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. 471 Department of Interior National Park Service January-March 1941

PUBLISHED BY THE UNIVERSITY OF HAWAII

Hawaii National Park
Edward G. Wingate, Superintendent
R. H. Finch, Volcanologist

NE PLUS HAUSTAE AUT OBRUTAE URBES

University of Hawaii
T. A. Jaggar, Geophysicist

THE FILLING IN OF KILAUEA CRATER

By R. H. FINCH

The net result of the first century of the recorded history of Kilauea Volcano, despite numerous breakdowns, has been a gradual filling of the crater. To facilitate computations of the volume of the uneven filling from 1823 to the present, the areas between convenient contours on the 1922 edition of the Kilauea Crater advance sheet of the U.S. Geological Survey were determined by planimeter. The collapse of 1823 left a comparatively narrow, black ledge around the inner margin of Kilauea Crater. This ledge, 3,400 feet above sea level, was taken as a base. The volume computed from this base plus the amount of the collapse in 1823 would give the total fill since the first recorded visit to Kilauea (in 1823) to the present time. The planimeter measurements indicate that the volumes given in Volcano Letter No. 470 for the collapses in 1823 and 1832 should be increased by about 10 per cent.

The amount of filling can be computed for only a few of the many periods of inflow and tumescence because of lack of adequate data. The volume for the period between 1823 and 1832 would be, to a close approximation, the amount engulfed in 1823 plus a layer 50 feet deep over the entire crater. Just prior to the collapse of 1832, the lava stood 50 feet higher than the black ledge of 1823. The total fill for the period then was about 23,850,000,000 cu. ft. The filling must have taken place within eight years as the lava was at as low a level in 1824 as in 1823, or perhaps a little lower. This would make the average per year about 3,000,000,000 cu. ft. The maximum rate of filling is not readily determinable and was quite likely much higher than the average.

Between 1840 and 1846 a large percentage of the increase in elevation of the crater floor was due to tumescence. However the ratio of the volume due to tumescence to that of inflow cannot readily be determined. In some places a canal or moat that separated the interior platform from the black ledge was 200 feet deep. Because the inner crater was

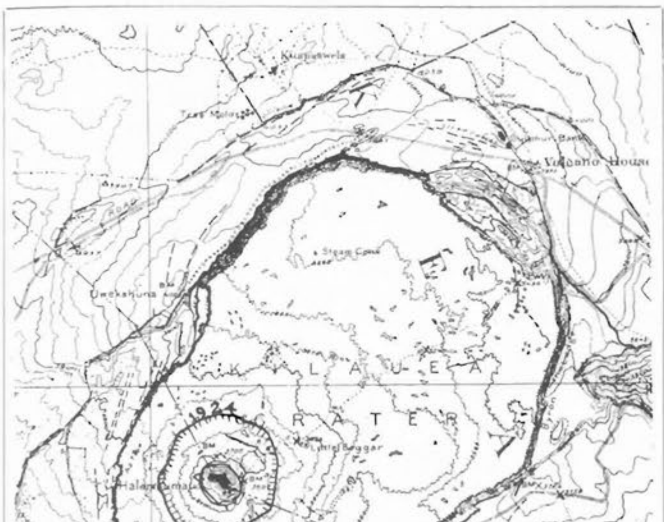
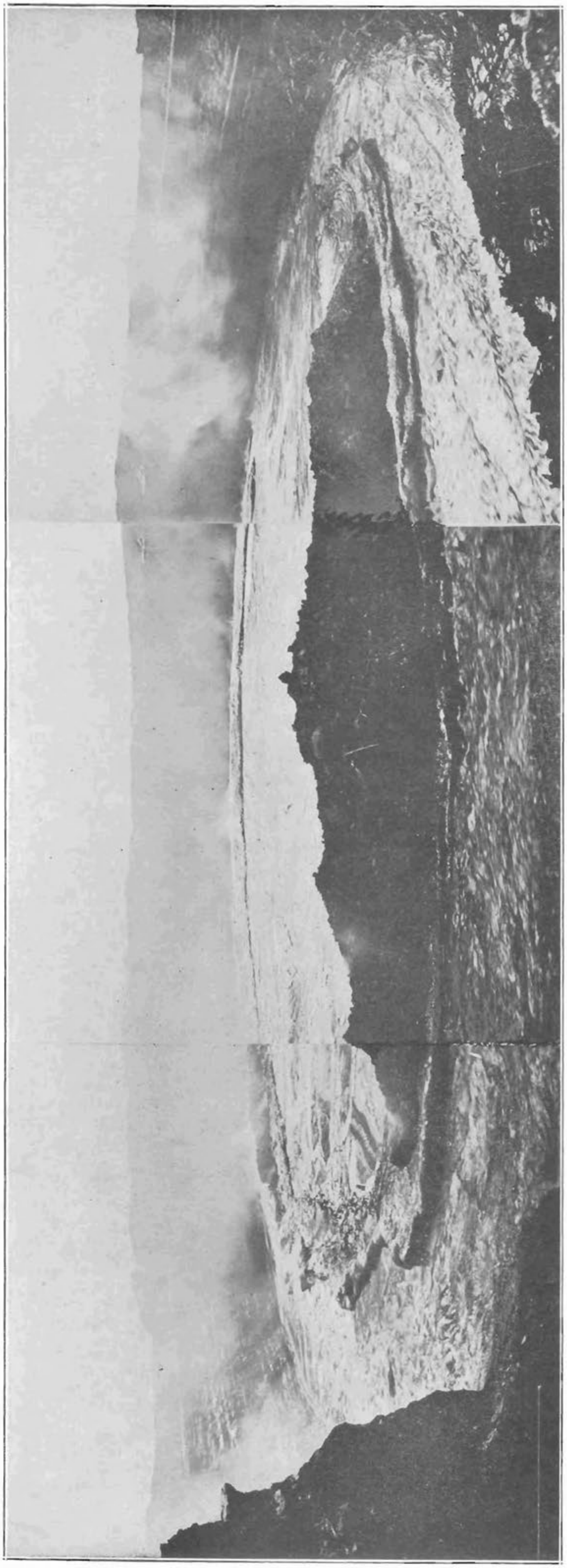


Fig. 1—Map of Kilauea, 1912 to 1924.



funnel-shaped, gaps were left between the resulting interior platform and the walls of the black ledge when the floor was bodily elevated. These gaps were the canals observed in 1844 and 1846 by Titus Coan and Prof. C. S. Lyman. The 200-foot depth of the canal does not necessarily mean that the platform was elevated uniformly through that range. The interior basin may have been elevated much less. Then too, the accumulation of talus blocks around the margin of the lower floor prior to the uplift would have been an important factor in making the margin the highest part of the elevated platform.

Brigham,[1] referring to Lyman's explanation of the canals of 1846, states, "The rise of a cylinder of lava a mile in diameter some 200 feet would be remarkable, but with an overflowing bowl of lava more than a thousand feet in diameter in its very midst the phenomenon would be incomprehensible." But that is exactly what did happen, as correctly explained by Lyman whose visit to Kilauea was at about the end of the tumescing period.

A similar phenomenon was the subject of daily measurements by the Hawaiian Volcano Observatory in 1919. Immediately after the collapse of November 28, 1919, it was noted that the bottom of Halemaumau (see map Fig. 1) was being elevated as a unit. In the lava lake was a ring-shaped island surfaced in many places with talus blocks as shown in Fig. 2. This island montained its identity while the lava column rose vertically 450 feet in 17 days. The upper half of Fig. 3 shows the plan of Halemaumau at the end of the uplift, and the lower half, a section, illustrates the nature of the island and the relation of the superficial lava lakes to the more plastic portions of the lava column. The fact that lava lakes are but comparatively shallow depressions in a pasty plug was not known to Brigham when he wrote.

Tumescing accompanied many, if not all, periods of rapid rise and inflow, but in most cases was not as pronounced as that between 1840 and 1846. The ascensive force of the lava affects not only the more mobile portions of the lava column, but the entire region surrounding Kilauea Crater.[2]

Sometime in 1846 it was observed that the surface of Kilauea was nearly back to its position before the collapse of 1840. This would make the fill of six years about equal to the amount engulfed in 1840, or 7,750,000,000 cu. ft. The average per year would be 1,290,000,000 cu. ft.

Dividing the total fill of several years by the number of years obviously does not give a true rate.

[1] William T. Brigham, **Volcanoes Kilauea and Mauna Loa**, p. 60.
[2] T. A. Jaggar and R. H. Finch, **Tilt Records for Thirteen Years at the Hawaiian Volcano Observatory**, p. 43.

Fig. 2—Halemaumau on Dec. 16, 1919, after a rapid rise from a depth of 591 feet. Photo by T. A. Jaggar.

Observations as to the time of beginning and ending of activity are lacking, and also, in some of the longer periods, one or more years may have been periods of inactivity or even recession. Nevertheless, it is a rough measure of activity. In 1919 the rise took place within 17 days, and the average rate fill for this period if continued for an entire year would have amounted to 2.2 cu. mi.

The 1922 map of Kilauea Crater is substantially correct for 1941 save for the 1924 enlargement of Halemaumau and the subsequent inflows. The least elevation change since 1823, unless it be near the southwest rim of Kilauea, is just below Byron's Ledge. There the present surface is but 100 feet above the back ledge of that year. The greatest depth of fill was a little more than 700 feet, at the rim of Halemaumau.

The total fill between 1823 and 1924 was 70,280,000,000 cu. ft. If we subtract the amount engulfed in 1924, 7,120,-000,000 cu. ft., from this total we will have the net fill up to the time of the inflow of July, 1924, or 63,160,000,000 cu. ft. To this net, however, must be added the total volume of the several inflows into Halemaumau from 1924 to 1934. These inflows have lessened the depth of Halemaumau from 1,335 feet below the rim in 1924 to its present depth of 770 feet. Part of the elevation of the Halemaumau floor has been due to the accumulation of landslides from the walls. It is thought that about 800,000,000 cu. ft. was due to inflows. The net fill between 1823 and 1941 then, is 63,960,000,000 cu. ft. The gross filling between 1823 and 1941 would be the above total plus the amount of engulfments from 1832 to 1922 inclusive, or 101,266,000,000 cu. ft.

The history of Kilauea shows that there has been a diminution in size of the volcanic conduit under the crater floor. In 1823 and 1832 nearly the entire crater floor responded to volcanic pressure changes. Between 1840 and 1846, half the crater floor was bodily elevated indicating plastic material under that much of the crater. Most of the inflows of that period, however, came from the site of Halemaumau, and the canal near the southwest end of the crater was obliterated before there were any appreciable flows in the remainder of the canal. The breakdowns of 1868, 1886, and 1891 showed that the mobile portion of the crater got progressively smaller until from 1891 on, it was confined to Halemaumau and the immediate vicinity. That a mobile lava column still exists under Kilauea is indicated by an accumulation of 17 seconds of northeast tilt at the Hawaiian Volcano Observatory since 1939. Northeast tilt at the Observatory means an increase in elevation of Kilauea mountain.

What happened at Kilauea for many years after the explosive eruption of 1790 is not known, but at least by 1823, 33 years afterwards, there was intense activity over the entire crater. The interval of inactivity after 1790 may have been much less than 33 years, for native accounts given in 1823 said that there had been many lava flows but no explosion since 1790.

If Kilauea continues to be periodic in its activity and repeats the conditions following 1790, the 1924 explosion should be followed by a very active Halemaumau in or before the latter part of this decade.

Hawaiian Volcano Observatory Report for January-March, 1941

VOLCANOLOGY

January 1941

An unusual feature of the month was the continuation of northerly tilt until the last week of the month. Seasonal southwesterly tilt normally sets in about the first of the year. The tearing down of a part of the Hawaiian Volcano Observatory should, apparently, have been effective in increasing the normal southwest tilt.

There were no reports of unusual activity on Mauna Loa and surface activity at Kilauea was confined to rock slides from Halemaumau walls which were frequent January 20-22.

February 1941

A light fume column was visible over Mokuaweoweo at 5:15 pm, February 11. On the morning of March 12, Navy aviators reported heavy fume from the same place.

During the two weeks ended February 16 there was a slight southeast tilt instead of the normal southwest tilt for this time of year. The amount was slight but the actual figures do not tell the whole story. To produce an easterly tilt in February it would appear that some deep-seated pressure change, call-

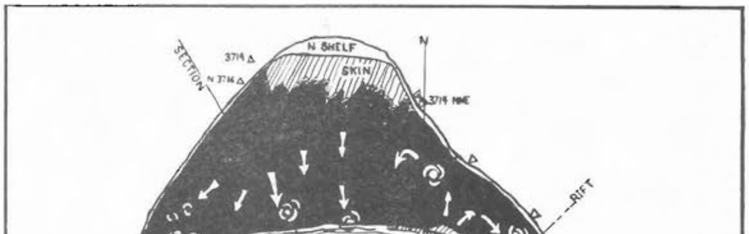


Fig. 3—Plan and section across Halemaumau, Dec. 15, 1919, showing the relation of lava lakes to the viscous and solid material below. From Volcano Observatory records by T. A. Jaggar.

ing for an easterly tilt, must first exceed the seasonal westerly tilt before it can become manifest.

Landslides from Halemaumau have a tendency to occur in groups and this was shown by several on February 17 and 21.

March 1941

Tilting of the ground at the Observatory continued to be erratic in March. In the first ten days the tilt was to the northeast and during the last week it was to the northwest. This means that there will be but little seasonal tilt to the southwest during the first four months of the year. Under normal conditions such a tilt would justify a prediction of volcanic activity but current work on the new hotel adjacent to the seismograph cellar may be affecting the records.

The 1940 Mauna Loa eruption cone was observed to be fuming on March 25.

Some of the local data for January, February, and March are as follows:

Week Ending	Halemaumau Slides	Halemaumau Crack Openings (Millimeters)	Seismic Disturbances
Jan. 5	0	2.5 opening	10
" 12	1	0.5 "	5
" 19	2	0.0	15
" 26	15	2.0 opening	18
Feb. 2	3	1.0 closing	7
" 9	0	3.5 "	15
" 16	1	6.0 opening	11
" 23	4	0.5 closing	21
Mar. 2	0	2.0 opening	7
" 9	0	6.5 "	7
" 16	0	1.5 "	5
" 23	0	0.5 "	7
" 30	0	5.0 "	11

R. H. F.

SEISMOLOGICAL DATA

Earthquakes

Date	Minutes of Tremor	Very Feeble	Feeble	Slight	Distant*	Weekly Seismicity†
January 5	10	0	0	0	0	2.50
" 12	5	0	0	0	0	1.25
" 19	12	2	1	1	1	7.00
" 26	10	8	0	0	0	6.50
February 2	7	0	0	0	0	1.75
" 9	12	1	2	0	1	5.50
" 16	9	1	1	0	0	3.75
" 23	17	3	0	1	0	7.75
March 2	2	5	0	0	0	3.00
" 9	3	4	0	0	0	2.75
" 16	4	1	0	0	0	1.50
" 23	6	1	0	0	0	2.00
" 30	5	6	0	0	0	4.25

* Including teleseisms or earthquakes over 5000 km from Kilauea.
† For local seismicity definition see Volcano Letter 371.

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

January 15, 7:45 am, very feeble, 0.8 mile deep, Chain of Craters between Kokoolau and Devil's Throat. 19° 23.0′ N; 155° 14.6′ W.

January 17, 7:30 am, slight, 14.0 miles deep under W slope of Hualalai near seacoast at Kaiwi Point. 19° 40.3′ N; 156° 03.5′ W. Reported felt at Naalehu, Kailua, Hookena, Hilo, and strongly felt by everyone at Puuwaawaa.

January 18, 9:34 am, feeble, probably originated about 15 miles N of Papaaloa, in general area of earthquakes of summer of 1940 which originated in same region.

January 19, 6:20 pm, very feeble, 11.0 miles deep under E slope of Mauna Loa, 17 miles W of Kilauea Crater. 19° 25.5′ N; 155° 27.8′ W.

January 20, 11:01 pm, very feeble, 4.0 miles deep, 1.7 miles SSE of Volcano Observatory; 0.3 mile S of S rim of Kilauea Iki.

January 21, 2:15 am, very feeble, probably originated SW rift of Kilauea near Hilina Fault.

January 21, 7:24 pm, very feeble, 10.0 miles deep, Mauna Loa NE rift near Puu Ulaula. 19° 33.0′ N; 155° 28.0′ W.

January 22, 3:26 am, very feeble, of shallow origin, Mauna Loa summit crater.

January 25, 3:56 am, very feeble, 15.0 miles deep, 4.0 miles NNW Kailua, W slope of Hualalai on seacoast. 19° 41.0′ N; 156° 01.0′ W. Reported felt at Kailua and Kealakekua.

January 26, 8:42 am, very feeble, 3.5 miles NE Puu Kulua, Mauna Loa NE rift.

February 3, 2:08 pm, feeble, 14.0 miles deep, E slope Mauna Loa, 5.1 miles W of W rim of Kilauea Crater. 19° 25.0′ N; 155° 20.0′ W. Reported felt by many persons in Pahala.

February 8, 9:19 am, feeble, located about 37.0 miles N of Hilo under sea floor; 24 miles NE of Ookala. 20° 10.2′ N; 155° 0.00′ W.

February 11, 9:56 pm, feeble, 60 miles N by E of Hilo. 20° 34.0′ N; 154° 49.0′ W.

February 13, 12:05 pm, very feeble, Kilauea Puna rift area in general vicinity of Kalapana.

February 18, 11:53 am, slight, 30 miles deep, 14 miles E of summit of Hualalai. 19° 41.0′ N; 155° 39.0′ W.

February 20, 12:48 am, very feeble, probably originated 8.5 miles SW of Kilauea Crater in vicinity of Kamakaia Hills.

March 1, 12:16 pm, very feeble, Mauna Loa summit crater.

March 1, 3:46 pm, very feeble, Mauna Loa NE rift, 15.0 miles from Hilo.

March 4, 12:37 am, very feeble, Hilina Fault 7.0 miles W of Kalapana.

March 6, 4:28 pm, very feeble, located at base of NE rim of Kilauea Crater and of shallow origin. Sharply felt at Volcano Observatory.

March 8, 9:14 am, very feeble, Kilauea SW rift near junction with Hilina Fault.

March 13, 12:49 pm, very feeble, Hilina Fault N of Apua Point.

March 22, 5:54 pm, very feeble, located under NE rim of Kilauea Crater.

March 25, 5:57 pm, very feeble, probably originated in the vicinity of Punaluu.

March 30, 0:54 pm, very feeble, located on the SW rift of Kilauea, 0.6 mile beyond the SW rim and 0.6 mile NE of Cone Peak. 1.6 miles deep. 19° 24.1' N; 155° 18.3' W.

March 30, 3:42 pm, very feeble, located 20 miles north of Hilo and 8 miles off shore of Laupahoehoe. Depth 20 miles. 20° 00.8' N; 155° 07.3' W.

March 30, 6:54 pm, same location as earthquake of 3:42 pm.

March 30, 9:23 pm, same location as earthquake of 3:42 pm.

March 30, 11:48 pm, same location as earthquake of 3:42 pm.

H. H. Waesche

Teleseisms

January 13, 6h 08m 03s am, probable distance from Kilauea, 3,480 miles.

February 8, 11h 18m 49s am, distance not readily determined, probably 4,540 miles.

Microseismic Motion

January

Light: 1, 4, 5, 8, 9, 15, 16.
Moderate: 3, 6, 7, 10, 14, 17, 19, 25.
Strong: 2, 11 to 13, 18, 20 to 24, 26 to 31.

February

Light: 17 to 22.
Moderate: 6, 7, 14 to 16, 23 to 25.
Strong: 1 to 5, 8 to 13, 26 to 28.

March

Light: 13, 21 to 23.
Moderate: 2 to 4, 6, 12, 18 to 20, 24.
Strong: 1, 5, 7 to 11, 14 to 17, 25 to 31.

Tilting of the Ground

The following tables show tilt by weeks as recorded by the Observatory seismograph and at Halemaumau, the algebraic sum toward or away from the Pit.

At the Observatory the total accumulated tilt for the year ending on each of the following dates was:

January 26 - 12.22" N and 11.16" E.
March 2 - 10.20" N and 12.64" E.
March 30 - 12.58" N and 10.41" E.

Table of Tilt

Week Ending	Observatory	Halemaumau West Station
January 5	0.95" W	0.00 - - -
" 12	1.49" N 6° W	2.77" N 64° W
" 19	1.80" N 76° W	1.61" S 10° E
" 26	0.77" S 21° W	1.31" N 28° E
February 2	0.91" S 14° W	2.90" S 28° E
" 9	1.82" S 72° E	3.19" S 22° W
" 16	0.73" S 13° E	5.42" N 38° E
" 23	3.44" S 24° W	1.31" S 10° W
March 2	1.88" N 45° E	2.26" S 55° W
" 9	5.53" N 18° E	0.00 - - -
" 16	4.63" S 54° W	2.32" S 6° W
" 23	5.81" S 19° W	1.37" N 21° W
" 30	2.17" N 19° W	0.44° S 16" E

Week Ending	Halemaumau Southeast Station	Pit Resultant
January 5	6.48" S 29° W	2.75" from
" 12	7.87" N 19° E	3.31" toward
" 19	13.93" S 15° E	12.98" from
" 26	3.24" N 31° W	3.28" toward
February 2	3.24" S 30° E	2.24" from
" 9	14.58" N 30° W	13.84" toward
" 16	13.71" S 61° E	8.74" from
" 23	5.83" N 78° W	3.91" toward
March 2	2.85" N 45° E	1.45" from
" 9	5.77" N 30° E	2.27" toward
" 16	3.40" S 2° E	3.37" from
" 23	5.93" S 7° W	4.82" from
" 30	5.93" N 7° E	4.52" toward

H. H. Waesche and P. E. Schulz

Crater Angles

Measurement of horizontal angles across Kilauea Crater from the Observatory, January 14, 1941, indicating closing of the Halemaumau value and opening of the Crater value compared with similar measurements made December 19. The amount of closing of the Halemaumau angle was 1.51" and of opening of the Crater value was 1.09".

Between January 14 and January 30, the Halemaumau angle closed 1.24" and the Crater angle closed 1.26".

Between January 30 and February 17, the Halemaumau angle opened 1.16" and the Crater angle opened 0.09".

Between February 17 and March 4, the Halemaumau angle closed 1.57" and the Crater angle closed 2.17".

Net Halemaumau change December 19 to March 4: Halemaumau 2.16" closed; Crater 2.25" closed.

H. H. Waesche

Kilauea Crater Floor Levels.

A level circuit was run from Spit B.M., S rim of Kilauea Crater, to NW Pit B.M., January 16, 1941. There was no relative change in elevation between these two stations compared with a similar run made September 18, 1940.

Chain-of-Craters Crack Measurements

On the Chain-of-Craters road there have been no appreciable changes in measured cracks except at #108, S rim of Aloi Crater. This crack has opened as follows:

December	27	measurement	was	97.75 cm
January	31	"	"	98.25
February	28	"	"	98.70
March	28	"	"	98.90
Total opening				1.15 cm

Devil's Throat rim cracks indicated only slight changes.

H. H. Woesche

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 investigations. Dr. T. A. Jaggar is their geophysicist resident in the National Park.

The **Volcano Letter,** a quarterly record of the 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. 472 | **Department of Interior** | **National Park Service** | **April-June 1941**

• The Volcano Letter, a quarterly record of the Hawaiian volcano laboratories, 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 Hawaiian Volcano Research Association and the 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, is leased and operated by the United States Government, Department of the Interior, National Park Service.

• The University of Hawaii (T. A. Jaggar, geophysicist) cooperates in maintaining a research laboratory at Hawaii National Park (Edward G. Wingate, superintendent, R. H. Finch, volcanologist). The Association and the University maintain outside seismograph stations and supplement the work of the government with research associates, instrumental plants, and special investigations.

CALDERAS AND THEIR ORIGIN, BY WILLIAMS

Review by R. H. FINCH

Calderas and their Origin, by Dr. Howell Williams, [Bulletin of the Department of Geological Sciences, University of California, Vol. 25, No. 6, 107 pages, 1941], offers geologists a thought-provoking and comprehensive discussion on caldera and crater formation. "Calderas are large volcanic depressions, more or less circular or cirque-like in form, the diameters of which are many times greater than those of the included vent or vents, no matter what the steepness of the walls or form of the floor." A crater is limited to "a constructive apparatus from which ejecta escape to build up positive land forms." It follows then that "calderas are almost invariably large volcanic basins produced by engulfment."

He lists six classes of calderas: 1, explosion calderas; 2, collapse calderas; 3, erosion calderas; 4, volcanic graben; 5, volcanic rents or fissure troughs; and 6, major volcano-tectonic depressions. Erosion calderas are probably included for the sake of completeness as they result from modification of other forms. It will be noted that some form of collapse is present in all classes except for the "rare and relatively small explosion calderas."

Uniformity in names such as Dr. Williams proposes would make for clarity, but it will be some time before all volcanologists will cease to use the word crater in the sense of depressions in the surface of the earth caused by volcanic processes. In some ways it would be more in keeping with the ordinary meaning of caldera if the proposed definitions of caldera and crater were interchanged. At Kilauea it is easy to think of Halemaumau as a cauldron in Kilauea crater.

It is gratifying to see proper recognition given to the splendid work of the geologists of the Dutch East Indies, especially Stehn, van Bemmelen, van den Bosch, and Neumann van Padang. The above are included under the term field volcanologists. This would imply that the other class would be library volcanologists. Williams' interest in calderas was aroused by a visit to Kilauea and subsequently he did extensive work on the Brokeoff caldera in California, the Newberry and Crater Lake calderas in Oregon. He also spent considerable time at the calderas in New Zealand, Dutch East Indies, and Japan.

One of the effects of the paper will be to lay forever the idea that explosions by themselves are competent to account for large calderas. In each case discussed, the volume of coarse lithic debris about the rim is strikingly insufficient to account for the material removed. It is surprising that so slight attention has been paid to the scarcity of the old lithic material around each volcano "that blew its head off," for this scarcity was recognized at Santorin by Fouque published in 1879, and by Diller at Crater Lake published in 1902. Van den Bosch is quoted as saying that it is the scarcity of such lithis debris that "explodes the explosion hypothesis."

That small craters may be due to explosions is accepted. Three examples of known small calderas produced by explosion, Rotomahana in New Zealand, Bondai-san in Japan, and Chaos Crags in California are described.

Before discussing 20 illustrative examples of collapse calderas about whose origin there is but little doubt, three calderas doubtfully ascribed to explosion are discussed. They are the Valles caldera in New Mexico, Aniakachak in Alaska, and Mount Multnomah in Oregon. The Valles caldera with diameters of 17 and 18 miles is "probably the largest caldera in the world." The discussion on these three calderas convinces one that Williams was quite conservative in labelling them "doubtfully ascribed to explosion."

These large calderas, often with rim volcanoes, suggest to the reviewer that the great volcanic arcs, such as the Aleutian, mark portions of ancient subsidence basins with rim volcanoes that were many hundreds of miles in diameter.

Krakatau is taken as the type where engulfment follows repeated and usually short-lived explosions of pumice and juvenile ash. An excellent review of the history of Krakatau is given. On page 262 listing some of the possible causes of the activity there, is the statement that the magma prior to 1883 may have been "potentially explosive owing to a high content of dissolved gases, perhaps absorbed from the walls of the reservoir." The mechanism of such an absorption introduces grave difficulties aside from the relatively small volume of gases available from such a source. Escher's gas-coring hypothesis is inadequate to account for the formation of large calderas and comes in for just criticism.

On page 256 occurs the statement that the earlier small explosions of Krakatau of May 20 "were chiefly of vulcanian type —— whereas the culminating explosions were of pelean type, the overwhelming mass of pumice being deposited with great rapidity as glowing avalanches (nuees ardentes)." This seems to be overworking the term nuees ardentes which by many means a more or less downward component of a pumice-charged explosion and not merely a glowing cloud. Ver Beek and Dana long ago assumed that the caldera at Krakatau was produced by engulfment and to this most of the later workers there, Stehn, van Bemmelen, van den Bosch, Neumann van Padang, Reck, and Williams, agree.

The next caldera discussed is Santarin caldera of Greece. The pioneer studies of Fouque have in the main been verified by the comprehensive work of Neumann van Padang and Reck. Fouque's calculation indicated that the ratio of pumice to old lithic material was about 99 to 1.

Eight pages are devoted to the history of Crater Lake which is in fact but a resume of his monograph on that subject which will appear shortly. The arguments that Crater Lake is due to engulfment should convince the most skeptical of the explosion school. The ancestral cone of Crater Lake is assumed to have had a small crater atop its summit at a height of about 12,000 feet. It would seem that a height of about 10,000 feet could account for the glaciation. The extra 2,000 feet in height would increase the total snowfall but slightly. The top may have been made up of at least two peaks. Such a difference in the original height would decrease the amount of material that disappeared from 17 cu. mi. to about 12 cu. mi. The estimate of the volume of the old lava in the ejecta is not over 2 cu. mi. Hence whether the amount engulfed was 12 or 17 cu. mi. affects his argument not at all. It is exceedingly hard to follow, however, the argument that the "frothy magma was expelled in so great a volume that instead of being thrown high above the cone it rose but a short distance and falling back on the slopes of the mountain rushed headlong in a series of glowing clouds (nuees ardentes)." The distribution of the pumice indicates that wind may have been an important factor in some of the blasts. The "prodigious speed" with which "the avalanches raced down the canyons and spread out on the encircling lowlands for distances as great as 35 miles" may be questioned. Apparently prodigious velocities of translation were not attained in the nuees ardentes (horizontal blasts) at Mt. Pele, Soufriere or Lassen. The velocity of the explosion avalanche at Bandai-san was 48 miles an hour.

The four great calderas of Kyusu, Japan, that lie along a north-south line are next taken up. Of the numerous calderas to be found in Japan these four receive special treatment because of the greatness of their size and because Aso is the only one well known outside of Japan. The smallest of these, Kikai, has an area of 230 km^2. Each has a "central cone," though active vent might be a more appropriate term; Sakurajima, for instance, is at the southern rim of the Aira caldera. The subsidence following the 1914 eruption of Sakurajima is nearly symmetrical about the Aira caldera instead of the Sakurajima cone.

Other cases described under the Krakatau type are Lago di Bolsena in Italy, Mount Gambier in Australia and the Knebel See in Iceland.

Next discussed are calderas whose collapses are occasioned by the lowering of the magma level in the central conduit by dike intrusion injection at depth or lateral outflow at low levels. Kilauea is taken as the type volcano. If explosions accompany the formation of this type, they are phreatic. Sandberg's contention that the walls of Kilauea represent the sides of the original conduit that has progressively grown smaller until it has reached the very small dimensions of Halemaumau is refuted. In defense of Sandberg's idea, however, it should be remembered that nearly the entire crater was active in 1823 and 1832, not, of course, over a conduit of that size but over a network of feeding fissures. Following a collapse in 1840 involving about one square mile, the collapsed area rose bodily in some portions at least 200 feet. Since 1891 the active conduit has been restricted to Halemaumau. The sinking of the lava column in 1919 is attributed to the opening of a lateral fissure. Why not attribute it to a withdrawal into the depths? If there can be deep-seated pressure increase under a volcano, then why not deep-seated decrease?

Stearns is followed in his belief that Mokuaweoweo is the result of the coalescing of small pit craters fluxed and stopped along the rift zone. However, arguments such as one or more peripheral cracks—not parallel to the rift zone—can be produced pointing to a more widespread collapse at Mokuaweoweo.

Other calderas of the Kilauea type discussed are Nyamlagera in Africa, Batoer on Bali, Medorika in the Kurile Islands, Nemrut Golu in Turkey, and Newberry caldera in Oregon.

Katmai is put in a class by itself. The discussion of the volcanoes up to Katmai suggests that there is a unity in the broader aspects of volcanism. General considerations make one question Fenner's rapid assimilation theory as an explanation of Katmai's activity. This theory is considered a possibility though Fenner himself raised four serious objections to it.

The discussion of cryptovolcanic calderas is especially interesting as indicating that vestiges of volcanism may still be found in regions long free from orogenic disturbances and quite deeply mantled with sedimentary deposits. Why subterranean explosions are thought to be a necessary accompaniment of such formations is not clear. A decrease of pressure, probably following an increase, and withdrawal of magma into the depth or dike intrusions could account for most of such depressions. The wide distribution of cryptovolcanic calderas is evidenced by the examples offered: Bosumtwi and Nebiewale of the Gold Coast of Africa, the Pretoria Salt Pan of South Africa, the Steinheim Basin and Rieskessel in Germany, and one each in Indiana, Illinois, Kentucky, Ohio, Tennessee, and Utah.

Glen Coe, Scotland, is taken as the type where a caldera results from the collapse of a large cylindrical block along ring fractures. Other calderas described with distinct ring fracture features are those of Ossipee, New Hampshire; Silverton, Colorado; and Buell-Park, New Mexico.

Stromboli is the type for the volcanic sector graben. The sector collapse here has progressed to the northwest producing a series of terrace-like benches. The Somma-vesuvius system is included in this type. As the Vesuvian cone has been built up near the lower western wall of the Somma caldera formed at the time of the 79 A. D. eruption one wonders why it is placed in this group.

Volcanic rents or fissure troughs are depressions formed on volcanic cones by horizontal movement. Crescentic troughs on several volcanoes of Java appear to be of this origin.

Some very large depressions related to areal eruptions from extensive fissure systems are classed as major volcano-tectonic depressions. Examples in Sumatra and New Zealand are cited. Such crustal collapses in regions without a large central vent edifice are on a vast scale and not readily apparent as such.

After the discussion of specific volcanoes, 16 pages are devoted to a review of the different theories that have been advanced to account for crater and caldera formations. Serious objections are found to all theories except explosion for small calderas and engulfment for large ones.

This caldera paper is an essential part of the library of every student of volcanoes. No single paper excels it in giving so comprehensive a view of the development of volcanic structures.

Hawaiian Volcano Observatory Report for April-June, 1941.

VOLCANOLOGY

April 1941

There was no visible activity at the Hawaiian Volcanoes during April. A glow was reported over the northeast slope of Mauna Loa the evening of April 1st. It is doubtful if it was of volcanic origin as the moon set at about the time and in the direction of the reported light. There were several earthquakes centering at Kilauea during the last 10 days of the month.

May 1941

Landslides were frequent at Halemaumau during the first half of the month. Pronounced southerly tilting that started on March 10, 1941 continued through April and May.

It appears that many of the Kilauea earthquakes occur at origins deeper than was common at times when molten lava was present as some of the feeble Kilauea shakes are reported as perceptible in Hilo.

June 1941

The 1940 cone in Mokuaweoweo continues to fume quite noticeably. Sulphate and sulphurous deposits are locally conspicuous on last year's lavas.

At Kilauea southwest tilt continued throughout the month. The short period irregularities in the tilt curve and the total accumulated tilt in April, May, and June were greater than common for the past several years. In fact the tilt charts for these months and March resemble those obtained prior to 1924 when there was molten lava in Halemaumau.

Some of the local data for April, May, and June are as follows:

Week Ended	Halemaumau Slides	Halemaumau Crack Openings (Millimeters)	Seismic Disturbances
April 6	1	2.0 closing	13
" 13	0	2.0 opening	9
" 20	3	0.5 "	37
" 27	2	4.0 closing	49
May 4	1	0.5 "	27
" 11	3	1.0 opening	13
" 18	0	0.5 closing	15
" 25	1	1.0 "	28
June 1	0	2.5 opening	14
" 8	2	0.5 "	13
" 15	0	0.0	4
" 22	0	2.5 opening	11
" 29	0	0.5 closing	10

R. H. F.

VOLCANIC ACTIVITY IN THE MARIANAS ISLANDS

An observer reports that on the night of March 28-29, 1941, while passing between the two northernmost islands of the Marianas, fire was observed shooting out of the top and lava flowing down from the volcano on Uracas Island. When first sighted the eruption of this volcano appeared as a bright clear light due to apparent refraction, but later, when closer, it appeared bright near the top and dull red farther down the mountain. It was visible about 40 miles at night. (Hydrographic Bulletin July 2, 1941)

April-June, 1941
SEISMOLOGICAL DATA By P. E. Schulz

Earthquakes

Date	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
April 6	10	3	0	0	0	4.00	1
" 13	9	0	0	0	0	2.25	0
" 20	30	5	0	1	1	15.00	1
" 27	38	10	1	0	0	15.50	0
May 4	21	6	0	0	0	8.25	0
" 11	10	2	1	0	0	4.50	1
" 18	13	2	0	0	0	4.25	2
" 25	19	9	0	0	0	9.25	0
June 1	13	1	0	0	0	3.75	0
" 8	8	5	0	0	0	4.50	1
" 15	2	2	0	0	0	1.50	0
" 22	10	1	0	0	0	3.00	0
" 29	5	2	3	0	0	5.25	1

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

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory of Hawaii National Park on the island of Hawaii. A new station was established May 22 on Haleakala, Maui, but no disturbances were recorded there during the quarter. Kilauea earthquakes were located by means of the main seismograph station located at the Observatory and the subsidiary stations on Uwekahuna Bluff and near the SE rim of Halemaumau. The more distant shocks were located with the aid of seismograms from Hilo and Kealakekua. The disturbances began recording at the time indicated, and wherever possible a determination of depth of focus has been made.

The number preceding each earthquake date is the serial number of the quake for the current year.

30. April 3, 10:25 am, very feeble, Mauna Loa NE rift near Puu Ulaula.

31. April 6, 5:22 am, very feeble, Mauna Loa NE rift 15 miles from Hilo Bay, depth 20 miles, 19° 38.1′ N, 155° 19.3′ W.

32. April 6, 5:51 am, very feeble, Mauna Loa NE rift, 19 miles from Hilo Bay, depth 18 miles, 19° 35.5′ N, 155° 20.3′ W. Reported felt by a few persons in bed at "29 miles," 1.5 miles east of the Observatory.

33. April 20, 1:17 am, very feeble, of Kilauea origin, probably some location as No. 34.

34. April 20, 1:34 am, very feeble, 0.4 mile east of Cone Peak on the Kilauea SW rift, 2.3 miles deep, 19° 23.7′ N, 155° 18.3′ W.

35. April 20, 2:40 am, slight, location same as No. 34.

36. April 20, 3:33 am, very feeble, location some as No. 34.

37. April 20, 3:51 am, very feeble, Kilauea SW rift, 0.9 mile from Cone Peak at 3,729 foot B. M.

38. April 20, 4:47 am, very feeble, location probably same as No. 37.

39. April 20, 10:46 am, moderate, 0.3 mile south of Keanakakoi Crater, depth 1.0 mile, 19° 23.9′ N, 155° 16.0′ W. Generally felt in the Kilauea area, Kau, and Kona, and by some persons in Hilo.

40. April 22, 6:04 am, very feeble, origin undeterminable.

41. April 24, 7:09 pm, very feeble, central portion of Kilauea Crater.

42. April 25, 2:23 pm, very feeble, location same as No. 41.

43. April 25, ?:36 pm, very feeble, location same as No. 41.

44. April 26, 8:17 am, very feeble, east flank of Mauna Loa about 8.5 miles north of the Volcano Observatory.

45. April 26, 4:10 pm, feeble, Kilauea Crater, 0.9 mile NE of the center of Halemaumau, depth 0.9 mile, 19° 25.1′ N, 155° 16.9′ W.

46. April 26, 7:13 pm, very feeble, probably Mauna Loa NE rift midway between Hilo and Mokuoweoweo. Reported felt by a few persons in Hilo.

47. April 27, 3:08 am, very feeble, SE rim of Kilauea Crater, 1.6 miles deep, 19° 24.4′ N, 155° 16.1′ W.

48. April 27, 4:47 am, very feeble, SE rim of Kilauea Crater, 0.9 mile deep, 19° 24.4′ N, 155° 16.1′ W.

49. April 27, 7:16 am, very feeble, center of Kilauea Crater, 1.0 mile deep, 19° 25.0′ N, 155° 16.3′ W.

50. April 27, 9:12 am, very feeble, probably north of Kilauea Iki.

51. April 28, 1:04 am, very feeble, origin undeterminable.

52. April 29, 7:08 am, very feeble, Kilauea Crater at the 3,646 B. M. just west of Halemaumau, depth 1.0 mile, 19° 24.7′ N, 155° 16.8′ W.

53. April 30, 10:20 am, very feeble, south rim of Halemaumau, depth 0.8 mile, 19° 24.2′ N, 155° 17.2′ W.

54. May 1, 9:03 am, very feeble, Kaoiki Pali 2.2 miles SW of the Halfway House on the Mamalahoa Highway, depth normal, 19° 20.2′ N, 155° 24.3′ W.

55. May 1, 8:43 pm, very feeble, probably of Kilauea Crater origin depth fairly great.

56. May 2, 10:53 am, very feeble, adjacent to the Mauna Loa NE rift zone 1.0 mile west of Kiipu Cone, depth normal, 19° 33.3′ N, 155° 20.0′ W.

57. May 6, 1:46 am, very feeble, Mauna Loa NE rift, 2.5 miles from Mokuaweoweo Crater, depth 7.5 miles, 19° 31.6′ N, 155° 31.5′ W.

58. May 9, 4:34 am, feeble, east flank of Mauna Loa

half way between Mokuaweoweo and Kilauea Craters, depth about 28 miles, 19° 27.5' N, 155° 27.6' W.

59. May 9, 3:23 pm, very feeble, central Mokuaweoweo Crater, depth 15 miles, 19° 29.0' N, 155° 36.3' W.

60. May 12, 5:10 am, very feeble, of Kilauea origin, exact locality undeterminable.

61. May 13, 3:47 am, very feeble, about 50 miles from the Observatory, off the SE shore of Hawaii probably on the extension of the Puna rift.

62. May 20, 3:10 am, very feeble, NE rim area of Kilauea Crater.

63. May 21, 8:20 pm, very feeble, junction of the SW rift with the SW rim of Kilauea Crater, depth 1.0 mile, 19° 24.1' N, 155° 17.7' W.

64. May 22, 1:59 pm, very feeble, Uwekahuna Bluff of Kilauea Croter, depth 5.0 miles, 19° 25.2' N, 155° 17.4' W.

65. May 22, 2:49 pm, very feeble, Kilauea Crater 0.3 mile NE of Halemaumau, depth 2.7 miles, 19° 24.9' N, 155° 16.8' W.

66. May 23, 8:25 am, very feeble, of Halemaumau origin, depth shallow.

67. May 23, 9:45 pm, very feeble, 0.8 mile SW of Kilauea Crater, depth 0.8 mile, 19° 24.1' N, 155° 18.3' W. Felt by a few persons at "29 miles" and at Hilo.

68. May 24, 11:10 am, very feeble, probably in the north portion of Kilauea Crater.

69. May 24, 6:46 pm, very feeble, east flank of Mauna Loa in the Keawe Wai region.

70. May 25, 6:30 pm, very feeble, 1.4 miles ESE of the Observatory, depth 4.0 miles, 19° 25.8' N, 155° 14.9' W. Felt by a very few persons in Hilo.

71. May 26, 1:49 am, very feeble, south of Halemaumau, depth 0.7 mile deep, 19° 24.5' N, 155° 17.3' W.

72. June 3, 5:35 pm, very feeble, center of Halemaumau, depth 1.0 mile, 19° 24.5' N, 155° 17.0' W.

73. June 4, 7:36 am, very feeble, south of Halemaumau.

74. June 4, 3:18 pm, very feeble, probably near summit of Mauna Loa.

75. June 5, 4:40 pm, very feeble, of Kilauea origin, location undeterminable.

76. June 8, 6:39 pm, very feeble, Mauna Loa NE rift 3 miles SW of Hilo Bay, depth 13.0 miles, 19° 42.7' N, 155° 07.5' W. Felt by a few persons in Hilo.

77. June 12, 9:59 pm, very feeble, 10 miles NE of Cape Kunakaki, 17 miles deep, 19° 39.2' N, 155° 42.5' W.

78. June 14, 1:33 pm, very feeble, east flank of Mauna Loa probably half way between Mokuaweoweo and Kilauea Craters.

79. June 16, 8:34 pm, very feeble, probably Mauna Loa NE rift in the Puu Kulua area.

80. June 24, 11:22 am, very feeble, of Kilauea origin, exact location undeterminable.

81. June 25, 2:35 am, feeble, SE flank of Mauna Loa, 7.7 miles WNW of the Observatory, depth 2.1 miles, 19° 28.9' N, 155° 21.6' W.

82. June 25, 10:54 pm, very feeble, Cone Peak on the Kilauea SW rift, depth 1.3 miles, 19° 23.7' N, 155° 18.6' W.

83. June 29, 6:48 am, feeble, Mauna Loa NE rift zone 4.5 miles NE of Puu Ulaula, depth 8.0 miles, 19° 34.5' N, 155° 26.1' W. Felt by a few persons at "29 miles."

84. June 29, 8:25 am, feeble, Mauna Loa NE rift 2.0 miles SW of Puu Ulaula, depth 7 miles, 19° 31.7' N, 155° 26.3' W.

Teleseisms

April 1, 00h 27m 43s distance undetermined
April 14, 08h 47m 30s distance approximately 3,600 miles
May 7, 11h 59m 05s distance undetermined
May 13, 5h 41m 51s distance 1,750 miles
May 16, 4h 03m 38s distance 5,955 miles
June 8, 8h 00m ?s low amplitude, distance doubtful

Microseismic Motion

	April	May	June
Light	None	2, 14, 19, 24, 26, 27, 29-31	1-3, 7-9, 11, 14-18, 21-26, 29, 30
Moderate	2, 12, 13, 15, 19, 20, 22-25, 28-30	11-13, 15-18 20-23, 25, 28	4-6, 10, 12, 13, 19, 20, 27, 28
Strong	1, 3-11, 14, 16-18, 21, 26, 27	1, 3-10	None

Tilting of the Ground Surface

Several changes have been made in this section of the Seismological Report, which appears at the bottom of this page. It is believed that the changes are justified in that (1) the original data are less manipulated, and (2) the same method is now applied to all 3 tilt stations.

At the Observatory the total accumulated tilt for year ending

April 30: 10.65"N and 10.65"E
May 31: 2.54"N and 10.41"E
June 30: 4.96"S and 7.87"E

MISCELLANEOUS DATA By P. E. Schulz

Crater Angles, Horizontal	Halemaumau Angle	Kilauea Crater Angle
March 4 to April 17	+0.1"	+2.0"
April 17 to May 6	-1.0"	-1.9"
May 6 to June 27	+2.2"	+3.0"
Net Change March 4 to June 27	+1.3"	+3.1"

Kilauea Crack Measurements

During the quarter 3 Halemaumau rim cracks opened 1.0 millimeter each, and 2 opened 1.5 millimeters each; 2 closed 1.0 millimeter each and one closed 1.5 millimeters.

No appreciable changes occurred in the Devil's Throat cracks. Of the remaining Chain of Craters road cracks only #108 parallel to the rim of Alai Crater changed; it opened 1.0 millimeter. Since January 1, 1940, crack #108 has opened 12.5 millimeters.

Week Ending	NE Rim Kilauea Crater			Halemaumau West Station			Halemaumau SE Station		
	Total Amount	Direction	Tilt to (+) or from (−) Halemaumau	Total Amount	Direction	Tilt to (+) or from (−) Halemaumau	Total Amount	Direction	Tilt to (+) or from (−) Halemaumau
April 6	1.61"	S67°W	+1.50"	2.68"	S52°E	+2.00"	2.27"	S13°E	−2.11"
" 13	0.46"	N37°E	−0.44"	1.64"	N7°W	−0.09"	3.73"	S86°E	−2.40"
" 20	2.09"	S21°W	+1.84"	1.49"	S12°W	−0.39"	5.18"	N78°W	+3.92"
" 27	2.61"	S62°E	−0.97"	3.58"	N51°E	+2.92"	0.00"	—	0.00"
May 4	0.52"	N76°W	+0.31"	0.75"	S63°E	+0.67"	2.43"	N79°E	−1.00"
" 11	0.99"	S59°E	−0.33"	6.56"	S17°W	−2.50"	4.54"	N22°W	+4.41"
" 18	2.23"	S12°W	+1.77"	4.62"	N29°E	+2.65"	3.40"	S4°E	−2.88"
" 25	6.22"	S01°E	+3.92"	1.49"	N38°E	+1.01"	3.73"	S9°W	−2.59"
June 1	2.50"	N29°W	−0.52"	1.49"	S45°E	+1.01"	4.54"	N10°W	+4.02"
" 8	3.30"	S04°W	+2.31"	1.49"	N45°W	−1.01"	8.10"	S13°E	−7.39"
" 15	0.65"	W	+0.48"	1.79"	S18°W	−0.72"	8.10"	N13°W	+7.39"
" 22	0.64"	S40°E	+0.12"	1.79"	N72°E	+1.70"	3.40"	S59°E	−3.05"
" 29	0.57"	S65°W	+0.36"	0.75"	N43°W	−0.48"	3.40"	N59°W	+3.05"
	Net tilt toward (+) 10.35"			Net tilt toward (+) 6.77"			Net tilt toward (+) 1.37"		

THE VOLCANO LETTER

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TILT RECORDINGS AT THE HAWAIIAN VOLCANO OBSERVATORY AND THEIR CONVERSION TO SECONDS OF ARC

By P. E. SCHULZ

The measuring and plotting of ground tilt is an important factor in volcanologic studies at the Hawaiian Volcano Observatory. The status of this work is summarized in "Tilt Changes at Kilauea" by H. H. Waesche, Volcano Letter No. 467, January-March 1940.

The purpose of the present article is to show the relationship of the undamped period of the Bosch-Omori seismograph to the conversion factor for stylus displacement to seconds of ground tilt, and the order of magnitude of error in tilt determination which results from the tilting of the instrument itself unless proper corrections are made.

The curve in Fig. 1 was computed for the Bosch-Omori seismograph from the formula developed in "Tilt Records for Thirteen Years at the Hawaiian Volcano Observatory" by T. A. Jaggar and R. H. Finch, Bulletin of the Seismological Society of America, Vol. 19, No. 1, March 1929 which is:

$$\phi = \frac{4\pi^2 L}{g T_0^2} \times \frac{Ds}{Al} = \frac{4\pi^2 \times 25}{978.236 T_0^2} \times \frac{1.0 \times .86}{102 \times 24.5} \times 206265$$

where ϕ is the tilt in seconds, L is the reduced length of the pendulum, D is the displacement of the stylus, s and l are the short and long sides of the pivoted stylus (magnifying arm) respectively, and A is the length of the seismograph boom. The right hand member of the equation is multiplied by 206265 so that the result will be in seconds.

The undamped period of 7.70 seconds of the Bosch-Omori seismograph at Kilauea seems to approach the ideal, for at this value the instrument is a sensitive 2-component tiltmeter whose styli are displaced one centimeter for each 1.21 seconds of tilt, and yet the instrument responds readily to microseisms, tremors, and local earthquakes. It follows that the registry of teleseisms is not all that could be desired, but the registering of teleseisms is a relatively unimportant part of the work of the Observatory.

Changes in the height of the magnifying lever above the recording drum, which occur from occasional instrumental maintenance, result in slight changes in magnifying lever-stylus length l. In the equation given above for the Bosch-Omori seismograph, however, changes of as much as 5 millimeters in this value do not appreciably alter the conversion factor ϕ.

Tilting of the ground itself, however, may be of sufficient magnitude to change the angle i (between the plumb line and the line joining the 2 suspension points) of the pendulum enough to cause appreciable changes in the undamped period of the instrument, and hence in the conversion factor. This condition exists at Kilauea. The 2 largest tilt-change components for short periods are those of 53 seconds to the north May 1918 to January 1919, and 81 seconds to the south December 1923 to July 1924. Had the north-south pendulum period been 7.70 seconds at the outset of each, it would have increased or decreased 0.06 and 0.09 seconds respectively depending on whether the pendulum was hung on the south side or the north side of the support. (The Bosch-Omori instrument at the Observatory has its masses suspended on the south and west sides of the supports). From Fig. 1 the conversion factor changes corresponding to 0.06 and 0.09 are 0.03 and 0.04. The net north-south tilting of the ground between the extremes of 1920 and 1939 was 110.0 seconds and the net east-west tilting between the extremes of 1913 and 1918 was 46.4 seconds. The 110.0-second tilt on a 7.70 seconds seismograph period basis causes a change in period of 0.12 seconds with a factor change, from Fig. 1, of 0.06. The 46.4-second tilt results in 0.04-second period increase or decrease in the east-west pendulum with a 0.02 factor change. The approximate average annual range of ground tilt on the northeast rim of Kilauea Crater is 15 seconds north-south and 5 seconds east-west. Even the largest of these figures results in only a 0.02 second period change which does not appreciably affect the conversion factor.

The north-south component of the Bosch-Omori seismograph was reoriented July 1, 1941 by rotating it clockwise 7½ degrees into a true east-west position. Since the true tilt varies with cosine of the orientation angle it follows that measured north-south tilt values were 99 percent of the true north-south tilt values before the reorientation.

The writer is indebted to Mr. R. H. Finch for suggesting the consideration of this subject.

Hawaiian Volcano Observatory Report for July-September, 1941

VOLCANOLOGY

July 1941

The 1940 cone in Mokuaweoweo was observed to be fuming strongly during the latter part of the month. The solfataric deposits on the 1940 lava showed a noticeable increase.

Two earthquakes that occurred on July 8 had their origin at the junction of Waldron and Byron ledges. This would indicate a slight sinking at the northern end of Kilauea Crater. There is evidence in several places that the crater floor has sunk slightly with reference to the crater walls since 1924.

August 1941.

During August, as for the three preceding months, a majority of the earthquakes recorded on the seismographs at the Observatory originated on the northeast slope of Mauna Loa. The rim cracks around Halemaumau showed a distinct opening during the last week of the month. The normal northeast tilt that did not set in until early in July, about two months later than common, continued through most of August.

September 1941

During the first two weeks in September earthquakes of Kilauea origin predominated. An earthquake on September 25 with origin on the east flank of Mauna Loa, about 15 miles from the Observatory, did considerable damage at Kapapala and Pahala. It was strongly felt all over the island of Hawaii and as far northwest as Oahu. The main shaking merged into a continuous tremor that continued for 45 minutes, quite similar in this respect to the shake of September 14, 1919, with about the same indicated origin.—R.H.F.

July-September, 1941
SEISMOLOGICAL DATA by P. E. Schulz

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseisms
July 6	6	1	0	0	0	2.00	0
" 13	5	4	0	2	0	7.25	0
" 20	8	4	1	0	0	5.00	0
" 27	11	2	0	0	0	3.75	1
Aug. 3	11	12	1	0	0	9.75	2
" 10	9	5	1	0	0	5.75	0
" 17	7	4	0	0	0	3.75	0
" 24	9	2	0	0	0	2.75	0
" 31	16	4	0	0	0	6.00	0
Sept. 7	9	10	0	0	0	7.25	1
" 14	15	6	0	0	0	7.25	1
" 21	10	6	0	0	0	5.50	0
" 28	75	5	3	0	1	28.25	0

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

Epicenters of the following local disturbances were determined by means of seismograms from the stations operated by the Hawaiian Volcano Observatory of Hawaii National Park on the islands of Hawaii and Maui. Kilauea earthquakes were located by means of the main seismograph station located at the Observatory and the subsidiary stations on Uwekahuna Bluff and near the SE rim of Halemaumau. The more distant shocks were located with the aid of seismograms from Hilo, Kealakekua, and Haleakala (Maui). The disturbances began recording at the Hawaiian Standard time indicated, and wherever possible, a determination of depth of focus has been made and is given relative to a horizontal plane of 4000 feet elevation passing approximately through the Observatory.

Building construction at the Observatory causing occasional disruptions such as stoppage of the master clock, of the automatic relay circuit, of the seismographs, and of the reception of the radio time signal has rendered the earthquake times given below inaccurate after August 5, 1941.

The number preceding each earthquake date is the serial number of the quake for the current year.

85. July 2, 01:11, very feeble, Mauna Loa NE rift, 1 mile NE of Puu Ulaula, depth 4.8 miles.

86. July 8, 10:14, slight, felt by many persons at Kilauea, NE rim of Kilauea Crater at the junction of Waldron's and Byron's Ledges, depth 0.7 mile.

87. July 8, 20:02, slight, felt generally in the Kilauea area, stronger than No. 86. Location and depth the same.

88. July 9, 15:25, very feeble, NE rim of Kilauea Crater near the Observatory.

89. July 9, 17:53, very feeble, probably on the Mauna Loa NE rift 19 or 20 miles from Hilo.

90. July 11, 21:30, very feeble, probably Mauna Loa NE rift near Hilo, of deep origin.

91. July 12, 17:46, very feeble, SW rim of Kilauea Crater 0.5 mile from the center of Halemaumau, depth 1.0 mile.

92. July 14, 02:40, very feeble, Hilina Pali fault zone about 4 miles south of Kamakaia Hills.

93. July 16, 04:25, very feeble, generally felt in Kona, just north of Akahipuu on the west Hualaloi slope, depth 18.5 miles.

94. July 17, 05:16, very feeble, central portion of Kilauea, of shallow origin.

95. July 18, 05:21, very feeble, Mauna Loa 1.0 mile NE of Kiipu Cone, depth 6 miles.

96. July 19, 07:44, feeble, Mauna Loa NE rift, 20 miles from Hilo, felt by few persons in Hilo, depth 8 miles.

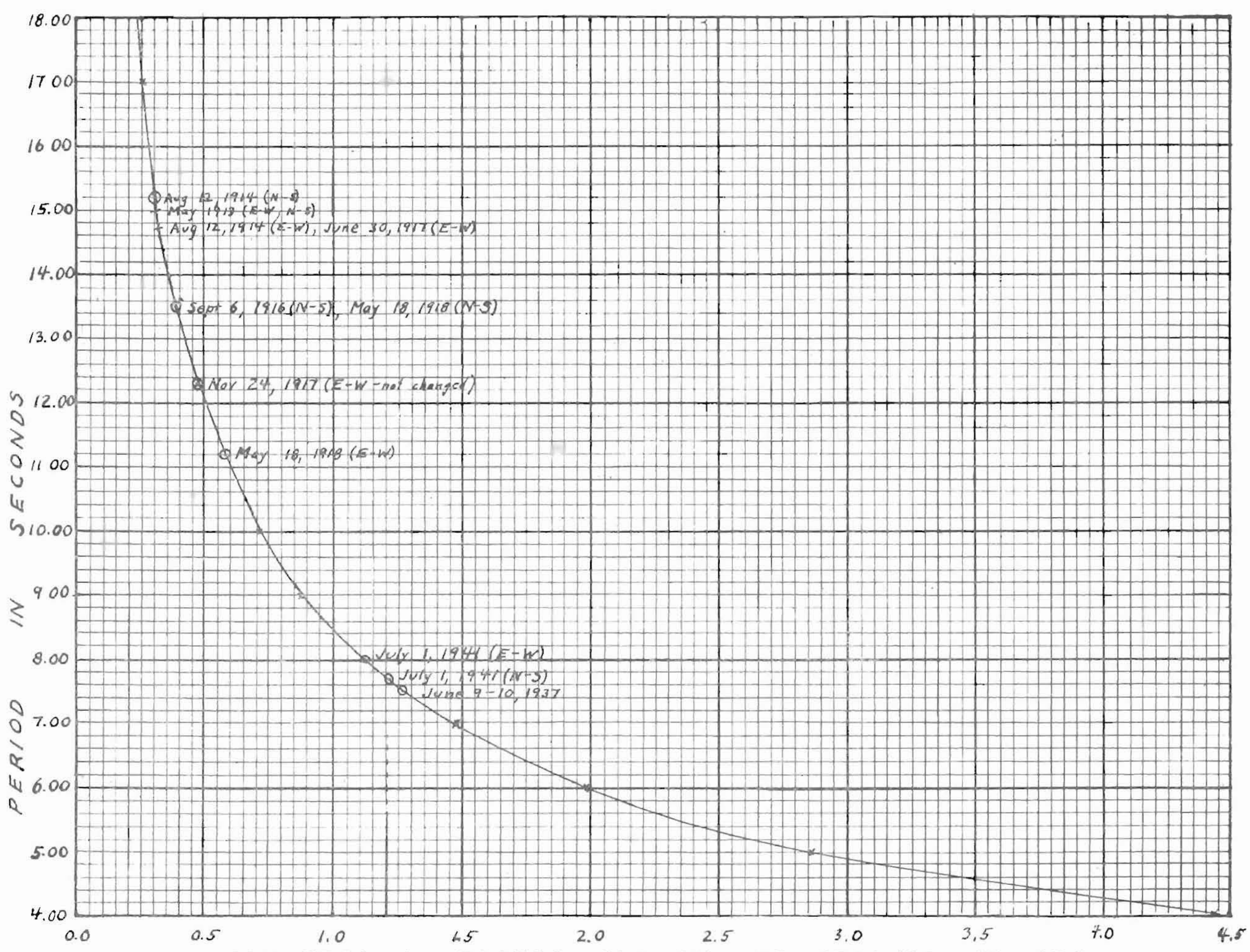

Fig. 1. Curve computed for the Bosch-Omori Seismograph pen arm displacement resulting from tilting of the ground.

97. July 21, 13:20, very feeble, Mauna Loa NE rift, 4 or 5 miles of Puu Ulaula, depth about 8 miles.

98. July 25, 13:31, very feeble, Kaoiki fault, 3.3 miles west of 3913 BM, Kilauea SW rim, depth 2.7 miles.

99. July 28, 03:07, very feeble, 1.1 miles ENE of Puu Ohale, depth 2 miles.

100. July 28, 07:31, very feeble, summit of Mauna Loa, 1.2 miles west of Mokuaweoweo, depth about 15 miles.

101. July 28, 08:32, very feeble, Mauna Loa, probably in the summit area, depth moderate.

102. July 30, 17:14, very feeble, Kilauea Crater area, of shallow origin.

103. August 1, 05:50, very feeble, Hilina Pali fault system, 3.0 miles NW of Apua Point, felt by a few persons in Hilo, depth 9 miles.

104. Aug. 2, 07:56, very feeble, Kilauea Crater, 0.2 mile west of Byron's Ledge, depth 1.0 mile.

105. Aug. 2, 10:30, very feeble, east flank of Mauna Loa, 5.3 miles NW of Uwekahuna, felt by a few persons at "29 miles," 1 mile east of the Observatory, depth 4.3 miles.

106. Aug 2. 13:21, very feeble, of Halemaumau origin, shallow depth.

107. Aug. 2, 20:09, very feeble, SW rim of Kilauea Crater, shallow depth.

108. Aug. 3, 11:16, very feeble, Puna rift, 0.1 mile NW of Devil's Throat, depth 1.5 miles.

109. Aug. 3, 12:43, very feeble, Puna rift, 0.1 mile east of Kokoolau Crater, depth 1.4 miles.

110. Aug. 3, 21:00, very feeble, probably along the Puna Rift near Kilauea Crater.

111. Aug. 3, 23:29, feeble, Puna rift, 0.2 mile north of Kokoolau Crater, depth 1.5 miles.

112. Aug. 4, 01:28, feeble, Puna rift, Kokoolau Crater, of shallow depth.

113. Aug. 4, 01:31, very feeble, Kilauea Crater probably near Byron's Ledge, shallow depth.

114. Aug. 5, 11:14, very feeble, probably Mauna Loa NE rift 4 or 5 miles NE of Puu Ulaula.

115. Aug 6, 17:15, very feeble, of Kilauea origin, possibly near the NW rim of the Crater.

116. Aug. 8, 22:28, very feeble, probably Mauna Loa NE rift area about 5 miles NE of Puu Ulaula.

117. Aug. 10, 09:32, very feeble, summit of Mauna Loa, 1.2 miles NE of Mokuaweoweo Crater, depth 12 miles.

118. Aug. 12, 22:40, very feeble, Mauna Loa NE rift, 8.0 miles NE of Puu Ulaula, depth 6 miles.

119. Aug. 14, 03:09, very feeble, Kilauea east flank 4.0 miles WSW of Pahoa, depth 16 miles.

120. Aug. 15, 17:?, very feeble, Mauna Loa NE rift probably about 6 miles NE of Puu Ulaula.

121. Aug. 17, 00:02, very feeble, Mauna Loa NE rift, Pukauahi Crater, depth 6 miles.

122. Aug. 22, 09:36, very feeble, Kilauea Crater, originated in the Halemaumau area at shallow depth.

123. Aug. 22, 11:04, very feeble, same as No. 122.

124. Aug. 27, 16:10, very feeble, probably in the vicinity of Hilea.

125. Aug. 28, 04:37, very feeble, Hilo 2.3 miles NW of the center, depth about 20 miles, felt by a few persons.

126. Aug. 30, 04:17, very feeble, Kilauea Crater, probably east central portion, of shallow depth.

127. Aug. 30, 17:56, very feeble, Kealakekua Bay, felt by a few persons in Kona, depth probably about 4 miles.

128. Sept. 1, 03:59, very feeble, Kilauea Crater central portion, felt by a few persons at Kilauea and "29 miles," of shallow depth.

129. Sept. 2, 01:10, very feeble, SE rim of Kilauea Crater, depth 0.8 mile.

130. Sept. 2, 10:08, very feeble, central Kilauea Crater, of shallow origin.

131. Sept. 2, 23:47, very feeble, probably 21 miles N of Hilo, depth 10 or 12 miles.

132. Sept. 5, 14:59, very feeble, 2.6 miles W of Uwekahuna near Kaoiki Pali, depth probably 10 miles.

133. Sept. 5, 21:26, very feeble, probably Puna rift near Heiheiahulu Crater.

134. Sept. 6, 18:34, very feeble, SE rim of Kilauea Crater 0.3 mile from Byron's Ledge junction, depth 3.5 miles.

135. Sept. 7, 03:20, very feeble, Kilauea Crater 0.2 mile SW of Halemaumau, depth 1.0 mile.

136. Sept. 7, 14:41, very feeble, pali NW of Kaoiki fault 3.9 miles west of Uwekahuna, depth 3.4 miles.

137. Sept. 7, 19:26, very feeble, Kilauea Crater, 0.2 mile south of 3646 BM, depth 0.8 mile.

138 Sept. 8, 09:20, very feeble, probably east central portion of Kilauea Crater.

139. Sept. 8, 16:25, very feeble, east rim of Keanakokoi Crater, depth 2.7 miles.

140. Sept. 8, 17:29, very feeble, NE portion of Kilauea Crater.

141. Sept. 9, 08:35, very feeble, 0.2 mile SE of Kilauea Crater near Keanokakoi, depth 1.5 miles.

142. Sept. 11, 15:17, very feeble, Kau Desert, 0.4 mile north of Cone Peak, depth 6.8 miles.

143. Sept. 14, 11:57, very feeble, probably NE central portion of Kilauea Crater.

144. Sept. 15, 01:48, very feeble, 2.0 miles east of the Observatory.

145. Sept. 16, 01:51, very feeble, 2.0 miles west of the south end of Pauahi Crater, depth 2 miles.

146. Sept. 18, 12:24, very feeble, probably of Halemaumau origin.

147. Sept. 19, 00.04, very feeble, SW portion of Mokuoweoweo Crater, depth 19 miles.

148. Sept. 19, 19:13, very feeble, NE portion Kilauea Crater.

149. Sept. 21, 16:42, very feeble, 0.3 mile SW of the center of Halemaumau, depth 1.7 miles.

150. Sept. 25, 02:07, very feeble, center of Kilauea Crater, depth 1.5 miles.

151. Sept. 25, 07:18, moderate to strong, SE flank of Mauna Loa 4.0 miles north of Kapapala Ranch House, depth 7.0 miles. Felt sharply over the whole island of Hawaii and by some persons in Honolulu. Dismantled all seismographs on the island of Hawaii (low magnification instrument not in operation) and at Haleakala on Maui. Several thousand dollars worth of damage done at Pahala where safes were moved over 1 inch northward, plaster cracked, pipes were sprung, roadfills cracked and some shoulders failed, furniture overthrown and dishes were broken in homes, pharmaceuticals at the Pahala hospital, chemicals in the Pahala Sugar Laboratories and package goods in stores were thrown from shelves. Some persons were injured in flight from houses. At Kapapala Ranch two windows and many dishes were broken, several stone walls were partially thrown down. No disturbance of the sea was reported observed at Punaluu. At Kealakekua a few books were thrown from shelves but no damage was reported. Boulders were shaken loose from steep slopes at the head of Wood Valley and on Hilina Pali. Numerous slides from Halemaumau's walls caused great dust clouds, but no damage was reported in the Kilauea area. Hilo also was strongly shaken but with only slight effect; an old earthquake crack in one building reopened. Residents in the Pahala and Kapapala area were agreed that this earthquake was stronger than any since 1929 and many claimed it was the strongest in 30 to 50 years.

152. Sept. 25, 07:30, feeble, approximately same location as No. 151, but probably deeper, sharply felt at Pahala and Kapapala.

153. Sept. 25, 07:43, feeble, probably near Ainapo, depth perhaps 20 miles, sharply felt at Pahala and Kapapala.

154. Sept. 25, 08:28, very feeble, 2.0 miles NE of Kapapala Ranch house, depth 7.0 miles, felt generally at Pahala and Kapapala.

155. Sept. 25, 09:51, very feeble, Kilauea Crater, probably of shallow Halemaumau origin.

156. Sept. 25, 10:54, very feeble, same as No. 155.

157. Sept. 25, 13:25, very feeble, SE flank of Mauna Loa, 4.0 miles NNW of Kapapala Ranch house, depth 7.0 miles, felt by many persons at Kapapala and Pahala.

158. Sept. 28, 14:11, feeble, Mauna Loa NE rift near Puu Ulaula, depth of the order of 20 miles; felt by some persons in Hilo and at "29 miles."

159. Sept. 30, 11:32, very feeble, Kilauea Kau rift 0.6 mile SE of Cone Peak, depth 2.3 miles.

160. Sept. 30, 11:32, feeble, Kilauea SE rim just SW of Keanakakoi Crater, depth 3.7 miles.

161. Sept. 30, 12:28, slight, Kilauea Kau rift, 1.2 miles SW of Cone Peak, depth 2.0 miles.

Teleseisms: Hawaii Standard time of first wave arrival used; J. S. A. data gives time of origin in Greenwich Time.

July 26, 09: 41 (?), unidentified phase; J. S. A. provisional data 20: 11: 21, 19°.1 N, 142°.2 E.

July 29, 15: 29, weak, undetermined, short period; J. S. A. data 01: 51: 28, 60°.7 N, 149°.5 W, shallow.

Aug. 2, 01: 21, distance 3775 miles; J. S. A. data 11: 41: 25, 30°.3 S, 177°.8 W possibly fairly deep.

Sept. 4, 00: 01, undetermined, recorded at Pasadena.

Sept. 13, 08: 03, undetermined.

Microseismic Motion

	July	August	September
Light	1—31	1—31	1-4, 7-30
Moderate	None	None	5, 6
Strong	None	None	None

Crater Angles, Horizontal: Measured from the 3974-foot bench mark on the NE rim of Kilauea Crater. Between June 27 and July 22, the Halemaumau angle closed 0.5" while the Kilauea Crater angle opened 3.5". Additional measurements were prevented by construction and weather conditions.

Kilauea Crater Levels

A level circuit was run from the SE crater rim to the Spit BM. From thence it was run via the Pit Seismograph counter clockwise around Halemaumau in a complete circuit. The results show an appreciable decrease in elevation of points adjacent to Halemaumau with respect to the Spit BM. Between January 16 and August 14-25, the level changes were:

South side crack #43	— 0.060 meter	(.1969 feet)
NW Pit BM	— 0.035 meter	(.1148 feet)
West Tilt Station	— 0.032 meter	(.1050 feet)
Pit Side Crack #40	— 0.029 meter	(.0952 feet)
Pit Seismograph BM	— 0.031 meter	(.1017 feet)

Crack Changes

On Friday of each week, 28 stations on rim cracks around Halemaumau were measured. During the quarter, there was a general increase in both the number of and amount of crack changes, especially in the case of openings. The total of 41 measured crack openings for the quarter amounted to 34.5 millimeters. Of these the least weekly opening was measured on July 25 and August 1, when in each instance only one crack opened 0.5 millimeter. Largest crack openings were recorded August 29, when 7 cracks opened 4.0 millimeters and September 26, when 7 cracks opened 13.5 millimeters. The largest opening unquestionably resulted from the earthquake of September 25. The total of 38 measured crack closings during the quarter amounted to 21.5 millimeters. July 4 revealed no closing; greatest closing was recorded September 26, when 8 cracks closed 6.5 millimeters.

Monthly measurements of 9 Chain of Craters cracks also showed progressive openings: July 25, none opened, and 3 closed 1.5 millimeters, on August 29, 3 opened 4.5 millimeters, and none closed, and on September 26, 6 opened 5.5 millimeters, and one closed 2.0 millimeters.

The Aloi rim crack showed a uniform rate of opening during the entire quarter save the last week in September when an opening of 7.0 millimeters was recorded due no doubt to the earthquake of September 25. The total opening of this one crack for the quarter was 15.5 millimeters.

The 5 rim cracks around Devil's Throat showed no appreciable change.

Tilt

The following tables give a summary of the tilting of the ground as measured at 3 stations on the summit of Kilauea Volcano. The ** sign indicates approximation only because of loss of tilt records from September 14 to 28 resulting from reconstruction in the seismograph cellar.

Week Ending	Tilt NE Rim Kilauea Crater			Tilt Halemaumau West Station			Tilt Halemaumau SE Station		
	Total Amount	Direction	Tilt to (+) or from (—) Halemaumau	Total Amount	Direction	Tilt to (+) or from (—) Halemaumau	Total Amount	Direction	Tilt to (+) or from (—) Halemaumau
July 6	1.67"	S11°W	+1.32"	3.10"	N29°E	+1.79"	1.61"	S60°E	—1.46"
" 13	1.28"	N48°W	+0.16"	1.49"	S45°W	—1.19"	3.56"	N39°W	+3.56"
" 20	1.21"	N12°W	—0.59"	1.49"	N45°E	+1.19"	4.99"	S86°E	—3.24"
" 27	2.47"	N39°W	—0.08"	0.00"	—	0.00"	23.98"	S15°E	—22.49"
Aug. 3	2.42"	N3°W	—1.46"	3.93"	S38°E	+2.18"	19.12"	S17°E	—17.30"
" 10	6.57"	S9°E	+3.47"	1.97"	N35°W	—0.98"	9.56"	N10°W	+8.59"
" 17	1.78"	S86°E	—1.28"	0.00"	—	0.00"	5.38"	N43°W	+5.38"
" 24	1.21"	N38°W	—0.04"	0.00"	—	0.00"	1.65"	N18°W	+1.59"
" 31	2.53"	N32°W	—0.41"	0.00"	—	0.00"	6.93"	N15°E	+4.47"
Sept. 7	2.93"	S55°W	+2.93"	3.22"	N26°E	+1.70"	3.11"	N9°W	+2.85"
" 14	1.91"	N86°E	—1.52"	1.37"	S44°E	+0.86"	1.91"	S64°E	—1.75"
" 21	Tilt undeterminable			1.58"	S49°W	—1.28"	0.00"	—	0.00"
" 28	Tilt undeterminable			8.46"	N88°E	+8.46"	25.69"	N35°W	+25.69"
Quarter Ending Sept. 28	Net tilt toward (+)2.03"**			Net tilt toward (+)12.73"			Net tilt toward (+)5.89"		

NE Rim Kilauea Crater

Year Ending	Total Amount	Direction	Tilt to (+) or from (—) Halemaumau	Net N-S Tilt	Net E-W Tilt
July 31	8.75"	S46°E	—2.11"	6.17"S	6.29"E
Aug. 30	11.95"	S16°E	+5.07"	11.50"S	3.27"E
Sept. 30	12.62"**	S 3°W**	+8.76"**	12.58"S**	0.73"W**

THE VOLCANO LETTER

No. 474 Department of Interior National Park Service October-December 1941

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LAVA FLOWS IN EASTERN PUNA

By GORDON A. MACDONALD
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Introduction. Only once since the beginning of written records in Hawaii have lava flows inundated part of eastern Puna. That once was in 1840. But there is ample evidence that in geologically recent times Puna has often been the site of eruption of cinder cones and extensive lava flows. More than sixty cinder and spatter cones dot the east rift zone of Kilauea volcano from the end of the Chain of Craters Road to Cape Kumukahi. Some are 150 to 200 feet high and half a mile or more in diameter, and others are mere hillocks. It is probable that all of the surface lavas throughout this region should be considered geologically Recent, but many of them are of such late date that it is surprising not to find more mention of them in native tradition. Few references to prehistoric lava flows have been preserved by the Hawaiian chroniclers however, perhaps because eruptions were so commonplace.

Much of the northeastern slope of Kilauea between the towns of Olaa and Pahoa is covered by flows of pahoehoe basalt that cannot be more than a few hundred years old. Not only are they nearly devoid of any soil or ash cover, but the vegetation which covers them is often scant and is of the type composed largely of small ohia trees and abundant staghorn fern which characterizes the younger lava flows, such as those of 1793 (?) and 1840. Through these younger lavas protrude **kipukas**, or "islands" of older rock, covered by several inches of ashy soil and the tree-fern jungle which typifies the more mature forests of Puna. Although these late lavas must certainly have been erupted within the time of residence of the present Hawaiian people, who are believed to have arrived in the islands about 1100 A.D.,[1] no mention of them is found in native tradition.

Traditional prehistoric eruptions. A few eruptions recorded by tradition before the arrival of the missionaries in 1820 may be mentioned. The dates are, of course, uncertain. The earliest is an eruption near Kapoho, probably between 1340 and 1380 A.D.[2] This eruption is incorporated in a legend which relates how Pele, goddess of volcanoes, attended in disguise a great **holua**, or sliding contest, held near Kapoho by Kahawali, the chief of the neighborhood. Challenging Kahawali to a race, Pele was badly beaten. She then asked the chief to lend her his sledge so that she might try again. When he refused, the angry goddess stamped upon the earth, and there burst forth showers of heated rocks. Realizing too late the identity of his competitor, the chief fled panic-stricken to Puu Kukii and then northward to the coast, pursued all the way by Pele's magmatic missiles. A crack trending N 60° E, which still exists between Kapoho and Koae, is said to have opened up before him, but he crossed it by laying down his spear for a bridge. Not until he had paddled far out to sea did he escape.

Translating this story into terms of the modern volcanologist, a flank eruption of Kilauea appears to have commenced with the opening of a fissure and the ejection of cinders at Kaholua o Kahawali (Kahawali's holua-slide). As the fissure opened farther and farther down the flank of the mountain the eruption progressively shifted farther seaward, building the line of small cinder and spatter cones which terminates at Kapoho.

Another eruption is said to have occurred near Kaimu in the reign of Alapai, probably between 1730 and 1754.[3] This eruption probably produced the fresh-appearing aa flow crossed by the Pahoa-Kalapana road a mile north of Kaimu. At this altitude the lava is covered only by lichens and moss, and appears as fresh as the 1922 lava in Napau Crater. But farther mountainward, in regions of greater rainfall, it supports thick vegetation, although not much more than the 1793 (?) and 1840 lavas.

Eruption of 1793 (?). When William Ellis, in 1823, questioned the natives about early eruptions of Kilauea, part of the meager information he elicited was mention of an eruption thirty years or so before.[4] The eruption was said to have produced voluminous lava flows contiguous to the cones of Honuaula, Puulena, and Kaliu, along the east rift zone of Kilauea, 3½ to 7 miles southwest of Kapoho. The boundaries of this lava flow as shown in the accompanying figure were mostly mapped by the topographers of the U. S. Geological Survey in 1922 (Kalapana quadrangle), but it was labeled "Lava flow of 1840." However, the distribution of the lava fits so well the traditional description of the 1793 (?) flow that there can be little doubt that it originated at that time. The lava differs in composition from the adjacent flow which reached Nanawale Bay in 1840, and moreover the map prepared by Commodore Wilkes only a few months after the 1840 eruption does not show the 1840 lava approaching within a mile of the line of

* Published by permission of the Director, Geological Survey, U. S. Dept. of the Interior.
1 Buck, P. H., **Vikings of the Sunrise**, p. 252, New York, 1938.
2 Ellis, William, **A Narrative of a Tour Through Hawaii, or Owhyhee**, pp. 219-223, Honolulu, 1917.
Hitchcock, C. H., **Hawaii and Its Volcanoes**, pp. 164-165, Honolulu, 1911.
3 Hitchcock, **op. cit.**, p. 164.
4 Ellis, **op. cit.**, pp. 214, 218.

cinder cones.[5] The 1793 (?) lava issued from fissure vents and is largely pahoehoe. Lava trees are well preserved along the narrow northern tongue of the flow north of the Pahoa-Kapoho road and northwest of Puu Honuaula.

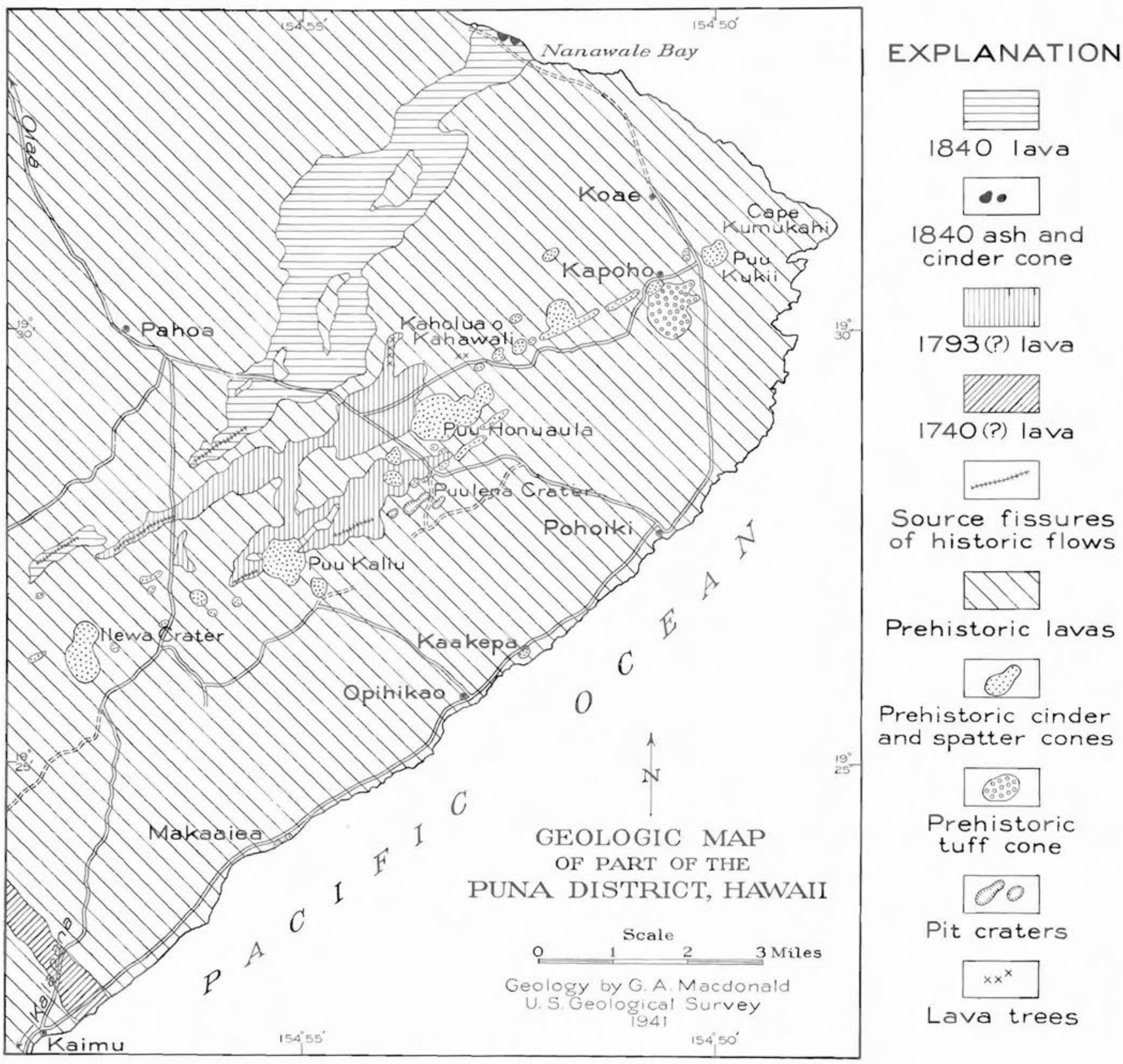
Eruption of 1840. The only large eruption which has occurred in eastern Puna since the advent of white men in Hawaii is that of 1840. The eruption was not witnessed by white men, but the region was traversed shortly afterward by Father Coan, who for 40 years was the faithful chronicler of Hawaiian volcanoes, and by Commodore Wilkes, Dr. Pickering, James D. Dana, and other members of the United States Exploring Expedition. The outbreak commenced with the appearance of lavas in Alae Crater, a pit crater near the Chain of Craters Road, on May 30.[6] The lava level rose about 300 feet in the pit crater but fell again when new eruptions appeared on the flanks of the lava cone Kane Nui o Hamo, and north and west of Napau Crater. The spatter left at the "high water mark" in Alae Crater was examined soon afterward by Dr. Pickering. Cracking continued along the east rift zone toward Kapoho, fissures a few inches to 10 or 12 feet wide being opened, but no lava reached the surface. Finally, on June 1, the principal flow commenced near the present Pahoa-Kalapana road. Three days later it reached the sea at Nanawale Bay, and it continued to flow into the sea for three weeks, building out the shore line about a quarter of a mile.

Where the lava encountered sea water, violent steam explosions resulted, and the liquid lava was hurled into the air as by a giant atomizer, to be drifted inland by the wind or heaped into small hills of glassy sand on the fresh lava at the edge of the water. Three of these hills were built, ranging in height from 150 to 250 feet, but because of their unconsolidated nature and their exposure to the full impact of the ocean waves and the nearly constant northeast trade winds, they were rapidly eroded away. There are now only two of them left, and the highest is only 78 feet high.

Coan[7] tells of a man who went to watch the 1840 flow and, wishing to take no chances, stopped some distance away on

[5] Wilkes, Charles, **Narrative of the U. S. Exploring Expedition, 1838-1842**, vol. 4, p. 110, 1845.
[6] Coan, Titus, **Missionary Herald**, vol. 37, p. 283, 1841.

[7] **Op. cit.**



open lava, whence he had a good view of the moving stream. He was therefore considerably startled suddenly to find the lava crust rising beneath his feet. Escaping from his dangerous position, he looked back and saw that where he had stood the crust had been buckled up to a height of 15 or 20 feet, and that liquid lava was escaping through crevices. This man appears to have had the unusual experience of standing on an actively developing tumulus.

Hawaiian Volcano Observatory Report for October - December 1941

VOLCANOLOGY

October 1941

Conspicuous fuming at Mokuaweoweo was noted early in the month. The majority of the October earthquakes were of Kilauea origin. The widely felt earthquake of October 25 had its origin near Waimea well down the northwestern slope of Mauna Kea. It was deep seated and may well have originated along the fundamental NW-SE rift of the Hawaiian ridge.

November 1941

As the month progressed it was found that the earthquakes of October 25 and November 8 were premonitory of the swarm of shakes that started at Waimea on the north slope of Mauna Kea on November 13. The shaking was more or less continuous, and by December 7 over 2,000 quakes had been recorded on the Mauna Loa seismograph, the instrument nearest the epicenter. No cracks were observed at the surface in the epicentral area. The characteristics of the shaking indicated that the focus extended into a region with an appreciable degree of mobility. This is not surprising when one considers that the quakes originated 27 miles below the surface.

December 1941

Immediately following the Waimea shakes, which ceased on December 8, there commenced a seismic lull that continued through the rest of December. There are some reasons for thinking that such a seismic lull indicates a high or increasing lava pressure under Hawaiian volcanoes.

SEISMOLOGY

Earthquakes October - December 1941

Week Ending	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Local Seismicity*	Teleseism
Oct. 5	20	1	1	1	0	8.50	0
12	7	4	0	0	0	3.75	0
19	14	0	0	0	0	3.50	0
26	4	1	2	0	0	3.50	0
Nov. 2	13	8	5	3	0	18.75	0
9	5	2	0	0	0	2.25	0
16	52	13	1	1	1	25.50	0
23	68	16	4	1	1	35.00	0
30	40	4	0	0	0	12.00	1
Dec. 7	373	2	0	0	0	94.25	1
14	49	2	0	0	0	12.75	0
21	9	2	0	0	0	2.75	0
28	5	0	1	0	0	2.25	0

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

The data of the following local disturbances was determined from six seismograph stations operated on the islands of Hawaii and Maui by the Hawaiian Volcano Observatory of the Hawaii National Park. Time is Hawaiian Standard. Distances are from Observatory.

The number preceding each earthquake date is the serial number of the quake for the current year.

162. October 7, 14:29, very feeble, distance 14 miles.

163. October 8, 05:24, very feeble, distance 16 miles NE slope, Mauna Loa.

164. October 10, 11:22, very feeble, distance 3 miles SW of Kilauea.

165. October 12, 08:07, very feeble, distance 4 miles SW of Kilauea.

166. October 20, 00:47, very feeble, N slope of Mauna Kea.

167. October 20, 00:51, feeble, near Mokuaweoweo.

168. October 25, 08:54, feeble, N slope of Mauna Kea near Waimea, generally felt on island of Hawaii.

169. October 28, 01:46, very feeble, distance 4 miles.

170. October 28, 08:06, slight, NE rift of Mauna Loa.

171. October 28, 08:07, very feeble, beginning in No. 170.

172. October 28, 08:15, feeble, distance 9 miles.

173-176. October 28, four very feeble shakes during forenoon.

177. October 29, 05:10, very feeble, distance 7 miles.

178. October 29, 08:54, very feeble.

179. October 29, 09:42, feeble, distance 7 miles.

180. October 29, 11:30, very feeble.

181. October 30, 08:31, very feeble.

182. October 30, 18:00, slight, distance 7 miles.

183. October 31, 11:51, slight, distance 7 miles.

184. November 2, 00:20, feeble, P uncertain.

185. November 8, 13:20, very feeble, distance 58 miles.

186. November 9, 05:44, very feeble, distance 16 miles NE slope of Mauna Loa, felt in Hilo.

187. November 11, 02:41, very feeble, distance 16 miles, felt locally.

188. November 13, 20:07, feeble, distance 52 miles, felt in Waimea.

189-196. November 14, 00:51-17:34, eight very feeble shakes, distance 58 miles, felt plainly at Waimea and lightly at widely scattered points on island of Hawaii, depth 27 miles.

197. November 15, 06:53, slight, distance 52 miles, 27 miles deep near Waimea, Hilo instrument dismantled.

198. November 15, 13:27, very feeble, felt in Waimea.

199. November 15, 18:37, feeble, distance 52 miles, felt generally in northern part island of Hawaii.

200. November 16, 02:31, feeble, distance 52 miles, near Waimea, depth 27 miles.

201. November 16, 02:35, very feeble.

202. November 16, 09:41, moderate, origin near Waimea 52 miles away and 27 miles deep, generally felt over island of Hawaii, some slight damage, instruments dismantled.

203-207. November 17, five very feeble shakes originating near Waimea.

208. November 18, 02:56, moderate-strong, strongly felt on entire island and to a lesser degree on Maui, near Waimea, slight damage, 27 miles deep.

209-210. November 18, two very feeble shakes, origin near Waimea.

211. November 18, 10:30, feeble, generally felt over island.

212. November 18, 10:33, feeble, generally felt over island.

213-216. November 18, four very feeble shakes with origin near Waimea.

217. November 19, 07:43, feeble, distance 52 miles, widely felt.

218-219. November 19, two very feeble shakes, origin near Waimea.

220. November 22, 10:04, feeble, near Waimea.

221-222. November 22, two very feeble Waimea shakes.

223. November 22, 21:23, slight, near Waimea, generally felt on island of Hawaii and by a few persons on Maui.

224. November 22, 22:12, very feeble, felt in Waimea.

225. November 24, 18:02, very feeble.

226-228. November 30, three very feeble Waimea shakes.

229. December 4, 09:30, very feeble, distance 52 miles, near Waimea.

230. December 6, 09:44, very feeble, distance 4 miles.

231. December 13, 23:15, very feeble.

232. December 18, 13:00, very feeble.

233. December 20, 15:30, very feeble.

234. December 24, 09:54, feeble, distance 5 miles.

235. December 30, 14:22, feeble, distance 5 miles.

Teleseisms

December 5, 10:29, distance 4,700 miles.

Microseismic Motion

Microseisms were light throughout the quarter.

Crack Changes

Crack movement around Halemaumau and along the Chain of Craters for the quarter was slight. Opening of the crack predominated over closing but most cracks remained unchanged.

Tilting of the Ground

The southeast Halemaumau station showed a slight accumulation of northerly tilt during the quarter. The accumulation of tilt at the west Halemaumau station was very slight to the ENE.

Table of tilt at Observatory on NE rim of Kilauea.

Week Ending		Amount of Tilt	Direction of Tilt
October	5	1.54"	N 51° E
	12	2.43"	N 69° E
	19	3.41"	N 18° E
	26	5.28"	N 66° E
November	2	1.64"	S 39° E
	9	3.52"	N 8° E
	16	4.32"	N 17° E
	23	0.30"	S 45° W
	30	1.70"	S 82° E
December	7	2.28"	N 32° E
	14	1.70"	S 82° W
	21	4.54"	S 34° E
	28	3.52"	S 49° W

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.

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