such as moving objects, rattling doors and the like. A strong quake is anything resulting in some damage and many people frightened. The only really strong shock of the last two years was the one which was previously mentioned, June 28, 1935. Moderate shocks occurred frequently in 1935 averaging about one a month. Outstanding ones were January 2, June 25, a whole series of them, some of which bordered on strong the night of September 30, October 1 and November 21 (see Figures 2, 3 and 4). A still smaller vibration than the very feeble earthquake is one known as a tremor. Some of these last several minutes and always continuously accompany the play of fountains during eruptions. During 1935, 296 earthquakes of all sizes registered at the Volcano Observatory and besides these there were 6,227 tremors. In 1936 332 earthquakes of all sizes registered and only 2,078 tremors. That is an average of almost one earthquake a day—if we assume that the earth rests on Sundays and holidays it looks as though there may be a better average than one a day. I shall leave that for the individual to work out, meanwhile most of the strong earthquakes of 1935 were under Mauna Loa and it erupted; most of the strong ones of 1936 were under or near Kilauea and nothing happened. Let's all watch the earthquakes of 1937 and—what's next?

Hawaiian Volcano Observatory Report for February 1937

VOLCANOLOGY

The month of February showed marked increase of seismic activity, and of opening of cracks around the rim of Halemaumau pit in Kilauea Crater. Microseismic motion continued strong. The cold, rainy weather continued. The winter rainfall has been as follows:

December, 18.93 in., maximum day December 30, 5.12 in.
January, 22.01 in., maximum day January 14, 6.12 in.
February, 20.46 in., maximum day February 18, 4.87 in.

Total 61.40 inches.

The following are the monthly data for observations at the Observatory near Kilauea Crater:

Week Ending	Seismicity	Slides	Crack Openings mm.	Local Quakes
February 7	7.75	3	16.5	24
" 14	9.00	0	23.5	28
" 21	10.25	2	19.5	32
" 28	5.50	3	16.0	12

Sequence of Events by Weeks

The first week showed dense vapor from Halemaumau lava floor, due to rainfall and some sliding there.

The second week showed increase of seismicity and of crack opening.

The third week continued the increase in tremor and slides were small.

The fourth week showed less quaking and crack opening.

Slides at Halemaumau

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

February 2, 10:03 am, a small slide S; 10:08 am, rocks dribbling down NE wall.

February 3, 8:58 am, rocks falling NE wall.

February 19, 10:45 am, small slide NE wall; 5:23 pm, noisy slide N wall.

February 27, 10:08 am, slides NW and N walls.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 26 rim crack locations resulted in aggregate movement as follows: week ending forenoon of—

February 5, 14 opened, 1 closed, opening 16.5 mm.
" 12, 19 opened, 2 closed, opening 23.5 mm.
" 19, 13 opened, 1 closed, opening 19.5 mm.
" 26, 10 opened, 0 closed, opening 16.0 mm.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earth-quakes	Feeble Earth-quakes	Slight Earth-quakes	Distant† Earth-quakes	Local* Seismicity
January 10......	5	4	0	2	1	7.25
" 17......	7	2	0	0	0	2.75
" 24......	4	4	0	0	2	3.00
" 31......	8	4	1	1	0	7.00

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:

January 6, 9:13 am, very feeble, located 0.5 mile S of Bird Park area and 4.1 miles deep. 19° 26.2′ N; 155° 18.7′ W.

January 7, 11:35 pm, very feeble, probably located in vicinity of Ahua Kamokukolau.

January 8, 6:53 am, slight, probably located in Hilina Fault system S of Puu O hale.

January 8, 10:56 am, very feeble, probably located in vicinity of Kilauea Iki.

† Includes teleseisms or those shocks over 5,000 kilometers distant.
* For local seismicity definition see Volcano Letter 371.

January 10, 10:50 pm, slight, located in Kilauea SE rift zone 2.5 miles SE of Makaopuhi Crater and 7.0 miles deep. Reported felt in Hawaii National Park, in Hilo and at Honomu. 19° 20.5′ N; 155° 9.2′ W.

January 11, 9:06 pm, very feeble, located 1.8 miles NW of the Volcano Observatory and 4.1 miles deep. 19° 26.9′ N; 155° 18.7′ W.

January 13, 9:40 am, very feeble, located 4.1 miles deep under Bird Park area. 19° 26.5′ N; 155° 18.3′ W.

January 20, 9:56 am, very feeble, located 1.1 miles deep near center of Kilauea Crater. 19° 24.8′ N; 155° 16.3′ W.

January 24, 7:31 pm, very feeble, probable location in ocean 20 miles N of Upolu Point. Reported felt at Hilo, Hakalau and Puu Waawaa.

January 24, 9:38 pm, very feeble, located 2.8 miles deep, Kilauea SE rift near Hiiaki Crater. 19° 22.6′ N; 155° 14.0′ W.

At 3:39 am, January 25, a disturbance which recorded as a tremor at the Observatory was reported felt at Puu Waawaa.

January 25, 5:37 pm, very feeble, located 13.0 miles deep off coast near Keauhou Point, 4 miles S of Hilina Pali. 19° 15.1′ N; 155° 16.2′ W.

January 28, 6:05 pm, feeble, located 0.5 mile deep in E portion of Kilauea Crater near Byron Ledge. 19° 24.9′ N; 155° 16.0′ W.

January 29, 4:38 pm, very feeble, probably located in Kilauea Crater.

January 30, 4:00 am, very feeble, probably located in Kilauea Crater.

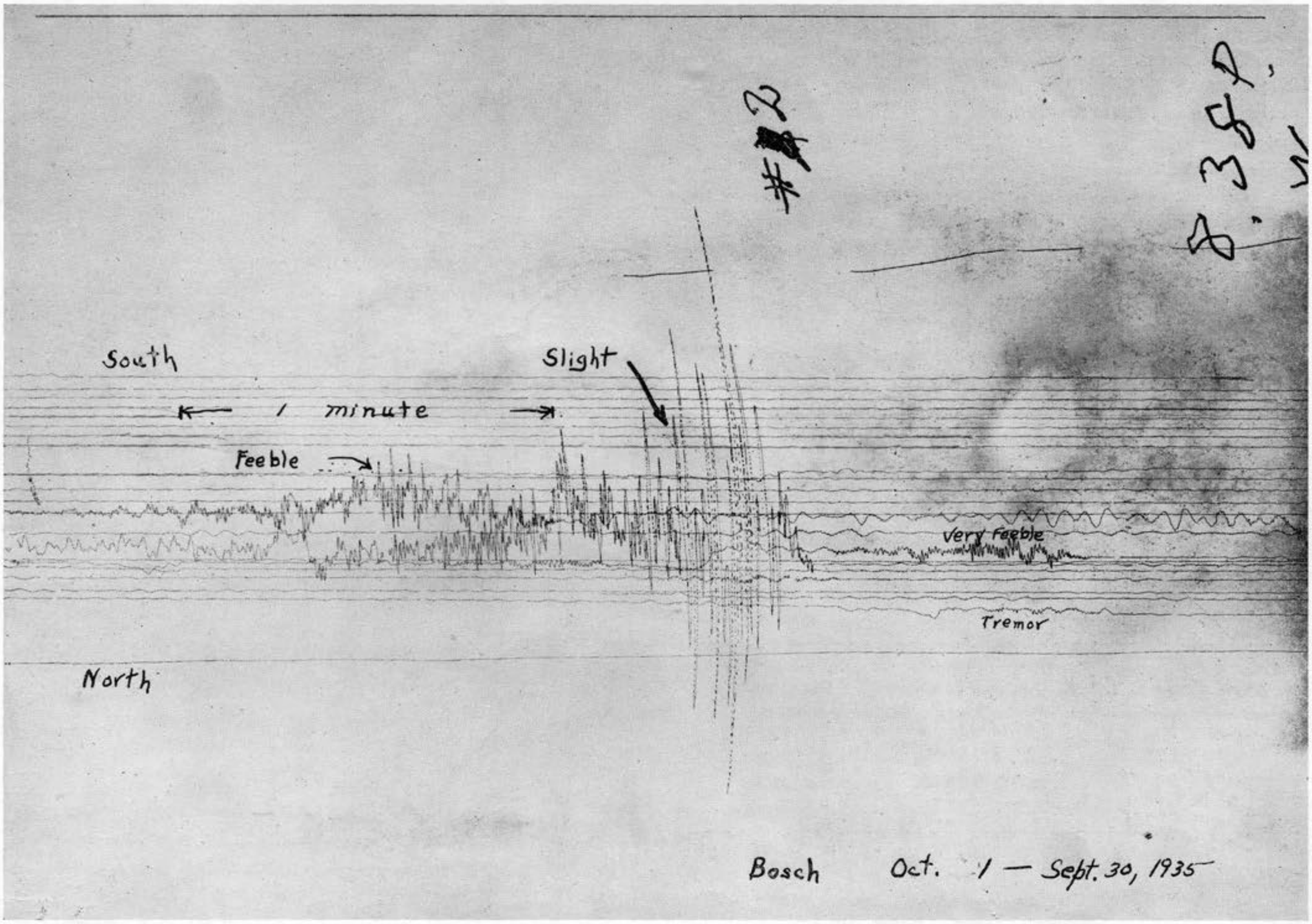


Figure 3.—North-South component of same series illustrated in Figure 2.

January 30, 11:26 am, very feeble, probable location 14 miles deep in marine extension of Kilauea SW Rift Zone, 5.0 miles E of Palima Point. 19° 9.3′ N; 155° 22.7′ W.

January 31, 7:33 am, slight, located 18 miles deep and 6.0 miles NW of summit of Mt. Hualalai. Reported felt at Hookena and at Kamuela. 19° 45.5′ N; 155° 55.3′ W.

Microseismic motion of the ground at Kilauea was strong throughout the month.

Registration of distant earthquakes at the Observatory was as follows:

January 7, the preliminary waves at 3h 04m 12s am, H.S.T., with a probable focal distance from Kilauea of about 6,100 miles. Radio reports indicated this disturbance as contemporaneous with a strong earthquake in Central Asia. The preliminary waves of a teleseism began recording at 12h 35m 38s am, H.S.T., January 23; estimated distance from Kilauea was 3,720 miles. The preliminary waves of a teleseism began recording at 8h 13m 23s, pm, H.S.T., January 24. Its estimated distance from Kilauea was 3,400 miles.

H. H. W.

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 31 was 2.05″ S. and 1.57″ W.

Table of Tilt

Week Ending	Observatory	Halemaumau West Station
January 10	0.44″ S 58° E	5.81″ N 70° W
″ 17	1.22″ S 14° E	6.29″ N 78° W
″ 24	1.36″ S 8° W	5.96″ N 88° W
″ 31	3.92″ S 23° W	6.85″ N 62° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
January 10	6.84″ N 47° W	1.57″ toward
″ 17	5.22″ S 75° W	4.01″ from
″ 24	3.73″ S 74° W	3.18″ from
″ 31	10.72″ S 62° W	5.84″ from

H. H. W.

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Slight Earthquakes	Distant† Earthquakes	Local* Seismicity
February 7	17	7	0	0	7.75
″ 14	20	8	0	0	9.00
″ 21	23	9	0	1	10.25
″ 28	8	3	1	0	5.50

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 and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began recording at the times indicated and whenever possible, a determination of depth of focus has been made.

† Includes teleseisms or those shocks over 5,000 kilometers distant.
* For local seismicity definition see Volcano Letter 371.

At 12:23 am, February 1, a tremor was recorded at the Observatory corresponding in time with a recorded Feeble earthquake at Kealakekua. It was reported felt in the Kona district.

February 2, 2:05 pm, very feeble, located 0.5 mile deep, E portion of Kilauea Crater, near Byron Ledge. 19° 24.9′ N; 155° 16.0′ W.

February 2, 8:59 pm, very feeble, a shallow quake located

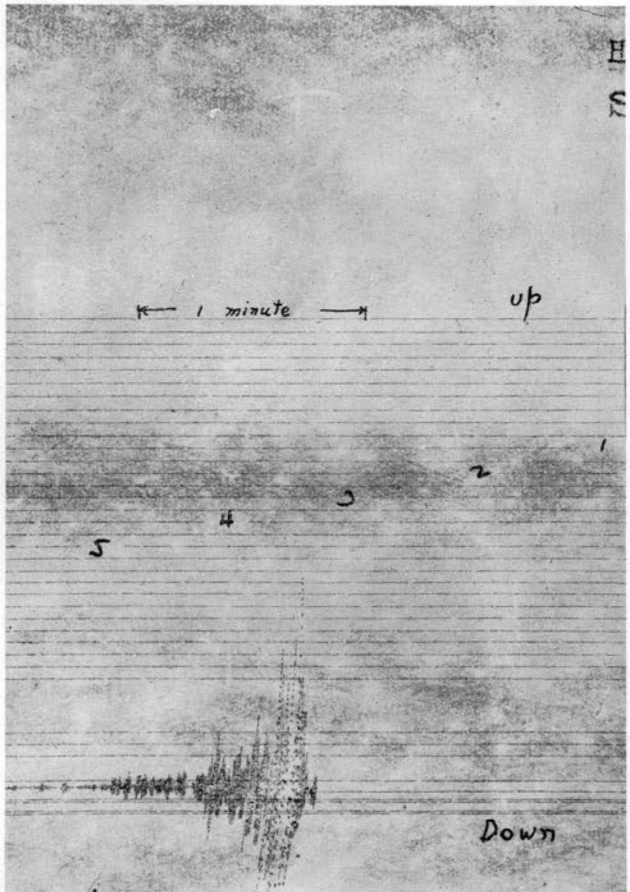


Figure 4.—Illustrates undamped vertical component of largest earthquake shown in Figures 2 and 3.

immediately south of Keanakakoi Crater. 19° 23.9′ N; 155° 16.0′ W.

February 3, 7:13 am, very feeble, located 1 mile deep and 0.4 mile NE Pit Seismograph. 19° 24.7′ N; 155° 16.7′ W.

February 3, 6:06 pm, very feeble, located in Kilauea Rim Crack Zone immediately north of Keanakakoi Crater. 1.2 miles deep. 19° 24.5′ N; 155° 15.9′ W.

February 3, 6:10 pm, very feeble, located 1.5 miles deep in NW portion of Kilauea Crater. 19° 24.7′ N; 155° 16.7′ W.

February 7, 4:22 pm, very feeble, probably located 0.8 mile NW of Kilauea Crater.

February 8, 10:47 am, very feeble, located 1.4 miles deep under SE rim section of Kilauea Crater. 19° 24.4′ N; 155° 16.1′ W.

February 9, 5:45 am, very feeble, located 4.0 miles deep and 12 miles S of Volcano Observatory at Keauhou Point. 19° 15.8′ N; 155° 13.7′ W.

February 10, 12:49 am, very feeble, probably located in Kilauea Crater.

February 10, 6:50 am, very feeble, located 1.2 miles under NW rim of Kilauea Crater in vicinity of Uwekahuna. 19° 25.5′ N; 155° 17.2′ W.

February 10, 12:40 pm, very feeble, located 0.5 mile deep under E rim of Kilauea Crater. 19° 15.8′ N; 155° 24.7′ W.

February 15, 5:09 am, very feeble, located 6.0 miles SE of Puu Ulaula, SE slope of Mauna Loa and 18 miles deep. 19° 29.3′ N; 155° 24.6′ W.

February 16, 3:50 pm, very feeble, probably located at shallow depth near center of Kilauea Crater.

February 16, 4:06 pm, very feeble, located 1.6 miles deep and 3.0 miles E of Kilauea Crater. 19° 25.5′ N; 155° 11.9′ W.

February 18, 2:38 am, very feeble, probably of moderate depth under SW portion of Mokuaweoweo Crater, summit of Mauna Loa.

February 18, 5:20 am, very feeble, located 2.0 miles deep in Chain of Craters Rift Zone, near Devil's Throat. 19° 22.6′ N; 155° 14.0′ W.

February 23, 6:20 am, very feeble, probably located in SE portion of Kilauea Crater.

February 26, 8:04 pm, slight, located 8.0 miles SE of Halemaumau near Hilina Pali and 10.0 miles deep. 19° 20.0′ N; 155° 23.3′ W. This shock was reported felt by many in Hilo and in Hawaii National Park.

February 28, 7:34 am, very feeble, probable location in E portion of Kilauea Crater.

Microseismic motion of the ground at Kilauea was strong throughout the month.

The preliminary waves of a teleseism began recording at Kilauea at 8h 42m 01s pm, H.S.T., February 20. Estimated distance was 3,430 miles.

H. H. W.

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 towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending February 28 was 5.56″ S and 0.60″ W.

Week Ending	Observatory	Halemaumau West Station
February 7	3.80″ S 32° W	3.81″ N 62° W
" 14	0.85″ S 69° E	5.10″ S 77° W
" 21	2.11″ S 27° W	3.10″ S 67° W
" 28	0.97″ S 4° E	6.88″ N 86° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
February 7	3.24″ S 56° W	3.27″ from
" 14	24.17″ N 32° W	19.06″ toward
" 21	4.11″ S 23° W	5.09″ from
" 28	8.26″ N 68° W	0.54″ from

H. H. W.

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory, February 25, showed closing of the Halemaumau value and an opening of the Crater value compared with similar measurements made January 21. From Kilauea SE rim to Uwekahuna there was closing of 0.84″, January 21 to February 3; opening of 4.59″, February 3 to February 12, and closing of 1.08″, February 12 to 25. Total opening 2.67″. From the Pit Seismograph to the NW Pit B.M. there was opening of 0.83″, January 21 to February 3; closing of 2.08″, February 3 to February 12, and closing of 2.25″, February 12 to February 25. Total closing 3.50″. H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

NE PLUS HAUSTAE AUT OBRUTAE URBES

THE VOLCANO LETTER

No. 445 monthly **Department of the Interior** **National Park Service** **March 1937**

Hawaii National Park
Edward G. Wingate Superintendent

NE PLUS HAUSTAE AUT OBRUTAE URBES

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

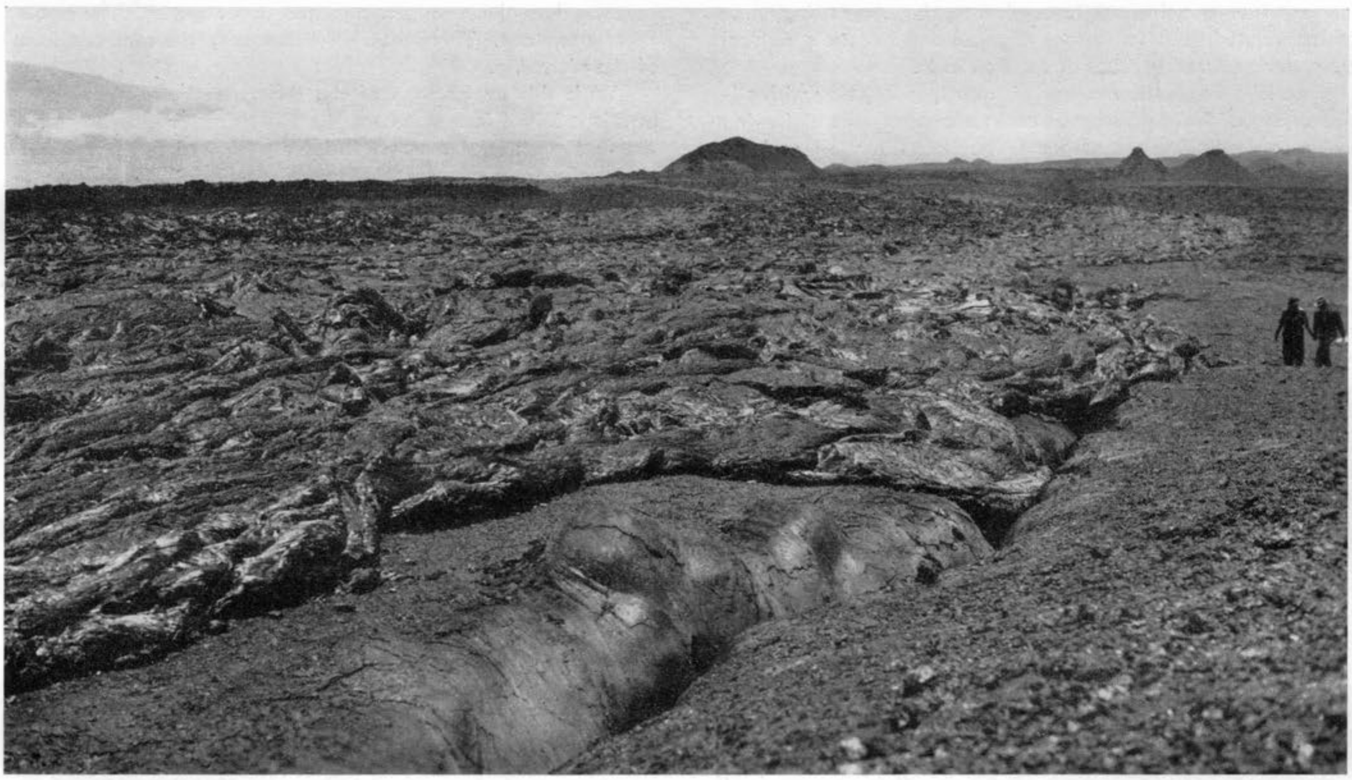


Figure 1. 1935 lava covering trail below summit crater.

MAUNA LOA*

We went up Mauna Loa from Kilauea on March 1st. The party included Mr. Coffman, chief forester of the Park Service, and Mr. Tillett, Superintendent of Territorial Emergency Conservation Work. The Red Hill resthouse was occupied as base.

We walked west two miles and studied the mountain slope towards Humuula. It is an even slope, interrupted by a few cones. In detail it is very rough where aa flows alternate with smooth ones of pahoehoe.

The proposed bank or wall to protect Hilo, across the Red Hill rift, where the flows emerge, will extend obliquely down the mountain north, when it is built. It will take advantage of existing depressions, where they are in the right direction. It will block them where they are not, diverting the stream.

This will create a channel towards Mauna Kea. The barrier would force any new flow obliquely down the slope towards the Hilo-Kona saddle.

There at the saddle the flow would make a lake. East of it on the Hilo side there would be a short high dam constructed. This would be between Puu Huluhulu and Mauna Kea, and it would extend south from Puu Huluhulu to Mauna Loa. It would block off the lava from Hilo.

It would be high enough to hold the lake until it spilled west towards Keamuku. This would protect the Ainahou and Puu Oo pasture land, and the Hilo drainage that supplies water to the city. Damming is practicable only where lava is a flat pool.

* Radio talk, KHBC, Hilo, Hawaii, March 9, 1937, and KGU, Honolulu, April 1, by T. A. Jaggar, Volcanologist, Hawaiian Volcano Observatory.

After the party had looked over this slope, and sized up the possibilities for a roadway from the Rest House down the rift northeast to some large cones, where the wall, five miles long, might start—there is smooth 1881 lava along this route —we spent the night in the Rest House, and the temperature was mild.

Next day against a bitter cold wind we rode up the rift five miles to the upper 1935 cone. This is yellow with sulphur, and steaming. It is one of many in a line. Here on November 21, 1935, the great eruption began.

At that time fountains of golden yellow slaggy foam shot up 500 feet. The whole crack for six miles from the summit crater was gushing. The torrents from it swept in many ribbons down the steep north slope away from the rift.

The liquid so bubbled and stirred itself as to crystallize in sugary lumps and sprouts. This is what is meant by aa lava. Near the actual vents the liquid that congeals is like candy or toffee. This is pahoehoe lava. It may be very stringy like coarse worsted. But its surface of ropes and folds is a natural glass, dark colored because of the iron in it.

The lava inside the mountain is mostly glassy slag with olivine crystals. The transition to aa in a quarter-mile of flowing is due to the boiling out of gases, the violent motion, and the rapid crystallization such as takes place in the centrifugals of a sugar mill.

Accompanying these changes there is great loss of heat. In the first 12 hours of an eruption there is enormous expenditure of energy. The gases are heat makers. Much more gas escapes than lava. The ebullition of gas comes from profound depths. The eruption pulls the cork. The opening of the mountain produces violent gas fizzing due to foaming up. The gas comes from whatever underground lava is relieved of pressure. Probably a big piece of mountain is lifted by the sudden frothing. The effervescence makes the inside lava swell. If you loosen the cork in a beer bottle, and start all the gas, and then try to put the cork back, you must make all that gas dissolve again, or else let it out. The volcano gases are heaters and liquefiers of the slag.

Probably some big force like the settling of the shell of the globe is always forcing the stiff inside lava up these volcano cracks. When the mountain gives way we get an eruption. Right now the lava is pressing up under Kilauea Volcano, the cork will lift, and the lava gas will spout up around the edges of the bottom of the pit.

What made the flow start out of the north flank in 1935? This came a week later than the big initial fountains. And the flow lava emerged from a crack 3,000 feet lower down the mountain slope. The answer appears to be that the internal swelling spreads down a rift belt, an old zone of vertical cracks that extend deep and are full of lava.

The top of the mountain is very heavy. The rift belt goes across the top. When splitting of the rift starts, the swelling lava inside acts as a wedge. The rapid foaming on top shrinks the lava inside as it loses heat and gas. Possibly the plug inside the top crater settles a little. The heavy summit squeezes together.

Down at the 9,000-foot level small cracks can still open in brittle old rock and let out the lowered liquid. It requires an enormous force to lift heavy slag to 12,000 feet elevation. The shrunken lava that has partly cooled glues together the top cracks. This hot paste is very tough like red-hot iron, and old places break more easily. The lower lava escaping at 9,000 feet still has gases heating and expanding it. It quietly welled forth and pushed down to lower places on the mountain. The smooth pahoehoe catches up with the aa, and finally passes the aa front. The movement is slow enough to let the glassy candy float to the top and make skin.

Then a strange and sudden change happens. Where the front that people visit had been a tumbling bed of coals, there quickly appears a gleaming glossy stream covered with beautiful membranes. These skins wrinkle, and festoon and tear and belch out glowing porridge. They puff into elephant toes. The top is silvery or opalescent, smooth and bulbous, flaming with the gas of burning sod below. Inside this crust the liquid has formed a tunnel for itself.

It was this tunnel that made the bombing effective. Let us imagine the water supply to a house under a cliff. The liquid enters the house from a hillside to the third floor. The inside pipe is broken and making a flood in the cellar. If you smash the source pipe and let out the water on the hillside, there will be no more flood in the cellar except for what liquid remains in the house plumbing.

The crusted flow on the mountain was the house. The top story inlet pipe was at 9,000 feet. The aviators of the Army bombed that place and smashed the upper tunnel. The liquid there came out. There was left below only the remnant lava of the plumbing.

With this explanation of the difference between the tremendous initial lava floods of the November, 1935, fountains the first week, and the smooth later flow, let us return to the proposed walls for protecting Hilo.

No bombing could have altered those first voluminous gushings of 1935. They travelled eight miles in a half day! If the lower vent had not opened they might have reached the sea in South Kohala in a week. Just this happened in 1859, a little farther west, for a very long and rapid aa flow.

Suppose such a flood were to burst out at the eastern or Hilo end of the northeast rift. This would be somewhere below Red Hill. It would enter Hilo Harbor in a week. It would burst forth with terrific fountains and might average five miles a day. The distance to Hilo is twenty-six miles. Mr. W. H. Shipman is among the people who can remember back to 1859.

Such lava would be intensely liquid and if it met barricades aligned down hill oblique to its natural course it would follow them. There is no question of damming across it. That is only for flat lakes. The plan is to create an artificial channel in the general direction of the natural slope. There are many natural channels. By taking advantage of them the cost of construction can be reduced.

The final Hilo Wall from Piihonua to Keaukaha is to be on such a natural slope. Its object is to give final protection to the harbor. It must be high enough to catch any flow in the Wailuku or Wailoa drainage valleys and deflect it eastward to the flat lauhala land of the cape south of Hilo Bay.

That land is all old Mauna Loa flows.

This Hilo project takes precedence of the Red Hill and Humuula projects for first construction. But it will not do to trust to the Hilo wall only. There are all the water supplies to protect, and the farms and suburbs and forest reserves. It is never good strategy to trust to one fortress for winning a battle.

The three projects interlock. They should all be started in the next three years. By average intervals, the next Mauna Loa eruption should be ready for outburst any year after 1939. Let us hope that it will be in the summit crater or at some other harmless location!

Mauna Loa in the textbooks is called the most active and bulkiest volcano on earth. Mauna Loa is the center of present-day activity in the Hawaiian Islands. Insurance against Mauna Loa eruptions and earthquakes, and consequent fires and floods, agitates the companies to know what rate to charge. If Hilo is safe the rate will be low. Marine insurance is equally important. Federal dredging to accommodate the biggest ships in Hilo harbor will be influenced by the harbor's safety. If they think it possible Hilo commerce will have to move to Kealakekua, the harbor will be less important. The army, the navy and shipping are all concerned. The Volcano Observatory has plans for a seismograph cellar on the Mauna Loa road soon to be constructed by C.C.C. labor. New instruments will be placed around Mauna Loa. Mauna Loa is just now the most interesting of world volcanoes. Hilo cannot afford to join the ranks of the world's disasters.

THE ILLUSTRATIONS

These photographs illustrate conditions at the north end of the summit region of Mauna Loa, as photographed by Ranger P. F. Murray June 15, 1936. At that time the upper cone at the 12,000-foot elevation was still emitting much hot sulphurous fume and yellow sulphur stained the cone. In Figure 1 this cone is beyond the large cone shown, this being a view close to the summit looking down the northeast rift. The trail here was covered for about a half mile with a new 1935 flow of thin shell pahoehoe shown in the foreground. A typical old crack of the rift belt is in the extreme foreground. The source of this flow was about three hundred yards northwest of the summit resthouse, from a crack that was probably the outlet for the 1935 lava lake that occupied the North Bay of Mokuaweoweo. Part of the flow poured down the open crack like the one in the foreground and the trail was covered within the area shown.

Figure 2 shows the 1935 fill of the North Bay, from the summit resthouse. The pahoehoe lava cascaded from a rim crack into the bay.

Figure 3 shows this rim crack in the foreground on the shelf where the resthouse is seated. A new small lava cone about ten feet high was built up only two hundred feet from the old stable of the resthouse. Some of this lava flowed toward the resthouse along the crater wall and disappeared through an upright crack in the wall; the remainder flowed to the right into the North Bay. The filling of the bay had been to a depth of some forty feet, and the pahoehoe surface stands within fifteen feet of the resthouse level. As shown by Figure 3, thin slabs of lava about four inches thick can be seen slumping down the wall crack completely around the north side of the bay from a level approximately fifteen feet below the house. This plainly marked rim crack extends around to the opening from the bay into the main bowl of Mokuaweoweo, according to Ranger Murray.

Figure 4 shows the summit resthouse of Mauna Loa, photographed in May, 1935, of iron and stone construction, and built with Hui o Pele funds.

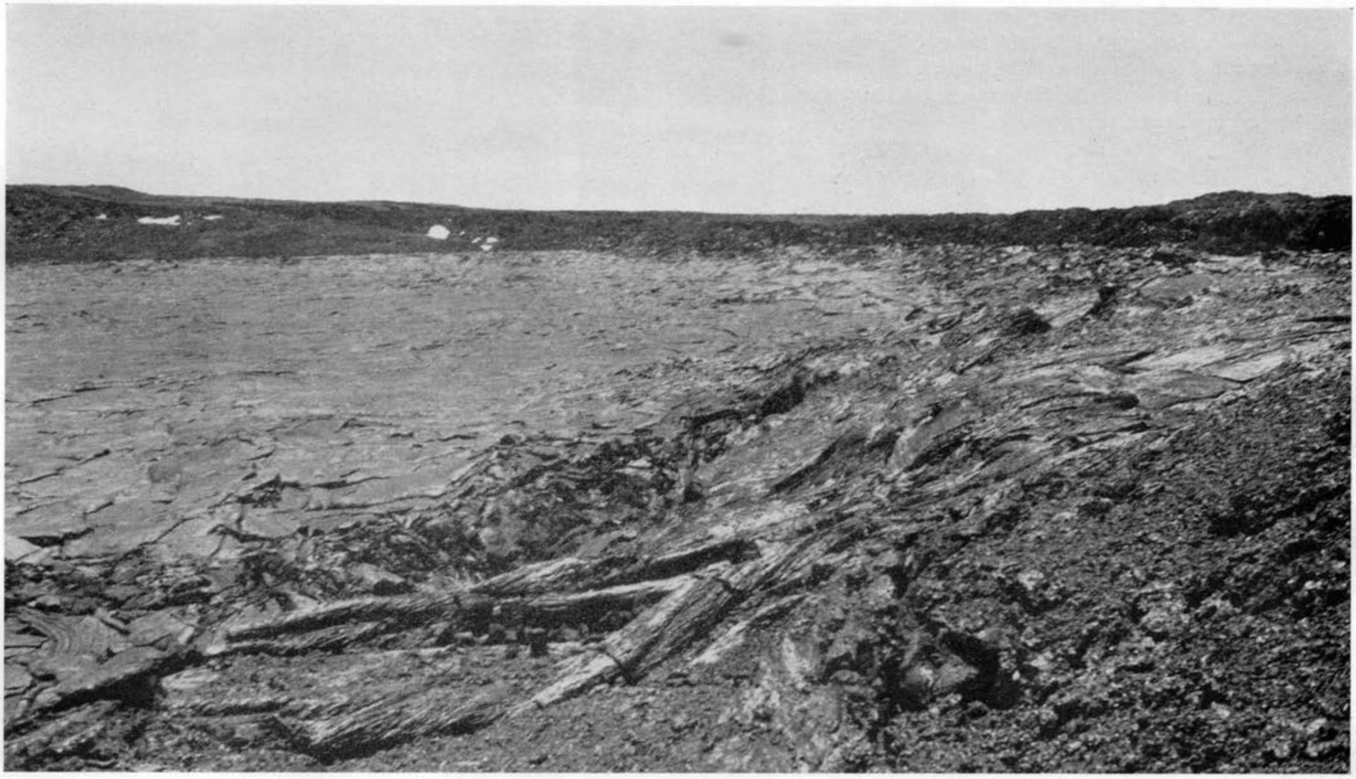


Figure 2. North Bay of Mokuaweoweo from resthouse region. New 1935 lava.

Hawaiian Volcano Observatory Report for March 1937

VOLCANOLOGY

The northeast rift of Mauna Loa was inspected March 2, the upper cones of 1935 were steaming mildly and one of them was stained with sulphur.

The following are the weekly data for observations of the Observatory near Kilauea Crater:

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Quakes
March 7	11.25	0	23.0	37
" 14	9.50	0	23.5	30
" 21	26.25	5	16.5	69
" 28	13.00	0	14.5	39

There were light earthquakes during the month perceptible at Kilauea and of Kilauea origin. There were three at Mauna Loa distances, and one felt strongly at Kailua, believed to originate east of Hualalai.

Sequence of Events by Weeks

The first week showed quiet conditions at Halemaumau.

The second week no slides were noticed, and blue fumes from the sulphurous patches at the bottom of pit were only slightly in evidence.

The third week, which had the most earthquakes, produced several slides.

The fourth week produced no reports of slides and there was fuming from SE and NW bottom solfataras.

Slides at Halemaumau

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

March 16, a fresh scar appeared on NE wall 300 feet below edge.

March 17, slides fell from the end buttress, 10:30 a.m. and 3:40 p.m. The earthquake 12:30 p.m. set going a slide NE, followed by dribbling of rocks more than an hour.

March 21, 5:20 p.m. slide started at NE rim.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 26 rim crack locations resulted in aggregate movement as follows: week ending forenoon of—

March 5, 15 opened, 2 closed, opening 23.0 mm.
" 12, 16 opened, 0 closed, opening 16.5 mm.
" 19, 12 opened, 0 closed, opening 16.5 mm.
" 26, 6 opened, 4 closed, opening 14.5 mm.

12 mm. of this was contributed by Crack No. 25, at the east end of the pit. This crack has opened continuously since the heavy sliding of October-November, 1936.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earth-quakes	Feeble Earth-quakes	Slight Earth-quakes	Distant† Earth-quakes	Weekly* Seismicity
March 7	29	6	0	0	0	11.25
" 14	24	5	1	0	0	9.50
" 21	49	16	2	2	0	26.25
" 28	36	2	3	0	1	13.00

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 and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began recording at the times indicated and whenever possible a determination of depth of focus has been made.

March 1, 7:28 pm, very feeble, probably originated in NE portion of Kilauea Crater.

March 2, 1:26 am, very feeble, located 18.0 miles deep under Mauna Loa NE rift zone in vicinity of Puu Ulaula. 19° 32.5′ N; 155° 26.6′ W.

March 3, 8:42 am, very feeble, located deep under SE portion of Mauna Loa 13.0 miles W of the Observatory. 19° 26.0′ N; 155° 27.5′ W.

March 4, 1:24 pm, very feeble, probably originated in NE portion of Kilauea Crater.

March 8, 12:17 pm, very feeble, located 1.0 mile deep near center of Kilauea Crater, 1.4 miles from the Observatory. 19° 25.1′ N; 155° 16.6′ W.

March 9, 6:56 am, very feeble, probable origin under NE rim of Kilauea Crater.

March 10, 3:04 am, very feeble, located in N portion of Kilauea Crater, 0.9 mile deep. 19° 25.7′ N; 155° 16.7′ W.

March 10, 6:05 pm, very feeble, located in fissures at SE rim of Kilauea Crater immediately west of Keanakakoi. 19° 24.2′ N; 155° 16.1′ W.

† Includes teleseisms or those shocks over 5000 kilometers distant.
* For local seismicity definition see Volcano Letter 371.

March 10, 10:09 pm, very feeble, located 12 miles deep, 6.0 miles NE of Puu Ulaula, Mauna Loa NE rift. 19° 35.0′ N; 155° 23.0′ W.

March 11, 7:10 pm, feeble, located 5.0 miles deep under shoreline at Apua Point, 13.0 miles SSE of the Observatory. Reported felt in Hawaii National Park and at Mountain View. 19° 15.8′ N; 155° 11.0′ W.

March 15, 12:41 pm, very feeble, located 1.0 mile deep, SE rim of Kilauea Crater and 0.5 mile SE of Pit seismograph station. 19° 24.0′ N; 155° 16.6′ W.

March 15, 12:50 pm, feeble, located 0.6 mile NE of Pit seismograph station in Kilauea Crater. 0.4 mile deep. Reported felt strongly by many in Hawaii National Park with particular strength at Kilauea Military Camp, N rim of Kilauea Crater. 19° 24.8′ N; 155° 16.7′ W.

March 16, 11:00 am, very feeble, located 1.0 mile deep under SE rim area of Halemaumau. 19° 24.5′ N; 155° 16.9′ W.

March 16, 1:13 pm, very feeble, located under S portion of Halemaumau, 1.6 miles deep. 19° 24.5′ N; 155° 17.2′ W.

March 17, 3:05 am, very feeble, located under NE rim fault zone, Kilauea Crater, 1.0 mile deep. 19° 25.4′ N; 155° 15.8′ W.

March 17, 12:29 pm, slight, located 1.0 mile deep, 0.6 mile E of E rim of Halemaumau in Kilauea Crater. Felt by many persons in Volcano area and to a point 2.0 miles E of the crater. 19° 24.5′ N; 155° 16.6′ W.

March 18, 2:36 am, very feeble, same location as preceding shock.

March 18, 12:10 pm, very feeble, located 16.0 miles deep and 8.0 miles E of summit of Hualalai. Reported felt strongly at Puuwaawaa Ranch and at Kailua, Kona. Dismantled Kona seismograph. 19° 41.0′ N; 155° 44.5′ W.

March 19, 8:39 am, slight, located 1.4 miles deep in fissure zone SE rim of Kilauea Crater and 0.9 mile E of Halemaumau. Reported felt at CCC Camp. 19° 24.4′ N; 155° 16.2′ W.

March 20, 12:15 pm, feeble, located 1.8 miles deep near the Old Stone Corral in Kilauea Crater. 19° 24.8′ N; 155° 16.3′ W.

March 20, 7:13 pm, very feeble, located 1.6 miles deep and 1.2 miles SE of Pit seismograph station. 19° 23.6′ N; 155° 16.2′ W.

March 20, 7:14 pm, very feeble, probably originated in Kilauea Crater about 1.0 mile SE of the Observatory.

March 21, 6:10 am, very feeble, located 4.6 miles deep and 0.9 mile northwest of Cone Peak, Kilauea SW rift zone. 19° 24.0′ N; 155° 19.3′ W.

March 21, 3:37 pm, very feeble, probably located under Halemaumau.

March 22, 10:50 am, feeble, located 1.4 miles deep, 0.4 mile S of Kilauea Iki. 19° 24.5′ N; 155° 15.1′ W.

March 22, 11:12 am, feeble, located 0.4 mile N of Ahua Kamakokulau, 2.0 miles deep. 19° 23.3′ N; 155° 16.2′ W.

March 24, 7:11 pm, very feeble, located in Kilauea SW rift zone, 4.3 miles deep and 2.5 miles SW of Halemaumau. 19° 23.0′ N; 155° 19.0′ W.

March 24, 9:35 pm, very feeble, located 10.0 miles E of Summit Crater of Mauna Loa, 7.0 miles deep. 19° 24.4′ N; 155° 32.0′ W.

March 26, 8:29 pm, feeble, located 8.0 miles deep and 7.0 miles S of Kilauea Crater in Hilina Pali Fault System. 19° 19.0′ N; 155° 16.0′ W.

Three minutes of continuous tremor registered March 26, beginning at 5:12 pm.

Microseismic motion of the ground at the Observatory was strong the entire month with the exception of March 25 when it was moderate.

The maximum wave of a teleseism recorded at 6h 37m 39s am, H.S.T., March 25. It was probably associated with reported shocks in California of that time and date.

H. H. W.

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 towards or away from the Pit.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
REPORT OF THE SECRETARY
ANNUAL MEETING, HONOLULU, 31st MARCH, 1937

To the Members of the
Hawaiian Volcano Research Association*

I have the honor to report upon the work of your association for the year ending at this date.

Figure 3. Mokuaweoweo Resthouse.

At the Observatory the total accumulated tilt for the year ending March 28 was 7.83" S and 2.6" W.

Week Ending	Observatory	Halemaumau West Station
March 7	1.23" S 71° E	4.77" N 77° W
" 14	0.94" N 35° E	6.29" N 73° W
" 21	3.33" S 49° W	6.88" N 4° W
" 28	1.42" S 45° W	4.29" S 78° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
March 7	4:15" N 60° W	0.58" from
" 14	7.06" N 51° W	0.99" toward
" 21	13.22" S 35° W	3.90" from
" 28	5.90" N 22° W	1.35" toward

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory, March 24, compared with similar measurements of February 25, showed opening of 2.5" across Halemaumau and an opening of 0:41 across the Crater from the SE rim to Uwekahuna.

H. H. W.

A year ago it was announced that a plan was being initiated for cooperation with the University of Hawaii. This plan was carried out and has proved to be helpful and advantageous. The services of Dr. Ballard—an expert physicist—were made available to us through its operation and important work in gas collection and spectroscopic analyses was undertaken. We were also able to add a permanent member to the clerical staff at Kilauea with a resultant saving to the Director of much necessary but time-occupying detail work in the sorting and classifying of documents and correct indexing of the very large number of exchange publications.

This saving of time has made it possible to devote proper attention to our monthly publication, The Volcano Letter, which has now been brought up to date—while the transferring of the detail work of editing and publication to Honolulu office has enabled it to be issued and distributed at the proper intervals.

The Volcano Letter in its enlarged and illustrated format has aroused considerable interest in many parts of the world and it has been gratifying to receive very many most favorable comments upon it. The now historic period, ending with the bombing of Mauna Loa in 1935, has been exhaustively dealt

* At this meeting an address by Dr. Jaggar dealt with the "Protection of Hilo Harbor."

with in this medium—no less than four successive issues having been required thoroughly to cover the subject.

Other publication work has been undertaken, such as an illustrated article upon the "Bombing of Mauna Loa," in the American Military Engineer, and "The Life of Bundjiro Kato" in the Bulletin of the Geological Society of America—both by Dr. Jaggar. A request story of the Mauna Loa incident has been completed by your Secretary in French, for a French-Canadian Journal of international circulation.

ciation of Volcanology which next meets in Washington in 1939.

While at the moment it may be said that the publications and the Observatory plant have been restored to their pre-depression efficiency—it is increasingly evident from the now-existing situation with respect to Mauna Loa that greater responsibilities than ever before are devolving upon this Association. We cannot escape the fact that it is we—as an agency, distinctively Hawaiian but recognized by the world of science

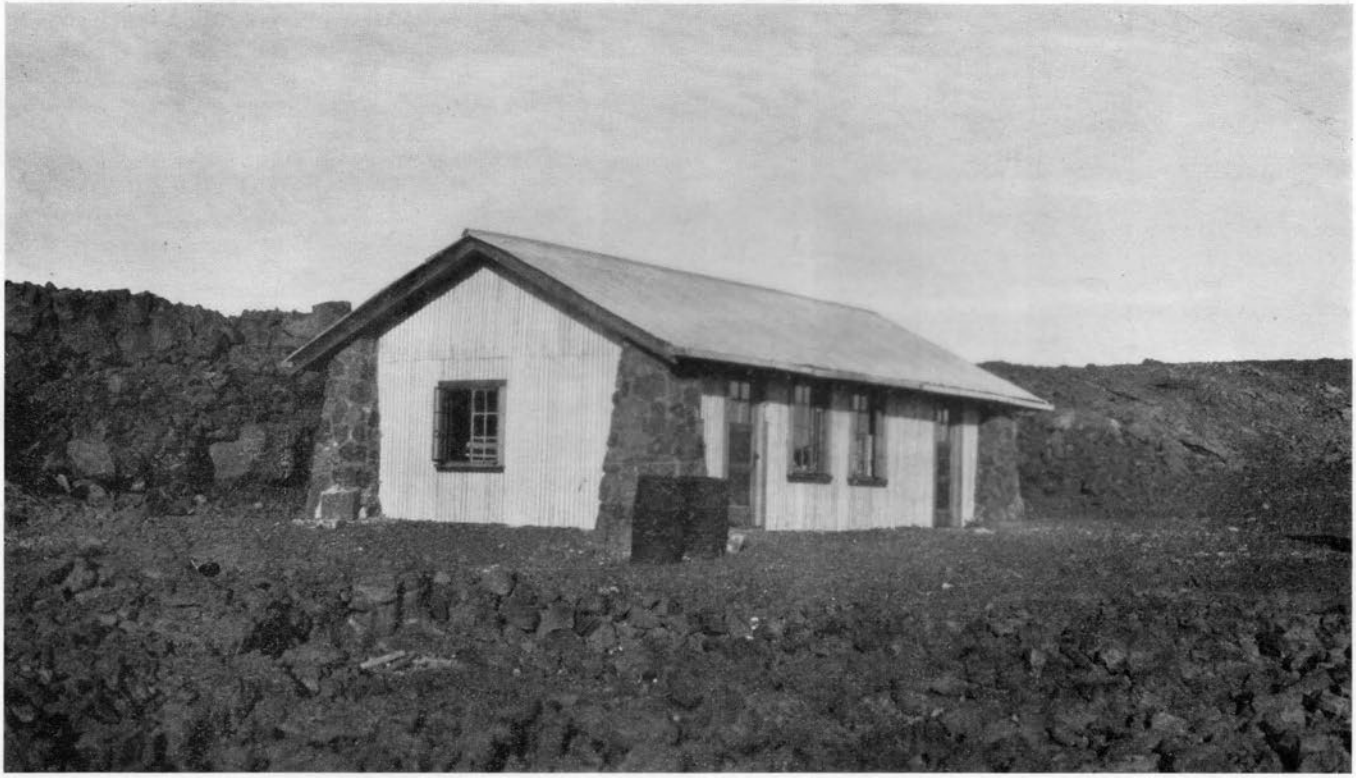


Figure 4. Resthouse, summit of Mauna Loa, constructed with Hui o Pele funds. May, 1935.

While on the subject of Mauna Loa, it may be mentioned that the great lava flow ended on January 2nd, 1936: summit emission of gas dwindled in March, but fuming and deposit of sulphur continued throughout the year. One of the most valuable lessons learned from this eruption by the people of Hawaii was that of the serious menace to Hilo and its nationally important harbor. It is upon this subject that Dr. Jaggar will address you tonight.*

In the spring of the year came an urgent request from the Royal Society of London for Dr. Jaggar to visit Montserrat in the British West Indies to help and advise in a serious seismic crisis that seemed to presage the possibility of a disaster comparable to that of St. Pierre in Martinique in 1902. Accordingly, Dr. Jaggar proceeded thither in April and, after thoroughly examining the situation, formulated a comprehensive program that—should disaster eventually occur—may be the means of saving very many valuable lives. It is of interest to recall that upon arrival in Montserrat, he found a number of Jaggar Shock Recorders were in use by the British authorities—having been made in the Kew Observatory near London. It should also be mentioned that the cost of this expedition was refunded to us by the Royal Society.

Your Association is honored by the election in Edinburgh of Dr. Jaggar as first vice-president of the International Asso-

* See Volcano Letter, January 1937.

as a pioneer—who are permanently called upon to direct and foster the progress of volcano research in Hawaii. It is not, as soom seem to think, a function of the Federal Government to educate our community here in Hawaii to an awareness of inimical forces close at hand. It is our function to do all that we can through our publications—and to take the initiative in matters of public safety. We have only to look back to as recent a time as December, 1935, to realize that, had we during the depression shirked this responsibility and been unprepared—a great disaster might have come upon the Territory; and the Federal Government might have been deprived of a harbor that may well prove vital in both war and commerce. It was this Association that saved the Volcano Observatory from extinction in 1934.

The whole question of safety for Hilo and its harbor, which looms large at this very moment, is one that—as we shall presently hear—is already receiving much serious thought in the Department of the Interior; in Hilo, and in Honolulu through the Territorial and other organizations whose interests are concerned.

It is our duty to undertake the initiative, to plan and to direct, and this is being done. Already, under the direction of the National Park Service—the Mauna Loa road—of supreme importance as a means of access to the mountain, is being extended towards Red Hill—a vital, strategic point for future operations—and has been completed by C.C.C. labor for nearly ten miles at $5000 per mile. This is probably one of the most economical applications of labor on record in Hawaii.

A Mauna Loa Observatory is of paramount importance to the near future. It will entail staff additions to the Kilauea Station and we must promote the means to take care of it. We are extremely fortunate at the moment in the hearty cooperation extended to us by the National Park Service in Hawaii. Its work during the critical period at the end of 1935 was beyond all praise, and we are hopeful that this cooperation may long continue.

But the lesson of that time has taught us that there is very much to be done and we have but little money with which to do it. We depend entirely upon a continuance of the support which has been so loyally given to us in the past and for which we are profoundly grateful.

A year ago an appeal was made to our members to help us by interesting their friends. While our membership has increased steadily during the year it is noticeable that most of the increase has come from the mainland and from foreign countries. It takes a lot of members at $5.00 a year to produce an income sufficient to enable us to undertake important projects—and it is possible that the very nearness of the people of these islands to all that we are trying to do—blinds them to its real importance. That we have been able to carry on for a quarter of a century, however, is a tribute to the generosity of our community leaders who have done so much to make Hawaii one of America's chief assets.

It is appropriate here to state, for libraries and institutions at a distance, that their memberships in this Association are supporting unique scientific research and publication. They are not merely subscribing to a magazine. The Volcano Letter and technical papers—for numerous recent ones we are indebted to the University cooperation—are efforts to make this research known. The Government through the National Park Service is not financed to publish technical articles. The Association in Hawaii assumes this task. It has been difficult to combine interesting the general public as well as the scientific reader, along with prompt report upon volcanic activity. These three motives have been wrestled with for twenty-five years, with very feeble sinews of war.

This Volcano Research Association in the central Pacific stands for a world study of world processes of nature. Its publications and their indexing are limited by the money available for printing. May our generous leaders in Hawaii soon receive the support that will pay for the printing of numerous manuscripts now filed away, awaiting suitable publication, and the indexing of the serial ones.

Respectfully submitted,
L. W. de VIS-NORTON,
Secretary and Assistant Treasurer.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

NE PLUS HAUSTAE AUT OBRUTAE URBES

THE VOLCANO LETTER

No. 446 monthly Department of the Interior National Park Service April 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

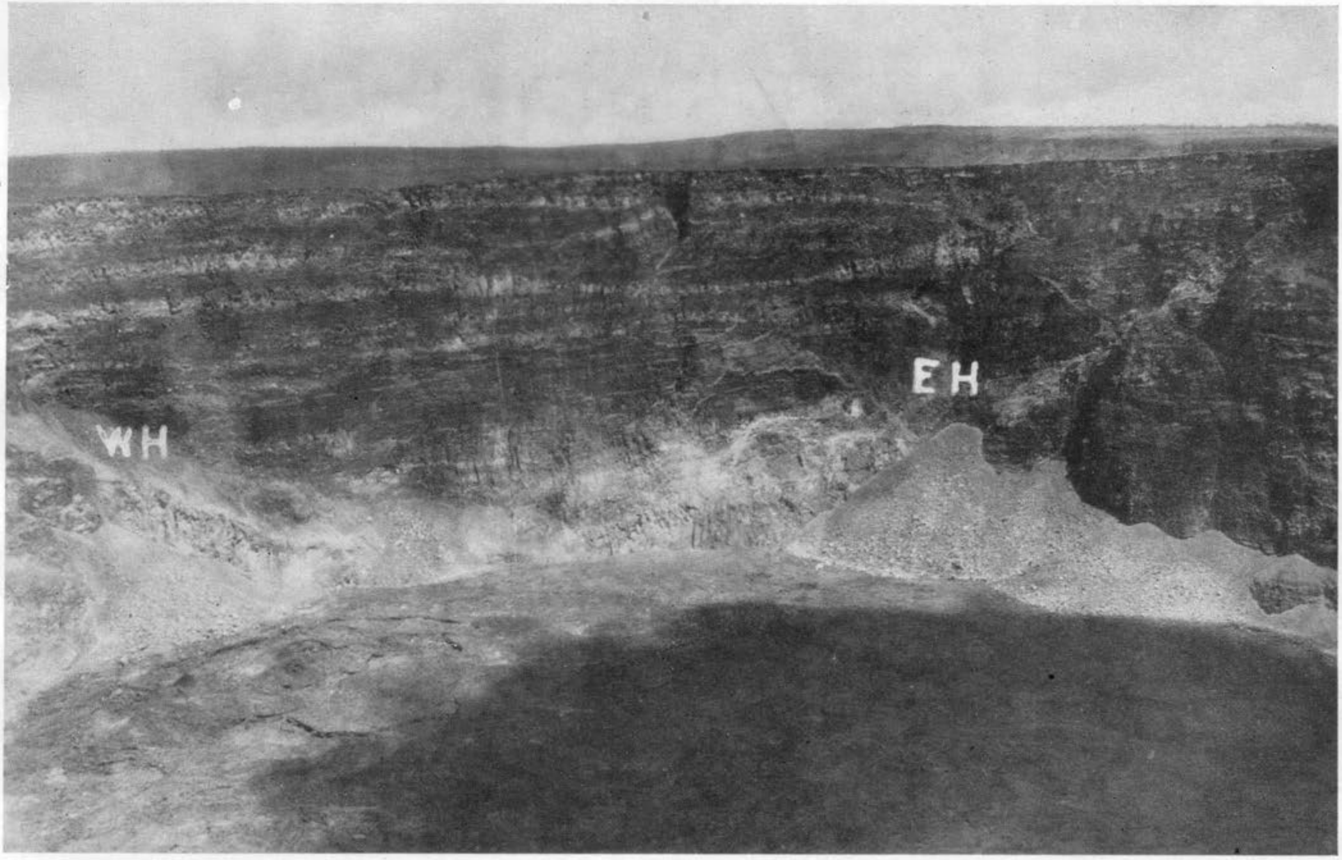


Figure 1. North wall Halemaumau before the landslip: WH the west horn, EH the east horn, of Canoe Sill.

CRACK MEASUREMENT AND TILT AT THE HAWAIIAN VOLCANO OBSERVATORY*

On February twenty-third of this year I had the pleasure of telling you something about the earthquakes on this island, their relation to the volcanoes, how they are detected and how located. It was a long subject to cover in fifteen minutes—in fact, I did not cover the subject in that time but went four minutes over the allotted amount. One might suspect from that state of affairs that earthquake studies took up about all of the time available to the personnel at the Observatory. It is true that the earthquake studies do consume a lot of time and energy, and they are a very important part of volcanologic research but they are by no means the only source of current information concerning the welfare of the volcano. There are other means of feeling out underground movements—not so spectacular but none-the-less important and probably even less ambiguous than earthshakings.

Each week there appears in the local newspapers a report of conditions for the preceding week, ending at twelve midnight Sunday. Among other things, the movement of cracks around Halemaumau and the tilt at the Observatory are reported. Not reported in the papers, but of great interest as significant observations are the results of triangulation and leveling determinations.

On the floor of Kilauea Crater and surrounding the rim of Halemaumau and roughly concentric to it, are a series of cracks. These cracks vary in width and depth from a few inches to several feet, and from some there issue considerable heat and steam. Every Friday morning two members of the

* Radio talk, KHBC, Hilo, Hawaii, April 6, 1937, by Hugh H. Waesche, Asst. Geologist, Hawaiian Volcano Observatory.

Observatory staff make a round of the pit and measure with a millimeter steel tape certain selected, marked localities along these cracks. The marks are copper studs on which are cut crosses for accurate reference. These studs are either cemented to or driven into the solid rock forming the respective sides of the crack toward or away from the pit. Thus, by regular measurement every appreciable movement may be and is detected. Gases and lava pressing up under the crater floor should open the cracks whereas a recession of lava and lowering of gas pressures should cause the cracks to close. It is possible also that tidal forces in the earth caused by moon and sun relationships may cause some changes in the cracks. Another factor, near the rim of Halemaumau, is undoubtedly the force of gravity ever tending to pull the large rim blocks bounded by these cracks, into the pit. Because of regular measurement of cracks indicating comparative movement the likelihood of material sliding in large amounts from certain localities around Halemaumau rim is known well in advance. The large slide of October twenty-second of last year was heralded by excessive crack opening, and a month before this occurred, the northeast area of the pit rim was wired off and warning signs were put up. The results of the crack measurements are plotted up on the basis of percentage opening for the total which makes an irregular curve and on the basis of actual amounts of opening for individual cracks. The latter curves are comparatively smooth and show that as the time approaches for a section of the rim to give away and fall into the depths below, the rate of opening increases more and more rapidly, or is accelerated.

In March, 1936, thirty-two crack localities were being measured. In March of this year only twenty-six were being measured. One crack at the northeast triangulation station gave way during the latter part of March last year. A new one was established twenty feet further back. This one was doomed to a short life. It disappeared with five others along the northeast and east rim of the pit last October and November. One crack, the famous number forty-six, began to show movement of a definitely progressive nature over a year before it fell in with the other just referred to. It opened by ever-increasing amounts, a total of thirty-six centimeters or approximately a foot and a half in about twenty-two months. In the last month alone, it opened ten centimeters, or about four inches, and this crack was nearly two hundred feet back from the rim. On Tuesday afternoon Naturalist Lamb and myself were taking pictures of the region. Thursday morning, October twenty-second, the ground where we had been was at the bottom of Halemaumau and the north side of crack forty-six was the rim of the pit.

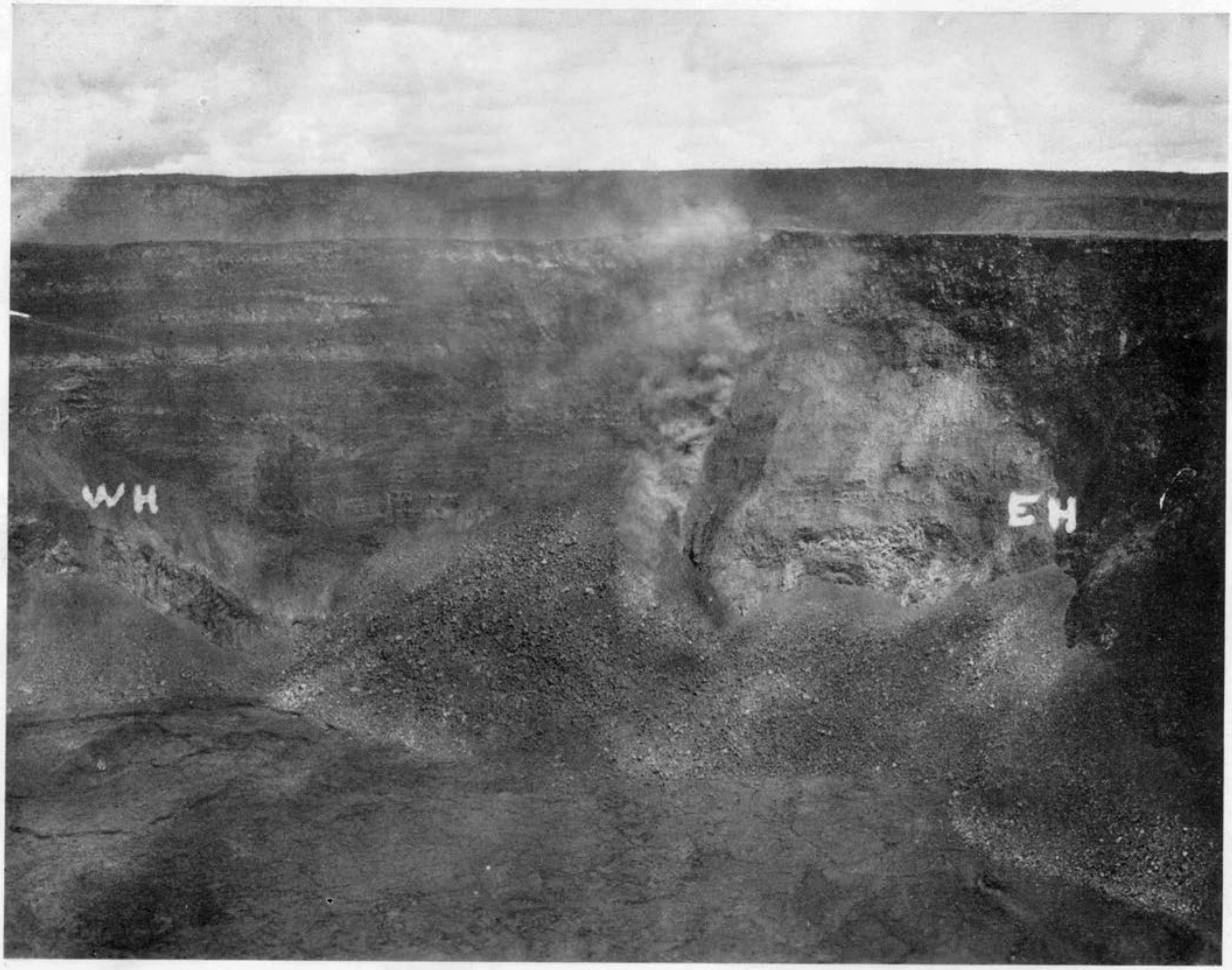


Figure 2. After collapse, October 22, 1936.

Generally speaking, all of the measured cracks have opened by varying amounts continuously during the period following the Halemaumau eruption of 1934. One exception is number forty-one, about eight hundred feet southwest of the pit. It has shown no change in the same time period. At present, crack number twenty-five on the east rim is moving most rapidly and some large rock falls from that portion of the pit should be imminent and are anticipated.

One of the earliest established and probably one of the most significant branches of routine research at the Hawaiian Volcano Observatory is that related to what is referred to in reports as tilt or tilting of the ground. This action, although well identified, is by no means too easy to measure. At the Observatory and at Halemaumau tilt is measured by the wanderings of the seismograph pens, with relation to a fixed value recorded on the smoked seismograph drum. Also, tilt around Halemaumau is measured by a special apparatus known as a clinoscope. Two of these are now in operation, one on the southeast rim, and one to the west of Halemaumau. A third instrument was located northeast of the pit but was disrupted by an earthquake. It is the earthquake situation which makes tilt measuring difficult here. The problem is to have an instrument as sensitive as a seismograph, of high magnification, which would be inexpensive but accurate, and earthquake proof. In Japan a partial solution, at least, seems to be a sealed horizontal pipe, about half full of water with means of measuring changes of level of the water at the ends of the tube.

Tilt has been defined by Dr. Jaggar and R. H. Finch as "a change in angular relation between a portion of the earth's surface and the plumb line." A plumb bob suspended from an arm on a tall flagpole should illustrate this by the bob swinging to or from the pole, or sideways as the ground tilted, thus changing the angle of the pole with relation to the horizontal. If it were possible to attach a pen to the top of the flagpole and this pen wrote on a sheet of paper which was permanently fixed to the sky in its position, then the pen would trace a picture of the tilt graphically on the sheet of paper, the size of the drawing depending upon the height of the pole, the taller the pole the larger the drawing.

Something of this nature is done at the Observatory. No flagpole is used but measured daily tilt on the Bosch-Omori seismograph is transcribed to a sheet of coordinate paper. Since the two pendulums of the seismograph are oriented north-south and east-west, these directions are used and all component directions resolved therefrom and a picture of what the top of the flagpole would have done is shown. It has been discovered that the ground on the northeast rim of Kilauea makes an

Figure 3. Crack No. 46 looking north before landslip.

Figure 4. Crack No. 46 looking south after landslip (man in Figure 3 would be in air beyond A).

annual loop as much as twenty seconds of rotational arc for the greater diameter which runs northeast, southwest. Minor irregularities and loops occur in the major annual loop. Marked directional tilts have occurred preceding eruptions both of Kilauea and Mauna Loa. In the first week of October, 1935, tilt at the Observatory began to move, following the vigorous earthquakes of September thirty-October one, in a southeasterly direction and continued to do so until November seventeenth, when the tilt direction changed back to the northeast and on November twenty-one Mauna Loa erupted, thus relieving the pressure which had tilted the ground some two or three seconds at the Observatory. The tilt resumed its normal trend and made its usual annual loop in 1936. So far this year the tilt has moved slightly west of south very rapidly, necessitating adjustment of the seismograph to take care of the change quite frequently. However, this movement seems to have slacked up now and little tilt of any kind has occurred in the past week or ten days. What this may mean is a little uncertain but may mean considerable lowering of downward pressure under the crater.

The clinoscopes previously referred to as located around Halemaumau are quite different from seismographs. They consist of a circular heavy mass of iron suspended from a tripod frame supported by piano wires. The mass is damped by a tank of oil in which it moves. Thus, the arrangement is that of a plumb bob or pendulum attached to delicate levers and pivots which extend up in the tripodal frame. At the end of the light lever or boom is a point which approaches the face of a target-like indicator. This target indicator is graduated into concentric circles with a separation of two millimeters. From the center point are radiating lines corresponding to the cardinal points of the compass. The migration of the lever pointer indicates tilt by amount and direction. The magnification of the clinoscope has been previously calculated so that actual angular and directional daily tilts of the ground may be plotted graphically just as in the case of the seismograph at the Observatory. Since the clinoscopes are on widely separated portions of the pit rim, and the direction of the center of the pit is known with reference to the tilt stations, it becomes possible to resolve the components in such a way as to determine the radial tilt to or from the pit. Tilt toward the pit should indicate lowering in that direction accompanying decreased pressures with the reverse being true of tilting from the pit.

Dr. Jaggar and Mr. Finch in 1929 described tilt records and results for the thirteen years from 1913 to 1925 inclusive. Their very interesting conclusions will bear repeating and are as follows:

"1. Seasonal tilts of twenty seconds or more in a half-year

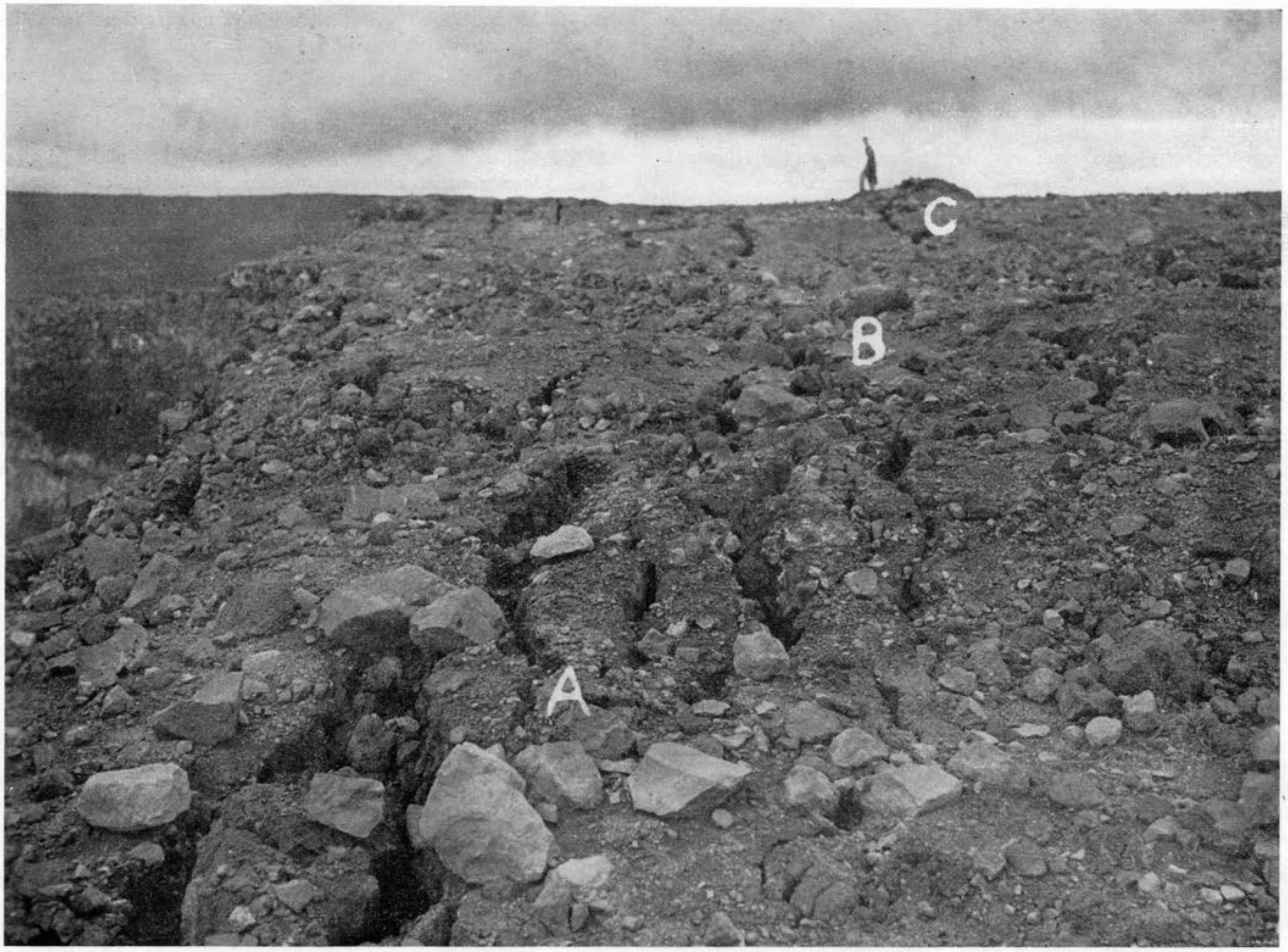


Figure 5. Before notch caved in 5:54 a.m. October 22 (taken October 20).

vary with air temperature, easterly tilts corresponding to cold months, westerly tilts to hot months.

"2. The range of angular tilting per half-year is greater when measured gushing up of lava is greater. The gushing up of lava and easterly tilting have been regularly greater in autumn and winter.

"3. There is practically no correlation between tilt and rainfall.

"4. Between 1913 and 1920 there was a northeasterly tilt of about eighty seconds accumulated at Kilauea, and an elevation of about 0.6 meters in the central part of the mountain, diminishing apparently to zero in a radius of ten kilometers. This was a partial eruptive cycle, characterized by rising lava.

"5. Between 1920 and 1926 there was a southwesterly tilt of about ninety-three seconds, accumulated at Kilauea and a depression at the central part of the mountain (distinct from collapse at the pit) of about four meters, diminishing in a radius of twenty-two kilometers to 0.09 meters. This was an extraordinary half-cycle of lava subsidence plus explosive eruption with engulfment.

"6. The total void computed from the engulfment and subsidence data is approximately 757 million cubic meters, of form suggesting the evacuation left by an intrusive sill of about thirty kilometers radius, swollen in the center.

"7. Local earthquake frequency and centripetal tilt accompany lava subsidence, otherwise there is little correlation between tilt and earthquakes.

"8. There is perfect correlation between Kilauea lava movement and Mauna Loa lava movement, whenever the Kilauea lava pit is not sealed. The east-west tilt curve exhibited accumulation of easterly tilt preceding every Mauna Loa eruption. The north-south tilt curve followed consistently the overflow and subsidence phases of Kilauea. These facts agree with the position of the instruments, north of Kilauea and east of Mauna Loa.

"9. Explanation of the correspondence between easterly tilt and lava gushing, on the one hand, and winter atmospheric mean lower temperature, on the other, is difficult. Two possible explanations are: (a) that solar heating in the summer checks volcanic radiation, whereas outward conduction is stimulated by the winter cold; (b) that a winter solstice tidal effect acts on the east-west fissure of the Hawaiian ridge, owing to a solar pull southward on the great mass of the ridge and on the equatorial protuberance. this might produce trigger stress for winter effervescence and tumescence, if the lava sponge below were in nice adjustment for gas-pressure release. Possibly both (a) and (b) work in concert."

If I may talk to you again at some future date, I should like to tell about level and triangulation values in the vicinity of the local volcanoes with corroboration of their action by volcanoes in other parts of the world.

Meanwhile, don't lose patience with Pele—Kilauea is going to erupt. However, I am glad this is a radio, so no one can ask me "when". Thank you.

Hawaiian Volcano Observatory Report for April, 1937

VOLCANOLOGY

The following are weekly data for observations of the Observatory near Kilauea Crater, including slides and rim-crack openings of Halemaumau Pit, the center of expected eruptions of the crater:

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Quakes
April 4	25.00	1	25.0 mm.	75
" 11	30.75	6	34.0 mm.	89
" 25	15.50	5	44.5 mm.	42
" 28	13.25	10	28.0 mm.	42
May 2	12.50	2	47.0 mm.	46

Slides continued the third week, 7 quakes were from Kilauea, 2 probably Mauna Loa, 1 at Hualalai.

The fourth week continued noisy slides and increased opening of eastern cracks, 4 quakes including a perceptible one were at Kilauea, 2 were probably at Mauna Loa.

The fifth week ending May 2 showed fewer slides but increased opening of an eastern crack, indicating approaching collapse of that rim. A distant earthquake released a prolonged local tremor April 29. Eight quakes were from Kilauea, two probably Mauna Loa.

Slides at Halemaumau, and fumes

Slides from the wall of the pit have been noted as follows: April 4, 2:50 pm, small slide made dust east.

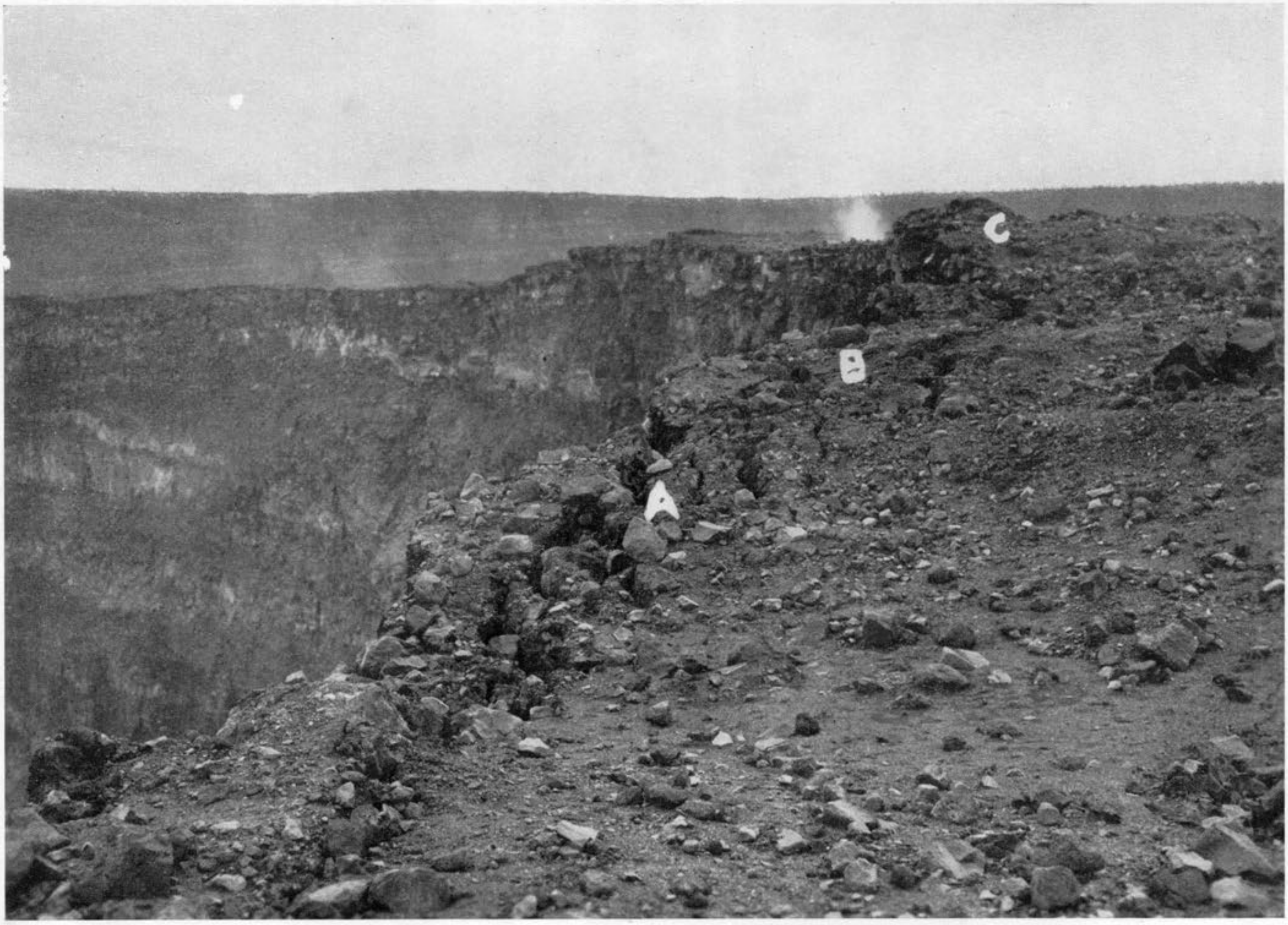


Figure 6. After the caving in, taken October 22.

Of felt earthquakes there were two in the feeble class, April 1 under Pahala (felt at Hookena), and Kau Desert, one under Hualalai felt strongly at Puuwaawaa ranch and otherwise generally felt April 18, and two April 30 at Kilauea.

Sequence of Events by Weeks

The first week ending April 4 had the Pahala shock and one reported slide at Halemaumau. There were 13 Kilauea quakes, four at northeast Mauna Loa rift, and one at southwest rift Mauna Loa.

The second week had numerous slides at east wall of Halemaumau, 15 quakes at Kilauea, 7 at Mauna Loa, including 2 stronger ones.

April 7, morning showed small slides had left scars on wall 400 feet under east cliff.

April 8, slides making dust NNE and E 12:38 pm, 1:05 pm, 1:10 pm, with rumbling heard at Uwekahuna, dust continuing to 1:20 pm. Intermittent dribbling of rocks 2:00 to 3:30 pm.

April 10, similar dribbling east 9:57 am. Fuming from solfataras at edges of floor was slight, becoming visible after April 9.

April 12, 3:20 pm, slide made dust cloud NE.

April 14, 3:25 pm, another at same place.

April 15, 11:47 am, slide made loud rumble, no dust.

April 16, all day 9 am to 5 pm, rock slides N and E, a noisy one sending up dust 11:30 am.

April 18, SE solfatara sent up conspicuous blue fume along with vapor of excessive humidity, noted 3 to 4 pm.

April 21, 9:57 am, small noisy slide NE.

April 25, 9:49 am, moderate slide NE after two small earlier ones, and followed by a large noisy slide 9:54 am, making dust cloud.

April 26, scars showed recent slides, and a small slide made the sound of falling rocks heard at Uwekahuna 11:30 am, and sent up dust.

Measurement of Halemaumau Rim Cracks

Weekly measurement of 26 rim crack locations resulted in aggregate movement as follows: week ending forenoon of—

April 2, 12 opened, 2 closed, opening 25.0 mm.
" 9, 14 opened, 0 closed, opening 34.0 mm.
" 16, 10 opened, 3 closed, opening 28.0 mm.
" 23, 8 opened, 1 closed, opening 44.5 mm.
" 30 9 opened, 3 closed, opening 47.0 mm.

On April 23 two cracks close to the east edge contributed most of the opening: No. 24 5.5 mm., No. 25 36.0 mm., and these are behind rim blocks of rock extending southward the edge that collapsed in October, 1936; they are going to fall soon. On April 30, crack No. 25 contributed 42 mm.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Moderate Earthquakes	Distant† Earthquakes	Weekly* Seismicity
April 4	56	16	3	0	0	0	25.00
" 11	67	20	1	0	1	0	30.75
" 18	31	9	1	0	0	1	13.25
" 25	36	5	1	0	0	0	12.50
May 2	35	8	1	1	0	1	15.75

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 and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible, a determination of depth of focus has been made.

March 29, 7:53 am, very feeble, probably located in Mauna Loa NE rift near Puu Ulaula.

March 29, 9:15 am, very feeble, located in Kilauea Crater.

March 29, 6:52 pm, very feeble, located in Kilauea Crater.

April 1, 5:31 pm, feeble, located in the vicinity of Pahala near the Kaapao Pali, and 20.0 miles deep. Reported felt in Hookena, where buildings creaked and hanging objects moved. 19° 13.3′ N; 155° 30.2′ W.

April 1, 6:49 pm, feeble, located 3.7 miles deep under Kalanaokuaiki Pali 1.3 miles SW of Puu Ohale. 19° 20.7′ N; 155° 17.8′ W.

April 3, 9:30 am, very feeble, located in vicinity of Kipuka Puaulu (Bird Park), 3.8 miles deep. 19° 26.5′ N; 155° 18.3′ W.

April 3, 10:55 am, very feeble, probably located under N rim of Kilauea Crater.

April 4, 1:52 am, feeble, located 0.5 mile west of Puhimau Crater 1.5 miles deep. 19° 23.7′ N; 155° 15.5′ W.

April 4, 8:10 am, very feeble, located 4.5 miles NW of the Observatory 1.4 miles deep. 19° 28.6′ N; 155° 18.9′ W.

April 4, 11:59 am, very feeble, thought to have been located in Chain of Craters area SE of Kilauea near Hiiaka Crater.

† Includes teleseisms or those shocks over 5000 kilometers distant.
* For local seismicity definition see Volcano Letter 371.

April 4, 5:11 pm, very feeble, probably located in SE portion of Kilauea Crater near Keanakakoi.

April 4, 11:41 pm, very feeble, of Mauna Loa origin.

April 5, 6:18 am, very feeble, probable location, Kilauea SW rift 0.7 miles NE of Cone Peak.

April 5, 9:47 am, very feeble, thought to have been located in Chain of Craters area, near Devil's Throat.

April 5, 10:57 pm, very feeble, located in Mauna Loa NE rift near Puu Ulaula and 18.0 miles deep. 19° 30.5′ N; 155° 29.0′ W.

April 6, 12:37 am, very feeble, located 1.5 miles W of Puhimau Crater and 0.5 mile SW of Kilauea Crater, 4.2 miles deep. 19° 23.7′ N; 155° 16.5′ W.

April 6, 11:15 am, very feeble, located 5.1 miles deep and 1.2 miles east of Kilauea Iki Crater. 19° 24.8′ N; 155° 13.5′ W.

April 6, 4:46 pm, very feeble, located 4.2 miles deep and 2.0 miles W by N of Uwekahuna. 19° 26.0′ N; 155° 19.8′ W.

April 7, 12:18 am, very feeble, located in vicinity of Lua Manu Crater 2.4 miles deep. 19° 24.1′ N; 155° 15.6′ W.

April 7, 9:51 am, very feeble. Probably located 2.3 miles SE of pit seismograph.

April 7, 11:02 pm, very feeble, located 4.2 miles deep in Kilauea SW rift zone near Cone Peak. 19° 21.9′ N; 155° 19.3′ W.

April 9, 12:18 am, very feeble, thought to have been located under Halemaumau.

April 9, 7:29 am, moderate, located near seacoast at Apua Point 3.0 miles S of Hilina Fault system and 7.0 miles deep. 19° 16.3′ N; 155° 12.2′ W.

April 9, 5:46 pm, very feeble, probably located in Kilauea SW rift, 3.8 miles from Halemaumau.

April 10, 9:24 am, very feeble, probably located 0.5 mile NE of Kilauea Crater.

April 10, 1:21 pm, very feeble, located 2.8 miles deep in Chain of Craters area near Hiiaka Crater. 19° 22.6′ N; 155° 14.0′ W.

April 11, 2:52 am, feeble, located near Mauna Loa NE rift 3.5 miles S of Puu Ulaula, 13.0 miles deep. 19° 29.4′ N; 155° 29.3′ W.

April 12, 7:38 pm, very feeble, located 2.4 miles deep near Lua Manu Crater. 19° 24.1′ N; 155° 15.6′ W.

April 13, 7:03 am, very feeble, located in rifts 0.4 mile N of Puu o Hale, 1.5 miles deep. 19° 21.5′ N; 155° 16.6′ W.

April 13, 8:33 am, very feeble, probably located 1.5 miles NE of Kilauea Crater.

April 15, 6:28 am, very feeble, located in cracks near NE rim of Keanakakoi Crater, SE portion of Kilauea Crater. 19° 24.2′ N; 155° 15.1′ W.

April 15, 6:21 am, very feeble, thought to have originated in Kaapo Pali near Pahala.

April 17, 12:14 am, very feeble, of Kilauea Crater origin.

April 17, 2:17 pm, very feeble, of Kilauea Crater origin.

April 18, 2:44 am, very feeble, located 1.2 miles deep under Byron Ledge, SE rim of Kilauea Crater and 1.0 mile east of Halemaumau. 19° 24.6′ N; 155° 15.9′ W.

April 18, 4:10 am, feeble, originated under Hualalai Volcano. Reported felt at 29.0 miles on Volcano Road, Hilo, Kamuela, and very strongly at Puu Waawaa Ranch House.

April 18, 8:50 pm, very feeble, probably located 1.5 miles E of Kilauea Crater and 1.0 mile S of Kilauea Iki.

April 19, 5:59 am, feeble, located under SE rim of Kilauea Crater, 1.2 miles deep. 19° 24.5′ N; 155° 15.5′ W.

April 20, 4:08 pm, very feeble, probably located in Hilina Fault zone N of Apua Point.

April 21, 11:59 pm, very feeble, probably located in Mauna Loa NE rift about 5.0 miles NE of Puu Ulaula.

April 23, 4:08 am, very feeble, probably located in Chain of Craters area near Devil's Throat.

April 30, 3:08 am, very feeble, located 0.7 mile deep near center of Kilauea Crater 19° 24.9′ N; 155° 16.3′ W.

April 30, 3:40 am, slight, located 0.8 mile deep near E edge of Keanakakoi Crater SE portion of Kilauea Crater. Reported strongly felt at the CCC Camp, felt at 29.0 miles on Volcano Hilo Road and dismantled pit seismograph. 19° 24.2′ N; 155° 15.9′ W.

April 30, 9:29 am, feeble, probably same location as preceding.

April 30, 12:35 pm, very feeble, thought to be of Kilauea origin.

May 2, 5:26 pm, very feeble, 5:27 pm, very feeble, and 5:29 pm, very feeble, all thought to be of Kilauea Crater origin.

Four minutes of continuous tremor began recording at the Observatory at 9:06 am, April 29.

Microseismic motion of the ground at the Observatory was strong throughout the month except from April 25 to 30 inclusive and April 18, when it was moderate.

The preliminary waves of a distant earthquake began to register at Kilauea at 4 hr. 39 min. 25 sec. pm, H.S.T., April 15. It was estimated to have occurred 2,700 miles distant, probably in Alaska. The preliminary waves of a teleseism began recording at Kilauea at 8 hr. 29 min. 41 sec. am, H.S.T., April 29. It was estimated to have been 3,560 miles distant.

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 towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending May 2, was 8.47″ S and 0.76″ W.

Week Ending	Observatory	Halemaumau West Station
April 4	1.64″ N 45° E	3.37″ N 60° W
" 11	0.73″ N 51° W	6.05″ S 76° W
" 18	1.11″ S 37° W	5.54″ N 67° W
" 25	0.17″ S 44° E	5.22″ S 73° W
May 2	1.17″ S 31° W	4.32″ N 71° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
April 4	7.23″ N 3° W	3.32″ Toward
" 11	4.47″ N 27° W	1.59″ From
" 18	4.99″ N 3° E	1.04″ From
" 25	6.48″ N 53° W	1.90″ From
May 2	3.95″ S 42° W	4.68″ From

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory, April 21, showed slight closing of both Halemaumau and Crater values compared with similar measurements March 24. From Kilauea SE rim to Uwekahuna there was closing of 1.75″, March 24 to April 8, and opening of 1.67″, April 8 to April 21. Total closing 0.08″. From the Pit Seismograph to NW Pit B.M. there was closing of 2.00″, March 24 to April 8, and opening of 1.66″ April 8 to April 21. Total closing 0.33″.

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

THE VOLCANO LETTER

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Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

Figure 1. Rim of Kilauea fire-pit falling in as lava below escaped to the submarine slope 1924. The collapse alternated with explosions of steam. An earth event limited to a single month.—Photo by Tai Sing Loo.

TRENDS IN THE PHILOSOPHY OF SCIENCE

T. A. Jaggar*

By the philosophy of science is meant the definition of its motives. What has a group of scientists in common? How has the motive of their labors changed in a hundred years since Darwin and Faraday worked? Whither are we bound, and what are the boundaries, in the professions called scientific?

Science is said to be any knowledge that appraises data with logic and care, and uses the method of classifying, generalizing, induction and deduction. But this would apply in some measure to literature, education, languages, history and economics.

The modern meaning of science is limited to the nature sciences, for which the earth is the chief subject, with its kinsfolk the stars, and its products and processes including man himself.

Language is the chief instrument of science, including mathematics, which Willard Gibbs defined as a language. Observation and experiment are the chief activities. Application to human service, and the reform of that service to man's benefit, are the chief goals of science.

Language, the chief promoter of science

It is curious there is no chapter on "language" in Karl Pearson's "Grammar of Science". We learn much of the unreality of matter, force, space and time, "intellectual concepts describing our perceptual routine". We learn about constructs, ejects, contingency and correlation. We are told that science lives upon inference and is a classification and analysis of the contents of the mind. But not a word appears to show that those contents, in the form of thinking, are what Watson calls "sub-vocal talking". An important eject is "other-consciousness", which must agree that two normal perceptive faculties construct practically the same universe. But do we always agree to this? Similarity of perceptive and reasoning faculties depends on a common thought-language.

This point appears frequently missed. Language, mathematics, and logic are not science. But they are the stuff without which science could neither be conceived nor conveyed. Clearly written and spoken language is at the root of accuracy. If you cannot say what you think, you cannot think what you think you cannot say.

Take the subject of forecast. Science is the study of nature; **natural** universe, earth, force, life; origin, progress and future of each of these. Do not omit the future. Science is the first human craft to treat prophecy without superstition. Prophecy based on measured accuracy is the supreme test of science. Astronomy can understand a Babylonian eclipse in the light of mathematical forecast, a new language. Truthful history by its cycles may illumine prophecy. Language by its structure is itself history. What is "prophecy" but the Greek for "speaking before"? It is important to know the history of mother-tongue, and to talk and think foreign tongues.

If we sav "inevitable" we are using a French word. Our word "passenger" is not identical with "voyageur". We have no word to connote "geschwister", meaning either brother or sister. We have no word such as an imaginary "menwo", meaning either men or women; "persons" or "people" is not an identical sense. "Onto" is not good English, but is a needed word. We have "widen", but we have no "smallen". "Scientist" hardly includes the ladies, and "men of science" certainly leaves them out. Such are the limitations of thinking.

One can be scientific in speech without language being a science. One can be mathematical in business without business being mathematical. One can be either qualitative or quantitative in science, without science being mathematics. So in the scientific laboratory one can be humanistic, artistic, businesslike or religious. But language is supreme in reasoning, and needs history and all scholarship for scientific use.

"The American Language" by Mencken shows how Americans are remodeling the thinking of the British empire by their straight-shooting lingo. Such language remodels thought and science. Illustrations of vividness are the phrases "What is your reaction?" and "That is not in the picture". The pencil or blackboard chalk illustrates the incessant use of pictographic language in science: we cannot explain without a map, curve, section, formula or sketch as we talk or think.

It may seem strange to stress the importance of words. The diplomats have an expression, "finding a formula". If they had "found a formula" August 1, 1914, the difference might have been to avoid the Great War. Writing science that is understood by the people may get suggestions for progress from a hundred minds; illustrations are the camera, telescope, and radio hobbies. How different this is from the jealousy for priority in Europe. "The best test of the truth", wrote Mr. Justice Holmes, "is the power of the thought to get itself accepted in the competition of the market".

Does science spend as much effort over its phrases as it does over its differential equations? Does it consider the comparative value for progress, of writing a sound newspaper editorial rather than a technical paper? Does it compare the outreach, in selling the goods, of spoken thought compared with the printed word? Spoken speech is creating classes for adults all over the world, because of the realization of our slovenly voices and use of words that people get from listening to radio. Radio is itself a means for propagation of the gospel of science.

Our technical memoirs are long, boresome and addressed to specialists. Difficulties of reading and abstracting, and photographic methods of filing, mean that the short paper has come to stay. The scientist counts on these to sell his goods, but technical terms hide scientists even from each other. Even school teachers have a jargon of technicalities, ratings and curves along with I.Q., P.Q., Hi/Y and as many alphabets as a British army corps. The passion for abbreviation in America is only exceeded by invention of words; realtor, cosmetician, groceteria, mortician, and lubritorium. Non-mathematical scientific papers might sometimes, in the same space, be made intelligible. Remember that mathematics is a different language.

University teachers, in my own experience of Munich, Heidelberg, and Harvard, defeated their own sciences for me as a budding student. Rosenbusch set me to work on one felspar crystal all summer, when I wanted petrography of field rocks. Groth fascinated me with mounted crystals, but I ought to have had association of minerals in nature. Germanized, I returned to Harvard and wrote a doctor's thesis designed to test the abrasion hardness of a large number of crystalline minerals measured with a microscopical instrument that I invented. Result, my Harvard professors said "a mere instrument would not be enough for a doctor's degree", and dissipated my efforts on a double thesis adding a field subject in geology. Here everything turned on the wrong interpretation of three words, "a mere instrument". It all threw me out of mineral collections, and into volcanic craters.

Science is learning the power of speech on the public. Commerce, engineering and industry employ all our sciences in advertising: right there by clear and forceful speech science may educate commerce, engineering and industry.

Experiment, the chief activity of science

In my youth Audubon was my ideal as a scientist, motionless for hours watching wild turkeys in the forest, sketching and painting them, and combining system and art in large

* Address at Hawaiian Academy of Science, Honolulu, May 6, 1937.

volumes of colored plates. Darwin extended this idea to breeding experiments with domestic turkeys. Faraday, Darwin and Pasteur established experiment as the final arbiter of science.

Probably ninety per cent of my audience are laboratory people. Even when your constructive work is in the field, as in the innumerable branches of engineering that have grown up since Audubon's time, you make laboratory tests before you act. Engineering is the most important scientific application in the world today. Vital sciences have been taken in as the soul and body of commerce, including industrial psychology, physical chemistry, biology, preventive medicine and public health, meteorology and radio. Even experimental ethics and social service are commercial sciences. This is a far cry from the lonely impoverished French artist watching the bird in the wet jungles of Louisiana.

Science holds men and women because today it is interested in people and action. It produces results. Engineers are interested in designs, professors in research, merchants in growth of service, sea-captains in increased efficiency, doctors in visible cures.

The old geology, zoology, botany, chemistry, physics and astronomy are being replaced by geophysics, biometry, experimental physiology, electro-chemistry, atomic physics and astrophysics.

Medieval science mingled art, religion and science. We have learned to separate the compartments, the experimental field today is unlimited, and the method involves a quest of objective proof in America, started by Benjamin Franklin using common sense, and willing to tackle any subject from thunderstorms to volcanoes.

Just a word about the old physics of the nineteenth century, which considered solids, liquids and gases in motion, at controllable room temperature and pressure as the subjects of investigation. We human beings, and the soil we dwell upon, are solids, liquids and gases in motion. We are constantly told that the old physics thought it had nothing more to discover. We are practically told by the atomists that, as organic human subjects of bio-physics, unless we can be agitated at high voltage as a rarefied gas, we are not interesting.

This appears to me to be pure hokum. The nineteenth century never had such complacency. There was never a time of such immense foresight and development as from Faraday, through Clerk Maxwell, Elihu Thomson, Hertz, Kelvin, Helmholtz, Roentgen, the Curie Family, and J. J. Thomson. Look at the other sciences, Humboldt, Lyell, Darwin, Haeckel, Huxley, and Bergson the philosopher: Virchow, Koch, Pasteur, and Osler: and in America, Rumford, Gray, Newcomb, Dana, Rowland, Agassiz, father and son, and Welch. The twentieth cen-

Figure 2. An expedition travels 12,000 miles for a single earth event—to photograph an eclipse of the sun—Navy Expedition, 1930, Niuafoou Island.

tury has barely scratched the surface with a few mathematical philosophers who are primarily linguists groping for ultimates. Otherwise we are working through corporate laboratories rather than individuals. This is good, but there is no sense in decrying the nineteenth century, nor in forgetting that our own seventy kilograms of flesh on solid rock has a problem apart from high voltage.

Reform, the chief goal of science

As science has become increasingly serviceable, so has it become less selfish. Stoddard has said "those peoples who first grasp and act upon the basic principles of the new knowledge will rightfully be the heirs of the future". Who will do it, the Germans, Italians, Russians or Americans? Reform has been disguised as research.

The twentieth century outlook on science has been jolted by the War and the Depression into seeing the need for more practical results, and the conquest of the world by extroversion. Here is a case of a new **word** for successful personality, the soul that opens outward instead of inward. We may have extrovert people, laboratories, cities, factories and nations. In this century the Wrights, the General Electric and Eastman Laboratories, the Peking Medical Center, Henry Ford, the Carnegie Institution, Rockefeller Medical Research, the Mayos, the Cancer Research Laboratories, and the Brookings Institute are all working on a theory of competitive donation. The Nobel and Cecil Rhodes Foundations and others are doing the same in Europe, Africa, Asia and South America.

Our government is extrovert, following upon the vague beginnings of the Monroe Doctrine, our missionary wars, the Open Door, and the Bryan and Kellogg Pacts. The South American pact and the Neutrality Law are a direct heritage of Woodrow Wilson. His League of Nations may seem eclipsed for the moment, but its scientific commissions are at work all over the world, and youth is arrayed against the armament trust. The present employment agencies and large engineering enterprises of the American government are extrovert science. Look over the list, and remember it is not confined to America. Public health, engineering, social security, public housing, slum clearance, agricultural relief, flood control, economic sciences, eugenics, home economics, home workshops, and adult education; add to this forestry, the great irrigation projects, the Tennessee Valley Authority, and the proposal to change the name of the Department of the Interior, which originally exploited our land in Audubon's time, to the Department of Conservation; and you have a world that would certainly astonish Andrew Jackson. Our extrovert government is opposed by the ancient acquisitive society of business. But science is responsible for our social consciousness of our kind. If psychology does what insurance has done, it may develop a cooperation of all science to higher accuracy, and higher truth than physics and mathematics.

The three fundamental concepts of all science are uniformity, evolution and value. Possibly evolution, uniformity, symmetry and rhythm are in Nature herself. Probably value and number are wholly human.

A tremendous gain over the nineteenth century is that physics, psychology and biology have all learned to distrust mechanism and to welcome positive liberalism. The intuitive of emotion, art, religion and philosophy, the elegance, symmetry, rhythm and universality of these cultures are more and more welcomed by science. Cosmopolitan demands will no longer allow science to dwell in a monastic cell.

Glenn Frank says that all laboratories have socially usable ideas that would lift the tone and temper of modern life. Our universities must dig up and put out the usable social ideas buried in each laboratory. Social science explores human nature for truth, searches for new ways, studies the "how", tests and "sees if", and finds out "whether". If your laboratory has an utterly new and usable idea, some island council should make you extrovert about it.

The Earth, the chief subject of science.

If you are studying the tonsils or teeth of school children or measuring binary stars, you may wonder what the earth has to do with it. This philosophy of science will be a success if it raises more questions than it answers. Science means the cooperation of all specialties. If they deal with human beings, they are concerned with civilization. The Polish Corridor, the Pyrenees, and Gibraltar are affecting the blood of future school children today. Civilization in America will be greatly affected by the eighty chemical plants in thirty different states of the DuPont de Nemours Company. They are placed in part for what the ground produces to make the earth yield up her increase.

Laboratory science likes to experiment with something like the fruit fly or white mice that will yield repetitions and controls. The earth, in explosive eruptions where lava flows drain out at the bottom of the sea (Figure 1), or in others capable of being bombed to save a city; the earth, in receiving the shadow of the moon (Figures 2 and 3) enduring seven minutes, does not admit of ten repetitions and ten experimental controls. But very important laws may be discovered from a single event.

The insurance man has the same problem; in life insurance he has hundreds of repetitions, and hundreds of controls. In disaster earthquake insurance, or in conflagrations, he has very few. Nevertheless, he learned something for his science in San Francisco, Tokyo and Napier. Henry Cabot Lodge, in spite of his opposition to Woodrow Wilson, said in a commencement address, "it is through the search for Utopias that the real advances have been made". Whatever your specialty in science, something about it may directly serve mankind out on the surface of the earth, and away from the congestion of cities. Science works either to discover the internal mind of nature, like Isaac Newton, or for a humanist love of nature like Audubon. The earth is a middle ground out of which we came ourselves; out of it comes all our food as well as the petroleum, iron and power that frame our civilization. The love of ultimates, describing something we cannot see in language which we do not understand, has tied science to cities.

But the age of infinite electric power is just across the threshold. Science is entering that door. The thing that created America was the frontier where man with axe and plow and rifle robbed nature and won freedom. The science of power is creating a new frontier that sees no limit to the materials and the arts that will build with the rock of the hill and the mud of the sea bottom. This is what is meant by the assertion that the earth is the chief subject of science.

It is the earth that affects our drinking water and our glands. It is the earth that produces a Utopia like the T.V.A. It is the earth that yields the atmosphere through which our airplanes fly. Seventy-two per cent of the earth's surface is a gigantic unexplored wilderness of fascinating possibilities possibly containing radium and all the rare earths and only just scratched for the first time by a recent invention that has taken a core six feet long from the mud covering this mysterious land. The core was obtained by shooting a tube straight down into the ground with a high-powered submarine gun (Figure 4). This wilderness is the bottom of the ocean.

The earth is necessarily the chief subject of science. It is conclusively so because science serves man. And man as the object of scientific effort is earthly, he is not celestial or electro-magnetic. It is in part science that is to blame, for

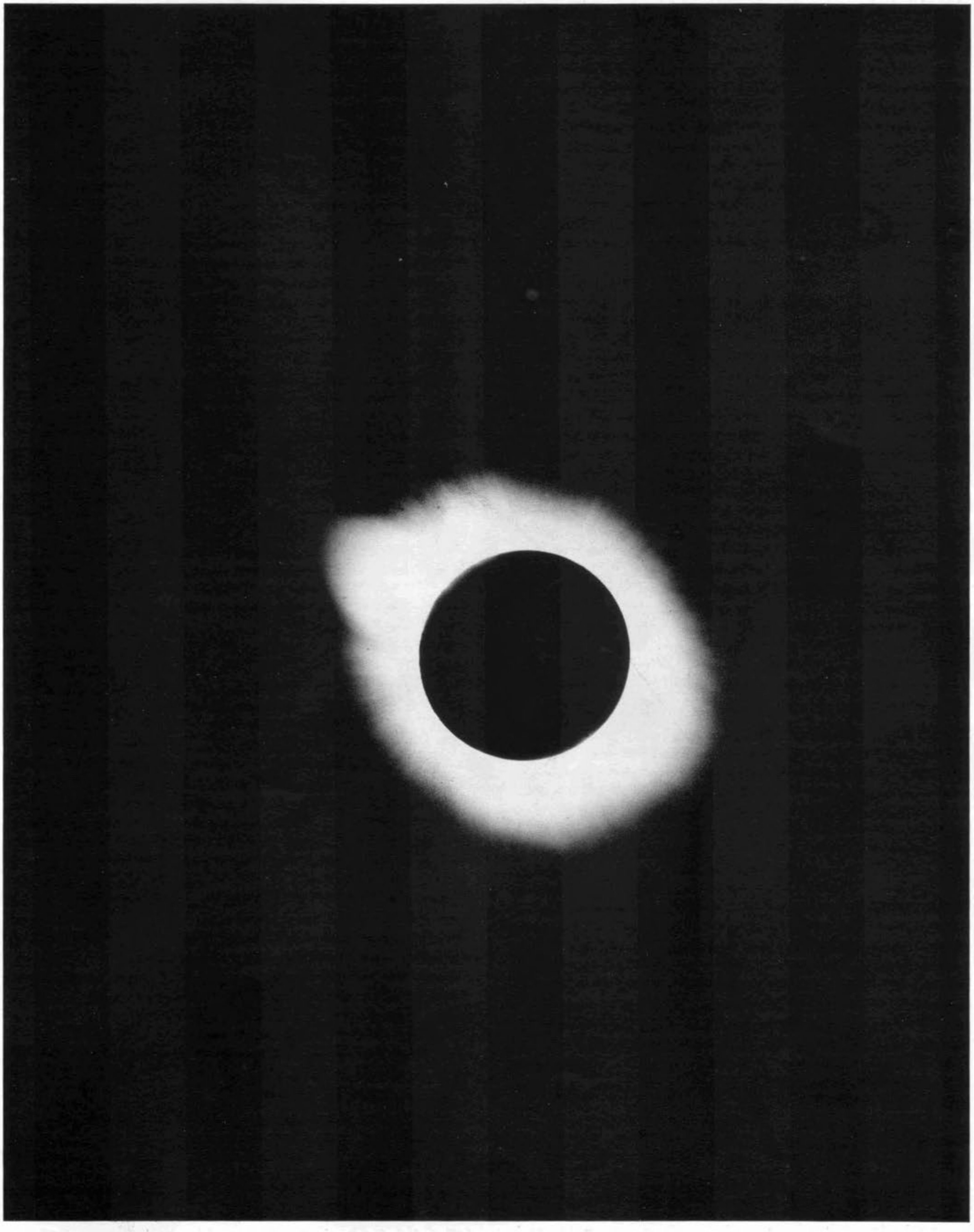


Figure 3. Photograph of the moon covering the sun's face. Niuafoou Island, October 21, 1930. Seventy men work three months for this photograph of an event lasting ninety-four seconds.

the misuse of science, that does not sufficiently consider man's happiness. Science agrees without protest to raising children in the sky-scraping gear wheels of a high stone-crusher like New York City, when there are thousands of square miles of country available with babbling brooks, grassy glades and sweet mountain air.

Science and education agree to an acquisitive society without protest, when every instinct of hygiene, sociality, uplift, public interest and experiment in the anthropometric laboratory suggests that human happiness lies in freedom, and in extroversion rather than acquisition. Science knows that an extrovert society will be more successful than an acquisitive one. Science has conquered distance and sluggishness, storm and savagery, famine and dearth.

But science shrugs its shoulder at the demand upon it to decentralize, to distribute and to invent a system of extrovert markets. Science knows it controls business, but it shrinks from reformation.

The terrestrial globe, the subject of the middle ground, producing the materials of physics and humanity intermediate between the electron and the germ cell, is pretty much left by the scientist to the rough and ready experiments of the prospector and pioneer, to the mountaineer and explorer, to the construction engineer and the navigator.

Laboratory science does not like to live in wild places. When we populate Howland, Jarvis and Wake Islands with a view to precise experiments in radio engineering and navigation of the air, we pick a group of Polynesian natives. If we were doing it in Antarctica we would pick a group of Eskimos or Icelanders. The suggestion is implied that no man or woman of European origin could reasonably be expected to live in a different climate. We are told that the Japanese have had similar difficulty in transporting their nationals to a colder belt. The earth is awaiting exploration by means of the new implements of modern science, but if modern laboratory science is afraid to dwell where the weather is hot, cold, dry or wet, the globe will remain undeveloped for the service of humanity.

Summary of trends in science

An attempt has been made in this essay for the speaker to review what fifty years of observation of natural history have impressed him as remaining unsaid and neglected in such general journals as "Nature" and "Science". The subject has been divided into four parts, in reviewing what seem to be the trends of scientific work in relation to human life for a century.

(1) First comes the overpowering importance of **Language,** both for thinking, and for arriving at agreement. Many scientists seem not to have realized with Willard Gibbs that logic, which comes from a Greek root meaning words, and mathematics, are languages and not sciences. It is not fair to say **mere** languages, because language itself, in the sense of the spoken tongue, is historically and constructively the most important implement in the whole range of all the sciences.

(2) Secondly, **Experiment** has been brought forward as the chief activity of science today. This is a great change from the time of Francis Bacon, who proposed categories, and extensions of science, which required observation rather than the invention of inductive tests.

A group of geologists, botanists, zoologists, and anatomists, meeting with natural philosophers and chemists at the Royal Society in 1845, was startled and delighted when Faraday sent in his nineteenth series of "experimental researches", to show that magnetic force produced an effect on polarized light. Medicine knew observational anatomy, and botany knew a systematic flora, but experimental physiology, phytometry, and phyto-chemistry had never been heard of.

There is of course nothing new nowadays in recognition of experimental work as a first essential of science. In my own science geology, however, the idea of experimental work in the field is decidedly new as a branch of pure science, and description of such work is notably lacking in the scientific journals.

(3) The third topic here considered, **Reformation** of the habits of mankind as the chief goal of science, is recognized by the gigantic efforts of special laboratories that the wealth of nations has produced, but is very little spoken of as an ethical ideal. The ethics of science emerges in the medical profession, and in some government activities actuated by political reform. In too many laboratories, however, science considers itself free, monastic, and privileged, or else it is frankly subservient to mercenary despotism.

The timidity of science in a bellicose world of overpowering industrialism and politics has had something to do with the two great catastrophies of the twentieth century.

(4) The last topic here considered, the **Earth** as the chief subject of science, involves a philosophical consideration, that few of you have ever thought of. Your own compartment was enough, and the earth could be left to the geologists.

What is the result? Thousands of men are at work building sensitive instruments, elaborating closed spaces for every possible temperature, pressure, and electrical condition, breeding insects, birds, animals, plants and bacteria for every possible service, and creating instruments of superlative grandeur, for evaluating the physical and chemical conditions of the universe of the stars. But all of this has preserved the habit of inertia in dwelling close to congestion centers, that existed in London in 1845.

It is only recently that the surface of the globe begins to be encased in a human net, demanding knowledge of the matter in outer atmosphere, mountain and plain, river and shoreline, sea-bottom and island; it is only recently that volcano and earthquake, simoon and flood, forest conflagration and drought, insect plague and blight, erosion and silt, have assumed proportions, where the interlocking of nations has made the misfortune of one a catastrophe for all.

Thus have sprung up geophysics, climatology, ecology, comparative anthropology, epidemiology, critical quarantine, and remedial construction in the service of insurance.

The people of London who looked upon Humboldt, Darwin and Livingstone as great explorers, have today barely begun to realize that travel is no longer a scientific virtue.

The discovery of the natural history of the earth by science can only be done by distributed laboratories that take pride in leading human enterprise to wealth that now is unsuspected. That wealth is partly materials, partly power, partly education. In metals China owns most of the tungsten, Canada the nickel, Peru the vanadium, South Africa the chromium, and America the molybdenum. The now precious xenon and krypton of the atmosphere are exercising the electric industry. The power of the sunshine and the tides is coming. **Science** it will be who shall educate the world to sheathe the sword, because happiness lies in experiments with mutual giving by men.

Hawaiian Volcano Observatory Report for May, 1937

VOLCANOLOGY

At Kilauea volcano the inner pit of the crater called "Halemaumau" went through another crisis of rim cracking on May 7, the east edge caving in, and carrying away a marked measurement-crack. This was an extension of the rim-breaking northeast that happened in October-November, 1936. Later in May the opening of eastern cracks diminished. There were two slight earthquakes, May 15 and May 30, the first of doubtful origin, the second about the Hilo end of the northeast rift of Mauna Loa. Thirteen very feeble shocks appeared to originate under Kilauea.

The following are the weekly Observatory totals for Halemaumau and the seismographs:

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Quakes
May 9	6.75	1	65.0	22
" 16	10.75	2	46.0	31
" 23	4.25	3	19.0	13
" 30	10.50	1	16.5	29

Sequence of Events by weeks

The first week produced the crisis of rim breakage at Halemaumau on the east side, just south of the notch which caved in last October. The description and photographs of that collapse appeared in Volcano Letter 446. The cracks there for several weeks have exhibited excessive opening. The index fissure was Crack No. 25, which expanded its opening 36, 42 and 57 millimeters respectively April 23, April 30 and May 7. On the last date came the falling in.

The second week showed eastern cracks continuing to widen and break the soil, and to make hot vapor.

The third week produced less widening of cracks and a few slides. New measurement marks back of northeast rim were established by placing copper studs on opposite sides of cracks. Seismicity declined.

The fourth week continued the lessening of crack-opening. In the wall of Halemaumau below the edge east an upright chasm was uncovered by a slide.

Slides at Halemaumau

Slides, and their effects, from the wall of the pit have been noted as follows:

May 7, evening, a length of about 40 feet along the rim caved in, probably 15 feet wide at the place of maximum breakage. Within this piece Crack No. 28 was destroyed and removed; this crack had not been opening, but was rigid with the rock that fell.

May 15, 2:35 p.m., a slide east, dust cloud and noise of falling rocks.

May 16, 8:30 a.m., a moderate slide sent up a dust cloud north.

May 18, 4:30 p.m., dust cloud from a slide northeast.

May 20, 11:05 a.m., a slide east sent a cloud of dust floating away westward.

May 21, 3:50 p.m., an east-northeast slide occurred.

May 25-26, night, a slide from the east wall uncovered an upright chasm, in the area of recent active caving fenced off from the Volcano House trail.

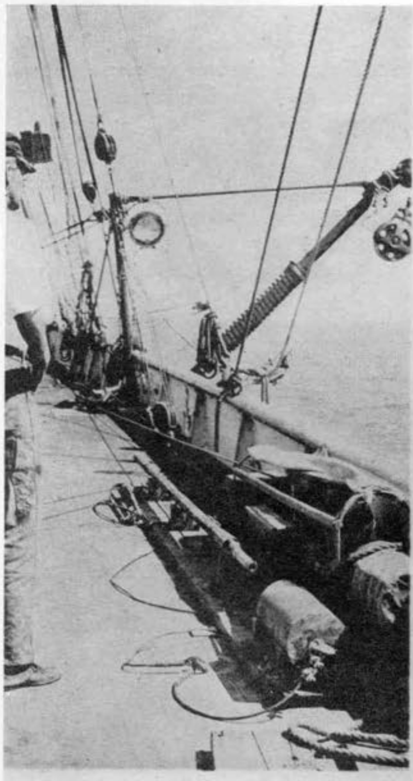


Figure 1. Apparatus in chocks on deck

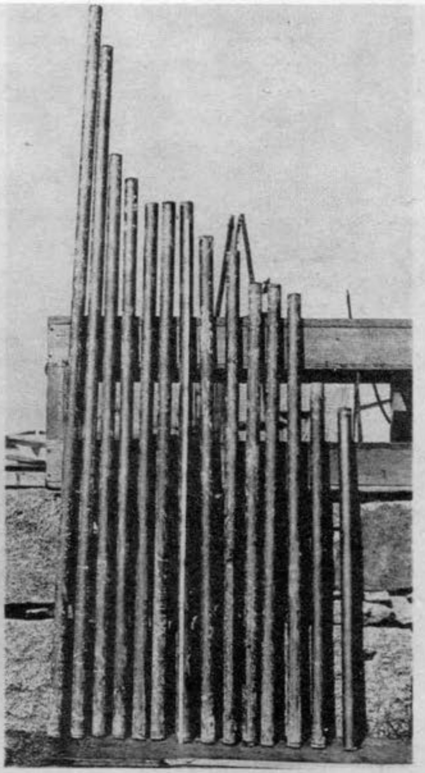


Figure 2. Cores taken August 1935 from depths of 200 to 1250 fathoms

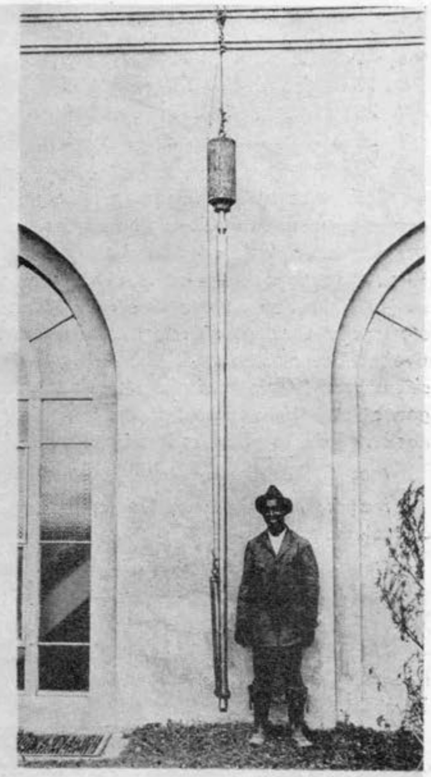


Figure 3. Core sounding apparatus ready for use

Figure 4. Core-drilling harpoon of Dr. Piggot. (Bull. Geol. Soc. Amer.—1936.) To sample the seventy-two per cent of unknown land—the sea-bottom. The gun takes cores 6 to 8 feet long in 200 to 1,250 fathoms of water.

Measurement of Halemaumau Rim Cracks

Weekly measurement of a varying number of rim crack locations destroyed and reconstructed during the month of May, resulted in aggregate movement as follows: week ending forenoon of—

May 7, 26 locations, 9 opened, 1 closed, opening 65.0 mm. collapse in evening destroyed No. 28.

May 14, 25 locations, 9 opened, 1 closed, opening 46.0 mm., to which Crack No. 25 contributed 40 mm. A new location, No. 37a, was established east of the road on an extension of Crack No. 37.

May 21, 26 locations, 7 opened, 1 closed, opening 19.0 mm., to which No. 25 contributed 14.0 mm. Four new measurement marks were established at northeast rim.

May 28, 30 locations, 13 opened, 1 closed, opening 16.5

mm., to which Crack No. 25 contributed 9.0 mm., showing marked decrease of rate. The ground extending the last cracks of the east notch, after May 7, to the south of the notch, was broken and hot, with the soil ruptured and weeds browned with new vapor. Measurement with thermometer May 11 of the cracks south of Nos. 24 and 25, at 10:00 a.m., air 24°C., showed maximum crack temperature 64°C.

The break across the road southeast of Halemaumau, on the eastern extension of Crack No. 37, recently repaired, is moving again. Slowly this crack has opened: it is over the old sulphur beds on the Kilauea floor margin. The extension of the crack east of the road gave maximum temperature 50°C.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earth-quakes	Slight Earth-quakes	Weekly* Seismicity
May 9	17	5	0	6.75
" 16	25	5	1	10.75
" 23	9	4	0	4.25
" 30	22	6	1	10.50

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 and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible, a determination of depth of focus has been made.

May 6, 10:06 am, very feeble, of Kilauea origin.

May 7, 7:44 pm, very feeble, accompanied a slide at E rim of Halemaumau.

May 8, 12:22 am, very feeble, located 2.7 miles deep 0.4 mile NW of Kilauea Military Camp. 19° 26.4′ N; 155° 16.7′ W.

May 14, 3:13 pm, very feeble, located 0.6 mile deep in Kilauea Crater adjacent to Kilauea Iki. 19° 25.3′ N; 155° 15.9′ W.

May 14, 3:29 pm, very feeble, located 1.3 miles deep under E rim of Kilauea Crater. 19° 24.9′ N; 155° 15.8′ W.

May 14, 3:56 pm, very feeble, same epicenter as preceding except 0.9 mile deep.

May 14, 5:37 pm, very feeble, of shallow depth in cracks immediately east of Keanakakoi Crater. 19° 25.4′ N; 155° 15.6′ W.

May 15, 1:18 am, a slight earthquake was recorded at the Observatory, Uwekahuna and the Pit. It registered as very feeble in Hilo and as a tremor in Kealakekua. Because of lack of definite phases its location was not determined although it is thought to have been of Kilauea origin.

* For local seismicity definition see Volcano Letter 371.

May 16, 7:42 am, very feeble, probably located 0.7 mile NE of Kilauea Crater.

May 21, 1:20 pm, very feeble, tentative location in Kilauea SW Rift about 10 miles from Halemaumau.

May 28, 12:09 am, very feeble, located in cracks east of Keanakakoi, SE portion of Kilauea Crater, 0.9 mile deep. 19° 24.1′ N; 155° 16.4′ W.

May 28, 6:12 am, very feeble, located 1.3 miles deep under east rim of Kilauea Crater near Kilauea Iki. 19° 24.9′ N; 155° 15.8′ W.

May 28, 8:50 am, very feeble, located 0.8 mile deep and 0.5 mile S of Kilauea Iki. 19° 24.6′ N; 155° 15.3′ W.

May 30, 2:53 am, very feeble, probably located under N rim of Kilauea Crater and near Kilauea Military Camp.

May 30, 3:03 am, slight, tentative location Mauna Loa NE Rift about 10 miles from Hilo. Reported felt one mile east of Hawaii National Park entrance.

Microseismic motion of the ground was strong May 3 to 16, May 22 to 24 inclusive, and was moderate the remainder of the month with the exception of May 30 when it was light.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau the algebraic sum of radial tilts towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending May 30 was 8.98″ S and 1.35″ E.

Week Ending	Observatory	Halemaumau West Station
May 9	0.83″ N 77° E	4.50″ S
" 16	1.03″ N 48° E	2.86″ N 37° W
" 23	0.45″ N 60° W	1.73″ N 71° W
" 30	0.62″ N 3.5° E	0.75″ S 12° E

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
May 9	8.10″ S 84° W	3.60″ Toward
" 16	8.94″ N 27° E	2.71″ Toward
" 23	1.49″ N 40° W	0.18″ From
" 30	3.63″ N 49° W	3.42″ Toward

H. H. W.

Crater Angles

Measurement of Horizontal angles across Kilauea Crater from the Observatory, May 27, showed slight closing of both Halemaumau and Crater values compared with similar measurements April 21. From Kilauea NE rim to Uwekahuna there was closing of 2.50″, April 21 to May 11, and opening of 0.84″ May 11 to May 27. Total closing 1.66″. From the Pit seismograph to NW Pit B.M. there was closing of 2.50″, April 21 to May 11, and closing of 0.42″ May 11 to May 27. Total closing 2.92″.

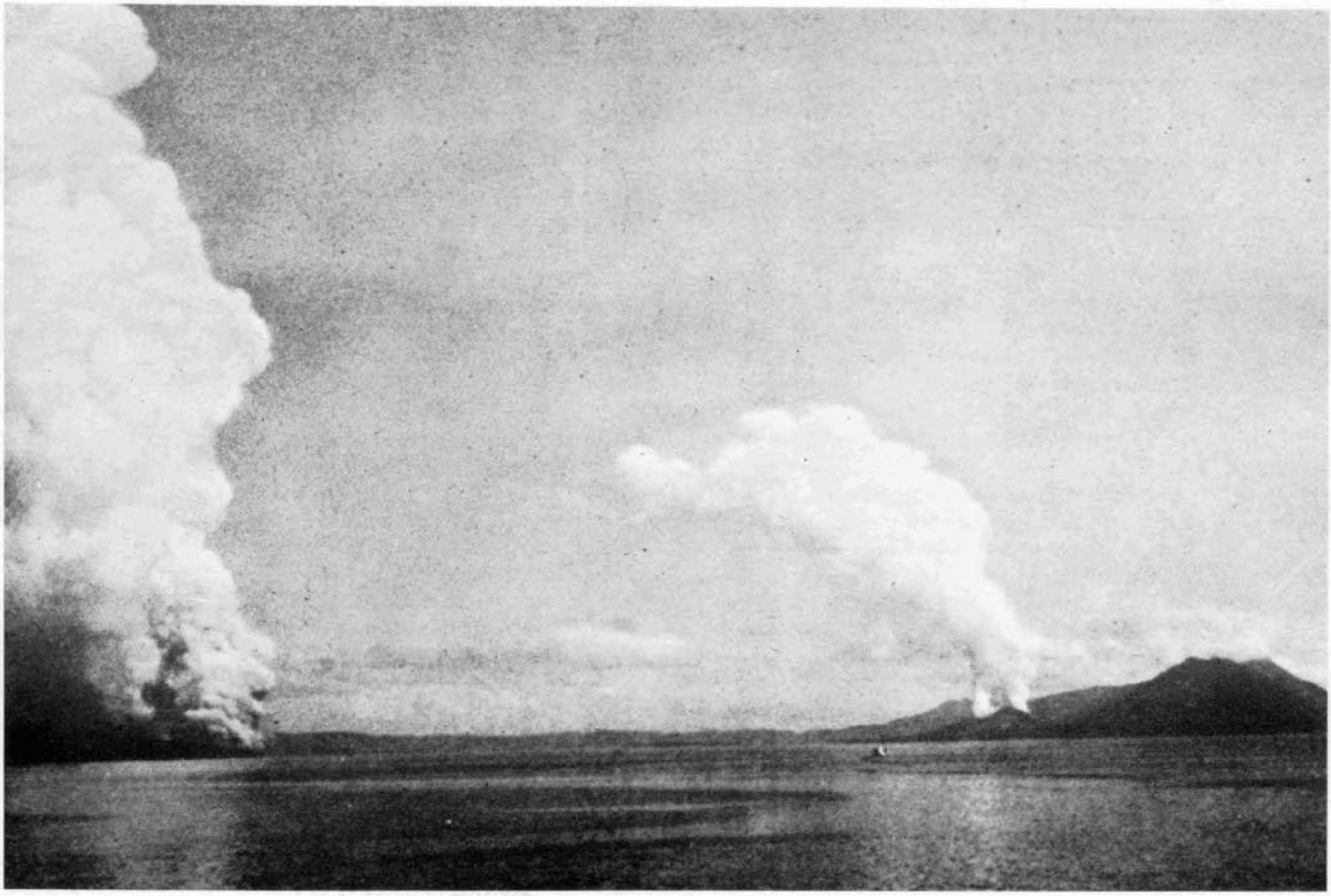
H. H. W.

THE VOLCANO LETTER

No. 448 monthly **Department of the Interior** **National Park Service** **June 1937**

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist



Volcanic eruptions that caused a temporary evacuation of Rabaul: Clouds of steam rising from the craters of Matupi (on the right) and Vulcan Island, the more violent of the two.

ERUPTIONS AT RABAUL, NEW GUINEA

Volcanoes of New Britain

At the northeast end of New Britain (formerly New Pommern), the middle larger island of the three that constitute the British mandated territory of New Guinea, the capital town in that tropical land of missions, mines and copra (Lat. 5° South, Long. 152° East) is called Rabaul.

It is on a protected harbor. An east-west arcuate belt of active volcanoes encloses the Bismark Archipelago to the north, and the middle of the bow, bellied southward, contains the volcano "Ritter Island". This island cone threw up flames and lava fountains in March, 1700, poured lava cascades in June, 1793, and made explosive eruption in March, 1888 (west of Mt. Nangila on map) that caused a tidal wave and ejected more than a third of a cubic mile of dust, gravel and rocks.

Ten years earlier two volcanoes erupted at the north end of the Gazelle peninsula where Rabaul now is; they were called "Ghaie" or Matupi, and "Raluan" or Vulcan. Matupi, 800 feet high, is a solfataric hill southeast of and close to Rabaul on the northeastern tip of the volcanic arc. The rift crosses Blanche Bay (Rabaul harbor) from southwest to northeast, and Vulcan island on the southwest side of the bay appeared above the waves in the 1878 eruption.

This eruption included both Vulcan and Matupi along a steam-blast rupture; it started February 4 and lasted four days for Vulcan and three weeks for Matupi. It made two tidal waves, and built at Vulcan a flat cone 70 feet high and 900 feet across; from a new crater on Matupi smoke, flames and pumice were ejected, piling dust and pumice on the country and blocking the channel.

Thus Matupi was the more violent in 1878, but it appears that Vulcan was the culprit in 1937. Vulcan had subsided to half its height by 1897; Matupi is a subsidiary crater to "Mount Mother", a mountain back of the town, and is visited for its steaming hot spring.

We are indebted to the Sydney "Mail" of June 9 for the following data about the town, the Papuan natives, and the eruptions:

With a northeast wind the fumes from Matupi start the natives talking about earthuakes, and about the memories of the terrifying eruption of sixty years ago; when the Beehive Islands at the entrance to the harbor lowered to their present height; and Vulcan Island was built up next to the southwestern shore of the bay, so that their banana plantations were weighted down with heavy ash; and fish and turtles were found cooked in the steaming waters.

About twenty years ago an "eruption" is reported whereby the Matupi Peninsula sank about eighteen inches, and rose to its former level within a few hours. One wonders whether this story might not refer to tidal wave effects of the "Father" eruption of 1912.

The natives of course attribute very feeble earthquakes, which are frequent in Rabaul, to "debbil-debbils", and just as the Hawaiian legend of Pele migrating from Kauai to Hawaii agrees with geology, so the shrewd Papuan observations tally with science.

Folklore has it that the active volcano "Father" (see Map) or "Ulawun" to the southwest, with two other hills known as "South Son" and "North Son", alternates in "smoking" with the Rabaul volcanoes known as "Mother", with her two offspring "North Daughter" and "South Daughter". It is of course the subsidiary crater of Matupi that does the smoking.

Geologists know that the "Father" group and the "Mother" group are on the northeast-southwest rift line of New Britain, and the alternation of activity is probable, just as between Mauna Loa and Kilauea.

Rabaul is built over volcanic ash and it is said to be extremely difficult sometimes to get an earth terminal for an electric circuit.

Vulcan Island after the nineteenth century was left about 100 acres in size, some 5 miles from Rabaul, a cone unconnected with the shore. It was 900 feet in diameter, 30 feet high, and fuming from solfataric vents.

The mission stations of Walour and Taviji were on the southwest shore of the bay close to this island, along the driveway leading from Rabaul around the bay. This leads to Kokopo, a village on the eastern point of New Britain, facing the strait that separates New Britain from New Ireland.

The 1937 Eruptions

During the past year earthquakes have been unusually numerous in Rabaul. Vulcan Island began to show signs of volcanic activity Friday morning, May 28, 1937, when the mission stations experienced severe earthquakes, and landslips were observed on the island. The earthquakes increased in violence during that day and the next.

On the afternoon of May 29 Vulcan Island broke forth into explosive eruption, throwing up clouds of fume, dust, ash, gravel and bowlders so thickly that day was turned into night.

An observer at one of the missions thought that the dusk was coming a few hours earlier than usual. Then he noticed that Vulcan Island was throwing bowlders many hundred feet into the air, and pumice was falling everywhere. He described seeing a ball of fire running along the top of the cone, this being followed by a terrific explosion.

Then Matupi Volcano broke out in sympathy, sending up sulphurous steam, cauliflower clouds, ash and pumice, but the main eruption that darkened the entire landscape was from Vulcan Island.

The water become violently agitated. The succession of explosive steam blasts came from the side of Vulcan Island apparently on a rift line extending in the direction of the Beehive Islands and Matupi Crater to the northeast. A dome-shaped jet of water was seen to shoot up about 50 feet, followed by another explosion hurling sea water up 100 feet. Then many explosions occurred at Vulcan Island itself, flinging up rocks and debris, the cauliflower clouds rising 4,000 to 5,000 feet.

Some of the longshore roads developed crater depressions and all were blocked with gravel and ashes. Plantations were damaged for many miles, crops of coffee and bananas were ruined and the coconut trees had their leaves broken down with heavy gray ash.

The dense black cloud appeared to descend from above on some of the mission villages, earthquakes were numerous, thunderstorms developed, trees were struck by lightning and were seen falling in earthquakes, heavy rains fell, and motor cars were choked with the dust and had to be abandoned in the mud.

Volcanologic evidence

We shall have to await scientific statements for an account of what happened in changes of the sea-bottom. The sea-bed is said to have changed in elevation so as to make a new survey necessary.

As usual with explosive eruptions great quantities of floating pumice appeared on the surface of Blanche Bay, and some of this was thought to be a new bank of sand and mud blocking the outer entrance to Rabaul Harbor. The ocean currents swept this out to sea within a week, and it was found that the outer channel was still navigable. Shipping could enter Blanche Bay and reach the wharves with safety.

What happened to Vulcan Island itself may well have been a rising of stiff magma along with the building up of a symmetrical cone and cup, as shown in the pictures. We learn from the accounts that the island has been raised from 30 feet to a large hill more than 700 feet high, and from an island 900 feet across, to a peninsula three-quarters of a mile in diameter connected with the mainland by the new accumulations.

There is no evidence nor probability that liquid lava flow occurred. The worst of the eruption was on Sunday, May 30. The eruption died away very rapidly. When Vulcan Island was enveloped in smoke, the first impression of the onlookers was that it had disappeared.

One observer described a sudden lift of the island when the water waves occurred which played havoc with many of the smaller vessels, some of them being beached high and dry on the foreshores. Soundings were taken by a survey ship on Saturday, June 5, showing plenty of depth in the main channel.

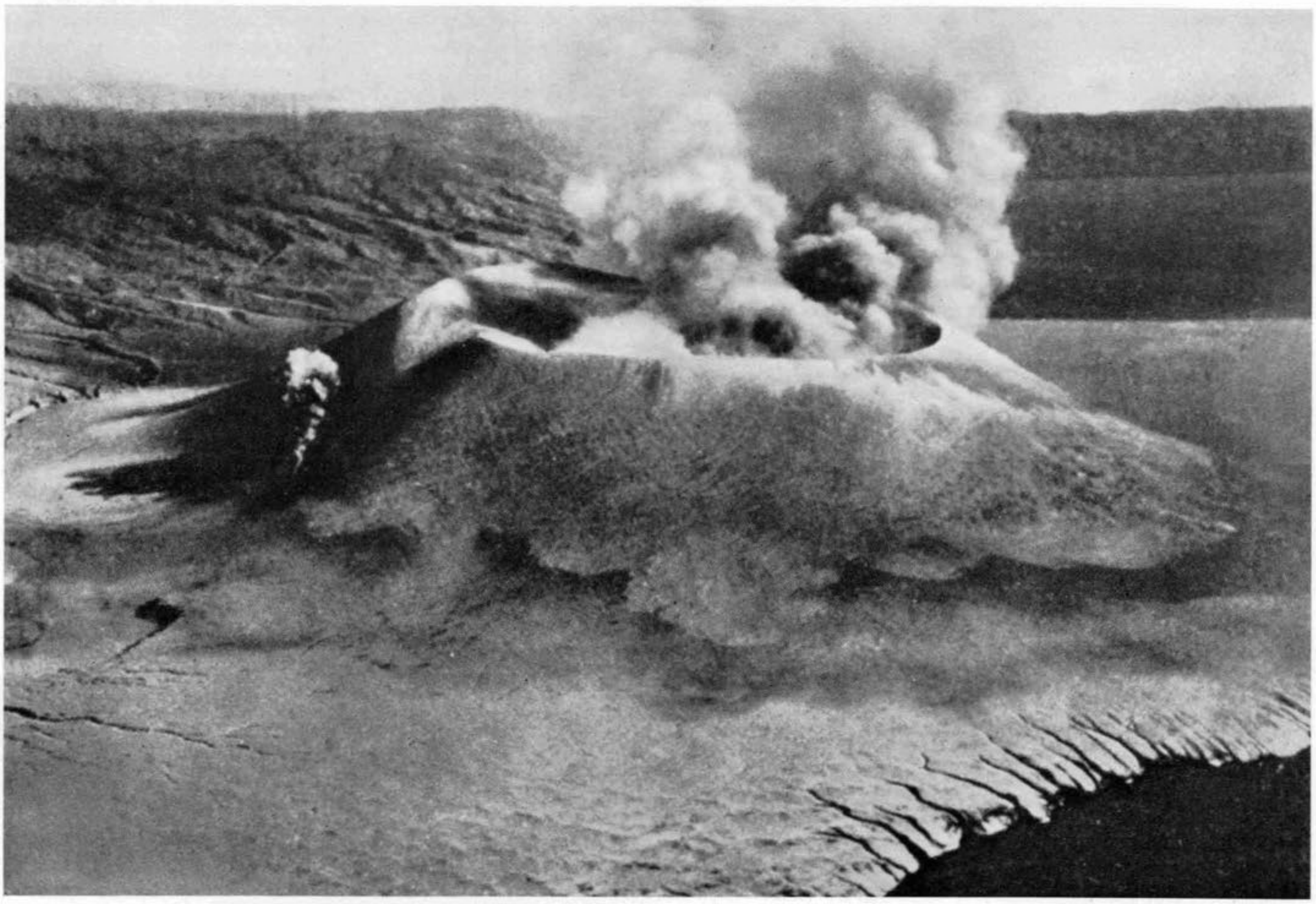
like "Anak Krakatoa", of a constructive effort of rising magma acting through the ages, and reacting with groundwater.

We may conclude that the nature of this eruption was not particularly different from other eruptions of this volcanic belt, and to judge from Sapper's report concerning Father Volcano in 1912, and Ritter Island in 1793, this belt of volcanoes is quite capable of pouring out lava occasionally.

Von Wolff reports the recorded specimens of lava from this bay to be pyroxene andesite, and of pumice from New Britain to be andesite pumice. The minerals are plagioclase, angite, hypersthene and magnetite. Silica varies from 57% to 62%, and iron oxides from 6% to 8%. Specific gravity is 2.36 to 2.51.

Effects on the People

The evacuation of Rabaul was ordered, and was carried out efficiently with the aid of ships that moved the people from Nodup (a village close to Rabaul), to Kokopo, twenty miles south. Some 4,500 people were moved, and about 20



The erupting crater of Vulcan Island (normally low-lying) seen from the air: a view showing molten pumice building the cone hundreds of feet high and flowing into the sea.

The observer in question reported that Vulcan Island rose rapidly at the time of the tidal crisis so that where there had been water and a few rocks, solid land appeared. The interpretation of the airplane photographs was that "flowing pumice" spread down the sides of the cone.

There was the usual reddish glow seen in the reflections from the crater on the clouds. This and the presence of pumice show that frothing magma took part in the groundwater explosions, and it is probable that this is just one more example,

stayed to guard the place. The rain of ashes and mud was the principal cause of damage in the town, the heavy weight breaking down structures and destroying vegetation. Food supplies were transported from Nodup to Kokopo by schooners, and a large camp was made at Kokopo with sanitation directed by the government. The refugees included 3,000 natives, 800 Chinese, and 700 whites.

Within a week the harbor was clear, and progress had been made in cleaning the town. The island superintendent of one trading firm suggested moving his headquarters to Madang, on the coast of New Guinea. This company's wharves at Rabaul were valued at $150,000, and could not be shifted. Moreover, the harbor is better at Rabaul than at Madang.

However, the trading firms had grave doubts about building and expanding on a place between two active volcanoes.

Ship Reports

Two larger steamers were in harbor, the "Golden Bear" of the Matson Line, and the "Montoro" of the Burns Philp Line. These were not injured and were instrumental in evacuating the population. Two steamers and a schooner were swamped.

At 1:00 P.M., May 28, the "Montoro" passengers, with ship moored to the pier at Rabaul, suddenly felt violent earthquakes and saw buildings rocking and palm trees falling, so that the roadways were blocked with fallen timber. Quakes continued throughout the afternoon and at 5:00 P.M. the "Montoro" sailed.

The "Golden Bear" was loading copra at a pier in the harbor when the eruption started the next afternoon, May 29, and a radio was sent to ask the "Montoro", then 120 miles at sea, to return. The land radio station was put out of commission by the eruption. The "Montoro" was showered with dust 100 miles away and in approaching the harbor found the ocean surface covered with pumice.

The columns of steam above the volcano rose white and fluffy, with an inky black inner column that exhibited rocketing bowlders falling back into the crater. With every new jet lightning and thunder occurred.

The explosion of Matupi came at 12:45 A.M., May 30, and large pieces of rock were flung up from its crater.

Captain Olsen of the "Golden Bear" had been doing heroic work, taking on board at Nodup hysterical women and children, hospital patients, and the Chinese population.

"The "Golden Bear" had at first been tied up at the wharf in Rabaul right in the path of the dust from Vulcan Island, and the falling pumice, heat and gasses were such that the danger was great, while the tidal waves chafed the lines, and grounded the ship. The water was covered with pumice and the outward channel looked as though new sand-bars had risen.

There might not be any channel and the course out involved passing close to the spouting volcano. The captain did not hesitate, but let go his moorings, ordered his crew below decks, cleared the channel and reached the open sea in a magnificent performance of seamanship. Then he turned about and anchored off Nodup.

The natives were loaded ten deep on the decks of both ships along with their dogs, cats and parrots. There was no panic. The launches pulled three boats at a time. The mission at Kokopo did splendid work in housing and feeding refugees.

The "Montoro" left on June 9, Captain Mitchie of that ship clearing for Sydney with some 200 refugees.

Some details of the eruptions

Rabaul was covered in places with dust four feet deep, and boats had been washed up into the streets. The tropical trees and shrubs were all broken and not a green or living thing was in sight. The water, light, and telephone systems were broken down, hardly a roof was intact, the roads were a mass of ruts, and the health commissioner could not allow any one to live there until the place was cleaned up.

Captain Olsen himself described the detail of the eruption as follows:

The ship was tied up at a dock near Rabaul at the time. Before doors or portholes could be closed a foot of pumice dust had settled in every nook and cranny of the ship, destroying clothes and other property. Most of the crew were ashore at the time of the terrific outburst of Vulcan Island. All returned to the ship, however, except Radio Operator V. M. Costner, who in the darkness may have fallen into the sea from the wharf, when attempting to grope his way back through the blinding, choking gaseous smoke which enveloped the town.

Captain Olsen is quoted as follows (Honolulu Star-Bulletin, July 12):

"About 4:10 P.M., May 29, I was outside on the starboard side of the lower bridge deck. Looking toward Vulcan Island, I saw a small white speck on the water near the island which swelled and rolled over, with the appearance of a large, fluffy cotton ball.

"It was only when the ball began to ascend into the air that I realized it was a volcanic eruption. After three or four minutes the island suddenly burst wide open, and with a tremendous roar sent a column of white steam and black lava smoke thousands of feet into the air.

"The mixture of gas and lava enveloped Vulcan Island and drifted in a northwesterly direction over the mainland, but after the first outburst the wind suddenly switched and sent the cloud of black smoke and debris in the direction of the "Golden Bear".

"The ship was enveloped in a cloud of gaseous ashes. All visibility was completely obscured. We left the ship under conditions difficult to describe. We crawled along on the wharf on our hands and knees. We felt our way along the car-tracks. We nearly suffocated. Fortunately, the wharf office door was unlocked and we all took shelter there against the heavy downpour of ashes."

A check of the men revealed Mr. Costner missing. In the late afternoon the Captain and the crew returned to the "Golden Bear" and succeeded in keeping her from being materially damaged by a series of minor tidal waves.

After reaching the Kokopo anchorage, May 30, Captain Olsen had a view looking northwest of the two volcanoes in action. Two great columns of white and black smoke ascended for thousands of feet. Spreading out and coming together at the top, they formed a gigantic archway over the entrance to the harbor.

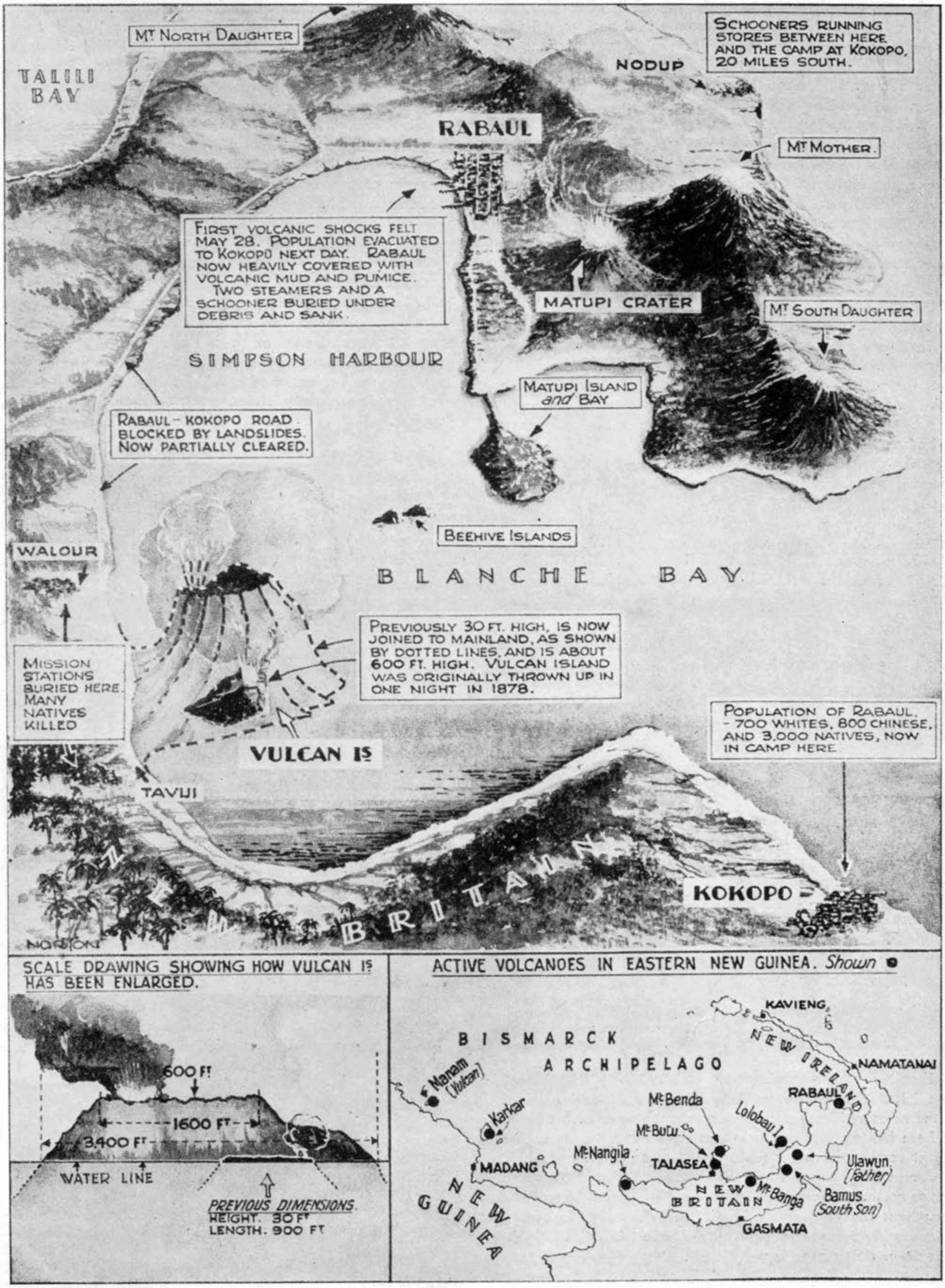
Vulcan Island, the largest and heaviest of the two eruptions, was a magnificent sight during the night. Great masses of fire would be thrown into the air for distances of 4,000 feet, measured by sextant. The barrage would curve over and outwards and, exploding, fall back to the earth in a rain of fire.

J. W. Faulkner took the place of the lost radio operator on the "Golden Bear" in Rabaul. His ship, the "Durour", was on a marine railway close to Vulcan Island when the outbreak occurred. He and his companion barely succeeded in escaping to Rabaul in a motor boat. His ship, with the natives on board, was completely engulfed and sank out of sight.

Faulkner described the rising of a reef some 10 feet above water near Vulcan Island. This happened during the earthquakes that occurred in the 24 hours before the eruption.

Conditions at first in Rabaul were terrible during the eruption. While refugees were being transferred to outside plantations, it was necessary to erect temporary dormitories for the sick and injured. Rescue parties went from house to house searching for any who might be trapped.

In Kokopo there was an acute shortage of food and water, bad sanitary conditions prevailed and anxiety was expressed over the possibility of dysentery and typhoid. The mosquitoes were bad and the people were destitute. The swimming pools were thrown open to the women and children, many of whom maintained a stoic calm throughout the ordeal. The casualty cases were attended by one doctor and numerous nurses.



The tragic course of events in stricken Rabaul.

Captain Olsen's estimate of the loss of life caused by the eruption was reported as approximately 250 natives, 10 Chinese children, and 1 European. In the Sydney account the losses of life were known to be two white men, and in the missions close to Vulcan Island not less than thirty native women and children, overwhelmed by mud and ash.

Whatever the fact, this small loss of life in a harbor populated by 5,000, with an active pair of volcanoes athwart it, is a splendid tribute to the efficiency of the sailormen, traders, missionaries and local authorities in facing a sudden crisis and moving 4,500 people. They were assisted by ships, airplanes and radio. It seems likely that a volcanologic observatory and a system of earthquake stations might learn the cycles of recurrence, and greatly assist the New Guinea government.

T. A. J.

VOLCANOLOGY

After the May crisis of caving in of the eastern rim of Halemaumau pit, Kilauea Crater entered upon a period of comparative quiet. The establishment of thirty marked crack locations around the rim of Halemaumau, which had been renovated in May, exhibited in June only a quarter of the aggregate crack opening of May. The numbers of quakes, tremors and slides remained about the same.

The following are the weekly Observatory totals for Halemaumau and the seismographs:

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Quakes
June 6	15.00	0	11.0	20
" 13	11.25	1	10.0	35
" 20	12.75	4	10.5	36
" 27	5.50	2	9.5	16

A car covered with six inches of volcanic ash, which stopped the engine and compelled its owner, who was leaving for Kopoko, to abandon it: a typical scene of desolation in Rabaul.

Feeble shocks somewhat felt occurred May 31, June 3, June 13, June 16, two on June 20, June 21 and June 25. Of the measured local earthquakes, sixteen were from Kilauea, six from Mauna Loa, and two from more distant sources. Two distant earthquakes were registered June 21 and June 24.

A remarkable slow horizontally-moving fireball from southwest to northeast, with flaming tail, and without noise was seen throughout the Territory of Hawaii at 9:50 p.m., June 4. It was probably seventy or eighty miles away to the southward from the middle of the larger islands.

Sequence of Events by Weeks

The first week produced nothing important at Halemaumau. Crack widening, seismic frequency and sliding had all lessened. The yellow sulphur heap at the northwest margin of Halemaumau floor continued to fume hotly, and there was much cracking and sulphurous stain that had developed at the S.S.E. and N.N.W. edges of the floor. These places steamed occasionally, especially during wet weather. The northeast edge of the floor was now completely covered by new overlapping talus heaps from the north to the east sides of the pit. These have all been added to between October, 1936, and May, 1937. The wall above is raw and freshly scarred, and the rim of the pit is considerably changed by notches which have enlarged its circumference.

The second week produced a lessening of seismicity and widening of cracks, and one slide was noticed.

The third week there were more slides, characterized by location on three sides of the pit, a new feature in that nearly all slides during the previous years had been from the east and northeast walls. Seismicity and crack widening continued about the same, with much of the latter limited to a single crack at the east rim.

The last week showed notable decline in all the measured features of seismicity, slides, crack openings, and numbers of quakes.

Slides at Halemaumau

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

June 9, 8:57 a.m., a slide at the northeast wall.
June 14, 2:07 p.m., rocks fell from the east wall.
June 17, 9:57 a.m., a slide started from about half-way down the south wall.
4:35 p.m., a slide occurred at the east.
June 19, 10:45 a.m., a large slide occurred on the west side of the pit.
June 22, 11:25 a.m., a slide at the east wall made a small dust cloud.
June 23, 8:30 a.m., a slide at the northwest wall made a fairly large dust cloud. Slides south, west and northwest have been very unusual for the last year.

Measurement of Halemaumau Rim Cracks

Weekly measurement of a constant number of rim crack locations as reconstructed during the month of May, resulted during June in aggregate movements as follows:

Week ending forenoon of:

June 4, 30 locations, 8 opened, 3 closed, opening 11.0 mm.

June 11, 30 locations, 7 opened, 4 closed, opening 10.0 mm.

June 18, 30 locations, 10 opened, 5 closed, opening 10.5 mm., of which 6 mm. was accounted for by Crack No. 25 at east rim.

June 25, 30 locations, 10 opened, 2 closed, opening 9.5 mm., of which Crack No. 25 accounted for 5.0 mm. Crack No. 25 is one of the steaming extensions of the caved-in cracks of the east notch that collapsed May 7.

T. A. J.

SEISMOLOGICAL DATA
TABLE

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant* Earthquakes	Weekly§ Seismicity
June 6	46	3	2	0	15.00
June 13	27	7	1	0	11.25
June 20	27	6	3	0	12.75
June 27	14	0	2	2	5.50

§ For local seismicity definition see Volcano Letter 371.
* Including teleseisms or those shocks over 5000 km. distant.

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 and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the times indicated and, whenever possible, a determination of depth of focus has been made.

May 31, 6:18 am, very feeble, located 1.2 miles deep in Kilauea Crater near the old Stone Corral. 19° 24.8' N; 155° 16.3' W.

May 31, 6:29 am, feeble, located in N portion of Kilauea Crater 1.0 mile E of Uwekahuna. 19° 25.5' N; 155° 16.5' W.

May 31, 7:32 am, very feeble, probably located in SE portion of Kilauea Crater.

June 3, 3:07 am, feeble, located in Hilina Pali Fault system 9.0 miles S of Halemaumau 10 miles deep. 19° 17.2' N; 155° 18.5' W.

vicinity of the old Prison Camp 1.2 miles NW of Uwekahuna. 19° 25.8' N; 155° 18.3' W.

June 14, 7:01 am, very feeble, located 4.3 miles deep under N rim of Kilauea Crater 0.5 mile NW of Volcano House. 19° 26.2' N; 155° 15.9' W.

June 16, 4:52 am, feeble, located 0.5 mile E of center of Halemaumau in Kilauea Crater 1.0 mile deep. 19° 24.5' N; 155° 16.7' W. Reported felt rather strongly at CCC Camp on SE rim of Kilauea Crater and moderately felt near Park Headquarters.

June 16, 10:35 pm, very feeble, located in Kilauea Crater.

June 17, 11:27 am, very feble, thought to have been located in SE portion of Kilauea Crater near Keanakakoi.

June 21, 2:16 pm, feeble, probably located in Chain of Craters rift near Puhimau Crater.

June 25, 6:20 am, feeble, probably located 9.0 miles S of the Volcano Observatory in the Hilina Pali fault zone.

Seventeen minutes of continuous tremor began recording at the Observatory at 12:13 pm, June 5 and sixteen minutes of continuous tremor began recording at 9:22 am, June 6.

Trees stripped of foliage and their broken branches strewn on the ground: havoc caused by volcanic showers during the eruptions near Rabaul, the capital of New Britain.

June 4, 10:40 am, very feeble, probable location in Kilauea Crater.

June 7, 6:46 am, very feeble, located 25.0 miles deep in Kohala District 5.0 miles east of Mahukona. 20° 10.3' N; 155° 49.0' W. Reported strongly felt in Kohala and at Kamuela.

June 9, 9:12 am, very feeble, of Kilauea origin.

June 12, 11:29 pm, very feeble, located 0.8 mile deep in E portion of Kilauea Crater. 19° 24.9' N; 155° 16.1' W.

June 13, 9:21 pm, very feble, located 3.8 miles deep in

Microseismic motion of the ground at the Observatory was light May 31, strong June 5, 6, 8, 15, 16, 17 and 19 and moderate the remainder of the month.

The preliminary waves of a teleseism began to register at Kilauea at 4h 55m 8s, am H.S.T., June 21. It was estimated to have occurred 5450 miles away. There was a partial trace of a teleseism recording at the Observatory June 24, 3:18 am H.S.T.

H. H. W.

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 towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending June 27 was 8.8" S. and 1.35" E.

TABLE OF TILT

Week Ending	Observatory	Halemaumau West Station
June 6	0.60" N 4° E	1.49" N 79° W
June 13	0.60" S 4° W	2.24" N 87° W
June 20	0.60" N 4° E	1.49" N 80° W
June 27	0.50" N 4° E	1.40" S 70° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
June 6	1.75" N 55° E	1.16" from
June 13	4.01" N 72° W	1.16" toward
June 20	4.18" S 71° E	5.06" from
June 27	7.65" N 28° W	6.12" toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory June 19, slight closing of the Halemaumau value and opening of the crater value as compared with similar measurements May 27. From Kilauea SE rim to Uwekahuna there was opening of 0.82" and from the Pit seismograph to NW Pit B.M. there was closing of 2.01".

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Ascsociation was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

NE PLUS HAUSTAE AUT OBRUTAE URBES

THE VOLCANO LETTER

No. 449 monthly **Department of the Interior** **National Park Service** **July 1937**

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WORK OF F. A. PERRET ON MONTSERRAT

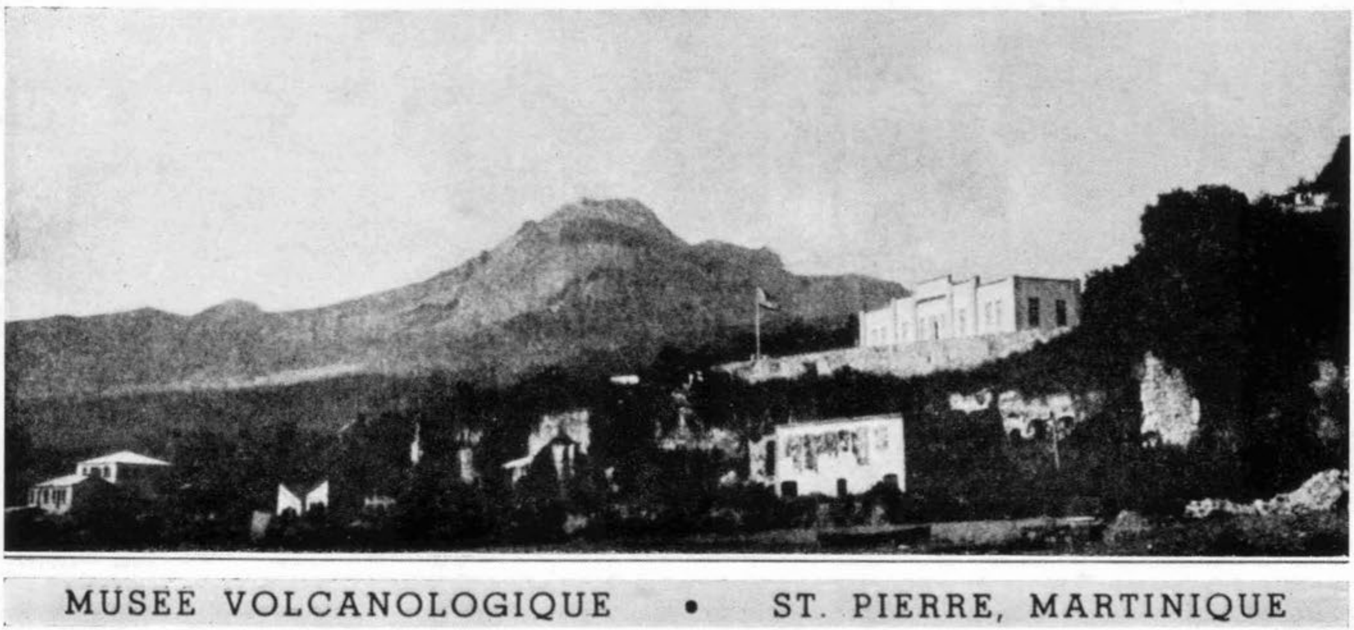


Figure 1. Museum at the ruins of St. Pierre, Martinique.

The Monserrat earthquake crisis of 1933-1936 was described in Volcano Letter No. 437, July 1936. Frank A. Perret, the volcanologist whose museum at St. Pierre, Martinique, is shown in Figure 1 (with the great new andesite dome of Mont Pele in the background) was called in to help by the governor of the Leeward Islands Presidency. Perret helped us in Hawaii in 1911, and his whole career has been devoted, as a volcanologist, to helping people in stricken volcanic lands. It may be of interest to show how such a man works. The Montserrat crisis was an apt illustration of such work, an island suddenly rushed into earthquake disaster in 1934, and its administration instinctively summoning the nearest expert for assistance.

The course of development of the Montserrat earthquake crisis, and its decline, are shown in the accompanying diagram, Figure 2. The columns are monthly seismicity. The four high ones May and December 1934, May and November 1935, were all times when churches and other masonry buildings fell, landslips occurred, and people were injured. These were earthquakes of grade VIII to IX Rossi-Forel. Frequency varied with intensity, and the sequence was from several and small shocks in 1933, itself a most unusual spell, to hundreds and severe earthquakes in summer and winter of the next two years. A terrifying feature of the crisis was the centering of these quakes at Gage's Soufriere, a crater gorge directly above the town Plymouth and only two miles away.

E. O. Hovey in revisiting the West Indies in 1903, after careful work on Mont Pele in 1902, described these "principal craters of Montserrat as appearing to be in almost exactly the same condition as that of Pele, before the 1902 series of eruptions began."

Along with the coming of the quakes, the Montserrat solfatara gorge started vomiting up noxious odors of hydrogen sulphide, whose "rotten-egg" smell penetrated the town, and the gas actually darkened the white paint of steamers lying at anchor in Plymouth harbor. (Map, Figure 3.)

A striking feature of the map is the 100-fathom dotted line at the north. This contour under the sea is a half-circle. It outlines an ancient big volcano. The volcanic activity of recent ages has migrated to the south end at the Soufriere Hills. These hills have hot solfataras steaming and depositing sulphur on three sides. The ancient northern volcano is mostly eroded away by the ocean, leaving a platform 20 to 30 fathoms beneath the waves.

The new gas development was noted in April 1933 and earthquakes that year were most frequent at St. George's north of Soufriere Hills. They increased in force and number to April, 1934 and the government commissioner sent telegrams to inquire about volcanic conditions, which were found not to have changed in St. Vincent, Martinique, Guadeloupe and Dominica.

New sulphur vents were opening at the Montserrat solfataras. The hospital and private buildings were damaged by a sharp shock April 9, 1934. Revising the whole method of building was suggested.

Vague reports were at hand of a volcano scientist camped

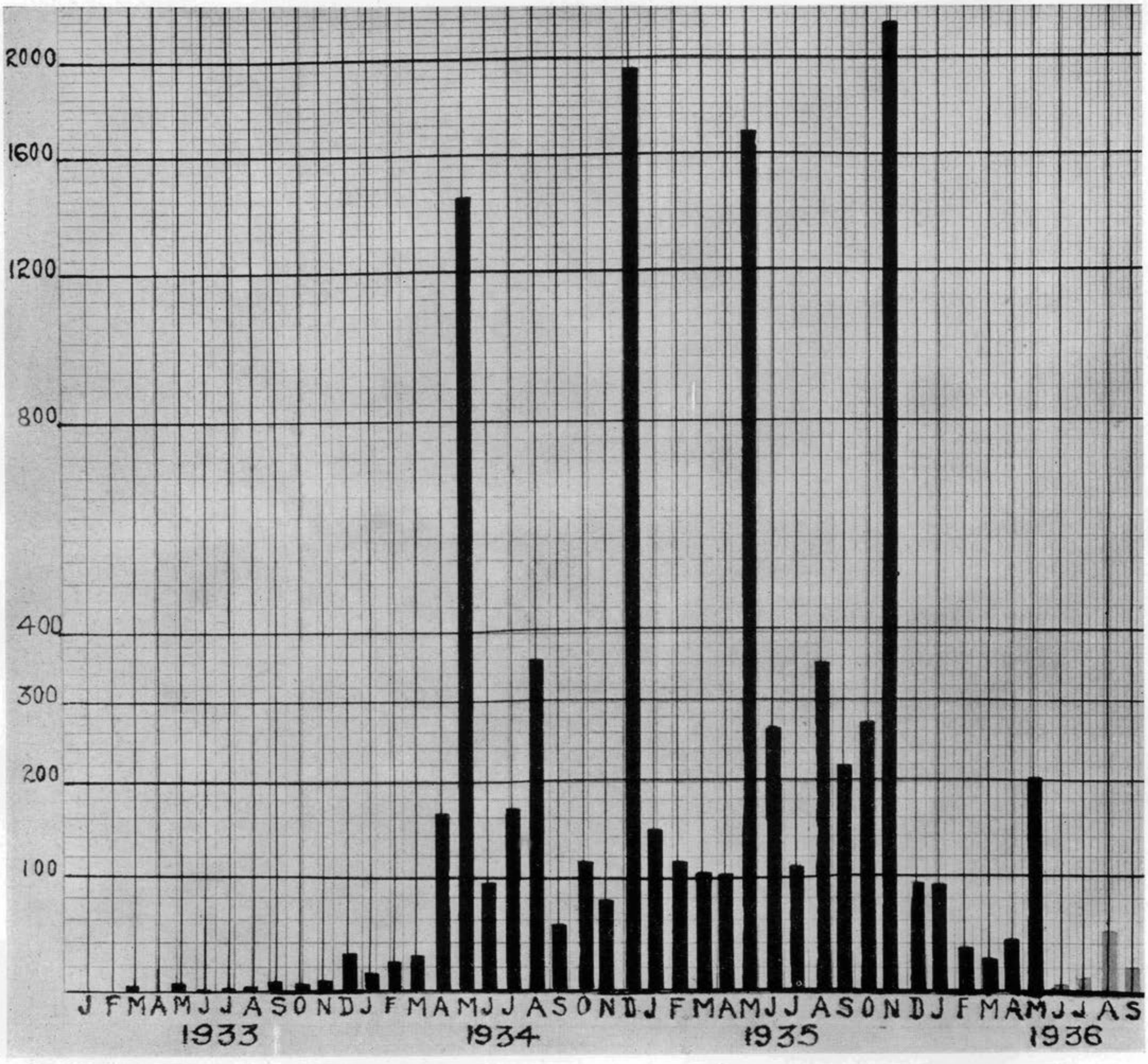


Figure 2. Chart of the rise and fall of earthquake activity in Montserrat.

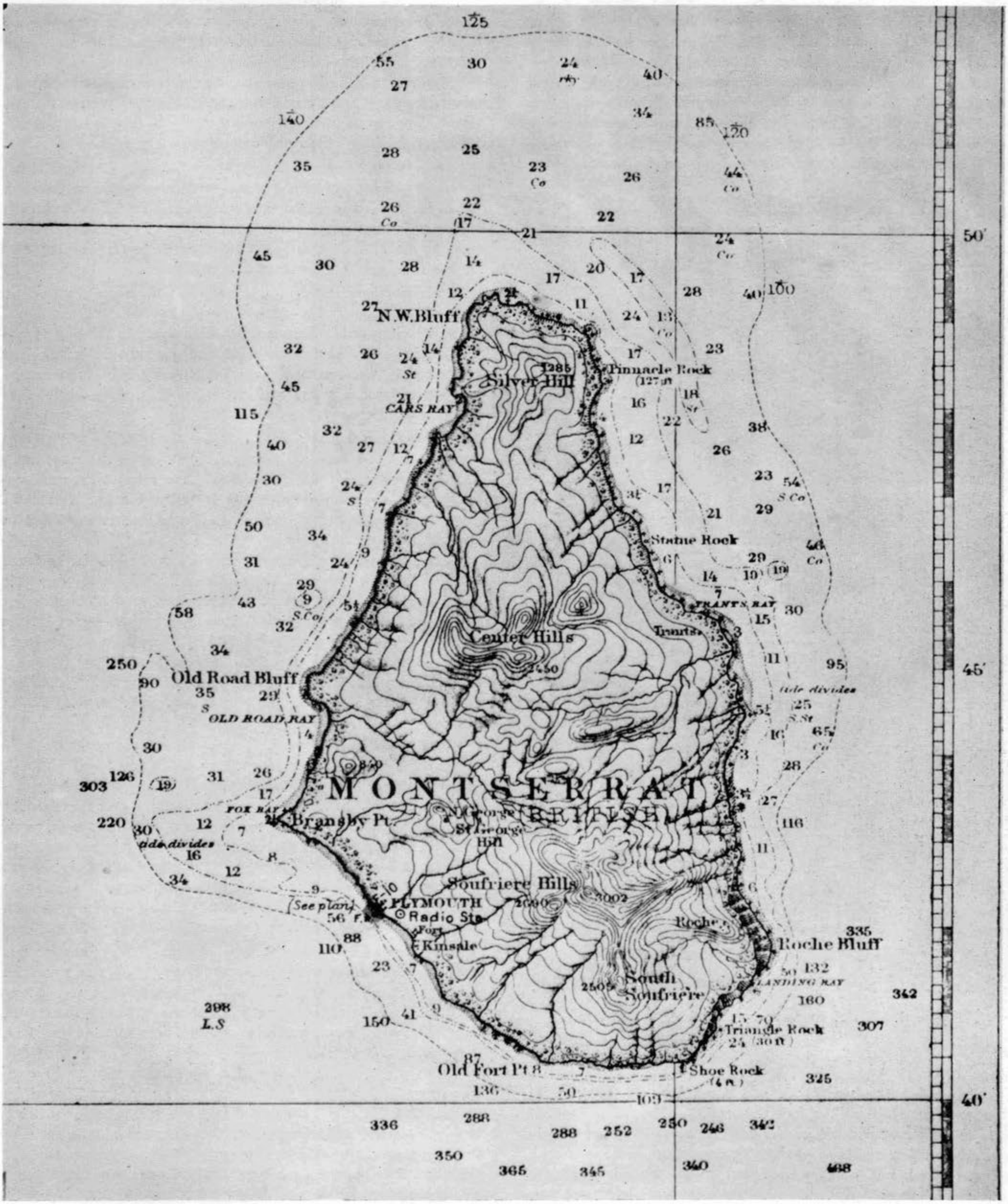


Figure 3. Chart of Montserrat, an island about ten miles long.

on Mont Pele with microphones in the soil. The British consul in Martinique phoned Perret, who was the reported scientist very much alive, and who reported Pele quiet.

May 13-14, 1934 produced sixty shocks, which cracked houses during an exceptional jolt at 2 a.m., the worst in thirty years. All of this was racking and weakening the old masonry.

Perret came by on a steamer en route to New York, visited Gage's Soufriere May 13th, predicted more shocks that day which duly came, and warned of more danger. A terrible shock came at 3 p.m. the 14th, seriously damaging the courthouse, all business was suspended, disorganization and disrupted sanitation were threatened.

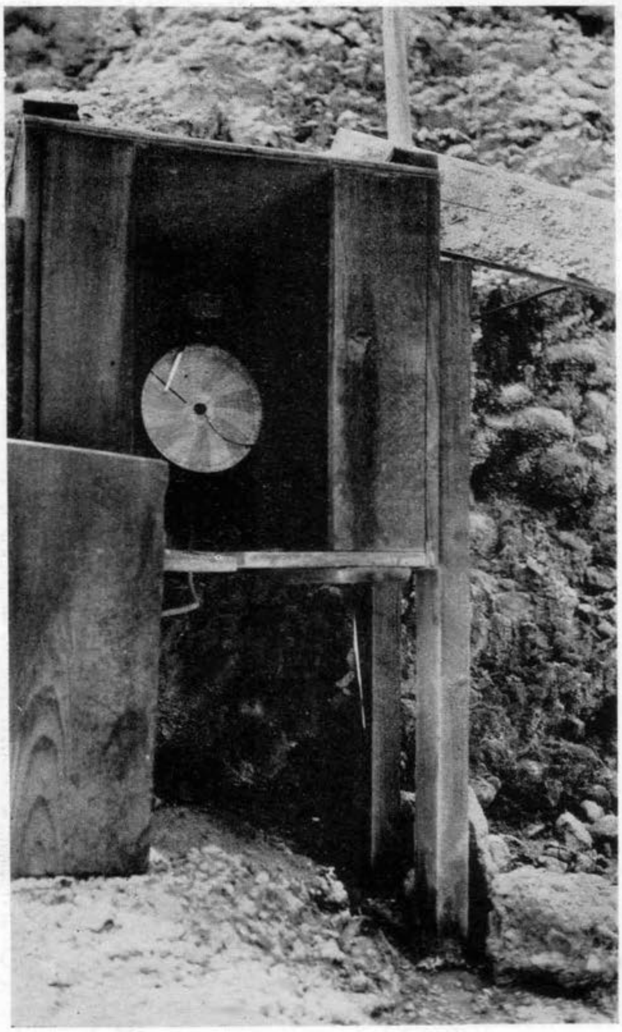


Figure 4. Bristol thermograph at Gage's Soufriere.

A warship was summoned and came May 21-31 to calm the people; earthquakes kept swarming. Following Perret's advice counts were made of the quakes, scientists of the agricultural station made daily visits to Gage's Soufriere and took temperatures, and notes were made on the chemistry of the waters and gases.

In July Mr. Perret was invited to return and install instruments; he had taken a water sample to Washington from the solfatara. No seismograph had yet been supplied.

Mr. Perret wrote Mr. Gomez, the director of agricultural station, suggesting a direction-finding seismoscope which was duly installed: "Suspend a series of weights of one pound each with fine wire as simple pendulums, of lengths varying 6, 12, 24, 48 and 96 inches. By watching these when shock occurs, some will swing, others not, showing period and direction of earth vibration. By setting up sets in different places much may be learned regarding the source of the shocks by coordinating directions."

Perret's hope is for a research organization eventually endowed for the Caribbees; with a base, a motor yacht with apparatus, ready to proceed without delay to any locality where trouble is reported, there to land and investigate conditions.

In Washington he secured support from the Carnegie Institution for investigating the Montserrat crisis, and sent vacuum tubes for collecting gases. He secured a Bristol gas-expansion recording thermograph with weekly charts, the lead-covered bulb to be buried in a gas fissure at Gage's solfatara; also microphone, and maximum thermometers.

He arrived and set up the instruments the end of November. Throughout his work he watched closely the luni-solar combinations, which might influence earth-tide stress in relation to gas tension in subterranean magma. The gas tension is localized in the crust. The earth tide varies seasonally, and varies exceptionally with certain sun and moon positions. The whole crust pumps with the earth tide.

The sudden frothing of volcanic magma in a subterranean fissure is a large force accumulated locally of a different kind, subject to release if the small tidal force relieves pressure exceptionally on certain dates. It is quite possible that deep plutonic earthquakes are so released, and are concerned with changes of state of magma.

Perret's reports to the governor were printed in the Leeward Islands Gazette between December 12, 1934 and May 19, 1936 in a series of letters from Montserrat, on the occasions of his several visits, coming sometimes by steamer, sometimes in haste by airplane and sloop from Martinique through Antigua. For a man of seventy they show extraordinary vigor; he made nine reports; and he built a hut within the crater gorge where he actually tried to sleep, until he injured throat and eyes with the deadly gases.

The Bristol thermograph (Figure 4) was set up in the bottom of the steaming gorge at Gage's. It registered 105° C. and the strong shocks also made of it a seismograph, by disturbing the ink pen. Mercury in saucers, for observation of small tremor, was placed in four localities. Gas tests were made with lead acetate and litmus paper. The hydrogen sulphide was tested thus even at Plymouth. The litmus at Gage's showed water sour with sulphuric acid, and air in the gorge which was alkaline. A gas irritating to eyes was thought to be hydrogen persulphide. Photographs were taken.

Vacuum tube collections were sent to Washington for gas analysis. The water analysis showed heavy charge of hydrogen sulphide, iron, alumina, sulphur, silica and organic matter; acidity 0.1 per cent, chlorine a trace; the gas analysis showed equal amounts of sulphur and chlorine. No fluorine could be detected in the waters.

A very sharp culmination of many earthquakes at 11 a.m. December 12, 1934 did more damage, was experienced by Perret, and differed from the widely felt May shocks in being highly localized, near Gage's, as though from magma close to the surface. This was disquieting with reference to possible eruption. The gas pressure had increased and spread at Gage's. The hydrogen sulphide was diagnosed as coming from dry vents lower than the wet solfatara. No tremors actuated the mercury surfaces between shocks, and the latter were sharp and brief. Absence of volcanic tremor indicated absence of moving magma, and the microphone confirmed this. The local observers were instructed to carry on with the instruments when Perret returned to Martinique.

Perret's second visit was in February-March 1935, and systematic observations had meanwhile been reported by the local men. He occupied his hut (Figure 5) in the crater gorge, observing the thermograph; the mercury bath with bell-glass cover mounted in a niche; a microphone buried in the ground; an air-microphone for the pressure-note of gas emission; a seismic pendulum for detecting direction of movement in earth shocks, with a mirror reflecting the beam from an electric torch at night.

A new hydrogen sulphide vent opened whistling the night of February 20, 1935. The other acrid alkaline gas that affected eye tissue made night stays impracticable. Tight-fitting goggles helped in daytime. Some subterranean sound was heard occasionally. The Bristol thermograph gave a deceptive indication of rising temperature on the record, which proved to be due to corrosion and weakening of the metal spiral. Check with thermometer proved error. "Bread-crust" bombs like Pele's were found in the gorge. Perret expressed intention of return in May, the critical month of 1933 and 1934.

The next visits of the American volcanologist were in April and May, 1935 and a severe, prolonged and deep shock did more damage on May 6, and exhibited much horizontal movement. The area shaken was farther north. The earthquake was preceded by early morning tremors, and very heavy rains came at 3:55 p.m. and were followed by aftershocks all night. The wide-spread effect relieved apprehension of volcanic eruption for Perret; the disturbance was not craterally localized.

Perret called attention to the sum total of the energy released and dissipated in the long series of earthquakes. If this energy had been concentrated in a single shock, like the Tokyo earthquake of 1923, the wreckage and loss of life might have been far worse. The comportment of the population, largely Negro, was good.

The deeper and more diffuse quality of the May 6 shock of 1935 satisfied the investigator that the volcano eruption danger had culminated at the December 1934 shocks, when high gas pressure and temperatures were dominant at the solfataras. Both had diminished in May 1935 when the deep earthquake came, and did tremendous seismic damage. Mr. Perret stated definitely to the authorities that possibility of more strong shocks remained, but that we might "now discard all likelihood of volcanic eruption."

To make such a statement as this required courage. The event bore out its accuracy. In a paragraph of his final report when the Royal Society Committee was about to take his place he says, "It has been inspiring to work in such an atmosphere of discipline and good will, and I shall remember with pleasure **—in spite of such anxiety and responsibility as cannot be imagined by those who do not know**—the days of my investigations here."

The boldface are the reviewer's. Here is a man working devoted and alone. He is working that black men may live and their habitations be preserved, in a hot and humid climate amid poison gas. He is apt to receive for it the nosey snubbing of "superior" men of science who dwell in superior laboratories in the urban atmosphere of a superior climate, and who do not dirty their fingers with the poisonous solfataras of volcanoes.

Withal his inventive ingenuity never relaxed. He finally installed at Howes Estate near the solfatara a "Seismeter" of his own construction made out of three pedometers of the pace-counting watch pattern. This is shown in Figure 6. Two are laid horizontally with their pendulum interiors at right angles to each other, to beat and record on their dials the "paces" of the earth east-west and north-south respectively. The third is laid vertically, as it would be if attached to a man's belt in walking, and records the upright jolts of the earth. All shocks above a certain minimum of intensity will record. By reading the three dials after one of the savage shakings of the earth, the number of units above the intensity minimum, prescribed by the sensitivity of the pedometer, for each direction, describes what has happened at the instrument locality.

Thus the quake of November 10, 1935 gave 1v, 9n, 3e; that of November 11 was much more vertical, 7½v, 6n, 5e; while that of November 12 was intermediate, 4½v, 2n, 1e. In these v is vertical, n is north-south, and e is east-west.

The seismeter has the further quality that its dials may be read after any shock series, but not changed; and it goes on summing up, just as the pedometer does for a pedestrian, the totality of earthquakes for any period of time, regardless of whether there is present an observer to read it. Thus this extraordinary worker in the wilderness finds time to invent and add to the progress of science, even in the midst of quakes and ruins and fumes!


View of Field Station and Head of Gorge - Gages Soufriere, Montserrat, B. W. I.

T. A. J.

Hawaiian Volcano Observatory Report for July 1937

VOLCANOLOGY

The only events of importance at Kilauea Crater have been two spells of local earthquakes lasting about a day each July 22 and July 30. Each of these produced moderate earthquakes which were felt. Numerous distant earthquakes were recorded.

The following are the weekly Observatory totals for Halemaumau and the seismographs:

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Tremors and Quakes
July 4	8.00	2	6.0	22
" 11	9.25	0	7.0	37
" 18	6.50	0	9.5	18
" 25	26.00	0	11.5	84
Aug. 1	22.75	0	5.5	45

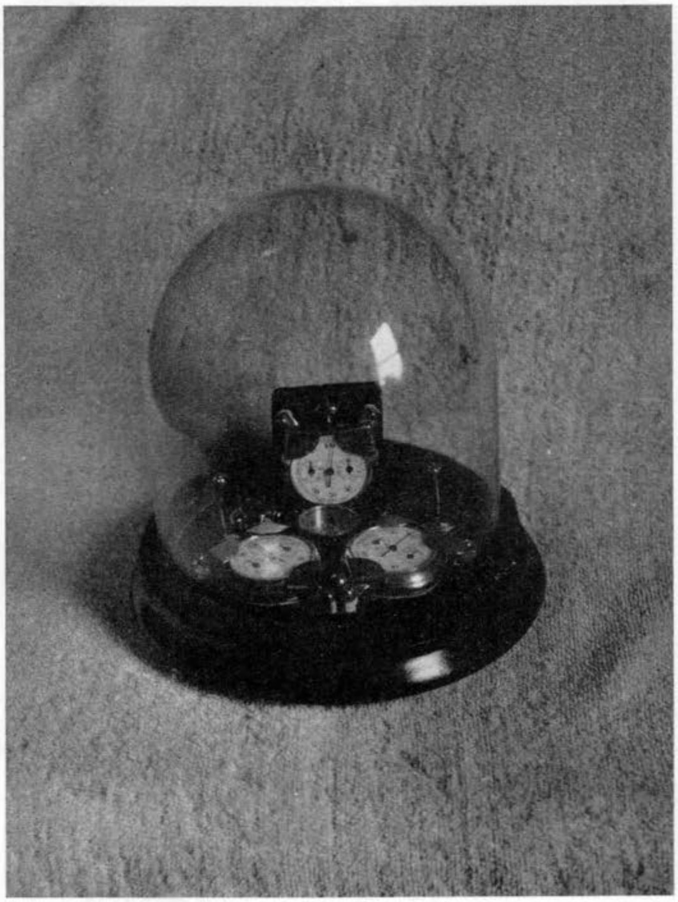


Figure 6. Experimental Seismeter installed at Gage's Oct. 25, 1935, records and integrates ground movement in vertical and horizontal components. (3) Totalizes on 9 dials (3 on each pedometer).

Frank A. Perret.

Sequence of Events by Weeks

The first week produced nothing more conspicuous at Halemaumau pit than two small slides.

The second week showed the pit still quieter.

The third week nothing was noted at Halemaumau but on July 14 Park officers on the upper Mauna Loa trail reported steam from a cone on the Northeast Rift at about elevation 11,000 feet, and bluish fume from cracks a quarter mile farther south.

The fourth week no slides were reported but the earthquakes of July 22 probably made avalanches. It was noticed July 25 that the northeast wall of Halemaumau has developed a buttress resulting from landslips on each side. The talus slopes NE, NW, SW, SSE, and E from the pit center all have buttresses of rock between them. The migration of landslip area from year to year since 1924 has kept the pit fairly symmetrical. The talus cones were made by such landslips and the buttresses are each backed by cracks concentric with the rim, and below the rim, that were formerly fissures in the upper country.

The last week produced excessive rainfall (more than 16 inches July 31-August 1), and a spell of earthquakes July 30.

Slides at Halemaumau

The only recorded slides from the wall of the pit were:

July 1, 1:22 p.m., made dust and noise.

July 2, 9:17 a.m., rocks fell from east wall 200 feet below rim.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim-crack locations resulted during July in aggregate movement as follows:

Week ending forenoon of:

July 2, 30 locations, 9 opened, 5 closed, opening 6.0 mm. At the east Crack No. 52 closed 4.5 mm.

July 9, 30 locations, 7 opened, 4 closed, opening 7 mm.

July 16, 30 locations, 8 opened, 1 closed, opening 9.5 mm.

July 23, 30 locations, 11 opened, 1 closed, opening 11.5 mm.

July 30, 30 locations, 3 opened, 4 closed, opening 5.5 mm. Most of this was at Crack No. 25, east rim.

SEISMOLOGICAL DATA

TABLE

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Moderate Earthquakes	Distant† Earthquakes	Weekly* Seismicity
July 4	16	4	0	1	0	1	8.00
" 11	35	1	0	0	0	1	9.25
" 18	12	5	1	0	0	0	6.50
" 25	70	9	1	0	1	3	26.00
Aug. 1	29	9	4	2	1	0	22.75

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 and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible a determination of depth of focus has been made.

June 30, 5:43 am, very feeble, located 3.5 miles deep under area 1.5 miles west of Kilauea Crater. 19° 25.0′ N; 155° 18.9′ W.

June 30, 8:46 am, very feeble, a deep quake with epicenter near Honokaa. 20° 4.0′ N; 155° 33.0′ W.

July 2, 9:16 am, very feeble, 2.6 miles deep and 2.0 miles west of Kilauea Crater. 19° 24.8′ N; 155° 19.4′ W.

July 3, 6:49 am, slight, 3.0 miles deep and 1.0 mile SW of Ahua Kamokukolau, 19° 22.0′ N; 155° 17.0′ W.

July 10, 9:43 pm, very feeble, thought to be of shallow origin near center of Kilauea Crater.

* For local seismicity definition see Volcano Letter 371.

† Includes teleseisms and distant earthquakes.

July 13, 5:40 pm, very feeble, originated near SE rim of Kilauea Crater.

July 16, 3:20 pm, very feeble, probably originated in rifts 1.5 miles S of Ahua Kamokukolau.

July 16, 6:51 pm, feeble, 3.5 miles deep in vicinity of Kipuka Ki, 2.0 miles NW of Uwekahuna. 19° 27.3′ N; 155° 19.2′ W.

July 18, 10:55 am, very feeble, 1.7 miles deep in W portion of Kilauea Crater near Uwekahuna Bluff. 19° 25.3′ N; 155° 17.0′ W.

July 18, 10:56 am, very feeble, 1.6 miles deep under Kilauea Crater rim near Uwekahuna Bluff. 19° 25.6′ N; 155° 17.1′ W.

July 18, 7:29 pm, very feeble, probably originated in NE rift of Mauna Loa near summit crater.

July 19, 8:36 am, very feeble, 1.7 miles deep in Kilauea Crater near the old Stone Corral. 19° 24.7′ N; 155° 16.3′ W.

July 22, 8:53 am, very feeble, probable origin, Kilauea SW rift near Cone Peak.

July 22, 10:38 am, feeble, probable origin in Chain of Craters near Puhimau.

July 22, 10:41 am, very feeble, 1.5 miles deep under SE rim of Kilauea Crater near Keanakakoi. 19° 24.5′ N; 155° 15.9′ W.

July 22, 10:53 am, very feeble, 2.2 miles deep, 6.0 miles N of Ahua Kamokukolau. 19° 23.3′ N; 155° 16.3′ W.

July 22, 11:14 am, very feeble, probably originated in Kilauea Crater near Halemaumau.

July 22, 11:18 am, very feeble, 1.6 miles deep, 1.8 miles NW of Puu Ohale. 19° 22.3′ N; 155° 17.9′ W.

July 22, 11:40 am, moderate, 1.8 miles deep and 1.7 miles SE of Pit seismograph. 19° 23.5′ N; 155° 15.8′ W. Reported felt in Park Headquarters Area and at Kilauea Military Camp.

July 22, 11:45 pm, very feeble, 3.0 miles deep SE rim of Kilauea Crater near Keanakakoi. 19° 23.0′ N; 155° 15.6′ W.

July 23, 3:30 pm, very feeble, probably of shallow origin near center of Kilauea Crater.

July 24, 3:20 pm, very feeble, probably originated in Chain of Craters Area near Puhimau.

July 30, 2:40 pm, moderate, probable origin, Mauna Loa NE rift near Puu Ulaula.

July 30, 3:46 pm, feeble 2.8 miles deep in vicinity of old Koa Mill, 1.5 miles N of Kilauea Crater. 19° 27.1′ N; 155° 17.0′ W.

July 30, 3:50 pm, feeble, 2.8 miles deep in Chain of Craters rift near Lua Mau Crater. 19° 23.9′ N; 155° 15.4′ W.

July 30, 8:05 pm, very feeble, 5.5 miles deep in Chain of Craters rift near Kokoolau. 19° 23.1′ N; 155° 14.0′ W.

July 30, 8:17 pm, very feeble, 3.5 miles deep near Kipuka Puaulu, 2.5 miles NW of Kilauea Crater. 19° 27.0′ N; 155° 18.9′ W.

July 30, 8:46 pm, very feeble, 2.4 miles deep near Ainahou Ranch House. 19° 20.8′ N; 155° 14.0′ W.

July 30, 9:14 pm, very feeble, probably originated in Chain of Craters near Pauahi.

July 30, 9:29 pm, feeble, 2.7 miles deep and 0.7 mile E of Hiiaki Crater, Chain of Craters rift. 19° 22.8′ N; 155° 13.5′ W.

July 31, 10:11 pm, slight, 4.7 miles deep under Kilauea Crater rim 0.5 mile NE of Uwekahuna. 19° 25.7′ N; 155° 17.3′ W.

July 31, 10:13 pm, slight, location of focus same as preceding quake.

July 31, 10:27 pm, very feeble, 5.0 miles deep and 1.0 mile NE of Volcano Observatory. 19° 26.5′ N; 155° 15.3′ W.

August 1, 2:56 am, feeble, location of focus same as preceding quake.

August 1, 9:43 am, very feeble, 2.8 miles deep in rift area 0.8 mile N of Puu Ohale. 19° 21.9′ N; 155° 16.8′ W.

A period of continuous tremor lasting 26 minutes began at 9:24 am, July 6.

Microseismic motion of the ground at the Observatory was light July 5, 10 to 13, 17, 19 to 21, and July 26; moderate June 28 to 30, July 4, 7 to 9, 14 to 15, 18, 22 to 23, 27 to 30, and August 1; strong remainder of month.

Teleseisms or Distant Earthquakes registered at Kilauea as follows: July 1, 4h 28m pm, H.S.T., undetermined phase; July 3, 7h 46m 19s pm, H.S.T., undetermined phase; July 11, 7h 13m 55s am, undetermined phase, reported by Central Station of the Jesuit Seismological Association as located 20° 7′ N; 108° 3 W (west coast of Mexico); July 22, preliminary phase, 6h 47m 56s am, originated 3,010 miles from Kilauea and epicenter reported by Central Station of Jesuit Seismological Association as 64° 5′ N; 145° W (Central Alaska); July 25, preliminary phase, 5h 26m 44s pm, H.S.T., distance—3,780 miles and July 25, 10h 18m pm, undetermined phase.

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 towards or away from the Pit.

At the Observatory the total accumulated tilt for the year ending August 1 was 9.8″ S and 1.85″ E.

TABLE OF TILT

Week Ending	Observatory	Halemaumau West Station
July 4	0.26″ N 20° W	1.55″ N 60° W
July 11	0.00	2.17″ N 68° W
July 18	1.13″ N 17° E	10.13″ N 82° W
July 25	0.36″ S 47° W	11.02″ N 71° W
Aug. 1	0.51″ S 60° E	6.35″ N 55° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
July 4	3.75″ N 60° W	2.22″ toward
July 11	3.40″ S 60° W	1.62″ from
July 18	10.85″ N 43° W	0.72″ toward
July 25	5.31″ N 86° E	12.89″ from
Aug. 1	10.37″ S 41° W	7.19″ from

H. H. W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis-Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

THE VOLCANO LETTER

No. 450 monthly **Department of the Interior** **National Park Service** **August 1937**

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

Mount Rainier National Park. Washington.

VOLCANOES IN THE NATIONAL PARKS—

Radio Talk, KHBC, Sept. 28, 1937, Hugh H. Waesche

Because of their spectacular nature and their interference with man's activities, volcanoes have always been of intense interest to the human race. With primitive peoples they have been associated with the supernatural, but when attacked by modern scientific thought they serve as major stepping stones in the solution of many problems concerning the origin and history of the earth on which we live. Most advanced, and going beyond previous thought is the systematic study of volcanoes with protection of life and property in mind.

Many of our National Park areas contain volcanoes as major features. Other National Parks contain volcanic features of secondary importance. Of twenty-seven National Parks listed August first of this year, five have volcanic histories of major interest, and at least nine others contain some evidence of past volcanic history. So, more than half of our National Parks have a geologic story to tell of which some portion is volcanic.

In this series of Parks, volcanic conditions of practically every kind known are demonstrated, from the currently very active lava volcanoes in Hawaii, to ash deposits laid down in Shenandoah and Mammoth Cave National Parks many millions of years ago in that geologic period known as the Ordovician, when man's arrival on earth was in the very distant future and probably all life was still confined to the oceans. This variety of volcanic evidence applies equally to both kinds of activity, and amounts of activity.

Five National Parks illustrate stages of volcanic activity very clearly. Hawaii National Park heads the list as the most active, being the location of Kilauea and Mauna Loa. Lassen Volcano in Northern California illustrates a second stage of activity as well as holding the unique position of being rated the only active volcano within the boundaries of continental United States, excepting Alaska. Mount Rainier in Washington represents the dormant stage, Crater Lake a dormant or extinct volcano with a special history, and Yellowstone, an ancient volcanic region much eroded but with enough residual heat to produce a very special type of geyser activity found at only three localities in the world.

Not one of these volcanoes has been listed definitely as extinct, as that is a term which should not be applied too hastily. No doubt some of these volcanoes are extinct, but definite statement to that effect would certainly be open to question. Vesuvius in Italy was considered extinct until seventy-nine A. D. but that opinion was rudely changed with the destruction of Pompeii.

Aside from the volcanoes in the National Parks there are others in National Monuments such as Katmai in Alaska, Sunset Crater, Arizona, Capulin Mountain, New Mexico, and the Lava Beds of California. Various types of volcanic structures are also exhibited in Craters of the Moon in Idaho, Devil's Post Pile in California, Devil's Tower, Wyoming, Grand Canyon National Monument and Death Valley National Monument.

It is not surprising that the first and greatest area to be set aside as a national park was volcanic. Only a volcanic region could produce the superlative and dynamic landscape which holds this honor. Everyone has heard of and knows something of Yellowstone, the "Grand Old Man" of all the parks, both in the United States and elsewhere. It is located in the northwestern corner of Wyoming with a slight overlap into the states of Idaho and Montana. This region was rather inaccessible and practically unknown until the middle of the last century. A few men had visited the region, however, and brought back glowing tales of the wonders to be seen there. As far as these reports were concerned the public was very incredulous and the situation was such that few dared to tell of the things they had seen, as several lecturers were actually stoned in the streets as imposters. The first official and accredited exploration of the Yellowstone region was made by the Washburn-Langford expedition of 1869. Their glowing reports of the wonders of the region led to its establishment as our first National Park in 1872.

The feature of greatest interest in Yellowstone is that unusual form of volcanic activity, the geyser. It is justly celebrated in this respect as there are only two other places in the world where geysers are common, New Zealand and Iceland, and Yellowstone has more geysers than those two combined. There are more than three thousand geysers or hot springs within the Park and every conceivable type or form of either is represented.

A geyser may be thought of as a water volcano. They can occur only in places where the internal heat of the earth is near the surface. Water from the surface plus some added from depth flows into an opening in the form of a more or less tubular vent, or maybe even a crack, and eventually reaches regions of highly heated rocks below. When this happens steam is formed but does not escape because of the heavy column of water above. After a time, however, the steam pressure becomes equal to or slightly greater than that exerted by the water column and as soon as this condition is reached the water is forced out and appears at the surface as a fountain.

The height of the fountain, frequency of play, and force of the water depend on conditions which vary widely with the different geysers. Such conditions are size of orifice at the surface, temperature below the surface, length and size of the tube leading to the hot rocks, ground water level, and probably other conditions which are not known.

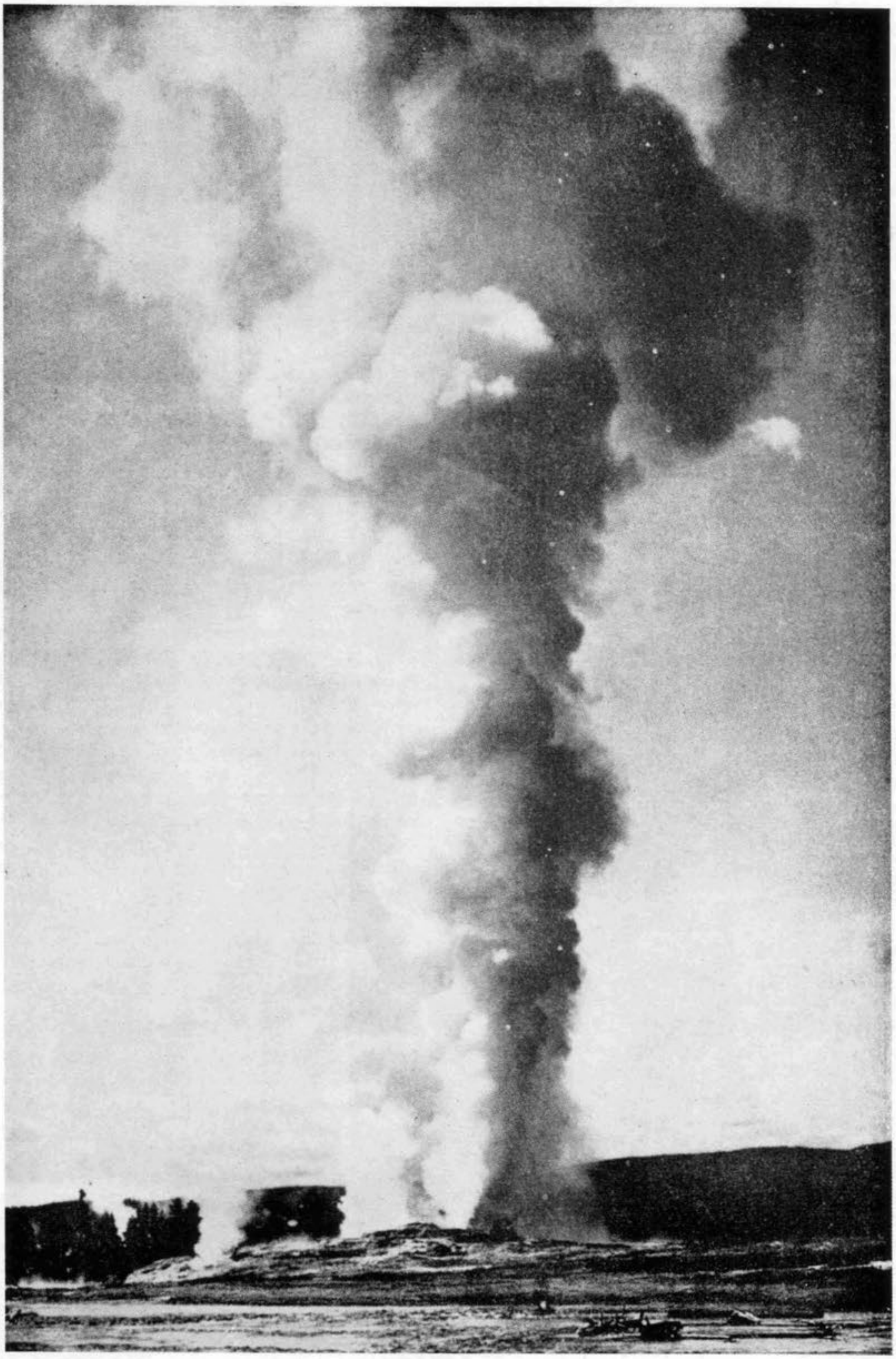
There are six principal geyser basins in the Yellowstone, all lying in the west and south-central sections of the Park. Some geysers erupt quite regularly. The most famous of these are Old Faithful, Daisy and Riverside. Old Faithful erupts about once an hour year in and year out and shoots a shaft of water over one hundred and fifty feet in the air for four minutes. The water temperature is about two hundred degrees Fahrenheit. Besides the geysers, the entire region contains many hot springs which are in most cases clear water with a beautifully colored background of orange, yellow, green or blue created by algae which live on the rocks forming the container. Other springs are filled with mud in constant agitation which, in one case, is named the Paint Pot. At Mammoth Hot Springs the water has brought to the surface large amounts of lime in solution which is precipitated on reaching the air. These mineral deposits build high terraces of beautifully encrusted basins over which the water flows.

Practically the entre region incorporated in Yellowstone is volcanic. Not only the surrounding mountains but the great interior plain is made of material once ejected as ash and lava from depths far below the surface. In some places entire forests have been buried by ashes blown from these ancient volcanoes, in another place lava which poured out on the surface cooled so rapidly that volcanic glass was formed, now represented by the famed Obsidian Cliffs. Yellowstone's volcanoes were probably active in that geologic age known as the Tertiary, millions of years ago. Since that time the region has quieted down, and has even been through a period of glaciation. The stage of erosion there, plus the lack of recent activity, marks the area as one in which a great volcanic exhibition had been through its youth, maturity and is now in advanced old age with only enough heat left over to keep the geysers busy.

Several hundred miles west of Yellowstone lies an area of a quarter million square miles which is the greatest field of volcanic activity in the United States and one of the greatest in the world. Large portions of the States of Washington and Oregon, and lesser portions of California, Nevada, Idaho, Montana and Wyoming are within this area. It includes the Cascade Range of Mountains extending from northern California across Oregon into Washington.

Within this range are three of our National Parks, all volcanoes, and they are, in order, south to north, Lassen Peak, Crater Lake and Mt. Rainier. Of this group, only Lassen is considered active. Crater Lake was probably active as recently as eight hundred years ago. Mt. Rainier near Tacoma, Washington, is considered "king" of all the towering volcanoes of this region. It is a huge volcanic cone over 14,000 feet in height and covering more than 100 square miles. A few steaming vents and hot springs are all that remain of activity which was evidently on a very grand scale in its past history. Now this huge mass of lava, cinders and ashes is covered by snow and ice resulting in a glacier system. Mt. Rainier is now an imperect cone, but once it was complete like the famous Fujiyama of Japan. Then it was probably 16,000 feet high. Sometime in its late history an explosion or engulfment occurred which took 2,000 feet off the top and left Mt. Rainier beheaded. Indian legends tell of a great eruption, but no man really knows when this great mountain was last active.

The southern limit of the Cascade Range is marked by Lassen Peak. This volcanic pile is the only aggressive member of the group to which it belongs. It had been quiet for over two hundred years although one or more doubtful eruptions are reported, and "mud" flows have occurred within the last five hundred years as estimated from buried logs.



Yellowstone National Park. Wyoming.

On May 30, 1914, a series of eruptions began from Lassen which lasted through June of 1917. The first eruption was short and mild, opening a new vent in the summit crater. The materials thrown out the first year were not excessively hot. By March of 1915 over one hundred and fifty explosions had occurred, probably aided by water from an unusually heavy winter snowfall. On May 19, 1915, there appeared the first glowing lava which spilled over the western edge of the crater to flow down the slope one thousand feet. That night several destructive mud flows poured into valleys down the slope.

Three days later a mushroom-shaped cloud of smoke and dust arose four miles in the air accompanied by a hot blast of gas which rushed down the northeast slope destroying every living thing for ten miles. So violent was this blast that trees on Raker Peak three miles away were all felled uniformly in the direction of the outburst. The heat turned snow in its path to water. After this convulsion the energy of the Volcano was mostly spent although occasional outbursts of steam and ash continued for two years when it finally subsided.

At the present time Lassen is quiet, although from time to time there are earthquake shocks. There are many hot springs, boiling mud pots and sulfurous deposits in and around Lassen Peak. A seismograph station is maintained at Lassen for recording earthquakes as is done here in Hawaii. Lassen was formerly a part of the study program of the Hawaiian Volcano Observatory. Lassen Peak is 10,453 feet above sea level and is surround by lava fields, and other volcanic cones illustrating many phases of volcanic activity. Lassen's activity will probably be resumed in the future.

Although Grand Canyon National Park is set aside as a great example of stream erosion, it has some evidences of volcanic activity of a minor nature which occurred millions of years ago. However, within sixty miles of Grand Canyon is one of the largest extinct volcanoes in the United States. This is the San Francisco Mountain area of Arizona. Included in this region is Sunset Crater, a 700-foot cinder cone and associated lava fields. The latter locality has been recently active—that is within a thousand years. Some of the lava associated with Sunset Crater is very similar to our Hawaiian aa. Sunset Crater is a National Monument.

The Devil's Tower in Wyoming is an interesting volcanic exhibit. It is a 600-foot pile of vertical jointed lava similar to that to be seen in Makaopuhi Crater here in Hawaii National Park. It tops a 600-foot mound of sedimentary rock and can be seen for a hundred miles in any direction. Some people think it is an intrusive plug, but there are others who think it is a remnant of an old intrusive sheet, and there is a lot of evidence to back this latter theory.

In the country north of Lassen National Park there is an area in California near the Oregon line known as the Lava Beds National Monument. This large region is typical of its name and contains many lava tubes similar to our Thurston Lava Tube. Some of the tubes contain ice the year around and are known as ice caves.

Alaska is one of the most active volcanic regions of the world. A belt of volcanoes extends for 1,500 miles through the Alaskan Peninsula to the west part of the Aleutian Islands. Katmai is one of this series of volcanoes. It is 6,970 feet high, located on treacherous Shelikof Strait, opposite Kodiak Island.

Very little attention was paid to Katmai until June, 1912, when it announced itself to the world with an explosion that was heard in Juneau, 750 miles away. Earthquakes followed this blast and then came a spell of smoke and dust causing sixty hours of darkness in Kodiak, a hundred miles away. Dust fell in Ketchikan, 900 miles away and fume was carried by the wind to Vancouver, fifteen hundred miles away. Hazy atmosphere was noted over the United States the succeeding weeks and even peculiar atmospheric effects were noticed in Europe the following summer.

The scene of this explosion was made a National Monument in 1918. One of the most interesting phases of development at Katmai was the formation of the valley of 10,000 smokes near by. This has been described at length in the National Geographic Society's publications.

This review of volcanic National Parks and Monuments is by no means conclusive. However, it does give an idea of the great variety of volcanic activity to be found within the United States and its territories, with unlimited possibilities for study and research, or entertainment for those who prefer a spicier type of geologic story, connected with their Parks. Volcanoes can be depended upon to put on a good show when they are so minded in spite of their temperamental natures. To people of Hawaii, visits to the other areas should be interesting.

Kilauea Lava Flow of 1823

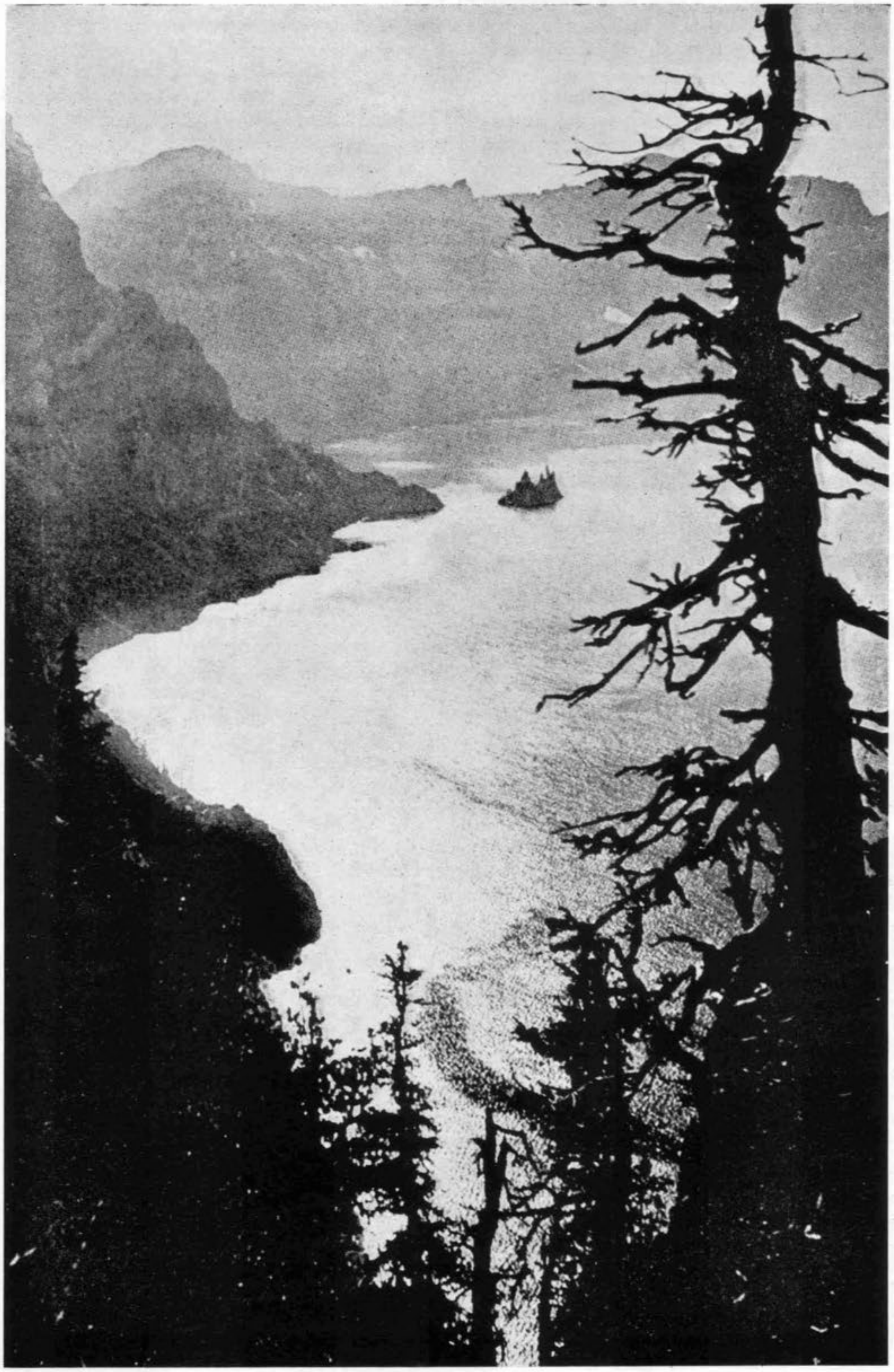
A major structural feature of Kilauea is the fracture zone extending twenty miles SW of the Crater, in the general direction of Pahala. This rift disappears out into the sea. It is commonly spoken of as the Kilauea SW Rift and is the feature indicated by that term frequently used in the Volcano Letter.

Although most of the Kilauea eruptions have occurred in the summit crater within historic times, some major activity has taken place in the regions associated with the SW Rift. The numerous prominent cinder cones and flows of the Kau desert in this vicinity testify to abundant activity before historic recording began.

The first nineteenth century flow from Kilauea occurred in 1823. It issued from the "Great Crack" twelve miles SW of Kilauea Crater. A minor flow took place in the SW rift zone eight miles from the Crater in 1868. The identity of this flow has often been confused with the more extensive flow of 1823. The confusion, however, has been straightened out with reasonable certainty by Stone, Stearns, and Jaggar, who have covered the question in published articles. The third and last SW Rift flow was that of 1920, resulting in the formation of Maunaiki. All of these flows are correctly shown on the latest maps. In the last 110 years there have been only three known periods of activity in the SW Rift.

The morning of February 26, 1937, a party of National Park officials visited the area of the Keaiwa Flow (local name for 1823 flow). This group included Mr. John D. Coffman, Chief Forester of the National Park Service, and Mr. E. E. Tillett, Field Supervisor of the Emergency Conservation work for the Islands.

The 1823 flow was found to be of considerable interest and unusual in that it seemed to have issued from the Great Crack which probably opened up immediately preceding the eruption and, no doubt, was accompanied by rather strong earthquakes. By Ellis' dates the outflow was about February, 1823, and the most serious earthquake about May. The lava formed a comparatively thin skin over older flows, leaving many small kipukas or islands of the older material and thus indicating a very fluid condition. Lining the Great Crack, there are rounded lava balls similar in appearance to bombs but of a much different origin and in two localities there are indications of phreatic explosions. The lava balls are accretion-spheres formed of hardened liquid lava around fragments in the chasm, swept out by later gushes which embedded them. The absence of cinder or driblet cones would indicate that the lava issued from the earth in a somewhat different fashion from the usual Hawaiian flow which has both at its source. A very striking and prominent feature is the presence of many tree molds. These are of a wide variety as to form. Some are several feet in thickness and



Crater Lake National Park. Oregon.

as much as six feet in height. The forms of the trees responsible are well preserved and the relative position of trunk and branches is often indicated. None of the molds observed was apparently formed by trees with a trunk of more than three or four inches in diameter. The direction of flow is clearly indicated by the flow lines around the molds and a piling up of the lava on their north sides. The flow definitely moved south as it should across the contours, toward the sea.

The history and general description of the flow has been so thoroughly covered by several writers that no further discussion will be given here. Those wishing to know more of an unusual Kilauea Rift flow are referred to the following articles:

1. Harold T. Stearns, "The Keaiwa or 1823 Lava Flow from Kilauea Volcano, Hawaii, Journal of Geology, Vol. XXXIV, No. 4, May-June, 1926.

2. Harold T. Stearns and W. O. Clark, "Geology and Water Resources of the Kau District, Hawaii," Water Supply Paper 616, U. S. Geological Survey, 1930.

3. T. A. Jaggar and Oliver Emerson, "Bulletin of the Hawaiian Volcano Observatory," May, 1924, pp. 34-35, and Nov., 1924, pp. 110-111; U. S. Geol. Surv. Figures 13-16, Vol. XIII, No. 6, June, 1925.

4. "The Keaiwa Flow of 1823, Hawaii," by John B. Stone, Amer. Jour. Sci., May, 1926.

5. "The 1823 Lava Flow from Kilauea," by R. H. Finch, Volcano Letter No. 18, 1925.

6. "Ball Lava," by J. A. Thomson, New Zealand Journal of Science and Technology, about 1925.

H. H. W.

Hawaiian Volcano Observatory Report for August 1937

VOLCANOLOGY

The most important event at Kilauea Crater was a fall of the rim rock of Halemaumau pit at the east, at 8:41 am August 22, carrying away the measurement marks of Crack No. 25 and also No. 24; at Crack No. 25 excessive opening had been revealed by measurement for weeks. The crash of the avalanche produced earthquake disturbance marked on the seismographs. The disturbance of the rim occasioned by this avalanche caused many subsequent slides, enlarging the talus, and gradually adjusting the cliff. There was increase of tremors for the last fortnight of the month, but no good method has yet been developed to prove cause and effect in the relation between slides and tremors. It is of interest to note, however, that the succession of cliff adjustments following a big avalanche is not unlike the succession of aftershocks following an earthquake.

The following are the weekly Observatory totals for Halemaumau and the seismographs.

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Tremors and Quakes
August 8	9.50	1	25.0	26
" 15	10.75	1	40.5	34
" 22	11.75	22	95.5	35
" 29	17.50	3	15.0	47

There were felt shocks of Kilauea origin August 3, 7, 10, 23, and 27; and two others of Mauna Loa and Hualalai origin August 16 and 18, felt on the west side of the island. Of all the measured shocks 27 indicated Kilauea distances of origin and three were from Mauna Loa or beyond. Distant earthquakes August 10 and August 20 indicated origins about 5,500 miles away, the second reported of destructive intensity on Luzon in the Philippines.

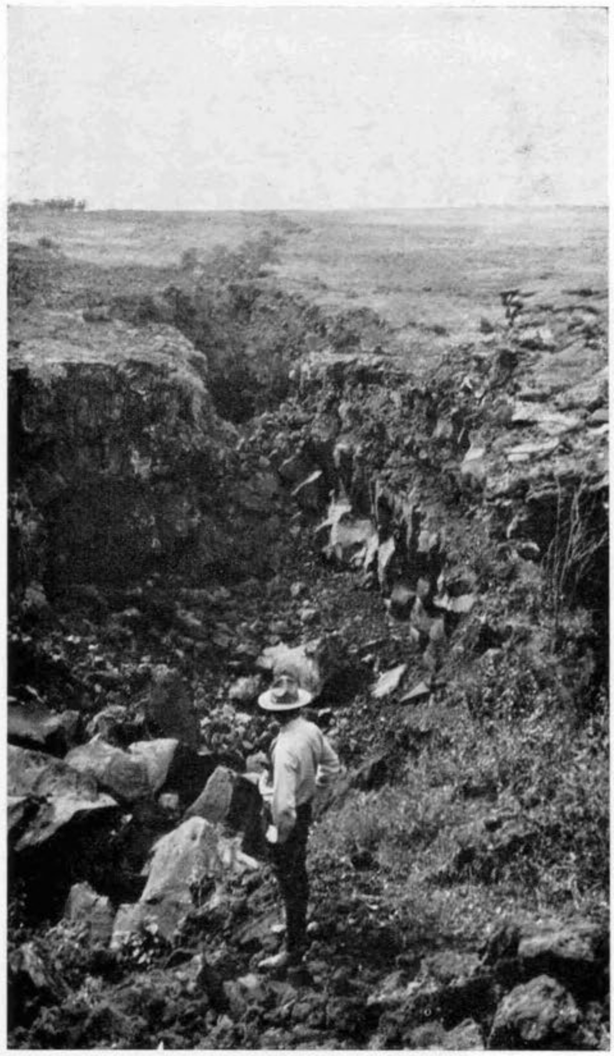
Sequence of Events by Weeks

The first week produced low seismicity and nothing more at Halemaumau pit than the excessive opening of Crack No. 25 at the east, which was one of the steaming extensions of the caved-in cracks of the east notch that had collapsed destroying Crack No. 28 on May 7. This opening of Crack No. 25 had been noticed repeatedly since May.

The second week produced only one slide, but the rate of opening of Crack No. 25 almost doubled.

The third week produced the avalanching crisis with Crack No. 25 opening three times as much as the week before and the observed slides numbering 22. Seismicity, owing to the increased numbers of tremors, rose steadily during the month.

The fourth week produced only three observed slides, the taluses at the base of Halemaumau wall had been enlarged, aggregate crack opening dwindled, but seismicity continued to increase.



Looking south along the great crack from which issued 1823 flow as viewed at Puna Trail crossing. Waesche.

Slides at Halemaumau

The recorded slides from the wall of the pit were:

August 2, 2:20 a.m., a noise like sliding during excessive rain, possibly a cataract at Uwekahuna.

August 12, 1:00 p.m., dust from west side of pit.

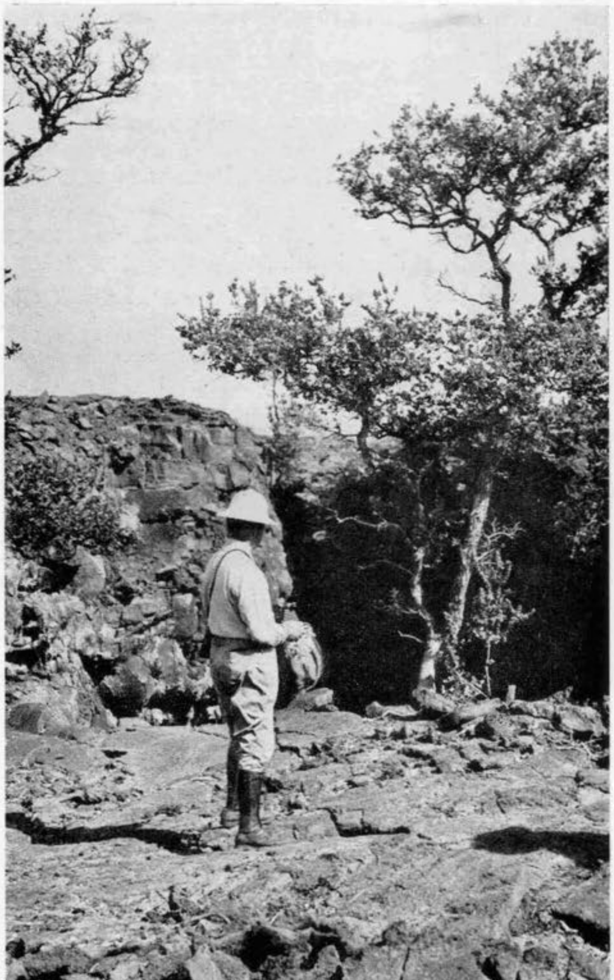
August 17, 2:30 p.m., eastern slide.

August 20, 11:20 a.m., western slide.

August 21, 11:40 a.m., noisy east slide, leaving scar 30 feet down.

August 22, 8:40 a.m., very large slide east making very feeble earthquake on seismograms.

August 22, 9:45 a.m., large dust cloud east.
August 22, 9:57 a.m., dust floated westward.
August 22, 10:28 a.m., eastern slide.
August 22, 10:35 a.m., eastern slide.
August 22, 10:50 a.m., slides continued.
August 22, 11:00 a.m., more slides.
August 22, 11:05 a.m., more of east rim fell.
August 22, 11:19 a.m., slide west-northwest.
August 22, 11:20 a.m., very large eastern slide.
August 22, 11:30 a.m., more slides.
August 22, 11:33 a.m., " "
August 22, 11:45 a.m., " "
August 22, 11:50 a.m., " "
August 22, 11:55 a.m., " "



Looking north along the great crack from same locality.
Waesche.

August 22, 12:10 p.m., " "
August 22, 12:19 p.m., " "
August 22, 12:20 p.m., rim rock fell and slides continued.
August 22, 3:00 p.m., rim rock fell in a large slide east; talus below now showed great enlargement.
August 24, 3:45 p.m., eastern slide.
August 25, 12:50 p.m., large dust cloud northwest rim.
August 26, 9:38 a.m., slight northwest slide.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted August in aggregate movement as follows:

Week ending forenoon of:

August 6, 30 locations, 12 opened, 1 closed, opening 25.0 mm. Crack No. 25 east opened 18.0 mm.

August 13, 30 locations, 13 opened, 1 closed, opening 40.5 mm. Crack No. 25 opened 31 mm.

August 20, 30 locations, 7 opened, 6 closed, opening 95.5 mm. Total opening was 99 mm., six cracks exhibiting a closing of 3.5 mm. Crack No. 25 by weeks had exhibited the following:

July 30, 6.0 mm. opened.

August 6, 18.0 mm. opened.

August 13, 31.0 mm. opened.

August 20, 96.0 mm. opened.

August 22, the cracked block collapsed, showing that the rate of opening had made forecast of the rim breakage.

August 27, 27 locations, 17 opened, 00 closed, opening 15.0 mm.

Cracks 24 and 25 had been destroyed August 22 and No. 51 on northeast rim was mutilated by unknown causes.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant† Earthquakes	Weekly* Seismicity
Aug. 8	18	6	2	0	0	9.50
Aug. 15	27	6	1	0	1	10.75
Aug. 22	27	6	2	0	1	11.75
Aug. 29	36	9	0	2	0	17.50

*For local seismicity definition see Volcano Letter 371.
†Including teleseisms or those shocks over 5,000 km. distant.

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 and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the times indicated and whenever possible, a determination of depth of focus has been made.

August 2, 3:45 am, very feeble, 1.3 miles deep E rim of Kilauea Crater near junction of Byron and Waldron Ledges. 19° 25.3′ N; 155° 15.6′ W.

August 3, 1:39 am, very feeble, probably originated in NE portion of Kilauea Crater.

August 3, 8:52 am, feeble, probably originated in Chain of Craters near Hiiaka.

August 6, 10:41 pm, very feeble, 2.4 miles deep, S rim of Kilauea Iki. 19° 24.8′ N; 155° 14.8′ W.

August 7, 7:09 am, feeble, 5.7 miles deep, SE rim of Kilauea Crater. 19° 24.2′ N; 155° 16.2′ W.

August 8, 4:40 pm, very feeble, of Kilauea origin.

August 8, 5:06 pm, very feeble, of Kilauea origin.

August 9, 5:39 pm, very feeble, 0.9 mile deep in rifts 0.4 mile W of Keanakakoi Crater. 19° 24.2′ N; 155° 16.4′ W.

August 9, 8:57 pm, very feeble, 3.6 miles deep in area 1.5 miles W of Kilauea Crater. 19° 25.0′ N; 155° 18.9′ W.

August 10, 5:13 am, very feeble, 0.7 mile deep SE rim of Kilauea Crater near Keanakakoi. 19° 24.4′ N; 155° 16.2′ W.

August 10, 5:00 pm, feeble, 2.3 miles deep, E portion of Kilauea Crater near Kilauea Iki. 19° 25.2′ N; 155° 15.9′ W.

August 11, 4:57 am, very feeble, 5.0 miles deep, 3.8 miles SE of Observatory. 19° 23.7′ N; 155° 13.1′ W.

August 12, 11:56 am, very feeble, of Kilauea origin.

August 12, 2:21 pm, very feeble, thought to have originated in Kilauea Crater immediately NE of Halemaumau.

August 16, 4:39 am, feeble, 18 miles deep, SW slope of Mauna Loa, 13 miles from Summit Crater. 19° 16.0′ N; 155° 38.0′ W.

Tree mold in 1823 Lava Flow. Waesche.

August 18, 5:27 pm, feeble, probably of deep origin under Hualalai. Felt in Kona and dismantled seismograph at Kealakekua.

August 18, 9:31 pm, very feeble, of MaunaLoa origin.

August 19, 3:22 am, very feeble, 1.0 mile deep, N portion of Kilauea Crater near Kilauea Military Camp. 19° 25.8′ N; 155° 16.6′ W.

August 21, 10:49 pm, very feeble, 0.8 mile deep, Kilauea Crater near E rim of Halemaumau, 0.4 mile N of Pit seismograph. 19° 24.7′ N; 155° 16.9′ W.

August 22, 4:21 am, very feeble, 3.8 miles deep, 3.2 miles N of Uwekahuna. 19° 28.2′ N; 155° 17.3′ W.

August 22, 8:41 am, very feeble, caused by slide from E rim of Halemaumau.

August 22, 11:49 pm, very feeble, E portion of Kilauea Crater 0.5 mile deep. 19° 25.0′ N; 155 ° 15.9′ W.

August 23, 12:45 am, very feeble, of shallow depth, Kilauea Crater 0.7 mile SSW of the Observatory. 19° 25.3′ N; 155° 15.9′ W.

August 23, 3:02 am, slight, 0.5 mile deep E portion of Kilauea Crater. Dismantled Pit seismograph. 19° 25.0′ N; 155° 15.9′ W.

August 23, 2:20 pm, very feeble, 1.0 mile deep, W edge of Keanakakoi Crater (SE rim of Kilauea Crater). 19° 24.1′ N; 155° 16.1′ W.

August 23, 7:41 pm, very feeble, 4.3 miles deep, 0.7 mile NW of Uwekahuna. 19° 25.6′ N; 155° 18.0′ W.

August 25, 12:04 am, very feeble, 0.7 mile deep under SE rim of Halemaumau. 19° 24.4′ N; 155° 16.9′ W.

August 27, 12:12 am, slight, 1.5 miles deep SE rim of Kilauea Crater, 0.3 mile NE of Keanakakoi. Reported felt by few near Hawaii National Park Headquarters and at CCC Camp. 19° 24.4′ N; 155° 15.8′ W.

August 27, 12:15 am, very feeble, 0.9 mile deep, Kilauea Crater, 0.3 mile N of Keanakakoi. 19° 24.6′ N; 155° 16.0′ W.

August 29, 7:36 am, very feeble, thought to have originated near Pit seismograph and shallow depth.

The preliminary waves of a teleseism began to register at Kilauea at 2h 38m 1s, pm, H.S.T. August 10. Distance was 5,520 miles. The preliminary waves of another teleseism began registering at 1h 41m 29s, am, H.S.T. August 20. Distance from Kilauea was 5.465 miles and reported location was in the Philippine Islands, where it was of destructive intensity, especially on the Island of Luzon.

Microseismic activity of the ground at the Observatory was light August 5 to 9, 18, 21, 27 to 29, strong August 3, 4, 24, 25 and moderate the remainder of the month.

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 toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending August 29 was 10.80″ S and 0.46″ E.

Week Ending	Observatory	Halemaumau West Station
August 8	1.12″ N 53° E	5.78″ S 82° W
August 15	1.17″ S 69° W	5.04″ N 40° W
August 22	0.31″ S 8° E	6.73″ S 73° W
August 29	0.58″ N 45° W	2.62″ S 44° W

Week Ending	Halemaumau Southeast Station	Pit Resultant
August 8	7.29″ N 63° W	0.67″ toward
August 15	0.23″ S 66° W	2.67″ from
August 22	5.18″ N 45° W	1.53″ from
August 29	7.78″ N 17° W	5.35″ toward

H. H. W.

THE VOLCANO LETTER

No. 451 monthly Department of the Interior National Park Service September 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

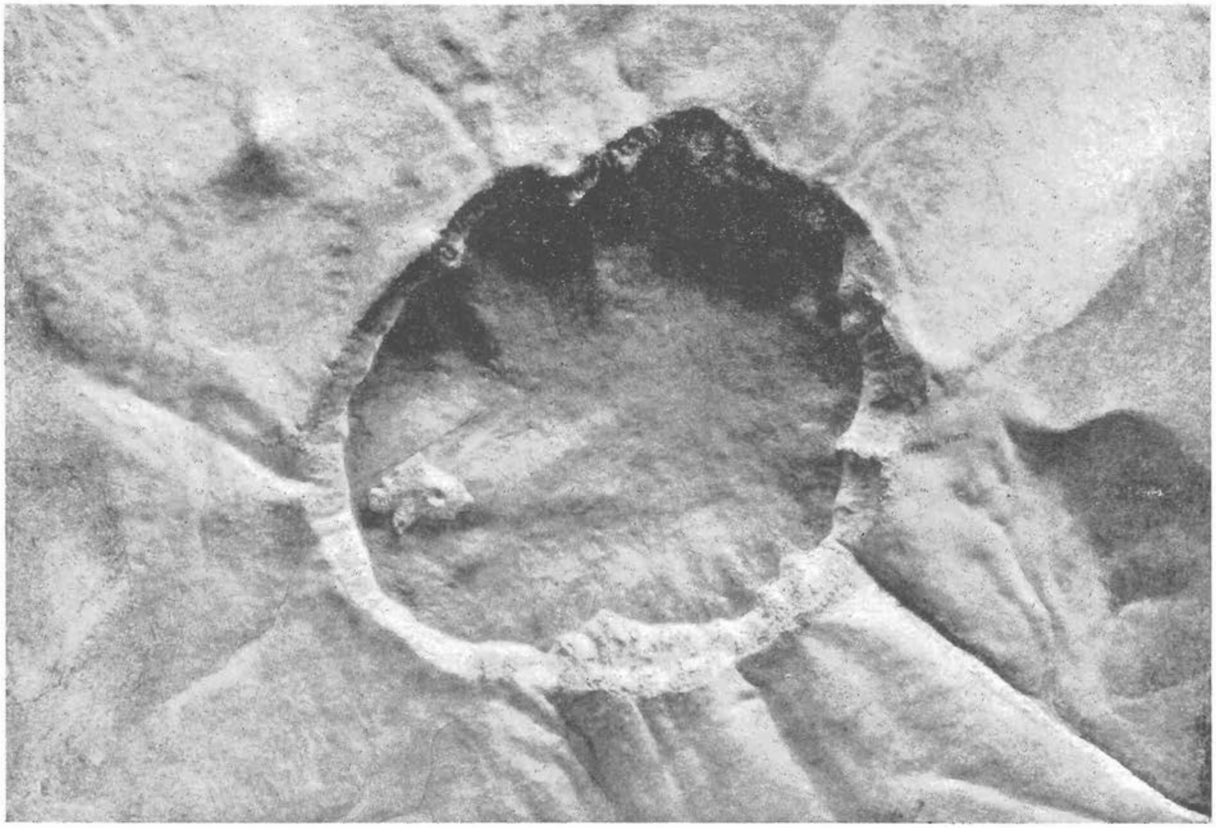


Fig. 1. Model of Crater Lake (after Diller).

CRATER LAKE NATIONAL PARK—

By H. H. Waesche

Certain areas in the United States and its territories have been set aside by the Federal Government as National Parks. Included in these are such well known places as Yellowstone, Grand Canyon and Yosemite Valley. National Parks are of importance because they contain within their boundaries some feature of both exceptional beauty and scientific interest which should be protected for the pleasure and benefit of the nation. Crater Lake National Park is one in this great system of recreational areas. It is probably not so well known as those mentioned but it is a region of unusual beauty and of great geologic interest.

The Park is located in south central Oregon, about seventy-five miles north of the California line. The central feature of the Park is Crater Lake which is a body of pure, sapphire blue water. The water is so blue that the officials often jokingly are accused by visitors of having put bluing in it. The Lake is relatively large, being from four to six miles across and two thousand feet deep. It is surrounded by cliff-like walls rising from five hundred to two thousand feet above the surface of the water. The walls are of many colors with reds, grays, purples, yellows and browns predominating. It is no wonder that such a spot is spoken of as the gem of our National Parks. Its moods are many, with color in unbelievable variations, ever changing with light alterations from sunrise to sunset. As a background and giving additional color there are many trees forming numerous patterns and designs of green. A gasp of admiration is the first expression offered by most visitors, followed by a moment of silence as though they were trying to believe that such a place could be real. As is true of most scenes of nature that are so striking, Crater Lake cannot be described, so we shall deal in this discussion with its history and geologic story.

Although pioneers entered what is now the state of Oregon at a comparatively early date, it was around eighteen fifty before they began to filter into the southern part of the state. The region was none too accessible and the sparse population was in constant dread of Indian wars. Gold had been discovered in California and many people were moving westward. Many of these, disappointed in California, migrated to Oregon. It was not long before gold was discovered there too and exploration and prospecting in southern Oregon advanced accordingly. A band of California prospectors came to the mining town of Jacksonville to prepare for a trip into the mountains, keeping their purpose a secret. They were betrayed by one of their members to a group of Oregon miners who learned that they were searching for a "Lost Cabin Mine," supposed to be near the head of the Rogue River. The Oregon group immediately started after the California party which tried unsuccessfully to evade them. Both parties eventually ran out of food and through the efforts of John Wesley Hillman, leader of the Oregon group, the parties combined in order to hunt for game. On June 12, eighteen fifty-three, Hillman went ahead of the hunting group, and rode up a deep canyon, which, judging from its size, he thought would lead to a higher slope. He let the mule pick its own way while he peered through the woods for game. Imagine his astonishment when the mule stopped on the rim of a deep blue lake lying many hundreds of feet below. Here he beheld a scene of unsurpassed beauty. Other members of the party soon joined the leader and they agreed to call the body of water "Deep Blue Lake."

Gold and Indian wars caused men soon to forget Crater Lake so that in eighteen sixty-two another group of miners "rediscovered" the lake only to learn afterwards of the Hillman party's previous visit. A third "discovery" was made in eighteen sixty-five by soldiers from Fort Klamath who called it Lake Majesty. The name was changed to Crater Lake in eighteen sixty-nine by some visitors from Jacksonville and it has been known by that name ever since.

In eighteen eighty-five William Gladstone Steel first visited Crater Lake. He had heard of this natural wonder as a school boy and had resolved to visit the locality. He came to Oregon in eighteen seventy-two but it was nine years later before he could find anyone who had heard of the lake and several more years passed before he found anyone who had seen it. He was so impressed when he finally reached his destination that he immediately started agitation to make the area a National Park. Seventeen years later his efforts were rewarded. Congress established Crater Lake National Park in May, nineteen hundred and two. Judge Steel devoted the rest of his life to the development of the park and was for years Park Commissioner. He died in October of 1934.

The U. S. Geological Survey made a survey of the area in eighteen hundred eighty-six and at the same time sounded the Lake.

Paved roads are now to be found in the Park and it is visited by over one hundred and sixty thousand persons annually.

The story of the origin of Crater Lake is coupled with the geology of the Cascade range of mountains. These mountains are formed on the surface of volcanic rocks which have been poured out through a series of vents along a weak zone of the earth's crust. The vents are represented by a long line of volcanoes extending from Lassen Peak in northern California to Mt. Baker in Washington. Others of this series are Mt. Shasta in California, Mt. Theilson, the Three Sisters and Mt. Hood in Oregon, and Mt. Rainier in Washington. All of them are now extinct or dormant, although hot springs and steam vents are found on Mt. Shasta, Mt. Rainier and Mt. Hood. Within historic times only one of the entire group has been conspicuously active. This one is Mt. Lassen in California which erupted in nineteen fourteen and again in nineteen twenty-three. Previously it had been inactive like the others but early explorers and Indians reported some eruptions. All of these volcanic peaks are comparatively high, ranging from ten thousand to nearly fifteen thousand feet above sea level. All are snow-capped the year around and abound in glaciers. They are some of the most picturesque and rugged mountains of the United States.

Crater Lake now occupies a yawning pit which marks the site of an old volcanic peak of this group which probably rivaled in grandeur the towering Mt. Rainier or Mt. Shasta. It is supposed to have been at least fourteen thousand feet high and may have reached the fifteen thousand foot mark. This former mountain has been given the name Mt. Mazama. Crater Lake is now six thousand feet and the rim is between seven and eight thousand feet above sea level. How do we know a mountain formerly existed here? What has become of that ten thousand foot mass of rock that once extended to the summit? That is the mystery of Crater Lake! Scientists are still trying to solve this great geologic mystery drama. A number of possible solutions have been offered but none seems satisfactorily to fit the facts of the case. Apparently where now all is peaceful and quiet, formerly gigantic forces of nature waged a fierce, spectacular struggle with each other.

The walls of Crater Lake are built up of alternate layers of rock. Some of these are dense and others are fragmental. This shows that Mt. Mazama was built by a series of explosions alternating with periods when molten lavas poured out of its vent and down its slopes. The explosions blew material high into the air which settled back around the old vent. The accumulation of explosive materials plus the outpourings of molten lava resulted in the building of the cone of Mt. Mazama. There must have been times when Mt. Mazama was quiet over periods of many years. This is shown by the irregular form of the rim and of materials deposited by running water and glaciers. At several points the Lake rim is indented by large U-shaped depressions which have the typical outlines of glacial valleys. These valleys have been cut off, as their cross sections show that they must have extended much farther up mountain slopes since destroyed. At other localities loose gravels and assorted materials show the effect of glacial deposition. In a few cases running water has cut "V" shaped valleys. One of the most interesting valleys of all is one which is filled by a great lava flow. Here one can see evidence of a regular succession of events which helps to prove the existence of Mt. Mazama, of glacial action, stream action and intermittent volcanic activity. First a "U"-shaped valley was formed in the alternate lava flows of Mt. Mazama, by a glacier, which represents a long period of snow accumulation and volcanic inactivity. Then the glacier receded and streams cut a "V"-shaped valley in the old glacial valley. This was followed by explosive activity which filled the floor of the valley with pumice, a light frothy volcanic rock. Soon after the explosion the valley was completely filled by a massive lava flow which even overflowed on the broader mountain slopes. Another explosion covered the lava flow with a layer of pumice similar to that over which it had flowed. At times forests grew on the slopes of Mt. Mazama as they do on Mt. Rainier today. The trees were even similar to those of the present. Charred logs, buried in volcanic ash, give mute evidence of the fate which overtook these trees. All of the rock layers do not run parallel to the mountain slopes. In a number of places peculiar layers cut across the other more horizontal layers at right angles. These forms are known as dikes. They show that the column of molten material in the old vent was under pressure and that there were weak places in the wall of the cone. The

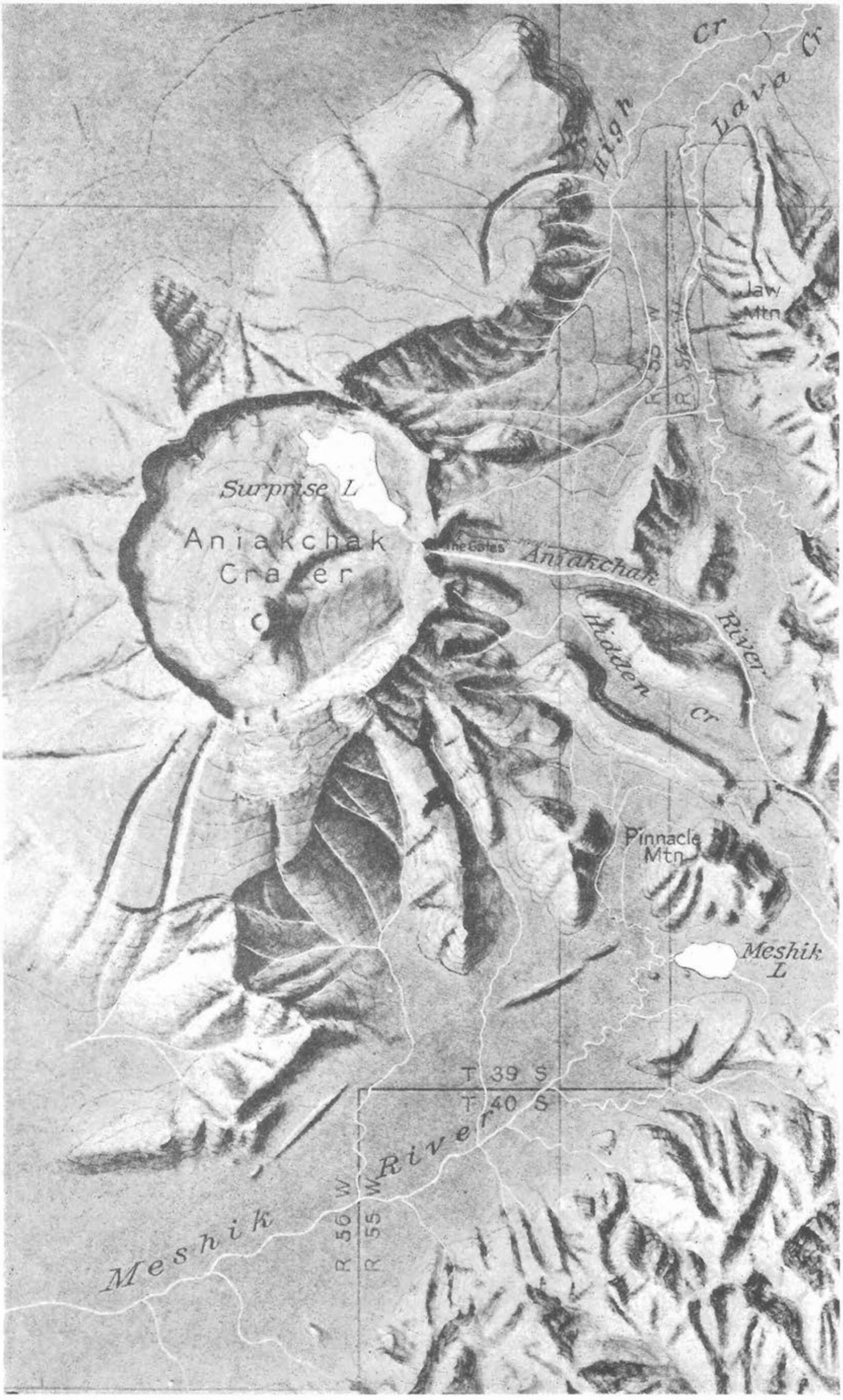


Fig. 2. Relief Map of Aniakchak Crater and Vicinity. Alaska Peninsula (after W. R. Smith).

pressure caused molten rock to flow into these weak zones, producing a number of radiating rib-like rocks which project from the flows because of their greater resistance to weathering. Such forms, likewise, indicate a former volcano.

The building of Mt. Mazama is no mystery—it is the destruction of the mountain which leads to extensive speculation. There are three explanations which have been offered to account for this great catastrophe. The first and oldest one has been the most popular. According to this theory the lava in Mt. Mazama's vent gradually receded into the earth because of the eruptions of a neighboring volcano. This removed the support of the upper part of the cone which caved in and was engulfed, leaving the large crater which the Lake now occupies. The second supposition was that gigantic explosions blew the mountain top off, and distributed it over the landscape for possibly hundreds of miles in every direction. The third possibility was a process similar to that going on today in Hawaiian volcanoes. There the molten lava rises and falls periodically in a large pit and in so doing causes sections of the rim of the pit to fracture and perhaps to fuse in the lava column.

The lack of large fragmental materials in the vicinity of Crater Lake which should be present if explosion had occurred, caused the earlier thinkers to accept the subsidence theory. More detailed examination of the surrounding areas by later investigators shows that explosive materials several hundred feet in thickness extend for many miles in every direction. Furthermore, some of the lava layers near the lake turn abruptly upward as though some force had bent them in that position; then, too, there is no known case of a whole volcano subsiding and it seems to be contrary to laws of earth structure for seventeen cubic miles of rock to go back into the earth where pressures should be high. On the other hand, numerous mountains of the same type as Mt. Mazama have been known to destroy themselves by explosion. Examples of the latter are the great explosion of Katmai in Alaska in 1912 and Krakatoa in Java in 1883. The best explanation at present seems to be a modification of the first two ideas. That is, the crater was probably produced from old Mt. Mazama by one or more explosions followed by slumping of the walls which sank into the pit, leaving the original upturned edges caused by the explosion in several places. Be that as it may—Mt. Mazama did exist and was destroyed, leaving a crater around four thousand feet in depth and averaging about five miles in diameter. And we still have our mystery!

Following the great mountain destruction, volcanic activity started again and built several small cones inside the crater. Two of these are now submerged below the lake but the third is over seven hundred feet in height and is quite a good sized volcano in its own right as it rises twenty-seven hundred feet above the crater floor. It possibly represents the last gasp of a dying volcano.

Meanwhile water was beginning to accumulate in the crater. The precipitation at Crater Lake National Park averages about seventy inches per year. At that rate any depression would soon tend to fill up, providing seepage and evaporation were not too great. This is what has happened. Figures show that evaporation at Crater Lake amounts to about fifty-five inches per year and that leaves fifteen inches to account for seepage through the lower slopes away from the Lake. There are no known major streams flowing into the Lake and none flowing out on the surface. The water is not salty but is quite fresh. Since rain water is practically distilled water and only slight solution of the rock walls takes place, this condition is easily explained.

Geologically speaking, Crater Lake is a young feature on the earth's surface. The extensive glaciation of the slope of Mt. Mazama indicates that it probably existed during the glacial age so that its destruction must have come about since that time. The last glacial period was between twenty-five and fifty thousand years ago. The age of the trees on Wizard Island, the largest of the cones in the crater, ranges up to eight hundred years. It is thought that Wizard Island was last active not more than two hundred years before the date of the oldest tree. That means that it was probably active within the last thousand years. To look at this young volcano one would think it had been active only yesterday, so fresh are its lavas and so little has it been affected by the erosive forces of the weather. The steepness of the crater walls and the rapid rate of erosion now going on show that the Crater is fairly new as the walls seem to be little changed by erosion.

The region around the Lake is heavily forested with hemlocks, pines and firs. Where these grow within the rim they both aid and retard erosion. They split the rocks with their growing roots and hold the soil in place on steep slopes by these same roots. Trees play an important part in the geology of this region.

Crater Lake, as is true of all lakes, is at best a temporary earth feature. Erosion of the walls with a consequent filling of the lake, aided by stream valleys cutting back the outer slopes, will eventually cause this mysteriously beautiful lake to be destroyed. However, it will take generations to accomplish this end so that man will enjoy this superb spot for many years to come.

ORIGIN OF CRATER LAKE CUP—

Mr. Waesche's moderate statement of the controversy about the origin of Crater Lake cup should be supplemented by the following reading for anyone interested:

1. Crater Lake National Park. Natinal Park Service pamphlet, Washington, 1936, page 9, "Destruction of the Mountain."
2. Mount Mazama: explosion versus collapse, by W. D. Smith and C. R. Sworzlow. Bull. Geol. Soc. Amer., Vol. 47, p. 1809. 1936.
3. The Glacial History of an extinct volcano, Crater Lake National Park, W. W. Atwood Jr. Journ. Geol., Vol. XLIII, No. 2, February-March, 1935.
4. Geological History of Crater Lake, by J. S. Diller, Department of the Interior, 1912 (Gov't Printing Office, Washington, 10 cents).
5. Engulfment at Krakatoa 1883. Review of Stehn, Volcano Letter No. 234, June 20, 1929.
6. Geology and Geography of Niuafoou Volcano, map and sections, Volcano Letter No. 318, January 29, 1931.
7. Volume relations of Explosive Eruption 1924 (Kilauea) Monthly Bulletin Haw'n Volc. Obs'y., Vol. XII, No. 12, December, 1924.
8. Geology and Mineral Resources of the Aniakchak District, Alaska, by R. S. Knoppen, Bulletin U. S. G. S. 797-F, 1929.

There is no reason for such an immoderate controversial position favoring only the explosive process as is taken by No. 2 above. Nature works gradually even at active volcanoes. The great steam blast eruptions of the world have been accompanied by what Mercalli called "sprafondomenti", deepenings by collapse.

Atwood and Stehn, Nos. 3 and 5, cited for support of explosion by No. 2, both endorsed engulfment. The National Park pamphlet No. 1 states a moderate position. Diller was moderate in all his writings, and a judicial observer (No. 4).

Niuafoou (No. 6) is clearly an **engulfment plus steam-blast** kind of sink crater, the dome was quite like Kilauea, and the crater lake was formed millions of years ago (cited in No. 2 (p. 1828) as formed in 1886; when in fact a mere minor steam-blast occurred).

Kilauea steam-blast eruptions are no different from those of basaltic volcanoes anywhere, and the combined engulfment and explosion of 1924 removed volumes one part by explosion and 250 parts by engulfment. (No. 7).

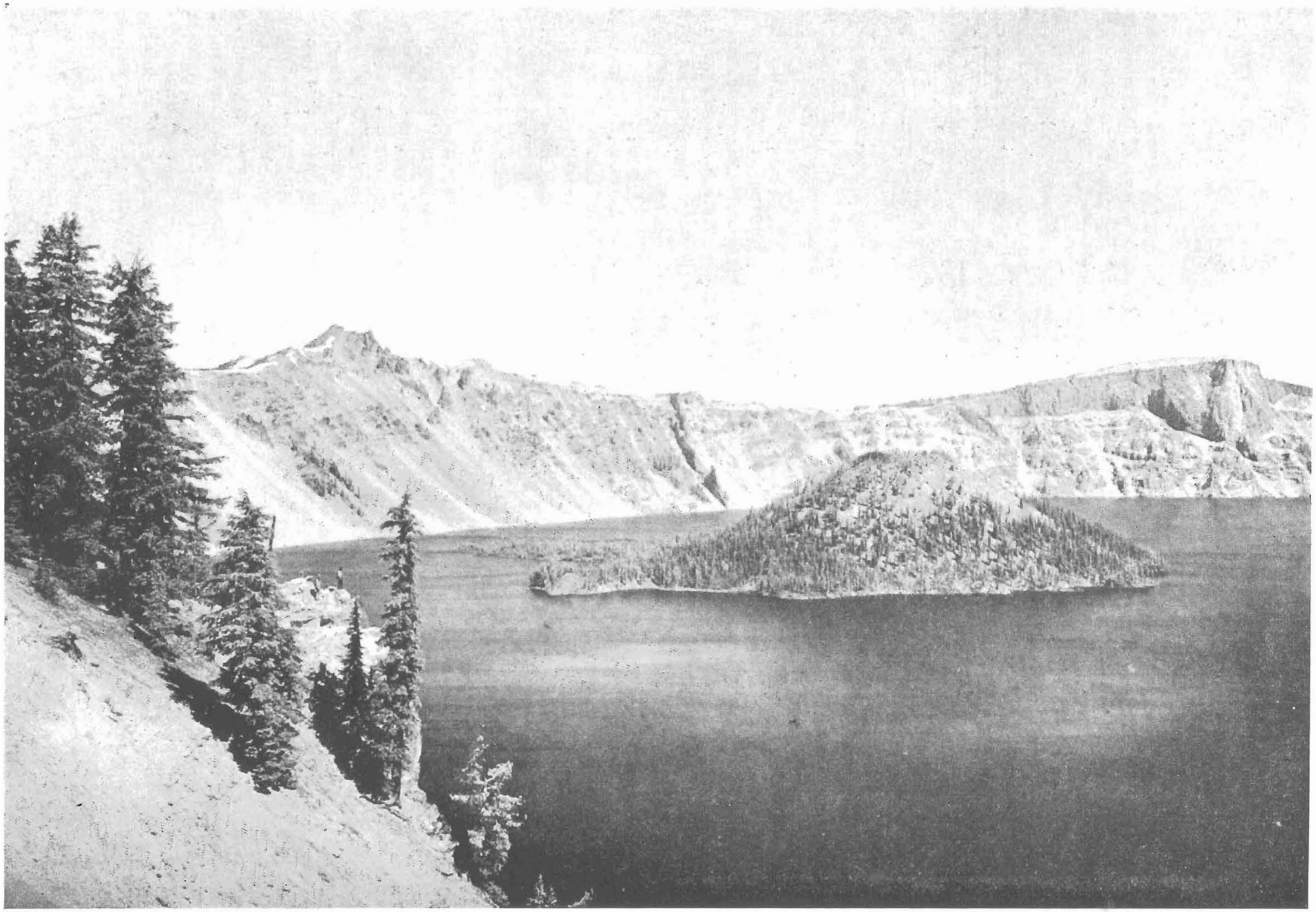


Fig. 3. Western Border of Crater Lake, from Victor Rock to Llao Rock (after Diller).

The basis for reconstruction of mountains over such saucer craters as Crater Lake, Niuafaou, Aniakchak, Batoer in Bali, or Aso in Kyushu, was stated admirably by Diller (No. 4, p. 24): "The glaciation and structure of the rim clearly establish the former existence of Mount Mazama but there may well be doubt as to its **exact form and size**".

Veniaminof Crater west of Aniakchok, (No. 8) but 5000 feet higher, is a triplicate of Aniakchak and Crater Lake, but full of ice spilling over in valley glaciers. It is the same height and size as Crater Lake, 6 miles across, and 8000 feet above sea-level; but it is a mountain, because it rises from sea-level.

Restore glaciation to the Cascade Range and you don't need a mighty peak of five cubic miles to scratch ledges, deposit till, and make U-shape valleys. The great Veniaminoff cup is itself at the **top** of a peak.

Finally, the geologist objection to voids underground is answered by underground intrusive bodies with straight-sided fracture boundaries that would fit together if the igneous matter (lava) were removed. If a void can form to let **up** the lava, it can form to let down the lava into crevices when whole mountain ranges are faulting and rifting.

At the Hawaiian volcanoes when lava lakes are rising and falling, this is happening all the time. The craters are on down-slipping fault rifts.

The tremendous event of the Vesuvian crisis, when a steam-blast eruption happens, is a "sprofondamento", a deepening. The amount of surface lava, dust and rocks is trivial compared to the crateral evacuation.

But the notion that such a volume as the contents of Monte Somma was left by the single evacuation of the Pompeiian eruption, is as fantastic as that Niuafoou crater was completely made in 1886.

The total volume of everything poured out and blown out of Vesuvius from 79 A. D. to the present would scarcely change the profile of the volcano. We know the history (Sapper). And we know that such eruptions as 1631 and 1906 engulfed the peak, which was subsequently restored from within.

A process of caving in and filling up again is normal extrusive volcanism and normal intrusive volcanism. The normal result is a gas loss to the atmosphere, a magma loss into crevices of the crust; and a compensating igneous bulk in the crust, for the substratum loss of igneous volume.

When the magma loss is a few cubic miles from a big cauldron, it means there has been a cycle of inflation; followed by a cycle of deflation, made up of hundreds of events such as submarine lava flows, or interstitial intrusive dikes along rifts tectonically opened.

The Hawaiian vents systematically robbed each other at progressively lower levels from 1855 to 1924. The 1924 vent was under the ocean where there is a slope to levels 18000 feet below sea-level in forty miles horizontally.

There was every opportunity for graben and cross-fault lava drainage in California and Oregon, from Miocene to Pleistocene time, for 20000 feet of depth, from the rim of Crater Lake to the broken shore blocks under the Pacific. And extrusive volcanism decayed from Miocene to the Present.—T.A.J.

Hawaiian Volcano Observatory Report for September 1937

VOLCANOLOGY

The month was notable at Kilouea Volcano for a decline of seismic phenomena and pit movements, except for a group of large distant earthquakes about the equinox, and at the same time a revival of many slides at Halemaumau in a new place, namely at the north.

The following are the weekly Observatory totals for Halemaumau and the seismographs.

Week Ending		Seismicity	Slides	Crack Openings, mm.	Local Tremors and Quakes
September	5	6.00	3	3.00	20
"	12	5.25	9	0.50	18
"	19	3.50	7	6.00	9
"	26	2.25	27	6.50	9
October	3	5.25	7	4.00	18

A shock was felt near Kilaueo Crater September 15. Most of the very feeble shocks were of Kilauea origin, and most of the local disturbances were tremors. Distant earthquakes were registered September 3, 15, 19, 20, 23 and 29.

Sequence of Events by Weeks

The first week produced three slides in Halemaumau.

The second week produced nine slides and the smallest total opening of cracks since November 28, 1936.

The third week produced seven slides and declining seismicity.

The fourth week produced crumbling of the Halemaumau wall at the north and northwest taluses, twenty-seven slides being counted, while seismicity continued to decline.

The fifth week produced seven slides, mostly at the northeast wall, and increased numbers of tremors.

Slides at Halemaumau

The recorded slides from the wall of the pit were:

August 30, 9:25 a.m., making fresh scar 300 feet below northwest rim, and recording on Halemaumau seismograph.

August 31, 11:00 a. m., large slide NW, sending up dust.

September 3, 12:30 p.m., eastern slide extending the notch of August 22 southward.

September 6, 9:47 a.m., noise of falling rocks east.

September 6, 9:57 a.m., dust at the east.

September 6, 11:05 a.m., dust at the east.

September 6, 12:10 p.m., dust at the east.

September 6, 12:33 and 12.38 p.m., more dust.

September 7, forenoon, slides had carried away part of the east edge.

September 8, 12:39 p.m., slide from 50 feet below rim east.

September 8, 1:10 p.m., large slide north.

September 8, 2:18 p.m., dust east.

September 15, 2:33 p.m., rim rock fell east.

September 18, 8:53 a.m., slide east without noise.

September 18, 9:00 a.m., dust at the east.

September 18, 9:10 a.m., heavy dust cloud east.

September 18, 1:00 p.m., eastern dust.

September 19, 12:20 p.m., thick dust cloud north.

September 19, 2:55 p.m., noise of falling rocks east side.

September 20, 9:30 a.m., noise of northern slide.

September 20, 9:45 a.m., northern dust cloud.

September 20, 10:30 a.m., northern dust cloud.

September 20, 10:35 a.m., northern dust cloud.

September 20, 11:25 a.m., dust seen from Observatory, north.

September 20, 12:40 p.m., noise of falling rocks north.

September 20, 12:45 p.m., largest slide of this day, noise and dust north.

September 20, 12:55 p.m., 2:40 p.m., 3:25 p.m., northern slides making dust.

September 21, 9:20 a.m., northwest dust clouds.

September 21, 9:25 a.m., northern slide.

September 21, 9:30, 9:52, 10:00, 10:05, 10:13, 10:17, 10:20, 10:24, 10:49, 11:05 a.m., and 12:05 p.m., northwestern slides making dust.

September 25, 10:25 a.m., dust and noise from the west.

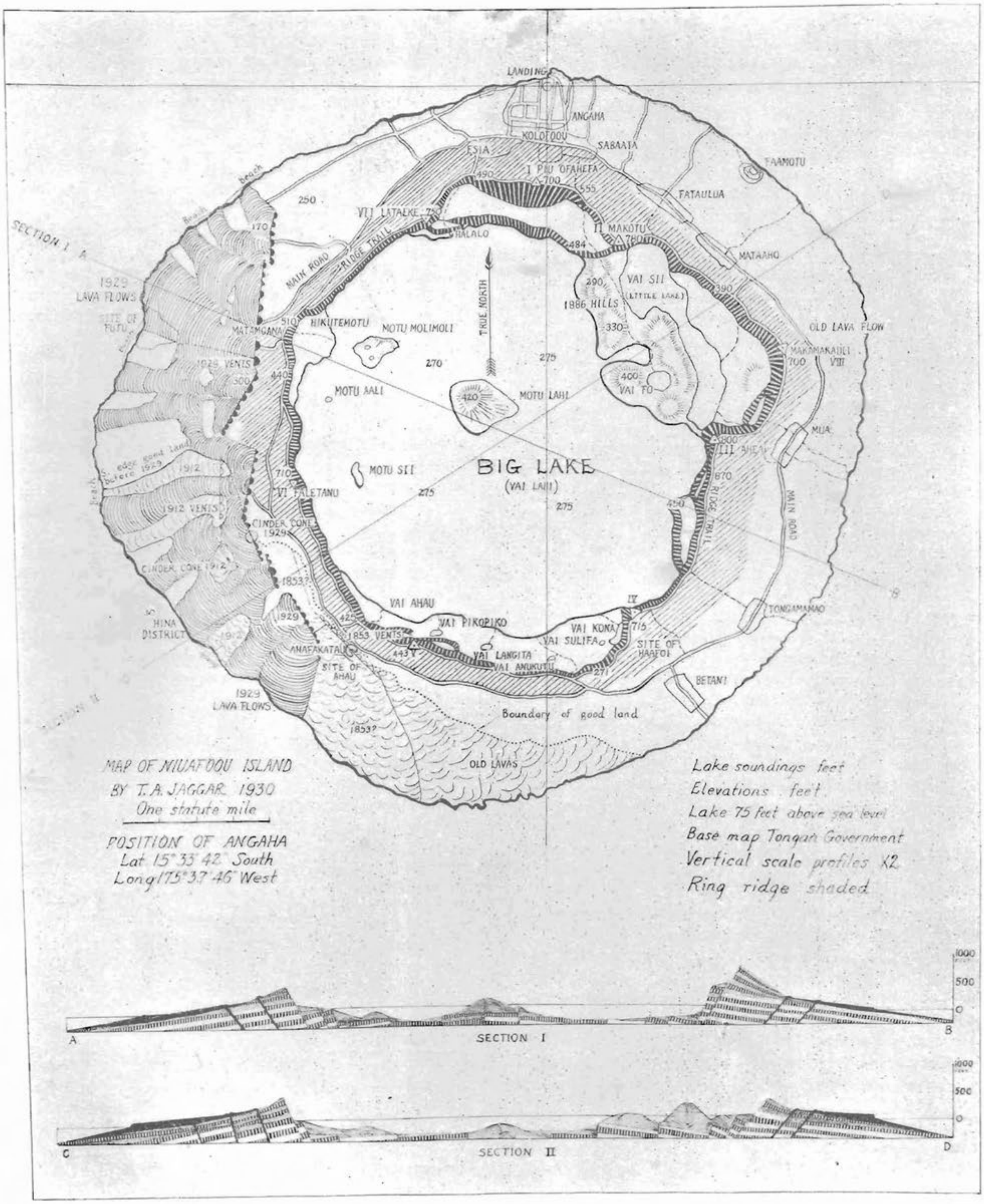


Fig. 4. Map of Niuafoou.

September 26, 10:02 a.m., 1:15 p.m., and 2:15 p.m., slides at the north side.

September 29, 10:25 a.m., slide at northwestern wall.

September 29, 1:10 p.m., sliding under both NE and N walls.

September 29, 1:15 p.m., 1:45 p.m., 1:50 p.m., and 3:25 p.m., slides from northeast wall.

October 1, 2:00 p.m., large slide at east wall.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted during September in aggregate movement as follows:

Week ending forenoon of:

September 3, 27 locations, 4 opened, 1 closed, opening 3.0 mm.

September 10, 27 locations, 3 opened, 4 closed, opening 0.5 mm.

September 17, 27 locations, 8 opened, 1 closed, opening 6.0 mm.

September 24, 27 locations, 6 opened, 0 closed, opening 6.5 mm.

October 1, 27 locations, 7 opened, 1 closed, opening 4.0 mm.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earth-quakes	Feeble Earth-quakes	Distant† Earth-quakes	Weekly* Seismicity
Sept. 5	16	4	0	1	6.00
" 12	15	3	0	0	5.25
" 19	6	2	1	3	3.50
" 26	9	0	0	2	2.25
Oct. 3	15	3	0	1	5.25

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 and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of depth of focus has been made.

August 31, 10:51 am, very feeble, 12 miles deep, Hilina Kapukapu Fault, 2.0 miles N of Keauhou Point. 19° 17:5′ N; 155° 14.1′ W.

September 1, 8:34 pm, very feeble, 1.4 miles deep and 0.6 miles NW of Uwekahuna. 19° 25.8′ N; 155° 17.7′ W.

September 1, 8:55 pm, very feeble, location same as preceding.

September 5, 6:44 pm, a tremor at the Observatory, very feeble in Kona. Probably originated under W slope of Hualalai near seacoast and about 10 miles N of Kealakekua.

September 9, very feeble 1.3 miles deep, NE portion of Kilauea Crater, 8:08 am, 0.8 mile SW of the Observatory. 19° 25.5′ N; 155° 16.2′ W.

September 12, 4:30 am, very feeble, 2.6 miles deep, N rim of Kilauea Crater, 0.6 mile W of Kilauea Military Camp. 19° 26.1′ N; 155° 17.1′ W.

September 12, 4:32 am, very feeble, 1.0 mile deep, 0.4 mile SE of Keanakakoi, 19° 24.1′ N; 155° 15.7′ W.

September 13, 3:56 am, very feeble, probably originated in area 1.0 mile E of Kilauea Iki.

September 15, 8:04 pm, feeble, 0.8 mile deep, Kilauea Crater 0:5 mile W of Byron Ledge, 19° 24.6′ N; 155° 16.2′ W. Reported felt by many in "CCC" Camp and near Park Headquarters.

September 19, 6:07 am, very feeble, 3.0 miles deep, 1.6 miles N of N rim of Kilauea Crater. 19° 27.6′ N; 155° 16.6′ W.

September 19, a tremor at the Observatory, very feeble on Kona instrument. Probably originated in Mauna Loa SW rift near 1919 source cone.

September 21, 8:59 pm, tremor at H.V.O., very feeble in Hilo, dismantled Kona seismograph, 25.0 miles deep, NE rift of Mauna Loa 4.0 miles W of Puu Ulaula, 19° 31.6′ N; 155° 31.0′ W.

September 27, 7:01 am, very feeble, of Kilauea origin.

October 1, 9:34 am, very feeble, 2.8 miles deep and 0.8 mile SE of the Observatory and 0.5 mile N of Kilauea Iki. 19° 25.6′ N; 155° 15.0′ W.

October 1, 7:05 pm, very feeble, 1.2 miles deep E portion of Kilauea Crater near Byron Ledge, 19° 24.9′ N; 155° 15.7′ W.

Microseismic motion of the ground at the Observatory was light September 2-7, 20, 22, and 28-30; strong September 10, 12, and 25; and was moderate the remainder of the month. All dates inclusive.

Teleseisms registered as follows:

September 3, "P" waves at 8h 25m 17s am, distance from Kilauea 2415 miles.

September 15, "P" waves at 2h 06m 45s am, distance from Kilauea 3485. Reported location Solomon Islands. 9° S; 164° E.

September 15, undetermined portion at 9h 26m am.

September 19, "P" waves, 8h 54m 15s, pm, no determination of distance.

September 20, undetermined portion at 11h 21m 50s pm.

September 23, "P" waves at 2h 45m 47s am, distance from Kilauea 3390 miles. Reported location, Solomon Islands 6° S; 154° E.

September 29, undetermined portion, 1h 16 m 6s am. Reported felt and to have been located in Japan.

Hawaiian Standard Time used for above reports.

H. H. W.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau the algebraic sum of radial tilts toward or away from the pit.

At the Observatory the total accumulated tilt for the year ending October 3 was 10.85″ S and 0.12″ E.

Week Ending	Observatory	Halemaumau West Station
September 5	0.20″ S 50° W	7.75″ S 83° W
September 12	0.33″ N 4° E	1.55″ S 59° E
September 19	0.75″ N 57° E	4.32″ N 74° W
September 26	0.63″ N 38° E	1.49″ S 60° W
October 3	0.88″ S 85° E	2.68″ S 87° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
September 5	8.46″ N 45° W	0.51″ Toward
September 12	1.20″ N 60° W	2.32″ Toward
September 19	2.11″ N 86° W	2.72″ From
September 26	4.70″ N 2° E	2.39″ Toward
October 3	1.75″ S 73° W	2.05″ From

Crater Angles

Crater angles measured September 5, showed closing of 2.65″ across Halemaumau and opening of 0.58″ as compared with similar measurements of June 29, 1937.

H. H. W.

* For local seismicity definition see Volcano Letter 371.
† Including teleseisms or earthquakes over 5000 km from Kilauea.

THE VOLCANO LETTER

No. 452 monthly Department of the Interior National Park Service October 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

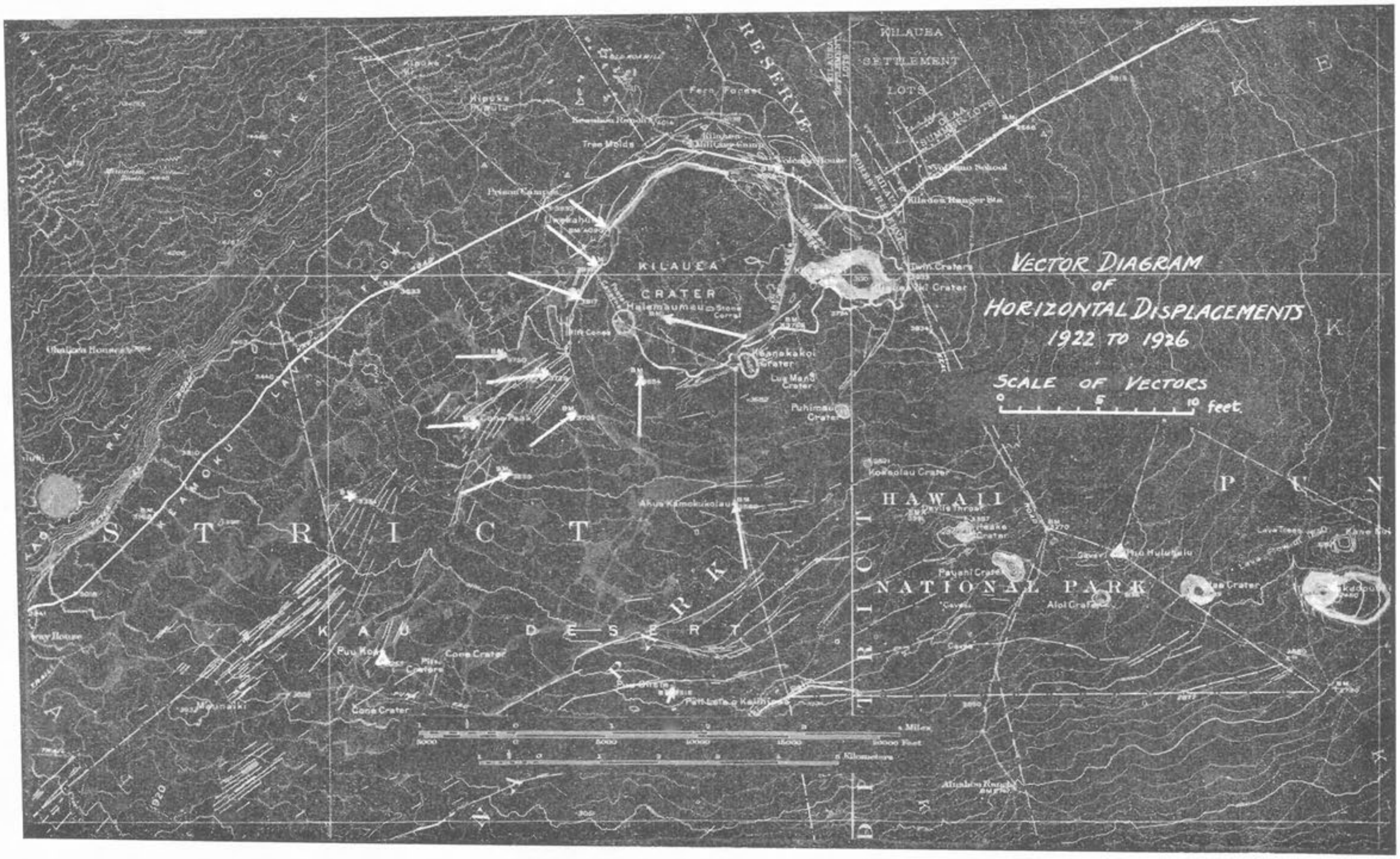


Figure 1. Map of Kilauea Crater; the tip of each white arrow on a monument; proved to move toward the center about 1924; by as many feet as the arrow is long by the scale.

TRIANGULATION AND LEVEL CHANGES AT KILAUEA—
Radio Talk June 22, 1937

By Hugh Waesche, Assistant Geologist, Hawaii National Park

On previous occasions (Volcano Letter February and April, 1937) I discussed earthquakes, crack measurements and tilting of the ground at Kilauea. Most of you probably are somewhat familiar with these phases of our work. Today I shall attempt to tell you about two other studies which have proved most interesting from the scientific standpoint but which are probably not so well known by the general public. (See also May and July 1936, Volcano Letter.)

Movements of the large volumes of lava below the earth's crust should create changes on the earth's surface. These movements in all probability would not be visible to the human eye, although in many cases they actually are. Two, well established, and reliable means of detecting such disturbances are by using instruments which would show by actual measurements, amounts of change of elevation and amount of horizontal displacement in and around volcanic areas. For changes of a vertical nature the precise level and for horizontal displacements on engineer's transit are used, to establish measurements of a refined type just as is done by the U.S. Coast and Geodetic Survey and the U.S. Geological Survey in their land survey and location work. A great amount of triangulation and leveling has been done in volcanic regions in Japan, particularly at Asama, with very definite and positive results. Similar work has been done in California along earthquake-making faults, with a great deal of success.

Measurements of this nature have been a part of the working program at Kilauea since the establishment of the Observatory in 1912. In 1920 at the First Pan-Pacific Scientific Congress in Hawaii, there was published among its recommendations the following: "Great earthquakes and volcanic eruptions are often preceded and followed by elevations, depressions and horizontal displacements in the regions concerned; therefore this Conference **recommends** that precise leveling and triangulation be carried on at definite intervals in selected seismic and volcanic districts in order to ascertain precursory and other changes in underground stress accompanying great seismic and volcanic disturbances."

Horizontal ground displacements may be thought of as expanding or contracting areas of the earth's surface. Their measurement with a transit is called triangulation. At Kilauea there have been four epochs or periods of such surveys. The first was as a part of the original Hawaiian Government Survey of 1871, reaching Kilauea in 1897; the second was by R. M. Wilson of the U.S. Geological Survey in 1922; the third was by J. C. Beam in 1926 and the fourth by Wilson in 1926. Inasmuch as the second and fourth were run by the same engineer under as near identical circumstances as possible, they are considered of greatest value. These two epochs are also of special interest in that respectively they precede and follow the explosive activity of Kilauea in 1924. Kilauea crater and the outer slope of the volcano, as far south as Puu O Hale, were a part of the surveyed area.

In triangulation procedure various points in a given area are selected as the key or control locations. From these stations angles are turned off repeatedly to other stations in the system or net, and from the average angle values, azimuth determinations and intervening distance calculations and relative positions are determined. It of course is not so simple as this may have sounded, as there are many sources of error, such as refraction because of heat and moving air and poor visibility. Corrections are made for all of these.

Careful comparison of results showed quite definitely that the older surveys did not agree with the newer ones, nor did the survey of 1922 agree with that of 1926. Of the sixteen stations used probably the most familiar to you are, the monument in front of the Volcano House, the Little Beggar on Kilauea crater floor, Uwekahuna and the Spit. Another quite familiar location point is on the summit of Puu Hulu Hulu which may be seen on a trip down the Chain of Craters road. In a general sort of way it was found that there was little or no change between certain specifically selected points well outside of Kilauea crater such as the Observatory, Ohale, Koae, and Puu Hulu Hulu. On the other hand, relative to these fixed stations other locations showed considerable movement toward Halemaumau accompanying the collapse after the explosive eruption. A map was plotted using vectors to show this movement. More or less radial movement toward the pit from all directions was thus definitely shown. (Figure 1.)

Triangulation on a minor scale is still carried on from the Observatory. The same "Berger" transit used by Wilson in his earlier surveys is set up on the Observatory bench mark about every ten days, and the angles across Kilauea crater, from its southeast rim to Uwekahuna on the northwest rim, and across Halemaumau in the same direction, are determined. Each angle is measured six times in a forward or clockwise direction and then repeated in a reverse direction in the same manner. The results are then averaged and calculations made, and this in turn plotted for comparison on coordinate paper; so that a continuous relative picture of opening or closing of the crater, and of the pit, is available. Over longer periods changes are readily observed, but for short periods, due to errors which are unavoidable, changes are not so marked. The probable error calculated by Wilson was plus or minus two and one half seconds of arc, which is more than the usual variations which are now encountered from one reading to the next. Recent readings since the Mauna Loa eruption of 1935 seem to indicate, to date, a gradual closing of both crater and pit angles, as though the lava underneath Kilauea may have receded following that eruption. It would be safer, however, to say that no apparent change of appreciable magnitude has occurred within the past two years.

As was the case with the triangulation surveys, the level surveys may be divided into epochs. There were three of them. The first run was made in 1912 by the Birdseye party of the U.S. Geological Survey; the second by R. M. Wilson in 1921 and 1922, and the third in 1926 and 1927, also by R. M. Wilson. The instrument used is shown in Figure 2, sighting on a rod not shown. Just as with the triangulation, the last two of these runs were made before and after the explosive eruption in 1924. There were two classes of level determinations. One class consisted of lines run from tidal bench marks at sea level to the summits of Kilauea and Mauna Loa. The second class was of a local nature run only in the vicinity of Kilauea. The first two were what is known as "third order" leveling and the third run was "first order" leveling. In "first order" leveling invar metal rods are used and the level is shaded; in earlier runs wooden rods were used. Accuracy is of a very high degree in "first order" levels.

Probably the greatest problem encountered in running the levels from Hilo to the Volcano was changes of rod length. The wooden rods of the early surveys were found to vary from their original Bureau of Standards length. This variation was usually an increase in length with increase of moisture absorption. After very careful analyses Wilson applied corrections to take care of this. His conclusions are published in Research Publication number 10 of the University of Hawaii (Ground Surface movements at Kilauea Volcano) and are most interesting. The level results seem to check the triangulation and tilt values and, at the same time, seem to be more tangible in their demonstration of a factor in volcanic change, which had been suspected here and demonstrated elsewhere.

It would be hard for a visitor who has been to Kilauea frequently to realize how great the level changes were after that 1924 eruption. The Volcano House seems quite substantially located on the northeast rim of Kilauea crater, yet between 1921 and 1926, the Volcano House went down nearly four feet (3.56). Uwekahuna too looks firmly planted—a sort of Gibraltar, yet it sank nearly five feet (4.56) in the same period. As far south as Puu Hulu Hulu and Puu Koae the ground sank between three and four feet. In a general way and as would be expected, amounts of depression increased toward Halemaumau, reaching a maximum sinking of thirteen feet near the old spatter cone, "Little Beggar," about two-tenths of a mile east of Halemaumau. In fact, it seems pretty certain from tilt and levelling data, that between 1912 and 1921 the entire slope of Kilauea to sea level rose; and then sank between 1921 and 1927 in gradually increased amounts as the crater of Kilauea was approached, and with a very rapid rate of change at Halemaumau. Hilo was thought possibly to have risen slightly, and then to have gone down about six-tenths of an inch after 1924.

Local levels in Kilauea crater were run regularly in 1934 and 1935 and until February 1936. This line started at the Spit bench mark, southeast rim of the crater and made a loop around Halemaumau. Occasionally the run was made just to the northwest bench mark on that rim of Halemaumau. This particular line is used in order to obtain relative displacements between the actual crater floor and its rim. Plotted results of this level line have proven very significant. Among other things it has been discovered that a relative change in Kilauea crater of several millimeters within twenty-four hours is not unusual. Following the 1934 eruption of Kilauea the northwest rim of Halemaumau apparently settled about six inches with reference to the southeast crater rim. In August 1935 the lowering ceased, and the value remained unchanged until Mauna Loa erupted in November. Immediately the Kilauea crater floor began to settle again, and by February 1936 it had settled another two inches. Apparently settling has continued and as soon as possible new determinations will be made.

From this brief review it will be seen that surveys of this sort are very important and informative parts of the Hawaiian Volcano Observatory program. This work will be continued and the results noted with interest relative to future eruptions and thus more knowledge of our volcanoes will be accumulated, and activity predictions made more accurate.

Hawaiian Volcano Observatory Report for October 1937

VOLCANOLOGY

The month at Kilauea Volcano showed little change in local tremors and movements about Halemaumau pit. As in September, there was a revival of slides from the walls toward the end of the month.

The following are the weekly Observatory totals for Halemaumau and the seismographs.

Week Ending	Seismicity	Slides	Crack Openings, mm.	Local Tremors and Quakes
October 10..........	7.00	4	7.00 mm.	12
" 17..........	6.25	0	0.00 mm.	12
" 24..........	4.75	4	2.50 mm.	14
" 31..........	6.00	2	4.75 mm.	16

A feeble shock October 18 and a stronger one classed as "slight" October 25 were felt in National Park and Hilo, and were Kilauea movements. Of nine measured shocks for the month seven were from Kilauea, one from Mauna Loa, and one from Mauna Kea.

Sequence of Events by Weeks

The first week produced four observed slides, the second week was very quiet, the third week with its four slides may have had them started by the earthquake of October 18. The fourth week showed only two slides that were observed, and an increase in number of spasmodic tremors.

Slides at Halemaumau

The recorded slides from the wall of the pit were:

October 4, 9:33 a.m., large slide NE.

October 4, 11:13 a.m., dust NE.

October 4, 11:18 a.m., dust from slide NW.

October 4, 1:39 p.m., another slide NW.

October 18, 11:15 a.m., dust observed over north rim.

October 18, 12:15 p.m., another slide at the same place.

October 19, 9:31 a.m., slide from NW wall heard at Uwekahuna Museum.

October 19, 10:08 a.m., slide at east rim observed from Tourists' Stand.

October 31, 11:20 a.m., dust rising at north wall.

October 31, 2:10 p.m., slide at the west wall.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted during October in aggregate movement as follows:

Week ending forenoon of:

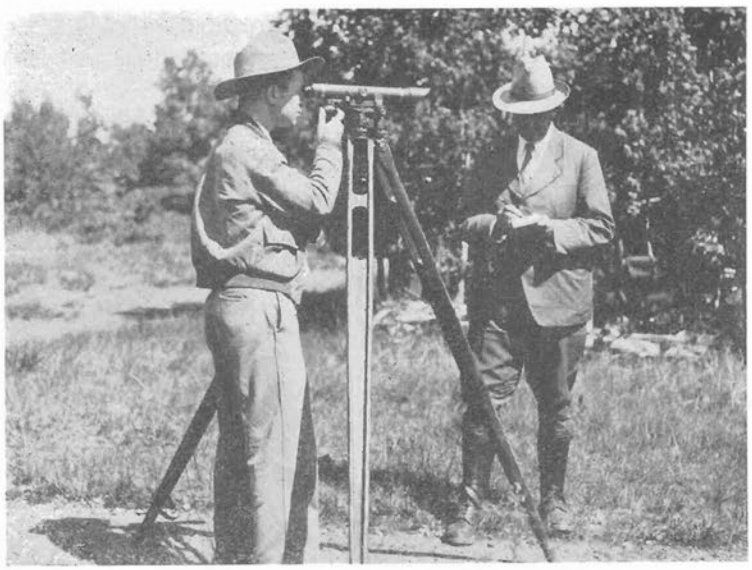


Figure 2. Precise level sighted on a rod marked in decimals of a foot, held upright by a rodman (not shown). Waesche sighting, Jaggar entering notes.

October 8, 28 locations, 11 opened, 3 closed, opening 7.0 mm.

October 15, 28 locations, 2 opened, 3 closed, opening 0.0 mm.

October 22, 28 locations, 6 opened, 2 closed, opening 2.5 mm.

October 29, 28 locations, 10 opened, 2 closed, opening 4.5 mm.

T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending	Minutes of Tremor	Very Feeble Earth-quakes	Feeble Earth-quakes	Slight Earth-quake	Distant† Earth-quakes	Weekly* Seismicity
Oct. 10......	26	1	0	0	2	7.00
" 17......	15	5	0	0	0	6.25
" 24......	11	2	1	0	0	4.75
" 31......	14	1	0	1	0	6.00

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 and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible a determination of depth of focus has been made.

October 7, 1:49 am, very feeble, 15 miles deep under Mauna Kea. 19° 48.7′ N; 155° 30.4′ W.

October 14, 10:32 am, very feeble, 1.8 miles deep in Kilauea Crater 0.5 mile W of Byron Ledge, 19° 24.6′ N; 155° 16.2′ W.

October 15, 3:24 pm, very feeble, of shallow origin in cracks SW of Keanakakoi. 19° 24.1′ N; 155° 16.2′ W.

October 17, 12:58 am, very feeble, 0.5 mile deep in cracks near SE rim of Kilauea Crater 0.5 mile SE of Pit seismograph. 19° 24.1′ N; 155° 16.6′ W.

October 18, 12:44 am, feeble, 28.0 miles deep, SE slope of Mauna Loa 10 miles west of Kilauea Crater. 19° 26.3′ N; 155° 25.0′ W. Reported felt at Hawaii National Park Headquarters and in Hilo.

October 19, 5:56 am, very feeble, 1.1 mile deep in Kilauea Crater 0.4 mile E of Pit seismograph. 19° 24.4′ N; 155° 16.7′ W.

October 22, 11:36 pm, very feeble, of shallow origin, SE rim of Kilauea Crater. 19° 24.0′ N; 155° 16.4′ W.

October 25, 5:43 am, slight, 9.0 miles deep in Hilina Fault system 8.0 miles S of the Volcano Observatory. 19° 19.8′ N; 155° 15.0′ W. Felt by many at Hawaii National Park Headquarters and in Hilo.

October 30, 11:44 am, very feeble, 4.1 miles deep and 0.4 mile W of Ahua Kamokukolau. 19° 22.9′ N; 155° 16.4′ W.

Microseismic motion of the ground at the Observatory was moderate October 4 and 5 and strong the remainder of the month.

A portion of a teleseism was recorded at Kilauea beginning at approximately 8h 11m pm, HST., October 4. Reported location was 3200 miles ESE of Hawaii; 22° N; 108° W. An unidentified portion of another teleseism began recording at approximately 7h 00m am, HST, October 6.

Periods of continuous tremor which registered on the Observatory seismograph were: 16 minutes beginning at 10:30 pm, October 6, and 9 minutes beginning at 1:43 pm October 16.

H.H.W.

* For local seismicity definition see Volcano Letter 371.
† Including teleseisms or earthquakes over 5000 km from Kilauea.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau the algebraic sum of radial tilts toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending October 31, was 9.83″ S and 0.38″ W.

Week Ending	Observatory	Halemaumau West Station
October 10	1.25″ N 9° E	1.55″ West
October 17	1.41″ S 35° W	3.37″ N 78° W
October 24	0.58″ S 11° E	1.43″ N 29° E
October 31	1.62″ N 40″ E	4.17″ S 53° W

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
October 10	3.47″ N 54° W	1.75″ Toward
October 17	3.99″ N 43° W	0.92″ Toward
October 24	3.18″ S 70° E	2.01″ From
October 31	8.29″ N 29° W	4.68″ Toward

H.H.W.

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory October 16, showed slight opening of the Halemaumau value, and closing of the Kilauea Crater value, compared with similar measurements September 15. From Kilauea Crater SE rim to Uwekahuna there was closing 1.16″, September 15 to October 6 and closing 2.68″, October 6 to October 16. Total closing 3.84″. From the SE Pit B. M. to NW Pit B. M. there was opening 1.57″, September 15 to October 6 and closing 1.48″, October 6 to 16. Total opening 0.09″.

Levelling at Kilauea

October 12 and 13, a series of levels was run from the Spit B.M. on the SE rim of Kilauea Crater, to the NW Pit B. M. on the NW rim of Halemaumau. A Stanley level was used, and the results obtained were the first check on this determination since February 10, 1936 when a U. S. Geological Survey model precise level was used. Between September 3, 1936 and January 26, 1937, five sets of levels over the same line were run, using a new U. S. Coast and Geodetic Survey type precise level. These in no case gave satisfactory checks on closure of the circuit. The run made with the Stanley level giving a satisfactory check, October 12, 1937 showed that results obtained with the Geodetic Survey level were of value in spite of inaccuracies, in that they were of qualitative value indicating continuous relative lowering of the floor of Kilauea Crater with reference to the SE rim since October 1934 at the close of the Halemaumau inflow at that time. Level determinations of October 12, 1937 showed that the NE rim of Halemaumau (floor of Kilauea) had relatively lowered 19.7 centimeters since February 10, 1936 (closing stages of Mauna Loa Eruption) and 37.8 centimeters since October 17, 1934, with reference to Spit B. M. SE rim of Kilauea. Between August 13, 1935 and November 26, 1935, relative change of elevation between the same stations was 4.0 millimeters, or essentially no change in the period leading up to the Mauna Loa eruption. The termination of the Mauna Loa eruption marked the beginning of another period of relative lowering of Kilauea Crater floor which has continued up to the present time. The period of unchecked levels run between September 3, 1936 and January 26, 1937 in general confirmed this apparent downward movement. It must be remembered that Spit B. M. on SE rim of the greater crater might have been relatively elevated, hence the word "apparent".

H.H.W.

THE VOLCANO LETTER

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Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

KILAUEA VOLCANO LABORATORY
OF THE UNIVERSITY OF HAWAII 1937—

By T. A. Jaggar

Research at the Kilauea Volcano Laboratory with workers from the University began on July 13 with the arrival of Dr. Stanley S. Ballard, accompanied by Mr. Paul Gow, chemist of the Hawaiian Sugar Planters' Association. They made preliminary chemical tests for three days, setting in operation oxy-flame blow-pipe apparatus for melting glass. This and numerous items of equipment and supplies for making vacuum tubes, and collecting volcanic gases were put in working condition.

Spectrograms made with the large quartz spectrograph of the H.S.P.A. in Honolulu show domination of carbon monoxide. An analysis carried out at the University by Assistant Professor J. H. Payne shows carbon dioxide, sulphur dioxide, nitrogen and oxygen, but no carbon monoxide nor hydrogen. The results show chemical reactions in progress even at the relatively low temperature of Sulphur Bank. The analysis residue is used for spectroscopic work. On August 17 Dr. Ballard and Dr. Eller set up new apparatus, and during the ensuing fortnight Dr. Ballard collected samples of specially dried gas with filter tubes for removing excess of carbon and sulphur.

Dr. Ballard reports as follows:

I left Honolulu bound for Hilo via Inter-Island steamer on Friday, August 13, arriving there the following day. We left the Big Island to return to Honolulu on Sunday, August 29. The two weeks spent at the volcano observatory were most worth while from the research point of view. The major accomplishment was the collection of four tubes of solfataric gas from the Sulphur Banks wells. One of these tubes was filled, using a method similar to that used for some of the collections of last year, in order to determine whether any major changes in the constitution of the gas had occurred since then. The other three were collected through an ice pack in order to condense out the large steam content and through two traps containing concentrated potassium hydroxide. The gases were passed through the potassium hydroxide solution in order to absorb the large content of carbon dioxide and sulphur dioxide which had been detected spectrographically and chemically in the 1936 collections. Spectrographic examinations had shown that so much carbon monoxide, carbon dioxide, or organic matter was present that other constituents could not be detected by this method. The chemical analyses conducted by Dr. J. H. Payne, Assistant Professor of Chemistry, had revealed a large sulphur dioxide content, so large in fact that the determination of nitrogen, oxygen, and combustible gases was difficult and uncertain.

Figure 1 shows 250 cc. tube connected with 70-foot well drilled at Sulphur Bank, Kilauea. This is set up for sucking the well gas through an ice pack. The inner box is packed with ice and covered. A hand suction pump is used.

Figure 2 shows the gas being drawn through two bulbs packed with ice and salt and a Milligan gas tower absorption bulb containing a 50% solution of caustic potash. A three-way stop-cock below is used to flush the line before collection. The bulbs are for the purpose of absorbing steam, carbon dioxide and sulphur dioxide.

Instructor Iwao Miyake did the following important work in checking over the Observatory shop tools and the seismographs of Halemaumau, Hilo, Uwekahuna and Kona:

1. Made a list of necessary shop supplies.
2. Turned out flange and mounted the new chuck for the Observatory shop lathe.
3. Overhauled the Uwekahuna seismograph. The vertical component was not working.
4. Overhauled the Pit seismograph and adjusted the clock contacts.
5. Built seismograph constant measuring device.
6. Overhauled the Kona seismograph and took complete data necessary for constant determination:
   a. Established known points on seismograph boom for future constant checking measurements.
   b. Worked out a routine for constant checking measurement and taught same to Mr. Yasunaka.
7. Overhauled Uwekahuna seismograph drive clock.
8. Installed and adjusted new electric contact points on Uwekahuna time marking clock.
9. Overhauled the Hilo seismograph and took complete data necessary for constant determination:
   a. Established known points on seismograph boom for future constant checking.
   b. Rebuilt timing clock and put in new electric contact points for time marking.

Mr. Miyake arrived July 14 and Dr. Eller July 31. Special studies were made of all the seismological instruments on the island of Hawaii, and the constants of the instruments were determined.

Mr. Miyake finished his shop work and seismographic tests August 4. Professor Eller continued work here until August 18.

Dr. Eller reports as follows on his new tilt-meter:

"As my main interest in the work at the H. V. O. is the study of tilt measurement, most of my time there was spent in that connection. Several trips to the pit and to the country around Kilauea served to make the general lay of the land familiar to me. This was followed by a study of maps of the region, for the purpose of planning possible points for future placing of tiltmeters for an extended program of tilt measurement.

"Also a recording tiltmeter, constructed in Honolulu, was adjusted and put in proper working order, and installed in the seismograph room at the Hawaiian Volcano Observatory. This is of a design which I hope will be found useful for future work. This meter is still in operation and I am receiving records from it each week. So far these records show little change from the original setting, due to slight activity in the Kilauea region during the past few months.

"A considerable study was made of the tilt records available at the Observatory, and notes taken from them for future study."

Dr. Jaggar was greatly assisted by the physicists in his work of designing and building a set of ten earthquake recorders to

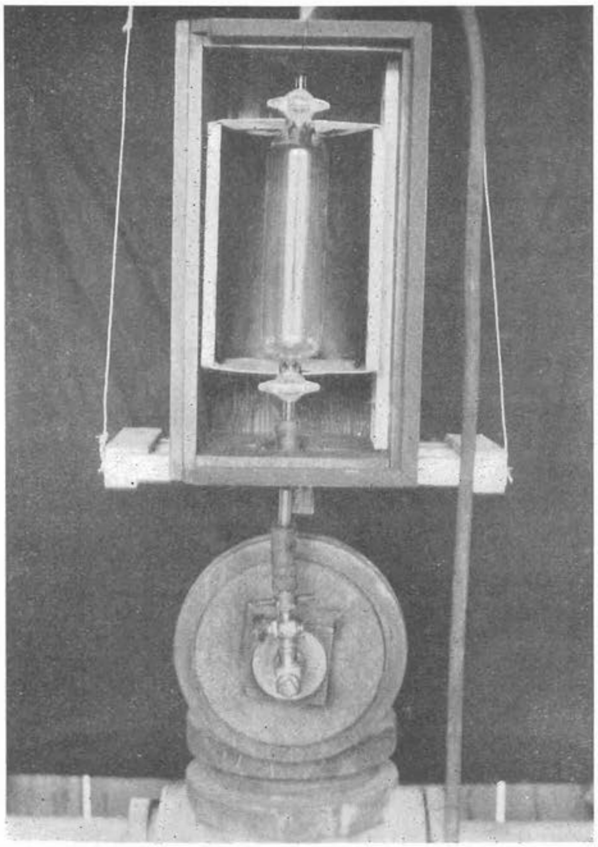

Figure 1. A tube for gas collection over Sulphur Bank well by suction and packing in ice.

be located at the telephone exchanges of the island. Several of these instruments have been tested out, at the Kilauea laboratories with a view to progressive improvement of detail.

The investigations of the summer of 1937 on volcanologic physics, by Professors Jaggar, Eller and Ballard, Instructor Miyake, and geophysical assistant Sato, aided by the mechanical staff of the Hawaiian Volcano Research Association, namely H. Yasunaka and A. Okuda, have started new work that will be carried out both here and in the University laboratories throughout the coming year. Aided by the Department of Chemistry and by the large spectroscope of the Sugar Planters' Association, a new effort is under way to understand the gas action and rock crystallization that constitute volcanic activity, and eventually makes the soil, air, and water of Hawaii.

The following address was delivered at Radio Station KHBC, Hilo, August 17, 1937, by Professor Eller:

"TILTING OF THE GROUND"

Two years ago plans began to develop at the University of Hawaii for cooperation in the work of the Hawaiian Volcano Observatory. So far active participation has been restricted to a few weeks during the summer when members of the teaching staff were free to work at Kilauea.

The Department of Physics of the University has entered into this program from several angles, as there are many problems connected with the work of the Hawaiian Volcano Observatory that are more physical than purely geological. In the main these are: the study of the gases from the volcano, and the volcanic rock, which are being examined spectroscopically to determine their constituents, both as to the elements present and their quantity; and the study of movement of the earth, both temporary and permanent.

Earth movements and displacements of seismic origin are of interest because of their possibilities in forecasting earthquakes or eruptions. The earth movements at Kilauea are observed primarily for the purpose of studying volcanic activity which might result in eruption. They are in the nature of quakes of varying degrees of magnitude, and tilting of the earth's surface. Observations and measurements of these movements were begun early in the history of the Hawaiian Volcano Observatory.

The earthquakes are recorded by several seismographs, three of which are at Kilauea, one in Kona and one at Hilo. From the records of these instruments it is possible to determine the magnitude, character and location of quakes originating in various parts of the island of Hawaii, say in Halemaumau, or Mauna Loa, both of which are sources of many of the disturbances noted. These quakes result from movement of the underlying lava, and by their nature assist in the forecasting of eruptions.

Tilting of the ground, sometimes sudden, but more often gradual, accompanies the movement of the underlying lava. A tilt is a change in the angular relation between a portion of the earth's surface and the horizontal. Tilting is usually very slight, and is measured in seconds of arc. A tilt of one second, which is fairly large as tilts go, represents the angle through which a line about three and one-half miles long is rotated about one end when the other end is raised one inch. Such ground movements can be measured by precise leveling, but this method is expensive and slow, and not suitable except over a fairly extended area.

It is apparent, then, that an instrument for measuring a localized tilt must be very sensitive to change of angle of its supports. The seismographs, such as are in use for earthquake measurement, are utilized for tilt measurement, and are sufficiently sensitive, but a seismograph installation is much too expensive to use for the large number of tilt stations that are needed.

A type of tiltmeter has been developed at the Hawaiian Volcano Observatory which is very satisfactory for indicating the tilt, both in magnitude and direction, but has the disadvantage that it is not a recording instrument. It must be visited and read to determine the tilt. Two of these instruments are in use on the floor of Kilauea crater, near Halemaumau, and are read at twenty-four hour intervals, but there is no record of any variations that might occur between readings, nor of the time when any particular amount of tilt takes place. Furthermore, these instruments are not of a type to be made self-recording, except photographically, and that has its disadvantages.

There is need for a tilt-measuring device that is sensitive, economical in construction and operation, which will record the tilt hourly, at least, and that need be visited not oftener than once a week, at which time the record can be removed and replaced by a new, blank record sheet. Many such instruments could be placed around Kilauea crater and the rifts about this region and a very complete record of the tilting of the ground obtained which would be of great value in the study of the lava movements below the ground, as well as in the prediction of future eruptions.

It is in connection with the development of such an instrument that I am spending a few weeks at the Hawaiian Volcano Observatory this summer. I have a model in operation from which daily records are now being obtained. This model appears to have possibilities for development into the type of device required for the more widespread study of tilts which I have mentioned.

At the present time tilting is being measured at Halemaumau, as before stated, and also at some of the seismograph stations, by measurements taken from the seismographs. Such measurements have been carried on continuously at the Observatory for many years, and have shown that volcano tilts coordinate with lava movement, and that seasonal tilts also occur over large areas. The annual variation of tilt at the main Hawaiian Volcano Observatory station takes place along a line about NNE and SSW. The tilt is greatest to the NNE about the end of December and the greatest SSW value is in May or June, and varies through a range of from twelve to eighteen seconds of arc in the different years. At the same time there is now a slight residual tilt toward the west which is at the rate of less than one second per year.

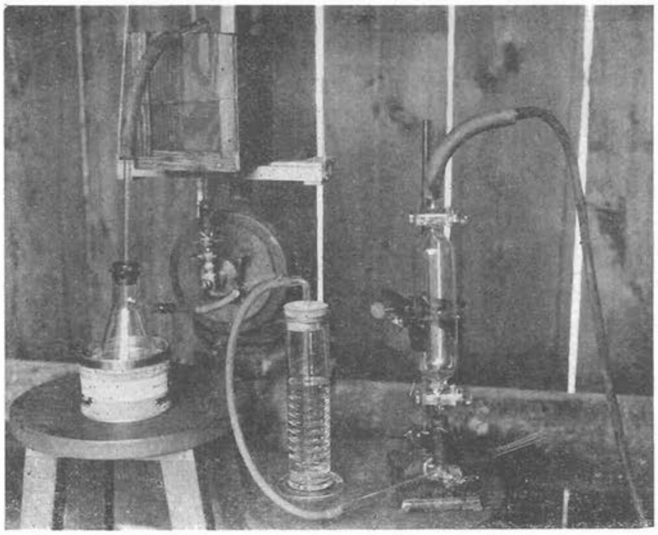

Figure 2. Gas drawn through salt-and-ice mixtures and KOH before reaching collecting tube.

The tilt stations on the crater floor, near Halemaumau, indicate in general, tilts to or from the pit as being predominant. This shows a swelling and subsidence with the rising and recession of the underlying lava, or one might say, a sort of diaphragm action of the crater floor. These movements at the pit are very localized, and do not show ground movements over a larger area as would stations around the crater rim, or at points on Mauna Loa.

In most cases the tilts as measured at the various stations have been gradual, with small daily change. Likewise a tilt of one day might be in an entirely different direction from that of the day before, but in general, over a period of several days, or in many cases several months, the tendency of the tilt is in one definite direction. Then there may be a reversal of the tilt over an extended period, so that at no point does the tilt continue indefinitely in one direction.

At times, especially of considerable seismic disturbance, a tilt of several seconds may occur between readings of the instruments. This large change probably takes place in a few seconds of time, at the time of the quake. But whether the tilt be large or small, gradual or sudden, it gives definite information of movement of underlying lava, and an extended tilt study should assist greatly in following the course of this movement.

Hawaiian Volcano Observatory Report for November 1937

VOLCANOLOGY

The Hawaiian volcanoes were quiet during the month, and there was little motion in the walls of Halemaumau pit at Kilauea.

The following are the weekly Observatory totals for Halemaumau and the seismographs.

Week Ending		Seismicity	Slides	Crack Openings	Local Tremors and Quakes
November	7........	6.75	2	3.00 mm.	19
"	14........	3.75	0	5.05 mm.	11
"	21........	4.00	2	0.00 mm.	11
"	28........	9.75	0	0.00 mm.	24

The slight earthquake November 27 damaged the Halemaumau seismograph and was felt in National Park. Of the measurable local seismic disturbances, sixteen were from Kilauea, one from Mauna Loa and one from northwest of Mauna Kea.

Sequence of Events by Weeks

The first week produced two slides from Halemaumau walls, two more were noted during the third week and on November 28 scars of a slide appeared in Puu Huluhulu crater after the sharp jerk of the earthquake of November 27.

Slides at Halemaumau

The recorded slides from the wall of the pit were:

November 1, 11:05 a.m., dust arose at NW wall.

November 2, 9:00 a.m., another slide in the same place.

November 21, 1:45 p.m., two slides north wall.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted during November in aggregate movement as follows:

Week ending forenoon of:

November 5, 28 locations, 6 opened, 4 closed, opening 3.00 mm.

November 12, 28 locations, 12 opened, 3 closed, opening 5.5 mm.

November 19, 28 locations, 6 opened, 4 closed, opening 0.0 mm.

November 26, 28 locations, 6 opened, 5 closed, opening 0.0 mm.

T. A. J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending		Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Slight Earthquakes	Distant† Earthquakes	Seismicity Weekly*
Nov.	7......	13	5	1	0	0	6.75
"	14......	7	4	0	0	1	3.75
"	21......	12	2	0	0	0	4.00
"	28......	15	8	0	1	0	9.75

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 seis-

* For local seismicity definition see Volcano Letter 371.
† Including teleseisms or earthquakes over 5000 km from Kilauea.

mograph station at the Observatory and the two subsidiary stations at Uwekahuna and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of the depth of focus has been made.

November 1, 2:49 a.m., very feeble, probably originated in area immediately NE of the Observatory, NE rim of Kilauea Crater.

November 1, 5:50 p.m., very feeble, 38.0 miles deep in vicinity of Waimea Table Land about 18.0 miles NNW of Summit of Mauna Kea. 19° 59.0′ N; 155° 30.8′ W.

November 3, 1:59 p.m., feeble, probably originated in Kilauea Crater near SE portion of Halemaumau.

November 6, 4:18 p.m., very feeble, probably originated in NE portion of Kilauea Crater.

November 8, 8:58 a.m., very feeble, 1.1 miles under Byron Ledge. 19° 25.0′ N; 155° 15.6′ W.

November 8, 10:13 a.m., very feeble, location same as preceding quakes but of slightly deeper focus.

November 8, 10:25 p.m., very feeble, probably orginated in SE rim area of Kilauea Crater near Keanakakoi.

November 11, 12:02 a.m., very feeble, probably originated in Western portion of Kilauea Crater near Uwekahuna.

November 17, 12:24 p.m., very feeble, 3.9 miles deep, 3.4 miles NW of the Observatory. 19° 27.8′ N; 155° 18.0′ W.

November 23, 4:37 p.m., very feeble, probably originated in NE rift of Mauna Loa about 15.0 miles from Hilo.

November 25, 10:10 p.m., very feeble, 2.2 miles deep NE rim Halemaumau, Kilauea Crater. 19° 24.9′ N; 155° 17.0′ W.

November 25, 10:11 p.m., very feeble, 1.4 miles deep NW portion of Kilauea Crater. 19° 25.6′ N; 155° 17.0′ W.

November 25, 10:23 p.m., very feeble, 1.5 miles deep in SE rim cracks, Kilauea Crater immediately NE of Keanakakoi. 19° 24.4′ N; 155° 16.2′ W.

November 25, 10:26 p.m. very feeble, location same as preceding quake.

November 26, 12:44 a.m., very feeble, of shallow origin SE rim cracks Kilauea Crater. 19° 24.2′ N; 155° 16.3′ W.

November 26, 11:50 p.m., very feeble, probably originated in E portion of Kilauea Crater.

November 27, 11:26 a.m., very feeble, 5.0 miles deep, SW rift zone at junction with Kilauea Crater. 19° 24.5′ N; 155° 17.7′ W.

November 27, 6:35 p.m., slight, 1.1 miles deep, 0.3 mile E of E rim Halemaumau and 0.4 mile from Pit seismograph. Reported felt at CCC Camp, SE rim of Kilauea Crater and around the National Park residential area. Pit seismograph was dismantled and the supports of N-S component broken. 19° 24.4′ N; 155° 16.7′ W.

Microseismic motion of the ground at the Observatory was strong throughout the month.

Four (4) minutes of continuous tremor began recording at the Observatory 3:53 a.m., November 21.

An unidentified portion of a teleseism began registering at Kilauea at 9h 03m 28s, p.m., H.S.T., November 9.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau the algebraic sum of radial tilts toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending November 28, was 10.05″ S and 1.55″ E.

Week Ending	Observatory	Halemaumau West Station
November 7	1.38″ N 48° E	2.62″ N 31° W
November 14	0.65″ N 61° W	2.80″ N 80° W
November 21	0.00″ 0	5.16″ N 82° W
November 28	1.00″ N 79° E	4.14″ N 71° W

Week Ending	Southeast Station Halemaumau	Halemaumau Resultant
November 7	1.62″ S 34° W	1.69″ From
November 14	3.43″ N 46° W	0.89″ Toward
November 21	6.42″ N 28° W	2.79″ From
November 28	8.59″ S 16° E	4.37″ From

H. H. W.

Crater Angles

Measurement of Horizontal Angles across Kilauea Crater from the Observatory November 27, showed slight closing of the Kilauea Crater value and slight opening of the Halemaumau value as compared to similar measurements October 16. From Kilauea Crater SE rim to Uwekahuna there was opening 0.09″, October 16 to November 10, and closing of 0.25″, November 16 to 20. Total closing 0.16″. From the SE Pit B. M. to NW Pit B. M. there was opening 1.40″, October 16 to November 10, and closing of 0.84″, November 10 to November 27. Total opening 0.56″.

H.H.W.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

The Hawaiian Volcano Research Association was founded in 1911 for the prosecution of volcano research, more particularly in the Hawaiian Islands and around the Pacific Ocean. Its laboratory at Kilauea Volcano, Hawaii, is leased and operated by the United States Government, Department of the Interior, National Park Service. The Association maintains seismograph stations at various places on the Island of Hawaii and supplements the work of the Government with buildings, research fellows, instrumental plants, explorations and special investigations for which there is no governmental provision.

The Volcano Letter, a monthly, eight-page, illustrated publication dealing with volcanic and seismic interests in Hawaii, the Pacific area, and other sections of the world, is issued by authority of the Department of the Interior, and is supplied free of charge to members of the Association and to a restricted exchange list. It is non-technical in nature and promotes popular interest in its particular field of science.

The Secretary of the Association is Mr. L. W. de Vis-Norton, whose address is 320 James Campbell Building, Honolulu, T. H. Contributions of articles, photographs, publications and clippings about volcano and earthquake events, instruments and investigations are always welcome, and if suitable, will be published with due acknowledgment.

THE VOLCANO LETTER

No. 454 monthly Department of the Interior National Park Service December 1937

Hawaii National Park
Edward G. Wingate Superintendent

Hawaiian Volcano Observatory
T. A. Jaggar Volcanologist

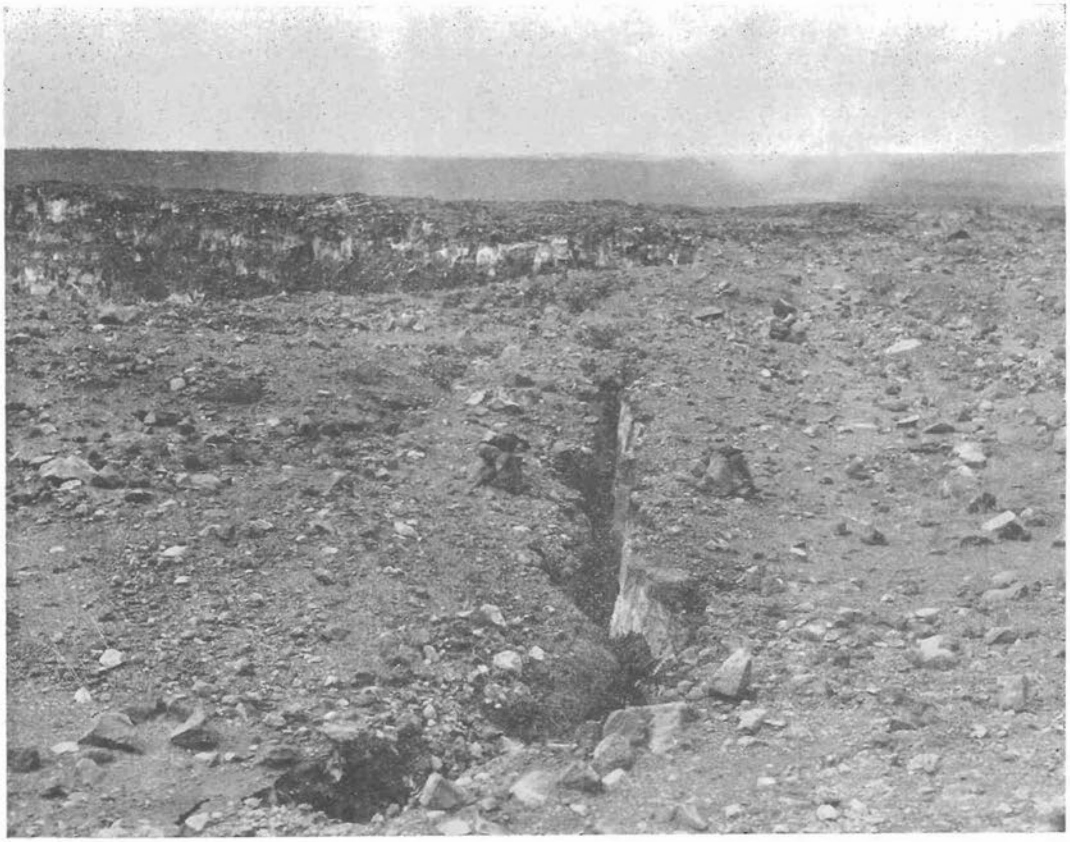

Figure 1. Crack on east margin of Halemaumau No. 25. Note two stone piles right side of crack, May 10, 1937.

WORK OF THE OBSERVATORY 1937—

The Hawaiian Volcano Observatory is administered under the Branch of Research and Education of the National Park Service. In collaboration is the Hawaiian Volcano Research Association, an educational corporation of the Territory of Hawaii which supplements the work of the Government. The staff in 1937 was:

- T. A. Jaggar, Volcanologist
- H. H. Waesche, Assistant Geologist in charge of seismology
- S. Sato, Librarian
- H. Yasunaga, General Assistant
- A. Okuda, Mechanic

Associates of the Observatory in Honolulu are:

- Willard H. Eller, Associate Professor of Physics
- Stanley S. Ballard, Assistant Professor of Physics
- Iwao Miyake, Instructor in Physics
- L. W. de Vis-Norton, Secretary and Assistant Treasurer, Hawaiian Volcano Research Association
- Mrs. B. Y. Ching, Clerk

The Directors of the Hawaiian Volcano Research Association are:

- F. C. Atherton, Castle & Cooke, Ltd.
- R. A. Cooke, C. Brewer and Co., Ltd.
- D. L. Crawford, University of Hawaii
- A. L. Dean, Alexander and Baldwin, President

W. F. Dillingham, Oahu Railway & Land Co.
J. R. Farrington, Honolulu Star-Bulletin
W. F. Frear, Bishop Trust Building
L. T. Peck, Stangenwald Building
W. W. Thayer, Stangenwald Building
L. P. Thurston, Honolulu Advertiser

Volunteer operators of seismographs for the Research Association on the island of Hawaii are:

R. V. Woods, Kealakekua
St. Mary's School, Hilo

The routine of the Observatory, besides the accumulation of data exhibited in the Volcano Letter, which involves attention to five seismographs, two clinographs, weather records, levelling and triangulation, and measurements at Halemaumau pit, includes also circulation of a weekly press report for Island newspapers, transmittal of a monthly report to the National Park Service, transmittal weekly and monthly of weather data to U.S. Weather Bureau and preparation of scientific papers.

Mauna Loa and Proposed Hilo Barriers

As outlined in Volcano Letter of January and March, this subject has been throughout 1937 an important activity of the Observatory, involving as it does a large engineering program for the protection of Hilo, the acquisition of additional land on Mauna Loa, and the establishment of a Mauna Loa seismograph at the terminus of the Park Road.

The Barrier Project for defending Hilo from lava flows was announced at a lecture by T. A. Jaggar to Hilo Chamber of Commerce January 19, followed by the proposal of the Hawaiian Volcano Research Association to acquire all lands on Mauna Loa above 7,000 feet that might be needed for patrol by the National Park Service. This action was authorized in February by the Board of Directors of the Research Association and an expedition over the ground on Mauna Loa was made in March by Chief Forester Coffman of the Park Service, and Mr. Tillett, Superintendent of Hawaiian Emergency Conservation Work, along with Superintendent Wingate, the Volcanologist and others. March 23 a resolution by Hilo Chamber of Commerce requested the Rivers and Harbors Committee of Congress to provide for a survey of the barriers for the protection of Hilo harbor. This was incorporated in the Rivers and Harbors Bill in May, and the bill was passed in August. The several owners of the upper lands on Mauna Loa, including the Territorial Government, expressed tentative approval of the enlargement of the Park, as might be later demanded by Act of Congress. In July and August Colonels Thomas and Browne of the U.S. Engineers went over the lands on Mauna Loa, Mauna Kea and at Hilo where the barriers would be constructed. General Markham, Chief of Engineers, inspected the field in November, and the U.S. Engineer in charge of Hawaii, Major P. E. Bermel, held a hearing in Hilo December 17 where the harbor protection was discussed.

On September 9 a site was selected on the upper side of the present terminus of the Mauna Loa road for a cellar of concrete with double walls to house a seismograph of Hawaiian type, and this cellar was nearly completed at the end of the year, built by Emergency Conservation labor.

Seismology and Engineering

Mr. Waesche was engaged in January in applying a relay to the radio apparatus receiving time signals, so that these signals were written directly on seismograph drums. He prepared earthquake maps of Kilauea crater and the island of Hawaii. He assisted in arrangements for a new kiosk at Halemaumau to exhibit to travelers history of eruptions. A levelling instrument gave much trouble during the year, but a substitute instrument was obtained, and it was discovered that the northwest Halemaumau benchmark had lowered relative to the Sand Spit south of Kilauea about fifteen inches since October 1934. In December a rotary wind-measuring instrument was set up on the Observatory roof, so as to record directly on the chronographs of the seismograph cellar. A similar instrument was obtained for the Rest House on Mauna Loa.

Investigation of simplified seismological instruments for volunteers has occupied the staff. Four new model shock recorders were built during the first half of the year having in view the recording of three components of motion by means of weights suspended by flat springs.

In May a second series of experiments was begun with normal pendulums designed to actuate a mercury contact, ring a bell, and exhibit intensity by length of swing.

The object of this work was to install annunciators at telephone exchanges which would give a numerical value to intensity of an earthquake. The operators would enter the number on a postal card sent the Observatory. It was finally decided to use a rectangular heavy mass capable of swinging in one direction only, with a very light horizontal high-magnification lever, making contacts with mercury in six cups. These connect with a six-point annunciator, grades one to six being shocks progressively stronger.

The normal activities of the Observatory in seismology and engineering will be found described in the articles by Mr. Woesche in Volcano Letters of February, April and October. The instrument that will be placed in the Mauna Loa cellar consists of a pair of pendulums built in our shop, magnifying earth motion one hundred times, and writing on smoked paper wrapped round a drum driven by clockwork. This instrument will be visited once a day by a member of the staff who will change the drum. The location is eleven miles from the Observatory WNW, on the Mauna Loa slope ten miles below the rest-house. This will give the Observatory a definite check on shocks occurring under the rift belt of Mauna Loa.

The shock recorders and annunciators are simple instruments in wooden cases designed to screw on a wall anywhere, announce an unfelt earthquake by ringing a bell, and proclaim its size by the distance to which the pendulum swings. When an electric annunciator dial is used the length of the swing is indicated by a number. The operator after noting the hour and the number, sets the annunciator back to zero. Plans for making one of the models self-recording are not yet perfected, but tests have been made with ink, smoked paper, and photographic film.

Kilauea Laboratory, University of Hawaii

The work of the University physicists was outlined in November Volcano Letter. S. Sato, a University assistant, is resident at the Observatory as librarian and has introduced order into the library by classifying, filing and card cataloging the earthquake and eruption notices clipped from the press, also the books, pamphlets, notes, and photographic negatives that are parts of the invaluable Kilauea records.

Among things filed are the long smoked paper seismograms, fixed with shellac varnish and stored by thousands. The work of classifying finds these congested by overflow from the metal case originally made for them. All the records are in a room eighteen feet square from which books had to be ejected with transfer to the University building five hundred yards away. In the attempt at economy of space, there have been packaging and storing surplus publications, correspondence, and the less used books, in the hot, dry, wooden Observatory attic; transferring seismological pamphlets to the Assistant Geologist's wooden office, and lastly filing, selecting reserves, and setting apart sets for binding, of the Observatory Bulletin and of the Volcano Letter, the entire file of the latter being kept in the old wooden Observatory building. This building also houses as fire hazards chemical and photographic work, electric soldering irons, and kerosene smoking apparatus for the daily seismograph routine in the basement. Here also are main switchboxes and fuses; and battery equipment for radio time signals.

This situation is a continuous fire menace for the storage of the valuable records and publication files of the twenty-six years of work of the Hawaiian Volcano Research Association. The record material cannot even be studied properly, for there is no room for large tables nor for modern filing cases and everything has to be distributed to five rooms in three different buildings.

There is no solution for this problem of congestion other than the creation of a new large fireproof Hawaiian Volcano Observatory building.

Dr. H. Nagaoka of the Institute of Physical and Chemical Research in Tokyo has discovered at Asama Volcano that a magnetometer needle moves suddenly during underground volcanic disturbance. Theoretically this should be true, for liquid lava on solidifying or liquefying changes its magnetic attractiveness. At Asama various intermittent disturbances of the magnetic needle are observed several weeks before an explosion

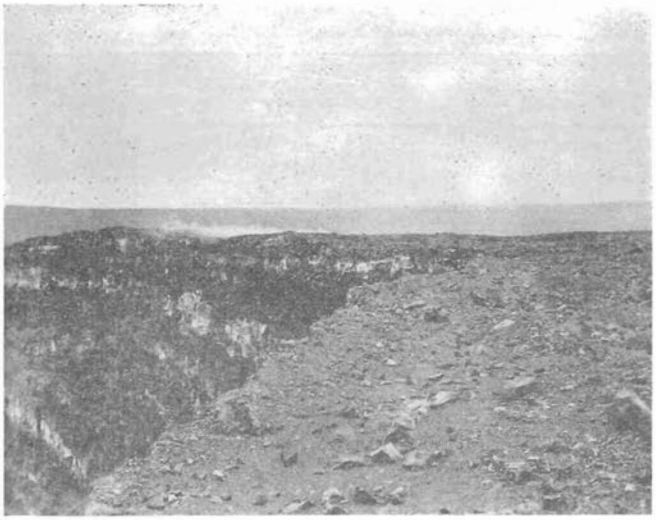

Figure 2. Crack locality No. 25 after caving into pit August 22, 1937. Photographs by Waesche.

of the volcano, and the rumbling is always accompanied by great magnetic changes. A specialized magnetograph was constructed giving the value of the time-rate of variation, serving as an indicator of rapid magnetic disturbances and registering the vertical component. It is relatively insensitive to magnetic storms. Professor Eller is greatly interested in the possibilities which this apparatus has for exhibiting the melting or the congealing of Hawaiian eruptive lava underground. Experiments are in progress for melting the lava and studying its change of magnetic properties.

As candidate for the degree of Master of Science Mr. A. E. Jones presented a thesis at the University of Hawaii on "Empirical Studies of the Seismic Phenomena of Hawaii" and on September 23, came up for examination which he passed satisfactorily. This thesis presents a statistical investigation of many seismograms of the Hawaiian Volcano Observatory.

In these days of Kodachrome photography an appeal may be made to amateur photographers interested in the Hawaiian volcanoes to explore the great rift belts and to photograph them. Either still or motion pictures in color, for purposes of projection and exhibition, should be made of the hundreds of subjects, such as cracks and pits and cones, that lie along the southwest rift of Mauna Loa in Kahuku, the northeast rift near the Rest House, the vicinity of Kulani; and the great extent of the Kilauea rift in the forest to the east of the Chain-of-Craters; and along the many pits and cones of the Kau Desert. There is here a magnificent opportunity for photographic exploration in the wilderness, something that few people seem to care to do.

Hawaiian Volcano Observatory Report for December 1937

VOLCANOLOGY

Until the solstice season of December 20, the month at Halemaumau pit of Kilauea volcano was extraordinarily quiet. After solstice local seismicity became three times as great, and five large distant earthquakes were recorded, in part from the Mexico-Central America region. Sixteen of the local shocks were from Kilauea, one from Mauna Loa and one from Hualalai.

The following are the weekly Observatory totals for Halemaumau and the seismographs:

Week Ending		Seismicity	Slides	Openings Crack	Local Tremors and Quakes
December	5......	3.75	0	3.5 mm.	10
"	12......	2.25	0	1.0 mm.	7
"	19......	2.00	0	6.0 mm.	7
"	26......	6.50	1	0.0 mm.	20
January	2......	7.50	0	2.5 mm.	19

Perceptible earthquakes occurred in Hilo December 28, Kona December 30, and at National Park January 1.

Sequence of Events by Weeks

The first week was quiet, with noticeable blue fume showing over Halemaumau during humid Kona weather.

The second week was even quieter, and the seismic index for the third week was astonishingly small just as it was a year ago at this period. This was interrupted by a landslip in Halemaumau the fourth week, and the fifth week showed increased numbers of earthquakes near and far.

Slide at Halemaumau

A recorded slide from the wall of the pit was:

December 21, 4:08 p.m., a considerable slide from the north rim.

Measurement of Halemaumau Rim Cracks

Weekly measurement of rim crack locations resulted during December in aggregate movement as follows:

Week ending forenoon of:

December 3, 28 locations, 11 opened, 6 closed, opening 3.5 mm.

December 10, 28 locations, 8 opened, 6 closed, opening 1.0 mm.

December 17, 28 locations, 10 opened, 2 closed, opening 6.0 mm.

December 24, 28 locations, 6 opened, 4 closed, opening 0.0 mm.

December 31, 28 locations, 8 opened, 3 closed, opening 2.5 mm.

T.A.J.

SEISMOLOGICAL DATA

Earthquakes

Week Ending		Minutes of Tremor	Very Feeble Earthquakes	Feeble Earthquakes	Distant* Earthquakes	Weekly† Seismicity
Dec.	5............	7	3	0	0	3.75
Dec.	12............	5	2	0	0	2.25
Dec.	19............	6	1	0	0	2.00
Dec.	26............	14	6	0	3	6.50
Jan.	2............	10	8	1	2	7.50

* Including teleseisms of earthquakes over 5000 km. from Kilauea.
† 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 and the SE rim of Halemaumau respectively. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began at the time indicated and whenever possible, a determination of the depth of focus has been made.

December 1, 9:15 am, very feeble, probably originated in Kilauea S W rift, 19 miles from the Observatory and 4.0 miles N of Palina Point.

December 2, 8:00 pm, very feeble, 3.1 miles deep, W rim of Kilauea Crater 0.6 mile SW of Uwekahuna, 19° 25.2′ N; 155° 17.9′ W.

December 3, 6:58 am, very feeble, 1.4 miles deep and 0.8 mile W of Puhimau Crater. 19° 23.6′ N; 155° 15.8′ W.

December 7, 12:47 pm, very feeble, 11.0 miles deep, 7.0 miles W of Volcano House. 19° 26.9′ N; 155° 21.8′ W.

December 12, 5:30 pm, very feeble, 21.0 miles deep under Hualalai. 19° 41.5′ N; 155° 50.7′ W. Felt in Kohala and at Paauilo.

December 25, 2:18 pm, very feeble, 2.5 miles deep and 0.4 mile SW Kokoolau Crater. 19° 23.1′ N; 155° 15.2′ W.

December 25, 5:26 pm, very feeble, 6.0 miles deep Kilauea SW rift 7.5 miles from Halemaumau. 19° 20.2′ N; 155° 22.2′ W.

December 26, 1:58 am, very feeble, probably originated in SW portion Kilauea Crater in vicinity of Halemaumau.

December 26, 6:42 am, very feeble, location of epicenter same as preceding but probably of slightly greater depth.

December 27, 2:19 pm, very feeble, 06. mile deep under W portion of Kilauea Iki, 0.2 mile E of Kilauea Crater rim. 19° 25.1′ N; 155° 15.4′ W.

December 28, 11:27 am, very feeble, 1.5 miles deep in Kilauea Crater immediately W of Kilauea Iki. 19° 25.3′ N; 155° 15.8′ W.

December 28, 7:15 pm, very feeble, 11.0 miles deep and 4.0 miles off coast S of Hilina Pali. 19° 12.6′ N; 155° 14.2′ W. Reported felt in Hilo.

December 29, 6:18 pm, very feeble, probably originated in Kilauea SW Rift.

December 31, 4:34 pm, very feeble, probably originated near center of Kilauea Crater.

January 1, 2:39 am, very feeble, 17.0 miles deep in Hilina Fault 3.5 miles S of Kamakaia Hills. 19° 16.0′ N; 155° 20.3′ W.

January 1, 9:16 am, feeble, 4.8 miles deep near Heake Crater, 19° 22.6′ N; 155° 14.1′ W.

January 1, 10:44 pm, very feeble, 13.0 miles deep under SW slope of Mauna Loa 5.0 miles NE of Kauna Point. 19° 05.6′ N; 155° 49.5′ W.

January 2, 6:01 pm, very feeble, probably originated in area approximately 12.0 miles NE of the Observatory.

Microseismic motion of the ground at the Observatory was moderate, December 16 to 21 and on December 24; the remainder of the month, the motion was strong.

Teleseisms registered as follows:

December 21, "P" waves at 5h 19m 20s pm, distance from Kilauea was about 3,200 miles and epicenter was apparently off W Coast of Mexico. 17° N; 106° W, by preliminary determination U. S. Coast and Geodetic Survey.

December 21, 9h 08m pm, no information obtained on location.

December 23, 2h 57m 25s pm, "P" waves, distance from Kilauea was approximately 3,700 miles. Epicential location 16° N; 98° W, by preliminary determination, U. S. Coast and Geodetic Survey.

January 1, 1h 07m 41s pm, "P" waves. No determination of distance.

January 2, 12h 06m 50s pm, "P" waves, probable distance from Kilauea, 3,600 miles.

Hawaiian standard time used for all preceding reports.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau the algebraic sum of radial tilts toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending January 2, was 9.7″ S and 0.47″ E.

Week Ending	Observatory	Halemaumau West Station
December 5	0.46″ S 41° W	2.92″ S 81° W
December 12	1.01″ S 50° W	2.98″ N 33° W
December 19	0.97″ N 65° E	2.38″ S 66° W
December 26	0.82″ S 26° E	4.23″ N 58° W
January 2	0.25″ N 27° W	0.00 Unchanged

Week Ending	Halemaumau Southeast Station	Halemaumau Resultant
December 5	9.17″ S 67″ W	0.56″ From
December 12	10.40″ S 73° W	1.91″Toward
December 19	10.08″ N 12° E	4.24″ Toward
December 26	1.62″ S	4.72″ From
January 2	6.29″ N 15°W	5.83″ Toward

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory, December 22, indicated opening of both the Halemaumau and Kilauea Crater values compared with similar measurements made November 27. At that time the Halemaumau value from the SE Pit B.M. to the NW Pit B.M. increased 2.51″ and the Kilauea Crater value from the SE rim to Uwekahuna increased 0.44″.

Leveling at Kilauea

On December 9, a series of levels similar to that of October 12 was run in Kilauea Crater from the Spit B. M., SE rim of Kilauea Crater to NW Pit B. M. on the NW rim of Halemaumau. Results of this run indicated relatively no change or not more than 4 millimeter lowering of the NW Pit B. M. relative to Spit B. M. The Lietz, Coast and Geodetic Survey type precise level was used for the December levelling. It checked favorably with the Stanley "Wye" level used for the October determination.

H. H. W.