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. 479 | Department of Interior | National Park Service | January-March 1943

PUBLISHED BY THE UNIVERSITY OF HAWAII

HAWAII NATIONAL PARK: Edward G. Wingate, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

LAVA SURGINGS IN HALEMAUMAU AND THE EXPLOSIVE ERUPTIONS IN 1924

By R. H. FINCH

The object of this paper is to show a possible relation between fluctuations in the lava column of Halemaumau and the steam blast eruptions in 1924, as well as to point out the limitations in the quantity of heat and amount of water available for such steam blasts.

A remarkable series of fluctuations in the height of the molten lava in Halemaumau commenced in December 1923 and continued until the lava disappeared on February 21, 1924. The fluctuations suddenly began near the culmination of the steady rise in the lava column that followed the collapse accompanying the small lava flow near Makaopuhi in August 1923. There were short-period fluctuations of approximately 6 to 8 hours, superposed on fluctuations with a period of almost exactly 1 week. The amplitude of the short-period fluctuations was about the same as that of the week-period fluctuations, often amounting to over 60 feet.[1] The general rise in the lava level continued until January 21. Until that date the risings usually exceeded the sinkings. After January 21, however, there was a gradual lowering and the sinkings usually exceeded the rises. This last relation continued until the lava disappeared from view on February 21.

After the disappearance of molten lava in February, harmonic tremor and the smoky condition of the pit, through which glow was occasionally visible, indicated that the lava column remained rather high and nearly stationary until the time of rapid subsidence in the latter part of April. The pasty lava that was revealed at the beginning of this subsidence strengthened such indications.

Previous to the disappearance of the lava, the area of the lava lake that was fluctuating through a range of 50 to 60 feet was about 40 acres. This meant that a large amount of molten lava was involved. In one half-hour period observed, over 10,000,000 cubic feet of lava poured into the lake basin. Some of the withdrawals were even more rapid. If, as seems probable, the total area in cross section of the feeding conduits was small compared to the lava lake, then surgings with similar volume, when confined to the conduits, would mean large vertical ranges. Even if much smaller volumes of lava were involved, the vertical range might well have been much larger than the observed 50 to 60 feet when the upper ends of the conduits terminated in a lake basin.

The possibility of large vertical ranges in the lava surgings being established, indications for such surgings are now required. Harmonic tremor[2]—seismic indications of underground movement of molten lava—furnishes just such evidence. This type of tremor diminished on the seismograms of the Hawaiian Volcano Observatory just before the lava disappeared in February and then was barely visible until April 29, when there was a noticeable increase. Coincidental with the increase in harmonic tremor, a strong southwest tilt and a marked subsidence in the lava column began. Lava drainage into the Puna rift[3,4] may have begun about this time.

A distinct increase in harmonic tremor started on May 7,

[1] Bulletin, Hawaiian Volcano Observatory, December 1923, January 1924, and February 1924.

[2] Jaggar, T. A. "Seismometric Investigation of the Hawaiian Lava Column." Seismological Society of America Bulletin, December 1920, page 267.

[3] Jaggar, T. A., and Finch, R. H. "The explosive eruption of Kilauea in Hawaii 1924." American Journal of Science, November 1924, page 358.

[4] Jaggar, T. A. "Kilauea's Lost Lava Flow." Paradise of the Pacific, Vol. 46, No. 6.

just 4 days prior to the onset of the explosions. This type of tremor was moderate to strong until May 17 and slight through the remainder of the explosive period. The maximum in explosive intensity was reached on May 17 to 18, though earthquakes increased in frequency after this date, reaching a maximum on May 24. There is evidence, then, of lava surging prior to and during the explosive period. If the amplitude of the harmonic tremor is an indication of the amplitude of the surgings, the range of movement of the lava column preceding and during the explosions may have exceeded those during the preceding winter.

Dr. T. A. Jaggar has demonstrated that the explosions in May 1924 must have had their origin in steam blasts.[5] The following discussion attempts to indicate in a more detailed way a possible mechanism and the periodicity of the steam blasts. The potency of volcanic heat in producing steam blasts is easily recognized. A cubic foot of water at a pressure of 1 atmosphere and a temperature of 1,700° F. would yield over 5,000 cubic feet of steam, or, if confined, produce a pressure of over 80,000 pounds per square inch. If one considers these figures only, the mechanism of volcanic steam blasts appears rather simple.

Difficulties arise, however, when one considers that with any ingress of water the hot volcano conduit system immediately produces a pressure that greatly retards, if not precludes, further entry of water. If the pressure build-up were at a moderate rate, then some seal to confine the steam before a disruptive pressure was reached would be necessary. (It would appear that landslide material could make but a poor seal, even with optimum arrangement.) If the pressure had built up rapidly, the heat supply would have had distinct limitations. It would have to come from a thin surface layer of the conduit walls and from any landslide material that fell into the conduit, say about one-eighth inch thick. The receding magma must have left appreciable areas of hot wall uncovered. A mechanism producing a very rapid generation of steam and not requiring a thorough seal, such as a "flash boiler," seems indicated.

Before proceeding with the discussion of a "flash boiler" system, a few words concerning the probable height and distribution of ground water in the vicinity of Kilauea seem desirable. For ideas on this subject, the writer acknowledges his indebtedness to Dr. G. A. Macdonald of the United States Geological Survey.

Conditions observed elsewhere in the Hawaiian Islands indicate that large amounts of ground water are trapped in compartments between dikes at relatively high levels. Dr. Macdonald believes that the ground water in some compartments near Kilauea may be as much as 1,500 feet above sea level. The normal elevation of the Ghyben-Herzberg lens of fresh water in the vicinity of Kilauea would be about 35 feet above sea level. The shape and orientation of such compartments in the vicinity of the Kilauea conduit system are probably very irregular. Evidence indicates considerable relatively high-level ground water in close juxtaposition to the volcanic conduits. As lava is a very poor conductor of heat, the horizontal temperature gradient in the conduit walls must thus have been very steep.

[5] Jaggar, T. A. Bulletin, Hawaiian Volcano Observatory, May 1924, page 35.

There can be but little doubt that an abundance of heat was available for the explosions. All that remains is to find a means whereby a considerable volume of ground water could be dropped into hot openings left empty by the receding lava.

The rapid subsidence that started on April 29 was accompanied by many earthquakes of Halemaumau origin. As previously mentioned, the retreat of the lava column was probably made up of fluctuations in which the drops exceeded the rises. The collapse of the entire floor of Halemaumau indicated a series of collapses of the walls of the feeding fissures. The downsurgings of the lava may well have timed the moment of the collapses. Sometime during this pulsating descent of the lava column, a trapped ground-water pocket was encountered, and with the shattering of the conduit walls a comparatively small amount of water gained access to the volcano system. This could account for the first small explosion on May 11. The next indicated withdrawal of lava and collapse of the conduit walls was on May 13, and explosions resulted. If the bottom of the pit was 1,000 feet below the rim, which, in turn, was 3,700 feet above sea level, and if the height of the trapped ground water was 1,500 feet above sea level, then 1,200 feet of fragmental material would have to be lifted to make an appreciable showing in the bottom of the pit. With an average specific gravity of 2 for such a plug, the pressure generated would have to exceed 1,000 pounds per square inch. Pressures of this magnitude should be developed easily. As the explosions progressed, there may have been an increase in the specific gravity of the fragmental material filling the vent because of an increase in the amount of dense material from more deep-seated walls of the conduit and a decrease in the percentage of vesicular lava from the upper walls. If, as is probable, there was a more or less progressive increase in depth of the seat of the explosions, there may not have been a striking increase in the weight of the plug, for there was a gradual increase in the depth of Halemaumau, the maximum being indicated about May 17.

In order to arrive at possible explosion pressures, let us assume probable temperatures and a possible amount of water. If, as has been assumed, most of the explosions occurred just following a downsurge in the lava column, the walls of the conduit had a temperature of about 1,700° F. Let us assume a surface area in the evacuated conduit of 6,000 square feet. An opening 50 feet long and 60 feet deep would furnish such an area. Hot fragmental material that might have fallen into the cracks would also have been an important additional source of heat. Hot volcanic gases would have been a minor contributing factor. If the explosion pressure was developed as a "flash boiler," then the heat available was confined to a layer about one-eighth inch thick in the rock surface. The volume of the rock, if one computes only the surface of the walls of the fissure, would be 62.5 cubic feet. With a specific gravity of 2.5, this volume of rock would weigh about 10,000 pounds. The number of available B.T.U.'s above 210° F. in 10,000 pounds of basalt with an initial temperature of 1,700° F. is 4,470,000, if we assume the specific heat of basalt in this temperature range to be 0.30.

If we assume a final temperature of 900° F. for the boiler system, the available heat in 10,000 pounds of basalt would amount to 2,400,000 B.T.U.'s. This amount of heat would be nearly enough to raise the temperature of 2,000 pounds of water from 66° to 210° F., evaporate it, and then superheat the steam to 900° F. Evaporation, of course, would take up most of the heat. The pressure generated by such a system with a constant volume would be over 3,000 atmospheres. Of course, there was no constant volume system, but the pressure developed must have been many times the minimum requirement of 1,000 pounds per square inch mentioned previously.

Now the question arises as to whether it is possible to inject suddenly an appreciable amount of water into an evacuated conduit. The Olaa well,[6] with a drawdown by continuous pumping of 8 feet, showed a continuous inflow of 80 gallons a second. If a void with the same capacity as that of the sump below the water surface were suddenly created, the amount rushing in during the first half second might well be several times that of any half second after pumping had been in progress for some time. Likewise the discharge during the first half second from water trapped in a dike compartment, when the wall separating it from a volcano conduit is suddenly shattered, might greatly exceed that of any subsequent half second. Furthermore, if the shattering occurred at the same time as a rapid downsurge of the lava, there might be a pressure decrease that would facilitate the inflow of water. A considerable vertical range in the shattered conduit would speed up the inflow of water, for the velocity of inflow varies roughly as the square root of the depth below the surface of the water table.

The temperature of the dust of the explosion column as it cleared the crater rim must have been nearly 900° F., for on several occasions it was observed to have a dull red glow. The expanding steam, then, in the midst of the hot dust, would have had a volume about 3,500 times that of its water equivalent when it reached atmospheric pressure and would have condensed only in the extreme upper and cooler portions of the cloud. Steam was first definitely observed in the explosion cloud on May 14, though whether it had its origin in the explosion or from steaming vents in the crater wall is not known. The amount of condensation of water vapor in the explosion clouds was never striking, in fact, not much more than might be expected from such a column of hot air with appreciable indrafts of humid air. The explosions must have been produced by relatively small amounts of steam.

Although there was no apparent regularity in timing with many of the explosions that occurred during the early part of the explosive period, the most common interval between explosions[7] was 6 to 8 hours. This interval was in accord with observations on lava fluctuations in Halemaumau. The early irregularities might be expected when one considers the possible existence of a network of feeding fissures under Halemaumau that decreased in number with increase of depth and the possibility that collapsing in the different walls may not have taken place simultaneously. Then, too, the explosion pressures themselves may have been the cause of some of the collapses and thus may have resulted in a series of explosions closely following one another. It should be noted that whether there was one feeding conduit with a diameter equal roughly to the bottom of Halemaumau or a series of feeding wells, the preceding discussion is little affected. If there were but one conduit, variation in the timing of the shattering of different portions of the conduit walls could have produced the observed effects.

Two conditions could have prevented further explosions: a lava column that had become stationary and the cessation of the shattering of the walls of the dike-inclosed compartments containing water.

Many of the explosions, perhaps all, produced air-pressure waves preceding the sound waves. This indicates that the onset of the explosions was rapid, like that of dynamite. The idea of a "flash boiler" mechanism to account for the May 1924 explosions of Kilauea does not seem incompatible with possible available heat and ground water nor with the observed facts of the explosions.

AUTHOR'S ACKNOWLEDGMENT: The author is indebted to Dr. T. A. Jaggar and Dr. G. A. Macdonald for reading and criticizing the manuscript, and to Mr. Williard M. Eller of the Hilo Electric Light Company, Ltd., for checking the computations.

COMMENTS

By T. A. JAGGAR

The foregoing discussion on a possible mechanism for comparatively shallow focus explosions is interesting.

I think of the surgings as deeper and place more emphasis on the magmatic furnace than on incandescent walls. With deeper surgings, the wall breakage with each retreat would let in fresh water from the Ghyben-Herzberg lens at the same time that magma was cascading into the evacuated chamber. The effect would be similar to the surface cascade shown in the figures in the Bulletin of the Hawaiian Volcano Observatory for August 1919.

With the Ghyben-Herzberg ground water standing at 35 feet above sea level, the bottom contact with salt water was 1,400 feet below sea level. If the lava outflow undersea was at one-fourth the depth found 40 miles off Cape Kumukahi (east point of the island) and emerged one-fourth the way down the submarine slope at an elevation of about 4,500 feet below sea level, it was 3,000 feet below the bottom of the fresh water lens.

If the rushing lava was cascading past Kilauea from a head relatively high within Mauna Loa, one cascade or rift tunnel could furnish either a continuous or intermittent furnace, such as the cascades and tunnels that were observed for days in 1919 to 1920.

Surgings and drainages would suck down air from the fissured mountain above ground-water level and so increase the

[6] Duncan, George. "The Dug Well at Olaa Mill." Volcano Letter No. 477, July-September 1942.

[7] Finch, R. H. "Seismic Sequences of the Explosive Eruption at Kilauea in May 1924." Seismological Society of America Bulletin, December 1924, page 217.

heat supply with intense gas oxidation. Cascades of retreat are nothing more than excessive convectional fountaining. Far below water level a downsurge of 10,000,000 cubic feet of lava within a half hour cannot leave a vacuum. Evacuated by steam explosions, a shatter chamber, below 1,500 feet of head of water and still lying higher than at least 3,000 feet of head of much heavier rushing lava that sends up a roaring gas furnace through the well, is likely to suck water into the chamber and make steam that pulsatingly escapes. The bulk of the magma rushes on to effervesce into the ocean. With surges of collapse a Bessemer-furnace process would be set up through the collapse debris. Flash-boiler heavings would punctuate the collapse around the deep chamber—collapses having nothing to do with faulting at the surface.

The mechanism may be thought of as a pouring torrent released through a rift tunnel. The geyser shaft was pulsating accordingly as ground water, alternately heated, blasted upward and rushed in cool. The blasts aided rupture for pumping in new water.

I think the end of the explosions resulted because of a backing up of the submarine outflow, the lava filling fracture fissures and losing pressure through satisfying the new rift-system that was generated in the first place by the tumescent stress under the whole island in surgings of 1915 to 1923. This merely makes the tumescence of the upper island extend itself eastward to the submarine island whenever the century-long cycle between steam blast eruptions shifts its surging from high under Mauna Loa to low under Kilauea or Hualalai. The 130-year period for explosions at Kilauea represents something fundamental in the volcano mechanism that cannot be satisfied with superficial relations only.

The arrangements of the 1919 to 1920 flow from Kilauea that built up Mauna Iki serve as a model of the 1924 system. The Mauna Iki flow was fed by a rift tunnel from Halemaumau through an arcade that still shows in the southwest wall. A little way down the slope from Halemaumau was a lava well, with fountaining lava and escaping gas. In 1924 the entrance arcade was somewhere in the depths under Mokuaweoweo; Halemaumau was the well over the rift tunnel; and the lava flow issued somewhere on the submarine slope east of Cape Kumukahi. With such an arrangement we get three possibilities:

(1) That the tunnel is shelled over water tight and lava tight, and the ground water outside like a tubular boiler. This is not possible, as it was recently feeding the pit and in April 1924 was in a belt of shattering.

(2) That the tunnel is a longitudinal rift torrent, open to the pit, its gases rising to the Halemaumau vents in debris; that these vents in turn are water pipes of the shatter belt under hundreds of feet of hydrodynamic head, the water surging downward as the lava fountains surge upward and downward.

(3) That the feeding vent is an independent upright dike under Kilauea, trending to Puna under the openings of 1920 (Mauna Iki), 1921 (Halemaumau), 1922-1923 (Makaopuhi), and April 1924 (Kapoho)—all sealing above and splitting wide open below to rupture a way along the under-ocean dome surface, just as the Kau Desert ruptured in December 1919 to January 1920. The water conditions were the same as (2).

Probably both (2) and (3) are true, the November 28, 1919 sympathy with the end of the Mauna Loa eruption being the beginning of the rupturing downward that fractured open the Kau Desert rifts in 1920. The upsurges of 1923 must have been dike splitting to introduce the dike fillings of the downsurges. A colossal volume of liquid had to go somewhere and come from somewhere, and neither source nor destination appeared.

All the events were a part of the same Mauna Loa-Kilauea pulse series—like 1914, 1916, 1919, 1920, 1921, 1922, and 1923—which left their output on the surface and also within the internal dikes of tumescence. Thus it is only reasonable to believe that the main vent is under Mauna Loa and deep, that the 1923 surgings were the culmination of lava lowering within Mauna Loa, and that the destination was on the same enormous submarine mountain beyond Cape Kumukahi. That Kilauea was internally robbed is proved by Wilson's shrinkage.[1]

Ground water was essential to the occurrence of any explosions at all. When the lava column, its outer armor broken, got below ground water, a phreatic accident was initiated. This means that if the 1942 flow from Mauna Loa, say, had had a head of ground water above, it would have been accompanied or followed by upper-well explosions. Just such explosions are the rule in heavily watered continental volcanoes. This would be particularly the case if the andesites were viscous and the fountaining subterranean. Ergo: Lassen, Vesuvius, Pelee, and Merapi.

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[1] Wilson, R. M. "Ground Surface Movements at Kilauea Volcano, Hawaii." University of Hawaii Research Publication No. 10, 1935.

Hawaiian Volcano Observatory Report for January-March, 1943

VOLCANOLOGY

January

The beginning of 1943 found both Kilauea and Mauna Loa inactive. Heavy rains during the first week of the month caused conspicuous steam clouds over the 1942 lava flow from Mauna Loa. These clouds started rumors that Mauna Loa was in eruption. A landslide at Halemaumau raised a conspicuous dust cloud at 13:45, January 26. There was an unobserved landslide from the southwest wall of Kilauea. At Kilauea 82 seismic disturbances were recorded and at Mauna Loa 32.

February

Only one of the 83 seismic disturbances recorded at Kilauea was strong enough to be perceptible at the Observatory. On the Mauna Loa seismograph, 33 quakes were registered. There was a perceptible widening of the cracks around Halemaumau.

The thermometer shelter was moved to the new observatory grounds in 1941. The new location, slightly lower than the old, is on the windward side of the northeastern-rim steam cracks; therefore, minimum temperatures now recorded are frequently lower than those at the old location.

March

The preponderance of Kilauea shakes over those of Mauna Loa origin, exhibited in January and February, continued in March. There were 71 shakes at Kilauea and 47 at Mauna Loa. None of the quakes appeared to have any special volcanic significance, and Hawaiian volcanoes remained quiet throughout the month.

R.H.F.

SEISMOLOGY

Earthquake Data, January-March, 1943

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Local Seismicity*	Tele-seisms
Jan.	3	9	1	0	0	2.75	0
	10	5	1	0	0	1.75	0
	17	9	4	0	1	6.25	0
	24	38	0	1	1	12.50	0
	31	15	2	0	0	3.75	0
Feb.	7	10	0	0	1	4.50	0
	14	29	1	0	0	7.75	0
	21	22	2	0	0	6.50	1
	28	27	1	0	0	7.25	0
Mar.	7	18	0	0	0	4.50	0
	14	14	5	2	0	8.00	0
	21	16	1	1	0	5.50	2
	28	9	0	0	1	4.25	0

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the Island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard. The number preceding each earthquake date is the serial number of the quake for the current year.

1. January 9, 20:04, very feeble, felt in S Kona.
2. January 11, 14:32, very feeble, Mauna Loa.
3. January 15, 17:41, very feeble.
4. January 16, 03:38, very feeble.
5. January 16, 04:22, very feeble, origin at Kilauea.
6. January 17, 14:08, slight, felt locally, NE rift Mauna Loa.
7. January 19, 02:48, slight, felt locally and in Hilo.
8. January 24, 03:09, feeble, felt in Pahala.
9. January 27, 19:06, very feeble, felt at Kukaiau.
10. January 30, 13:53, very feeble.
11. February 1, 22:10, slight, felt in Hilo, Mauna Loa origin.
12. February 8, 10:35, very feeble.
13. February 15, 06:30, very feeble, felt in Kohala.
14. February 16, 03:59, very feeble.
15. February 27, 07:04, very feeble.
16. March 10, 07:34, feeble, Kilauea shake.
17. March 10, 22:52, feeble, Kilauea shake.
18. March 11, 03:06, very feeble.
19. March 11, 04:11, very feeble.
20. March 11, 10:26, very feeble.
21. March 12, 19:26, very feeble.
22. March 13, 19:25, very feeble.
23. March 15, 12:06, feeble, between Mauna Loa and Mauna Kea.
24. March 16, 01:54, very feeble.
25. March 25, 13:05, slight, Mauna Loa.

TELESEISMS

February 21, 23:00, slight.
March 15, 12:30, very slight.
March 21, 10:10, very slight.

MICROSEISMIC MOTION

Microseisms were present throughout the quarter but especially noticeable on February 13 only.

TILTING OF THE GROUND

The normal southwest tilt prevailed during the quarter save for a slight north-northeast tilt during the last few days of January and the first few days of February. For the past several months the tilt stations at Halemaumau showed almost no movement.

Table of Tilt at Observatory on NE Rim of Kilauea

Week Ended		Amount	Direction
January	3	0.27″	S28° E
	10	1.46″	S42° W
	17	0.48″	S
	24	1.33″	S
	31	0.51″	S13° E
February	7	1.40″	N53° E
	14	0.74″	S80° W
	21	1.17″	N71° W
	28	1.39″	S38° W
March	7	0.57″	N45° E
	14	1.00″	S76° W
	21	0.72″	S
	28	0.84″	W

CRACK MEASUREMENTS

All cracks around Halemaumau except one showed a slight opening during the quarter. One crack along the Chain of Craters Road showed a slight opening; the other crack in this area exhibited no movement.

R.H.F.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

in cooperation with

UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record 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 Government, Department of the Interior, National Park Service.

The **University of Hawaii** cooperates in maintaining a research laboratory at Hawaii National Park. The **Association** and the **University** maintain outside seismograph stations and supplement the work of the government with research associates, instrumental plants and special investigation. Dr. T. A. Jaggar is their geophysicist resident in the National Park.

The **Volcano Letter**, a quarterly record of Hawaiian volcano laboratories and published by the University of Hawaii, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the above establishments.

THE VOLCANO LETTER

No. 480 | Department of Interior | National Park Service | April-June 1943

PUBLISHED BY THE UNIVERSITY OF HAWAII

HAWAII NATIONAL PARK: Edward G. Wingate, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

LAVA RIVERS AND THEIR CHANNELS

By R. H. FINCH

Estimates by reliable authorities of the depth of rapid-flowing lava rivers of Mauna Loa and the observed depth of the channels after flowing has ceased are often in disagreement. The discrepancy arises from the fact that the observed channel depths are too great.

Lava rivers are comparatively narrow streams flowing within well-defined banks. Where such streams flow out onto a relatively flat terrain, especially if the lava is in the aa stage, a slow-moving lava field covering a considerable area may develop. Short-lived lateral overflows often build up the banks of the channel so that frequently lava rivers are appreciably depressed within their banks. Discrepancies persist, however, even after due allowances for such depressions are made. In 1942, for instance, after the Mauna Loa flow had ceased, a channel about 16 feet deep was found where the river was estimated to have been not over 4 to 6 feet deep and depressed within its banks from 3 to 4 feet. This leaves a discrepancy of over 6 feet to be accounted for. In some cases, discrepancies are even greater.

The order of magnitude of the depth of Mauna Loa lava rivers is determined by noting the behavior of a stream at a cascade and by estimating the percentage of the large bank segments that remain visible after having broken off and fallen into the stream. Often lava rivers branch to make braided streams (fig. 1). The majority of these branches persist but a short time and thus offer opportunities to check estimates of depth. Here, estimated and measured depths are in close agreement. The shallow depth of short-lived streams might be taken as an indication that time is an all-important factor in regard to depth and that long-continued rivers erode or melt material to form a deep channel. These possibilities can be discarded, however, as such erosion cannot be appreciable. Moreover, the possibility of lava fusing the bottom of its channel to give the indicated increase in depth is very remote, because the temperature required to fuse lava does not obtain in such a river. Some other explanation must be sought. Furthermore, because lava rivers tend to crust over and the crust tends to become broken into blocks which sink into the melt, one might expect the channel to grow progressively shallower unless there is some mechanism whereby such sunken blocks are continually removed.

Dr. T. A. Jaggar made the first detailed observations on the mechanics of a Mauna Loa lava river at the Alika flow in 1919.[1] Describing the lava river, he stated: "The effect in the lava stream was as though the bottom were everywhere at shallow depth, and perhaps itself shifting downhill at a slower rate than the liquid film on top." In another paragraph he said: "After seeing the marked differentiation between the liquid lava in the channel and the evident semi-solid matter of the channel bottom and sides—the writer surmised that there were here present two kinds of magma, just as in Halemaumau. There we have the sharply differentiated lake magma and bench magma."

Irregularities in the bottom of lava rivers often manifest themselves as stationary waves at the surface. The progressive movement downstream, observed on several occasions, of some of the obstructions causing these stationary waves is a good indication of the dual nature of such streams—that is, of an upper rapid-flowing stream with low viscosity superposed on a sluggish viscous one. The closing stages of Mauna Loa lava rivers fur-

[1] Jaggar, T. A. "Activity of Mauna Loa." Bulletin, Hawaiian Volcano Observatory, October 1919, page 136.

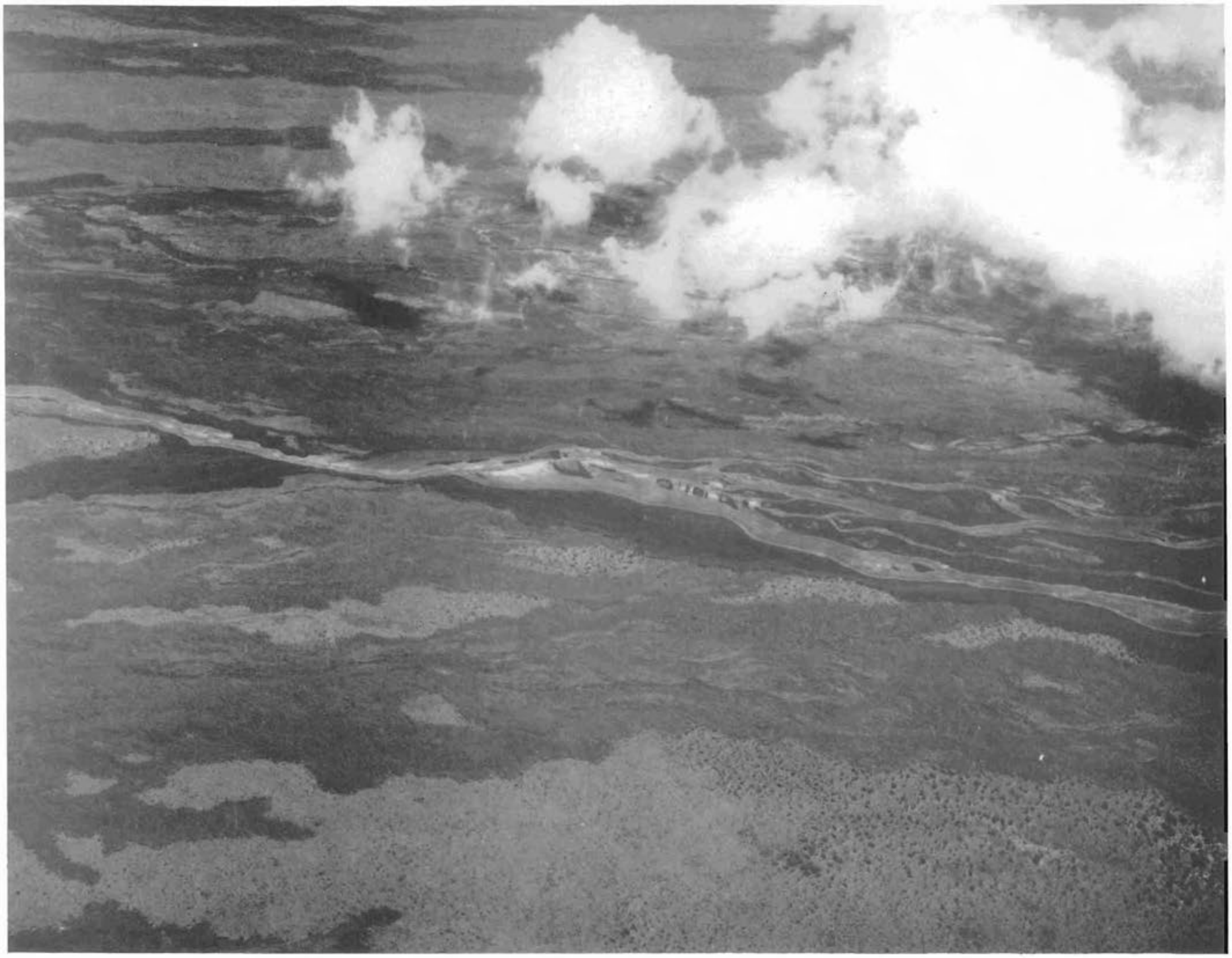

Figure 1—The 1942 Mauna Loa lava river a little below the source cone, where it divided to form a "braided" stream. These branches returned to a single channel lower down. (Photo by Base Photo Laboratory, A.A.F.—APO No. 953.)

nish further evidence on the dual nature of such streams. When diminishing activity at the source cuts off the supply, the material in the upper river quickly drains away, while the slower-moving lower stream continues for some time. Accurate timing of the cessation of the two streams would give some idea of their relative viscosities. Probably, just as perceived by resistance to sounding pipe in Halemaumau, there is gradation of viscosity from liquid vitreous foam on top of the lava rivers to semi-crystalline paste at the bottom. The flowing onward of this paste at the end of an eruption should shallow the delta region stream and deepen the upstream gorge. Exactly this occurred in 1919, 1935 and 1942.

Dr. Jaggar's observation in 1919 that the rapid-flowing Mauna Loa lava rivers are shallow and superposed on slow-moving channel material seems to be justified.

THE VISCOSITY OF MAUNA LOA LAVA FLOWS

By R. H. FINCH

The viscosity of flowing lava is constantly changing. The change is generally to a higher viscosity, because of a decrease in temperature. At the surface of a lava flow, the change is much more marked than in the interior. In pahoehoe flows, the formation of skins gives a very high viscosity for an outer layer. This outer layer, being a good insulator, helps the interior to maintain a high temperature and a relatively low viscosity. The surface granules of an aa flow likewise act as an insulator and allow this type of lava to flow to considerable distances. The rapid cooling of overflows from lava rivers and of the tongue-like extensions by which lava advances causes a rapid change in viscosity within a few seconds.

Because of these factors, one might expect to find a great range in the estimates of the viscosity of lava flows. The data for the estimates of the Alika flow were taken where it crossed the road, which is 9 miles from the source. The apparent viscosity of the lava river changed but slightly in the nine miles, although from the preceding article one might expect that the volume of the low-viscosity surface portion of the river was relatively greater near the source than at a point 9 miles away. The figure determined by Palmer[1] may be essentially correct for a lava river near the source. Palmer gave the viscosity of the Alika flow as 15 times that of water. Whether the Palmer value is multiplied by 2, or 3, or even 10, it gives us the order of magnitude of the viscosity and is much nearer the truth than the computations of Nichols.[2] The tremendously high viscosity arrived at by Nichols—4,300,000 times that of water—was largely due to erroneous assumptions in regard to field data. For the Alika flow, he made his computations for a river channel and used a depth that was undoubtedly too great. In his computations on the 1887 flow, he had the flow moving as a unit. This, of course, was not the case.

A rough check on the errors in the Nichols' determination is provided by the data he gives on the temperature of dry melt. The formula he used gave the Alika and the 1887 flows higher viscosities than those of dry melts! Now it is well known, although often overlooked, that to reheat lava and get the same degree of mobility that it had when cooling at, say 650° C., it must be heated several hundred degrees higher. Day[3] gives the difference in temperature for lava in which movement can just be detected and the same lava reheated until it will flow under its own weight as 700° C. This is about the same temperature difference that Rittman[4] believed obtains for similar stages in Vesuvian lava. Shepherd[5] has pointed out the importance of small percentages of volatiles in melts and hence the danger of comparing the viscosity of lava flows with the viscosity of reheated devolatilized or partially devolatilized lavas.

The determinations of viscosity made by Nichols appear to be applicable to the tongue of a lava flow that has about ceased moving, but not to Mauna Loa lava rivers. His value may be too low for a moving lava field devolatilized and away from the river.

[1] Palmer, Harold S. "A Study of the Viscosity of Lava." Bulletin, Hawaiian Volcano Observatory, January 1927, page 1.
[2] Nichols, Robert L. "Viscosity of Lava." Journal of Geology, April-May 1939, page 295.
[3] Day, A. L. "Some Causes of Volcanic Activity." Franklin Institute, 1925, page 5.
[4] Rittman, A. "Oral communication." 1934.
[5] Shepherd, E. S. "The Gases in Rocks and Some Related Problems." American Journal of Science, 1938, page 311.

Hawaiian Volcano Observatory Report for April-June 1943

VOLCANOLOGY

April

April was a month of low seismicity. At Kilauea, 36 seismic disturbances were recorded and at Mauna Loa, 35. None of the shakes was perceptible in the vicinity of the Observatory. The scarcity of earthquakes and a southwest tilt that was less than normal for this season of the year may be taken as indications of rather high internal pressure in the Mauna Loa-Kilauea system. However, despite the scarcity of earthquakes and lack of much tilt, landslides from the walls of Halemaumau were rather frequent.

May

The spell of seismic quiet that marked April continued through May. At Kilauea, 29 seismic disturbances were recorded and at Mauna Loa, 26. An earthquake that originated on the eastern flank of Mauna Loa was felt slightly at widely scattered points in the eastern part of the island of Hawaii at 5:10 a.m. on April 8.

Fume in about the usual amount was observed from the center of Mokuaweoweo on May 29. Several places in the vicinity of the source cone of the 1942 Mauna Loa flow were still quite hot on May 29. The odor of free sulphur was detected at one hot spot about one-quarter mile below the cone. This spot appears to be the place from which conspicuous fume was emitted during the progress of the flow and for a week or two after the eruption ceased.

Along the northwestern edge of the flow, not far from the previously mentioned hot spot, new black aa spatter may be found on the old lava. No cone structure or spatter rampart was built up here and there is little evidence to show where the spatter came from, as the source was buried by a subsequent aa flow. The only clue is the end of a small new crack in the old lava. This crack may be taken as an indication that 1942 lava in an old tube developed sufficient pressure to disrupt the roof at this place and forcibly eject black aa spatter.

June

June is the third month with little seismic activity. At Kilauea, 22 local disturbances were recorded and at Mauna Loa, 15.

After a heavy rain during the latter part of June, the outline of the 1942 Mauna Loa flow was plainly revealed by dense steam clouds. In other words, the 1942 lava, nearly 14 months after the flow ceased, is still hot.

BLOCK LAVA IN THE 1942 FLOW FROM MAUNA LOA

A small patch of block lava may be found in the midst of aa lava near the northwestern edge of the 1942 Mauna Loa flow about one-quarter mile below the source cone.[1] This lava resembles broken brick, having none of the spiny or clinkery surface characteristic of aa. When viewed from a distance, however, its fragmental nature gives it the appearance of aa.

Block lava is distinctly different from slabby pahoehoe. The blocks were formed during the declining days of the eruption by the collapse of the walls of the lava river channel just below the source cone. An appreciable number of the blocks fell upon an aa stream, which transported them to their present position. The uniformity that exists to a greater or lesser degree in the size of the blocks is to be expected when one considers that the thickness of the different flows from which they originated was about the same. Moreover, the larger fragments would be broken during the transportation. R.H.F.

[1] For use of the term block lava, see R. H. Finch, Journal of Geology, October-November 1933, page 769.

SEISMOLOGY

Earthquake Data, April-June 1943

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Local Seismicity*	Tele-seisms
April	4	9	0	0	0	2.25	0
	11	3	0	0	0	0.75	2
	18	16	0	0	0	4.00	0
	25	7	0	0	0	1.75	0
May	2	5	0	0	0	1.25	0
	9	12	1	1	1	6.50	0
	16	11	1	0	0	3.25	0
	23	4	0	0	0	1.00	0
	30	6	1	0	0	2.00	2
June	6	4	0	0	0	1.00	0
	13	4	0	0	0	1.00	0
	20	5	0	1	1	2.75	0
	27	5	0	0	0	1.25	0

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the Island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard. The number preceding each earthquake date is the serial number of the quake for the current year.

26. May 7, 02:09, feeble, felt Kapapala to Hilo, E slope Mauna Loa.
27. May 8, 04:10, slight, generally felt eastern Hawaii, near Mokuaweoweo.
28. May 9, 02:20, very feeble.
29. May 10, 05:20, very feeble.
30. May 30, 12:53, very feeble.
31. June 14, 03:24, very feeble.
32. June 14, 21:38, slight, widely felt island of Hawaii, near Waimea.

TELESEISMS

April 5, 05:51, moderate.

April 8, 21:25, slight.

May 25, 12:50, moderate, distance 8250 km.

May 26, 00:20, slight.

MICROSEISMS

Microseisms were strong on April 10 and 11, moderate on April 28 to 30 and June 10 and 11, and slight throughout the rest of the quarter.

Tilting of the Ground

During the late winter and spring of the year, the southerly tilt was less than normal. The change to northerly tilt occurred about the middle of June. Westerly tilt, which was normal for the first five months of the year, ceased about the middle of May, and the usual easterly tilt began. There was but little movement at the tilt stations near the rim of Halemaumau during the period April to June.

Table of Tilt at Observatory on NE Rim of Kilauea

Week Ended		Amount	Direction
April	4	0.87″	S34° W
	11	1.37″	N63° W
	18	0.51″	N45° E
	25	0.39″	N71° W
May	2	0.88″	S74° W
	9	0.88″	S56° W
	16	0.51″	N45° W
	23	0.76″	S19° E
	30	0.65″	N68° E
June	6	0.60″	S37° W
	13	0.76″	S72° E
	20	0.76″	N18° W
	27	1.08″	N63° E

Crack Measurements

A majority of the cracks in the vicinity of Halemaumau showed slight openings. The opening near the south rim was appreciable in April and May. In June, one of the cracks along the Chain of Craters Road opened 6 millimeters; no movement was detected at other cracks in this vicinity. R.H.F.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION

in cooperation with

UNIVERSITY OF HAWAII

The **Hawaiian Volcano Research Association** was founded in 1911 for record 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 Government, Department of the Interior, National Park Service.

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

The **Volcano Letter**, a quarterly record of Hawaiian volcano laboratories and published by the University of Hawaii, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the above establishments.

THE VOLCANO LETTER

No. 481 | **Department of Interior** | **National Park Service** | **July-September 1943**

PUBLISHED BY THE UNIVERSITY OF HAWAII

HAWAII NATIONAL PARK: Edward G. Wingate, Superintendent; R. H. Finch, Volcanologist

UNIVERSITY OF HAWAII: T. A. Jaggar, Geophysicist

WORK OF UNIVERSITY AND RESEARCH ASSOCIATION

By T. A. JAGGAR

In June, 1938, Dr. T. A. Jaggar, after reviewing twenty-six years of work at the Hawaiian Volcano Observatory, reported in Volcano Letter 460 a planned program for the Hawaiian Volcano Research Association. The plan included making secure the scientific archives, getting the new Observatory building, completing technical publications, creating a publication committee, shifting the volcanologist's work to new hands, and allowing Dr. Jaggar, as Research Associate of the University of Hawaii, to act as editor and writer with the Hawaiian Volcano Research Association collaboration. Various reports on the progress of the plan have been made. Cooperation of the three establishments, Hawaii National Park, University of Hawaii, and Hawaiian Volcano Research Association, was described in Volcano Letter 454, for December, 1937. Dr. Jaggar finished his writing of the "Volcanology" for the quarterly Observatory report of July-September, 1940. "The Physical Plant" of the Hawaiian Volcano Observatory in Hawaii National Park was reviewed by P. E. Schulz in Volcano Letter 475 of January-March, 1942. This issue of the Volcano Letter is a report by the Research Associate of the University of Hawaii on the accomplishments by the University and the Hawaiian Volcano Research Association in accordance with Dr. Jaggar's plan.

The scientific records are being worked over by both R. H. Finch, Volcanologist, and by Dr. Jaggar. The latter has sent two finished memoirs to the Geological Society of America. The new Observatory building at National Park is occupied. The publication committee in Honolulu consists of F. C. Atherton, Gregg M. Sinclair, and T. A. Jaggar. Finch writes, and Jaggar edits the quarterly Volcano Letter published by the University under authority of the National Park Service: its primary function is to maintain a continuous record of the volcano measurements. The making of duplicates of the more valuable volcano records by microfilm, photostat, and carbon copies to be kept at the University has been started.

Some publications appearing later than those listed in Volcano Letter 456 are given below:

PUBLICATIONS OF THE OBSERVATORY

Wentworth, Chester K. *Ash Formations of Hawaii*, Third Special Report of the Hawaiian Volcano Observatory. Honolulu, 1938. (Copies of this volume will be sent to anyone applying for it while the edition holds out.)

Waesche, H. H. *Maui Earthquake of 1938*. Volcano Letter 457, March, 1938.

Philippson, P. and Jaggar, T. A. *Excursion to Nyamlagira Volcano*. Volcano Letter 458, April, 1938.

Verhoogen, Jean. *Eruption of Nyamlagira 1938*. Volcano Letter 459, May, 1938.

Jaggar, T. A. *Planned Program for Hawaiian Association*. Volcano Letter 460, June, 1938.

Waesche, H. H. *An Equatorial Cruise*. Volcano Letter 461, July, 1938.

——— *Chain-of-Craters Earthquakes 1938*. Volcano Letter 462, August-December, 1938.

——— *Time-control of Seismographs*. Volcano Letter 464, April-June, 1939.

Jaggar, T. A. *Expedition to Lava-bombing Site*. Volcano Letter 465, July-September, 1939.

Waesche, H. H. *1935 Lava in Mokuaweoweo Crater*. Volcano Letter 466, October-December, 1939.

Jaggar, T. A. *Exploration NE Rift Mauna Loa*. Volcano Letter 466, October-December, 1939.

Waesche, H. H. *Tilt Changes at Kilauea*. Volcano Letter 467, January-March, 1940.

——— *Mauna Loa Summit Eruption 1940*. Volcano Letter 468, April-June, 1940.

Ballard, Stanley S. and Payne, J. H. *Chemical Study of Kilauea Gases*. Volcano Letter 469, July-September, 1940.

Finch, R. H. *Engulfment at Kilauea*. Volcano Letter 470, October-December, 1940.

——— *The Filling in of Kilauea Crater*. Volcano Letter 471, January-March, 1941.

Williams, Howell and Finch, R. H. *Calderas and Their Origin*. Volcano Letter 472, April-June, 1941.

Finch, R. H. *Volcanic Activity in the Marianas*. Volcano Letter 472, April-June, 1941.

Schulz, P. E. *Tilt Conversion to Seconds of Arc at Hawaiian Volcano Observatory*. Volcano Letter 473, July-September, 1941.

Macdonald, G. A. *Lava Flows in Eastern Puna*. Volcano Letter 474, October-December, 1941.

Schulz, P. E. *Physical Plant of Hawaiian Volcano Observatory*. Volcano Letter 475, January-March, 1942.

Finch, R. H. *The 1942 Eruption of Mauna Loa*. Volcano Letter 476, April-June, 1942.

Duncan, George. *Dug Well at Olaa Mill*. Volcano Letter 477, July-September, 1942.

Finch, R. H. *Surface Ash Deposits at Kilauea.* Volcano Letter 478, October-December, 1942.

——— and Jaggar, T. A. *Lava Surgings in Halemaumau 1924.* Volcano Letter 479, January-March, 1943.

——— *Lava Rivers and Their Channels.* Volcano Letter 480, April-June, 1943.

——— *Viscosity of Mauna Loa Flows.* Volcano Letter 480, April-June, 1943.

PUBLICATIONS IN OUTSIDE JOURNALS

Jaggar, T. A. *A Star Zenith-finder.* Trans. Amer. Geophys. Union, Wash'n. 1938. 60 Pp., illus.

Payne, J. H. and Ballard, Stanley S. *Hydrogen Sulphide at Kilauea 1940.* Science, Vol. 92, 1940. Pp. 218-219.

Ballard, Stanley S. *Solfataric Gases at Kilauea.* Phys. Rev., Vol. 54, 1938. P. 236.

Jaggar, T. A. *Magmatic Gases.* Amer. Jour. Sci., May, 1940. P. 313.

Waesche, H. H. *Ground Tilt at Kilauea Volcano.* Jour. Geol., August-September, 1942. P. 643.

Schulz, P. E. *Summit Eruption of Mauna Loa 1940.* Geol. Soc. Amer. Bul., Vol. 54, 1943. P. 739.

Macdonald, G. A. *Eruption of Mauna Loa 1942.* Amer. Jour. Sci., April, 1943. P. 241.

Eller, W. H. *A New Recording Tiltmeter.* Seis. Soc. Amer. Bul., July, 1939. P. 481.

WORK OF THE UNIVERSITY

The last lecturing to students by Dr. Jaggar was to a class of 70 in July, 1938, and to audiences of 300 persons in the Adult Education Service in March, 1939. Funds were appropriated for special geophysical research in the University by the Territorial Legislature for the biennia 1939-1941, 1941-1943, and 1943-1945, and Dr. Jaggar was appointed Research Associate in charge, to work in collaboration with University departments, the Hawaii National Park, and the Hawaiian Volcano Research Association. After December, 1941, research manuscripts were compiled (to the number of twelve by 1944) and sent to the Government. At regular intervals reports on the geophysical research, including illustrations and laboratory phases, have been made to the President of the University. Laboratory work on "Abrasion Hardness" of substances has been in progress since July, 1942, in a laboratory and shop created by the Association.

The manuscript reports include inventions used in exploration, in seismology, in mineralogy, and in volcanology, which cover a range of activities of the Hawaiian Volcano Observatory from microscope to mountain top, and under the waters of the ocean, from Alaska to New Zealand, and from Italy to Central America. The manuscripts and their illustrations are voluminous, serving in the laboratories to assemble for University use a compendium of forty years of work in geology, and bringing into system what would otherwise have been loose notes. The compendium is matter for scientific recording; publication is gradually being achieved. Samples of such publication are the papers previously listed on ash, magmatic gases, and tilting of the ground. The effort in all this work has been to aim at the principles of comparative volcanology, and not merely to give local description.

Titles of typescripts (the first fourteen written by Dr. T. A. Jaggar) that have been filed are as follows:

1. "Origin and Development of Craters." 843 pages, 93 plates. (Prepared under a grant from the Geological Society of America.)
2. "Expeditions on Certain Hawaiian Beaches." 11 pages, 1 plate.
3. "Conflagration from Earthquakes." 7 pages, 1 plate.
4. "Exploration of Alaskan Beaches." 21 pages, 1 plate.
5. "Mechanical Features of Vehicles for Exploration." 32 pages, 8 plates.
6. "Aleutian Shorelines." 117 pages, 65 plates.
7. "Volcano Explorations in Japan." 120 pages, 49 plates.
8. "Artificial Defense Against Lava-flow Damage." 139 pages, 12 plates.
9. "Expeditions to New Zealand, Tonga, Samoa, and South Sea Islands." 162 pages, 27 plates.
10. "Journals of Caribbean Earthquake Disasters." 276 pages, 36 plates.
11. "Lava Activity of Hawaii Island." 275 pages, 93 plates.
12. "Steamblast Disasters in Caribbean and Pacific." 284 pages, 39 plates. (Received as a memoir by Geological Society of America.)
13. "Volcanoes Around the Pacific." About 1200 pages, with 100 plates selected.
14. "Abrasion Hardness." About 200 pages, with miscellaneous illustrations. (Is in preliminary typescript and photostat.)
15. "Volcano Warfare," by L. W. de Vis-Norton, Secretary-Treasurer of the Hawaiian Volcano Research Association. 15 chapters, 243 pages.

Number 1 is a memoir embodying twenty-six years of experience at the Hawaiian Volcano Observatory, outlining the field of volcano science, and developing some principles of crater evolution. It assembles observations, maps, sections, diagrams, curves, photographs, reviews, and narrative histories of craters. Numbers 2, 4, and 6 deal with the physical geology of Hawaiian and Alaskan shorelines. Numbers 3 and 7 describe explorations among Japanese volcanoes and some disasters due to earthquakes adjunct to volcanic districts. Numbers 5 and 13 have chapters dealing with instrumental invention and special cross-country vehicles designed to apply power engines in exploration instead of pack animals. These publications also describe Pacific and other volcanic activities. Number 8 is a report on the history in Hawaii of an engineering attempt to protect Hilo harbor from lava-flow damage. Number 9 describes expeditions to New Zealand in 1920, Howland and Baker Islands in 1924, and Niuafoou in Tonga in 1930 by Dr. Jaggar, and to six equatorial islands of the Pacific by H. H. Waesche in 1938. It was in 1938 that an earthquake annunciator was experimented with on two of the islands, just as in New Zealand, on Niuafoou, and on Howland portable shock-recorders had been planted for testing seismicity. Number 10 is a comparative study of two earthquake disasters in the field at opposite ends of the Caribbean Sea—the Cartago shocks of Costa Rica in 1910 and the Montserrat spasms of 1933 to 1936. Number 11 is a condensation of Kilauea record books from 1909 to 1935. Number 12 is based on the author's investigation of the Pelée and Soufrière disasters in Martinique and St. Vincent in 1902, and the comparative volcanology of Kilauea, Tarawera, Sakurajima, Katmai, Taal, and Tomboro volcanoes, with especial reference to the reports of wounded persons. Number 13 is a book on twentieth century volcanology. Number 14 is unfinished and dependent on investigations in progress designed to show that physical hardness is probably a fundamental property of the association of particles measurable in terms of kinetic energy. Number 15 is Mr. Norton's book, a popular exposition of field volcano science, admirably suited to magazine publication if it can be illustrated with pen sketches by a good artist.

A sixteenth typescript of importance is a master's thesis entitled "Chemical Decomposition of Rocks at Kilauea" written by K. T. Mau in June, 1940. It includes 103 pages, 13 tables, and 8 figures. This work awaits publication: it investigates relationship between solfataric alteration and final resulting soil. Rock samples were analyzed chemically, microscopically, and spectroscopically. Natural solfatara alteration is examined with reference to decrease and increase of constituents. Decomposition by hot acid steam prolonged for six months artificially included combinations with air, carbon dioxide, and sulphur dioxide. Sulphur dioxide was proved the most active decomposing agent. Methods of analysis are described critically, and the analyses carried to 24 constituents including nickel, copper, chromium, vanadium, strontium, barium, and zirconium. The spectrographic analysis adds cobalt.

These writings are to be issued as scientific memoirs or books as the occasion to publish arises and are in part on their way into print. Other compilations dealing with field and laboratory notes on experiments with volcanoes, experimental geology, graphical position-finding by stars, simplified earthquake recorders, and Aleutian geology are in various stages of manuscript compilation.

The laboratory and offices of this work for the University are divided between 25 Hawaii Hall Annex, which is Dr. Jaggar's Honolulu office, and the Kilauea Laboratory of the University in Hawaii National Park. Dr. Jaggar's annual routine is divided between six summer months at Kilauea and the six winter months in Honolulu. The research associate's personal instruments, tools, and collections from expedition fields are in Honolulu, and the accumulated instruments and records of thirty or more years of the Volcano Observatory are at Hawaii National Park. Cordial assistance is given by the University departments and by the Hawaii National Park. The immediate cooperation of University departments of chemistry and physics at the Kilauea Laboratory was suspended in 1941.

WORK OF HAWAIIAN VOLCANO RESEARCH ASSOCIATION

In 1941, the Hawaiian Volcano Research Association assisted with materials, equipment, and labor in promoting the duplication of records for the University, and in improving the shop of the Kilauea Laboratory and the Chemical Building in Hawaii National Park when the Volcano Observatory was moved. At that time there was great disruption owing to the moving of the hotel to the old Observatory site. The Association has financed illustrations for manuscripts and preparation of collections. In 1941, Dr. Jaggar's assistant at the University was Sutejiro Sato. In 1942, the assistant was Miss Ruth Baker (Mrs. Burton Loucks) who resigned in 1943. Mr. Sato and Miss Baker typed the numerous manuscripts and did valuable work of classification and labelling, assisted in experiments and compiling, as well as in handling much material that required heavy work in the moves from building to building, and from Kilauea to Honolulu and back. The Kilauea laboratories are two buildings distinct from the new Observatory building. Formerly the property of the Research Association, they have since been rebuilt and transferred to the Park Service for the use of the University workers.

The present Board of Directors of the Hawaiian Volcano Research Association consists of: F. C. Atherton, president; W. F. Dillingham and A. L. Dean, vice-presidents; L. W. de Vis-Norton, secretary and treasurer; and C. M. Cooke, J. R. Farrington, W. F. Frear, G. M. Sinclair, W. W. Thayer, and L. P. Thurston. In 1942, there were sixty members and fourteen donors in the Association.

At that time many boxes of records and specimens from expeditions had accumulated. When the crisis of war activity called for suddenly speeded-up laboratory activity in Honolulu there was no room in which to operate. Accordingly, the Association rented a small building near the University where Dr. Jaggar, as their Scientific Director, placed and classified the collections. These included minerals and implements of his own, formerly the subjects of abrasion hardness investigation at Harvard University and the Massachusetts Institute of Technology. A shop was equipped for rebuilding instruments. Throughout 1942 and 1943 a succession of model sclerometers has been tested on specimens of glasses, minerals, woods, and metals.

A paper on the "Hardness of Hawaiian Woods" was read before the Hawaiian Academy of Science October 16, 1942, and a sclerometer was exhibited in the form of a drill-press with a steel milling tool. It was shown that the hardness of substances varied inversely as the depth of boring during a constant interval, the result having been read by micrometer indicator where the pressure and speed were kept constant.

Such model instruments, used where volume abraded under identical conditions is the end sought, are parallel to the devices employed in metal-working where "machinability" is measured. Complexity of the aggregate of particles, whether atoms, molecules, or granules in a bond, and such qualities as sharpness of tool, toughness, brittleness, and viscosity of substances, all make the investigation a prolonged puzzle. Simple indentation is used in metallurgy as a measuring device. This, however, gives inconsistent results, and is quite inapplicable to minerals, rocks, glasses, and porcelains. Progress has been made since the work on abrasion hardness of woods was made public, and it is believed that a device will be worked out that will be fundamentally sound as a physical implement.

Preparation of a manuscript in connection with the subject of abrasion has proceeded with the assembling of matter from modern reference books. It deals with the great recent extension of the grinding industry and the metallurgy of alloys and welding, a science now so important in ship and airplane construction. There is also much need for abrasion measurement of woods, plastics, earthenware, stones, and minerals. Implements are now in use that deal with wear and degradation in commerce, or with ductile or malleable flow, but the aspect in physics of mutual collision-resistance by molecules appears to have been neglected in elementary textbooks.

The results of founding the Hawaiian Volcano Research Association in 1911 were the creation of the Volcano Observatory at Kilauea, establishment of Hawaii National Park, sending forth of Pacific expeditions, extension of work to California, Alaska, and the Caribbean, and obtaining the increasing cooperation of the Federal Government, the University of Hawaii, and outside research establishments. In volcanology, there is the same need for study of the hot interior earth, including the foundation of three-quarters of the earth's surface under oceans, as there is in astronomy for the physical exploration with instruments of the hot stars of the outer universe. The importance of the Research Association's making such field study possible should be emphasized.

As accented in Volcano Letter 454, the greatest need at present is for a fireproof building for valuable records in the University grounds in Honolulu: the records are now scattered in pine buildings. On February 6, 1940, the total destruction of the hotel by fire at Hawaii National Park taught a lesson. The second need in the current situation is a lava diversion channel, constructed according to surveys which have been finished, to defend Hilo from a Mauna Loa flow: the summit eruption of November, 1943, may be the portent of a coming 1945 outflow.

The Research Association is grateful to E. G. Wingate, superintendent, Hawaii National Park, for construction improving the Kilauea laboratories of chemistry and geophysics for University use. Unfortunately, a grant for critical hydrogen study made in 1941 by the Geological Society of America was suspended by the war crisis.

Summarizing joint activities of the last five years, we report memoirs completed, many thick illustrated and bound reports put into use, laboratories extended, publications issued, physical investigations in progress of service to technology made, records duplicated, a popular book sent to a publisher, and collections of specimens from world localities assembled. These are products of the University of Hawaii and the Hawaiian Volcano Research Association. Likewise, the engineering and scientific staff of Hawaii National Park has continued steadfastly its task of accumulating records and meeting crises in the face of untold reduction of resources.

Hawaiian Volcano Observatory Report for July-September 1943

VOLCANOLOGY

July

The spell of seismic quiet that started in April continued through July. Of the 28 seismic disturbances recorded at Kilauea, 2 are classed as earthquakes and the rest as tremors. Thirty-one seismic disturbances were recorded at Mauna Loa.

Following a heavy rain during the afternoon of July 8, steam clouds were conspicuous over the 1942 flow. The outline of the clouds was so sharp that rumors of a Mauna Loa eruption were started.

August

There was less seismic activity in August than in July. At Kilauea, 21 seismic disturbances were recorded and at Mauna Loa, 26.

Several slides from the walls of Halemaumau were noticed during the first half of the month.

September

Eighteen seismic disturbances were recorded at Kilauea and 20 at Mauna Loa.

September marked the sixth consecutive month in which but very few earthquakes were recorded at the Hawaiian Volcano Observatory. This is the longest period of seismic quiet in the history of the Observatory and is probably the longest in the last 120 years.

The present 6 months period of seismic quiet occurs during the longest period without volcanic activity at Kilauea on record. Nearly 9 years have elapsed since molten lava was visible in Kilauea. For about 6½ years no fume has been visible in Halemaumau, and but very little steam has escaped.

R.H.F.

SEISMOLOGY

Earthquake Data, July-September 1943

Week Ended		Minutes of Tremor	Very Feeble	Feeble	Slight	Local Seismicity*	Teleseisms
July	14	9	0	1	1	5.25	0
	11	9	0	0	0	2.25	1
	18	2	0	0	0	0.50	0
	25	3	0	0	0	0.75	0
August	1	5	0	0	0	1.25	1
	8	6	0	1	0	2.50	0
	15	2	1	0	0	1.00	0
	22	5	0	0	0	1.25	0
	29	5	0	0	0	1.25	0
September	5	3	0	0	0	0.75	1
	12	3	0	0	0	0.75	0
	19	6	2	0	0	2.50	4
	26	2	2	0	1	3.50	0

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from seismograph stations operated on the island of Hawaii by Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard, 10 hours and 30 minutes slower than Greenwich. Distances are from the Observatory. The number preceding each earthquake date is the serial number for the current year.

33. July 1, 01:51, slight, felt locally and at Kapapala, near Ainapo.
34. July 3, 04:26, feeble. NE rift Mauna Loa above Puu Ulaula.
35. August 7, 12:40, Puna rift, 17 miles.
36. August 9, 02:14, very feeble.
37. September 13, 12:34, very feeble, near Mokuaweoweo.
38. September 17, 05:11, very feeble, felt Kohala.
39. September 21, 09:04, very feeble.
40. September 21, 16:17, very feeble, Kilauea crater.
41. September 21, 17:19, slight, Kilauea crater.

TELESEISMS

July 11, 15:49, slight.
July 28, 16:45, moderate, distance 7400 km.
September 13, 16:01, slight.
September 13, 17:45, slight.
September 13, 20:59, moderate, distance 5900 km.
September 19, 14:46, slight.

MICROSEISMS

Microseisms were moderate from July 6 to 9 and on July 19. During the remainder of the quarter microseisms were present though slight.

Tilting of the Ground

Westerly tilt prevailed during July and until the latter part of August when easterly tilt set in and continued through September. There was a slight and more or less continuous northerly tilt during the quarter. After having been nearly stationary for several months, the tilt instruments near the rim of Halemaumau showed some oscillations during the latter part of September.

Table of Tilt at Observatory on NE Rim of Kilauea

Week Ended		Amount	Direction
July	4	0.40″	W
	11	0.74″	N10° E
	18	1.12″	N13° E
	25	0.77″	S51° W
August	1	0.77″	N71° W
	8	0.27″	N27° W
	15	0.27″	N27° W
	22	0.48″	W
	29	0.54″	N26° E
September	5	0.17″	S45° E
	12	0.62″	N79° W
	19	1.45″	N48° E
	26	0.54″	S64° E

Crack Measurements

The majority of the cracks around Halemaumau showed no movement during July while most of those along the Chain of Craters Road closed slightly. With the exception of 1 crack which opened 3 millimeters, there was very little movement at the Halemaumau rim in August. The majority of the cracks along the Chain of Craters Road opened slightly. In September there was but very little movement either at Halemaumau rim or along the Chain of Craters Road.

R.H.F.

HAWAIIAN VOLCANO RESEARCH ASSOCIATION
in cooperation with UNIVERSITY OF HAWAII

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

The **Volcano Letter**, a quarterly record of Hawaiian volcano laboratories and published by the University of Hawaii, is issued by authority of the Department of the Interior and supplied to a restricted membership and exchange list of the above establishments.

THE VOLCANO LETTER

No. 482 | Department of Interior | National Park Service | October-December 1943

PUBLISHED BY THE UNIVERSITY OF HAWAII

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ACTIVITY AT MAUNA LOA IN NOVEMBER 1943

By R. H. FINCH

Conspicuous fume clouds over Mokuaweoweo and spells of continuous tremor on the seismographs indicate that there was slight activity at Mauna Loa in November 1943. The first observation of unusually heavy fume arising from Mokuaweoweo was made on October 10 by A. L. Jess from the summit of Mauna Kea. Steam always rises from the west central part of the crater. Mr. Jess made his observations at 6:45 a.m. and reported heavy fume from the southwestern part.

There had been some indications of a sustained and fairly high pressure under the Kilauea-Mauna Loa volcano system for several months. The indications were chiefly lack of southwest tilt in the spring of 1943 and extraordinarily low seismicity from April to the middle of October. Northeast tilt in the fall of 1943 was about the seasonal normal or, at least, not enough to indicate a return of lava to Kilauea. The number of seismic disturbances at Mauna Loa in October greatly exceeded those at Kilauea: they were 33 and 22, respectively. In November the corresponding numbers of seismic disturbances were 93 and 79. The majority of the November disturbances occurred on the 21st, 22nd, and 23rd. The excess of the number of Mauna Loa shakes over those from Kilauea in October and the observed fume on October 10 were definite indications of a growing uneasiness of Mauna Loa. The indications were not definite enough, however, to indicate impending activity at Mauna Loa.

Further evidence of Mauna Loa's uneasiness was the conspicuous earthquake at 5:22 p.m. (war time) November 10, in which movement of a large block in the southwestern slope of Mauna Loa was involved. Then during the morning of November 11, employees of the Puu Oo ranch on the southeastern slope of Mauna Kea observed conspicuous fume clouds over Mokuaweoweo. During the late afternoon of the same day a conspicuous fume cloud over the southern end of Mokuaweoweo was observed from Park headquarters. The fume was observed from the same place a few times on subsequent days.

Like the spells of continuous tremor, the fuming was intermittent. A National Park party was at the summit of Mauna Loa on November 19, and noticed nothing more than rather heavy steaming from the usual vents in the west central part of the crater. Tremor that continued for several minutes at a time became conspicuous on the seismographs on November 21, reached a maximum on November 22, and practically disappeared on November 23. It is interesting to note that a few reports of glow over Mauna Loa at this time were made on days of maximum spells of continuous tremor. The reports of glow would indicate that cracks heated to incandescence were exposed or else small amounts of molten lava reached the surface. The slight amplitude of the continuous tremor indicates that but a small amount of molten lava was involved, whatever the height the lava may have reached in the Mokuaweoweo conduits.

This quiet November 1943 activity brings to mind the possibility of there having been several unrecorded outbreaks in the past. If such activity had occurred when Kilauea was also active, the continuous tremor on the seismographs might well have been masked by harmonic tremor originating at Halemaumau. The continuous tremor of full-fledged Mauna Loa eruptions, having a much greater amplitude, usually overshadows the harmonic tremor from Kilauea. A conspicuous cloud developed over Mokuaweoweo in March 1921 at a time of intense activity in Halemaumau. There must have been, for a short duration, a pronounced increase in temperature of some of the cracks in the floor of Mokuaweoweo. Whether any molten lava reached the surface at that time is not known.

Apparently most, but not all, Mauna Loa summit eruptions have produced spectacular lava fountains. It is not surprising to find reports of a few outbreaks which produced little or no lava. In 1875 there was a short summit eruption in which pronounced glow was lacking. Starting in December 1887, a fume column was observed over Mokuaweoweo for more than a month. The fact that no glow was reported during this time does not necessarily mean that some short-lived glow would not have been observed had cloud conditions been favorable at the time of observation. From the Volcano House on September 10, 1907, about 8 months after the eruption of that year, a black cloud was observed over Mokuaweoweo that lasted for at least 1¾ hours. Some observers reported a glow in the cloud. At 4:00 a.m. September 11, a glow attributed to a lava flow was reported in the vicinity of Red Hill.

Fume and steam, unless dense, is more conspicuous by transmitted light than by reflected light. For instance there is a steam vent between 11,000 and 12,000 feet on the northeast slope of Mauna Loa whose presence is often plainly revealed at the Observatory by the rays of the setting sun in spring and early summer. At other times of the year the steam is seldom if ever seen. As viewed from the Observatory in June, the sun sets nearly behind the vent. Then the ascending steam is sometimes so conspicuous that it resembles lava fountains. It is interesting to note that the fume clouds of November 1943 were mainly observed by reflected light. That is, their presence was easily observed without the magnifying effect afforded by transmitted light at times of sunrise or sunset.

There is a fairly good correlation between summit eruptions and subsequent flank flows. Whether the fuming of November 1943 is to be interpreted as an added indication of a flank eruption within the next two years remains to be seen.

Hawaiian Volcano Observatory Report for October-December 1943

VOLCANOLOGY

October

The seismic lull that started in April 1943 was interrupted about the middle of October by the occurrence of several shakes, most of which were of Kilauea origin. During the month, 22 seismic disturbances were recorded at Kilauea, and 33 at Mauna Loa.

Large dust clouds from landslides were observed over Halemaumau on October 12 and 20.

November

The preponderance of Mauna Loa shakes over those of Kilauea origin in the latter part of October and the first part of November was the only authentic indication of a growing uneasiness of Mauna Loa. The interpretation of the seismograph records of the earthquake of November 10 suggests a rotational movement of a block in the southwest slope of Mauna Loa. Ninety-three seismic disturbances were recorded on Mauna Loa; 79 were recorded at Kilauea. The majority of the disturbances occurred on November 21, 22, and 23, or at the time of the maximum activity of Mauna Loa.

December

A conspicuous fume cloud was observed over Mokuaweoweo on December 19, first from Kona and later from Waimea. However, there were no signs of continuous tremor on the seismographs on this day. On December 25, steam in somewhat greater amount than usual was observed under the high western wall of Mokuaweoweo, but there was no fuming in the vicinity of the 1940 cone or elsewhere in the crater.

The number of seismic disturbances at Mauna Loa again exceeded that from Kilauea, 52 to 38, respectively.

R.H.F.

SEISMOLOGY

Earthquake Data, October-December 1943

Week Ended		Minutes of Tremor	Feeble Very	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
October	3	1	0	0	0	0	0.25	0
	10	1	0	1	0	0	1.25	0
	17	4	0	0	1	0	3.00	0
	24	4	2	0	1	0	4.00	0
	31	5	3	0	0	0	2.75	0
November	7	2	2	0	0	0	1.50	2
	14	7	2	0	0	1	5.75	0
	21	17	2	0	0	0	5.25	1
	28	59	0	0	0	0	14.75	0
December	5	9	2	1	0	0	4.25	0
	12	13	0	1	0	0	4.25	0
	19	5	2	1	0	0	3.25	0
	26	5	1	0	1	0	3.75	1

* For definition of local seismicity, see Volcano Letter No. 371.

The data of the following local disturbances were determined from stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard. Distances are from the Observatory. The number preceding each earthquake date is the serial number for the current year.

42. October 7, 08:50, feeble, Kilauea shake.
43. October 16, 02:36, slight east slope Mauna Kea, felt at Hakalau and locally.
44. October 18, 05:06, very feeble, Kilauea shake.
45. October 20, 02:07, slight, felt locally and at Hilo. Five miles deep under southern end of Kilauea crater.
46. October 22, 18:43, very feeble.
47. October 30, 18:23, very feeble, Kilauea shake.
48. October 30, 19:06, very feeble.
49. October 31, 13:28, very feeble, Kilauea shake.
50. November 4, 00:38, very feeble.
51. November 5, 15:35, very feeble.
52. November 8, 14:15, very feeble, felt in Pahala as a sharp jolt.
53. November 10, 16:18, very feeble, felt at Pahala.
54. November 10, 16:22, moderate, dismantled instruments, widely felt southern half island of Hawaii; stonewalls thrown down southwest of Pahala.
55. November 16, 23:26, very feeble.
56. November 21, 22:51, very feeble.
57. November 29, 13:45, feeble.
58. December 1, 19:52, very feeble.
59. December 3, 11:09, very feeble, lower SW rift of Mauna Loa.
60. December 7, 05:47, feeble, NE rift of Mauna Loa.
61. December 13, 19:43, very feeble.
62. December 15, 08:58, feeble, felt at Pahala.
63. December 18, 21:14, very feeble.
64. December 22, 19:50, slight, felt locally and at Hilo, southwest slope of Mauna Loa.
65. December 24, 01:51, very feeble.

TELESEISMS

November 3, 04:12, moderate, Alaska, 4550 km.
November 5, 22:15, slight, 8000 km.
November 20, 08:56, slight.
December 23, 08:45, slight, 6360 km.

MICROSEISM MOTION

Microseisms were strong on October 8, 16, December 9 to 10, and December 26 to 27, and moderate on November 18, 26, and 27. Throughout the rest of the quarter slight microseisms were recorded.

Tilting of the Ground

Normal northeast tilt prevailed during October, November, and until the middle of December except for the pronounced northwest tilt accompanying the distinct earthquake of November 10. The quake produced a permanent offset to the west in the E-W tilt curve. The sharp northerly tilt due to the quake was followed by a southerly tilt of like amount within about a day.

During 1943 there was a slight accumulation of westerly tilt due largely to the quake of November 10. The total northerly tilt for the year slightly exceeded the southerly.

Table of Tilt at Observatory on NE Rim of Kilauea

Week Ended		Amount of Tilt	Direction of Tilt
October	3	1.21″	N54° E
	10	1.02″	N45° E
	17	1.30″	N22° E
	24	0.78″	N52° E
	31	1.18″	S24° W
November	7	1.85″	N31° E
	14	3.87″	N82° W
	21	0.62″	N11° W
	28	0.48″	S
December	5	0.88″	N16° W
	12	1.48″	S81° E
	19	0.84″	S45° W
	26	0.43″	S34° E

Crack Measurements

Crack movement during the quarter was slight. Five cracks near Halemaumau opened an average of 2 millimeters. The rest of the cracks measured near Halemaumau and those along the Chain of Craters Road were stationary.

R.H.F.

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