

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 Hawai'i (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 be 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

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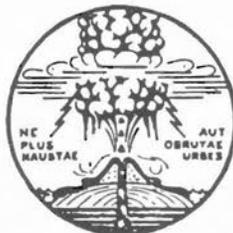
THE VOLCANO LETTER

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PHILIPPINE VOLCANOES DURING 1953 AND EARLY 1954

By GORDON A. MACDONALD and ARTURO ALCARAZ

The work of the Philippine Commission on Volcanology, created in mid-1952, includes continuous watch over volcanoes that are in eruption or show indications of possible impending eruption, periodic examinations of other active volcanoes (not in eruption), and, as time permits, studies of the dormant and extinct volcanoes of the archipelago. During 1953 and early 1954 continuous observations were made at Hibok-Hibok and Taal volcanoes and short investigations at Didicas and Mayon volcanoes. Canlaon and Bulusan volcanoes were viewed from a distance.

Arturo Alcaraz has been in charge of the field operations of the Commission on Volcanology since December, 1952. Gordon A. Macdonald spent December, 1953, and January and early February, 1954, in the Philippines assisting in the work of the Commission. We wish to express our thanks to the members of the Commission and to the U. S. Geological Survey for making our respective work possible; and to our coworkers, Gregorio A. Andal, Benigno Yambao, and Eugenio Omahoy, for much assistance and pleasant companionship in the field.

Throughout the known part of geologic time, volcanoes have played an important part in the development of the Philippine Archipelago. Volcanic rocks of uncertain age appear among the metamorphosed basement rocks in the Northwestern Cordillera, Mountain Provinces, and Sierra Madre of Luzon Island; on Marinduque and Masbate islands; on the islands of the Palawan group; on Panay, Cebu, Bohol, Samar, and Mindanao islands; and on islands of the Sulu group (Irving, 1951). Volcanic rocks known or believed to be of Tertiary age are exposed at various places from central Luzon to Zamboanga (Irving, 1953). But it is with the volcanoes of Pleistocene and Recent age that we are principally concerned.

The new geologic map of the Philippines (Irving, 1953) shows numerous areas of Quaternary volcanic rocks, scattered all the way from the Babuyan Islands, north of Luzon, to the Sulu Islands, south of Mindanao. Of the major islands in the archipelago, only Palawan, Panay, Cebu, Bohol, Masbate, and Samar lack Quaternary volcanics. Many of the cones, probably of Pleistocene age, are moderately dissected by erosion. Examples

of these include Mariveles Mountain on the Bataan Peninsula, Mount Arayat in the central plain of Luzon, Mount Macolod at the southeastern edge of Lake Taal in Batangas Province, Mounts Isarog and Iriga in Camarines Sur Province, the small cone at the southern end of Marinduque Island, Mount Mambajao on Camiguin Island, and many others. In the vicinity of the city of San Pablo, in the area between Mounts Banahaw and Malepunyo, there are many small depressions, several of them occupied by crater lakes. These appear to be diatremes, formed by short-lived volcanic explosions with or without accompanying collapse, perforating the plateau of Quaternary tuff.

Eleven Philippine volcanoes have erupted during historic times. Thirteen others show solfataric activity. These active and solfataric volcanoes are listed in the accompanying table and shown on the map (Fig. 1). Data concerning historic eruptions have been assembled by Andal and Yambao (1953).

Mount Santo Tomas, or Tonglon, near the city of Baguio, has in the past been listed as a volcano in solfataric condition, or even as having erupted in 1641 (Musser and Neumann van Padang, 1937; Andal and Yambao, 1953). These reports must, however, refer to some other locality, because examination of Mount Santo Tomas during February, 1954, showed it to consist of ancient, interstratified volcanic and sedimentary rocks of probable Tertiary age.

Didicas volcano, in the Babuyan Islands north of Luzon, resumed eruption in March, 1952, after a period of quiescence lasting nearly a century. Eruptive activity between 1856 and 1860 had built a mountain that rose some 700 feet above sea level, but subsequent wave action had reduced it to three small rock masses 200 to 270 feet high. Relatively quiet eruption resulted in the building of a blocky dome, from which escaped large volumes of steam and sulfurous gases. The new Didicas dome covered the former rock masses, and by late 1953 the top of the dome was about 830 feet above sea level (Alcaraz, Abad, and Tupas, 1953). Mild vulcanian explosions at the summit of the dome were reported during the early stages of the activity. Ash fell on Calayan Island, 25 miles to the north, but in quantities

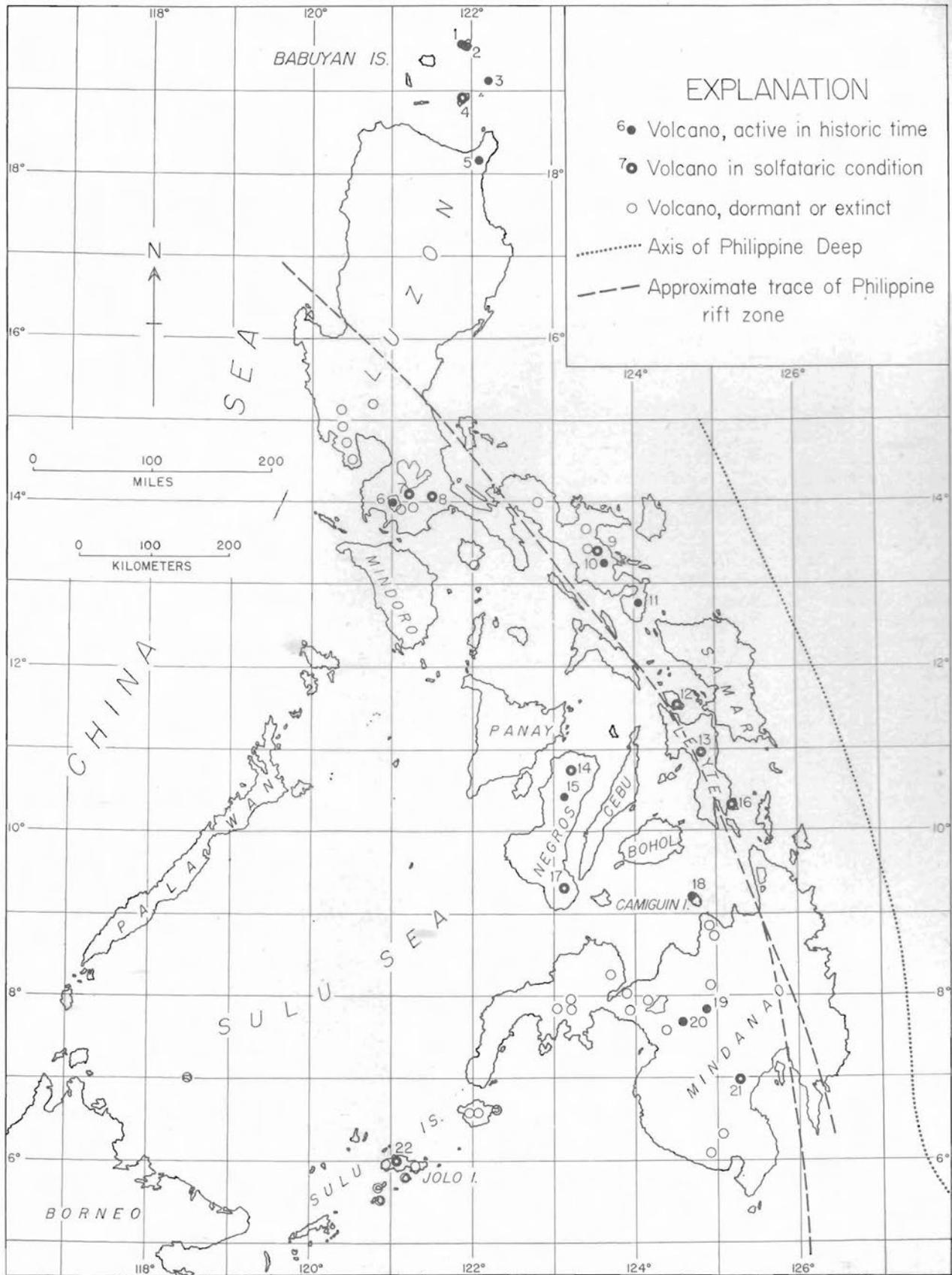




FIGURE 2. Didicas volcano from a point 0.25 mile to the east-northeast, on March 30, 1952. The blocky character of the dome and the banks of crumble breccia on its flanks are clearly visible. One of the old Didicas Rocks can be seen at the right. Photo by Arturo Alcaraz.

too small to cause damage (Andal and Yambao, 1953). In June, 1953, G. A. Andal and L. F. Abad were able to land on the dome and reported that the activity had subsided appreciably.

After its catastrophic eruption in 1911, Taal volcano remained entirely quiet until early 1953. During February, 1953, reports were received of signs of renewed activity, but examinations of the volcano on February 12 and 19 revealed no sign of change from the conditions observed during a survey of the volcano in February, 1949. The temperature of the water of the crater lake was found to be 32°C. In May, 1953, steam vents and hot springs became active in a zone about 100 meters long at and near the southwestern shore of the crater lake. Some sulfur gas is present in the steam. On May 19 the temperature of the steam was 98°C., and the temperature of the crater lake had risen to 36°C. By mid-June the temperature of the steam had increased to 101°C., but since then it has remained stable, with occasional decreases to about 100°C. During the remainder of 1953 the volume of steam fluctuated, but generally it was somewhat less than during May and June. There was a slight northwestward shifting of the active area. In early 1954 there has again been some increase in the apparent volume of steam, which in early March was about twice that observed in May, 1953.

The renewal and gradual increase of solfataric activity at Taal volcano seems unquestionably to indicate a rise of magma at depth or some other change in subsurface conditions resulting in a greater supply of heat to the volcanic vent. No other signs of impending eruption have been observed, and people are still being permitted to reside on Volcano Island, though some have left voluntarily. Close watch is being kept for increased earthquake activity or other signs of eruption; residents of Volcano Island have been informed of the possibility of eruption, and a plan for possible evacuation of the

island and areas along the shore of Taal Lake has been prepared.

Mayon volcano, in Albay Province, is the most frequently active volcano in the Philippines and is believed to have the most perfectly symmetrical cone in the world. Since 1800, Mayon has had 31 recorded eruptions, with an average interval of one each 4.9 years. The actual interval has varied, however, from less than 1 to 26 years. The 1928 and earlier eruptions have been described by Faustino (1929). Since that time, eruptions have occurred in 1938, 1939 (a single brief explosion), 1943, and 1947. During late 1953 and early 1954 Mayon volcano was fuming quietly. Most of the fume rose from fissures in and around the small, blocky mass of 1947 lava in the small crater.

Mayon volcano is a composite strato-volcano, composed dominantly of pyroclastics but with numerous interbedded lava flows. The flows are of block-lava type, transitional toward aa. Pyroclastic beds on the northern slope of the volcano above the Mayon resthouse consist largely of Strombolian cinder. Abundant mudflows have formed a broad apron completely around the base of the cone and have been responsible for most of the damage to life and property during historic times.

Bulusan volcano, in Sorsogon Province, has not erupted in recent years. The last eruptive period began on January 18, 1916, and continued intermittently until 1922. During that period there were 17 separate mild explosions, each lasting only a few minutes. Ash fell on towns west, southwest, and south of the volcano, but not in sufficient amount to cause damage. Maso (1928: 765) describes what appears to have been a block-lava flow in the crater during November and December, 1918. The flow pushed its snout out through a breach in the crater rim, and from the snout fragments rolled down the ravine below the breach, black by day but exhibiting dull red incandescence at night. He also describes what

FIGURE 3. Fumaroles at the southwestern edge of the crater lake of Taal volcano, January 3, 1954. Photo by G. A. Macdonald.



FIGURE 1. Map of the Philippine Islands, showing the location of volcanoes active in historic time, those in solfataric condition but not historically active, and known volcanoes of probable Quaternary age that have shown neither eruptive nor solfataric activity during historic times. The latter are taken from the new geologic map of the Philippines (Irving, 1953). The active and solfataric volcanoes are numbered on the map as follows: 1, Smith; 2, Babuyan Claro; 3, Didicas; 4, Camiguin de Babuyan; 5, Cagua; 6, Taal; 7, Maquiling; 8, Banahaw; 9, Malinao; 10, Mayon; 11, Bulusan; 12, Biliran; 13, Burauen area; 14, Silay; 15, Canlaon; 16, Cabalian; 17, Magaso; 18, Catarman (Hibok-Hibok); 19, Calayo; 20, Ragang; 21, Apo; 22, Bud Dajo.



FIGURE 4. The dome of Hibok-Hibok volcano seen from the top of the 1948 lava flow, December 19, 1953. Part of the old crater wall is visible on the left skyline. The dome is nearly buried by its long slopes of talus (crumble breccia). Photo by G. A. Macdonald.

appear to have been small, avalanche-type *nuées ardentes*. In his own words, "Sometimes instead of rocks a mass not unlike mud detached itself from the said hot base and showed a great effervescence while sliding down the ravine and raised a white yellowish cloud which had a great ascensional force. After the effervescence had ceased the bottom of the ravine and the vegetation on its sides was seen covered with white dust. . . ."

The last known eruption of Canlaon volcano, on Negros Island, occurred during 1906. The volcano was viewed from the air on January 22, 1954. The mountain has two principal peaks. The northern peak is vegetated to its top, is moderately eroded, and does not appear to have been recently active. The southern peak appears to be a rounded cinder cone, little vegetated and entirely uneroded, sitting on a forested and moderately eroded base which is probably a composite cone. A prominent crater is present in the southern peak. No fumarolic activity was visible.

Calayo and Ragang volcanoes, on Mindanao Island, were not visited during 1953 or early 1954. The last recorded eruption of the former was in 1887 (Andal and Yambao, 1953: 22), while the latter was reported to be active in 1915 (Smith, 1924: 216). Makaturing volcano, also in Mindanao, has been listed by several writers as active. However, there is serious doubt that it ever was active within historic times. Maso (1922: 142) wrote, "Considering the different actual conditions of the Makaturing and of the Ragang one is inclined to believe that all the historic eruptions attributed to the former occurred in the latter. Writers give the years 1834, 1840, 1858, 1871 and 1873, but nearly all these dates are somewhat doubtful because of the lack of reliable particulars and of the fact that the writers are at variance about the same."

Hibok-Hibok volcano, on the northern end of Camiguin Island, just north of Mindanao, was in eruption from 1948 to early 1953. During that period two block-lava flows were extruded on the eastern flank of the mountain, mudflows devastated an area on the northern slope, a dome was built in the summit crater partly overlapping onto the flanks of the mountain, and destructive

nuées ardentes took the lives of about 500 persons in the sector northeast of the summit (Alcaraz, Abad, and Quema, 1952). As a result of this, the zone around the volcano was closed to public occupation by Presidential order, until such time as the danger from the volcano should subside.

Three visits were made to Hibok-Hibok during December, 1953, and January, 1954. Records from a new, more sensitive seismograph installed in the town of Mambajao, near the base of the volcano, indicated that very few earthquakes were originating beneath the volcano. There had been no ash eruptions since July 14, and no large avalanches from the dome had been reported since May. Eugenio Omahoy, the volcanological observer stationed in Mambajao, had detected no changes in the size or outline of the dome since May, except for the collapse of one prominent spine. In December the dome was examined from the upper part of the valley down which had rushed the *nuées ardentes* of December, 1951, and many smaller, later avalanches. In January the dome itself was climbed and examined at close hand. The dome was fuming quite strongly, but there was no sign of present or recent active growth. Talus banks extended far up the flanks of the dome, in places nearly to its summit. Except in small local areas, the rock ribs between the talus banks had been reduced by crumbling to a slope of stability. Several small spines were present on the dome, and at the summit there was a narrow spine, about 100 feet high, that appeared from some angles to be curved like the dorsal fin of a shark. Some of the spines, including the eastern end of the large spine at the summit, appeared about to collapse. These collapses undoubtedly will cause small avalanches, but it is unlikely that the avalanches will travel far enough to cause damage to inhabited areas. Deposits of recent avalanches are all small and extend little beyond the edge of the dome itself.

Therefore, it appears that, barring renewal of eruptive activity, danger from the dome is over. On that basis, it was recommended that the ban on occupation of the town of Mambajao and the agricultural lands

FIGURE 5. The summit of the Hibok-Hibok dome, seen from the southeast, January 26, 1954. The spine at the top of the dome is badly fissured. The mass in the left foreground was formed in an early stage of the dome growth. Later, activity shifted slightly northeastward and produced the more recently active mass in the background. Photo by G. A. Macdonald.



around the foot of the volcano be abolished, but a new, smaller restricted zone with a radius of 3 kilometers be established around the summit of the volcano, in which no residence would be permitted. These recommendations have been acted upon. At the same time, the dangers of residing upon an active volcano were pointed out to the local populace. A close watch is being kept on the volcano for any signs of renewal of eruptive activity.

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PHILIPPINE VOLCANOES (LISTED FROM NORTH TO SOUTH)

ISLAND	NAME OF VOLCANO	
	Active during historic time	Solfataric
Babuyan Islands	Smith Babuyan Claro (?) Didicas	Camiguin de Babuyan
Luzon	Cagua Taal Mayon Bulusan	Maquiling Banahaw (possibly active in 1730) Malinao
Visayan Islands		
Biliran		Biliran
Leyte		Mt. Danan } Casiboi Crater } Bu- rauen area
		Cabalian
Negros	Canlaon	Silay Magaso (Cuernos de Negros)
Camiguin	Hibok-Hibok (Catarmán)	
Mindanao	Calayo (Masuan) Ragang	Apo
Jolo (Sulu Archipelago)		Bud Dajo (possibly active in 1641)

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JANUARY-MARCH, 1954

By JERRY P. EATON

VOLCANOLOGY

January

January was a quiet month for Hawaiian volcanoes. Only 27 earthquakes were recorded by seismographs of the Hawaiian Volcano Observatory. Seven of them originated under Kilauea, 12 under Mauna Loa, and 8 recorded too weakly to be located.

An earthquake at 9:39 P.M. on January 20, issuing from a focus 10 miles deep under Red Hill on the northeast rift of Mauna Loa, was felt in the Volcano district, Hilo, Pepeekeo, Kukuihaele, and Papaloa, Kona. Two smaller earthquakes from foci under the east rift of Kilauea were felt in Hilo; the first at 4:36 A.M. on January 24 and the second at 11:48 A.M. on January 31. At 2:27 A.M. on January 17 a slight earthquake was felt at Kalahiki, Kona.

Tilting of the earth's surface measured at the Volcano House on the northeast rim of Kilauea caldera was southwestward at a rate which is normal for this season of the year. Measurements of cracks in the floor of Kilauea do not show any significant change in the volcanic pressure under the volcano.

February

Hawaiian volcanoes remained quiet during February. Only 3 of the 27 earthquakes recorded by the Hawaiian Volcano Observatory seismographs were felt. Fourteen earthquakes originated on Mauna Loa, including those at 3:59 P.M. on February 6, 3:15 A.M. on February 16, and 5:32 P.M. on February 22, which were felt in Kona. Kilauea was shaken by six earthquakes, none of which was felt. Seven of the recorded earthquakes were too feeble to be located.

Tilting of the earth's surface at the northeast rim of Kilauea caldera proceeded in a southwesterly direction at a rate approximately normal for this season of the year.

March

Thirty-six earthquakes were recorded by seismographs of the Hawaiian Volcano Observatory during March. During most of the month seismic activity remained at the low level established during January and February; only 15 earthquakes were recorded from March 1 to March 29. Nine of them originated at Kilauea. The remaining six, including the earthquake at 4:19 P.M. on March 16, which was felt in Captain Cook, issued from Mauna Loa.

A series of small tremors felt in Hawaii at about 8:30 P.M. on March 23 was not recorded on any of the Observatory's seismographs.

Two strong earthquakes, which originated at a depth of about 15 miles on the east rift zone of Kilauea or the eastward extension of the Hilina fault system between the rift zone and the south shore in the vicinity of Kalapana, rocked the Island of Hawaii early on the morning of March 30. The first shock was recorded on the seismographs at the Volcano Observatory at 6:40:07 A.M.; the second at 8:42:01 A.M.

Both earthquakes were felt over the entire Island of Hawaii, and at least the second, which was the larger of the two, was felt on parts of Maui. Extensive, but mostly moderate, damage was caused in the Hilo and Puna districts. Although the shaking was most intense in the Puna district, where water tanks were thrown down and stone fences were damaged, the most spectacular damage occurred in and near Hilo, where many windows were broken and portions of a few houses were deranged or thrown down.

On March 30 and 31 a total of 16 aftershocks, several of which were felt in Puna and Hilo, stemmed from the same region as the two large quakes. The largest of these occurred at 6:57 A.M. on March 30 and at 3:04 P.M. and 4:00 P.M. on March 31. The

aftershock sequence extended into April, with small earthquakes at 3:57 P.M. on April 1 and 2:05 P.M. on April 8.

Concurrent with the large earthquakes in Puna and the associated aftershocks, seismic activity increased near Kilauea caldera. Four quakes originated in this region on March 30 and 31, and two more occurred on April 1. Of these six earthquakes, those at 11:19 A.M. on March 30 and 6:35 A.M. on April 1 were felt in the Volcano area.

The normal seasonal southwestward tilting at the Volcano House on the northeast rim of Kilauea caldera reversed for about 1 week at the time of the Puna earthquakes. Subsequently, southwestward tilting normal for this season has been re-established.

No general change in the width of cracks in Kilauea caldera, which might indicate changing pressure under the volcano, accompanied the Puna earthquakes.

SEISMOLOGY

Earthquake Data, January-March, 1954

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

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Tele-seisms
Jan. 3	2	3	0	0	0	0	2.0	0
10	3	4	0	0	0	0	2.75	0
17	5	3	1	0	0	0	3.75	1
24	4	2	0	1	0	0	4.0	0
31	3	1	0	1	0	0	3.75	4
Feb. 7	6	3	0	0	0	0	3.0	0
14	7	0	0	0	0	0	1.75	4
21	6	0	0	0	0	0	1.5	0
28	1	2	0	0	0	0	1.5	1
Mar. 7	8	2	0	0	0	0	3.0	0
14	3	1	0	0	0	0	1.25	1
21	1	2	0	0	0	0	1.25	1
28	25	10	2	2	1	4	36.25	4

* For definition of local seismicity see Volcano Letter 371 or 512. Each local earthquake is assigned a seismicity value according to its strength, as follows: tremor, 0.25; very feeble, 0.5; feeble, 1.0; slight, 2.0; moderate, 3.0; strong, 4.0. These values are totaled to give the weekly local seismicity. Continuous volcanic tremor is ignored in the calculation. The strength assigned to the earthquake depends on the double amplitude of the maximum oscillation it causes on the Bosch-Omori seismograph, as follows: tremor, less than 0.5 mm.; very feeble, 0.5 to 4 mm.; feeble, 4 to 11 mm.; slight, 11 to 25 mm.; moderate, 25 to 60 mm.; strong, greater than 60 mm.

Table of Tilt at Seismograph Stations on Rim of Kilauea Caldera

Week Beginning	Whitney Station (Northeast rim)		Uwekahuna Station (West rim)	
	Amount	Direction	Amount	Direction
January 3	0.5"	E 14° S	1.3"	S 14° W
10	1.2"	S 6° E	1.2"	S 34° W
17	0.1"	S 21° E	0.5"	N 45° W
24	0.8"	S 18° W	0.6"	E
31	1.5"	S 29° W	1.6"	N
February 7	0.8"	S 18° W	1.3"	S 14° E
14	0.2"	S 45° W	1.9"	S 9° E
21	0.9"	W 16° S	4.2"	N 33° W
28	1.4"	S 45° W	1.2"	N 34° W
March 7	0.8"	S 45° W	1.2"	S 34° E
14	1.1"	S 13° W	1.6"	N 11° W
21	1.2"	S	0.3"	N
28	0.7"	N 9° W	2.9"	S 27° W

Local Earthquakes

The data for the following local earthquakes were determined from seismographs on the islands of Hawaii and Maui operated by the Hawaiian Volcano Observatory. Locations given are epicenters. The times given are arrival times at the Whitney Laboratory of Seismology, on the northeast rim of Kilauea caldera. They are stated to the closest minute in Hawaiian Standard time, which is 10 hours slower than Greenwich Civil

time. The number preceding each earthquake is the serial number for the current year. The intensity rating (Feeble, Moderate, etc.) given is that for the Whitney Laboratory. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney station.

- Jan. 3, 03:06, very feeble. Kilauea caldera.
- Jan. 6, 09:11, very feeble.
- Jan. 9, 03:17, very feeble (Mauna Loa, feeble). Southeast flank of Mauna Loa 3 miles west of Halfway House.
- Jan. 9, 13:57, very feeble. Southeast flank of Mauna Loa 5 miles southeast of Halfway House.
- Jan. 10, 00:19, very feeble.
- Jan. 12, 08:01, very feeble (Mauna Loa, feeble). Southeast flank of Mauna Loa.
- Jan. 13, 04:30, tremor (Mauna Loa, very feeble). Southeast flank of Mauna Loa near Halfway House.
- Jan. 13, 22:48, very feeble.
- Jan. 14, 17:28, not recorded at Kilauea (Mauna Loa, very feeble).
- Jan. 14, 03:04, very feeble.
- Jan. 15, 13:17, tremor (Uwekahuna, very feeble). Kilauea caldera.
- Jan. 16, 12:49, not recorded at Kilauea (Kona, very feeble). Kona.
- Jan. 17, 02:27, tremor (Uwekahuna, very feeble). Felt in Kalihiki, Kona.
- Jan. 17, 05:29, very feeble.
- Jan. 17, 15:39, Kilauea.
- Jan. 17, 17:17, not recorded at Kilauea (Kona, very feeble). Kona.
- Jan. 19, 12:11, tremor (Mauna Loa, very feeble). Southeast flank of Mauna Loa.
- Jan. 20, 21:39, tremor (Uwekahuna, very feeble). Hilina Pali.
- Jan. 20, 21:39, feeble (Mauna Loa, slight). Felt in Papa-loa, Kona; Hawaii National Park; and Kukuhihae, North Hamakua. Ten miles deep under Red Hill on the northeast rift of Mauna Loa.
- Jan. 20, 21:40, very feeble.
- Jan. 22, 03:13, tremor (Uwekahuna, very feeble).
- Jan. 24, 04:36, slight. Felt in Hilo. Twelve miles deep under Alae crater on the east rift of Kilauea.
- Jan. 26, 06:48, tremor (Mauna Loa, very feeble).
- Jan. 28, 13:15, not recorded at Kilauea (Kona, very feeble). Kona.
- Jan. 29, 22:54, very feeble. Kaoiki fault.
- Jan. 30, 08:31, very feeble. Southwest rift of Kilauea near the coast.
- Jan. 31, 11:48, slight. Felt in Hilo. East rift of Kilauea about 6 miles from the Observatory.
- Feb. 6, 15:59, tremor (Mauna Loa, very feeble). Felt in Kalihiki, Kona, Kona.
- Feb. 6, 20:41, tremor (Mauna Loa, very feeble). Southeast flank of Mauna Loa.
- Feb. 7, 14:15, tremor (Mauna Loa, very feeble). Deep under the summit of Mauna Loa.
- Feb. 7, 19:50, tremor (Uwekahuna, very feeble). Kilauea caldera.
- Feb. 10, 22:14, very feeble (Mauna Loa, feeble). Southeast flank of Mauna Loa.
- Feb. 12, 03:24, tremor (Uwekahuna, very feeble).
- Feb. 12, 03:51, very feeble. Kilauea.
- Feb. 12, 13:10, not recorded at Kilauea (Kona, very feeble). Kona.
- Feb. 12, 15:30, not recorded at Kilauea (Hilo, very feeble). Near Hilo.
- Feb. 13, 13:01, tremor (Uwekahuna, very feeble).
- Feb. 13, 23:44, very feeble. Kilauea.
- Feb. 16, 03:15, not recorded at Kilauea (Kona, feeble). Felt in Captain Cook, Kona.
- Feb. 16, 08:31, not recorded at Kilauea (Mauna Loa, very feeble). Northeast rift of Mauna Loa.
- Feb. 18, 14:39, not recorded at the Whitney Laboratory (Mauna Loa, very feeble).

42. Feb. 19, 06:31, not recorded at the Whitney Laboratory (Uwekahuna, very feeble). Southwest rift of Kilauea.
43. Feb. 19, 21:27, not recorded at Kilauea (Mauna Loa, very feeble). Mauna Loa.
44. Feb. 20, 02:33, not recorded at the Whitney Laboratory (Mauna Loa, very feeble). Summit of Mauna Loa.
45. Feb. 22, 17:32, not recorded at the Whitney Laboratory (Mauna Loa, very feeble). Felt at Kalihiki, Kona, Kona.
46. Feb. 23, 16:50, not recorded at the Whitney Laboratory (Mauna Loa, very feeble). Southeast flank of Mauna Loa.
47. Feb. 24, 01:04, tremor (Uwekahuna, very feeble).
48. Feb. 24, 03:36, not recorded at the Whitney Laboratory (Mauna Loa, very feeble).
49. Feb. 25, 15:38, not recorded at the Whitney Laboratory (Mauna Loa, very feeble). Southeast flank of Mauna Loa.
50. Feb. 26, 09:50, not recorded at Kilauea (Mauna Loa, very feeble).
51. Feb. 26, 14:15, tremor (Mauna Loa, very feeble). Mauna Loa.
52. Feb. 26, 14:16, not recorded at Kilauea (Mauna Loa, very feeble). Mauna Loa.
53. Feb. 27, 14:53, tremor (Uwekahuna, very feeble). Kilauea.
54. Mar. 3, 23:30, not recorded at the Whitney Laboratory (Uwekahuna, very feeble). Kilauea.
55. Mar. 6, 02:35, very feeble. East rift of Kilauea.
56. Mar. 6, 21:49, very feeble. Kilauea.
57. Mar. 9, 02:51, very feeble. Kilauea caldera.
58. Mar. 9, 03:22, very feeble. Kilauea caldera.
59. Mar. 12, 15:32, not recorded at the Whitney Laboratory (Hilo, very feeble). Near Hilo.
60. Mar. 15, 06:50, very feeble. Kilauea caldera.
61. Mar. 16, 16:19, tremor (Kona, feeble). Kealakekua fault.
62. Mar. 19, 00:23, tremor (Mauna Loa, very feeble). Southeast flank of Mauna Loa.
63. Mar. 24, 07:25, very feeble. East rift of Kilauea near Alae Crater.
64. Mar. 26, 00:28, very feeble. Southwest rift of Kilauea 4 miles southeast of Kapapala Ranch.
65. Mar. 26, 03:08, not recorded at the Whitney Laboratory (Mauna Loa, very feeble). Southeast flank of Mauna Loa.
66. Mar. 26, 15:02, not recorded at the Whitney Laboratory (Uwekahuna, very feeble). Kilauea caldera.
67. Mar. 26, 16:07, not recorded at the Whitney Laboratory (Mauna Loa, feeble). Northeast rift of Mauna Loa near the Mauna Loa seismograph.
68. Mar. 29, 19:31, tremor (Mauna Loa, very feeble). Deep under the northeast rift of Mauna Loa.
69. Mar. 30, 06:40, strong. About 15 miles deep between the east rift of Kilauea and the sea near Kalapana.
70. Mar. 30, 06:57, slight. Aftershock of No. 69.
71. Mar. 30, 07:02, tremor (Uwekahuna, very feeble). Kilauea caldera.
72. Mar. 30, 07:38, very feeble. Aftershock of No. 69.
73. Mar. 30, 08:42, strong. About 15 miles deep between the east rift of Kilauea and the sea near Kalapana.
74. Mar. 30, 09:08, very feeble. Aftershock of No. 73.
75. Mar. 30, 10:08, tremor (Uwekahuna, very feeble). Aftershock of No. 73.
76. Mar. 30, 10:17, very feeble. Aftershock of No. 73.
77. Mar. 30, 10:26, very feeble. East rift of Kilauea.
78. Mar. 30, 11:19, strong. Felt in Hawaii National Park. Kilauea caldera.
79. Mar. 30, 12:13, tremor (Mauna Loa, very feeble). Aftershock of No. 73.
80. Mar. 30, 13:31, tremor (Uwekahuna, very feeble). Aftershock of No. 73.
81. Mar. 30, 14:44, tremor (Mauna Loa, very feeble). Aftershock of No. 73.
82. Mar. 30, 15:42, very feeble. Aftershock of No. 73.
83. Mar. 30, 18:15, very feeble. Aftershock of No. 73.
84. Mar. 31, 00:30, very feeble. Aftershock of No. 73.
85. Mar. 31, 01:09, tremor (Uwekahuna, very feeble). Aftershock of No. 73.
86. Mar. 31, 01:30, very feeble. Kilauea caldera.
87. Mar. 31, 05:46, very feeble. Kilauea caldera.
88. Mar. 31, 15:04, feeble. Aftershock of No. 73.
89. Mar. 31, 15:48, very feeble. Aftershock of No. 73.
90. Mar. 31, 16:00, moderate. Aftershock of No. 73.

Distant Earthquakes

The following earthquakes of distant origin were recorded on the seismographs of the Hawaiian Volcano Observatory. Locations of the epicenters and the magnitudes are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey. The time given is that of the first detectable emergence of the quake on the Bosch-Omori horizontal or Sprengnether vertical seismograms, in Hawaiian Standard time.

- Jan. 19, 18:40:00. Pacific Ocean south of Mexico, $8\frac{1}{2}^{\circ}$ N., $103\frac{1}{2}^{\circ}$ W., magnitude 6.
- Jan. 31, 15:16:40. Volcano Islands, $24\frac{1}{2}^{\circ}$ N., $142\frac{1}{2}^{\circ}$ E., magnitude $7\frac{1}{4}$.
- Feb. 4, 23:29:31. Off coast of New Britain, $4\frac{1}{2}^{\circ}$ S., 153° E., magnitude $6\frac{3}{4}$ -7.
- Feb. 6, 14:28:01.
- Feb. 6, 20:24:15. New Hebrides Islands, 15° S., $167\frac{1}{2}^{\circ}$ E., magnitude $6-6\frac{1}{2}$.
- Feb. 10, 14:43:07. Ningsia Province, China, $39\frac{1}{2}^{\circ}$ N., 101° E., magnitude $7-7\frac{1}{2}$.
- Feb. 18, 14:51:22. Off coast of Nicaragua, $11\frac{1}{2}^{\circ}$ N., $87\frac{1}{2}^{\circ}$ W., magnitude $6\frac{3}{4}$ -7.
- Feb. 19, 09:17:17. Kermadec Islands, 30° S., 178° W., magnitude $7-7\frac{1}{2}$.
- Feb. 19, 11:45:33. Coast of Nicaragua, $12\frac{1}{2}^{\circ}$ N., $87\frac{1}{2}^{\circ}$ W., magnitude $6\frac{3}{4}$ -7. Felt at Managua.
- Feb. 20, 08:46:36. Flores Sea, 7° S., $124\frac{1}{2}^{\circ}$ E., magnitude $6\frac{1}{2}$ - $6\frac{3}{4}$.
- Mar. 2, 20:13:50. New Guinea, $5\frac{1}{2}^{\circ}$ S., $142\frac{1}{2}^{\circ}$ E., magnitude $7-7\frac{1}{4}$.
- Mar. 19, 00:12:00. Santa Rosa Mountains, California, 33.3° N., 116.1° W., magnitude $6-6\frac{1}{4}$. Slight property damage.
- Mar. 21, 13:55:34. Northwestern Burma, $24\frac{1}{2}^{\circ}$ N., 95° E., magnitude $7-7\frac{1}{4}$. Felt in Eastern India.
- Mar. 28, 10:44:04. Rat Islands, Aleutian Islands, 52° N., 176° E., magnitude $6\frac{1}{2}$.
- Mar. 28, 18:13:13. Near north coast of Luzon Island, Philippine Islands, $19\frac{1}{2}^{\circ}$ N., $121\frac{1}{2}^{\circ}$ E.
- Mar. 28, 20:34:45. Near south coast of Spain, 37° N., $3\frac{1}{2}^{\circ}$ W., magnitude $7\frac{1}{4}$ - $7\frac{1}{2}$. Extensive property damage at Granada and Malaga.

VOLCANO NOTES AND NEWS

RABAUL OBSERVATORY

The following notes are abstracted from an account of the Volcanological Observatory at Rabaul and its operations, prepared by Mr. J. G. Best, volcanologist at the Observatory, and forwarded through the kindness of Dr. N. H. Fisher, Chief Geologist of the Bureau of Mineral Resources, Commonwealth of Australia.

The Volcanological Observatory at Rabaul is built on the northern rim of the Blanche Bay caldera, 600 feet above sea

level. The site overlooks the township of Rabaul and affords an excellent view of the various craters within Blanche Bay.

The Observatory was completed shortly before the capture of Rabaul by the Japanese in early 1942. Subsequently, however, the upper portion of the building, together with all records, was destroyed, and all instruments and fittings removed from the instrument cellar. In December, 1951, work was commenced on reconstruction of the Observatory. The upper portion of the building was restored and now contains a laboratory, records room, and office, as well as temporary housing for the staff.

Upon the erection of permanent housing for the staff, these living quarters will be converted for use as a museum, photographic dark room, and workshop.

The instrument cellar is beneath the office building. It is 25 feet long, 15 feet wide, and 9 feet deep, and is concrete lined. Four concrete instrument piers are set well below the floor of the cellar and are based on the surface of a lava flow which lies 8 feet below the cellar floor. A 3-inch gap, loosely filled with soil and covered with tarred paper, is left between the piers and the cellar floor.

Three Benioff seismometers, a Benioff recorder, and two tiltmeters have been installed in the instrument cellar. The start of recording with the Benioff instruments has been held up through lack of accessories.

At Rapindik, $3\frac{1}{4}$ miles southeast of the Observatory, an Omori-type seismograph with low magnification and mechanical recording was installed in May, 1950. It is so placed to detect seismic activity of volcanic origin at the active centers in Blanche Bay.

The two tiltmeters at the Observatory are normally read daily and the readings plotted graphically. Temperatures of hot springs, wells, fumaroles, and solfataras at 51 points in the Blanche Bay area are taken weekly and recorded graphically. In the event of an upward trend in temperature, the frequency of the readings would be increased. Analysis of volcanic exhalations is to become routine, being done jointly with the weekly temperature readings. Photographic records of selected fumaroles and other thermal points also are to become a routine feature. The Commonwealth Department of Public Works operates a Stevens continuous-recording water gauge in Simpson Harbour and the volcanological staff have access to this instrument for any information required. In addition, tide poles are installed at selected points around Blanche Bay and are read weekly, so that changes in the level of the strandline can be detected.

A systematic investigation is to be made of all volcanic areas in the Territory of Papua and New Guinea, and eventually regular inspections will be made of the more active areas. Preliminary investigations of several areas have already been made.

To keep in touch with events at other centers, a system of reporting seismic and volcanic phenomena has been introduced. This involves the reporting by radio of all important earthquakes and changes in volcanic activity. Monthly reports of all relevant information from outside areas are forwarded to the Observatory by government stations through the Territory.

ACTIVITY OF MOUNT ASAMA

By T. Minakami

Asama volcano resumed activity on December 27, 1953, after a complete quiescence of 38 months. The usual Asama eruptions are Vulcanian in type and of explosive character, with furious detonations lasting several minutes throwing up abundant ejecta including numerous lava blocks and bombs. The interval between successive eruptions is usually several days, even during such markedly active periods as 1935-38. The present activity differs from this in that each explosion is on an extremely small scale compared with the usual ones and occur very frequently. During the period from the beginning of the eruption to the end of February, 1954, the number of separate explosions observed has ranged from 0 to 10 per day, and because observation is not possible during hours of darkness the total number of explosions probably is about 30 per cent greater than this. The kinetic

energies of individual explosions during the present activity are estimated to range from 10^{14} to 10^{16} ergs, whereas those of the ordinary explosions of Asama are estimated to be nearly 10^{10} ergs. The explosions have ejected volcanic ash and pumice-like gravel. No serious damage has resulted, although ice skating at rinks at Karuizawa, near the southeastern foot of the volcano, was disturbed by the fall of fine ash.

Highly sensitive seismographs at the Asama Volcano Observatory indicated an increase in frequency and amplitude of micro-earthquakes originating from Asama volcano during the late summer and autumn of 1953. On August 2 and 3 a swarm of at least 200 microearthquakes originated in the neighborhood of the summit crater. After that, the emission of vapor (including volcanic gases such as SO_2) from the crater became very irregular in quantity. At times the gas was very abundant, and at other times it was very sparse. This is a common occurrence at Asama preceding and during eruption. On November 5, when the summit of the mountain was visited by a party including the writer and Dr. G. A. Macdonald of the Hawaiian Volcano Observatory, vapor was so abundant that the crater floor was invisible. Rumbles from the crater were heard at the Volcano Observatory on December 20, a week before the outbreak.

ACTIVITY OF OTHER JAPANESE VOLCANOES

Early in February newspapers reported a submarine disturbance observed by crews of MATS aircraft in the vicinity of Minami Iwo Jima, about 30 miles south-southeast of Iwo Jima in the Volcano Islands group. The surface of the ocean was reported to be boiling and steaming, presumably as a result of volcanic eruption in the ocean. Activity in the same general area was reported in March, 1953 (Volcano Letter 520: 7).

Charles G. Johnson, of the U. S. Geological Survey, Pacific Geological Surveys, reports that volcanic explosions began on Suwanose Island in the northern Ryukyu group at about 12:30 P.M. on February 22. Ash fell as far as 20 nautical miles south-southwest of the island.

Mr. Johnson also reports that the activity of Oshima volcano, which began on December 29, 1953 (Volcano Letter 522: 6), ceased, at least temporarily, about February 15. The last strong activity was on January 27, when bombs were reported hurled 1,000 feet into the air, and a small lava flow covered part of the crater floor. This violent activity subsided about 4:30 P.M. on January 27. Small explosions occurred for about 6 minutes on January 31 and intermittently for about 2 hours on February 1, followed by intermittent small-scale activity until February 15.

ERUPTION OF MERAPI VOLCANO

Merapi volcano, in east-central Java, probably is the most dangerous volcano in Indonesia, partly because of the type of its activity, and partly because of the concentration of a dense agricultural population of some 3 million persons in the area close around its base. For several months the Volcanological Survey of Indonesia had been calling attention to the restlessness of the volcano, and warning that it might erupt. The eruption came on January 18. Scant newspaper reports state that the outbreak came in the form of a violent explosion, and that it was preceded by two perceptible earthquakes. The press descriptions suggest that *nuées ardentes* may have formed on the flanks of the mountain. On January 20 the reported casualties were 68 known dead and 145 injured. Many thousands of people were being evacuated from danger areas.

STAFF OF HAWAIIAN VOLCANO OBSERVATORY

U. S. Geological Survey:

Gordon A. Macdonald, Volcanologist, Director
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 Chester K. Wentworth, Geologist, part-time
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 Haleakala Station:
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THE ERUPTION OF KILAUEA VOLCANO IN MAY, 1954

By GORDON A. MACDONALD and JERRY P. EATON

INTRODUCTION

Kilauea Volcano erupted early on the morning of May 31, 1954, after a dormancy of 18½ months. Although it could not be specifically predicted, the eruption was not unexpected. The termination of activity at Kilauea in November, 1952, was neither accompanied nor followed by any abnormal tilting that would suggest reduction of volcanic pressure beneath the volcano. On the contrary, during 1953 there was an accumulation of approximately 12 seconds of northward tilting at the Whitney Laboratory of Seismology on the northeastern rim of Kilauea caldera, in excess of the usual seasonal tilting. This suggested an actual increase of volcanic pressure beneath the caldera, resulting in a tumescence of Kilauea Volcano. Short periods of volcanic tremor during February and March, 1953, indicated subsurface movement of lava at Kilauea. All indications were that molten lava continued to stand at a high level within the conduit. In the report on activity of Hawaiian volcanoes during 1953 (Macdonald and Eaton, in preparation), submitted to the U. S. Geological Survey in mid-May, 1954, it was stated: "Under such conditions, eruption might come with very little forewarning."

Kilauea continued restless through the early months of 1954, but although eruption remained a possibility at any time, there was no evidence that appeared adequate for the basis of a prediction of an outbreak at any specific time.

NARRATIVE OF THE ERUPTION

Numerous small earthquakes occurred during the night of May 30-31. Slight earthquakes were recorded at 3:42 and 3:47 A.M. These awakened many persons, including the writers, in the region near Kilauea caldera. Shortly afterward Macdonald became conscious of a faint, persistent low-pitched roaring, almost a felt vibration rather than a recognizable sound, somewhat resembling the vibration caused by a heavy truck in low gear climbing a distant hill. The sensation continued as long

as the observer remained motionless. A moderate earthquake occurred at 3:51 A.M., followed by a strong quake at 3:54 A.M. The latter was violent enough to dismantle the Bosch-Omori seismograph, and immediately both of us went to the Whitney Laboratory of Seismology to restore the instrument to operation.

Halemaumau had been visited at approximately 3:30 A.M. by G. H. Ruhle, Naturalist of Hawaii National Park, who reports that complete darkness reigned and everything appeared as usual. When we reached the seismograph vault, at approximately 4:03 A.M., there still was no sign of glow at Halemaumau. The seismograph was restored to operation, and a drum bearing a new record sheet placed on the instrument at 4:08 A.M. At 4:09 A.M. we observed the beginning of registration of volcanic tremor on the seismograph. Rushing from the vault, we observed (at approximately 4:10 A.M.) a bright glow at Halemaumau, reflected on a rising cloud of gas that already had reached a height of about 2,000 feet above the crater rim. The fume cloud continued to expand upward. About daylight the pilot of a plane inbound to Hilo reported it to have reached a height of 30,000 feet, where it was spreading out like a great mushroom.

We reached the Volcano Observatory at about 4:20 A.M. Half a mile away, a dense column of fume was rising from the northeastern part of Halemaumau Crater, nearly hiding the top of a giant lava fountain that appeared from time to time, with its top about 100 feet above the rim of the crater. This fountain rose from the crater floor, 470 feet below the rim. Thus, its total height was between 550 and 600 feet. Thin fume rose from the entire area of the crater, and a second principal fume column rose near the southwestern edge. These columns of fume rose nearly vertically above the crater. There was little low-lying fume, such as made approach to the lee side of the crater almost impossible in June, 1952.

At 4:27 A.M. the eruptive activity was entirely confined to Halemaumau Crater. Between 4:30 and 4:35

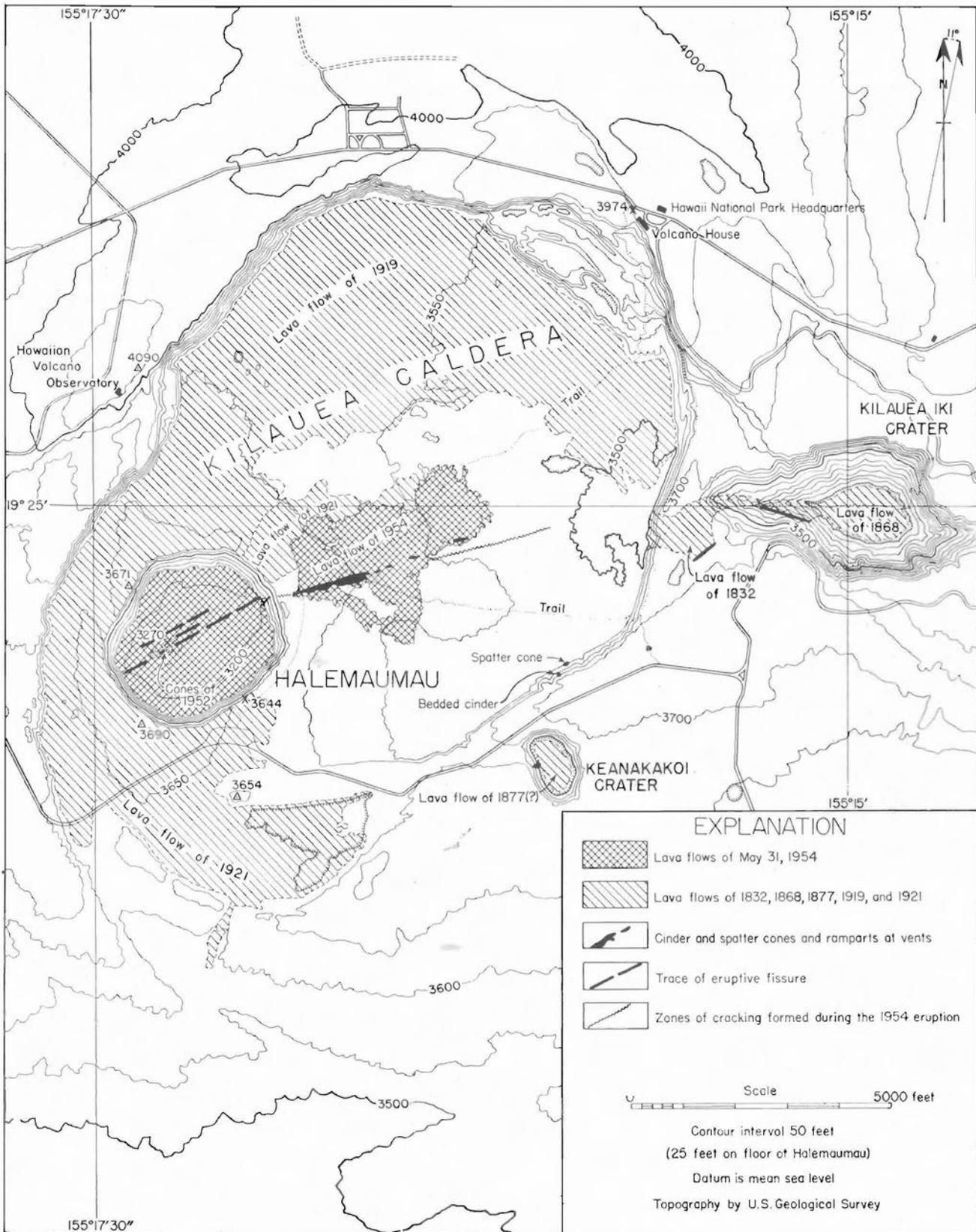


FIGURE 1. Map of Kilauea caldera, showing the location of the eruptive fissures and lava flows of the 1954 eruption, and some older flows outside Halemaumau.

A.M. lava issued from a fissure on the floor of Kilauea caldera northeast of Halemaumau. Ranger D. J. Tobin, Jr., of Hawaii National Park, viewed this event from a point near Kilauea Iki, nearly in line with the opening fissure. He states that at first the incandescent lava welled out gently, with little or no fountaining, followed by a gradual waxing of the fountains to a height of 50 to 100 feet. Because of the cloud of fume rising from Halemaumau immediately behind the new outbreak, he was unable to tell whether the arrival of lava at the surface was preceded by an outburst of fume from the fissure outside Halemaumau.

At 4:35 A.M. the line of fountains on the caldera floor northeast of Halemaumau was estimated to be 300 feet long, with its western end about 300 feet from the rim of Halemaumau. During the next few minutes the fountain chain spread rapidly, mostly eastward but also slightly toward the west. By 4:50 A.M. the principal chain was 1,400 feet long. Three other shorter chains were active farther east-northeast (Figs. 1 & 2). Very active flows of pahoehoe were spreading from the base of the fountains, and had already reached lengths as great as 1,000 feet.

We reached the rim of Halemaumau Crater at approximately 4:55 A.M. The entire crater floor was covered with a pond of incandescent lava. Across the floor diagonally from east-northeast to west-southwest, approximately along the line of the eruptive fissure of 1952, stretched a row of lava fountains from a few feet to more than 100 feet high (Fig. 1). The fissure bisected the cones left by the 1952 eruption, and lava poured from the cones into the surrounding pool. At the southwestern end of the line, approximately in the position occupied by the principal fountain during the early days of the 1952 eruption (Macdonald, 1952), was a fountain 250 to 300 feet high (Fig. 3). At the northeastern end the huge fountain visible earlier from the Volcano Observatory continued to play to a height at least 100 feet above the observers' heads (Fig. 4). Between these two end fountains the row of smaller fountains was nearly continuous.

Northwest of the principal row of fountains lay another shorter row, parallel to the first, and extending just northwest of the 1952 cones. Between these two rows of fountains was a third short row of three fountains, just northeast of the 1952 cones (Fig. 1). All of the fountains of the second and third rows were small. Few of them exceeded 10 feet, and none exceeded 25 feet in height.

Possibly the most spectacular feature of the eruption was the cascade of brilliant, orange-yellow lava that poured from the eruptive fissure 300 feet above the floor, on the northeastern wall of the crater (Fig. 4). Plunging down the wall, this "fire-fall" of incandescent liquid joined the turbulent pool around the base of the northeastern fountain. The lava issued at the head of the cascade quietly, with little spattering and no fountaining, as though it were poor in gas. At the base of the cascade a row of small fountains issued from the eruptive fissure, merging southward with the big northeast fountain.

Spreading out from the rows of source fountains, the lava was quickly covered with a thin black crust that was rifted apart by movement to reveal in a network of cracks the bright orange liquid beneath. Distinct waves,

set up by surging at the fountains, swept outward across the surface of the lake. At the foot of the crater walls, the surging liquid alternately covered and revealed a bright band 5 to 10 feet in height. Locally, foundering of fragments of the crust resulted in small secondary fountains, apparently caused by release of air and other gases carried down by the sinking crusts. Many of the secondary fountains were evanescent, and shifting in position. Others, however, occurred persistently along certain lines, apparently determined by the boundaries of flow units. The most prominent line of that sort extended from the southeast to northwest edges of the lake, passing just northeast of the 1952 cones, and apparently marked the boundary between two principal convective cells surrounding the southwest and northeast fountains respectively.

A gap of 200 feet separated the westernmost fountains on the caldera floor from the rim of Halemaumau Crater (Fig. 1). By 5:40 A.M., lava liberation had nearly ceased along the westernmost 100 feet of the fountain chain, and activity at those vents consisted largely of roaring gas release, accompanied by showers of incandescent ejecta. The preponderance of gas at these vents, together with the gas-poor character of the lava forming the cascade on the adjacent wall of Halemaumau, suggests that in the section of the fissure near Halemaumau there was a partial separation of the gas and liquid phases, the gas-rich portion rising nearly vertically to feed the westernmost vents of the fountain chain on the caldera floor, and the liquid largely draining into Halemaumau, forming the cascade.

No conspicuous crack was visible on the wall of Halemaumau above the head of the cascade, or between the rim of Halemaumau and the end of the fountain chain to the east. In the latter gap there were many cracks in a zone about 50 feet wide along the projected course of the eruptive fissure farther east, but none of them were continuous for more than a few feet, or were more than 2 or 3 mm. wide.

Eastward, the principal line of fountains was approximately 1,400 feet long, and essentially continuous. The fountains forming this "curtain of fire" were a few feet to about 100 feet high, and the accumulation of ejecta from them was rapidly building a spatter rampart. Fragments of ejected pumice were drifted southwestward by the trade wind, partly mantling the southern slope of the spatter rampart and the adjacent lava. Along its southwestern part the rampart was breached, and several flow units were escaping northwestward, merging into a single, very active flow of pahoehoe. A smaller flow moved southeastward on the southern side of the rampart. A large river issued from the fountain pit at the eastern end of the spatter rampart and moved southeastward, spreading out to form a broad flow that merged with the lava flowing eastward north of the spatter rampart and with other lava from vents farther east.

Three other short rows of small fountains, less than 20 feet high, lay respectively 200, 400, and 900 feet east of the principal fountain chain. These also built small ramparts and cones of spatter, and liberated small flows. A somewhat more conspicuous row of fountains, 300 feet long, lay 1,800 feet east of the principal fountain chain.

All of these short rows of fountains were essentially parallel to the principal chain, but were offset en echelon from it. West of the easternmost row, a zone of narrow, diagonal cracks extends across an embayment in the new flow toward the next group of vents. Another zone of narrow cracks extends eastward for about 900 feet beyond the new lava, as a prolongation of the line of the principal fountain-chain (Fig. 1).

By 6:45 A.M. new lava had accumulated to a depth of more than 50 feet in Halemaumau Crater, nearly burying the cones of the 1952 eruption. Dense, bluish-white fume filled the crater, nearly obscuring the floor. Two principal fume columns rose from the northeast and southwest fountains. Strong winds, which were directed centripetally entirely around the crater, blew these fume columns inward, causing them to meet a few hundred feet above the crater rim. Above that level the fume cloud rose nearly vertically. No doubt the violent centripetal winds were caused by the strong convective rise of warm air and fume above the crater. Small, violent whirlwinds caused dust-devils around the edge of the crater, and swept across the crater floor, carrying off whirling fragments of the thin crust of the lava lake.

At 7:10 A.M. a good view of the northeastern portion of the crater floor was obtained by Eaton from the northern rim. The northeast fountain consisted of a surging, dense, domical core rising about 200 feet above the crater floor, with frequent bursts of scattered incandescent ejecta as high as the crater rim. The main outward flowage from the base of the fountain was southward. Concentric lobe-shaped markings on the crust of the new lava developed around the base of the fountain. These were stretched outward as the current spread from the fountain source at a velocity of 5 to 10 miles per hour. The circulation appeared to move in a circle and return toward the northwest base of the fountain, but dense fume caused poor visibility of that part of the floor.

At 7:30 A.M. fountain activity, both in Halemaumau and on the caldera floor to the northeast, was decreasing. The largest fountains northeast of Halemaumau were only about 75 feet high, and the westernmost 200 feet of the eruptive fissure was almost dead. The southwest fountain in Halemaumau was about 150 feet high, with occasional bursts reaching 200 feet. The northeast fountain was about 450 feet high. Other small fountains, 10 to 50 feet high, were active in the central part of the floor. The cascade had dwindled to a mere trickle, and by 8:00 A.M. it was entirely inactive.

Between 8:00 and 9:00 A.M. the flow on the caldera floor was still advancing slowly, but had reached nearly its full extent. The three segments of eruptive fissure east of the principal cone chain were nearly inactive, and at the fourth (easternmost) segment activity was very weak. At the latter the repetitive pattern of behavior consisted of a few seconds of quiet followed by loud hissing, culminating in a dull, hissing explosion that threw fragments of pasty lava 15 feet in the air. Along the main section of the active fissure lava fountains still played to heights of 50 to 75 feet.

Between 10:00 and 11:00 A.M. activity within Halemaumau was restricted largely to the northeast and southwest fountains. A prominent sinkhole was active from time to time near the northeastern end of the 1952

cones. Many small avalanches were occurring on the crater walls. Striking the fluid lava of the lake, these caused violent splashing and sank quickly out of sight, to be followed for several minutes by a group of small, secondary fountains. The lava fountains northeast of Halemaumau continued to decrease in size, and by 11:00 A.M. were essentially inactive. By 1:00 P.M. the southwest fountain in Halemaumau had decreased to a height of only 50 feet, and the northeast fountain was throwing only occasional showers of spatter to heights of less than 25 feet. A slump scarp was starting to form around the edge of the crater floor.

At 1:30 P.M. fountains along the central part of the chain northeast of Halemaumau again became weakly active, throwing sporadic showers of incandescent ejecta to heights as great as 25 feet. This revival was brief. By 4:00 P.M., the fountain activity outside Halemaumau was completely ended except for occasional very weak flings and weak, whistling gas release. A little sluggish movement continued in the flow until evening, and glow was visible in the throats of the cones until the night of June 1.

By 3:00 P.M. the northeast fountain in Halemaumau was completely inactive, and the southwest fountain was throwing weak, sporadic bursts of ejecta to heights up to



FIGURE 2. Lava fountains along the fissure northeast of Halemaumau and flow spreading from them. At the right, fume rises from the northeastern edge of Halemaumau. Photo from Uwekahuna about 6 A.M., by Ralph T. Kanemori, Modern Camera Center, Hilo.

25 feet. Similar, but smaller fountains were active in the pit of the principal 1952 cone and just northeast of the 1952 cone group. The slump scarp around the edge of the floor continued to grow in height. By 4:00 P.M. it averaged about 25 feet high, and by the morning of June 1 its height was estimated at 40 feet.

During the evening of May 31 occasional small showers of red-hot cinders were being thrown from the throat of the 1952 cone, but the principal activity was at a vent about 500 feet northeast of the 1952 cones (Fig. 1). At intervals of a few minutes noisy, semi-explosive bursts from that vent threw showers of incandescent ejecta to heights of about 100 feet. The ejecta falling and accumulating around the vent were building a small cone. The vent continued in similar activity until the

afternoon of June 3. During daylight hours each blast was seen to be accompanied by a puff of bluish-white fume.

On the morning of June 1 two small flows were active near the northeast and east-northeast edges of the floor of Halemaumau, and occasional weak lava movement was visible near the southwestern edge. This condition continued throughout the day. During the afternoon a tiny lava fountain, about two feet high, was visible at the head of the east-northeast flow. On June 2 the southwest and east-northeast flows had ceased, but the northeast flow continued active and was developing into a small lava lake. This lake was approximately 300 feet long and 100 feet wide, and was situated on the course of the eruptive fissure. Slow circulation in it, from east to west, was accompanied by occasional disintegration and foundering of the crust and small secondary fountains. No primary fountaining was visible. The lake became inactive about 3:00 A.M. on June 3. The last weak blasts from the semi-explosive central vent were observed at about 6:00 P.M., June 3. Thus, the duration of the eruption was approximately three and one-half days.

Gradual shrinkage of the new lava fill in Halemaumau continued through the eruption and for several days thereafter. Old features, such as the 1952 cones and the prominent fault scarp running northwestward from them, temporarily buried by the new lava, reappeared. The slump scarp around the edge of the crater floor eventually reached a height of approximately 45 feet.

THE LAVA

The lava poured out onto the caldera floor northeast of Halemaumau is basalt containing only 1 to 2 per cent olivine. The olivine is present both as scattered phenocrysts up to about 2 mm. across, and as microlites visible only under the microscope.

The flow consists almost entirely of pahoehoe. Aa is present in small patches only locally. A particularly interesting feature is the development of typical clinkery aa in narrow bands, generally less than a foot wide, along the lines of principal shear near and parallel to the margins of lava streams. Part of the pahoehoe, especially that liberated late in the eruption, is dense, but much of it is very vesicular and shelly. Many toes near the edge of the flow are hollow, consisting of a thin crust 2 to 6 inches thick, covering a central opening as much as 2 feet in diameter. These toes appear to have been inflated by gas, like balloons.

An upper layer of vesicular pahoehoe crust, generally 1 to 3 inches thick, appears to have been essentially isolated from the underlying flow by a layer of gas bubbles. This crust behaved semi-independently from the flow beneath it, being dragged along by movement of the underlying liquid, folded and rolled into ropy forms, and locally fractured and tilted. At the edges of the flow this crust was in places thrust out as much as 3 or 4 feet over the adjacent rocks.

The area covered by the flow northeast of Halemaumau is approximately 139 acres, and the volume of the flow is approximately 1.5 million cubic yards.

The rapid gush of liquid lava into Halemaumau during the first eight hours of the eruption produced a fill averaging 63 feet in thickness, with a volume of approxi-



FIGURE 3. Southwest fountain in Halemaumau, seen from the east rim about 6:30 A.M., May 31. To the right small fountains are playing along fissures that cross the 1952 cones. The bright lines on the crater floor are cracks in the dark lava crust, revealing the incandescent material beneath. Photo by Ralph T. Kanemori, Modern Camera Center, Hilo.

mately 15 million cubic yards. Most of the lava was extruded during the first two hours. About noon on May 31, there began a rapid sinking of the lava level over the entire floor of Halemaumau, leaving a narrow band of congealed lava clinging to the crater walls. By the evening of May 31 the slump scarp thus produced around the edge of the floor was about 25 feet in height, and by the end of the eruption the scarp had increased to an average of 32 feet. Thus the permanent fill of new lava in Halemaumau had an average thickness of 31 feet, and a volume of approximately 7 million cubic yards.

In Hawaii, shrinkage of ponded lavas on cooling and loss of gas commonly produces slump scarps, indicating a decrease of volume of as much as 20 per cent (Macdonald, 1954). However, the decrease of volume of the new fill in Halemaumau was approximately 52 per cent. This proportion appears to be far too great to have resulted from shrinkage due to loss of gas and cooling. Furthermore, the major part of the sinking of the new lava surface was too rapid to have resulted from those causes. The conclusion appears inescapable that some of the new lava disappeared downward, presumably draining back into the fissures through which it had previously risen. The slower sinking, of approximately 7 feet, after the evening of May 31, may have resulted partly from additional draining away of the liquid, but unquestionably also in part from loss of gas and cooling.

RADIOACTIVITY

An attempt to determine the degree of radioactivity of the fume was only partly successful. An hour after the outbreak of the eruption Macdonald took a Geiger-Muller counter into the fume cloud at the southwestern edge of Halemaumau. The fume was rising almost directly upward, however, and only occasionally did moderately dense clouds blow momentarily over the ground at the rim. At no time was it possible to keep the counter

tube in dense fume for long periods. Two counts for periods of only one minute each were obtained. A third count was made in fume rising from a crack several feet away from the crater rim. All of these counts were within the range normally obtained in the Kilauea area at times of no surface volcanic activity, and counts made on the caldera floor away from the crater rim on the morning of May 31. Thus, the counts obtained give no evidence of any concentration of radioactive material in the fume cloud, just as earlier counts have revealed no concentration in active flows or pumice ejected by the lava fountains (Macdonald and Orr, 1950, p. 24; Finch and Macdonald, 1953, p. 76).

EARTHQUAKES ASSOCIATED WITH THE ERUPTION

Following the cessation of the last eruption of Kilauea in November 1952, seismic activity remained at a low level for about five months. On April 29, 1953, three moderate earthquakes originating on the southwest rift of Kilauea initiated a mild resurgence of seismic activity which continued through May, June, and July. August, September, and most of October were extremely quiet months at Kilauea.

A sequence of moderate to strong earthquakes on October 26 and 27 stemming from the upper part of Kilauea's east rift was the first major seismic event at the volcano following the 1952 eruption. After another three weeks of quiet there began a series of frequent, small earthquakes originating at Kilauea caldera which continued until the end of the year.

The first three months of 1954 were very quiet. Coincident with the occurrence of two large earthquakes



FIGURE 4. Northeast fountain in Halemaumau, seen from the east rim about 6:30 A.M., May 31. The cascade on the crater wall is visible just to the right of the fountain. The crater wall to the right is approximately 400 feet high. Photo by Ralph T. Kane-mori, Modern Camera Center, Hilo.

along the east rift of Kilauea between Pahoa and Kapapana on March 30, the series of frequent, small to moderate quakes stemming from Kilauea caldera began again. This series continued until the outbreak of the eruption on May 31.

The majority of these earthquakes were of shallow origin, not more than three to five miles deep, although

between May 13 and 18 four quakes originated under the caldera region at depths of 15 to 25 miles. Predominantly, these quakes were small, only eight being felt in spite of the shallow focal depths. From March 30 through May 31 about 90 quakes were large enough to be identified as being of Kilauean origin, while almost 900 quakes, too small to locate but apparently from Kilauea, were recorded at the Uwekahuna station. Like the larger members of the same group these small quakes appear to have been predominantly of shallow origin. Two characteristic types occurred. One had very sharp preliminary phases and an S-P interval of between 0.2 and 1.5 seconds. The other had no identifiable phases; it consisted only of a train of very irregular waves. Both types were recorded only by instruments around Kilauea caldera and, undoubtedly, were of local origin.

At 3:26 A.M. on May 31 intermittent, high-frequency spasmodic tremor began recording on the Sprengnether vertical seismograph at Uwekahuna. About 3:37 A.M. a series of small, sharp quakes began recording at a rate of about one per minute, the records of the quakes superimposed on the now continuous spasmodic tremor. After 3:42 A.M. these frequent quakes and the continuous spasmodic tremor became so large that the Sprengnether record was unreadable.

Between 3:37 A.M. and the beginning of harmonic tremor at 4:09 A.M., 33 quakes, several of which were felt, were recorded on seismographs around Kilauea caldera. The large quake at 3:54 A.M., which originated at a shallow depth just east of Halemaumau, awakened people generally in the vicinity of the caldera.

It appears probable that the spasmodic tremor and earthquake sequence immediately preceding the eruption were caused by the splitting open of the eruptive fissure and the intrusive rise of the fluid lava through the opening fissure at moderate to shallow depths in the volcano. When the lava reached the surface and the sporadic rise through the opening fissure gave way to a free and voluminous outflow of lava at the surface, harmonic tremor with approximately 10 times the amplitude of the preceding spasmodic tremor suddenly appeared on the seismographs.

Less than one minute after the sharp beginning of strong harmonic tremor on the Bosch-Omori seismograph, the authors rushed from the seismograph vault and found Kilauea already in eruption. This sharp beginning of harmonic tremor and its coincidence in time with the beginning of the eruption is a further check on the long-standing belief that harmonic tremor is generated by the movement of magma through fissures feeding the eruption. The intensity of harmonic tremor recorded by instruments around the caldera correlated closely with the rate of outpouring of lava by the volcano. Continuous harmonic tremor ceased when lava fountaining died out about 2:00 P.M. on May 31. Following the cessation of lava fountaining in Halemaumau and along the rift on the caldera floor, several small vents on the floor of Halemaumau continued in mild gas and cinder activity. One of these continued to throw up occasional showers of cinders until the afternoon of June 3. Associated with the mild explosions from these vents frequent packets of harmonic waves, each about 15 seconds in duration and closely resembling harmonic

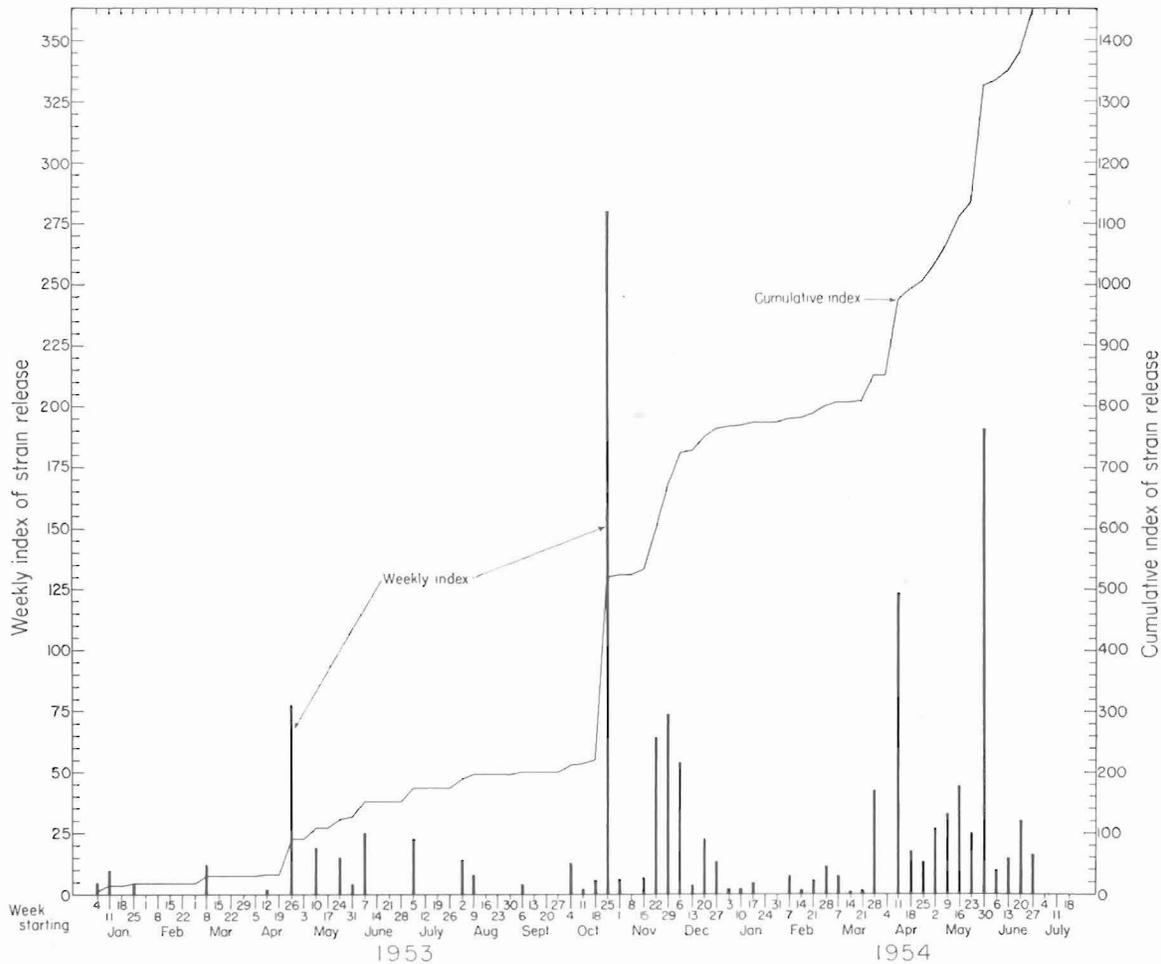


FIGURE 5. Graph showing weekly strain release index (vertical bars) and cumulative strain release index (continuous curve) for the Kilauea caldera region from January 1953 to mid-July 1954. An increase in steepness of rise of the cumulative curve represents an increase in rate of strain release through earthquakes.

tremor, were recorded by the Sprengnether vertical seismograph. These packets, about 3,700 in all, increased and decreased in frequency of occurrence in rather close correspondence to the frequency of explosions at the cinder vents although no coincidence in time between vent explosion and recorded packet could be demonstrated.

STRAIN-RELEASE INDEX

Benioff (1954) has pointed out that, under certain simplifying assumptions, if a uniformly strained body be released suddenly from its strained state by faulting, a fraction of the energy so released radiating outward as seismic waves, the amount of strain released is proportional to the square root of the energy released. If magnitudes of the earthquakes considered are available this energy can be obtained from the Gutenberg-Richter (1942) magnitude-energy formula. To date, determination of magnitudes of local Hawaiian earthquakes has been impeded by proximity of recording stations to the epicenters and variable focal depths. Pending a solution of this problem an approach somewhat different from Benioff's will be followed.

Supposing that we are dealing with regular, sinusoidal, body waves in a homogeneous medium, at any distance from the focus the S-P interval multiplied by the amplitude of the largest wave is constant and is proportional to the square root of the energy in the earthquake. For earthquakes of moderate range in size recorded at small epicentral distances the above relationship permits us to calculate a quantity proportional to the strain release without knowing the earthquake's magnitude.

Dealing only with local earthquakes, we can adopt one instrument as standard and avoid the reduction of recorded amplitudes to earth amplitudes. Thus, the product $(S-P) \times A$, where S-P and A are, respectively, the S-P interval and the maximum amplitude of a given earthquake recorded on the Sprengnether vertical seismograph at Uwekahuna, is a measure of the strain release or the faulting or fracturing which generated the earthquake.

Because of the extreme difference between the energy released by a large earthquake and that released by a small one, $(S-P) \times A$ shows a great variation from large to small earthquakes. Since the many small earth-

quakes which precede eruptions of Hawaiian volcanoes and which appear to be a significant premonitory symptom of eruption are dwarfed relative to the infrequent, much larger earthquakes occurring at times remote from eruptions, an additional weighting device is employed. The strain release index of a given earthquake is defined as: $S-R \text{ Index} = \sqrt{(S-P) A}$, where S-P and A are as defined above.

To obtain geologic units small enough that its rocks may be considered to be acted upon by a single system of forces it is necessary to divide the volcanoes into units, guided insofar as possible by the known geology. For the present purpose the Kilauean unit is taken as the volcano Kilauea minus the eastern half of its long east rift zone. S-R Indices for earthquakes larger than tremors originating in this unit were computed for 1953 and the first half of 1954. When records from the standard instrument, the Sprengnether vertical seismograph at Uwekahuna, were not available records from other instruments located around Kilauea caldera were used. In such cases, empirically determined amplitude correction factors were applied to obtain S-R Indices corresponding to those from the Sprengnether seismograph.

In Figure 5 are plotted weekly S-R Indices (the sum of the S-R Indices of earthquakes occurring during a given week) and cumulative weekly S-R Indices. The slope, not the height, of the latter curve is significant: it is a measure of the rate of strain release in the volcano.

CONCLUSION

The 1954 eruption of Kilauea is one of the shortest on record, being exceeded in brevity during recent years only by that of February, 1929, which lasted two days. The total final volume of lava left in Halemaumau and on the caldera floor was only about one-twelfth that extruded during 1952, but the rate of lava output during the first few hours of the eruption was very high, approximately equal to that during the corresponding part of the 1952 eruption.

The fissure eruption on the caldera floor east-northeast of Halemaumau appears to have been unique in the recent history of Kilauea caldera. A search of the literature reveals no record of similar activity at least since 1877. Before that, the records are too incomplete to constitute any good basis for comparison. The eruptive fissure extends almost directly toward the vents of the eruptions of 1832 and 1868. Neither of these eruptions was on the caldera floor. The eruption of 1832 occurred on the Byron Ledge, spilling lava both into the caldera and into Kilauea Iki Crater. That of 1868 occurred on the wall of Kilauea Iki and sent no lava into the caldera proper. Both, however, were intimately associated with caldera activity, and the alignment of the 1954 fissure with these earlier vents suggests that this is an important zone of weakness across the caldera floor.

On or about May 4, 1877, an eruption occurred along a fissure at the southeastern edge of Kilauea caldera. An entry by Thomas E. Cook in the Volcano House record book, under the date of May 21, 1877, states that the fissure from which the flow of lava took place commenced at the caldera wall and extended up to within 20 or 30 feet of the top of the wall (Brigham, 1909, p. 132). Under the date of May 6, 1877, Sanford B. Dole

states, also in the Volcano House record book, that the lava spouted from the fissure to heights of 50 to 150 feet (Brigham, 1909, p. 131). Activity appears to have lasted only a few hours, but lava covered several acres of the caldera floor. The eruption was accompanied by draining of Halemaumau, leaving a fuming pit about 250 feet deep. The large size of the fountains and the location of the fissure indicate quite certainly that the eruption came from a primary, deep-seated vent, and was not merely an overflow from Halemaumau.

Eruption may have occurred in Keanakakoi Crater at about the same time. There appears, however, to be considerable doubt regarding the date of the lava that forms the floor of Keanakakoi (Stearns and Clark, 1930, p. 79).

The location of the eruptive fissure of 1877 is not known with certainty. H. A. Powers suggests (personal communication) that the small spatter cone at the southeast edge of Kilauea caldera just north of Keanakakoi (Fig. 1) may have been formed at that time. The suggestion is highly plausible, but cannot be confirmed. Both the spatter cone and a 2-foot bed of cinder on the caldera wall south of it, 150 feet above the caldera floor, may have been formed during the 1877 eruption.

None of the lava outpourings on the caldera floor between 1877 and 1954 appear to have been from primary, deep-seated vents. In 1884 and 1885 lava flowed northeastward from Halemaumau to the caldera wall near Kilauea Iki, building a small cone, known as Little Beggar, near its point of emergence. Little Beggar was a well-known landmark on the floor of Kilauea caldera until it was buried by the 1954 eruption. It was a "rootless" dribble cone (Wentworth and Macdonald, 1953, p. 52) built by spatter from an opening in the roof of a lava tube. L. A. Thurston believed that overflows during 1894 destroyed the original Little Beggar cone, and built another in its place (Stearns and Clark, 1930, p. 79). However, comparison of a photograph of Little Beggar in 1889 published by Brigham (1909, p. 157), with others taken during recent years indicate that it probably was the same cone. If there were two Little Beggars they were very closely similar in form and identical in origin. It appears probable that the 1884-85 flow was simply a drainage from the Halemaumau lake, through fissures in the edge of the broad, shield-shaped Halemaumau cone. Certainly no strong lava fountaining occurred at the 1884 vent. The 1894 lava flooding in the same general area undoubtedly was merely an overflow from the Halemaumau lake.

The outpourings of 1918 and 1919 also were obviously merely overflows from the Halemaumau lake, even though the latter sent a big stream of lava all the way to the northern wall of the caldera. The 1921 flow, over the southern portion of the caldera, issued from cracks southwest of Halemaumau formed at the time of the 1919-20 outbreak in the Kau Desert. Two prominent conelets were formed at the points of issue of the lava. However, the fountains at these vents were low and poor in gas, and photographs of the conelets show them to have been dribble cones. Almost surely, the eruption of 1921, like those of 1884, 1894, 1918, and 1919, was merely an overflow from the Halemaumau lake.

Persons familiar with the behavior of Kilauea previous to the great collapse in 1924 have remarked on the dis-

tinct change in character of its behavior during the 1952 and 1954 eruptions (Isabel P. Jaggard, personal communication). Unquestionably, these last two eruptions have resembled much more closely the eruptive habit of Mauna Loa than that of Kilauea during the 19th, and early part of the 20th centuries. Probably, however, the change does not represent any fundamental alteration in the eruptive habit of Kilauea, but rather merely reflects the absence of an open vent between eruptions (or lava overflows). The open conduit, marked by the presence of the active lava lake most of the time from 1823 to 1924, prevented the accumulation of any large "head" of gas on the magma column, and consequently the formation of large gas-rich fountains such as have characterized the activity of Mauna Loa and the 1952 and 1954 eruptions of Kilauea. There is no good reason to believe, however, that the "permanent" lava lake and open conduit have been characteristic of Kilauea volcano throughout its period of growth. Its geologic structure and the formations at prehistoric vents indicate, on the contrary, that throughout most of its growth it has closely resembled Mauna Loa. The century of nearly constant lava lake activity, which ushered in our knowl-

edge of Kilauea, may well have been an unusual period in the long-term history of the volcano.

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REPORT OF THE HAWAIIAN VOLCANO OBSERVATORY FOR APRIL-JUNE, 1954

By GORDON A. MACDONALD

April

Seismic activity on the island of Hawaii was appreciably greater than normal during the month of April. A total of 69 earthquakes larger than tremors was recorded on seismographs operated by the Volcano Observatory on the island of Hawaii. Of these, 44 originated in Kilauea Volcano, 19 of them in or near the crater area, and most of the rest along the east rift zone, which extends from the crater eastward through Puna to Cape Kumukahi. Three of these earthquakes were felt in the Volcano district on April 15, and one each on April 1 and 22. The quake felt in Hilo on April 8 was an aftershock of the large quakes that originated in Puna on March 30. Another, felt in Hilo on April 26, had its focus on the east rift zone of Kilauea near Napau Crater.

Only six earthquakes were definitely related to Mauna Loa, although the origins of 14 others could not be located with certainty. On April 23 and 24, three small quakes originated beneath the western slope of Hualalai Volcano.

Tilting of the ground surface at the northeastern rim of Kilauea caldera was southwestward, but at a rate somewhat less than normal. This apparently represented a slight increase of volcanic pressure beneath Kilauea.

Although Kilauea Volcano was definitely restless, there was as yet no indication of imminent eruption.

A new seismograph station at Pahoa, in eastern Puna, was put into operation on April 1. The station is situated on the grounds of the Pahoa school, through a cooperative agreement with the School Department of the County of Hawaii. The station is equipped with a Loucks-Omori two-component horizontal seismograph, with static magnification of 250, recording on

smoked paper with a recorder speed of 60 mm. per minute. Time marks on the record originate from an I.B.M. master clock in the station. The clock time is corrected by means of the Bureau of Standards time signal, broadcast over station WWV, and marked directly on the record by means of a device constructed by Jerry P. Eaton. The station operator is Kongo Kimura.

May

The outstanding event of the month was the outbreak of Kilauea on May 31, described in preceding pages.

Earthquake activity at Kilauea remained greater than usual throughout May. Both the total number of quakes recorded and the weekly seismicity index ranged from two to four times the normal. Thus the volcano was obviously uneasy, but no single event or pattern of events was recognized that would make possible a definite prediction of coming eruption. A large number of very small earthquakes recorded on the Sprengnether vertical seismograph at the Uwekahuna station may, on further analysis, prove to have characteristics that would aid prediction if similar swarms occur in the future. This is the first pre-eruption seismic activity recorded on seismographs of high sensitivity in Hawaii.

Ground tilting at the northeastern rim of Kilauea caldera was approximately normal during May. The seasonal reversal from southward to northward tilting took place a little earlier than usual, and as a result there was a slightly larger than usual accumulation of northward tilting during the month. It was, however, well within the limits of variation of non-eruption years. Thus there was little or no evidence of change of magmatic pressure beneath Kilauea during the months just preceding the eruption.

June

The eruption of Kilauea that began at 4:09 A.M., May 31, ended late in the afternoon of June 3. No eruptive activity occurred during the remainder of the month.

Seismic activity at Kilauea remained somewhat greater than normal through the month of June. The seismograph at the Whitney Laboratory of Seismology recorded a total of 65 earthquakes. Most of these came from a depth of several miles beneath the Kilauea crater area, and represented continued uneasiness of Kilauea volcano. Ground tilting was normal for this season of the year, indicating no marked change of volcanic pressure during or following the eruption.

From June 16 to 20 a swarm of small quakes originated apparently at a depth of about 25 miles in the vicinity of the Mauna Loa seismograph station. Many of these were felt at Umikoa, and some at other localities on the north and east flanks of Mauna Kea.

Several small quakes were felt in Kona during June. Two of these, on June 1 and 16, dismantled the seismograph at Kona-waena school. The quakes originated in central Kona, probably on the Kealakekua fault.

Starting early on the morning of May 31, and continuing throughout June, a very large number of landslides occurred on the walls of Halemaumau Crater. More broken rock accumulated at the foot of the wall during the month of June than during the entire interval between the 1952 and 1954 eruptions. Several segments of the crater rim collapsed. One of these was almost directly in front of the visitors' overlook, but the greatest instability was on the northern wall. There, an average width of about 10 feet of the rim collapsed over a distance of several hundred feet, taking with it one benchmark and several other surveying stations used by the Volcano Observatory. Cracks near the northern rim show an aggregate opening of about one foot. Less-pronounced cracking occurred on the caldera floor southeast, south, and west of Halemaumau. The crack at station 40, west of the west tilt cellar, opened 9 mm. during June.

The summit region and northeast rift zone of Mauna Loa were examined on June 24 to 27. No signs of any unusual conditions were detected. There have been no apparent changes in Mokuawewewo caldera since the end of the 1949 eruption.

A new seismograph station at Kamuela, on the northern part of the island of Hawaii, was put into operation on June 9. It is situated on the grounds of the Waimea school, and is equipped in the same manner as the Pahoa station (see above). The station operator is Thomas C. Mills.

SEISMOLOGY

Earthquake Data, April-June, 1954

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

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Local Seismicity*	Tele-seisms
April 4	0	3	0	0	0	0	1.50	0
11	6	9	0	2	0	1	14.00	1
18	3	1	1	1	0	0	4.25	0
25	4	5	0	0	0	0	3.50	3
May 2	7	9	0	0	0	0	6.25	1
9	7	5	1	0	0	0	4.25	2
16	12	10	2	1	0	0	12.00	0
23	13	9	2	0	0	0	9.75	0
30	984	22	2	1	1	1	268.00	1
June 6	20	8	0	0	0	0	9.00	3
13	815	16	0	0	0	0	212.00	2
20	5	12	1	0	0	0	8.25	1
27	5	11	3	0	0	1	13.75	1

* For definition of local seismicity see Volcano Letter 371 or 512. Each local earthquake is assigned a seismicity value according to its strength, as follows: tremor, 0.25; very feeble, 0.5; feeble, 1.0; slight, 2.0; moderate, 3.0; strong, 4.0. These values are totaled to give the weekly local seismicity. Continuous volcanic tremor is ignored in the calculation. The strength assigned to the earthquake depends on the double amplitude of the maximum oscillation it causes on the Bosch-Omori seismograph, as follows: tremor, less than 0.5 mm.; very feeble, 0.5 to 4 mm.; feeble, 4 to 11 mm.; slight, 11 to 25 mm.; moderate, 25 to 60 mm.; strong, greater than 60 mm.

Table of Tilt at Seismograph Stations on Rim of Kilauea Caldera

Week Beginning	Whitney Station (Northeast rim)		Uwekahuna Station (West rim)	
	Amount	Direction	Amount	Direction
April 4	1.03"	W 36° S	1.32"	N 14° W
11	0.36"	E	2.58"	S 7° E
18	0.60"	W 37° S	0.32"	S
25	0.61"	W 11° N	2.74"	N 21° W
May 2	0.60"	N 37° E	1.72"	S 22° E
9	0.42"	W 34° S	2.58"	N 30° W
16	0.61"	N 11° W	1.43"	N 27° W
23	1.18"	N 24° E	0.96"	S
30	1.03"	W 24° N	5.30"	N 25° W
June 6	1.08"	N	0.72"	N 27° W
13	0.24"	E	1.60"	S
20	1.23"	N 29° W	1.43"	S 27° E
27	0.72"	N	1.36"	SE

Local Earthquakes

The data for the following local earthquakes were determined from seismographs on the islands of Hawaii and Maui operated by the Hawaiian Volcano Observatory. The number preceding each quake is the serial number for the current year. Only earthquakes classed as feeble or larger are included in the list. Many very feeble quakes, to which serial numbers are assigned also, are omitted. Locations given are epicenters. Except where otherwise indicated, the times given are arrival times at the Uwekahuna station, on the western rim of Kilauea caldera. They are stated in Hawaiian standard time, which is 10 hours behind Greenwich civil time. The intensity rating (Feeble, Moderate, etc.) given is based on the Bosch-Omori seismograph at the Whitney Laboratory of Seismology. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney station.

- 92. Apr. 1, 06:34:49, strong. Felt in Hawaii National Park. Kilauea caldera.
- 93. Apr. 1, 15:56:42, slight. Felt in Puna. East Puna.
- 94. Apr. 1, 17:52:30, feeble. Kilauea caldera.
- 101. Apr. 11, 02:20, not recorded at the Whitney Laboratory (Pahoa, slight). East Puna.
- 116. Apr. 15, 06:27:11, very feeble (Uwekahuna, feeble). Kilauea caldera.
- 117. Apr. 15, 06:27:50, slight (Uwekahuna, moderate). Felt in Hawaii National Park. Kilauea caldera.
- 118. Apr. 15, 06:43:03, very feeble (Uwekahuna, feeble). Kilauea caldera.
- 119. Apr. 15, 07:01:11, slight (Uwekahuna, moderate). Felt in Hawaii National Park. Kilauea caldera.
- 120. Apr. 15, 07:15:00, strong. Felt in Hawaii National Park. Kilauea caldera.
- 123. Apr. 15, 19:19:53, not recorded at the Whitney Laboratory (Pahoa, feeble). East Puna.
- 131. Apr. 17, 17:25:34, very feeble (Uwekahuna, feeble). Kilauea caldera.
- 138. Apr. 22, 14:31:54, slight. Felt in Hawaii National Park. Kilauea caldera.
- 141. Apr. 23, 16:13:23, feeble. Koaiki fault.
- 143. Apr. 23, 23:14, not recorded at the Whitney Laboratory (Kona, feeble). Kona.
- 149. Apr. 25, 11:22:17, not recorded at the Whitney Laboratory (Pahoa, feeble). East Puna.
- 177. May 6, 20:31:41, very feeble (Mauna Loa, feeble). Northeast rift of Mauna Loa near Puu Ulaula.
- 190. May 14, 07:53:19, not recorded at the Whitney Laboratory (Pahoa, feeble). East Puna.
- 192. May 15, 01:45:36, feeble. Three miles south of Uwekahuna at a depth of 15 miles.
- 197. May 18, 03:34:34, feeble. Kilauea caldera.
- 198. May 18, 10:36:40, feeble. Six miles south of Uwekahuna at a depth of 20 miles.
- 199. May 18, 16:56:48, very feeble (Kona, strong). Felt in Kealakekua and Capt. Cook, Kona, Kona.

203. May 20, 20:40:03, slight. Kilauea caldera.
 212. May 24, 09:11:56, feeble (Uwekahuna, slight). Kilauea caldera.
 218. May 26, 16:39:42, feeble (Mauna Loa, strong). Kaoiki fault near Halfway House at a depth of 6 miles.
 233. May 31, 03:42:32, slight (Uwekahuna, moderate). Kilauea caldera.
 236. May 31, 03:46:57, very feeble (Uwekahuna, feeble). Kilauea caldera.
 237. May 31, 03:47:38, very feeble (Uwekahuna, feeble). Kilauea caldera.
 238. May 31, 03:48:06, very feeble (Uwekahuna, feeble). Kilauea caldera.
 239. May 31, 03:48:16, feeble. Kilauea caldera.
 246. May 31, 03:50:44, moderate (Uwekahuna, strong). Felt in Hawaii National Park. Kilauea caldera.
 247. May 31, 03:50:59, very feeble (Uwekahuna, feeble). Kilauea caldera.
 253. May 31, 03:54:05, strong. Felt in Hawaii National Park. Kilauea caldera just east of Halemau-mau.
 258. May 31, 14:45:40, very feeble (Uwekahuna, feeble). Kilauea caldera.
 266. June 1, 20:42:53, very feeble (Kona, strong). Felt in Kona, Kona.
 267. June 2, 00:03:03, feeble. Kilauea caldera.
 289. June 16, 09:42:28, very feeble (Pahoa, feeble). East rift of Kilauea.
 299. June 18, 03:00:03, very feeble (Mauna Loa, feeble). Approximately under the Mauna Loa seismograph station at a depth of about 25 miles. This is one of the largest of a series of more than 100 very feeble quakes and innumerable tremors originating from this focus on June 18, 19, 20, and 21. Many of these quakes were felt at Umikoa on the northeast flank of Mauna Kea, and several were felt at Kamuela and Hilo.
 429. June 23, 02:03:09, feeble. Kilauea caldera.
 445. June 29, 02:35:27, very feeble (Mauna Loa, slight). Same epicenter as No. 299.
 456. June 30, 17:20:11, feeble. Kilauea caldera.

Distant Earthquakes

The following earthquakes of distant origin were recorded on the seismographs of the Hawaiian Volcano Observatory. Locations of the epicenters and the magnitudes are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey. The time given is that of the first detectable emergence of the quake on the Sprengnether vertical seismograms, in Hawaiian standard time.

- Apr. 2, eP 05:07:35, 28½° S., 177° W. Kermadec Islands.
 Apr. 17, iP 10:17:51.4, 51½° N., 179° W. Andreanof Islands, Aleutian Islands. Felt on Adak. Magnitude 6¾-7.
 Apr. 26, eP 10:33:29.4, 51° N., 158½° E. Off southeast coast of Kamchatka. Magnitude 6½-6¾.
 Apr. 29, eP 00:57:15.3, 29½° N., 112½° W. Gulf of California. Magnitude 7¼-7½.
 Apr. 29, eP 01:42:11.2, 29½° N., 112½° W. Gulf of California. Minor damage in Western Mexico. Magnitude 7½-7¾.
 May 5, iP 23:10:59.4, 27½° N., 112½° W. Gulf of California. Magnitude 6¾.
 May 9, eP 20:53:03.4
 May 13, iP 04:56:12.6, 17° N., 95½° W., Oaxaca, Mexico. Minor damage. Magnitude 6-6½.
 May 14, iP 12:49:13.7, 36° N., 137° E. Near coast of Honshu, Japan. Felt in Eastern Honshu. Magnitude 7.
 June 3, eP 21:01:29.0, ½° S., 91½° W. Galapagos Islands. Magnitude 6¼-6¾.
 June 6, eP 07:02:04, 3½° S., 136½° E. Western New Guinea. Magnitude 7.
 June 7, eP 00:24:37.5, 3½° S., 152° E. New Britain Region. Depth 450 km. Magnitude 6¾.
 June 11, iP 19:42:34.4, 18° S., 179° W. Fiji Islands. Depth 550 km. Magnitude 6½.
 June 15, eP 03:41:02.6, 5° S., 77° W. Northern Peru. Magnitude 6½-7.
 June 16, iP 15:49:31.5, 56° N., 159½° W. Off south coast of Kodiak Island. Magnitude 6½.
 June 23, eP 22:07:28.2, 18½° N., 145½° E. Marianas Islands.

VOLCANO NOTES AND NEWS

TANGIWAH RAILWAY DISASTER

Christmas Eve of 1953, and the visit of Queen Elizabeth to New Zealand, were marred by disaster. Shortly after 10:20 P.M. on December 24, the Wellington-Auckland express train plunged into the gorge of the Whangaehu River near Tangiwai station. Casualties numbered 151, of which 131 are known dead, and 20 are missing. The immediate cause of the catastrophe was the destruction of the railway bridge by a large mudflow (lahar) originating on Ruapehu volcano and rushing down the Whangaehu River. The following account of the causes of the catastrophe is derived largely from a report by James Healy, Supervising Geologist of the Geological Survey Branch, New Zealand Department of Scientific and Industrial Research. The report is contained in a longer report of the Board of Inquiry into the Tangiwai Railway Disaster (Government Printer, Wellington, 31 pp., 1954).

Ruapehu is a composite volcanic cone south of Lake Taupo, in the central part of the North Island of New Zealand. At its summit is a broad crater, a mile long and half a mile wide,

within which is an inner cone with a crater containing a small lake. The central cone is surrounded on three sides by fields of snow and ice, occupying the larger crater. On the east, however, the central cone slopes directly down to the Whangaehu Glacier, on the outer flank of the mountain. The crater lake is generally unfrozen, being warmed by rising volcanic steam. The water of the lake may rise until it spills out through the lowest notch in the crater rim, melts a channel beneath the adjacent ice field, and finally emerges to form a branch of the Whangaehu River. Recent activity of Ruapehu has been restricted largely to the inner cone. During the last eruption a dome of lava grew in the crater during March and April, 1945, followed by explosions that continued until early 1946. The explosions left a crater 1,000 feet deep, and covered the summit of the mountain with loose ash and larger ejecta.

In prehistoric times large mudflows buried much of the region around the base of Ruapehu. Mudflows down the Whangaehu River occurred on four previous occasions during the past century. Those of 1889 and 1895 resulted from eruptions in the crater lake; those of 1861 and 1925 were cold mudflows result-

ing from release of the water of the lake below the glacier. None appears to have equaled in size that of 1953.

After the end of explosive activity in 1946, the crater began to refill with water, and by August 1953 the lake level had again stabilized and the outlet tunnel under the glacier had been re-established. The new lake level was 20 to 25 feet higher than before 1945. Water appears to have been seeping through a barrier of ash and scoria alongside the outlet tunnel, to form another channel beneath the ice at a lower level.

No new volcanic activity appears to have contributed to the origin of the 1953 mudflow. The cause of the sudden release of water from the crater lake, which resulted in the disastrous mudflow, appears to have been fissuring, and collapse of the barrier of ash at one side of the entrance of the outlet tunnel. Collapse of the barrier may have resulted partly from erosion by the stream of water in the hidden channel beneath the ice, and partly from weakening of the barrier by seepage of water through it (Healy, 1954). The lake level dropped 26 feet, and the rate of discharge is believed to have reached 30,000 cubic feet per second. As the flood moved down the Whangaehu Valley it brought with it huge quantities of loose ash and boulders, together with blocks of ice from the glacier. At the lower end of the Whangaehu Gorge the flood, at its maximum, filled a channel 105 feet wide to a depth of 22 feet (as compared to the

river flow on December 28, which occupied a channel only 20 feet wide and 1.5 feet deep).

Mudflows, both hot and cold, are a common cause of disaster in volcanic regions, and methods for warning and control of mudflows are one of the most pressing problems in practical volcanology. During the past few months two persons were killed by mudflows on the slopes of Hibok-Hibok volcano in the Philippines. These mudflows resulted from torrential typhoon rains falling on the loose debris left on the upper slopes of the volcano by the recent eruptions. On January 23, 1954, A. Alcaraz and G. A. Macdonald warned the municipal council of Mambajao of the possibility of such mudflows, and advised that local people should not live within a few feet of stream courses.

UNITED NATIONS TRAINEE IN VOLCANOLOGY

Gregorio A. Andal, assistant geologist of the Philippine Commission on Volcanology, arrived at the Hawaiian Volcano Observatory on June 7 for a stay of nearly two months. Mr. Andal's visit is under the auspices of the United Nations Technical Training Program. He will spend his time in Hawaii studying Hawaiian volcanoes and volcano observatory methods. On his departure from Hawaii, early in August, he plans to spend an additional two months on similar study in Japan.

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VOLCANIC ERUPTIONS OF 1953 AND 1948 ON ISABELA ISLAND, GALAPAGOS ISLANDS, ECUADOR¹

By ADRIAN F. RICHARDS²

1953 FLANK ERUPTION OF SIERRA NEGRA (Volcan Grande)

On August 27, 1953, the northern flank of Sierra Negra (Volcan Grande), situated on southern Isabela (Albemarle) Island, the largest of the Galapagos Islands, was reported in a state of eruption. The reports were contained in radio messages sent by the captains of several tuna clippers to the Scripps Institution of Oceanography, University of California, and the U. S. Hydrographic Office (Notice to shipmasters, volcanic activity, Pacific Ocean: U. S. Hydrog. Office, Hydrographic Bul. No. 36, Sept. 5, 1953). Joe Marques, Master, and Robert Robbins, Navigator and Radio Operator, of the "Normandie," and Captain George Zeluff of the "Paramount" have furnished the writer with their observations of the beginning of this eruption.

During the afternoon of August 27 a presumed new lateral fissure, believed to trend northeast-southwest and estimated to be two miles long, opened about three-fourths of the way up the northern side of Sierra Negra, at an approximate altitude of 3,700 feet. The beginning of the eruption was witnessed from the "Paramount," located in Bolívar Canal nearly 30 nautical miles north of the fissure site. A very large, light-colored eruption column was observed to ascend to a height of more than 30,000 feet, and voluminous flows of lava started to issue from the ends of the fissure and flow north towards Elizabeth Bay.

¹ Contribution from Scripps Institution of Oceanography, New Series, No. 741.

² Scripps Institution of Oceanography, La Jolla, California. The writer wishes to express his appreciation to all of the men of the tuna fishing fleet who have contributed the information which has made this report possible. The assistance of Professors F. P. Shepard and Chas. H. Behre, Jr., who have critically read the manuscript, is also appreciated. Professor Behre has also aided the writer with the nomenclature of the Isabela Island volcanoes.

During the night of August 28 a bright red reflection in the sky was observed from the "Normandie," which was then off the west end of San Cristobal (Chatham) Island, approximately 90 miles east of the volcano. On the 29th the eruption was viewed from the "Normandie" in Elizabeth Bay, about 20 miles from the fissure. Unfortunately much "smoke"—slightly darker than the fog—and haze obscured the site of the eruption. However, at night visibility improved, and cherry-red lava could be seen flowing down the northern side of Sierra Negra. Lava from the north end of the fissure appeared to flow due north, to the shore of Elizabeth Bay, about 5 miles from the fissure. It is not known whether or not the lava flowed into the bay. From the southern end of the fissure the lava stream apparently divided and flowed toward both sides of Point Moreno, which is located approximately 10 miles northwest of the fissure. "Red eruptions," probably lava fountains or showers of incandescent cinder, ascended an estimated 400 feet (as seen from 20 miles away) above the fissure at intervals of seven to eight minutes. Most of the visible activity appeared at the northern extremity of the fissure.

On August 31 a bright reddish glow, reflected from low clouds, was seen from James Bay on the western side of San Salvador or Santiago (James) Island, nearly 40 miles north-northeast of the volcano. On September 10 the "Normandie" was near Webb Cove, about 15 miles west of the fissure. Volcanic activity, if present, was not observed, due to heavy fog, mist, and clouds which obscured the island from view.

Ray Maderis, Navigator of the "Equator," has informed the writer that on October 7 volcanic activity on southern Isabela Island was observed from Baltra Island, about 60 miles to the northeast.

At the end of January, 1954, the "Paramount" again visited Isabela Island. Visibility from Elizabeth Bay was

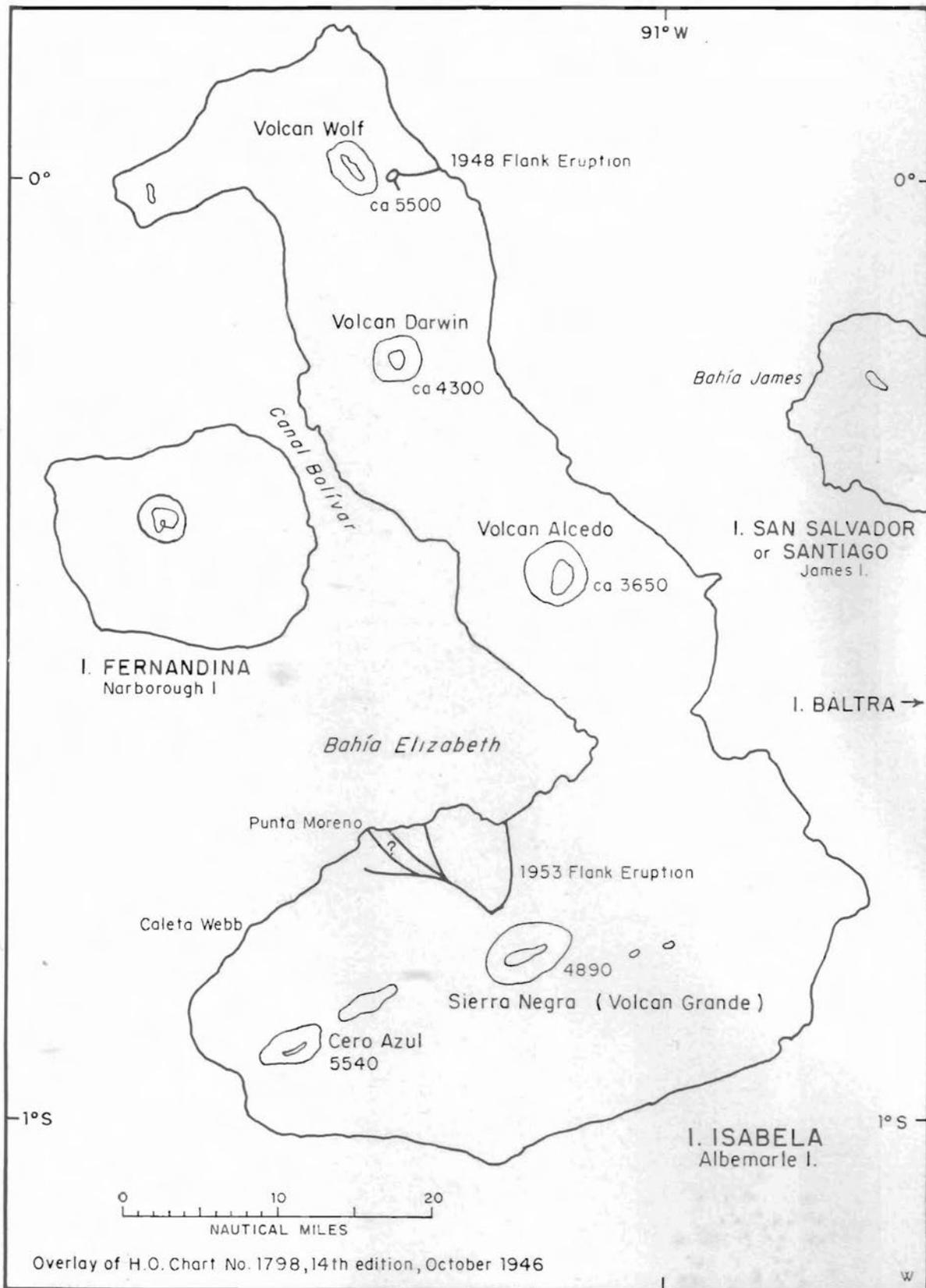


FIGURE 1. Location of the 1948 and 1953 flank eruptions on Isabela Island.

excellent and Captain Zeluff reported that he observed the lava flows to be located approximately as shown in Figure 1. No cone was seen at the site of the fissure, where fumarolic activity was observed. The violent phase of the eruption ceased between October 7 and the end of January, 1954. The exact date is unknown.

1948 FLANK ERUPTION OF VOLCAN WOLF

According to notations made in the log book of the "Paramount," and information obtained from Joseph Madruga, Master of the "Paramount" at that time, an eruption occurred on January 24, 1948, from a new peripheral vent near the east summit of Volcan Wolf on northern Isabela Island. To the writer's knowledge this eruption has not been previously recorded in the literature.

At the beginning of the eruption Volcan Wolf was observed from Banks Bay, about 11 nautical miles southwest of the volcano. A light-colored eruption column originating from the new vent was observed to ascend more than 10,000 feet above sea level. Throughout the time that the "Paramount" was in the vicinity of the volcano, an intermittent rumbling noise was heard. At night red incandescent bombs were seen ejected an estimated 200 to 300 feet above the vent, and Banks Bay was illuminated by the volcanic activity as brightly as during a night with a full moon.

On the 25th Madruga was flown near the eruption site in the fish-spotting Piper Cub belonging to the "Paramount." A small cone, estimated to be about 100

feet high, was seen forming on the southeastern side of the volcano near the peak, at an altitude of approximately 4,000 feet. The crater of the cone glowed cherry-red, and lava appeared to be flowing over the rim. However, the base of the cone could not be clearly seen, and consequently it is possible that the lava could have been emerging from a fissure in the cone instead of flowing over the rim. Large bombs or blocks of lava were also seen shooting skyward.

A single stream of lava from the crater of the parasitic cone was observed flowing very slowly down the flank of the volcano. Several days later, according to Madruga, other fishermen noticed that steam was rising from the shore, and it appears probable that the lava had reached the sea, about 3.5 miles from the cone. On the day of the flight a small second stream of lava was observed flowing a short distance south from the cone. The approximate position of the cone and two flows, based on the data given by Madruga, are shown in Figure 1.

The violent phase of the activity continued for at least four or five days before the "Paramount" left Isabela Island. At the end of January, or early in February, the ship was at Wolf (Wenman) Island, 85 miles north of the volcano, and a red glow from the eruption was clearly visible at night. The date of the end of the eruptive activity is not known to the writer.

REFERENCE

Report of the M. V. ROYAL PACIFIC: U. S. Hydrographic Office, Bul. 36, Sept. 5, 1953.

A METHOD FOR RECORDING RADIO TIME SIGNALS ON SEISMOGRAMS

By JERRY P. EATON

One of the most exacting requirements in seismology is the accurate timing of seismic events. For earthquake work the precision in timing currently sought is one-tenth of a second. To attain this precision an accurate time base must be provided on the seismogram. The usual procedure is to maintain a station clock, capable of running at a very uniform rate, which is equipped with contacts for marking minutes and hours on the seismogram. Time indicated by this clock is then checked periodically against the accurate radio time signals broadcast by the National Bureau of Standards Stations WWV or WWVH; by one of the U. S. Naval Radio Stations NSS, NPG, NPM, or NBA; or by similar institutions abroad.

Granted that a reliable station clock is available, the accuracy of the seismogram time base is limited by the accuracy of the radio time signal and the accuracy of the comparison of clock and radio time. Of the American stations, WWV, WWVH, and NSS broadcast time signals accurate at least to a few hundredths of a second. Signals broadcast by NPM and NPG appear to be accurate to within about one-tenth of a second. Thus, any

of these stations provides time precise enough for the needs of earthquake seismology.

The most satisfactory method for comparing radio and clock time is to record the radio time signal directly on the seismogram, permitting a clock correction to be measured with at least as great a precision as that attainable in measuring individual seismic events on the seismogram. Special receivers built to close a relay in the seismograph timing circuit in response to the make-break continuous wave signals sent out by the Naval Radio Stations are usually employed for this purpose.

At the Hawaiian Volcano Observatory the need arose to adapt a small commercial communications receiver (Hallicrafters S-38C) to the task of closing a relay in response either to the NPM (Oahu) continuous wave signal or to the WWVH (Maui) modulated signal. A diagram of the rather simple and inexpensive solution to this problem is given in Figure 2. The audio frequency emf appearing across the speaker transformer primary, T , is rectified in a voltage-doubling circuit employing two germanium diodes, D . The output of this system is applied to the coil of a plate circuit relay, Rel . With the

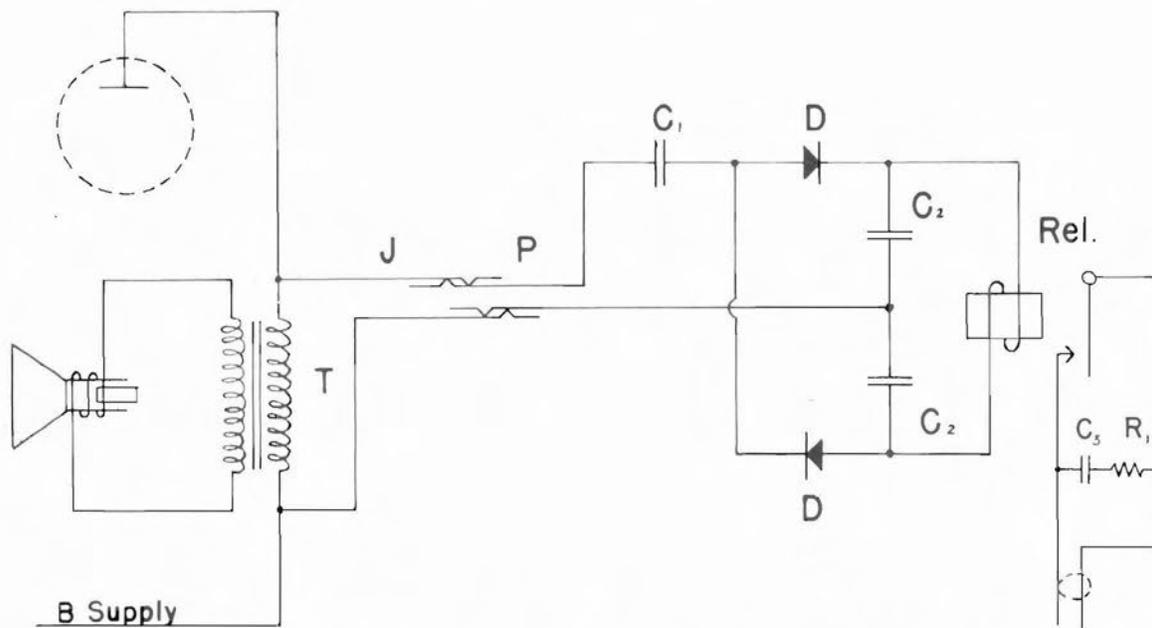


FIGURE 2. Radio adapter for recording time signals. T—Speaker transformer, J—Phone jack, P—Phone plug, C_1 — $2\mu\text{F}$ capacitor, C_2 — $1\mu\text{F}$ capacitor, C_3 — $0.25\mu\text{F}$ capacitor, D—Germanium diode (G.E.1N91 or 1N34A), Rel.—Plate circuit relay (Potter-Brumfield I,S-5, 5000Ω coil), R_1 —20 to 50Ω 1 watt carbon resistor. The $1\mu\text{F}$ and $2\mu\text{F}$ capacitors preferably should be pyranol, but electrolytic capacitors are satisfactory if polarization is maintained.

circuit components used the relay closes on about 10 volts, whereas a good, strong signal develops up to 60 volts across the relay. Since this recording device requires no operating power supply, the relay, two diodes, four condensers, and one resistor required in its construction are simply mounted on a $1 \times 4 \times 10$ inch wooden block. The device is attached to the radio circuit by means of a phone plug and jack so that it need not interfere with other use of the receiver.

Signals broadcast on any frequency which can be used provided the structure of the signal is suitable for recording. At the Volcano Observatory the signal from WWVH has proved to be most useful. Beginning on the hour, WWV broadcasts a 600 cps audio frequency and a one cps modulation consisting of five 1000 cps pulses at the beginning of each second. This one cps modulation, or "tick," as it sounds on the receiver, is omitted on the 59th second of each minute. During the fourth minute of the hour the audio frequency is omitted; code, voice announcements, and the one cps modulation are broadcast during this minute. At exactly five minutes after the hour a 440 cps audio frequency comes on. This frequency and the one cps modulation continue for four minutes, then the 440 cps tone goes off and another minute of code, voice announcements, and "ticks" follows. The foregoing 10-minute cycle is repeated six times per hour and continues day and night. Except for minor periodic interruptions, the WWVH signal is the same as that of WWV. The adapter described above closes the relay during period of audio frequency, code, voice announcements, and, with moderate signal strength, at each of the one cps

"ticks." The timing event most clearly recordable is the return of the audio frequency after the one minute of audio frequency silence.

If photographic recording is employed the adapter relay contacts can be placed in parallel with the clock relay contacts to permit the radio time signal to be re-

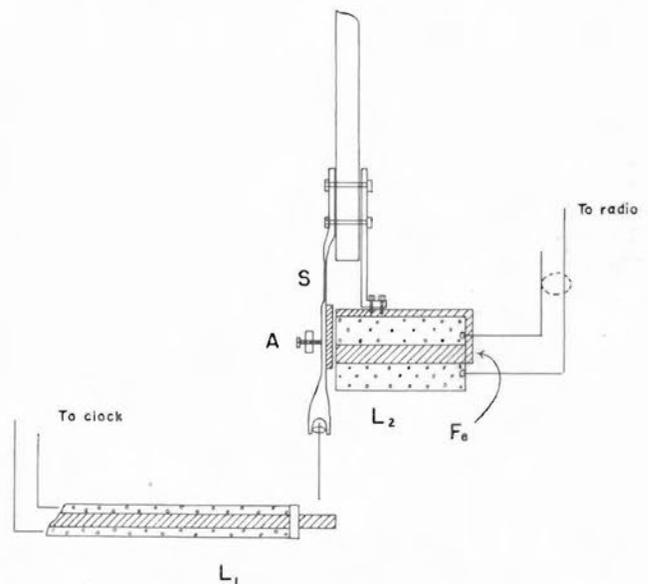


FIGURE 3. Radio time-signal marking pen for mechanical recorder. L_1 —Pen lift magnet, L_2 —Pen deflector magnet, Fe—Iron core and armature, A—Amplitude adjustment screw, S—Flexible pen arm.

corded by the minute-mark deflector system. If mechanical recording is used and the writing points are lifted to record time marks, it is convenient to record the radio time signal by a separate writing point which is deflected horizontally by the radio signal and is lifted from the paper by the clock signal. In practice the clock correction is obtained once a day when the record is changed. The operator drops the timing needle onto the drum and tunes the radio to record the signal. After the signal has been recorded he lifts the timing pen to avoid interference with the seismograph pens during the registration of earthquakes.

Figure 3 is a diagram of the time marker used with the mechanically recording Loucks-Omori seismographs built at the Observatory. The pen is lifted by the regular pen-lift magnet used to record clock time. In addition the pen is carried on a flexible arm which is deflected horizontally by another electromagnet controlled by the radio.

One difficulty encountered in the use of this time-marking system originated in the "feedback" through

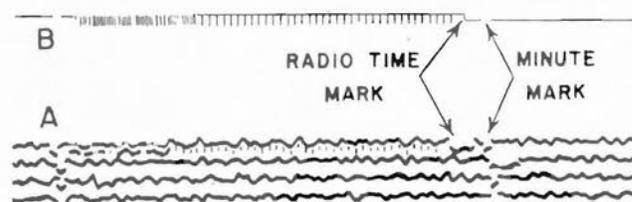


FIGURE 4. WWVH time signals recorded on an optical (A) and mechanical (B) seismograph.

the receiver of the static generated at the relay contacts. This difficulty was overcome by employing a half-wave doublet antenna with a twin-line lead-in to the receiver; by placing a simple capacity-resistance filter across the relay contacts and near each heavy inductance in the time-signal marking circuit; and by using shielded conductors in this circuit.

Figure 4 illustrates WWVH time signals recorded on the photographic record of the Sprengnether and on the smoked-paper record of the Loucks-Omori.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR JULY-SEPTEMBER, 1954

By GORDON A. MACDONALD and JERRY P. EATON

VOLCANOLOGY

July

Earthquake activity on the island of Hawaii continued somewhat greater than usual throughout July. The seismograph at the Whitney Laboratory of Seismology, on the northeast rim of Kilauea caldera, recorded 58 quakes during the month. This is approximately twice the number usual during times of volcanic quiet. The more sensitive Sprengnether seismograph at Uwekahuna recorded a much larger number of very small earthquakes.

Most of the quakes originated within a few miles of the Whitney and Uwekahuna stations, probably beneath Kilauea caldera and the east rift zone near the caldera. On July 3, at 11:53 A.M., a strong earthquake was widely felt over the southern part of the island, and did minor damage in Hilo. Its epicenter was about a mile north of Alae Crater, five miles southeast of the caldera. J. B. Wosky, Superintendent of Hawaii National Park, reported that during and after the quake numerous heavy rock falls occurred on the seaward face of Puu Kapukapu, in the vicinity of Halape, at the coast south of Kilauea caldera. Other small shocks of this group were felt lightly in the Volcano district on July 25 and 26.

Several small earthquakes, originating farther east on the Kilauea rift zone, were recorded at the Pahoa station. A light quake, probably of local origin, was felt in central Kona on July 29.

Tilting of the ground surface at the northeastern edge of

Kilauea caldera was northward at a rate only slightly greater than usual at that time of year. There did not appear to be any marked change in volcanic pressure, indicated by ground tilting.

Occasional rock falls continued on the walls of Halemaumau Crater, but their frequency during the latter half of July was somewhat less than during June. Fresh cracking of the ground surface was observed near the west, southeast, and north rims of Halemaumau.

August

Kilauea Volcano continued somewhat uneasy during August. The seismograph at the Whitney Laboratory of Seismology recorded 46 earthquakes during the month. This is somewhat more than the number normally recorded in times of volcanic quiet. Most of the quakes originated beneath or near Kilauea caldera. Tilting of the ground at the northeastern rim of the caldera was northward at a rate slightly greater than usual at that season. There was no indication of any decrease of volcanic pressure beneath Kilauea.

A sharp earthquake was felt in Kona at 11:27 P.M. on August 1. Its origin was within a few miles of the seismograph station at Konawaena school, probably on the Kealakekua fault near the northern edge of Kealakekua Bay. At 2:27 P.M. on August 7 a strong quake originated beneath Kilauea caldera. It was felt by many persons in the Volcano area, and by some in Hilo and Kona. A moderate quake at 11:16 P.M. on August 30, felt by residents of the Volcano area, also originated beneath Kilauea caldera.

September

The seismograph at the Whitney Laboratory of Seismology recorded 94 earthquakes during the month, approximately three times the number recorded during normal times of volcanic quiet. During the week starting September 12 alone, 56 quakes were recorded. Most of the earthquakes appear to have originated beneath the Kilauea caldera area or the adjacent part of the east rift zone. Several during mid-September appeared to originate at depths of 25 to 30 miles beneath the caldera or the nearby slope of Mauna Loa. One at 2:43 A.M. on September 13 was felt in Hilo.

Several quakes were felt in Kona during early September. These originated on the western slope of Mauna Loa, probably on the Kealakekua fault. No other signs of uneasiness of Mauna Loa were noted.

Tilting of the ground at the northeast rim of Kilauea caldera was approximately normal in direction and amount for that season of the year. Thus no marked change in volcanic pressure beneath Kilauea was indicated.

Neither during the May-June eruption of Kilauea, nor in the four months following the eruption, has there been any indication of reduction of volcanic pressure beneath Kilauea Volcano. Magma appears probably to be still standing at a high level in the conduit. Under such conditions, eruption may occur with little or no warning other than the numerous earthquakes that indicate continued uneasiness of the volcano.

SEISMOLOGY

Local Earthquake Data, July-September, 1954

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

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Total	Local Seismicity*
July 4	2	4	0	0	0	0	6	2.50
11	10	15	2	0	0	0	27	12.00
18	6	6	1	0	0	0	13	5.50
25	1	9	0	2	0	0	12	8.75
Aug. 1	1	9	0	1	0	0	11	6.75
8	6	6	0	0	0	2	14	12.50
15	1	4	0	0	0	0	5	2.25
22	3	5	2	2	0	0	12	9.25
29	7	7	0	0	1	0	15	8.25
Sept. 5	3	4	1	0	0	0	8	3.75
12	32	19	3	2	0	0	56	21.00
19	9	9	0	1	0	0	19	8.75
26	5	8	1	0	0	0	14	6.25

* For definition of local seismicity see Volcano Letter 371 or 512. Each local earthquake is assigned a seismicity value according to its strength, as follows: tremor, 0.25; very feeble, 0.5; feeble, 1.0; slight, 2.0; moderate, 3.0; strong, 4.0. These values are totaled to give the weekly local seismicity. Continuous volcanic tremor is ignored in the calculation. The strength assigned to the earthquake depends on the double amplitude of the maximum oscillation it causes on the Bosch-Omori seismograph, as follows: tremor, less than 0.5 mm.; very feeble, 0.5 to 4 mm.; feeble, 4 to 11 mm.; slight, 11 to 25 mm.; moderate, 25 to 60 mm.; strong, greater than 60 mm.

Table of Tilt at Seismograph Stations on Rim of Kilauea Caldera

Week Beginning	Whitney Station (Northeast rim)		Uwekahuna Station (West rim)	
	Amount	Direction	Amount	Direction
July 4	0.4"	S 56° W	1.8"	S 31° E
11	1.0"	N	1.3"	S
18	1.3"	N 30° E	2.7"	S 21° E
25	0.4"	N 18° W	3.0"	N 19° W
Aug. 1	0.8"	N 18° W	2.2"	N 26° W
8	1.0"	N 21° W	1.7"	N 22° W
15	0.9"	N 56° E	0.3"	N
22	0.4"	S 33° W	0.4"	N 45° E
29	1.3"	N 21° E	2.9"	S 12° E
Sept. 5	0.4"	N 18° E	2.1"	S 26° E
12	1.0"	N 53° E	1.0"	S 18° W
19	0.2"	N 45° W	2.3"	N 17° W
26	0.6"	S 37° E	1.0"	N

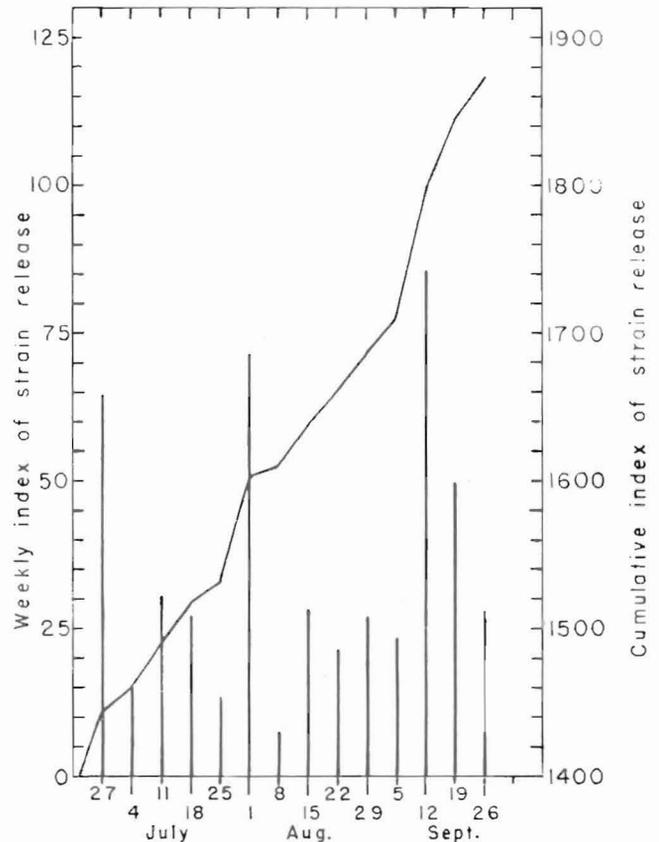


FIGURE 5. Graph showing weekly strain release index (vertical bars) and cumulative strain release index (continuous curve) for the Kilauea caldera region from late June through September, 1954. An increase in steepness of rise of the cumulative curve represents an increase in rate of strain release through earthquakes.

Local Earthquakes

The data for the following local earthquakes were determined from seismographs on the islands of Hawaii and Maui operated by the Hawaiian Volcano Observatory. The number preceding each quake is the serial number for the current year. Only earthquakes classed as feeble or larger are included in the list. Many very feeble quakes, to which serial numbers are assigned also, are omitted. Locations given are epicenters. Except where otherwise indicated, the times given are arrival times at the Uwekahuna station, on the western rim of Kilauea caldera. They are stated in Hawaiian standard time, which is 10 hours behind Greenwich civil time. The intensity rating (Feeble, Moderate, etc.) given is based on the Bosch-Omori seismograph at the Whitney Laboratory of Seismology. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney Station.

- 461. July 1, 09:06, feeble (Mauna Loa, moderate). Felt in Hawaii National Park. About 10 km deep under Kilauea caldera.
- 462. July 2, 06:00, feeble. Kilauea caldera.
- 465. July 3, 11:52:35, strong. Felt quite generally over southern half of Hawaii. About 12 km deep under Alae Crater on the east rift of Kilauea.
- 476. July 11, 12:07:26, feeble. East rift of Kilauea near Napau Crater.
- 486. July 15, 17:10:07, feeble. Kilauea caldera.
- 500. July 22, 13:35 (Pahoa), not recorded at Kilauea (Pahoa, feeble). East rift of Kilauea near Pahoa.

501. July 22, 15:38 (Pahoa), not recorded at Kilauea (Pahoa, feeble). East rift of Kilauea near Pahoa.
502. July 22, 20:36:50, feeble. Kilauea caldera.
506. July 25, 18:17:55, slight. Felt in Hawaii National Park. Near Mauna Loa seismograph station about 10 km deep.
508. July 26, 00:51:44, slight. Felt in Hawaii National Park and in central Kona. Along the Kaoiki fault west of the Observatory at a depth of 10 km.
520. Aug. 1, 23:27:48, not recorded at the Whitney Laboratory (Kona, feeble). Felt in central Kona. Central Kona.
521. Aug. 2, 13:40:33, strong. Felt in Volcano area. About 15 km deep under Alae Crater on the east rift of Kilauea.
523. Aug. 7, 14:26:17, strong. Felt generally over central Hawaii. 25 km deep under Kilauea caldera.
536. Aug. 16, 04:45:33 (Pahoa), not recorded at Kilauea (Pahoa, feeble). East rift of Kilauea near Pahoa.
540. Aug. 18, 07:13:56, slight. Kilauea caldera.
542. Aug. 20, 01:58:54, feeble. East rift of Kilauea near Makaopuhi Crater.
559. Aug. 30, 23:17:04, moderate. Felt in Volcano area. 20 km deep under Makaopuhi Crater.
564. Sept. 1, 15:17:49, not recorded at the Whitney Laboratory (Kona, slight). Felt in central Kona. Central Kona.
570. Sept. 7, 14:48:36, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
576. Sept. 8, 23:03:52, feeble. Kilauea caldera.
588. Sept. 12, 21:58:59, slight. Under Kilauea caldera at a depth of 20 km.
590. Sept. 12, 23:08:26, tremor (Mauna Loa, very feeble). This very feeble earthquake is included in the list because it is typical of about 250 earthquakes (tremor and very feeble in strength) which originated on Sept. 12 and Sept. 13 at a depth of about 45 km below the southeast flank of Mauna Loa between the Mauna Loa seismograph station and the Volcano Observatory.
595. Sept. 13, 02:42:53, feeble. Felt in Hilo. 5 km east of Puu Kapukapu along south coast of Kilauea at a depth of about 15 km.
598. Sept. 13, 18:22:05, feeble. 20 km deep under east rift of Kilauea near Makaopuhi Crater.
602. Sept. 15, 01:23:06, feeble. Kilauea caldera.
604. Sept. 16, 08:15:04, slight. Kilauea caldera.
622. Sept. 22, 00:19:35, slight. Kilauea caldera, 15 km deep.
630. Sept. 25, 21:12:07, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.

Distant Earthquakes

The following earthquakes of distant origin were recorded on the seismographs of the Hawaiian Volcano Observatory. Locations of the epicenters and the magnitudes are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey. The time given is that of the first detectable emergence of the quake on the Sprengnether vertical seismograms, in Hawaiian standard time.

- July 1, eP 16:51, 13½° N., 123½° E. Southeastern Luzon, P. I. Many casualties and extensive property damage. Mag. 6¾-7¼.
- July 5, eP 22:13:27.6, 46½° N., 153½° E. Kurile Islands. Mag. 6½-7.
- July 6, eP 01:20:35.3, 39½° N., 118½° W. Near Fallon, Nevada. Several injured and moderate property damage. Mag. 6¾-7.
- July 6, eP 12:14:58.6, Fallon, Nevada, aftershock. Mag. 6¼-6¾.
- July 17, eP 23:17:39.4, 35½° N., 140½° E. Near east coast of Honshu, Japan. Felt. Mag. 6½.
- July 30, eP 15:12:46.3, 39° N., 140° E. Ningsia province, China. Mag. 6½.
- July 31, eP 17:33:41.0, 3° S., 140° E. Northern New Guinea.
- Aug. 4, eP 22:57:26.1, 52° N., 176° E. Rat Islands, Aleutian Islands. Mag. 6-6¼. Depth 60 km.
- Aug. 9, eP 09:25:26.7, 53° N., 161° E. Off east coast of Kamchatka. Mag. 6½-6¾. Depth 60 km.
- Aug. 17, iP 18:50:26.9, 21½° S., 176° W. Tonga Islands. Mag. 7-7¼. Depth about 150 km.
- Aug. 23, eP 19:58:52.1, 39½° N., 118½° W. Near Fallon, Nevada. Minor property damage at Fallon and Lovelock. Mag. 6½-6¾.
- Aug. 27, eP 01:04:41.5, 24½° N., 143° E. Volcano Islands. Mag. 6¾. Depth about 100 km.
- Aug. 31, eL 12:30, Fallon, Nevada, aftershock. Mag. 5½-6½.
- Sept. 2, eP 09:00:08.4, 10° S., 166° E. Santa Cruz Islands. Depth about 100 km.
- Sept. 3, eP 17:39:32.9, 3° S., 139½° E. Northern New Guinea. Mag. 6¼. Depth about 60 km.
- Sept. 4, eP 21:54:18.5, 19° S., 176° E. Fiji Islands region. Mag. 6½.
- Sept. 6, eP 08:39:35.0, 51° N., 158° E. Near southeast coast of Kamchatka. Mag. 6½. Depth about 60 km.
- Sept. 12, eP 16:18:01.7, 21° S., 175½° W. Tonga Islands. Mag. 6¾. Depth about 150 km.
- Sept. 15, iP 08:03:27.2, 18° S., 178½° W. Fiji Islands. Mag. 7. Depth about 600 km.
- Sept. 17, iP 01:11:18.3, 20½° S., 177½° W. Fiji Islands region. Mag. 7-7¼. Depth about 250 km.
- Sept. 19, eP 14:52:10.8, 1½° S., 120½° E. Celebes. Mag. 5¾-6.
- Sept. 30, eP 17:03:21.0, 11° S., 166° E. Santa Cruz Islands. Mag. 6½-7.

VOLCANO NOTES AND NEWS

ERUPTION OF NGAURUHOE

Ngauruhoe Volcano, on the North Island of New Zealand, broke into violent eruption on June 4. The volcano is a conical mountain 7,515 feet in altitude, 175 miles southeast of Auckland. The following information was furnished by James Healy, New Zealand Government volcanologist, and Brenda Bishop, Secretary of the Pacific Science Council.

The volcano had been in activity for some time, sending big ash clouds high into the air. On the morning of June 4 the entire top of the mountain was reported to be aglow even in daylight. Flying over the volcano, Healy found the crater full of lava, with spurts of orange-red lava going some 500 feet into the air, and two lava flows moving down the slopes of the mountain. One flow came down directly on top of the lava flow

of 1949, and the other a little farther south. Very little ash was being liberated. The lava flows were visited on June 5. They had nearly come to rest, but large blocks were rolling down the mountainside following numerous explosions at the crater. On June 6 activity was more explosive and more ash was being liberated. The explosive phase continued for several days, but on a lesser scale than in 1949.

Another increase of activity occurred on the night of June 9. Spectacular flows of lava were visible from Chateau Tongariro during the evening, but by 3 A.M. on June 10 the spurt of activity was nearly over. The lava flow is reported to be of aa type, and in places to exceed 70 feet in thickness. A cinder cone built in the crater of the volcano was reported to have reached a

height of 200 feet on June 9, and to be breached toward the west where the lava flows escaped.

In September Ngauruhoe was still active. Strong explosions took place on the night of September 2. Several lava flows have been reported on the flanks of the cone during June, July, and August. One of the largest occurred on August 18.

Ruapehu Volcano, 12 miles southwest of Ngauruhoe, was reported steaming in early October. Healy flew over the crater on October 8, and reported that the steam was thick enough to obscure part of the crater lake. Ruapehu Volcano erupted in 1895. Another eruption in 1945 caused the temporary drying up of the crater lake. During that eruption a small lava dome was built in the crater.

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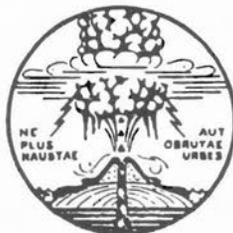
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KAUAI, AN ANCIENT HAWAIIAN VOLCANO

By G. A. MACDONALD¹, D. A. DAVIS¹, and D. C. COX²

Kauai is one of the oldest, and structurally the most complicated of the Hawaiian Islands. Like the others, it consists principally of a huge dome-shaped shield volcano, built up from the sea floor by many thousands of thin flows of basaltic lava. The volume of this great shield was on the order of 7,000 cubic miles. Through much of its growth it must have resembled rather closely the presently active shield volcano Mauna Loa, on the island of Hawaii. When the Kauai volcano started its growth is not known with certainty. It is believed that activity started late in the Tertiary period of geologic time, possibly in the early or middle part of the Pliocene epoch, some 8 to 10 million years ago. Growth of the shield was rapid in the geological sense, and probably was completed before the end of the Pliocene epoch.

Toward the end of the growth of the shield, its summit collapsed to form a broad caldera, the largest that has been found in the Hawaiian Islands. Like the calderas of Kilauea and Mauna Loa, that of Kauai had boundaries which were rather indefinite in part. The principal central depression was bordered by less depressed fault blocks, some of which merged imperceptibly with the outer slopes of the volcano. Elsewhere the caldera rim was low, and flows spilled over it onto the outer slopes. The well-defined central depression of the major Kauai caldera was approximately 10 to 12 miles across.

At about the same time as the formation of the major caldera, another smaller caldera was formed by collapse around a minor eruptive center on the southeastern side of the Kauai shield. Lavas accumulated in the calderas, gradually filling them, and burying talus that formed

along the foot of the boundary cliffs. These lava flows differed from those that built the major portion of the shield in being much thicker and more massive, as a result of ponding in the depressions. The petrographic types are for the most part the same throughout. Both the flank flows that built most of the shield, and the flows that filled the calderas, are predominantly olivine basalt. Picrite-basalt (oceanite), with very abundant large phenocrysts of olivine, and basalt containing little or no olivine are present, but together comprise less than 10 percent of the whole. Late in the period of filling of the major caldera a small amount of basaltic andesine andesite was extruded.

Near the end of the period of filling of the major caldera further collapse occurred, forming a large triangular graben (down-faulted trough) on the southwestern side of the shield. Lava flows erupted within the caldera poured southwestward over the cliff bounding the graben and spread over the gently sloping graben floor. Other flows were erupted along the fault forming the northeast edge of the graben. Near the present Waimea Canyon their advance was obstructed by the fault scarp at the western edge of the graben. The cliff along the northeastern edge of the graben eventually was buried by lava flows from within the caldera, but that along the western edge continued to stand above the level of the flows in the graben. The flows accumulated in the graben are of the same types as those that filled the caldera, and like them are mostly thick and massive because of ponding and the gentle slopes over which they spread.

The rocks of the major Kauai shield volcano are known as the Waimea Canyon volcanic series. The thin flows that accumulated on the flanks of the shield, and that comprise the major portion of the volcanic edifice,

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northeast-southwest lines across the eastern two-thirds of the island. The lavas, cinder cones, and ash beds of this period of volcanism are known as the Koloa volcanic series. The Koloa lavas include olivine basalt, picrite-basalt of mimosite type with few phenocrysts of olivine, basanite, nepheline basalt, melilite-nepheline basalt, and ankaratrite (nepheline basalt very rich in pyroxene and olivine). Inclusions of dunite, composed almost entirely of olivine, are common in the Koloa flows. Just before and during the eruption of the Koloa volcanics, voluminous landslides and mudflows brought down a large amount of rock debris and soil from the steep slopes of the mountainous central upland and deposited it as breccias at the foot of the steep slopes in valley heads and along the border of the marginal lowland. Streams distributed part of the material across the lowland. The breccias and conglomerates thus formed, and later buried by Koloa lavas, are named the Palikea formation.

The structures formed at Koloa vents include cinder cones, one tuff cone, and lava cones. The latter are miniature shields resembling the major Kauai shield volcano, and like it formed by repeated outpourings of fluid lava. The tuff cone, at Lae o Kilauea, was formed by phreatomagmatic explosions caused by rising magma coming in contact with water-saturated rocks. It resembles Diamond Head and Punchbowl cones on the island of Oahu.

Koloa volcanism continued for a long period. It was not, however, continuous over the entire eastern part of the island. Locally long periods of quiet occurred, allowing streams to re-excavate some of the canyons filled by earlier Koloa lavas, and weathering to form deep soils later buried by new Koloa flows. Some of the canyons formed by erosion between Koloa eruptions

were several hundred feet deep. Koloa eruptions probably continued through the Pleistocene and into the Recent epoch. The latest Koloa flow appears very recent. The lava is essentially unweathered and the surface features of the flow are well preserved. It overlies lithified calcareous sand dunes formed during a low stand of the sea, probably at the time of the last advance of the Pleistocene glaciers.

At times during the Pleistocene epoch lowered sea levels permitted erosion of stream valleys and sea cliffs to more than 200 feet below present sea level. Coral reefs were formed during some of these low stands of the sea and calcareous beaches accumulated. A test boring about 1.5 miles north of Kapaa penetrated a calcareous beach buried 240 feet below present sea level beneath Koloa lavas. Calcareous sand dunes also were formed, and now stand with their bases submerged in the ocean. The tuff cone at Lae o Kilauea was formed by phreatomagmatic explosions caused by rising hot magma encountering water-saturated rocks. The explosions threw up fragments of reef limestone. Much of the apron of Koloa lavas around the northeast side of the island probably rests on a platform formed below present sea level by wave erosion and the growth of coral reef.

At other times during the Pleistocene the sea stood higher than at present. Some stream terraces may be graded to a stand of the sea as high as 260 feet above present sea level, but no positive evidence for stands higher than 40 feet have been found. Well-preserved shorelines are recognized approximately 40, 25, and 5 feet above sea level. Some of the present coral reef probably was formed when the sea stood about 5 feet higher than now, and has been planed down to its present level by solution and wave erosion.

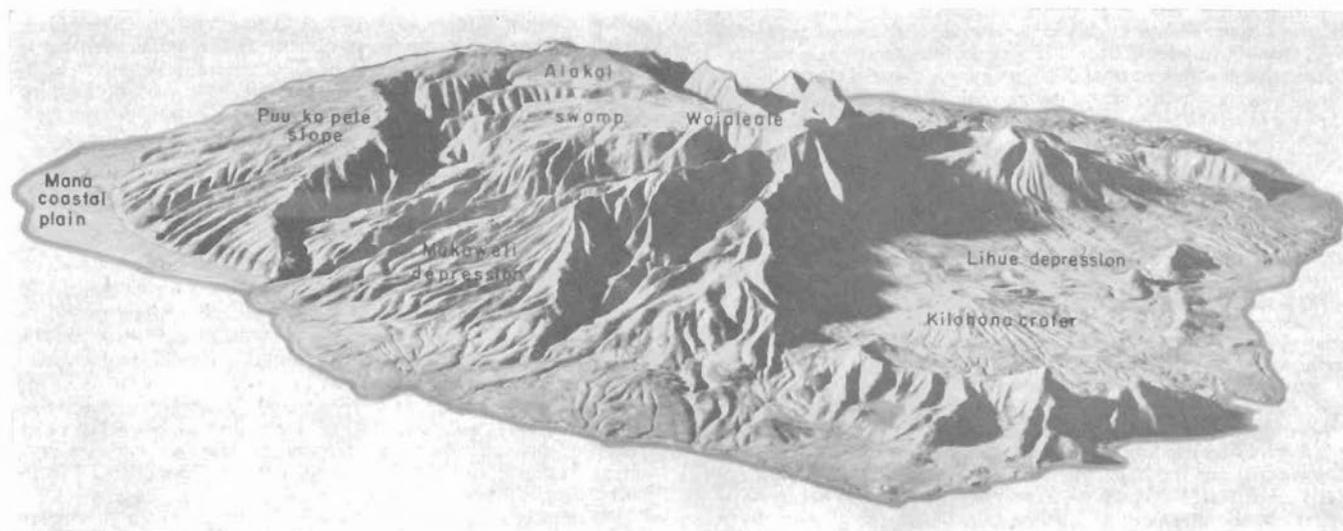


FIGURE 2. Photograph of a topographic model of Kauai, at the University of Hawaii. The model is viewed from the south, and shows at the right the Lihue basin, on the eastern side of the island. In the left center is the Makaweli graben, with Waimea Canyon at its western edge.

HAWAIIAN VOLCANO OBSERVATORY REPORT FOR OCTOBER-DECEMBER, 1954

By GORDON A. MACDONALD and JERRY P. EATON

VOLCANOLOGY

October

Kilauea volcano remained in a restless condition during October. About two-thirds of the 70 earthquakes recorded on the seismograph at the Whitney Laboratory of Seismology stemmed from the region of Kilauea caldera and the adjacent portion of the east rift zone. None of these earthquakes was reported felt.

Approximately one-third of the earthquakes recorded during the month originated beneath Mauna Loa. Among these were the four earthquakes reported felt on Hawaii during October. At 8:50 P.M. on October 7 the southern part of the island was shaken by an earthquake from an epicenter about 10 miles north of Naalehu. The largest quake of the month, which occurred near Hookena at 6:26 A.M. on October 11, was felt over most of the island. Two aftershocks, the first at 6:39 A.M. and the second at 6:52 A.M. on October 11, were felt in South Kona.

Tilting of the ground at the northeast rim of Kilauea caldera was approximately normal in direction and amount for this season of the year.

November

Kilauea volcano continued moderately uneasy through November. The seismograph at the Whitney Laboratory of Seismology recorded 72 earthquakes during the month. The more sensitive seismograph at the Uwekahuna station recorded approximately 385 quakes. Both the total number of earthquakes and the amount of energy released in earthquakes, which is represented in a general way by the seismicity index, were approximately three times as great as during periods of volcanic quiet.

Most of the earthquakes that could be located came from points of origin near Kilauea caldera. Two of these, at 11:09 P.M. on November 23 and 11:34 A.M. on November 26, were felt in Hawaii National Park. Two other quakes, felt at Kamuela at 10:56 A.M. on November 19 and 3:02 P.M. on November 20, appear to have come from a depth of about 20 miles beneath the northwest flank of Mauna Kea, 10 miles southeast of Kamuela. On November 21, a small quake came from a shallow focus 3 miles south-southeast of the summit of Mauna Loa.

Tilting of the ground at the northeastern rim of Kilauea caldera was approximately normal during most of the month. However, from November 27 to 30 it was northeastward at a rate decidedly greater than normal. This may have been related to heavy rains rather than to changes of volcanic pressure.

December

Kilauea volcano continued uneasy through the month of December. The seismograph at the Whitney Laboratory recorded 91 earthquakes during the month, more than twice the number normally recorded during times of volcanic quiet. The local seismicity, which is a rough indication of the amount of energy released by the earthquakes, was more than three times as great as that normally experienced during quiet periods. The more sensitive seismograph at the Uwekahuna station recorded 353 earthquakes during December. Most of the quakes originated at or close to Kilauea caldera. Several interesting quakes came from foci approximately 28 miles deep beneath the caldera. Others were of exceedingly shallow origin.

Many earthquakes originated also along the east rift zone of Kilauea volcano both in the vicinity of the Chain of Craters Road in Hawaii National Park, and in east Puna. A large number of small quakes, and a few fairly large ones, came from foci only about 5 miles from the Pahoa seismograph station. The Pahoa seismograph was dismantled by these quakes several times during the month. Two of the quakes, at 11:00 A.M. and 4:02 P.M. on December 14, were felt quite strongly 4.5 miles east-southeast of Pahoa.

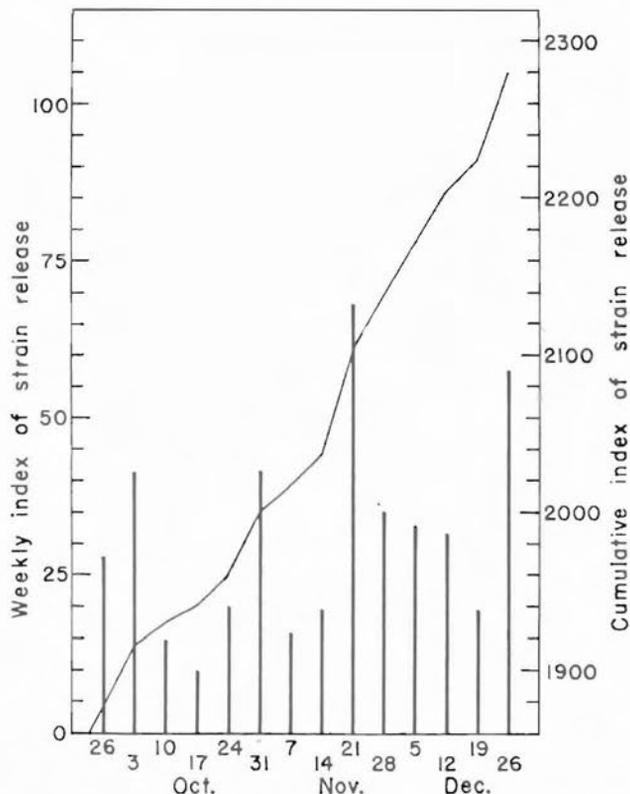


FIGURE 3. Graph showing weekly strain release index (vertical bars) and cumulative strain release index (continuous curve) for the Kilauea caldera region from October through December, 1954. An increase in steepness of rise of the cumulative curve represents an increase in rate of strain release through earthquakes. Earthquakes on the Kilauea rift zone east of Kalalua Crater and on the Hilina and Kaoiki fault zones are not included.

An earthquake at 2:30 P.M. on December 4, felt by some persons from Hilo to Pahala, originated at a depth of about 10 miles beneath the south flank of Kilauea just south of the caldera. A quake felt slightly at Captain Cook and Pahala at 8:59 P.M. on December 5, and another felt in the Volcano district at 10:26 P.M. on December 14, originated beneath the Kilauea caldera area. Another, felt in the Volcano district at 8:49 A.M. on the 28th, appears to have stemmed from the Kaoiki fault, which separates Kilauea and Mauna Loa.

Quakes felt in Kona at 7:15 P.M. on December 6, 6:00 P.M. on December 11, and 9:10 P.M. on December 24, probably came from foci beneath the western flank of Mauna Loa. A quake felt in Kamuela and Hawi at 12:46 P.M. on December 23, originated near Kamuela.

Particularly noteworthy volcanologically, although they were felt by no one, were several periods of almost continuous small earthquakes recorded at the Mauna Loa and Uwekahuna stations. The longest of these periods extended from 2:00 P.M. on December 3 to 9:45 A.M. on December 4. Other shorter periods of this continuous spasmodic tremor, from 10 minutes

to more than one-half hour in duration, occurred at intervals from November 30 to December 5, and on December 21. These quakes appear to have come from a depth of 25 to 30 miles beneath the Kilauea caldera area.

Tilting of the ground surface at the northeastern edge of Kilauea caldera was slightly southwestward during the month. Because the normal tilting at this season is slightly northeastward, this suggests the possibility of a slight decrease in volcanic pressure beneath Kilauea. However, the reversal to southwestward tilting normally takes place in January, and exceptionally heavy rains during December may have had enough effect on the temperature of the rocks near the seismograph station to cause the reversal to southwestward tilting to occur a little earlier than usual, independently of any volcanic effect. Tiltmeters at Uwekahuna and on the caldera floor showed no marked centripetal tilting.

Although Kilauea volcano shows definite signs of uneasiness, there is at the end of December no definite evidence that eruption is imminent. However, conditions somewhat resemble those preceding the eruption on May 31, and there is little or no evidence of any reduction in pressure since before the May eruption. Molten lava may still be standing at high levels in the conduit of the volcano, and it is not unlikely that eruption might again occur with little or no additional forewarning.

SEISMOLOGY

Local Earthquake Data, October–December, 1954

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

Week Beginning	Minutes of Tremor	Very Feeble	Feeble	Slight	Moderate	Strong	Total	Local Seismicity*
Oct. 3	5	9	2	0	1	1	18	14.75
10	5	7	1	0	1	0	14	8.75
17	3	6	1	0	0	0	10	4.75
24	6	9	1	0	0	0	16	7.0
31	4	9	0	0	2	0	15	6.5
Nov. 7	4	5	0	1	0	0	10	5.5
14	1	6	3	0	0	0	10	4.75
21	7	19	2	1	0	0	29	15.25
28	11	14	1	1	0	0	27	12.75
Dec. 5	10	13	1	0	0	0	24	10.0
12	4	8	1	1	0	0	14	8.0
19	6	7	1	0	0	0	14	6.0
26	6	14	3	2	0	0	25	15.5

Table of Tilt at Seismograph Stations on Rim of Kilauea Caldera

Week Beginning	Whitney Station (Northeast rim)		Uwekahuna Station (West rim)	
	Amount	Direction	Amount	Direction
Oct. 3	0.3"	N 45° E	2.9"	S 12° E
10	0.9"	N 40° E	3.0"	S 32° E
17	0.1"	E	0.7"	S 27° E
24	1.0"	N 76° E	0.7"	N 27° W
31	0.3"	S 63° E	0.6"	E
Nov. 7	0.3"	S 63° E	1.3"	S 17° E
14	0.6"	N 22° E	0.4"	N 45° E
21	1.2"	N 29° W	1.1"	S 33° W
28	2.2"	N 61° E	2.3"	N 34° W
Dec. 5	0.5"	N 26° E	0.6"	S
12	0.7"	S 59° E	1.4"	N 63° W
19	1.8"	S 42° W	2.6"	N 7° W
26	0.8"	S	1.6"	N 36° W

* For definition of local seismicity see Volcano Letter 371 or 512. Each local earthquake is assigned a seismicity value according to its strength, as follows: tremor, 0.25; very feeble, 0.5; feeble, 1.0; slight, 2.0; moderate, 3.0; strong, 4.0. These values are totaled to give the weekly local seismicity. Continuous volcanic tremor is ignored in the calculation. The strength assigned to the earthquake depends on the double amplitude of the maximum oscillation it causes on the Bosch-Omori seismograph, as follows: tremor, less than 0.5 mm.; very feeble, 0.5 to 4 mm.; feeble, 4 to 11 mm.; slight, 11 to 25 mm.; moderate, 25 to 60 mm.; strong, greater than 60 mm.

Local Earthquakes

The data for the following local earthquakes were determined from seismographs on the islands of Hawaii and Maui operated by the Hawaiian Volcano Observatory. The number preceding each quake is the serial number for the current year. Only earthquakes classed as feeble or larger are included in the list. Many very feeble quakes, to which serial numbers are assigned also, are omitted. Locations given are epicenters. Except where otherwise indicated, the times given are arrival times at the Uwekahuna station, on the western rim of Kilauea caldera. They are stated in Hawaiian standard time, which is 10 hours behind Greenwich civil time. The intensity rating (Feeble, Moderate, etc.) given is based on the Bosch-Omori seismograph at the Whitney Laboratory of Seismology. If the intensity was greater at one of the other stations, the name of that station and the intensity rating there are given in parentheses after the rating at the Whitney Station.

641. Oct. 1, 14:49:57, feeble. East rift of Kilauea near Kilauea caldera.
648. Oct. 2, 22:22:54, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
649. Oct. 3, 11:09:02, feeble. Near Kilauea caldera at a depth of 20 km.
653. Oct. 5, 12:23:54, very feeble (Mauna Loa, feeble). Felt in Hawaii National Park. Northeast rift of Mauna Loa near Puu Ulaula.
658. Oct. 6, 13:42:46, feeble. Near Kilauea caldera.
661. Oct. 7, 18:43:22, moderate. East rift of Kilauea near Pauahi Crater at a depth of about 10 km.
662. Oct. 7, 20:56:25, moderate (Naalehu, strong). Felt Kalaheiki, Capt. Cook, and Hawaii National Park. Southeast flank of Mauna Loa about 20 km. north of Naalehu.
664. Oct. 8, 11:56:39, very feeble (Mauna Loa, feeble). Southeast flank of Mauna Loa near the Mauna Loa seismograph station.
665. Oct. 9, 04:20, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
666. Oct. 11, 01:18:41, feeble. Near Kilauea caldera.
667. Oct. 11, 06:26:33, strong. Felt in Kalaheiki, Capt. Cook, Kamuela, Hawaii National Park, Hilo, and Honokohau. West shore of Mauna Loa near Hookena.
677. Oct. 15, 23:16:50, feeble. Near Kilauea caldera.
679. Oct. 16, 06:16:32, not recorded at the Whitney Laboratory (Pahoa, feeble).
684. Oct. 18, 23:07:05, tremor (Kamuela, feeble). West flank of Mauna Kea.
686. Oct. 19, 01:25:41, feeble. Near Kilauea caldera.
698. Oct. 27, 13:30:14, feeble. Near Kilauea caldera.
708. Nov. 4, 04:49:21, moderate. Near Napau Crater on the east rift of Kilauea at a depth of about 10 km.
714. Nov. 6, 16:04:36, moderate. Felt in Hawaii National Park. Near Kilauea caldera at a depth of about 20 km.
723. Nov. 11, 01:53:43, slight. Near Kilauea caldera at a depth of about 15 km.
737. Nov. 17, 04:30:48, feeble. Near Kilauea caldera.
738. Nov. 18, 19:30:39, not recorded at the Whitney Laboratory (Naalehu, feeble). Near the summit of Mauna Loa.
743. Nov. 19, 10:55:34, feeble (Kamuela, strong). Felt in Kamuela. Fifteen km. southeast of Kamuela at a depth of about 35 km.
745. Nov. 20, 15:02:51, very feeble (Mauna Loa, slight). Felt in Kamuela. Ten km. west of Pohaku-Loa at a depth of about 30 km.
748. Nov. 21, 19:32:55, very feeble (Mauna Loa, feeble). Ten km. southeast of Mokuaweoweo at a depth of 10 km.

753. Nov. 23, 07:47:54, not recorded at the Whitney Laboratory (Pahoa, moderate). East rift of Kilauea near Pahoa.
756. Nov. 23, 08:21:25, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
763. Nov. 23, 23:08:35, slight. Kilauea caldera.
771. Nov. 26, 02:20:19, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
773. Nov. 26, 02:30, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
776. Nov. 26, 05:50:24, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
779. Nov. 26, 11:34:05, feeble. Felt in Hawaii National Park. East rift of Kilauea near Kilauea caldera.
786. Nov. 26, 15:37:59, feeble. Near Kilauea caldera.
789. Nov. 27, 08:04:58, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
797. Dec. 1, 17:27:34, feeble. Near Kilauea caldera.
811. Dec. 4, 06:35:56, not recorded at the Whitney Laboratory (Mauna Loa, feeble). About 45 km. deep in the vicinity of Kilauea caldera.
815. Dec. 4, 08:49, not recorded at the Whitney Laboratory (Mauna Loa, feeble). About 45 km. deep in the vicinity of Kilauea caldera.
818. Dec. 4, 14:29:36, slight. Felt in Hilo and Pahala. Hilina Pali.
833. Dec. 5, 10:46:42, feeble. East rift of Kilauea near Napau Crater.
837. Dec. 5, 20:59:15, tremor (Pahoa, feeble; Kona and Mauna Loa, very feeble). Felt in Capt. Cook and Pahala. About 45 km. deep in the vicinity of Kilauea caldera. This is the largest of a swarm of more than 200 small earthquakes originating at about the same place on Dec. 4 and 5.
840. Dec. 6, 08:55:07, not recorded at the Whitney Laboratory (Kona, feeble). Offshore west of Hualalai.
841. Dec. 6, 19:15, not recorded at the Whitney Laboratory (Kona, feeble). Felt in Capt. Cook.
848. Dec. 9, 16:02:18, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
863. Dec. 14, 11:01:04, not recorded at the Whitney Laboratory (Pahoa, moderate). East rift of Kilauea near Pahoa.
866. Dec. 14, 17:35:26, very feeble (Kamuela, feeble). Between Mauna Loa and Hualalai at a depth of about 15 km.
867. Dec. 14, 22:25:52, moderate. Felt in the Volcano area. Kilauea caldera.
868. Dec. 15, 11:21:30, feeble. Near Kilauea caldera.
887. Dec. 22, 02:50:52, not recorded at the Whitney Laboratory (Pahoa, feeble). East rift of Kilauea near Pahoa.
889. Dec. 23, 12:45:54, not recorded at the Whitney Laboratory (Kamuela, moderate). Felt at Kamuela and Hawi. About 25 km. deep near Kamuela.
899. Dec. 27, 03:19:30, tremor (Pahoa, feeble). East rift of Kilauea near Pahoa.
904. Dec. 28, 03:06:36, moderate. Just south of Kilauea caldera. Shallow.
905. Dec. 28, 03:31:26, slight. Just south of Kilauea caldera. Shallow.
906. Dec. 28, 07:26:22, slight. Just south of Kilauea caldera. Shallow.
907. Dec. 28, 08:49:17, feeble (Mauna Loa, slight). Felt in the Volcano area. Kaoiki fault near Halfway House at a depth of 15 km.

Distant Earthquakes

The following earthquakes of distant origin were recorded on the seismographs at the Hawaiian Volcano Observatory (19° 25.4' N. latitude, 155° 17.7' W. longitude). Beginnings of phases are given in Hawaiian standard time, which is 10 hours slower than Greenwich civil time. Locations of epicenters, magnitudes, and depths of focus are from the notices of Preliminary Determinations of Epicenters published by the U. S. Coast and Geodetic Survey.

- Oct. 2, eP 16:56:10.9, 10° S., 166° E. Santa Cruz Islands. Magnitude 6 $\frac{3}{4}$ -7.
- Oct. 3, iP 01:26:28.2, 60° N., 151° W. Kenai Peninsula, Alaska. Minor damage at Anchorage, Seward, Valdez and Homer. Magnitude 6 $\frac{1}{2}$ -7. Depth about 100 km.
- Oct. 3, eP 13:33:53.4, 1/2° S., 127° E. Molucca Islands.
- Oct. 17, eL 13:13, 13 $\frac{1}{2}$ ° N., 116 $\frac{1}{2}$ ° W. Lower California. Felt in San Diego and Imperial Valley, California. Magnitude 6.
- Oct. 20, eP 21:02:05, 14° N., 90 $\frac{1}{2}$ ° W. Guatemala. Magnitude 6 $\frac{1}{2}$.
- Nov. 1, eP 18:13:42
- Nov. 1, eP 22:36:16.7, 7 $\frac{1}{2}$ ° S., 119° E. Sumbawa Island region. Magnitude 6 $\frac{1}{2}$ -6 $\frac{3}{4}$.
- Nov. 12, eP 02:34:06, 31 $\frac{1}{2}$ ° N., 116° W. Lower California. Felt in San Diego and El Centro, California. Magnitude 6-6 $\frac{1}{2}$.
- Nov. 12, eP 11:56:15, 15 $\frac{1}{2}$ ° S., 174° W. Tonga Islands.
- Nov. 15, iP 06:36:01.5, 19 $\frac{1}{2}$ ° N., 145 $\frac{1}{2}$ ° E. Marianas Islands. Magnitude 6 $\frac{1}{2}$ -6 $\frac{3}{4}$. Depth 200 km.
- Nov. 18, eP 20:05:49.1, 41° N., 131 $\frac{1}{2}$ ° E. Sea of Japan. Magnitude 6 $\frac{1}{2}$ -6 $\frac{3}{4}$. Depth about 600 km.
- Nov. 25, iP 01:23:12.9, 40 $\frac{1}{2}$ ° N., 126° W. Off Cape Mendocino, California.
- eT 01:55:40, Felt in Northern California. Magnitude 6 $\frac{1}{4}$ -6 $\frac{1}{2}$.
- Nov. 25, iP 11:41:20.5, 21 $\frac{1}{2}$ ° S., 179° E. Fiji Islands region. Magnitude 6 $\frac{1}{2}$. Depth about 650 km.
- Dec. 16, iP 01:14:32.0, 39 $\frac{1}{2}$ ° N., 118° W. Near Fallon, Nevada. Moderate property damage. Magnitude 6 $\frac{3}{4}$ -7 $\frac{1}{4}$.
- Dec. 21, iP 10:03:14.7, 41° N., 124° W. Humboldt County, California.
- eT 10:38:26, Several injured and extensive property damage. Magnitude 6 $\frac{1}{4}$ -6 $\frac{3}{4}$.
- Dec. 26, eP 19:40:15.2, 19° S., 178° W. Fiji Islands. Depth about 500 km.
- Dec. 26, eP 20:59:26.2, 4 $\frac{1}{2}$ ° S., 130° E. Banda Sea.
- Dec. 27, eP 15:10:28.8, 5° S., 152 $\frac{1}{2}$ ° E. New Britain region.
- Dec. 30, eP 01:39:10.1, 53° N., 168° W. Fox Islands, Aleutian Islands. Felt on Unalaska. Magnitude 6 $\frac{1}{2}$ -6 $\frac{3}{4}$. Depth about 60 km.

VOLCANO NOTES AND NEWS

VOLCANIC ACTIVITY IN JAPAN

By Helen L. Foster

(From personal observations and data supplied by Central Meteorological Observatory, Tokyo.)

Mihara-yama, O-shima.—Mihara-yama, on O-shima, has been quiescent since February, 1954, although steam and other gases have been emitted continuously from various parts of the crater in varying amounts. At times steam and gas emission has been quite heavy with billowing clouds rising 100 to 300 meters into the air.

Volcanic tremors were recorded at intervals in April, June, and on September 25. At 4:25 P.M. on September 24 an earthquake originated beneath O-shima which, on the island, had an intensity of II on the scale of VII used by Central Meteorological Observatory, Japan.

On November 2, 1954 at 5:45 A.M. volcanic tremors were recorded for periods of about 12 minutes at 30-minute intervals. On November 6 and 7 when the crater was visited volcanic tremors were continuing, and steam and gas emission had increased considerably. At times, steam clouds rose to a height of 500 meters. Ground temperatures in the crater area seemed higher than in previous months. Sublimates were being deposited in increased amounts in many places in the crater. Numerous new fissures, particularly in the remnants of the 1951 cinder cone, were observed. Some old fissures had opened wider and were emitting steam. A small cone formed in January, 1954, was considerably broken, partly by fissures which opened in August and partly by new collapses.

On November 9 the volcanic tremors again ceased and steam and gas emission decreased.

1954 Eruptions of Asama-yama.—The 1953 and January and February, 1954, activity of Asama-yama was reported in Nos. 522 and 523 of the *Volcano Letter*. Since then small explosions have continued. The Karuizawa Weather Station recorded about 50 small explosions in January, about 70 in February, 31 in March, 17 in April, 19 in May, 4 in June, 6 in the latter part of July, 4 in August, and 2 on September 6 including quite a large explosion at 5:58 P.M.

After an inactive period in September and October a small explosion occurred at 1:45 P.M. on November 2 and another at 1:50 P.M. on November 4. A small amount of ash was ejected on November 4.

Volcanic ash has been ejected during many of the explosions, but no serious damage has been reported. All of the explosions have been comparatively small.

Submarine Eruption of Myojin-sho.—Myojin-sho is a rock bank in the Beyoneisu-retsugan (Bayonnaise Rocks), about 50 kilometers south of Aoga-shima, Izu Islands. It was the site of violent volcanic eruptions in 1952 and 1953 and became especially well known because of the loss of the Kaiyo-maru, a patrol ship of the Japanese Hydrographic Office, in an eruption on September 24, 1952. (See *Volcano Letter* No. 518.)

Renewed eruption at Myojin-sho has been reported by a fishing boat, the Eikichi-maru. Members of the crew witnessed two explosions between 2:00 and 3:00 P.M. on November 4, 1954. The eruptions were not recorded on the seismograph or wave-recorded at Aoga-shima and no steam cloud was seen from there.

The Tori-shima Weather Station, about 160 kilometers south of Myojin-sho, reported several ocean swells during a 3-hour period on November 5 which might have been caused by eruptions at Myojin-sho.

CATALOGUE OF PHILIPPINE VOLCANOES

Late in 1953 appeared Part II of the *Catalogue of the active volcanoes of the world, including solfatar fields. Part II, Philippine Islands and Cochin China*, by M. Neumann van Padang, closely follows the plan of Part I. (See *Volcano Letter* No. 516.) In 49 pages, it lists and briefly describes 41 volcanoes and solfatar fields in the Philippine Archipelago, and 2 in Cochin China. Of the Philippine volcanoes, 16 have had historic activity, 12 are in a solfataric and fumarolic state, and 3 are solfatar and fumarole fields not belonging to any well-defined volcano. Both the Cochin China volcanoes have been active in historic time. Like Part I, this new section of the Catalogue will be of great value as a reference work.

The Catalogue is being published by the International Volcanological Association, part of the cost of printing of Parts I and II being borne by a grant-in-aid from UNESCO. A limited number of copies of Part II are available from Professor Francesco Signore, General Secretary of the Association, Via Tasso 199, Napoli, Italy, for \$3.60 (U.S.).

ERUPTION IN THE GALAPAGOS ISLANDS

Alcedo Volcano, in the central part of Isabela (Albermarle) Island, erupted on November 9. According to Adrian Richards, of the Scripps Institution of Oceanography, fume rose from the crater and from numerous fissures on the east flank of the cone. The eruptive activity of Alcedo on the first day was reported to be less intense than that of Sierra Negra (Volcan Grande), on the south end of Isabela Island, during 1953 (see *Volcano Letter* No. 525). Later (exact date unknown) a small flow of lava was reported high on the north-northwest side of the cone, and shimmering heat waves were observed above the crater during daylight and a bright glow from the crater at night.

Richards states that the eruption of Alcedo was preceded in late 1953 or early 1954 by upheaval of the shore in the vicinity of Bahia Urvina and for three miles southward. The upheaval raised the reef surface as much as 15 feet, and caused the shoreline to migrate about 2,400 feet seaward. The raised area is on the western flank of the Alcedo cone.

This appears to be the first recorded eruption of Alcedo volcano, although eruptions elsewhere on the island occurred in 1797, 1800, 1813, and 1847. An eruption in the northern part of Isabela Island in April, 1925, was recorded by William Beebe; and eruptions occurred at Wolf volcano in 1948 and at Sierra Negra volcano in 1953. The latter two eruptions, in the northern and southern parts of Isabela Island, respectively, are described by Richards in *Volcano Letter* No. 525.

FRENCH BIBLIOGRAPHICAL DIGEST

Just received is the third issue of the second series of the French Bibliographical Digest, devoted to Geology. This series is intended to make French scientific work better known in the United States, and numbers are sent free of charge upon request. Correspondents are asked to specify the subjects in which they are interested. Requests should be addressed to the Cultural Division of the French Embassy, 972 Fifth Avenue, New York 21, N. Y. The present number of the Digest contains 102 pages, and lists approximately 500 titles, most of them accompanied by brief abstracts. One of the several sections deals with volcanology and paleovolcanology. Another volume in preparation will include papers on geophysics.

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