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. 507 | U. S. Geological Survey | January–March, 1950

PUBLISHED BY THE UNIVERSITY OF HAWAII

THERMAL WATER ON KILAUEA VOLCANO

By RUY H. FINCH and GORDON A. MACDONALD

The numerous steam vents within Kilauea caldera are well known. For the most part the steam contains no other gases and appears to represent merely ground water of meteoric origin which has been heated to, or slightly above, the boiling point by contact with bodies of hot rock. At Sulphur Bank and at the nearly buried solfataric area east-southeast of Halemaumau the steam is mixed with a small proportion of sulfur gases and carbon dioxide of magmatic origin, but even there the majority of the steam probably is derived by heating of ground water.

In addition to the steam vents at Kilauea caldera, there are four known occurrences of warm water on Kilauea volcano. It has been reported in a crack near Waiwelawela Point, 12 miles east of Pahala (Stearns and Clark, 1930, p. 190), but no record of the temperature of the water at that locality is known. The warm water undoubtedly results from heating of basal ground water by contact with hot intrusive rock along the southwest rift zone of Kilauea.

The other three occurrences of warm water are all in eastern Puna, on or near the east rift zone of Kilauea. One of these is the well-known "Warm Spring" near the northern base of Puu Kukae, about 0.8 mile east-northeast of Kapoho. The water is basal ground water. It forms a pool in a crack at the foot of the small fault scarp which marks the southern edge of a small graben, or block of rock which has sunk down between two faults. Brigham (1868, p. 374) reported that in 1864 this pool (called by him the "Blue Grotto") had a temperature of 90° F. At present the temperature is only a little above the average air temperature. Measurements on January 11, 1950, gave a water temperature of 84° F. and an air temperature of 79°.

Another pool of warm water is situated half a mile northwest of that just described and within the same graben. The water is in a crack at the back of a shallow cave, the entrance of which is at the base of a low northward-facing fault scarp about 750 feet south of the higher fault scarp that marks the northern edge of the graben. The locality is about 0.6 mile north of the highway junction at Kapoho and 0.2 mile east of the Kapoho-Koae road. At one time the water was bottled for sale under the trade-mark "Volcano Water." The temperature of the water is only a little above that of the air outside the cave. On January 11, 1950, the water temperature was 83° F., and the temperature of the air in the cave was 77°.

The third occurrence of warm water is at Pohoiki, about 3 miles south of Kapoho. There basal springs issue just above sea level from a cobble beach at the head of a small bay. The springs are within the zone of splash from the ocean waves and are distinctly brackish. On January 11 the water temperature was 91° F., and the air temperature 77°.

No other warm waters are known on the island of Hawaii, although steam issues from vents in the caldera of Mauna Loa and on both rift zones. The amount of warm water, at first glance, seems surprisingly small in view of the large amount of volcanic heat undoubtedly still present beneath the surface. However, because of the high permeability of the rocks, as Stearns and Clark (1930, p. 190) have pointed out, most juvenile and meteoric hot waters probably become diluted and cooled at the basal water table and do not reach the surface.

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ORIGIN OF PUEHU CINDER CONE, KAU

By GORDON A. MACDONALD and RUY H. FINCH

Puehu cinder cone is a small but prominent cone situated just south of the main highway from Kilauea caldera to Honuapo, about 0.4 mile southwest of the junction with the road to Punaluu. It lies on the southern slope of Mauna Loa about 1.2 miles west of the boundary between the surface lavas of Mauna Loa and Kilauea and is surrounded and partly buried by aa lavas of Mauna Loa. The cone is being excavated to supply cinders for use on roads. Before the mining of cinders began, the cone was about 50 feet high above the lavas on its downhill side, and its exposed base was about 200 feet above sea level. At present a large pit on the southeastern side of the cone exposes cinder for a depth of about 100 feet and has not yet reached the base of the cone.

Stearns and Macdonald (1946, pl. 1) classified the cone as a littoral cone of the Kau volcanic series, formed by steam explosions where lavas of Mauna Loa entered the sea. The better exposures which have resulted from recent excavation indicate that interpretation to be erroneous.

Puehu cone clearly is a cone formed at a primary lava vent. The ejecta exposed in the new cuts are typical of primary cinder cones built at vents. They are moderately to highly vesicular, or even pumiceous, cinder and spatter. Moreover, several thin layers of lava are interbedded with the cinder, some of them obviously rootless flows formed by the aggregation of heavy showers of fluid spatter on the flanks of the cone. Some of these flows still show welded spatter on their surfaces. Lava extends all the way to the summit of the cone, 25 feet higher than the surface of the adjacent aa flow on the uphill side of the cone. On the northeastern side of the cone there is exposed a 15-foot thick section of thin-bedded pahoehoe, the beds ranging from 1 to 6 inches thick and averaging 2 to 3 inches. The rock is olivine basalt with sparingly to moderately abundant phenocrysts of olivine up to about 4 mm. long; much of it is highly vesicular. Such very thin-bedded, highly vesicular pahoehoe typically is found in close proximity to primary vents. Neither it nor the rootless flows would be expected to form on a littoral cone where relatively viscous aa lava enters the sea, nor have they been observed on known littoral cones.

Besides the presence of the aforementioned features typical of cones formed at primary vents, there is a complete absence of the features typical of littoral cones. The angular grains of relatively dense glass, which are characteristic of littoral cone deposits (Macdonald, 1949, p. 72), could not be found. Neither are there present any of the angular blocks of relatively dense lava which are common on the slopes of Puu Hou, the littoral cone formed by the Mauna Loa flow of 1868, and the older littoral cones farther west.

The lower slopes of Puehu cone in the new excavations are covered by as much as 15 feet of yellow Pahala ash, with one intercalated lava flow. The cinder layers in the cone were partly truncated by erosion before deposition of the ash. The Pahala ash is absent from most of the top of the cone, but 2 to 3 feet of ash are preserved in local pockets. Most of the ash appears to have been eroded off the upper slopes of the cone. The ash overlying the lower slopes appears to be the result of primary deposition, and there is no evidence that the thickness of the ash layer resting on the lower slopes of the cone was appreciably increased by secondary deposition of ash eroded from the top of the cone.

The presence of 15 feet of Pahala ash overlying the lower slopes of the cone indicates that the cone is somewhat older than previously was believed. Obviously, it must already have been in existence during the period of deposition of the Pahala ash, and therefore it is older than the rocks of the Kau volcanic series, which are younger than the Pahala ash. However, the Pahala ash has a thickness of 55 feet on Puu Enuhe, only 2.5 miles northwest of Puehu cone (Stearns and Clark, 1930, p. 66). Consequently, it is probable that only part of the total thickness of the Pahala ash overlies the Puehu cone and that the cone is of late Pahala age.

Puehu cone is situated about 12 miles east of the southwest rift zone of Mauna Loa and even farther from any other known vents of Mauna Loa. It lines up with no known Mauna Loa rifts. In contrast, it is only about 3.5 miles from the closest visible vent on the southwest rift zone of Kilauea volcano and lies directly in line with that rift. The cone itself is somewhat elongated in a direction parallel to the Kilauea rift, possibly because the vent fissure had that trend. Although it cannot be definitely proved, it appears highly probable that the cone was formed by eruption from the southwest rift of Kilauea and that it belongs to Kilauea rather than to Mauna Loa.

It is concluded that Puehu cone is a primary cinder cone formed by eruption at a lava vent during late Pahala time, and that it probably belongs in the Hilina volcanic series of Kilauea volcano and is correlative with the upper part of that series exposed in Hilina Pali. If this interpretation is correct, the southwest rift zone of Kilauea must have been in existence at least by late Hilina time, thus strengthening the conclusion of Stearns and Macdonald (1946, pp. 135–136) that the Hilina volcanic series was derived from Kilauea, as opposed to the belief of Stone (1926, pp. 38, 49–50) and Powers (1946, p. 6) that the Hilina lavas are part of Mauna Loa.

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HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JANUARY–MARCH, 1950

VOLCANOLOGY

January

The year opened with both Kilauea and Mauna Loa inactive save for the usual steam vents and solfataras.

Only 24 earthquakes were recorded during the month. This is the smallest monthly total since October, 1948. Twenty-two of the shakes were recorded on the Mauna Loa seismograph and 17 at Kilauea.

There was an accumulation of 7.8 seconds of arc tilt to the south-southwest during January. This is a little more than usual for this season of the year.

The fact that the lava fill in Halemaumau is still hot was shown by pronounced steaming following heavy rains on January 10.

February

A total of 29 earthquakes was recorded during February. Of this number, 26 were recorded on the Mauna Loa seismograph and 21 at Kilauea.

Dust clouds were especially conspicuous in the Kau Desert on February 12.

A landslide of appreciable magnitude from the walls of Halemaumau was observed at 09:50 on February 13.

March

Northerly tilt during March indicates that there was a distinct pressure build-up at Kilauea. This increase of pressure was strong enough to overcome the southerly tilt usual for March and to show a positive northerly tilt of 6 seconds of arc. This is the strongest northerly tilt recorded here for several years.

The distribution of the earthquakes recorded during March also indicates a slight uneasiness under Kilauea volcano. Of the 37 shakes recorded during the month, 35 were registered on the Kilauea seismograph and 16 on the Mauna Loa instrument. Most of the earthquakes of Kilauea origin had shallow foci.

Mokuaweoweo was visited by G. A. Macdonald and J. B. Orr on March 28 to 30. No activity was observed other than the mild solfataras, and no changes were noted since the last visit in October, 1949, other than minor collapses in the small cones built during the 1949 eruption. Solfataras are located in the crater of the 1940 cone, on its northern slope, and on the caldera floor north of it. The gas liberated is largely steam, but contains a little sulfur dioxide and in places a small amount of sulfur is being deposited. The 1949 cones are still hot at many places, a little steam is being given off, but no sulfurous gas was detected. Pale yellow stalactites, probably of sulfates, are forming in the hollow 1949 cone. Collapse of the walls of the crater of the 1949 lava cone has reduced the depth of the crater to about 15 feet.

R. H. FINCH

CRACK MEASUREMENTS

None of the cracks that are regularly measured showed an appreciable movement during the 3 months ended March 31.

TILTING OF THE GROUND

Strong southerly tilt set in shortly after the beginning of the year and continued until February 9. The accumulation for the period amounted to 11 seconds of arc. From February 9 to March 5 there was no accumulation of tilt in the N-S direction. Strong northerly tilt commenced on March 6, or about 1 month earlier than usual. The northerly tilt from March 6 to 31 amounted to 6 seconds of arc.

Table of Tilt at Seismograph Vault on Northeast Rim of Kilauea Caldera

Week Beginning		Amount	Direction
January	1	1.4″	S 41° E
	8	2.0″	S 10° E
	15	2.2″	S 52° W
	22	2.0″	S 10° W
	29	1.4″	S 41° W
February	5	2.2″	S 45° E
	12	0.5″	S 64° W
	19	0.3″	N 61° W
	26	1.2″	S 65° W
March	5	1.2″	N 36° W
	12	0.2″	N
	19	2.2″	N 4° E
	26	2.3″	N 3° E

SEISMOLOGY

Earthquake Data, January–March, 1950

(Based on Bosch-Omori seismograph on rim of Kilauea caldera.)

Week Beginning		Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
January	1	4	0	0	0	0	0	1.00	0
	8	4	0	0	0	0	0	1.00	1
	15	3	2	0	0	0	0	1.75	0
	22	2	0	1	0	0	0	1.50	0
	29	3	0	0	0	0	0	0.75	0
February	5	4	0	0	0	0	0	1.00	0
	12	0	1	0	2	0	0	4.50	0
	19	6	1	0	0	0	0	2.00	0
	26	3	2	1	0	0	0	2.75	1
March	5	7	2	0	0	0	0	2.75	0
	12	7	2	0	1	0	0	4.75	0
	19	7	0	0	1	0	1	8.75	0
	26	11	2	0	0	0	0	3.75	0

* For definition of local seismicity, see Volcano Letter 373.

The data for the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

1. Jan. 13, 11:54, very feeble. Inland from Kealakekua Bay.
2. Jan. 20, 19:31, very feeble. Mauna Loa.
3. Jan. 21, 04:40, very feeble. Near summit of Mauna Loa.
4. Jan. 25, 16:26, feeble. Felt at 29 Miles and Hilo.
5. Feb. 12, 06:09, slight. Felt locally and at Naalehu. Near Makaopuhi.
6. Feb. 13, 11:59, slight. Felt locally and at Hilo. Eight miles deep under east slope of Mauna Loa.
7. Feb. 15, 16:52, very feeble. Mauna Loa.
8. Feb. 19, 08:00, very feeble.
9. Feb. 26, 14:01, very feeble. Kilauea.
10. Feb. 28, 04:26, very feeble. Mauna Loa.
11. Mar. 1. 08:00, feeble. Southwest of Hilo.
12. Mar. 7, 21:47, very feeble. Mauna Loa.
13. Mar. 11, 19:59, very feeble. Kilauea.
14. Mar. 17, 02:35, slight. Shallow; under Kilauea.

15. Mar. 17, 04:05, very feeble.
16. Mar. 24, 14:14, slight. Shallow; under Kilauea.
17. Mar. 25, 05:43, strong. Widely felt on island of Hawaii. Seismographs dismantled. 15-20 miles deep under 5,000-foot contour, east slope of Mauna Loa.
18. Mar. 28, 10:57, very feeble. Mauna Loa.
19. Mar. 31, 03:43, very feeble. Kilauea.

TELESEISMS

Jan. 9, 17:30, slight. Off south coast of Mexico.
Feb. 28, 00:30. North coast of Hokkaido.

MICROSEISMS

Microseisms were moderate during the first 2 weeks of January and the last few days of March and slight on other days.

TEMPERATURE MEASUREMENTS

The temperature of the steam well at the Sulfur Bank was 206° F. in October, 1949, then dropped to 204° F. in November. The 204° F. temperature continued until the latter part of March, when a temperature of 202° F. was measured.

MAGNETIC OBSERVATIONS

H. R. Joesting and J. H. Swartz of the Geophysics Branch of the Geological Survey, and R. E. Wilcox of the Volcano Investigations Unit, spent the first 3 weeks of February at the Observatory setting up procedures to be followed in a program of magnetic observations and calibrating instruments and instructing Observatory personnel in their use. The instruments to be used are two Askania-type magnetometers built by Wolfson of Toronto. A series of permanent observation stations is being established on Kilauea and the lower slopes of Mauna Loa, and periodic readings will be taken to determine the variation in the vertical component of the earth's magnetic field, particularly the changes in differences between the various stations.

The magnetic permeability of rocks is decreased by an increase of temperature, and above a certain temperature (known as the Curie point) they become entirely non-magnetic. Thus a body of hot magma rising beneath the surface of the volcano should be non-magnetic, and the rocks around and above it should become less and less magnetic as they are heated up. It is hoped that this reduction in strength of magnetism may be detectable at the surface, and that the effect may appear long enough before the magma reaches the surface to be useful in predicting eruptions.

During February and early March, 29 stations were established around and in Kilauea caldera, along the Chain of Craters road and the upper part of the Hilina Pali road, and along the road to the Mauna Loa seismograph. At each station concrete blocks were built on which to set up the tripod of the magnetometer. It is planned to occupy each of the stations at least once a month, and oftener if possible.

On March 27 to 30 a series of dip-needle measurements was made on Mauna Loa by G. A. Macdonald of the Observatory staff and J. B. Orr of Hawaii National Park as part of the general study by the Observatory of earth magnetism in the vicinity of the volcanoes. The measurements were made along the trail from Kilauea to the summit of Mauna Loa, part way around the summit caldera, and across the floor. Preliminary analysis of the results shows that in general the strength of the magnetic attraction was less along the rift zones than elsewhere on the mountain. It is to be expected that these zones would be hotter than the rest of the mountain and have a smaller magnetic attraction.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
In cooperation with the UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for the recording and study of volcanoes in the Hawaiian Islands and around the Pacific Ocean. Its equipment at Kilauea Volcano, Hawaii Island, has been transferred to the United States Geological Survey.

The **University of Hawaii** cooperates in maintaining a research laboratory at Kilauea. The Association and the University supplement the work of the government with research associates, instrumental equipment, and special investigations. Dr. T. A. Jaggar is their geophysicist resident at Kilauea.

The **Volcano Letter**, a quarterly record of Hawaiian volcano observations, is published by the University of Hawaii and supplied to members of the Research Association and to exchange lists of the above establishments.

THE VOLCANO LETTER

No. 508 **U. S. Geological Survey** **April–June, 1950**

PUBLISHED BY THE UNIVERSITY OF HAWAII

THE JUNE 1950 ERUPTION OF MAUNA LOA

By R. H. FINCH and GORDON A. MACDONALD*

Part I

NARRATIVE OF THE ERUPTION

INTRODUCTION

Following the end of the 1949 summit eruption of Mauna Loa, magma pressure remained high, and the molten lava continued to stand high in the conduit. A moderate release of fume continued in the summit caldera throughout the rest of 1949 and the spring of 1950. A normal accumulation of eastward ground tilting was recorded at the Volcano Observatory during the fall of 1949, but during the spring of 1950 westward tilting was markedly less than usual, apparently indicating a tumescence of the mountain. On the basis of past history, it was expected that the summit eruption would be followed by a flank eruption, probably within 2 years; the apparent high position of the magma column suggested that the interval might well be shorter. During May many earthquakes originated at Mauna Loa and pointed to a distinct uneasiness of the volcano. These culminated on May 29 with a strong earthquake originating on the southwest rift near the summit. In a bulletin released by the Observatory, published in newspapers on May 30, Finch called attention to the unrest of the southwest rift of Mauna Loa and stated that if the eruption came soon it would take place there. The expected eruption came on the evening of June 1, 1950.

ACKNOWLEDGMENTS

Many people gave valuable aid during the eruption by contributing information on the activity. It is impossible to list all by name, but to all of them we extend our sincere thanks. Some persons should receive special mention. Colonel L. W. Bryan, island commander of the Hawaii National Guard and island forester of the Territorial Board of Agriculture and Forestry, was exceedingly active in making observations from the air and deserves much credit for his work in keeping track of the flows and warning of danger from them during the first days of the eruption. His unsurpassed knowledge of the terrain was of very great aid. William Stearns and Donald Campbell of Murray Aircraft Agricultural Service contributed many excellent observations from the air. Sergeant Wilmot Vredenburg of the Hawaii Police Department passed on much information on the activity of the Ohia Lodge flow near the highway. Ernest Martin, manager of Kahuku Ranch, contributed information on the lava flows in the Kau District from personal observations and from those of his cowboys. Mrs. Myrtle Hansen of Naalehu was exceedingly helpful in relaying information from various sources in the Naalehu and Waiohinu area as well as in contributing her own observations on the lava flows and earthquakes.

Harry Blickhahn, editor of the *Hilo Tribune-Herald,* and Vern Hinkley, managing editor of the *Honolulu Star-Bulletin,* also were very helpful in passing on information and photographs as they received them.

Pilots of Army and Navy planes made observations from the air, and several of these, as well as observations by commercial pilots, were relayed by the staff of the Civil Aeronautics Authority at Hilo.

Members of the staff of Hawaii National Park contributed many valuable observations on the flows and vent activity. F. A. Hjort, chief ranger, and V. R. Bender, ranger, made aerial observations on the morning of June 2 and observations on the ground at the lower line of vents on June 3 and 4. F. R. Oberhansley, superintendent, I. J. Castro, assistant superintendent, and Herbert Quick, superintendent of construction and maintenance, observed the vent activity from the air on June 3.

* Director and Geologist, respectively, Hawaiian Volcano Observatory, U. S. Geological Survey, Hawaii National Park.

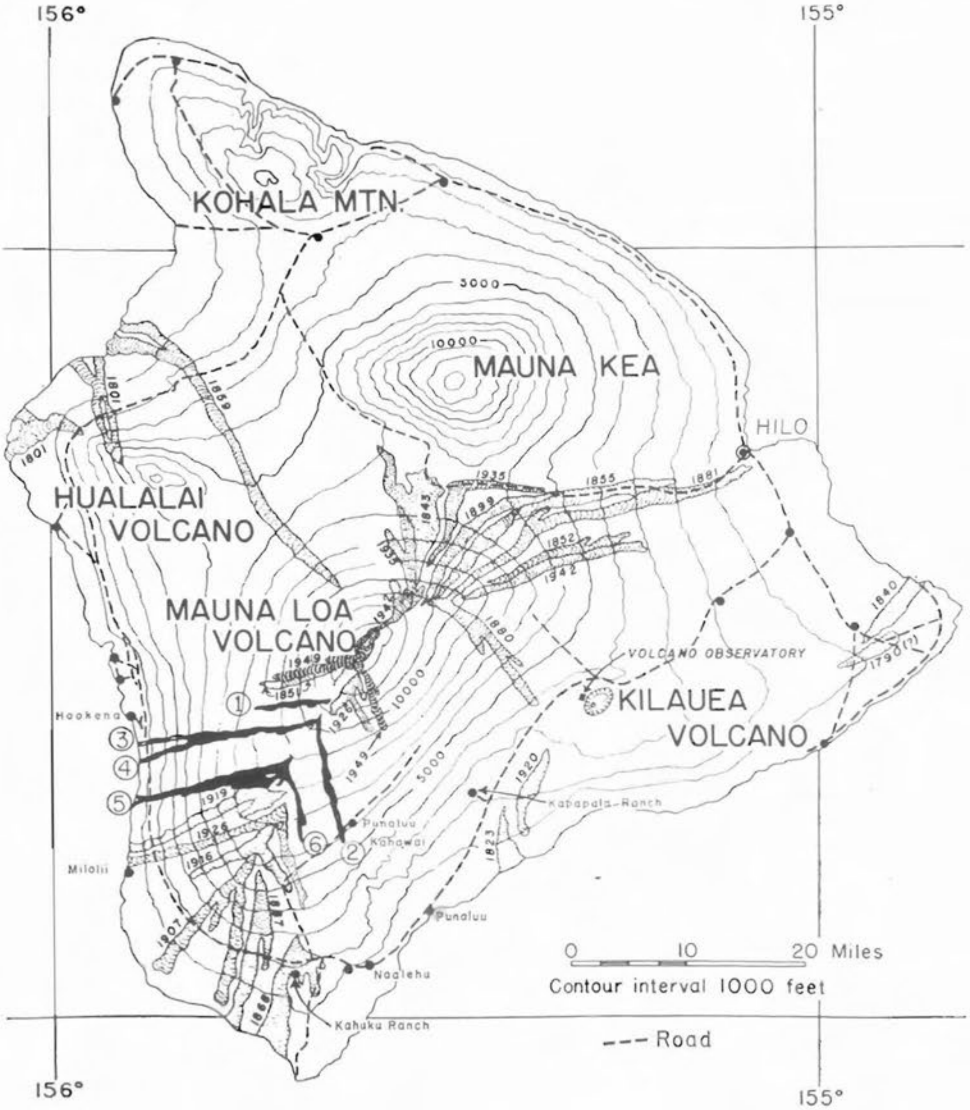

FIGURE 1. Map of the island of Hawaii, showing the approximate positions of the lava flows of June, 1950 (solid black). Numbers in circles indicate the flows referred to in the text: 1. Flow from the initial outbreak above 11,000 feet altitude; 2. Punaluu flow; 3. Hookena flow; 4. Magoon Ranch flow; 5. Ohia Lodge flow; 6. Kahuku flow. Older historic flows are stippled. Most of the flows originate along the two major rift zones.

D. H. Hubbard, naturalist, made observations from the sea and from the ground at the northern side of the Hookena flow on June 2 and 3.

D. C. Cox, geologist for the Hawaiian Sugar Planters' Association, cooperated with the Volcano Observatory staff in making observations on the lava flows and the vent activity and furnished the Observatory with a complete set of his field notes.

Several members of the U. S. Geological Survey not attached to the Observatory staff also cooperated in the investigation and were of great aid in the collection of data in the field. They include C. K. Wentworth, geologist for the Honolulu Board of Water Supply and part-time geologist for the Observatory; D. A. Davis, district geologist; M. H. Carson, district engineer; G. D. Robinson, assistant chief of the General Geology Branch; and Arnold Mason, geologist with the Pacific Geological Surveys Section. H. R. Joesting and J. R. Swartz of the Geophysics Branch carried on magnetometer observations during the eruption.

NARRATIVE

On the evening of June 1, 1950, Mauna Loa volcano erupted from its southwest rift. Glow was first seen from the Volcano House at Kilauea at about 9:25 P.M., but harmonic tremor started registering on the seismograph at 9:04 and it is probable that the eruption actually started then or very shortly afterward. About 9:10 Mr. and Mrs. Alfred Hansen, in Naalehu, heard a deep rumbling from the direction of the top of the mountain.

The first outbreak was high on the rift. At first two narrow illuminated columns of fume were visible, but these rapidly expanded down the mountain slope. A fissure 2.5 miles long opened from about 12,600 to 11,250 feet altitude, the upper end being close to the small pit crater Lua Hou and the lower end near Sulphur Cone. From this fissure poured great volumes of fume rising in a relatively narrow column about 2 miles into the air then spreading laterally to form a mushroom-shaped cloud brightly illuminated by the glare of the incandescent lava beneath. A flood of fluid gas-rich lava poured from the fissure and down the mountainside, most of it going westward toward the Kona District. Many short flows were formed, and one long flow (flow 1, Fig. 1) extended downslope about 5 miles to an altitude of about 9,000 feet. Robert Duncan of Pahala reported hearing the roar of the lava fountains about 15.5 miles away, at the junction of the Kapapala Ranch road with the highway.

The outbreak at the upper source lasted only a few hours. By 12:30 A.M. on June 2, the glow at the upper source was distinctly less, and by 1:30 A.M. it was feeble. At that time the activity at the upper source had diminished greatly and may already have been finished.

At 10:15 P.M. on June 1, observers at the Volcano Observatory and along the Kau-Volcano highway noticed a small puff of fume rising from a point on the rift at about 8,250 feet altitude approximately 8 miles southwest of the lower end of the glowing fume column at the upper source. At 10:23 bright glow appeared on the fume cloud, indicating that fluid lava had reached the surface. The illuminated fume column rapidly spread as the length of the erupting fissure increased. Margaret Finch, watching from the Volcano Observatory, observed the glow expanding up the mountain, indicating that the fissure opened upslope. The glow from this lower source continued to increase rapidly until 10:45, when it was obscured by clouds. Lava fountain activity was very strong. At 11:40 Finch and Macdonald could hear the roar of the lower fountains distinctly at the point where the highway crosses the western branch of the 1907 lava flow, nearly 15 miles from the site of the eruption.

Early on the morning of June 2 the activity was observed from the air by Frank Hjort. He reported lava fountaining from a line of fissures about 7 miles long extending from about 10,500 down to 8,000 feet altitude. Between the main line of fissuring and the shorter westerly line a broad pond of molten lava had accumulated. Floods of very fluid lava were pouring westward toward Kona, in a series of anastomosing streams. Lava from the principal fissure was pouring over the shorter westerly fissure, partly drowning it. Sulfur dioxide fumes were very strong. About noon Ross Bender flew over the source area. He reported two principal lines of lava fountains playing along fissures at approximately 10,000 and 8,500 feet altitude. The source at 10,000 feet was largely obscured by fume, but no lava movement was observed there or in the flows originating there. From the source at 8,500 feet great floods of lava were pouring westward. At the time of his first observations lava fountains were playing from several isolated stretches of the fissure below 9,000 feet, but while he watched the activity increased and fountains developed along the intervening portions of the fissure, making the curtain of fountains essentially continuous. Some of the fountains he estimated to be about 300 feet high.

A similar condition was reported on the afternoon of June 3, when Frank Oberhansley, I. J. Castro, and Herbert Quick flew over the scene of activity. The lava fountains formed an almost continuous "curtain of fire," averaging 150 to 200 feet high, with some of the bursts reaching 300 feet or even more.

The line of fissures forming the lower source was not continuous. Over a stretch of about 2.5 miles, between 8,950 feet and 9,750 feet altitude, there appears to have been no lava liberation. Between 9,750 and 10,500 feet altitude there was a line of active fountains 1.6 miles long. Below 8,950 feet altitude there was a series of nearly aligned fissures, en echelon and commonly slightly overlapping.

During the first few hours of the eruption two very rapid flows were poured out from the vent area centering at 10,000 feet altitude. One of these (flow 2, Fig. 1) advanced south-southeastward in the general direction of Punaluu. By daybreak on June 2 it had passed the ranch road a short distance west of Punaluu Kahawai. On the morning of June 2 it was examined from the air by L. W. Bryan. At that time it had reached an altitude of about 5,500 feet, approximately 10 miles from its source, but its advance appeared to be essentially over.

The other flow (flow 3, Fig. 1) from the 10,000-foot source moved rapidly westward into the Kona District. At 12:20 it was less than a mile above the highway, and Ruth Macdonald reported that the roar and explosions caused by the lava advancing through the forest were clearly audible and the glare from hot lava and burning vegetation was strong. The flow crossed the highway at about 12:30, destroying Hookena Post Office, several houses, and a filling station. There was a light but steady fall of fine black ash and some Pele's hair mixed with rain. The flow reached the sea, 0.8 mile below the highway, at about 1:05 A.M. on June 2, having covered its 15-mile course down the mountainside at an average rate of 5.8 miles an hour. Where the hot lava entered the sea, a great billowing column of steam arose. However, observers reported no apparent increase in the amount of ash in the air. This first flow to reach the ocean is termed hereafter the Hookena flow.

By daylight lava movement in the Hookena flow had greatly diminished. By 11:00 A.M. it had practically ceased, and very little steam was rising where the flow entered the ocean.

Early on the morning of June 2 another flow branched off from the Hookena flow. The new flow (flow 4, Fig. 1) diverged southward from the older one, and at about 5:00 A.M. it crossed the highway at the Magoon Ranch house, 1.2 miles south of the earlier flow. The ranch house was destroyed, as also were two or three other

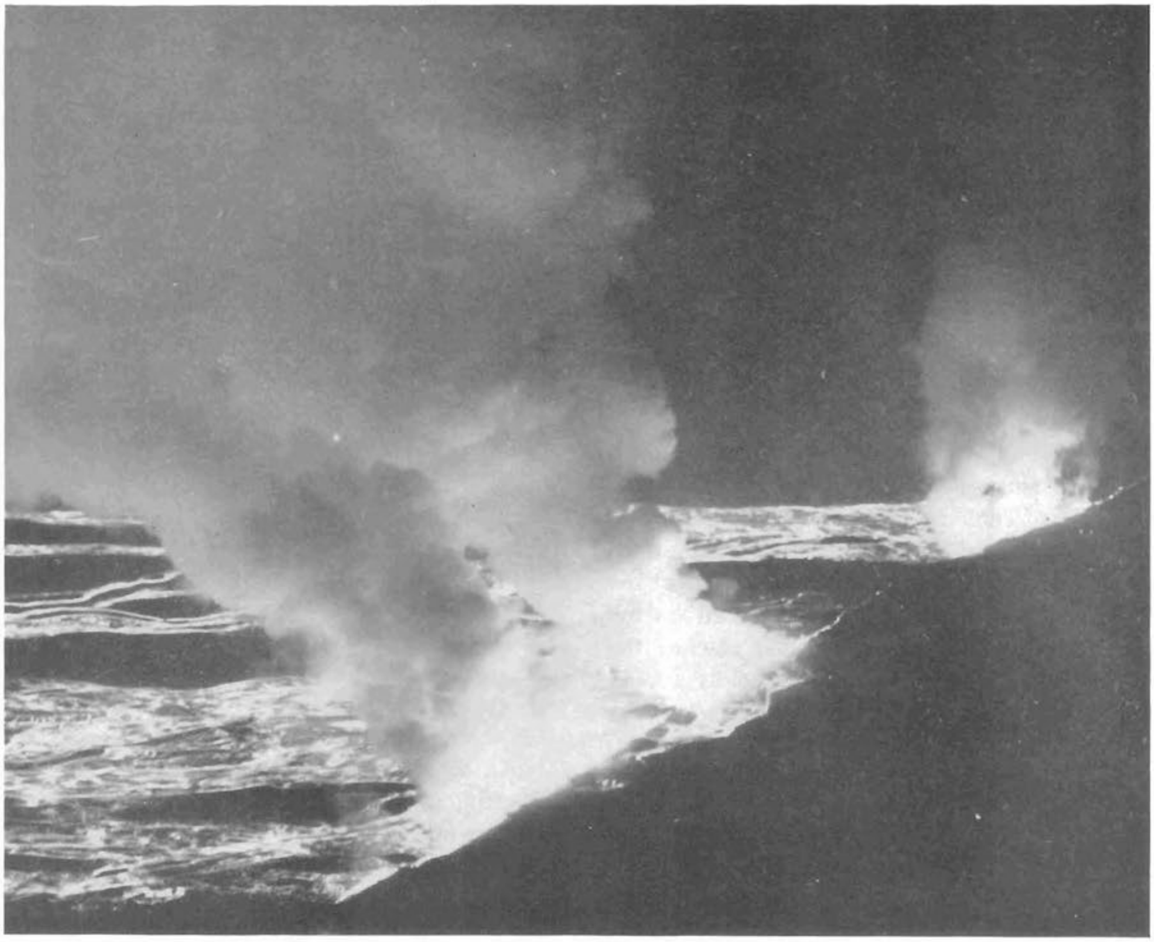

PLATE 1. Floods of lava and clouds of fume issuing from the eruptive fissure at 3:00 A.M. on June 2, 1950. The lava is flowing westward toward Kona. PHOTO BY HONOLULU STAR-BULLETIN.

houses. The flow was aa in character. Along the highway just south of the main ranch house, the advance of the lava was checked by a loose stone wall, about 3 feet high. The lava eventually piled up enough to spill over the wall, but it does not appear to have seriously damaged the wall, and for a distance of about 250 feet it spread only 15 to 20 feet beyond the wall. Farther north the flow continued unchecked on down the mountainside. It entered the sea at 12:04 P.M., destroying another house and part of a coconut grove.

For about an hour and a half before it reached the ocean, the advance of the flow was observed by Macdonald and B. J. Loucks. By that time the lava had lost its initial great fluidity and was creeping ahead at a rate of only about 750 feet an hour. The flow was descending a steep slope half a mile inland and spreading out as a broad fan over the flat sparsely vegetated terrane near the coast. As the edge of the flow engulfed the few large trees there were minor explosions, with flashes of flame. Occasionally similar roars and flashes came from the central part of the flow, probably from tree trunks buried in the flow. Many tree trunks were carried down with the flow from farther upslope. Some of these rode along on the flow surface or projected upward from it, flaming like torches.

At 11:30 A.M. the volume of lava in the flow suddenly increased, and a new flood of lava moved out over the older still-moving flow on the steep slope below the highway. At the base of the slope the new aa front spread out fanwise over the older lava, flowing at about twice the speed of the earlier front, which itself was still advancing. At 12:04 the first front entered the ocean, and a huge column of steam arose in great billows with a cork-screw motion rotating counterclockwise. No sign of ash being thrown up where the flow entered the sea could be seen. At 12:10 the second gush of lava reached the sea. The steam column increased, but there was no evidence of any strong explosive action or any appreciable amount of ash being thrown up. In the meantime the constant light fall of fine black ash, with some Pele's hair, continued as it had all morning.

By the afternoon of June 3 movement in the Magoon Ranch flow appeared to have largely or wholly ceased although the column of steam rising where the flow entered the ocean appeared strong.

Another flow appears to have started late on the night

PLATE 2. Lava fountains as much as 250 feet high playing along part of the fissure on the morning of June 2, 1950. OFFICIAL PHOTOGRAPH, FLEET AIR PHOTOGRAPHIC LABORATORY UTILITY SQUADRON 7, U. S. NAVY.

PLATE 3. Braided lava streams flowing westward near the active rift on the morning of June 2, 1950. OFFICIAL PHOTOGRAPH, FLEET AIR PHOTOGRAPHIC LABORATORY UTILITY SQUADRON 7, U. S. NAVY.

of June 1, advancing westward south of the Magoon Ranch flow. Because it later destroyed the Ohia Lodge, this flow (flow 5, Fig. 1) may be called the Ohia Lodge flow. The earlier flows started at the erupting fissure at about 10,000 feet altitude, but the Ohia Lodge flow originated at the lower line of fissures between 8,000 and 9,000 feet altitude. At 12:20 P.M. on June 2, Macdonald and Loucks were with a police detail and a small group of refugees at Ohia Lodge waiting developments from this new flow which was known to be advancing through the forest a short distance above the road. Because of the large amount of smoke and fume, combined with a low cloud cover, visibility was very poor and the exact location of the flow front was unknown. About 12:30 a patroling National Guard plane flew over at very low altitude and dropped two Mae West life jackets to which were attached warnings to leave immediately for the southward. These instructions were carried out.

At approximately 2:00 P.M. the Ohia Lodge flow reached the highway about a quarter of a mile south of Ohia Lodge and 4 miles south of the Magoon Ranch flow. At about 3:30 P.M. it entered the ocean just north of Heku Point, having taken an hour and a half to cover the 1.3 miles from the road to the sea. Again a great billowing cloud of steam arose with a counterclockwise rotational movement, but again there was no sign of violent explosion or of the formation of any appreciable amount of ash where the lava entered the sea.

By 5:00 P.M. a line of steaming water, marking the sub-sea course of the flow, extended out to sea for about half a mile from the point where the Ohia Lodge flow entered the ocean. Close to the shore and directly over the submerged flow, the water was boiling, and a semicircular area of hot turbulent water extended for a mile offshore. Many fish were killed and were seen drifting or were washed up on the shore during succeeding days. The prevailing currents drifted the area of hot water southward. Off Milolii, 5 miles south of the flow, many charred logs were seen floating in the water. These were the remains of tree trunks carried down on the top of the flows and dumped into the sea.

At 4:00 P.M. the Ohia Lodge flow was about 750 feet wide and 10 feet thick at the highway. Its outer edges were slowly moving fields of aa, creeping along at a rate of only a few feet an hour. Near its center there appeared to be a narrow, more rapidly moving, lava river, but visibility was very poor and the edge of the flow was still too hot to climb. The flow was still spreading a little laterally. Occasionally trees were pushed over at the edge of the flow. Others burst into flame while they were still standing as the heat from the lava dried out the foliage and raised it to kindling point. Minor explosions were heard from time to time as trees were engulfed in hot lava and the water in their tissues suddenly transformed into steam.

The odor of hydrocarbon gas, probably largely methane, was strong, and the flow smelled much like a leaking gas stove. Yellow flames were common along the edges and top of the flow, issuing from the lava, and there were also many blue flames resembling the flame of a well-adjusted gas burner. These gases undoubtedly were derived from the destructive distillation of the vegetation buried and engulfed by the lava. Many flames burned at cracks in the old lava—commonly 10 to 15 feet and rarely as much as 50 feet or even more from the edge of the new flow. Some of these flames were quite steady, but many went out periodically at the surface only to re-ignite within the crack and burst out again at the surface with a loud "whoomp"! Some of these gas ignitions were explosively violent, throwing rock fragments several feet.

Along the edge of the flow the vegetation was partly broken, leaves were partly blown off trees, and leaves of ti plants were shredded and broken off. Most of the breaking appeared to have been by blasts from the direction of the flow. These were probably in part marginal explosions caused by ignition of hydrocarbon gases, but some of the damage was observed to be caused by the small but strong whirlwinds which formed over the flow and moved across it.

At 6:00 P.M. it was possible to climb the edge of the flow and go out onto it about 150 feet. Beyond that point the gas and heat were unbearable. From the vantage point on the top of the flow, the central lava river could be seen clearly. It was about 25 feet wide. At highway level it was flowing at an estimated rate of 15 miles per hour, but about half a mile upslope from the highway there was a broad double lava cascade on a steeper slope where the speed was estimated to be 25 miles an hour. Temperature measurements on the river ranged from 880° to 900° C. A spectacular feature of the lava river was the many large blocks which it carried along. The blocks were as much as 20 feet high and 30 feet long, although most of them were much smaller. Most were largely incandescent, though a few were largely dark. Occasionally large blocks became wedged sideways in the channel, causing local overflows. The blocks appeared to have been dragged along by a lower, less rapidly moving and probably more viscous stratum in the river. Some could be seen to be moving distinctly less rapidly than the surficial part of the river around them.

Condensation of water in the steam cloud which rose where the lava entered the sea caused a continuous rain beneath the cloud. That the rain was caused largely by the cloud is shown by the fact that just south of the edge of the cloud there was no rain and the night was

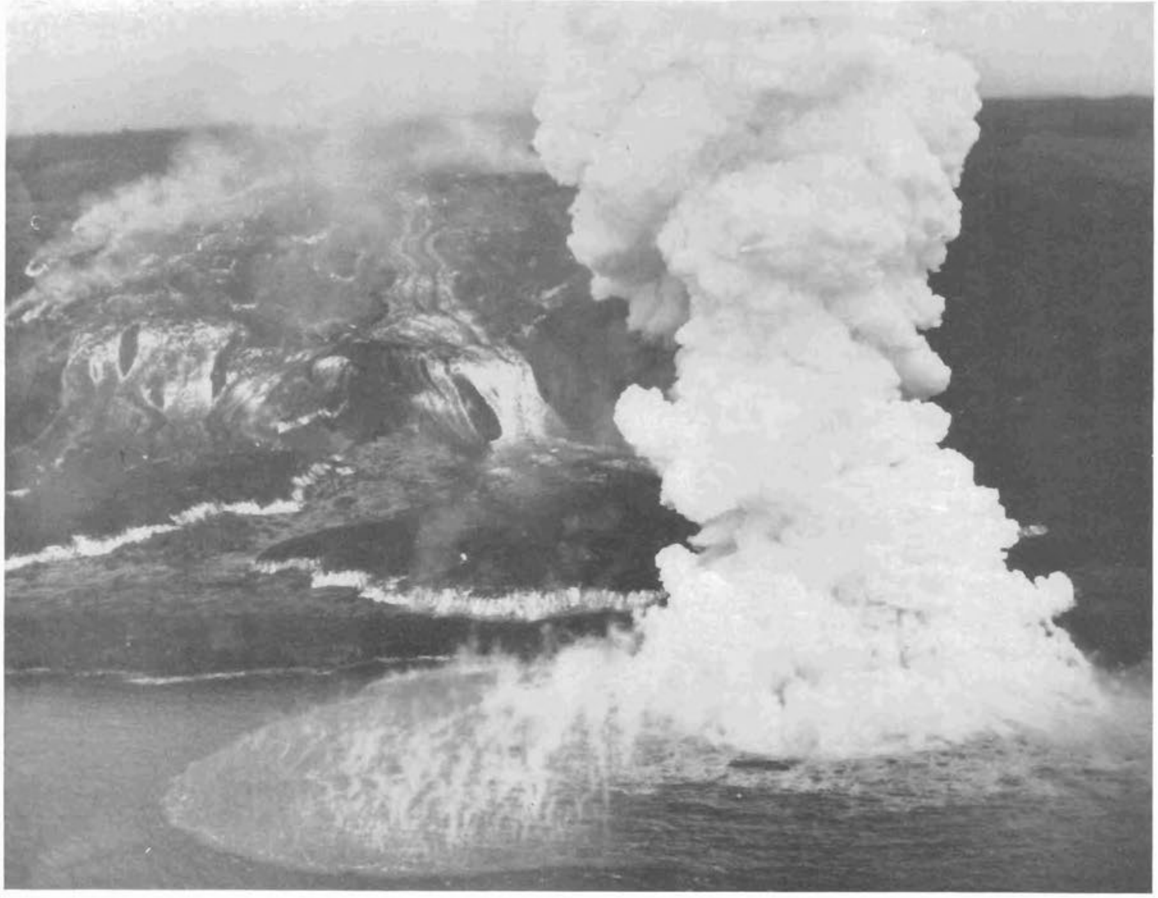

PLATE 4. Ohia Lodge flow pouring into the ocean at about 4:00 P.M., June 2, 1950. In the foreground a high column of steam is rising where the southernmost tongue reaches the ocean. Boiling and steaming water is visible off shore. In the background the flow is descending the mountainside, with smoke rising from the burning forest. Two large, brightly glowing fronts of aa are visible near the left side of the picture. OFFICIAL PHOTOGRAPH, AIR NATIONAL GUARD, 199 FIGHTER SQUADRON.

fairly clear. There was enough salt in the rain beneath the steam cloud to cause the drops to sting the face and eyes and to form a peculiar thin glaze on cars. This glaze was very difficult to remove, even by washing.

At 12:20 A.M. on June 3, Macdonald and Loucks started down the southern side of the flow from the highway. About half a mile from the ocean the flow reached the top of a steep slope formed by a buried fault scarp. There it divided into three branches. At a point just above the steepening of slope the speed of the lava in the river was estimated to be about 15 miles an hour, but as it cascaded down the buried scarp the lava reached a speed estimated at 25 to 30 miles an hour. Temperatures on the cascade were as high as 930° C. On the flatter ground below the scarp the flow slowed and spread out to form a broad fan about three quarters of a mile wide. The central lava river was the most active, and the steam column caused by it was the largest. The river appeared as a bright orange-red streak with long dark streaks paralleling the edge of the river. The southern river was moving less rapidly, and its surface was largely covered with dark blocks between which could be seen red glow.

There was a light but continuous fall of black ash of sand and silt sizes. Some of this ash may have been formed by steam explosions where the lava entered the sea, but much of it appeared to be fine debris picked up from the flow by the numerous small whirlwinds which swept over its surface.

Just above the big cascade blue or greenish-blue flames were common in the slow-moving margin of the flow, and yellow flames even more common. Dancing pale blue flames, resembling will-o-the-wisps, occasionally were seen for a few moments over the main lava river, as much as 35 to 50 feet above the river, and isolated from it by clear air. Some of these appeared to be nearly formless, but others looked like fire-balls.

The Ohia Lodge flow below the highway was examined on the morning of June 3 by D. C. Cox, D. A. Davis, and C. K. Wentworth. At 10:30 A.M. the condition was much like that of the previous night. At 10:35 a sudden increase in the volume of lava in the flow was observed. The speed of the lava in the big cascade between the highway and the shore increased notably, and a sheet of more rapidly moving lava appeared to override the older, less-rapidly flowing sheet.

By 11:15 the surge had decreased and the speed of flow lessened again. Davis estimated the speed in the cascade to be about 20 miles an hour during the peak of the surge and 5 to 6 miles an hour as the surge abated. During the surge the lava fan at the foot of the cascade had built up appreciably. At 11:30, after the surge had ceased, the surface of the central part of the fan was seen to be subsiding as the fluid lava underneath drained away, leaving higher ridges around its edges. The observers on the landward side of the fan could see no lava spilling from the outer edge of the fan into the sea, hence the drainage must have been through hidden subterranean passages. The drainage into the sea was accompanied by an increase in the size of the steam column, some minor explosions along the shore, and pushing up of small lava ridges from the water just offshore.

From 1:00 P.M. June 3 until 7:00 A.M. June 4, the Ohia Lodge flow about 2,000 feet inland from the road was observed by Wentworth, Davis, and Cox. Two streams of lava descended a steep slope in a cascade about half a mile long and reunited to form a single stream before reaching the road. At the foot of the cascade the flow was about 1,000 feet wide. Just north of this main flow another tongue of lava was advancing slowly seaward, burning trees and knocking them over. Optical pyrometer measurements made by Davis and Cox on the surface of the lava river indicated temperatures ranging from 850° to 980° C. About 2:00 P.M. the volume and velocity of the main flow commenced to increase. This surge reached its maximum about 2:30, after which the volume again decreased. Wentworth estimated the volume of actively moving lava in the flow during the surge to be five to ten times as great as that before and after the surge. Similar surges were observed in both channels of the flow at intervals of 65 to 85 minutes during the rest of the afternoon and night. Davis estimated the speed of flow in the main rivers to range from 5 to 20 miles an hour, and angular measurements by Wentworth and Cox during a surge at 11:25 P.M. demonstrated speeds of 7.8 to 8 miles an hour. The front of each surge advanced down the lava river channel, as an aa front 10 to 25 feet high, with loud clinking and crunching sounds. During the larger surges new lava spread from the river over much of the surface of the flow and, directly preceding and during some of the surges, there appeared to be a definite, though small, heating up and inflation of the stationary aa fields at the edge of the flow.

During the afternoon of June 4 the Ohia Lodge flow was watched by Arnold Mason of the U. S. Geological Survey. Conditions remained much as on the preceding day. Several surges of lava were observed, the last three at approximately 5:30, 6:00, and 6:30 P.M. When Finch and Cox arrived at 6:30 P.M. they found that at the road level the flow had been considerably widened by a new tongue which had come down parallel to the older one on its northern side, destroying Ohia Lodge. A sluggish lava river in the new tongue was feeding a slow-moving aa front just below the road. The entire flow at road level was about a quarter of a mile wide. Another tongue still farther north was advancing slowly through the forest about half a mile above the road. Its presence was revealed by occasional glimpses of glowing lava and by a bright glow from burning vegetation.

Davis returned to the Ohia Lodge flow above the road about noon on June 5. The width of the flow had increased to approximately 1,500 feet, and the active channels were entirely in the northern part of the flow. The lava was moving much more slowly than on the two preceding days, and the surges were smaller and of shorter duration. The maximum speeds in the lava rivers were estimated at 4 to 5 miles an hour. The new tongue north of the main flow was still advancing. Cox and Macdonald returned to the flow at 2:00 P.M. and went out onto the flow about 250 feet. The southern edge of the flow was still hot, but essentially motionless. The northern edge, beyond the river, was moving slowly. The flow as a whole had increased in thickness to an average of 20 to 25 feet. On the flat near the coast the flow had spread about 750 feet farther south than on June 3. The coastline had been transformed from a shallow embayment to a slight promontory.

Late in the evening of June 2, or early on June 3, another flow (flow 6, Fig. 1) started from the vent area at 8,300 feet altitude and moved southward down the mountain slope toward the main buildings of the Kahuku Ranch. This has been named the Kahuku flow. The upper portion of the flow was narrow, from 0.1 to 0.15 mile wide. On June 3 the flow was very active, with a narrow bright red lava river in the middle of a dark streak of aa. On June 4 the flow was still very active but was spreading out to form a front nearly half a mile broad at about 7,200 feet altitude, 3½ miles from its source. The lava river was reported to be on the order of 100 feet wide. On June 5 Don Campbell, from aerial observations, reported that the Kahuku flow was still advancing but appeared to have slowed. On the morning of June 6, James Beatty reported that the front had reached an altitude of about 6,500 feet. Movement continued through June 6 and the early hours of June 7, bringing the lower end of the flow to approximately 6,300 feet altitude, 5.8 miles from its source. On the afternoon of June 7 the lower portion of the flow appeared dead, but there was still some movement in the flow near the vents. By the morning of June 8 the flow was completely dead.

Frank Hjort and Ross Bender reached the vent area

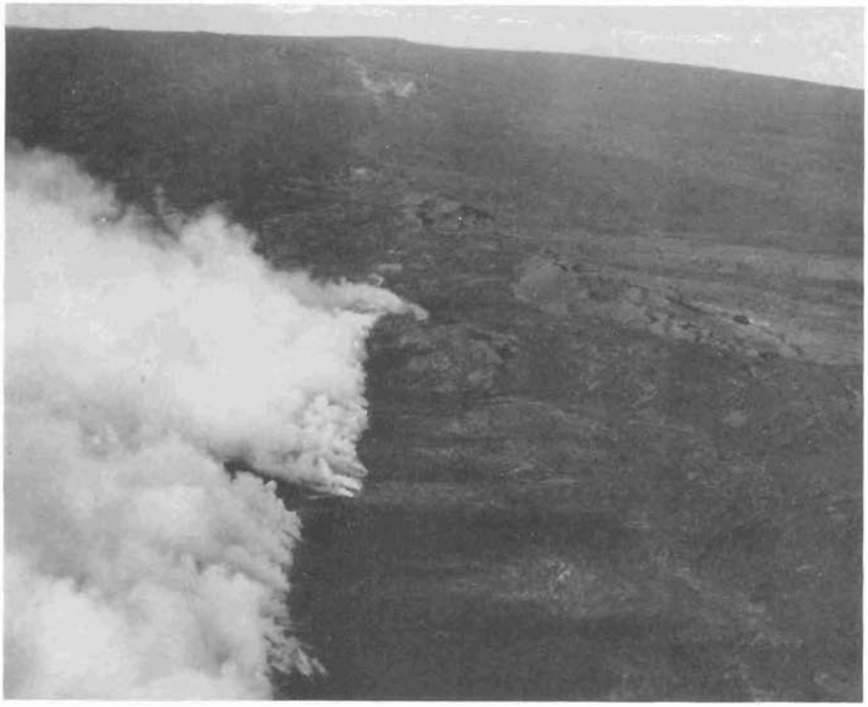

PLATE 5. Heavy fume clouds rising from the rift between 9,000 and 10,000 feet altitude, June 9, 1950. The heads of the Punaluu and Hookena flows are visible in the middle distance, and behind them fainter fume rises in the vicinity of Sulphur Cone. PHOTO BY WERNER STOY, CAMERA HAWAII.

on the afternoon of June 3 and camped at 8,700 feet altitude near the upper end of the lower line of vents. The fissure near 10,000 feet altitude was fountaining sporadically, but most of the activity was concentrated along the lower fissures below 8,900 feet altitude. From 4:30 to 8:00 P.M. activity on the lower fissures was continuous but varied rhythmically in intensity and character. Approximately once an hour an upsurge of activity commenced near the upper end of the fissure and migrated down along the fissure. Each revival of activity commenced at a large spatter cone at about 8,800 feet altitude with a loud roaring noise much like the exhaust from a steam boiler. This rush of gas was followed by a spray of lava droplets and red-hot cinder. The roaring release of gas migrated downhill along the rift, at some places giving rise to noises like thunder or heavy artillery. As the gas release ceased, the fountain activity and amount of lava liberation increased progressively along the rift until it was essentially continuous along the 2 miles of fissure which was in view. The fountains were lower than earlier in the eruption, playing to heights of about 50 feet. This activity gradually abated, and there was a lull of 20 minutes to a half-hour duration before the violent gas release started again at the upper end of the fissure and the cycle was repeated.

Most of the liberated lava was pouring westward toward Kona and feeding the Ohia Lodge flow. A front of hot lava 0.7 mile long had accumulated on the east side of the rift and was spilling southeastward to feed the Kahuku flow. At the head of the Kahuku flow the lava plunged over the steep slope of a buried cinder cone making a spectacular double cascade some 500 feet long and 200 feet wide. The rate of flow in the cascade was probably of the order of 35 miles an hour. Near the base of the cascade the highly fluid lava struck a bump on the channel floor, and the liquid was directed upward and outward into the air. At first view, from a distance, it appeared to Bender to be a fountain in the river, but on closer inspection its true nature was obvious.

A party composed of Geological Survey and National Park personnel reached the vent area on the afternoon of June 6. The cascade at the head of the Kahuku flow was still active, but the speed of flow had greatly decreased, not exceeding 10 miles an hour on the steepest slope. Fluctuations in the volume of flowing lava were obvious and occurred at approximately half-hour intervals. During the night of June 6 the lava fountains along the rift were low and sporadic. Increases in activity continued to occur about every half hour and progressed downslope along the rift. Only once was the increase in lava output preceded by a loud blowing noise and shower of incandescent cinder from the large spatter cone at 8,800 feet altitude.

On the morning of June 7 activity along the rift was still weak. Above 8,600 feet altitude the vents were fuming strongly, but no lava was being poured out. Below that altitude fountaining continued, but none of the fountains was more than 25 feet high, and most were only a few feet.

About 3:00 P.M. Davis, Cox, and Macdonald crossed the still hot pond of shelly pahoehoe which had fed the Kahuku flow and approached within 15 feet of the lava river. At 8,440 feet altitude two branches of the river plunged over a 25-foot cascade and joined at its foot.

Most of the river was moving only 3 or 4 miles an hour and was largely crusted over with a skin of wrinkled and ropy pahoehoe. In the cascade, however, the speed of flow was estimated at 30 miles an hour, and the crust was broken up to reveal the incandescent liquid beneath. Measurements with an optical pyrometer on the hot lava in the cascade yielded temperatures from 1030° to 1040° C.

Below the cascade the lava river flowed directly along the eruptive fissure, burying several lava fountains which occasionally shot through the river. Near the foot of the cascade there was a dome-shaped fountain which averaged about 10 feet across at its base and 5 feet high. This fountain resembled the dome of water which forms over the mouth of some artesian wells. Its bright orange hemisphere looked like half an orange set on the lava river. Just downstream from the dome fountain the rush of the liquid lava leaving the cascade gave rise to a hydraulic jump, with a standing wave 4 to 8 feet high.

About 500 feet down the rift from the cascade a small lava fountain was shooting 10 to 25 feet high. It was not a continuous jet, but consisted of repeated spurts of lava which separated in the air into large blobs. This fountain was typical of many which could be seen on down the rift. At the base of the fountain lava was flowing out pulsatingly, the pulses coming every 1 to 2 seconds, giving rise to a heaving motion much like that commonly observed in a pot of boiling thick porridge. A small lava shield was building up around the vent, but most of the lava was flowing down the slope of the shield to join the main river. The latter closely paralleled the erupting fissure for about a quarter of a mile then joined a large stream of lava flowing toward Kona.

Fluctuations in the amount of lava output came at roughly half-hour intervals. Following surges, the level of the lava in the river dropped, exposing along the banks rows of hot flexible lava stalactites which swayed back and forth in the blasts of gas or as their ends touched the flowing liquid much like willow roots along a creek. Many of them eventually were broken off, probably as they became more brittle with cooling, and floated away in the stream.

About 4:30 P.M. on June 7 there commenced a revival of activity along the entire rift. By 7:00 P.M. sporadic lava fountaining could be seen at a distance along the fissure near 10,000 feet altitude, and a little red lava could be seen moving in the head of the Hookena-Magoon Ranch flow. Along the fissure below 8,900 feet altitude the amount of fountaining and lava outpouring had increased. The surges in the lava river grew in size until, during peaks, the river channel was filled to the brim and locally overflowed sending tongues of pahoehoe rolling toward the observers. The height of the standing wave of the hydraulic jump below the cascade increased to about 12 feet and that of the dome fountain to about 8 feet. The temperature of the lava appeared to increase with the activity, and at 7:20 P.M. pyrometer measurements on both the cascade and the dome fountain gave temperatures of 1070° C. Some of the lava spilled eastward and formed a stream across the lower end of the former lava pond to the head of the Kahuku flow. Most of it, however, continued to westward.

As darkness came, many flames were visible over the vents along the rift. Most of them were at vents from which lava was no longer issuing, but some were at spattering vents. No flames were observed at vents from which lava was flowing in abundance. Most of the flames were greenish-yellow, but some were pale greenish-blue. The average length of the flames above the mouths of the conelets was about 5 feet, but some were as much as 20 feet long.

The revival of activity continued until about 2:00 A.M. on June 8. After that the strength of activity gradually decreased. At 6:00 A.M. the rift was still moderately active, but much less so than on the previous evening. A roaring gas vent was heard occasionally at about 8,400 feet altitude. The cascade at the head of the Kahuku flow was no longer active, and crossings of the flow itself at two places revealed it to be completely dead.

G. D. Robinson and B. J. Loucks reached the Ohia Lodge flow on the afternoon of June 6 and spent most of the night observing it in the area between the highway and the sea. About half a mile below the highway the channel divided into two branches, the southernmost of which was the more active. A short distance farther downslope the southerly channel again divided, so that there were three channels. Surges in activity were observed at approximately half-hour intervals. During lulls in the activity the lava movement was largely restricted to the central channel, but during the larger surges all three channels became very active. Will-o-the-wisps were again observed over the flow. On June 7 the Ohia Lodge flow was still very active, the principal movement at the highway being in a lava river which was flowing in a channel about 15 feet deep near the northern edge of the flow. William Stearns reported that a new spur on the southern side of the flow, about 5 or 6 miles long, was advancing slowly.

On June 8 a small overflow occurred on the southern side of the Ohia Lodge flow about a quarter of a mile above the highway. The tongue advanced only a few hundred yards before rejoining the main flow. On June 9 the flow appeared to have become distinctly more sluggish. The flow was again visited on June 10 by Robinson and Wentworth, in company with H. R. Joesting and J. H. Swartz of the Geological Survey and Juliette Wentworth. Conditions were much the same as they had been when last seen by Robinson on the morning of June 8. However, in the interim, lava had been newly added, by repeated overflows of the channel, to the surface of much of the flow in the vicinity of the road. Several surges of activity were observed during the evening, the intervals between surges ranging from 13 to 45 minutes. Pyrometer measurements by Robinson on large glowing blocks in the river and on the surface of the river itself yielded temperatures ranging from 840° to 940° C. Cherry-red lava exposed in a cave in the older stationary aa margin of the flow gave a temperature of 675° C.

On June 11 Macdonald and D. H. Hubbard examined the flow where it entered the sea. No movement could be detected in the major part of the flow on the coastal flat, and the volume of steam being formed at the ocean was small. Lava was still pouring over the escarpment a quarter of a mile inland, but it was rather dull red in color and appeared much more viscous than during earlier observations. The speed of the lava on the steep cascade was only about half a mile an hour. Two strong surges of lava at the cascade were observed, one at 2:30 and the other at 4:30 P.M. At the foot of the cascade the lava turned southward and spread out to form a big aa flow which was advancing seaward along the southern edge of the older flow at a rate of approximately 1,000 feet an hour. The front of this flow was the largest the writers have observed in Hawaii. It was about 1,000 feet wide, at least 50 feet high, and very active. One after another, blocks up to 10 feet in diameter became detached from the front of the flow and rolled to the base. The blocks were accompanied and followed by trains of finer incandescent debris, and patches of incandescent lava were revealed as the blocks broke away from the front. Clouds of pale brown dust arose from the pulverization of the fragments rolling down the flow front. A hundred yards from the active front the radiant heat was so great that the observers' faces were scorched, and cameras became so hot they were difficult to hold.

At 3:00 to 4:00 A.M. on the morning of June 12 there was widespread overflowing of the channel of the Ohia Lodge flow at the level of the highway. Later in the morning and during the afternoon the glow in the flow was dull and lava movement was small. Shortly after 9:00 P.M. a bright glow was seen inland from the road, and by 10:15 a new surge of lava was producing flooding on the northern side of the flow. This appears to have been the last big surge. Movement in the flow at the highway stopped on June 13, although on June 14 cowboys of the C. Q. Yee Hop Ranch reported lava still moving in the flow 6 miles above the highway. At about noon on June 15 the pilot of a Navy plane reported lava bubbling from the lower 200 yards of the source fissure and fume being liberated along about 3 miles of fissure. From that time on, glow at the source area was observed nearly every night until June 22. On the afternoon of June 22, John Peoples of the U. S. Coast Guard flew over the source area and reported hot bubbling lava and a large amount of fume along the rift.

The last well-authenticated observation of glow at the source was by Finch, at 1:00 A.M. on June 23, and the eruption is believed to have come to an end on that date. Aerial observations on later days revealed much fume along the fissures but no signs of moving lava. Fume liberation continued abundant through the remainder of June.

A further discussion of special features of the eruption will appear in the next VOLCANO LETTER.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR APRIL–JUNE, 1950

VOLCANOLOGY

April

The northward tilt that started early in March continued through April. The northward tilt of 3.2 seconds of arc in April, when coupled with the 6 seconds in the same direction in March, indicates a distinct pressure increase under Kilauea Volcano.

Seasonal westward tilt ceased on March 14 and an eastward tilt set in to continue until the last of April. If an eastward tilt indicates a pressure increase under Mauna Loa then there has been a simultaneous increase of pressure under Kilauea and Mauna Loa.

Of the 77 earthquakes recorded during April, 61 were recorded at Kilauea and 56 on the Mauna Loa seismograph. The Kilauea total is larger than usual and points to uneasiness at Kilauea. However, the foci of most of the shakes were shallow and many were under the northern end of the caldera. The shallowness and location of foci far from the volcanic axis at Halemaumau appear to decrease their significance as an indication of impending activity.

Some of the cracks in the vicinity of the Halemaumau rim opened slightly. A more-or-less expected accompaniment of the continued pressure build-up was the spreading of some of the cracks on the caldera floor that are connected with the rift system of Kilauea.

May

The monthly total of earthquakes for May was 102. During the first half of the month more of the earthquakes originated under Kilauea than Mauna Loa, but during the latter half Mauna Loa quakes predominated. As far as earthquakes were concerned it appeared as though uneasiness had shifted from Kilauea to Mauna Loa. Many of the shakes originated under the upper end of the southwest rift of Mauna Loa.

During the first 2 weeks of May there was a slight east-southeast tilt. Then a distinct north-northeast tilt set in to continue until May 29. Following the strong earthquakes of May 29 there was a tilt of 2.4 seconds of arc to the southwest, or opposite the usual direction for the latter part of May.

June

A total of 279 earthquakes was recorded on the Kilauea seismograph during June. Owing to the frequent dismantling of the Mauna Loa seismograph during the progress of the flank eruption the total for that instrument is unknown but probably about the same as for Kilauea. Most of the earthquakes originated along the southwest rift of Mauna Loa.

There was an accumulation of 6.4 seconds of arc tilt to the northeast during the first 14 days of June, then a slight northwest tilt for the rest of the month. It is interesting to note that a marked decrease in the rate of output of lava from the southwest rift of Mauna Loa coincided roughly with the cessation of rapid northeast tilt.

SEISMOLOGY

Earthquake Data, April–June, 1950
(Based on Bosch-Omori seismograph on rim of Kilauea caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Mod-erate	Strong	Local Seis-micity*	Tele-seisms
April 2	10	0	2	0	0	0	4.50	0
9	7	0	0	0	0	0	1.75	0
16	12	0	0	0	0	0	3.00	1
23	17	4	1	0	0	0	7.25	0
30	20	8	1	1	0	0	10.00	1
May 7	16	5	1	0	0	0	7.50	0
14	13	4	1	0	0	0	6.25	0
21	7	2	0	0	0	0	2.75	1
28	29	17	2	2	0	1	25.75	0
June 4	86	44	12	8	8	0	95.50	0
11	34	15	4	2	3	1	37.00	0
18	7	3	0	0	1	0	7.25	1
25	5	1	1	0	0	0	2.75	0

* For definition of local seismicity, see Volcano Letter 371.

The data for the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

20. April 5, 04 : 50, feeble. Felt locally. Kilauea quake.
21. April 8, 00 : 35, feeble. Mauna Loa shake.
22. April 23, 01 : 15, very feeble. Kilauea.
23. April 25, 10 : 09, very feeble. Mauna Loa.
24. April 27, 23 : 53, very feeble. Kilauea.
25. April 28, 02 : 26, feeble. Kilauea.
26. April 29, 21 : 11, very feeble. Mauna Loa.
27. May 3, 03 : 48, very feeble.
28. May 3, 12 : 08, very feeble. Mauna Loa.
29. May 3, 22 : 19, very feeble. Kilauea.
30. May 4, 01 : 01, very feeble.
31. May 4, 04 : 35, feeble.
32. May 4, 05 : 51, slight. Felt at Kapapala.
33. May 4, 05 : 54, very feeble. Felt at Kapapala.
34. May 4, 06 : 02, very feeble. Felt at Kapapala.
35. May 4, 07 : 31, very feeble.
36. May 6, 03 : 47, very feeble.
37. May 7, 03 : 10, very feeble. Mauna Loa.
38. May 8, 12 : 01, very feeble.
39. May 8, 12 : 41, very feeble. Mauna Loa.
40. May 11, 13 : 06, very feeble.
41. May 11, 19 : 38, feeble. Mauna Loa.
42. May 13, 09 : 27, very feeble. Mauna Loa.
43. May 14, 18 : 39, feeble. Mauna Loa.
44. May 18, 10 : 47, very feeble. Mauna Loa.
45. May 18, 14 : 44, very feeble. Mauna Loa.
46. May 19, 00 : 02, very feeble. Mauna Loa.
47. May 20, 01 : 57, very feeble. Mauna Loa.
48. May 26, 01 : 45, very feeble. Mauna Loa.
49. May 27, 11 : 33, very feeble. Kilauea.
50. May 28, 08 : 27, very feeble. Mauna Loa.
51. May 29, 15 : 17, strong. Upper southwest rift of Mauna Loa. Widely felt. All instruments dismantled. Damage to water tanks, stone walls, etc., in Kona.
52. May 30, 14 : 37, very feeble. Mauna Loa.
53. May 30, 17 : 28, slight. Mauna Loa.
54. June 1, 13 : 59, very feeble. Mauna Loa.

June 1, 21 : 04, harmonic tremor of Mauna Loa eruption starts. Recorded continuously through June 3, then with lesser amplitude and intermittently until afternoon June 13.

Earthquakes accompanying the first 13 days of the Mauna Loa eruption.
Most of the quakes originated on the southwest rift of Mauna Loa.

Serial Numbers	Date	Number of Shakes
55– 58, inclusive	June 2	4
59– 73, inclusive	3	39
74– 91, inclusive	4	39
92–107, inclusive	5	28
108–115, inclusive	6	23
116–126, inclusive	7	15
127–133, inclusive	8	7
134–143, inclusive	9	10
144–146, inclusive	10	3
147–158, inclusive	11	23
159	12	6
160–164, inclusive	13	7
165–168, inclusive	14	13

169. June 15, 10 : 14, slight.
170. June 16, 16 : 03, very feeble.
171. June 16, 23 : 13, very feeble.
172. June 17, 06 : 31, very feeble.
173. June 19, 09 : 22, very feeble. Felt locally. 7 miles deep, east slope of Mauna Loa near Ohaikea.
174. June 21, 07 : 06, moderate. Felt locally. Kilauea.
175. June 21, 08 : 03, very feeble.
176. June 21, 08 : 29, very feeble.
177. June 26, 19 : 56, feeble. Felt at Naalehu.

TELESEISMS

April 18, 05 : 00, slight. Southwest of Galapagos.
April 30, 01 : 00, slight. North of Easter Island.
May 25, 15 : 27, slight. New Hebrides.
June 24, 12 : 34, slight. New Hebrides.

MICROSEISMS

Microseisms were moderate on April 4–5, 29–30, and May 10–11. They were present though slight on other days throughout the quarter.

CRACK MEASUREMENTS

Accompanying the rapid northward tilt during March, April, and May there was a distinct opening of some of the cracks on the caldera floor that are roughly aligned with the southwest rift of Kilauea. At one station there was an opening of 4 millimeters and at another the opening amounted to 9 millimeters. Such an opening is an expected accompaniment of the doming indicated by tilt. A portion of the crack at the tourist station on the east rim of Halemaumau opened 8 millimeters between March 31 and June 30.

TILTING OF THE GROUND

The strong northward tilt which started in March continued until May 29 and amounted to 11.4 seconds of arc. A distinct southerly tilt followed the large earthquake of May 29. Northward tilt was resumed on June 5. Between June 5 and June 17 there was a rapid northward tilt amounting to 3.8 seconds. From June 17 to the end of the month, northward tilt was about normal for this season of the year.

The lack of normal westerly tilt that was noted in March continued until April 10 when a positive eastward tilt commenced that continued until June 14 except for some rapid fluctuations from May 29 until June 8. There was an unusually rapid eastward tilt of 5.9 seconds between June 7 and June 14. From June 14 to June 30 there was a slight westward tilt, which is opposite to the normal direction for this season of the year.

Table of Tilt at Seismograph Vault on Northeast Rim of Kilauea Caldera

Week Beginning	Amount	Direction
April 2	0.2″	N 45° E
9	0.3″	N 45° E
16	1.0″	N
23	1.4″	N 60° E
30	1.8″	N 16° E
May 7	0.5″	W
14	1.2″	N 37° E
21	1.0″	N 7° E
28	1.7″	S 40° W
June 4	3.5″	N 70° E
11	3.0″	N 51° E
18	0.3″	N 27° E
25	0.1″	E

TEMPERATURE MEASUREMENTS

The temperature of the steam well at the Sulfur Bank was constant at 204° F. in April, May, and June.

MAGNETIC OBSERVATIONS

Routine magnetometer measurements were continued at intervals of approximately 1 month. H. R. Joesting and J. H. Swartz of the Geological Survey's Geophysics Branch spent a week at the Observatory during the eruption of Mauna Loa in June, making additional measurements and calibrating instruments.

Until May 9 most of the stations on the line along the Mauna Loa truck trail showed a decrease in vertical magnetic intensity with respect to the base station near the rim of Kilauea caldera at Uwekahuna. The next measurements, on June 9 and 12, showed a marked increase in the strength of attraction at most of the stations. Several of the stations showed a very rapid rise between June 9 and 12. It is possible that the beginning of this rise may have coincided roughly with the beginning of the Mauna Loa eruption.

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NE PLUS HAUSTAE AUT OBRUTAE URBES

THE JUNE 1950 ERUPTION OF MAUNA LOA

By GORDON A. MACDONALD and R. H. FINCH

Part II

SPECIAL FEATURES

LAVA FLOWS

The lava of the 1950 eruption of Mauna Loa ranges from basalt to olivine basalt. The first lava erupted along the upper part of the rift contains very few olivine phenocrysts, and no dunite inclusions were observed. In contrast, the lavas erupted later from the portion of the rift below 11,000 feet altitude contain many phenocrysts of olivine up to about 5 millimeters long. Angular inclusions of dunite, up to about 3 centimeters across, are fairly common in the lavas from the lower vents. It appears probable that the marked difference in abundance of olivine phenocrysts in the early and late lavas is the result of sinking of olivine crystals in the magma column before the eruption. The first lavas liberated at the upper vents were derived from the upper part of the magma column, which had been impoverished in olivine. Later the lava was derived from a lower level in the magma column, in which the abundance of olivine phenocrysts had been increased by sinking of crystals from higher levels. A similar, but even more marked, difference has been found between the early and later lavas of the 1840 eruption of Kilauea (Macdonald, 1944).

Figure 1 is a map showing the distribution of the lava flows. All of the flows except the upper flow (no. 2) and the Kahuku flow (no. 7) have been plotted from vertical air photos taken at the request of the Volcano Observatory by Richard O. Mahan for the R. M. Towill engineering firm in Honolulu.

The accompanying table shows the approximate area and volume above sea level of each of the major lava flows of the 1950 eruption and the estimated average thickness of each flow. The areas were scaled from the map of the flows. The average thickness of several separate segments of each flow was estimated from ground observations at several points along the flows and from the appearance in the aerial photographs, then the average thickness of the whole flow was calculated from these values. The volumes were calculated by using the scaled areas and the estimates for average thickness of successive portions of the flows. It is believed that any error in thickness and volume is on the conservative side. The total area of the flows above sea level is 35.6 square miles, and the volume is on the order of 514 million cubic yards. It is estimated that more than 100 million cubic yards of lava flowed out under the ocean and is now lost to view. The total volume of lava erupted, therefore, was very probably more than 600 million cubic yards, or somewhat more than the estimated volume (600 million cubic yards) of the largest previous historic eruption, the 1859 lava flow of Mauna Loa (Stearns and Macdonald, 1946, p. 79). It is estimated that between one-half and two-thirds of the total volume of lava was poured out during the first 36 hours of the 1950 eruption.

AREA, THICKNESS, AND VOLUME OF 1950 LAVA FLOWS ABOVE SEA LEVEL

NAME OF FLOW	NUMBER ON MAP (FIG. 1)	AREA	AVERAGE THICKNESS	VOLUME
		Sq. miles	*Feet*	*Cu. yds.*
Upper rift . . .	1	3.74	4.5	17,000,000
Upper west flank	2	1.25	7.6	11,000,000
Hookena	3	6.73	8.3	59,000,000
Magoon Ranch	4	5.74	9.3	55,000,000
Punaluu	5	7.25	13.5	101,000,000
Ohia Lodge . .	6	8.47	27.6	241,000,000
Kahuku	7	1.44	12.0	18,000,000
Keokeo	8	1.00	12.0	12,000,000

TEMPERATURE MEASUREMENTS

Approximately 75 readings were made with an optical pyrometer during the eruption. Of these, about one-third were made during daylight hours and are of little value. Comparison of readings made during daylight with those made at night indicates that the extraneous illumination during daytime results in readings which are consistently too high. Most daylight readings appear to be between 50° and 100° C. higher than read-

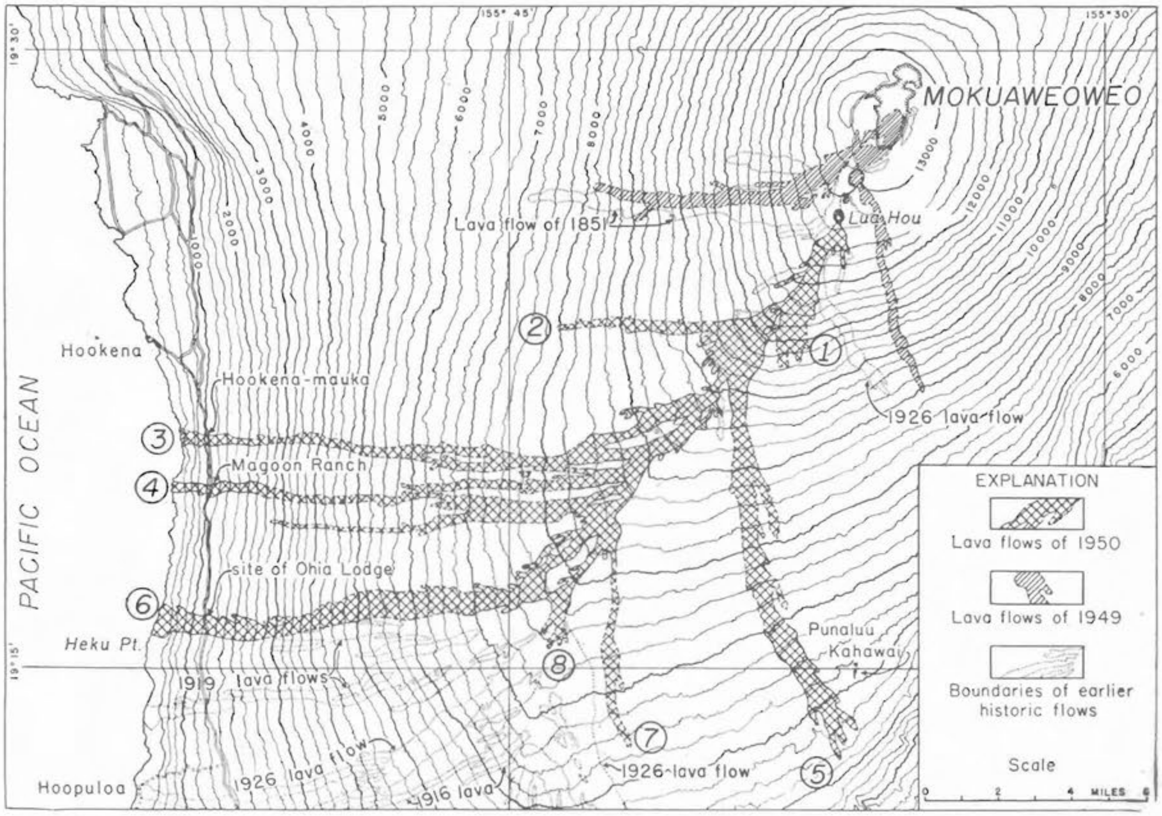

FIGURE 1. Map of a portion of the southwest rift of Mauna Loa showing the 1950 and some earlier historic lava flows.

ings on the same object at night. The values cannot, however, be successfully corrected, because the amount of extraneous light was variable and undetermined. Only the night readings have been used. The values obtained at night were quite consistent. Repeated readings on the same near-by object at intervals of a few seconds showed variations of only a few degrees. On the other hand, readings on the surface of the lava river showed a range of approximately 100°, owing at least in part to variations in the amount and thickness of crust on it.

Only a few of the pyrometer readings were made under close approximations to "black body" conditions. Therefore a small correction for the coefficient of light absorption of gray bodies should be applied. The amount of the correction has not been determined, but, for leucite basanite of Nyamuragira, Verhoogen (1948, p. 131) found it to be about 20° at 1,000° C. It is probable, therefore, that the observed temperatures given in the accompanying table should be increased by about 20°.

It is noteworthy that the temperatures of the dome fountain and of the river at the vents are of the same order of magnitude as those obtained by Verhoogen (1948, pp. 133–136) at Nyamuragira. In comparison, the temperature at the surface of the Kilauea lava lake in 1916 was about 1,000°, that at a depth of 1 meter was about 860°, and that at a depth of 13 meters was about 1,170°. The latter temperature was believed to be higher than that of the magma rising through the conduits (Jaggar, 1917). The high temperature of 1,100° measured in the throat of the inactive spatter cone on June 7, 1950, probably was partly the result of gas heating.

There probably was very little lowering of apparent temperature by crust on the very turbulent lava in the river at the vents, and the actual temperature of emission of the lava may be taken as close to 1,070°. On the other hand most of the readings on the lava river at the highway probably were to some degree affected by the presence of crust on the river. The actual internal temperature of the river at the highway was probably near the upper end of the range of observed temperatures—in the vicinity of 950°. Thus the lava of the Ohia Lodge flow cooled about 100° in traversing the 10 miles from the vents to the highway. At 950° it was still fluid and free-flowing. At 675° it had become immobile. The temperatures of 850° to 870° measured in cracks in the stagnant aa on June 2 may have been appreciably higher than the internal temperatures because of surficial heating by burning gases. During the 1949 eruption of Mauna Loa, lava with a temperature of about 760° was found to be still capable of a little movement (Macdonald and Finch, 1949, p. 5).

TEMPERATURE MEASUREMENTS

OBJECT MEASURED	NUMBER OF READINGS	TEMPERATURE °C. RANGE	AVERAGE	DATE
Cascade in lava river at vents . . .	5	1030–1070	1050	June 7
Dome fountain in river at vents . .	3	1060–1080	1070	June 7
Lava river of Ohia Lodge flow near highway	16	850–980	916	June 2–4
Lava river of Ohia Lodge flow about ½ mi. from ocean	3	910–930	920	June 3
Lava river of Ohia Lodge flow near highway	15	840–940	898	June 10
Glowing lava in flaming crack in aa at nearly motionless edge of flow at highway (flow had crossed highway about 6 hours earlier) .	3	850–870	860	June 2
Glowing lava in crack in aa at stationary margin of flow at highway (flame absent) .	Several	....	675	June 10
Glowing throat of spatter cone at vents (not active when readings were taken, but active a few hours earlier, and still emitting gas) . .	3	1090–1110	1100	June 7

RADIATION STUDIES

Two series of counts with a Geiger-Muller counter were made on June 2 and 5 at 11 stations along the highway at and near the Ohia Lodge flow. The number of clicks per minute varied considerably, but the averages close to the flow and on the flow are a little less than those at a distance from the flow. The averages are as follows:

500 to 1,000 feet from flow	21 clicks per minute
10 to 300 feet from flow	20 clicks per minute
On flow 75 to 250 feet from edge .	17 clicks per minute

It is possible that the higher temperature on and near the flow affected the sensitivity of the instrument, reducing the count. However, at no time was the temperature of the wand holding the tube high enough to be unbearable, or even particularly uncomfortable, to the unprotected hand of the operator. The evidence appears to indicate that there was no marked increase in radiation as the flow was approached, and, therefore, that the lava was not appreciably radioactive at the level of the highway. No counter readings were made at the vents.

Samples of lava collected where the flow crossed the road showed no radioactivity when tested by Dr. Harvey E. White of the University of California.

TILTING OF THE GROUND

Indications of a pressure build-up under both Kilauea and Mauna Loa volcanoes in February, March, April, and May were given by the tilt curves obtained at the Whitney Laboratory of Seismology on the northeast rim of Kilauea Caldera. Normally there is a seasonal southwest tilt during the first 5 months of the year (Powers, 1947, p. 2). In 1950, however, seasonal tilt was exceeded by oppositely directed volcanic tilt so that south tilt ceased on February 9 and west tilt on March 19.

A rapid northward tilt started on March 6 and continued until the end of June, except for a southward tilt of 2.2 seconds of arc from May 29 to June 5. Over half of this southward tilt, or 1.2 seconds, accompanied a strong earthquake on May 29. The northward tilt from March 6 until May 29 amounted to 11.5 seconds of arc. The 77 earthquakes recorded in April, a majority of which originated at Kilauea, together with the strong north tilt, indicated a distinct uneasiness of Kilauea Volcano.

A positive easterly tilt which followed the cessation of seasonal west tilt on March 19 continued through May 28. The 102 earthquakes recorded during May, a majority of which originated under Mauna Loa, together with the easterly tilt, indicated that Mauna Loa had become more uneasy than Kilauea. There was a sharp westerly tilt on May 29 and 30 following the strong quake on May 29. Despite some fluctuations there was an accumulation of 6.0 seconds of arc of east tilt from May 31 to June 14. It is interesting to note that strong east tilt accompanied the outbreak of Mauna Loa and continued until there was a noticeable decrease in lava output. Evidence is accumulating that there is a correlation between east tilt and Mauna Loa eruptions. In 1950 east tilt set in 2 months and 12 days prior to the outbreak of Mauna Loa. Distinct east tilt preceded the 1949 eruption by 2 months and 8 days.

HARMONIC TREMOR

Very conspicuous harmonic tremor (Finch, 1944) was recorded on the seismographs at Kilauea, on the east slope of Mauna Loa, and at Kealakekua in Kona for over an hour after the eruption began. In the following discussion the records from the Kilauea seismograph on the northeast rim of Kilauea Caldera only are used. During the summit eruptions in 1940 and 1949 the Kilauea instrument, 22 miles from the site of the eruption, recorded harmonic tremor for 5 and 12 hours, respectively. The tremor was recorded for a similar number of hours during earlier eruptions. Though the upper eruption source of the 1950 outbreak was at a distance of 24 miles, or a little greater than in 1940 and 1949, the maximum double amplitude recorded in 1950—5 millimeters—was several times that of earlier years. The period of this large-amplitude early tremor was 0.5 seconds.

Instead of the tremor slowly dying out after a few hours, as it usually does, in 1950 it continued to be recorded intermittently until June 13, although about 4 hours after the initial outbreak at 12,600 to 11,250 feet altitude most of the lava was issuing from vents between 10,500 and 8,000 feet, about 30 miles from the Kilauea seismograph.

After the first few hours the amplitude of the tremor decreased greatly, but the double amplitude still ranged

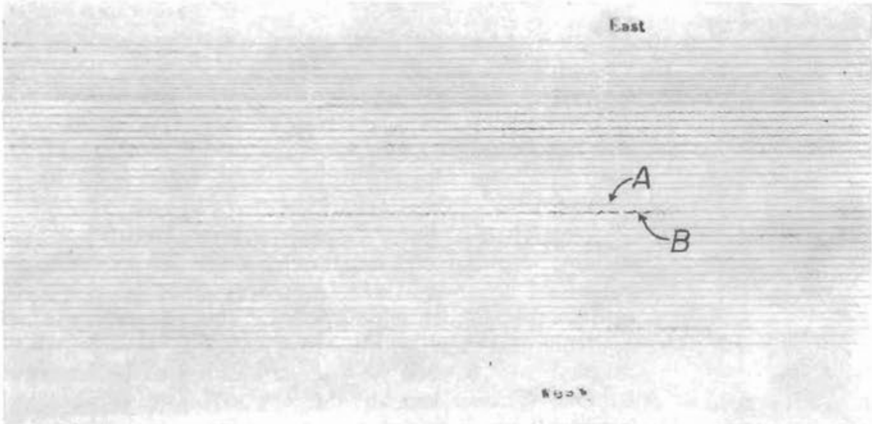

FIGURE 2. Harmonic tremor as recorded 30 miles from eruption source on June 2, 1950. A is the record of an earthquake, and B is due to an artificial disturbance.

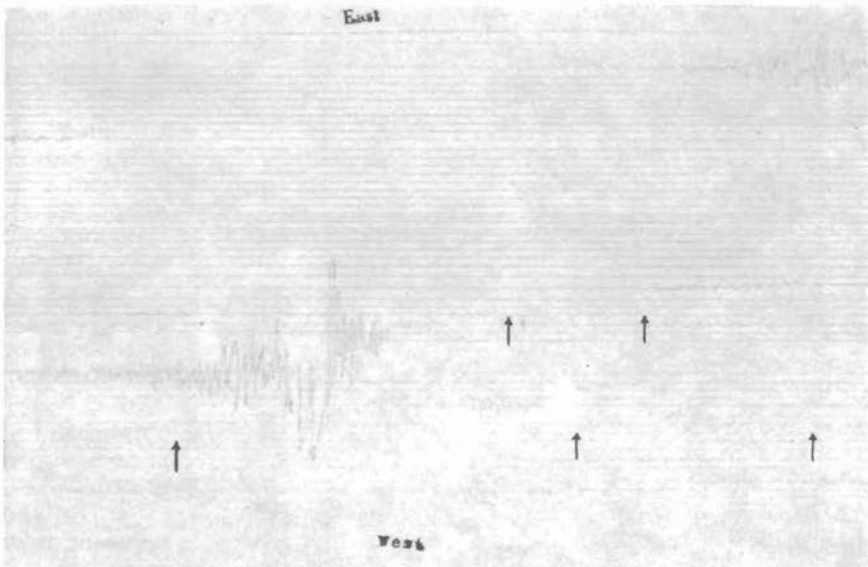

FIGURE 3. From the record of June 3, showing five spells of unusual harmonic tremor with a period of about 2 seconds. Arrows point to the beginning of each spell.

up to 0.7 millimeter (Fig. 2), which is equal to or larger than recordings in 1940 and 1949. The period of the tremor ranged up to 1.5 seconds.

The large amplitudes of the harmonic tremor at the onset of the eruption, and the fact that tremors continued after the distance to the source increased from 24 to 30 miles, indicated that the rate of output of lava was greater than usual.

On June 3 it was noticed that the harmonic tremor was not continuous, indicating fluctuations in the volume of lava being emitted. Direct observations both at the source and where the lava crossed the road showed fluctuations in volume.

Whether the harmonic tremor is produced by movements of lava in the primary conduits under Mokuaweoweo, the summit crater of Mauna Loa, or in the eruption fissures is not known, though evidence favors the latter. As noted above, in most eruptions harmonic tremor is recorded for a few hours only. In the 1942 flank eruption, harmonic tremor was recorded for a few hours during the preliminary activity at the summit (distance 22 miles) and then for 7 days after the lava broke out along the northeast rift at a distance of only 14 miles from the recording instrument. The facts that the tremor ceased being recorded a little before activity at the summit stopped and resumed, to continue for 7 days, after the lava broke out at a distance of 14 miles, indicate that the tremor originates in the eruption fissures.

On June 2 another type of harmonic tremor, apparently not previously recorded at the Hawaiian Volcano Observatory, was noticed (Fig. 3). The most frequent period of this type of tremor is roughly 2 seconds. Fourteen spells of this type of tremor were recorded on June 3, and 13 on June 4. Smaller numbers were recorded on other days, with the last on June 12.

EARTHQUAKES

Earthquakes and tilting of the ground surface during March and April caused speculation as to the possibility of an eruption at Kilauea. In May, however, quakes of Kilauea origin became less numerous and the number with Mauna Loa origin predominated. Many of the Mauna Loa quakes originated under the upper end of the southwest rift.

The following table shows the number of earthquakes per week recorded at the northeastern rim of Kilauea Caldera during May and June:

Week Beginning		No. of Quakes
April	30	30
May	7	21
	14	18
	21	9
	28	58
June	4	158
	11	60
	18	11
	25	7

A larger number of earthquakes during the early part of a flank eruption than during a summit eruption is to be expected because of the greater length of fissuring. In 1950 there was a progressive fissuring of the southwest rift for a distance of 13 miles. Normally, when both Mauna Loa and Kilauea are quiet, only five or six earthquakes per week are recorded.

LACK OF LITTORAL EXPLOSION

The absence of large littoral explosions or the formation of much ash where the lava entered the ocean was a striking feature of the 1950 eruption. Many aa flows entering the sea cause violent steam explosions which throw into the air large amounts of ash and which build littoral cones of ash and cinder (Macdonald, 1944). This happened in 1840, 1868, 1919, and 1926 (Jaggar, 1919, 1926). Many pahoehoe flows enter the water quietly, with only moderate evolution of steam, because the quickly formed pahoehoe skin provides an insulation which separates the very hot lava inside from the water. Aa flows, on the other hand, typically have a much broken and discontinuous surficial layer which permits the water easy access to the hot interior, with resultant strong explosions. A minor amount of such activity apparently did occur during the 1950 eruption. On June 3, D. C. Cox, going down the southern edge of the Ohia Lodge flow with D. A. Davis and C. K. Wentworth, noticed an increase in the amount of falling ash as they approached the coast and came under the steam cloud. Also, some of the moving pictures taken from the sea show small puffs of dark cloud, almost certainly ash, mixed with the white steam. However, littoral explosion and ash-making were very minor, certainly not nearly comparable with those in 1919 and 1926. Probably this was because the main lava rivers entering the sea were hotter and had a more unbroken surface than those of the 1919 and 1926 flows, thus preventing such rapid and easy entrance of the water to the hot interior. Once the flow into the ocean was well established a continuous crust may have formed over the lava river, acting as an insulator in

Figure 4. A lava river of the Ohia Lodge flow entering the sea. When such a river with practically unbroken surface entered the ocean, it produced but little steam. Bursts of steam were produced whenever blocks projecting above the surface of the river struck the water.—Photo by T. Matsumoto: courtesy Trans-Pacific Airlines.

much the same way as does the pahoehoe skin. Figure 4 shows such a lava river entering the sea and producing but very little steam. Whenever a block of appreciable size (some appear as dark objects in Figure 4) that was carried along by the lava river entered the water, it did produce a large burst of steam.

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HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JULY–SEPTEMBER, 1950

VOLCANOLOGY

July

The southwest rift vents of Mauna Loa emitted conspicuous amounts of fume during July.

A total of 69 earthquakes was recorded in July. Of these 59 were recorded at Kilauea and 25 at Mauna Loa. A majority of the earthquakes were of Kilauea origin, and they originated at shallow depths near the northern edge of Kilauea Caldera.

A slight westward tilting, or opposite in direction normal for this season of the year, indicates a pressure decrease under Mauna Loa. Northward tilt during July was greater than normal and indicates an increase of pressure at Kilauea.

The southwest rift vents of Mauna Loa were inspected on July 11. Large quantities of fume were being liberated.

August

In August, as in July, Kilauea was more active seismically than Mauna Loa. A total of 320 earthquakes was recorded in August. Of these, 312 were on the seismograph at Kilauea and 30 on the seismograph on the east slope of Mauna Loa. Most of the quakes originated at shallow foci under the northern end of Kilauea Caldera. Shaking was nearly continuous on August 2, when 241 quakes were recorded. Only three of these 241 quakes were felt. An earthquake accompanied by a roar was felt at Naalehu at 10:58 A.M., August 11. Another perceptible quake with epicenter low down under the northeast slope of Mauna Loa was felt in Hilo and at Kilauea at 12:18 P.M., August 27.

Tilt in the east–west direction during August was of the usual seasonal value. Rapid north tilt which started on July 15 continued until August 16. From August 17 to the end of the month there was a slight accumulation of south tilt. The accumulation of northward tilting since the first of the year, 9 seconds of arc, indicates a pressure increase preceding, during, and after the June eruption of Mauna Loa.

Fume was observed over the southwest rift of Mauna Loa on several days during the month.

Landslides from the Halemaumau rim were observed on August 29.

September

A total of 25 earthquakes was recorded in September. Of this number, 21 were recorded at Kilauea and 13 on the Mauna Loa seismograph.

East tilt was less than usual for September and may be taken as an indication of a slight pressure decrease under Mauna Loa. North tilt was normal for this season of the year.

Fume was observed over the southwest rift of Mauna Loa several times during the month. Following heavy rains on Mauna Loa on September 29 and 30 large fume clouds developed over the June, 1950, eruption source. The mixed steam and fume clouds started reports that Mauna Loa was erupting.

SEISMOLOGY

Earthquake Data, July–September, 1950

(Based on Bosch-Omori seismograph on rim of Kilauea Caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Local Seis-micity*	Tele-seisms
July 2	5	0	0	0	1.25	1
9	2	2	0	0	1.50	1
16	6	3	0	0	3.00	0
23	23	3	2	0	7.25	2
30	223	43	2	1	81.25	0
Aug. 6	24	4	1	0	8.00	1
13	14	2	0	0	4.50	1
20	3	0	0	0	0.75	0
27	4	1	1	0	2.50	0
Sept. 3	7	0	0	0	3.25	0
10	2	1	1	0	2.00	1
17	7	0	0	0	1.75	0
24	3	1	0	0	1.25	1

* For definition of local seismicity, see Volcano Letter 371.

The data for the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

178. July 1, 12:55, very feeble. Mauna Loa.
179. July 12, 03:12, very feeble. Kilauea.
180. July 12, 20:46, very feeble. East slope Mauna Loa.
181. July 19, 20:48, very feeble. Southwest slope Mauna Loa.
182. July 20, 03:45, very feeble. West slope Mauna Loa.
183. July 21, 15:29, very feeble. Kilauea.
184. July 23, 13:11, very feeble. Kilauea.
185. July 24, 15:42, feeble. Felt locally. North end Kilauea Caldera.
186. July 25, 19:30, very feeble. Kilauea.
187. July 26, 12:14, feeble. Mauna Loa.
188. July 29, 18:56, very feeble. Kilauea.
189. July 31, 04:29, slight. Felt locally. North end Kilauea Caldera.
190. July 31, 15:18, very feeble. Kilauea.
191. Aug. 1, 02:57, very feeble. Kilauea.
192. Aug. 1, 20:43, very feeble. Kilauea.

193–231 inclusive, Aug. 2, 39 quakes originating under north end of Kilauea Caldera.

232. Aug. 3, 02:15, very feeble.
233. Aug. 3, 04:43, very feeble.
234. Aug. 8, 06:04, very feeble. Kilauea.
235. Aug. 8, 10:21, very feeble. Kilauea.
236. Aug. 9, 14:27, very feeble. Kilauea.
237. Aug. 10, 07:35, very feeble.
238. Aug. 11, 10:58, feeble. Felt at Naalehu.
239. Aug. 13, 05:15, very feeble. Kilauea.

240. Aug. 19, 05:12, very feeble. Felt locally. Kilauea.
241. Aug. 27, 12:18, feeble. Felt locally and at Hilo. North slope Mauna Loa.
242. Aug. 28, 10:25, very feeble. Upper northeast rift Mauna Loa.
243. Sept. 15, 07:42, very feeble. Kilauea.
244. Sept. 16, 21:51, feeble. Felt locally and at Hilo. Northeast rift Mauna Loa.
245. Sept. 30, 17:06, very feeble. Mauna Loa.

TELESEISMS

July 8, 16:09, slight. Near Easter Island.
July 12, 01:27, slight. Aleutians.
July 29, 06:58, slight. Molucca Passage.
July 29, 13:58, slight. Solomon Islands.
Aug. 6, 16:57, slight. Mindanao, P. I.
Aug. 15, 04:24, strong. Burma border.
Sept. 10, 05:25, slight. New Hebrides.
Sept. 28, 20:36, moderate.

MICROSEISMS

Microseisms were strong on August 13, 14, and 15, and moderate on August 16 and from September 11 to 19. On other days they were slight.

CRACK MEASUREMENTS

One end of the crack near the tourist station on the east rim of Halemaumau opened 1 centimeter from June 30 to September 30. At a greater distance from the end of the crack the opening was 2 millimeters. Other cracks measured showed but very little movement.

TILTING OF THE GROUND

A slight westerly tilt in July may be taken as an indication of a pressure decrease under Mauna Loa. Normally there is an east tilt in July. During August and September usual seasonal tilt obtained.

Except for a south tilt August 17 to 21, north tilt was continuous and in a little greater amount than normal for this season of the year.

Table of Tilt at Seismograph Vault on Northeast Rim of Kilauea Caldera

Week Beginning		Amount	Direction
July	2	0.9″	N 15° W
	9	0.5″	S 64° W
	16	1.0″	N 6° E
	23	1.0″	N 20° W
	30	2.4″	N 17° E
August	6	1.4″	N
	13	2.6″	S 82° E
	20	0.8″	W
	27	0.5″	N 14° E
September	3	0.8″	N 18° W
	10	0.9″	N 57° E
	17	0.5″	N 45° E
	24	0.6″	S 53° W

TEMPERATURE MEASUREMENTS

The temperature of the steam well at the Sulfur Bank was constant at 204° F. in July, August, and September.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

In cooperation with the UNIVERSITY OF HAWAII

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THE VOLCANO LETTER

No. 510 U. S. Geological Survey October–December, 1950

PUBLISHED BY THE UNIVERSITY OF HAWAII

THE DECEMBER 1950 SUBSIDENCE AT KILAUEA

By R. H. FINCH

At noon on December 8, 1950, after several weeks of generally normal seismic conditions, the frequency of occurrence of earthquakes recorded by the seismographs suddenly increased. Simultaneously a rapid southwesterly tilt started at the Whitney Station on the northeast rim of Kilauea.

The origins of the early earthquakes were in the vicinity of Kokoolau Crater (Fig. 1), 4 miles from the Whitney Station, under the upper end of the system of fissures between the east and southwest rifts of Kilauea. During the night of December 8–9, earthquakes continued to originate in the region of the early shakes; others showed greater distances as though there was a progressive cracking to the southwest. By early morning on December 9 many of the quakes were being plainly felt at Kapapala (Fig. 1). The indicated origin of some of the stronger shakes on this date was a little to the east of Kamakaia Hills. The strongest quake of the series occurred at 21:25, December 10, with an indicated origin also a little to the east of Kamakaia Hills, and was generally felt over the eastern half of Hawaii.

The epicenters of the quakes were distributed over a linear extent of 15 miles, from the Chain of Craters Road to the upper end of the 1823 lava flow. The indicated depth of focus of many of the earthquakes was 4–5 miles.

The total number of earthquakes recorded during the period of rapid subsidence, December 8–14, was at least 656. The maximum number of quakes in any one day was more than 200 on December 10. For several hours each day on December 8, 9, and 10 quaking was so nearly continuance that it was impossible to separate the records of numerous small quakes. The following table shows the number of earthquakes by day:

DATE	NUMBER OF QUAKES
Dec. 8	133+
9	149+
10	200+
11	112
12	33
13	17
14	12

On December 11 a small crack trending NNE–SSW with a few millimeters downthrow on the Kilauea Caldera side was noted on the road near Kokoolau Crater. Two small cracks trending NE–SW were later observed about 2 miles to the southwest of Kokoolau Crater.

The fact that the earthquakes accompanied a rapid subsidence of the entire top of Kilauea was shown by tilt records. A seasonal northeasterly tilt usually continues until the latter part of December, when a seasonal change to the southwest usually occurs. A rapid southwesterly tilt at the Whitney Station started on December 8 and continued for 4 days with a cumulative total of 14.5 seconds of arc. During the same 4 days the cumulative total at the Uwekahuna Station (Fig. 1) was 22.1 seconds of arc to the east-southeast. In both cases tilting was much more rapid than normal seasonal tilting. These values place the maximum subsidence a little to the northeast of Halemaumau, about the same position as that of the maximum subsidence of 1920–24 determined by Wilson[1] on the basis of leveling. Calculations indicate that the maximum subsidence in 1950 was in excess of 1 foot. Figure 2 shows the tilt curves obtained at the Whitney Station. The

[1] WILSON, R. M. GROUND SURFACE MOVEMENTS AT KILAUEA VOLCANO HAWAII. Hawaii Univ. Res. Pub. No. 10. 1935.

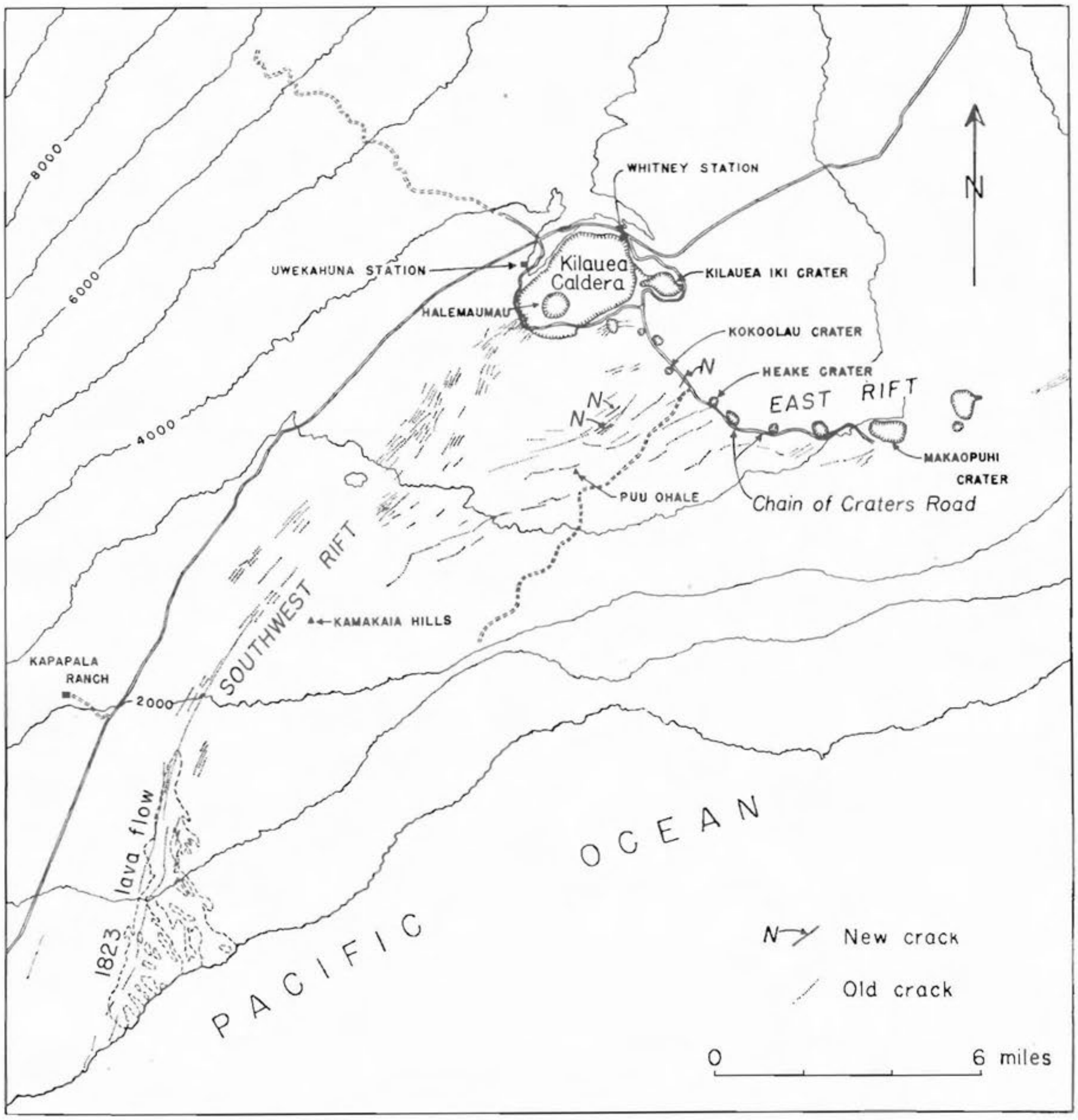

FIGURE 1. Map of Kilauea Caldera and vicinity. The 656 earthquakes recorded during the December, 1950, subsidence originated along the rift zone extending from Kokoolau Crater to beyond the Kamakaia Hills. New cracks were observed at places marked N.

sinking implied by the 14.5 seconds of arc south–southwest tilt is less than the implied tumescence during the 5 months from March to July, 1950, when there was a tilt of 21 seconds to the north–northeast.

Tilting, earthquakes, and cracks at the surface indicate that a considerable area, probably several miles in diameter around Kilauea Caldera, subsided. The location of the earthquakes and the new cracks indicate that a triangular block bounded by the east and southwest rifts and a line from Kokoolau Crater to the upper end of the 1823 lava flow underwent a greater movement than adjacent areas.

Several short spells of harmonic tremor recorded on December 10 and 11 indicate that there was some movement of magma at a depth of 4 or more miles (the depth of focus of many of the earthquakes). Tilt records indicate that pressure continued to build up under Kilauea for nearly 2 months after Mauna Loa ceased to erupt in June, 1950. Whether the rapid pressure decrease in December was accompanied by a retreat of the lava into the depths or by a more or less horizontal drainage into the southwest rift or elsewhere is not known. The writer favors the possibility of retreat of the lava column to depth.

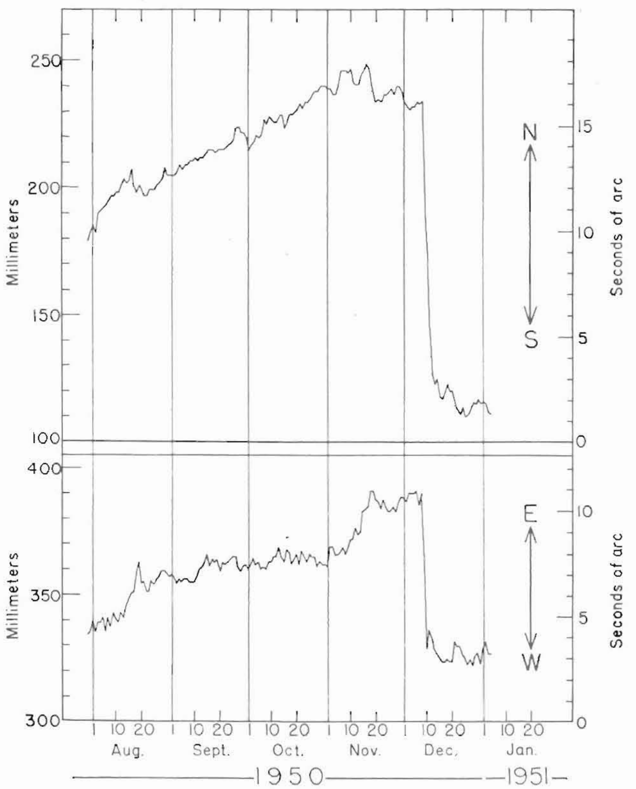

FIGURE 2. Graph of ground tilting at the Whitney Laboratory of Seismology at the northeast rim of Kilauea Caldera from August to December, 1950, showing the rapid south and west tilt on December 8 to 12. The resultant tilt for these 4 days was 14.5 seconds of arc to the south–southwest. Tilting at normal rates preceded and followed the rapid tilting.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR OCTOBER–DECEMBER, 1950

VOLCANOLOGY

October

Only 25 earthquakes were recorded in October. Of these, 24 were recorded at Kilauea and 19 on the Mauna Loa seismograph. A slight earthquake that was felt all over the island of Hawaii on October 11 originated at a depth of about 25 miles under the east slope of Mauna Loa.

Northward tilting of the ground was about normal for this season of the year and eastward tilting was less than usual.

The vents of the 1950 lava flows on the southwest rift of Mauna Loa continue to liberate fume. The fume was especially conspicuous on October 19.

November

Both Mauna Loa and Kilauea continued quiet during November. Kilauea has had no surface manifestation of activity in more than 16 years. There have been two spells of subterranean activity during these 16 years with sufficient magnitude to be easily detected by seismographs and tiltmeters. One was in November–December, 1944, and the other in April, 1950.

Forty earthquakes were recorded in November. Of these, 38 were recorded at Kilauea and 20 on the Mauna Loa instrument. Many of the quakes originated at shallow depths under the northern end of Kilauea Caldera. A continuous tremor was recorded on all seismographs on the island from 13:17 to 13:37 on November 17.

Northeastward tilting of the ground was about normal until November 16. Following heavy rains on November 15, 16, and 17 there was a slight southwest tilt. For the month as a whole there was a slight eastward tilt.

Landslides from the Halemaumau rim were common in November. The heavy rains of November 15, 16, and 17 produced conspicuous steam clouds in Halemaumau.

A conspicuous cloud was observed over the 1950 flow vents from Mauna Loa on November 15.

December

The total number of earthquakes recorded in December was 701. Of this total, 656 were recorded during 7 days—December 8–14. Owing to the frequent dismantling of the Mauna Loa seismograph no total can be given for that station.

A total of 1,702 earthquakes was recorded during 1950.

The rapid subsidence of Kilauea that began on December 8 may be taken as an indication of a sinking of the lava column under Kilauea. There had been a definite increase of magmatic pressure under Kilauea for 2½ months prior to the outbreak of Mauna Loa on June 1. The pressure build-up, as indicated by north tilt, continued definitely until the middle of August and probably until November 19. The rapid subsidence began, then, about 3 weeks after the cessation of the pressure build-up.

Tilting of the ground was slight in December except for the 14.5 seconds of arc south–southwest tilt accompanying the December 8–14 subsidence.

Conspicuous clouds were observed over the southwest rift of Mauna Loa on December 12 and less conspicuous ones on several other days.

Several landslides from the Halemaumau rim were observed.

During strong winds on December 26 most of the Kau Desert was obscured by dust clouds.

SEISMOLOGY

Earthquake Data, October–December, 1950

(Based on Bosch-Omori seismograph on rim of Kilauea Caldera)

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Teleseisms
Oct. 1	6	0	0	0	0	0	1.50	2
8	6	2	0	1	0	0	4.50	0
15	5	0	0	0	0	0	1.25	1
22	3	0	0	0	0	0	0.75	1
29	4	3	0	0	0	0	2.50	1
Nov. 5	9	1	0	0	0	0	2.75	3
12	8	1	0	0	0	0	2.50	0
19	7	1	0	0	0	0	2.25	0
26	3	4	0	0	0	0	2.75	1
Dec. 3	220	46	7	13	3	0	120.00	2
10	250	62	39	24	6	1	202.50	1
17	11	3	2	1	0	0	8.25	0
24	6	1	0	0	1	0	5.00	0

* For definition of local seismicity, see Volcano Letter 371.

The data for the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the U. S. Geological Survey. Time is Hawaiian Standard, 10 hours slower than Greenwich. The number preceding each earthquake is the serial number for the current year.

246.	Oct. 8,	05:49, very feeble.
247.	Oct. 11,	20:06, slight. Felt over most of Hawaii. 20–25 miles deep under east slope of Mauna Loa.
248.	Oct. 12,	07:33, very feeble.
249.	Oct. 31,	02:53, very feeble.
250.	Nov. 1,	15:28, very feeble. Kilauea.
251.	Nov. 4,	03:02, very feeble. Kilauea.
252.	Nov. 11,	23:34, very feeble. Kilauea.
253.	Nov. 13,	18:22, very feeble. Kilauea.
254.	Nov. 19,	23:23, very feeble. Kilauea.
255.	Nov. 26,	19:53, very feeble. West slope, Mauna Loa.
256.	Nov. 30,	14:18, very feeble. Mauna Loa.
257.	Dec. 1,	01:37, very feeble. Kilauea.
258.	Dec. 2,	20:54, very feeble. Southwest slope, Mauna Loa.
259.	Dec. 7,	00:27, very feeble.
260.	Dec. 7,	05:40, very feeble. Southwest slope, Mauna Loa.

Earthquakes accompanying the subsidence at Kilauea. Moderate or stronger quakes only are listed separately.

SERIAL NUMBER	DATE
261–278	Dec. 8
279–327	Dec. 9
328–398	Dec. 10
399–430	Dec. 11
431–437	Dec. 12
438–442	Dec. 13
443–447	Dec. 14

290.	Dec. 9,	05:43, moderate. Widely felt. East of Mauna Iki. 4–5 miles deep.
323.	Dec. 9,	20:45, widely felt. Instruments dismantled. Near Kamakaia Hills.
325.	Dec. 10,	05:57, moderate. 4–5 miles deep, near Kamakaia Hills.
326.	Dec. 10,	08:23, moderate. Below Kamakaia Hills.
369.	Dec. 10,	17:29, moderate. Kamakaia Hills.
370.	Dec. 10,	17:57, moderate. Near Puu Ohale.
379.	Dec. 10,	21:25, strong. Widely felt. Instruments dismantled. Kamakaia Hills.
421.	Dec. 11,	12:53, moderate. 4–5 miles deep below upper end 1823 lava flow.
431.	Dec. 12,	06:28, moderate. Depth shallower than preceding quakes.
448.	Dec. 15,	02:13, very feeble. Kilauea.
449.	Dec. 16,	07:17, feeble.
450.	Dec. 18,	05:54, very feeble. Felt plainly at Naalehu. Above South Point.
451.	Dec. 20,	23:19, feeble.
452.	Dec. 21,	20:00, very feeble.
453.	Dec. 21,	21:17, feeble.
454.	Dec. 22,	03:07, slight. Felt locally. Mauna Loa.
455.	Dec. 22,	04:07, very feeble. Kilauea.
456.	Dec. 26,	02:55, moderate. 8 miles deep south of Kilauea Iki. Widely felt.
457.	Dec. 27,	18:58, very feeble.

TELESEISMS

Oct. 5,	06:21, moderate. Costa Rica.
Oct. 7,	17:34, slight. Moluccas.
Oct. 21,	00:04, slight. West coast of Mexico.
Oct. 23,	06:24, slight. Guatemala.
Nov. 2,	05:40, moderate. Felt at Darwin, Australia.
Nov. 7,	16:28, moderate. Solomon Islands.
Nov. 9,	16:36, very slight.
Nov. 11,	00:04, very slight.
Dec. 2,	10:01, moderate. New Hebrides.
Dec. 4,	06:38, slight. New Britain.
Dec. 9,	12:26, slight.
Dec. 13,	16:00, slight.
Dec. 14,	04:40, very slight.

MICROSEISMS

Microseisms were strong on November 3, December 2–13, and December 26–31. They were of slight or moderate amplitude on other days.

CRACK MEASUREMENTS

A majority of the cracks that were measured around the rim of Halemaumau showed distinct openings. Quite likely some of the openings were due to earthquakes. Cracks on the crater floor that are more or less aligned with the southwest rift closed slightly during the sinking spell of December 8–14. During this same spell some of the old cracks by Kokoolau Crater, near where new cracks appeared at the surface, showed distinct openings.

TILTING OF THE GROUND

Seasonal northeast tilt continued until November 17 when a southwest tilt set in. This change in direction came about 1 month earlier than usual and was probably due to unusually heavy rains on November 15, 16, and 17. Seasonal southwest tilt continued through the end of the year, except for the rapid southwest tilt December 8–12.

Table of Tilt at Seismograph Vault on Northeast Rim of Kilauea Caldera.

Week Beginning	Amount Seconds	Direction
October 1	1.21	N 5° E
8	0.54	N 63° E
15	0.60	N 36° W
22	0.86	N 8° W
29	0.60	N 79° E
November 5	0.95	N 50° E
12	2.28	E
19	1.02	S 70° W
26	0.86	S 34° E
December 3	6.24	S 37° W
10	9.48	S 25° W
17	1.02	S 45° E
24	0.76	N 18° W

TEMPERATURE MEASUREMENTS

The temperature of the steam well at the Sulfur Bank varied from 204° to 204.5° F.

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